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Status of Lake St. Clair Submerged Plants, Fish Community, and Sport Fishery

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Abstract.–Lake St. Clair is located near the geographical center of the Great Lakes and is bisected by a commercial shipping lane and an international boundary. With a large human population in close proximity, the lake provides economically and socially important recreational opportunities for the people of southeast Michigan. The fish community of the lake is an important recreational resource. Since the early 1980s, the lake underwent invasions of white perch, spiny water flea, zebra mussel, round goby, and tubenose goby. Their initial impacts on this resource have been documented, but the long-term and cumulative effects remain uncertain. Using trawls and trap nets to sample fish populations, hydroacoustics and hook tosses to sample aquatic plants, and an angler diary program to collect data on sport fishing effort and catch, this study documents the status of the fish community and important fish habitat, primarily submergent plants, in the lake between 2002 and 2006. A total of 34 fish species were represented in the trawl survey. Yellow perch densities were highest in June trawls and age-specific densities indicated highly variable recruitment, with a strong cohort produced in 2003. Smallmouth bass recruitment was also variable, but age-0 densities and mean lengths were high in 2005 and 2006, suggesting those cohorts should be strong contributors to the fishery in future years. A total of 25 fish species were encountered in the trap net survey from 2002 to 2006. Rock bass were the most abundant species, but large predators such as smallmouth bass, channel catfish, walleye, muskellunge, and northern pike were also important components of the catch. While age distribution of smallmouth bass and walleye suggested variable recruitment, muskellunge and northern pike recruitment appeared more stable. The channel catfish population was dominated by large individuals and offers trophy fishing opportunities. Recoveries of tagged smallmouth bass reported by anglers were largely confined to Lake St. Clair. In contrast, anglers reported catching walleye tagged at the Anchor Bay site from locations as far north as the St. Clair River at Port Huron, and as far south as Maumee Bay, Lake Erie. The angler diary catch rates reflected the recruitment of the 2003 walleye and yellow perch cohorts to the fishery in 2005 and 2006. Muskellunge catch rates appeared to decline, possibly reflecting impacts of disease in the population. In this study, we monitored the benthic plant community in Lake St. Clair during the period from 2003 through 2007 with weighted hook sampling and hydroacoustic gear. A total of 22 species of aquatic plants were encountered during the plant survey. Four species dominated the submerged macrophyte community. In combination, muskgrass, wild celery, Richardson's pondweed, and common naiad accounted for 75% of the total wet weight sampled.

Introduction

Lake St. Clair is centrally located in the connecting channel between Lake Huron and Lake Erie in the Laurentian Great Lakes (Figure 1). The interface between the St. Clair River and Lake St. Clair is a unique freshwater delta system with expansive marshes. For decades, the lake supported a sport fishery renowned for smallmouth bass, muskellunge, walleye, and yellow perch (see Appendix 1 for scientific names of fishes and aquatic organisms mentioned in this report). These predator populations were supported by a diverse and abundant forage fish community. Since the early 1980s, the lake has experienced invasions of white perch, spiny water flea, zebra mussel, round goby, and tubenose goby. With establishment of ruffe in the Lake Superior and Lake Huron basins, colonization by this exotic species may also be imminent. The short-term and long-term effects of invasive species on the Lake St. Clair fish community remain uncertain.

Approximately 4 million people live within a 1-hour drive of Lake St. Clair. Jamsen (1985) reported that nearly 22% of all Michigan Great Lakes sport fishing effort in 1981 was spent on Lake St. Clair. In 1983 and 1984, the annual estimated fishing effort on Lake St. Clair averaged 1.9 million angler hours (Haas et al. 1985). The value of the Lake St. Clair sport fishery to the state economy in 1983 and 1984 averaged 8.7 million dollars (based on $36.50 per 8 hour day of fishing: United States Department of the Interior, Fish and Wildlife Service and United States Department of Commerce, Bureau of Census 1989) and would be valued over 13 million dollars by 2008 allowing for a 3% annual inflation rate. Clearly, extensive sport fishing effort and harvest in Lake St. Clair generate important socioeconomic benefits.

While the importance of the sport fishery in these waters is great due to the fisheries resources available in the system and proximity to the metropolitan Detroit area, catch surveys on Lake St. Clair and the connecting waters are extremely expensive. As a result, unique sport fisheries for Great Lakes muskellunge and smallmouth bass have been largely unmonitored. Furthermore, walleye originating from spawning sites in Lake Erie migrate into Lake St. Clair. Exploitation of walleye in Lake Erie is monitored annually, but in Lake St. Clair and the connecting channels, these Lake Erie walleye stocks are subjected to differing levels of exploitation from those in Lake Erie proper (Haas et al. 1988).

Aquatic plants are a primary habitat component for fish and waterfowl in Lake St. Clair. Increasingly, aquatic plants are viewed as a public nuisance by water recreationists and some aquatic plant control efforts have been proposed or initiated in the open waters of Lake St. Clair. Aquatic plants are also negatively impacted by activities such as dredging, which have become more common with declining water levels.

This survey was designed to monitor the status of the Lake St. Clair fish and aquatic plant communities from 2002 through 2007. The study objectives were to: (1) measure yellow perch and forage fish relative abundance, (2) assess adult game fish populations, (3) document smallmouth bass dynamics, (4) document abundance and distribution of aquatic plants, (5) monitor sport fish catch rates, and (6) identify management recommendations.

Methods

Study Area

Lake St. Clair has a surface area of 1,114 km^2, an average depth of 3 m, and a maximum natural depth (i.e., excluding the dredged shipping channel) of only 6.4 m (Bolsenga and Herdendorf 1993). The lake is located about midway between Lake Huron and Lake Erie, sandwiched between the St. Clair River and the Detroit River (Figure 1). The St. Clair River delta, with expansive marsh areas and natural channels, is a unique geological formation. Due to shallow depths and high flow volumes, the hydraulic retention time for Lake St. Clair is short. In general, the lake is characterized by two distinct water masses. The western portion of the lake is dominated by Lake Huron water flowing through the St. Clair River channels and sweeping south to the Detroit River. The southeastern area of the lake reflects the contributions of nutrients and silts from the Thames River, the primary tributary.

Fish Collections

Bottom trawls were used to sample the fish community at an index area in Anchor Bay (Figure 2) to monitor changes in species densities, yellow perch growth (as indicated by mean length at age), age structure, and annual spawning success for yellow perch and smallmouth bass. The index site was sampled in early June and September, from 2002 to 2006. All sampling took place during daylight hours. All trawling was conducted from the Michigan Department of Natural Resource (MDNR) research vessel *Channel Cat* in water depths exceeding 2 m. Trawling gear consisted of a 10.7-m headrope otter trawl towed with single warp and a 45.7-m bridle. The trawl was constructed of 76 mm, 38 mm, and 32 mm graded stretched measure mesh from gape to cod end with a 9 mm stretched mesh liner in the cod end. Whenever possible, tows were made with the trawl on the lake bottom, underway for 10 minutes at approximately 2.0 knots. Sometimes tow duration was shortened to avoid heavy plant growth or other physical obstructions.

Trawl catches were standardized as the number of fish caught per hectare by estimating the area swept by the trawl during each tow. Area swept was calculated based on the known gape of the trawl and the linear distance between starting latitude/longitude and ending latitude/longitude. Trawl gape of the 10.7-m headrope trawl had been previously measured at 7 m with Scanmar gear. We used ArcGIS geographic information software to determine the linear distance between starting and ending locations.

Fish collected with trawls were identified and enumerated. Total weight and number for each species were recorded. June trawling captured age 1 and older individuals for most species, since age 0 fish were too small for effective capture with the trawl. By September, age 0 fish for most species were recruited to the trawling gear. For trawl tows with high forage fish catches (typically total forage weight exceeding 10 kg) a 25% to 40% subsample was used to estimate the total number and weight for each species in that tow. Fewer than 5% of all trawl catches were subsampled.

Trap nets were used to capture smallmouth bass and walleye for tagging and to provide an index of relative abundance (catch-per-unit effort, CPUE, as number of fish caught per 24 hours or trap day) for a variety of species. This method assumes that CPUE is linearly related to fish abundance, and that a percent change in abundance will be reflected in the same percent change in CPUE (Bannerot and Austin 1983). Five trap nets were fished at the same locations in Anchor Bay during May (Figure 2), from 2002 to 2006. The Global Positioning System (GPS) was used to locate the same sampling locations each year. The trap nets had 1.8-m deep pots of 5.1-cm stretch mesh, 7.6-cm stretch mesh hearts and wings, and 91.4-m long leads of 10.2-cm stretch mesh. Five nets were fished throughout each sample period and were normally tended 3 times each week. The nets were typically set in early May and fished until the Thursday before Memorial Day weekend. However, due to scheduling conflicts, the sampling period in 2003 was delayed about a month.

The entire catch from each trap net was identified and enumerated. Size data and bony structures (for age interpretation) were collected from smallmouth bass, walleye, muskellunge, and northern pike. Sex and maturity were determined for smallmouth bass, walleye, muskellunge, and northern pike based on extrusion of gametes under light abdominal squeezing. Trap nets fished an average of 52 hours between lifts. Catch-per-net-lift data for yellow perch and walleye were standardized to catch per 24-hour period by dividing the catch per net lift by the hours fished, then multiplying by 24.

Biological measures for select species.–Scale samples were taken from yellow perch collected in June and September trawls for age determination. Scale samples for age determination were collected from smallmouth bass, walleye, muskellunge, and northern pike caught from 2002 to 2004. Scale impressions were made on clear piece of acetate and viewed on a microfiche projector for age interpretation. Length-at-age-at-capture (growth) for each species was compared to State of Michigan averages (Schneider et al. 2000). In 2005, a digital image analysis system (ImagePro Plus©; version 5.1.0.20) was acquired and age determination with sectioned fin rays and spines was undertaken. In 2005, fin rays were used for age determination of muskellunge and northern pike. In 2006, fin rays or spines were used for age estimation of walleye, smallmouth bass, muskellunge, and northern pike. Fin rays were also used for age determination of trawl-caught yellow perch over 200 mm total length (TL) in 2006.

We estimated survival for smallmouth bass based on age-specific catch rates from the trap net survey from 2002 to 2006. A standard catch curve analysis (Quinn and Deriso 1999) was applied to the mean catch by age. Survival was estimated from the slope of the descending limb of the curve with included ages 5 to 10.

The diet of two Lake St. Clair predators, smallmouth bass and walleye, were monitored. The stomachs of all smallmouth bass and walleye collected with trawls from 2002 to 2006 were removed and examined for food items. Immediately upon capture, the fish were eviscerated and all stomach contents were identified to the lowest taxa possible. The diet was analyzed for frequency-of-occurrence: the percentage of fish with non-empty stomachs that contained at least one of a selected food item (Windell and Bowen 1978).

Smallmouth bass and walleye tag-recapture.–Smallmouth bass and walleye were tagged by MDNR personnel during spring trap-net surveys from 2002 to 2006 in Anchor Bay, Lake St. Clair. Upon capture, both species were immediately placed in an on-board live tank equipped with continuously circulating lake water. Fish were removed individually from the live tank and tagged. For walleye, most fish under 500 mm were tagged with size 10 or 12 monel metal strap tags affixed by overlapping the tag snugly around the dentary bone of the lower jaw. Most walleye over 500 mm were tagged with size 12 monel metal strap tags affixed by overlapping the tag snugly around both the maxillary and premaxillary bones of the upper jaw. For smallmouth bass, most fish under 350 mm were tagged with size 12 monel metal strap tags affixed by overlapping the tag snugly around the dentary bone of the lower jaw. Most smallmouth bass over 350 mm were tagged with size 12 monel metal strap tags affixed by overlapping the tag snugly around both the maxillary and premaxillary bones of the upper jaw. All tags were inscribed with the Lake St. Clair Fisheries Research Station address (MDNR, Mt. C., 48045) and an individual tag number. We tagged 1,770 smallmouth bass and 941 walleyes at the Anchor Bay trap net site from 2002 to 2006. Tag-recapture data were solicited from anglers and commercial fishermen on a voluntary basis.

Tag recovery data were summarized by location and calendar day and mapped using ArcView© geographic information system software. Dates of tagging and tag recovery for recaptured walleye were summarized by calendar day and thus were independent of the calendar year.

A generalized stochastic model, referred to as the ESTIMATE model (Brownie et al. 1985), was used to analyze the results of the walleye tag-recapture study. This model provided unbiased maximum likelihood estimates of recovery and survival rates. Since the tag-recovery rate is a product of the exploitation rate and the reporting rate (Krementz et al. 1987), walleye total mortality (natural logarithm of survival rate) may be partitioned into fishing and natural mortality rates if an estimate of the tag reporting rate is available (Horsted 1963). The z-statistic (Brownie et al. 1985) was used to compare annual tag recovery rate estimates for walleye.

In many studies the reporting rate is assumed to be 100%, that is, all tags recovered by the fisheries are seen and subsequently reported. If 100% reporting is assumed, then the recovery rate is an estimate of the exploitation rate. More likely, reporting rate is less than 100% and may vary over time (Rawstron 1971), space (Chadwick 1968; Henny and Burnham 1976; Reeves 1979; Green et al. 1983), or other factors (Rawstron 1971; Green et al. 1983). Thomas and Haas (2005) estimated that non-reporting for Lake Erie walleye tags was 2.73 and that adjustment was applied to observed numbers of tags returned during this study.

Estimating Angler Catch Rates

A diary program is one method of obtaining data to quantify fishery parameters. Diary programs have been used to monitor sport fisheries or fish populations in a variety of locations (Bray and Schramm 2001; Ebbers 1987; Gabelhouse and Willis 1986). We used a voluntary angler diary program to estimate catch rates of sport anglers fishing on Lake St. Clair. Cooperating anglers recorded their fishing activity in diary booklets provided by the MDNR and Ontario Ministry of Natural Resources (OMNR) each season. Anglers were asked to record all their fishing activity from April through the end of the open water season. Angler diary booklets were recovered from the anglers each fall. Data were keypunched into computer spreadsheets or databases. Effort was recorded as rod hours fished. Overall, angler catch rates for targeted species were calculated as the quotient of total number of fish caught and total effort.

Aquatic Plant Survey

Since 2003 we have used a combination of remote sensing with hydroacoustic equipment and plant sampling with a weighted hook to survey and map submerged plants during July through August. The first major survey of submerged plants in Lake St. Clair was conducted in 1978 (Schloesser and Manny 1982) by the United States Fish and Wildlife Service, Great Lakes Fishery Laboratory (now United States Geological Survey (USGS)) at 115 stations (Figure 3). All of our hook and hydroacoustic sampling activities were centered on these station locations to facilitate comparisons with the historic data.

Various types of rakes or grapnel hooks have been used by researchers and managers to collect submerged plants by dragging along the bottom. We developed a sampling hook, based on Hough et al. (1989), constructed from iron pipe filled with lead and eight tines made of steel drill rod (Figure 4). The hook was dragged on the lake bottom for a distance of approximately 10 m, and this process was repeated from 2-8 times to ensure that an adequate plant sample had been collected. The plants from all hook drags at a station were combined, weighed (wet), visually rated as light, medium, or heavy and a photograph was taken. Each sample was then separated to species which were individually weighed (wet) to hundredths of a kilogram. Secchi depth, bottom type, and water temperature were also recorded.

Hydroacoustic estimates of plant canopy volume were made using Biosonics© hydroacoustic equipment consisting of the DE-X Series Digital Scientific Echosounder fitted with a 420 kHz split beam analog transducer. The hydroacoustic transducer was hard-mounted to the gunnel of our outboard survey boat with the GPS antenna positioned directly over the transducer. A hand winch, aluminum shaft, and ferrule arrangement allowed the transducer to be raised and lowered to account for different weather and wave conditions.

We chose to overlay a square hectare plot centered on the 1978 plant stations established by USGS. A technique was developed using GIS to create boat transect routes on a computer before going into the field. At the time of sampling, each track was uploaded to the GPS and followed while the hydroacoustic data were being collected (Figure 5). We ran 11 hydroacoustic transects east and west spaced 10 m apart across each hectare. All hydroacoustic information was saved to computer files for archiving, processing, and computer analysis. A typical section of hydroacoustic echo trace containing plant information is shown in Figure 6 which is available real-time and during post-processing activities.

Several computer programs were used to analyze and map data on submerged plants. Hydroacoustic data were subsequently processed using EcoSAV® Version 1.0 (BioSonics Inc, Seattle, U.S.A., www.biosonicsinc.com), using default values for all parameters (BioSonics 2004). Figure 6 shows a typical section of hydroacoustic echo trace containing plant information. Plant height, percent cover, and water depth information were extracted by post-processing with EcoSAV plant analysis software. Spatial patterns in selected EcoSAV output variables were examined using the software packages Surfer® (Version 8.05, Golden Software, Inc., Colorado, U.S.A., www.goldensoftware.com) and ArcView® 3.2 (Environmental Systems Research Institute, Inc. California, U.S.A., www.esri.com). We used ArcView to locate and map stations, develop survey transects, and upload transects to our GPS, and eventually to clip the hydroacoustic data excluding values outside hectare boundaries. For developing contour maps, we used Surfer to perform point kriging with a linear variogram model (slope = 1, anisotropy ratio = 1 and angle = 0).

We calculated plant canopy volume as a percent of the total water column, using methods similar to those described by Valley et al. (2005). Plant canopy volume has also been termed biovolume (Valley et al. 2005) or Percentage Volume Inhabited (Winfield et al. 2007). Our boat speed was 3 – 4 knots which separated GPS reports every 3 – 5 meters. This represented the distance between data records and defined the size of the ping cycles (typically 10-11 pings per cycle). EcoSAV processing of hydroacoustic data files calculates one data location for each record as the mid point between GPS cycle boundaries. From the plant variables reported by EcoSAV, we calculated plant canopy volume for each ping cycle using the following formula: plant canopy volume (%) = PlantHeight / Depth x Plant Cover (%) where: PlantHeight = the mean plant height for only those pings signaling the presence of plants; Depth = a best depth estimate for a ping cycle determined from a patented algorithm (Sabol and Johnston 2001); and Plant Cover = the percent of all pings in a report cycle signaling the presence of plants.

We used plant wet weight and visually rated plant data from this study to apply to the USGS visual rating data to estimate what the weights would have been in 1978 and 1995.

Results

Index Trawl Survey

A total of 34 fish species were represented in the catch for 85 trawls made at the index area from 2002 to 2006. Yellow perch and spottail shiners dominated the 2002 to 2006 spring trawl catches (Table 1). Alewives, caught as yearlings in the spring trawls, were absent from the catch from 2003 to 2006. Silver redhorse and smallmouth bass, which were sporadically caught in the spring trawls from 1996 to 2001, were consistently present each year from 2002 to 2006. In the fall, spottail shiners and mimic shiners dominated the catch (Table 2). Alewives, caught as young-of-year in the fall trawls, were absent or nearly absent from 2003 to 2006. Emerald shiners increased after 2003 and were the second most abundant species in the 2006 fall trawls. Since 2001, largemouth bass have been consistently higher in abundance than during 1996 to 2000.

Yellow perch densities were much higher in the June index trawls (Table 1) than in September (Table 2), but no trends were apparent across years. Age-specific densities clearly illustrate the variable recruitment experienced by yellow perch in Lake St. Clair. The 1993, 1994, 1998, and 2003 year classes were particularly strong (Table 3), while 1992, 2000, 2002, and 2005 year classes were weak. Age-0 yellow perch densities in the September index trawls also indicated that 1998 and 2003 produced strong year-classes, while 2000 and 2002 were nearly missing (Figure 7).

Overall, no clear trend in yellow perch size at age was apparent across the study period (Table 4). Growth appeared to have improved from below to near the statewide average for age 1, 2, and 3 fish in the 2002 to 2006 period. However, older age groups were consistently smaller than the statewide average.

Densities of age-0 smallmouth bass in the September trawls varied across years (Figure 8). Smallmouth bass age-0 mean length also varied across years. For 2005 and 2006, both densities and mean length were high, suggesting smallmouth bass year-class strength should be strong for both years.

A total of 49 smallmouth bass and 95 walleye stomachs were examined for diet items. At least one food item was found in 36 smallmouth bass and 56 walleye stomachs. Smallmouth bass diet was diverse and included eleven species of fish with gizzard shad (17%) and round gobies (14%) occurring most frequently (Table 5). Walleye stomachs contained 4 species of fish, with alewife (14%) occurring most frequently. However, it should be noted that no alewives were found in walleye stomachs after 2002.

Only yellow perch and spottail shiners were found in the stomachs of both smallmouth bass and walleye. Burrowing mayfly nymphs (Hexagenia or Ephemera spp.) were found in 9% of the walleye stomachs. No invertebrates were seen in smallmouth bass stomachs.

Index Trap-net Survey

Trap net lifts ranged from 34 to 64 annually, with a total of 246 lifts over the 5 year period from 2002 to 2006 (Table 6). A total of 25 fish species were caught in the trap nets over the 5 year period (Table 7), with rock bass, smallmouth bass, and channel catfish among the most abundant species each year. There were no obvious trends in catch rates from 2002 to 2006 for any individual species. The mean catch per net lift was rather consistent each year, except for 2005, when it was at least 50% lower than for any other year. Catch rates for several individual species were also lowest in 2005, including channel catfish, common carp, freshwater drum, pumpkinseed, rock bass, smallmouth bass, and yellow perch. The sampling period in 2005 was characterized by clear water (high secchi depth) and cool water temperatures.

Ages were determined for 2,080 smallmouth bass captured in the trap nets from 2002 to 2006. Smallmouth bass ranged in age from 2 to 14 years. The 1998 year-class was the dominant year-class in 2002, 2003, and 2004, accounting for 71%, 57%, and 41% of the total catch during those respective years (Table 8). In 2005, the age composition was fairly evenly distributed with ages 4, 5, 6, and 7 accounting for a combined 79% of the total catch. In 2006, age 4 (2002 year-class) was the dominant cohort, accounting for 34% of the total.

Age specific catch rates for smallmouth bass (Table 9) suggest that fish older than age-8 were more abundant in the population from 2002 to 2006 than during previous survey periods. The elevated mean age from 2002 to 2005, highest of any year in the survey history, also reflect the presence of older bass in the population. However, total CPUE during the period for 2002 to 2006 has generally been much lower than those reported during the survey in the 1970s and 1980s. Catch curve analysis for smallmouth bass ages 5-10 produced an annual survival rate estimate of 51% for the period from 2002 to 2006.

Ages were estimated for 967 walleye captured in the trap nets from 2002 to 2006. Walleye ranged in age from 1 to 13 years. A pattern of alternating weak and strong year-classes was apparent, particularly in 2004, 2005, and 2006 (Table 10). During those years, the strength of the 1999, 2001, and 2003 year-classes contrasts starkly with the weak 2000, 2002, and 2004 year-classes.

Muskellunge captured in the trap nets from 2002 to 2006 ranged in age from 4 to 19 years, with a mean age of 8.7 years (Table 11). Ages 6, 7, 8, and 9 were the dominant ages accounting for 65% of the catch. Age 10 and older fish accounted for 29% of the trap net muskellunge catch, while fish younger than age 5 were rarely caught. There was an apparent increase in the frequency of older muskellunge in the survey catch during 2005 and 2006. Mature males ranged in age from 4 to 18 years, while females ranged from 6 to 19 years. There were no obvious strong or weak year classes evident from the annual age distributions, suggesting fairly consistent recruitment.

The trap net survey provided an opportunity to document some characteristics of muskellunge spawning activity in the index survey area of Anchor Bay, Lake St. Clair. Over the 5 year period of the survey, muskellunge were caught in 89 (36%) of the 246 survey trap net lifts. Muskellunge caught included 164 ripe males, 71 ripe or gravid females, and 14 muskellunge for which sex was not determined. Ripe female muskellunge were captured as early as May 5th and as late as June 11th. Water temperatures recorded when ripe female muskellunge were captured ranged from 8 ºC to 18 ºC. Ripe females were caught in 45 (50%) of the 89 trap net lifts that included at least 1 muskellunge. About 80% of the 45 net lifts that included at least 1 ripe female, also included at least 1 ripe male. Among the five net locations, the two southern-most locations (nets 8 and 9) accounted for 72% of the ripe female muskellunge caught during the five year period. Water depths at nets 8 and 9 ranged from 2.7 m to 3.6 m.

Northern pike captured in the trap nets from 2002 to 2006 ranged in age from 1 to 11 years, with a mean age of 4.3 years (Table 12). Ages 3, 4, and 5 were the dominant ages accounting for over 70% of the catch. Sex was determined for only 53 (16%) of the 340 northern pike captured during the survey period, and only 20 of those fish were ripe or spent females. There were no obvious strong or weak year classes evident from the annual age distributions, suggesting fairly consistent recruitment.

Growth rates for both walleye and smallmouth bass were above the statewide average (Figure 9). On average, age 4 Lake St. Clair walleye were 65 mm larger than the statewide average. For smallmouth bass, Lake St. Clair fish averaged 20 mm larger than the statewide average.

Lake St. Clair muskellunge were growing at or near the statewide average for most ages (Figure 10), but dipped below statewide average for ages 9 and 10. Northern pike were growing well above statewide average (Figure 10). Age 4 northern pike were an average of 130 mm longer than the statewide average.

The other major predator species captured in the Lake St. Clair trap net survey was channel catfish. Channel catfish caught in the survey trap nets ranged from 381 – 864 mm in total length (Figure 11), with 27% exceeding the Michigan Master Angler entry criteria of 686 mm. Although ages were not determined for channel catfish, the high proportion of large individuals in the population suggests that Lake St. Clair channel catfish were experiencing fast growth or high survival rates.

Rock bass were the most abundant species captured in the survey trap nets in Lake St. Clair, with over 8,000 fish captured and measured. Rock bass ranged in total length from 102 – 279 mm (Figure 12). Fish over 203 mm in total length accounted for 67% of the catch.

Smallmouth Bass and Walleye Tag Recapture

Commercial and sport fishermen caught and reported a total of 143 tagged walleye from the Anchor Bay site from 2002 through 2006 (Table 13). The majority of the tag recoveries reported came from anglers. The number of tag recoveries reported ranged from a low of 9 in 2005, to a high of 40 in 2003. Overall, 15% of tagged walleye at large from 2002 to 2006 were reported recovered.

Sport fishermen caught and reported a total of 54 tagged smallmouth bass from the Anchor Bay site from 2002 through 2006 (Table 13). The number of tag recoveries reported ranged from a low of 1 in 2005, to a high of 25 in 2006. Overall, only 3.1% of all tagged smallmouth bass at large from 2002 to 2006 were reported recovered.

The geographical distribution of walleye and smallmouth bass tag recoveries differed markedly. Walleye recoveries were reported from as far south as Lake Erie and as far north as Lake Huron (Figure 13). Smallmouth bass recoveries all came from Lake St. Clair and the St. Clair River. (Figure 14). We compared the areal distribution and tagging statistics of walleye tag recoveries within Lake St. Clair from fish tagged in Michigan waters of Lake Erie with those tagged in Anchor Bay of Lake St. Clair (Figure 15). We combined recapture data for walleye tagged at our Monroe site on Lake Erie and Huron River site since they are close together and appear to behave in a very similar way. We assumed that the distribution and extent of fishing pressure in Lake St. Clair was identical for walleye tagged in the two water bodies. Analyses of the size at tagging (Anchor Bay mean length 493 mm; Lake Erie 496 mm) and the calendar day of angler capture (Anchor Bay calendar day 196; Lake Erie 197) showed that they were not significantly different in their distribution and extent of fishing vulnerability. Figure 15 clearly shows that distributions of the two tag recovery groups were very different and that walleye tagged in Lake Erie tended to move straight through the middle of Lake St. Clair or were caught in Ontario waters of Lake St. Clair. Anchor Bay tagged fish were captured by anglers primarily in Anchor Bay. A non-parametric test of the two spatial distributions (Mardia 1967) showed that their centroids were significantly different (Mardias U =39.18, P = 0.000). It was possible that the tagging location was affecting these results so we sorted out the recaptures taken during the first post-tagging year and reran the analyses. Angler recaptures from walleyes tagged more than one year previous showed a greater separation in Lake St. Clair (Figure

16) so we feel confident that walleye tagged at these sites behave differently in Lake St. Clair. Another explanation is that we have tagged different spawning stocks of walleye in Anchor Bay compared to fish tagged in Michigan waters of Lake Erie.

Catch Rates from Angler Diaries

The four primary species sought by anglers participating in the angler diary program were walleye, yellow perch, smallmouth bass, and muskellunge. During the 5 years of this study, diary program participants reported results from 5,059 trips on Lake St. Clair targeting those species. In general, the total number of trips reported each year declined as angler participation declined and new angler recruitment slowed. On an annual basis, the greatest effort was directed at walleye, followed by yellow perch, muskellunge, and smallmouth bass (Table 14).

While there were no consistent trends in catch rates across the 5 year study period for any of the four major species, there were several interesting patterns. Walleye catch rates were lowest in 2004, but increased by almost 3-fold in 2005, and remained high in 2006, as the strong 2003 walleye cohort entered and dominated the fishery. The lowest yellow perch catch rate was also recorded in 2004, and increased by 50% in 2005, and was the highest for the study period in 2006. Muskellunge catch rates increased slightly from 2002 to 2004, then declined slightly in 2005 and 2006.

The muskellunge and smallmouth bass fisheries were largely catch-and-release, with 99% of all muskellunge and 90% of all smallmouth bass released. In contrast, walleye anglers harvest the majority of their catch, with less than 20% of the walleye caught each year released, except for 2005, when 53% of the walleye caught were released. Similarly, yellow perch anglers harvested 60% to 70% of the perch they caught, except for 2005 and 2006, when they released about 50% of the catch. These high release rates are attributed to high catches of small or sub-legal size fish resulting from the strong 2003 cohorts for both walleye and yellow perch.

Aquatic Plant Survey

A total of 96 stations were sampled with plant hook and hydroacoustics during the five year period from 2003 through 2007. There were a total of 247 station visits during the five year span with the following numbers each year; 44 in 2003, 30 in 2004, 55 in 2005, 43 in 2006, and 75 in 2007. Figure 17 shows locations of stations with number of years each one was sampled. All plant hook sampling and hydroacoustic transect data were compiled and summarized for this report.

Hydroacoustic data files were analyzed with EcoSAV software producing tabular summaries of geographic coordinates, water depth, plant height, and plant coverage for each GPS signal. Total wet weights for all plant species were calculated from the hook data. Since these data were very intensive within the hectare sample area and hectares widely separated, all data were loaded into Surfer software to generate densely packed and evenly spaced grid estimates using a kriging algorithm for each of the variables of interest. The gridded data were used to generate contour maps that clearly showed spatial differences in depth and plant community. Several of the contour maps only show information from four years, 2004 through 2007, because hydroacoustic equipment was updated in 2004 and we questioned whether acoustic information was being collected differently. Figure 18 contains generalized water depth contours showing that the lake is deepest (over 6 m) in the center of the main basin and quite shallow throughout relative to the rest of the Great Lakes. In recent times the entire lake with the exception of the dredged navigation channel probably had enough light penetration to the bottom to support submerged plant growth. The overall mean secchi depth was 1.95 m excluding stations where the secchi disk was visible on bottom. The plant species distribution map (Figure 19) shows that submerged plants were present over most of the lake during some portion of the five year period.

Four species (muskgrass, wild celery, Richardson's pondweed, and common naiad) dominated the submerged macrophyte community making up approximately 75% of the total wet weight sampled (Table 15). The remaining species contributed relatively small portions to total weight except for the group labeled unidentified filamentous algae (mostly Cladophora sp.) which made up over 7% of the total. Contour maps of wet weight from hook sampling were generated for these major species to show their areal distribution (Appendices 2-6). The maximum number of species collected at a station was 13 and the mean number was 4.87 (Table 16). Annual mean wet weights per hook toss values ranged from a low of 0.18 kg in 2003 to a high of 0.35 kg in 2006 (Table 16; Figure 20). The mean number of species per station varied across years from a low of 4.16 in 2003 to a high of 5.83 in 2004.

The hydroacoustic analyses from the combined five-year dataset allowed mapping of plant cover (Figure 21), plant wet weight (Figure 22), plant height (Figure 23)., and percent of water column in plant canopy (Figure 24). Seven areas of the lake with relatively high plant cover were designated with circles numbered from 1-7 (Figure 21). Submerged plant areas labeled 2 and 5 had the greatest percent cover, wet weight, plant height, and plant canopy volume. We also looked for changes between stations and years by comparing percent of total hook sample weight at frequently visited stations. The location of twelve plant stations sampled each of five years is shown in Appendix 7. These stations were available for sampling each year because they were close to the boat launch facility and were positioned along the lee shore which allowed sampling during relatively poor weather. Bar charts were created comparing annual percentages for each station to aid in these comparisons, (Appendices 8-19).

Discussion

Yellow Perch and Other Forage Species

Yellow perch abundance was consistently high in trawls in June and low in September. These changes likely have little to do with seasonal changes in lakewide abundance, but more to do with the spatial distribution patterns of yellow perch in Lake St. Clair and their vulnerability to capture as their behavior changes. We suspect yellow perch are closely associated with submerged aquatic macrophytes in September, and are largely inaccessible to survey trawls, which are ineffective in sampling fish from dense macrophyte beds. In fact, the highest catches of yellow perch in the September index trawls were often taken in tows that also collected a large quantity of aquatic plants. Also, anglers consistently reported good perch fishing in association with macrophytes in September over the course of this study.

Yellow perch exhibited highly variable recruitment during this study. Age 0 catch rates from September index trawls suggested that the 2003 year class was much stronger than any other cohort in the study period. Combined age-specific catch rates for ages 1 and older from the June index trawls in 2004, 2005, and 2006 also indicated the 2003 cohort was exceptionally strong in Lake St. Clair. Yellow perch recruitment was also strong in Lake Erie (Belore et al. 2007) and Saginaw Bay (Fielder and Thomas 2006) in 2003. Similarities in recruitment patterns between Saginaw Bay and Lake St. Clair/Lake Erie suggest regional climatic conditions may play an important role in yellow perch reproductive success. However, other factors can also be involved. In the case of Saginaw Bay in 2003, record year-class indices for both walleye and yellow perch have been attributed to an absence of adult alewives, following the lakewide collapse of the Lake Huron alewife population (Fielder et al. 2007).

Young yellow perch (ages 1 – 3) appear to be growing slightly faster during the study period (2002-2006) compared with the previous 5 year period (1997-2001). Thomas and Haas (2004) reported that the diet of Lake St. Clair yellow perch was dominated by the large burrowing mayfly (Hexagenia spp.). Qualitative observations during recent summers at Lake St. Clair suggest that the abundance of another large burrowing mayfly (Ephemera spp.) has increased in recent years and may be providing an enhanced food resource for young yellow perch (M.V. Thomas, personal observation). However, no improvement in growth for yellow perch age 4 or older was apparent. With a diverse and abundant forage fish community present in Lake St. Clair (Thomas and Haas 2004), factors involved in slow growth for older yellow perch remain undetermined.

Lake Huron alewives use connected shallow, nearshore waters, such as Saginaw Bay and Lake St. Clair, for spawning and nursery habitat. The alewife population in Lake Huron crashed in 2003 and has remained at extremely low levels of abundance (Schaeffer et al. 2007). Consequently, trawl catches of age 0 alewives in index trawls in Anchor Bay have declined to near zero since 2003. Absence of age 0 alewives from the lake may have implications for other Lake St. Clair fish populations. First, alewives were an important diet item for Lake St. Clair walleye prior to the collapse (Thomas and Haas 2004), so walleye foraging behavior in Lake St. Clair could change. Second, age 0 alewives may compete with other planktivorous species or planktivorous early life stages of other fish species. With less competition for limited planktonic food resources, growth and survival of other planktivorous fish species could increase. We suspect the pronounced increase in emerald shiner densities in Lake St. Clair index trawls since 2004 is an example of such a response.

Thomas and Haas (2004) attributed a general decline in abundance of johnny darter, logperch, and trout-perch in Lake St. Clair to competitive interactions with the exotic round goby. Round gobies can be aggressive competitors with small native benthic fishes (Janssen and Jude 2001; French and Jude 2001; Dubs and Corkum 1996; Jude et al. 1995). Index trawl catches since 2002 suggest that logperch densities in Lake St. Clair have recovered, and trout-perch densities were improving as well. However, johnny darter densities remain extremely low. Similarly, the colonization of Saginaw Bay by round gobies was coincident with a dramatic decline in johnny darter catch rates in survey trawls (Fielder and Thomas 2006). In fact, no johnny darters were captured in Saginaw Bay survey trawls from 2003 through 2007 (MDNR, unpublished data), raising the possibility that johnny darters have become locally extinct in Saginaw Bay. We anticipate that similar declines in less common darter species (such as the eastern sand darter, channel darter, and river darter) in Lake St. Clair are likely and could result in local extinction of populations of those species which are listed as threatened or endangered by the State of Michigan.

The densities of age 0 largemouth bass in September index trawls has been elevated since 1999. This trend matches a drop in Lake St. Clair water levels below the long-term mean for the first time in roughly 30 years (Figure 25). Largemouth bass prefer to spawn in shallow, warm waters (Heidinger 1975; Nack et al. 1993). Low water levels in Lake St. Clair since 1999 have likely resulted in habitat changes benefiting largemouth bass, such as warmer water in nearshore areas promoting earlier spawning and a longer growing season for juveniles. Additionally, shallower waters in the numerous canals along the shoreline may have promoted increased aquatic macrophyte growth, providing enhance shelter and foraging habitat for juvenile largemouth bass.

Smallmouth Bass

Previous research on Lake St. Clair smallmouth bass indicated that June water temperatures greater than 15 ^{0}C promoted better spawning success and year-class strength (Bryant and Smith 1988). Similarly, warmer summer water temperatures have been linked to stronger year classes in other waterbodies including eastern Lake Ontario (Casselman et al. 2002), eastern Lake Erie (Einhouse et al. 2002), and the Sylvania Lakes in the Upper Peninsula of Michigan (Clady 1975). From 2002 to 2006, we found age 0 smallmouth bass densities and mean length at age were variable in Lake St. Clair, with no apparent statistical relationship. Catch rates for adult smallmouth bass in the survey trap nets suggested that the 1998 year class was the strongest recruited to the survey gear between 2002 and 2006. Although densities of age 0 smallmouth bass were rather low in the 1998 index trawls, the mean length for age 0 smallmouth bass was the second highest of the time series, just slightly smaller than the highest mean length achieved by the 2005 cohort. Larger age-0 bass in the fall experience greater overwinter survival rates than smaller age-0 fish (Gutreuter and Anderson 1985, Ludsin and DeVries 1997, Garvey et al. 1998), presumably because they have greater energy stores needed for overwinter survival, and thus contribute the most individuals to the newly formed year class (Pine et al. 2000). If mean length of age 0 smallmouth bass is a good indicator of year class strength, the 2005 cohort should recruit to the survey trap nets as a strong age 3 cohort in 2008.

Smallmouth bass catch rates in the index trap nets were generally lower from 2002 to 2006, than during trap net surveys in the late 1970s and mid-1980s on Lake St. Clair (Bryant and Smith 1988). These data would suggest that smallmouth bass abundance at the Anchor Bay trap net site was lower during the recent time period. However, other factors could also have been involved. For example, with increased water clarity, smallmouth bass could have been more efficient at avoiding entrapment in the survey nets. Similarly, lower water levels could have resulted in shifts in smallmouth bass spawning locations and associated movement patterns that reduced catches at the Anchor Bay index trap net area.

A diet study in 2000 and 2001 documented that Lake St. Clair smallmouth bass were preying extensively on the exotic round goby (O'Keefe 2003). While sample sizes were limited, our results indicated that smallmouth bass in Lake St. Clair continued to forage on round goby, but also included a variety of other fish species such as gizzard shad, spottail shiner, trout-perch, and yellow perch. Interestingly, invertebrates such as crayfish and burrowing mayflies were conspicuously absent from smallmouth bass stomachs during this survey period. Crayfish have been reported as an important component of smallmouth bass diet in many other locations (Frey et al. 2003; Olson and Young 2003; Weidel et al. 2000; Zimmerman 1999). In addition to limited numbers of stomachs examined, samples were only collected during June and September. Crayfish may be an important diet component for smallmouth bass in Lake St Clair during other times of the year. Crayfish are present in Lake St. Clair and represent a large portion of the diet for rock bass (O'Keefe 2003).

Smallmouth bass spawning is known throughout the nearshore waters of Lake St. Clair (Goodyear et al. 1982). Based on tag recoveries, smallmouth bass caught in the Anchor Bay index trap nets tended to remain in Anchor Bay or move into the St. Clair River channels. Since smallmouth bass fishing is well known in the Ontario waters of the lake, this tag recovery pattern suggests minimal mixing between smallmouth bass spawning in the Anchor Bay area and those spawning in the Ontario waters of the lake. A previous tagging study on Anchor Bay smallmouth bass also indicated a similar movement pattern was prevalent (Bryant and Smith 1988).

Bryant and Smith (1988) reported that 20.9% of the 2,323 smallmouth bass tagged from 1981-1983 were reported recovered. Their study included reward tags to decrease angler non-reporting of tagged fish. In contrast, our study did not include reward tags, and only 3.1% of all tagged smallmouth bass at large from 2002 to 2006 were reported recovered. Based on creel survey data for Lake St. Clair from 2002 to 2004 (MDNR unpublished data), anglers released over 90% of the smallmouth bass they caught each year. We suspect that this pervasive practice of catch and release among smallmouth bass anglers resulted in non-reporting of many tagged fish because anglers don't see the jaw tag, or do not want to stress the fish by taking the time to read the tag. Recent changes to the MDNR tagged fish webpage request anglers that practice catch and release to quickly, but carefully, remove the tag with needlenose pliers for later reporting. We are hopeful that this will improve tag reporting rates by non-harvest anglers.

Walleye

Walleye are a major species in the sport fishery in the Great Lakes waters of Southeast Michigan, and one of the most sought-after species in the Lake St. Clair open water fishery. While adult walleye were commonly encountered in net surveys on Lake St. Clair, age 0 walleye have been consistently absent from MDNR trawl surveys conducted since 1996 (Thomas and Haas 2004). Trawl surveys have been used effectively to monitor age 0 walleye abundance in the western basin of Lake Erie (Thomas et al. 2007) and in Saginaw Bay, Lake Huron (Fielder and Thomas 2006). We submit that complete absence of age 0 walleye from Lake St. Clair index trawls since 1996 is strong evidence that very few or none are produced by walleye spawning in the waters of Lake St. Clair, the St. Clair River, or any of the Michigan or Ontario tributaries. Perhaps the most important implication is that the sport fishery for walleye in Lake St. Clair is largely dependent on immigration of fish from Lake Erie. While walleye from Saginaw Bay are also known to contribute to the sport fishery in Lake St. Clair and the connecting channels, tag recovery distributions suggest such movements are fairly uncommon (Fielder and Thomas 2006).

Age distributions for walleye caught in the Anchor Bay index trap nets from 2002 to 2006 clearly illustrated an exceptionally strong 2003 year class and exceptionally weak 2000 and 2002 year classes. This pattern matches age 0 walleye trawl indices for Lake Erie walleye recruitment very well (Thomas et al. 2007). In fact, the 2003 walleye cohort in Saginaw Bay was also exceptionally robust (Fielder and Thomas 2006).

Walleye diet was less diverse than smallmouth bass diet in Lake St. Clair from 2002 to 2006. While alewives were the dominant forage fish species in the walleye diet, none were found in walleye stomachs after 2002. In fact, the walleye diet was more diversified and included forage fish (emerald and spottail shiners, as well as yellow perch) and burrowing mayfly nymphs after 2002.

A general pattern of increasing error around the mean lengths at older ages was apparent for walleye, and also for smallmouth bass, muskellunge, and northern pike (Figures 9 and 10). Several factors can contribute to this type of pattern. Differences in growth rates between males and females become more pronounced at older ages, leading to greater variance around the mean. Errors in age determination also increase with increased age and further add to variance around the mean. Finally, sample sizes generally decrease for older ages, leading to further increases in variance.

We compared the areal distribution and tagging statistics of 143 walleye tag recoveries from the Anchor Bay tagging site in Lake St. Clair. About half of the angler recaptures were north, or upstream, of the Anchor Bay tag location suggesting that walleye intercepted at that location are equally likely to spend time up or downstream. Anchor Bay tagged walleye were recovered by anglers in the St. Clair River (26.57%), Lake St. Clair (58.74%), Detroit River (13.29%), and Lake Erie (1.40%). Within Lake St. Clair, these walleyes showed a strong preference for the Michigan side of the lake (Figure 13).

As part of Federal Aid in Sport Fish Restoration (F-81-R-8) Study 230460, Lake Erie walleye tag data were analyzed to estimate annual rates for tag recovery and survival during the period from 1990 through 2006. Walleye tag and recovery data from the Ohio, Ontario, and Michigan surveys covered the period from 1990 through 2006. Analysis of the combined data produced an estimate for mean annual survival of 63.2% and mean recovery rate of 3.29%. These values, adjusted by a reward/non-reward ratio of 2.73 (Thomas and Haas 1999) were used to estimate instantaneous natural mortality (M). An exploitation estimate of 9.0% was generated by expanding mean recovery rate (3.29%) by the non-reporting rate (2.73). The resulting value for M was 0.35. We assumed that these values were appropriate surrogates for the Anchor Bay tagged population since some portion belonged to Lake Erie spawning populations and the others were living under very similar habitat conditions.

We analyzed angler tag recoveries to determine the contribution of different marked walleye populations to the Lake St. Clair sport fishery. Figure 26 shows the geographic location of all tagged walleye populations that eventually contributed to angler harvest in Lake St. Clair. The numbers shown by each tag site indicate the site-specific recovery rate (%) within Lake St. Clair. Thirteen of the Lake Erie tag sites produced walleye harvest in Lake St. Clair with the major sites being the Huron River, off the mouth of the Raisin River, Maumee River, and Sugar Rock.

Other Major Predator Species

A self-sustaining muskellunge population (believed to be the endemic Great Lakes strain of muskellunge) has supported an extensive sport fishery in Lake St. Clair for more than 50 years. During this survey, we found mature, ripe muskellunge were fairly common in the open waters of Anchor Bay, Lake St. Clair. Ripe females were captured throughout the month of May, and even as late as June 11, in

2003, when the survey period was delayed due to vessel repairs. There was an increase in older aged muskellunge in the trap net catch in 2005 and 2006. We suspect this is an artifact of the change from scales to fin ray sections for age determination. Other studies have found age determination for muskellunge using fin ray sections improved accuracy over determination based on scales, particularly for older fish (Fitzgerald et al. 1997; Brenden et al. 2006). We found muskellunge less than age 6 were rarely caught in the survey trap nets. We suspect the lack of young muskellunge in the catch is a result of spatial distribution of young, immature fish during the spawning season, rather than a sign of limited recruitment.

Among the five trap net sites in Anchor Bay, the majority of the spawning female muskellunge were caught at the two southern-most sites. Further investigation of the physical conditions at those net sites could provide additional details on the habitat characteristics of spawning sites for Great Lakes muskellunge in Lake St. Clair. Factors such as substrate type and aquatic plant abundance would be useful features to quantify. Measurement of egg densities and larval survival would also be informative.

Emerging diseases have been an issue for the Lake St. Clair muskellunge population in recent years. In 2003, muskellunge with external sores were found to be infected with a Piscirickettsia sp., an intercellular species of bacteria that can cause damage to kidneys and other tissues. A rhabdovirus was found in muskellunge sampled in 2004, 2005, and 2006 which was identified as Viral Hemorrhagic Septicemia (VHS) virus (Elsayed et al. 2006).

Muskellunge mortality events were evident on Lake St. Clair and the Detroit River in the spring of 2003 and 2006. Both years, numerous dead muskellunge were observed by anglers and agency personnel during April and May. In 2003, most of the dead muskellunge appeared to be larger and presumably older fish. Based on field observations, the 2006 die-off included a wider size/age range of muskellunge. Despite repeated efforts by MDNR personnel to collect samples fresh enough for laboratory analyses, only 1 sample fresh enough to permit laboratory testing was collected. That sample, collected in 2006, tested positive for both viral hemorraghic septicemia virus and Piscirickettsia spp. bacterial infection. Consequently, the individual roles of Piscirickettsia sp. and VHS virus in the observed mortality episodes could not be isolated.

Despite what appeared to be substantial muskellunge mortality events in 2003 and 2006, there was no obvious trend in muskellunge catch rates in the Anchor Bay trap net survey between 2002 and 2006. In fact, the muskellunge catch per net lift and catch per 24 hours fished in 2007 was essentially unchanged from 2006 (MDNR, unpublished data). This could be an indication that muskellunge abundance changed little between 2006 and 2007. However, we also recognize the possibility that the MDNR trap net survey in a localized area of Anchor Bay, during spawning season, may not provide a representative picture of the overall abundance of muskellunge across Lake St. Clair. In contrast, angler diary catch rates for muskellunge declined by about 40% between 2006 and 2007, suggesting muskellunge density was lower after the 2006 mortality event (Thomas and Haas 2008).

Muskellunge populations in inland waters are sometimes negatively impacted by northern pike populations. A common observation in many lakes is that if northern pike were introduced into an area formerly occupied by muskellunge, muskellunge abundance became reduced or eliminated, while northern pike flourished (Inskip 1986). Various factors in this negative relationship have been speculated including the timing of spawning, as well as rapid early growth and consumption of young muskellunge by northern pike (Diana 1995). Unlike those waters, Lake St. Clair has supported viable, self-sustaining populations of northern pike and muskellunge for many decades. Researchers have hypothesized that spatial or temporal segregation limits competitive interactions between northern pike and muskellunge in waterbodies supporting sympatric populations. During this study, we documented spatial and temporal overlap of muskellunge and northern pike spawning in Lake St. Clair was occurring on a limited basis. Farrel et al. (1996) found similar overlap between St. Lawrence River muskellunge and northern pike populations. This overlap of spawning could result in natural hybridization between the two species, producing the hybrid “tiger muskellunge”. In fact, anglers have reported catching several fish in recent years with patterns of coloration that match those described for muskellunge x northern pike hybrids by Casselman et al. (1986). Low water levels may be a factor in shifting the spatial distribution of northern pike from shallow nearshore beds of emergent vegetation to more off-shore beds of submergent vegetation. This would effectively increase the spatial overlap of spawning between the two species and possibly increase the frequency of natural hybridization.

Large channel catfish were common in the trap net catch during this survey. Conversely, small or juvenile catfish were absent from both the trap net survey and the trawl survey during this same time period. The same gears capture both juvenile and adult catfish during MDNR surveys on Lake Erie and Saginaw Bay, suggesting that densities of young channel catfish in Lake St. Clair are comparatively low. Therefore, we suspect that the Lake St. Clair channel catfish population is characterized by low recruitment, low exploitation, high survival, and dominated by old fish. It is also possible that the channel catfish population in Lake St. Clair is maintained by emigration of fish from other locations, such as Lake Erie. Creel surveys on Lake St. Clair from 2002 to 2005 documented low angler interest in fishing for channel catfish, and average annual harvest of less than 800 fish (MDNR unpublished data). We view this as further evidence that exploitation is likely quite low for channel catfish in Lake St. Clair.

Lake St. Clair channel catfish have been included in various consumption advisories for many years as a result of chemical contamination. In 2007, Lake St. Clair channel catfish over 457 mm total length were listed under consumption advisories by the Michigan Department of Community Health due to elevated levels of PCBs. Consumption advisories can affect angler behavior, reducing or redirecting fishing activity and harvest (Jakus et al. 1997; Burger 2004). Consumption advisories could be a factor in the apparent lack of interest in channel catfish fishing and harvest on Lake St. Clair. However, the abundance of “trophy” sized channel catfish in trap nets in Anchor Bay during May indicates that a “trophy” catch-and-release fishery could be supported by the population.

Fish Species Diversity

In combination, sampling with trap-nets and trawls in Anchor Bay, from 2002 to 2006, captured 38 fish species. In comparison, a lakewide trawl survey from 1996 to 2001, captured 62 fish species in Lake St. Clair (Thomas and Haas, 2004) including 37 of the species found during this study. Bowfin was the only new species recorded during the 2002 to 2006 survey period. Twenty-four species captured in the lakewide trawl survey were not collected in the more recent time period. Most of those species were uncommon or rare in the earlier survey and many were only found in nearshore sampling which was not part of the 2002 to 2006 survey.

No new invasive aquatic fish species were collected during the 2002 to 2006 trawl or trap net surveys. Meanwhile, alewife, an invasive species that has been present in the Great Lakes for over 5 decades, has become practically extirpated from Lake Huron and Lake St. Clair. Ironically, researchers have hypothesized that the alewife population collapse in Lake Huron is linked to food web changes driven by exotic zebra and quagga mussels (Hecky et al. 2004). Within Lake St. Clair and the rest of the Great Lakes, the ecological impacts of invasive aquatic species continue to unfold (Leach et al. 1999).

Catch rates from angler diaries

Our data did not reveal consistent trends in catch rates for any of the four primary species (walleye, yellow perch, smallmouth bass, and muskellunge) sought by sport anglers in Lake St. Clair. Walleye catch rates were lowest in 2004, corresponding with the lowest estimated abundance of age 2 and older walleye in Lake Erie since 1978 (Thomas et al. 2007). The strong 2003 year class of walleye in Lake Erie contributed to the sport walleye harvest in Lake St. Clair in 2005, as age 2 fish, but many were below the minimum size limit (330 mm or 13 in.), so anglers released 53% of the walleye caught in 2005.

Muskellunge catch rates were on a slightly declining trend from 2004 to 2006. Given the recent history of muskellunge mortality events and disease issues in Lake St. Clair, this warrants further monitoring. Participation by muskellunge anglers in the diary program has waned in recent years and efforts to bolster it should be considered.

A carefully designed creel survey can provide fisheries managers with accurate estimates of sport fishing effort, harvest, and catch rates. Unfortunately, the extensive size of Lake St. Clair, numerous public and private access sites, and high volume of non-fishing boat traffic combine to make creel surveys of Lake St. Clair both challenging and expensive. As a result, creel survey data for the US waters of Lake St. Clair have been sparse and temporally fragmented. Harvest and effort data for the Lake St. Clair sport fishery was last collected with a full creel survey from spring 2002 to winter 2005 (Thomas and Towns 2011). We elected to use a volunteer angler diary program to provide continuous monitoring of catch rates for the major sport fish species, not as a replacement for a catch survey. We recognize that volunteer angler diary data must be interpreted carefully. Other studies have found that participants in such programs tend to fish more frequently, belong to fishing clubs, and experience higher catch rates than the general fishing public (Bray and Schramm 2001, Prentice et al. 1995). Trends in fish abundance may not be well reflected in catch rates for avid anglers because those anglers are more persistent and effective at catching fish (Baccante 1995). Thus, actual trends in fish abundance may be masked by angler diary catch rates. Because well designed creel surveys randomly sample anglers and provide unbiased lakewide estimates of harvest, effort, and catch rates, we believe an angler diary program is not a valid substitute for full creel surveys for monitoring trends in fish abundance. We believe the greatest value of an angler diary program may lie in the maintenance of a collaborative relationship between ardent anglers and fisheries management professionals.

Aquatic Plants in Lake St. Clair

Enough data on the Lake St. Clair plant community has been collected now to describe its character and content relative to what was historically present and when quantitative sampling began in the late 1970s. A qualitative study of the biology of Lake St. Clair including plants was conducted in 1891. That study reported finding that macrophytes, particularly muskgrass, covered the entire bottom of the lake (Reighard 1894, Pieters 1894). The first comprehensive submerged plant survey was conducted by the U. S. Fish and Wildlife Service's Great Lakes Fishery Laboratory (now United States Geological Survey's (USGS) Great Lakes Science Center) at a number of stations established in 1978 (Schloesser and Manny 1982). At that time, density of the plant community at each station was categorized as "Sparse", "Medium" or "High" based on visual examination of the grapnel samples (Schloesser and Manny 1984). More recently, we collaborated with USGS helping to continue their sampling at all Lake St. Clair stations in 1995 and 2007. It is our intention to use hydroacoustic and plant hook data collected in this study to compare with historical and current USGS results to improve our understanding of species diversity and overall density of the important Lake St. Clair plant community.

We constructed maps that compared plant cover across years (Figure 27) to visually describe the apparent change in plant cover between 1978 and recent years. There were some plants in 1978 in more areas than the map indicates however, their low density did not register at the minimum level chosen to span the entire time period. The 1978 USGS survey of plants showed minimal coverage across the lake with only some inshore areas of Anchor Bay having substantial submerged plant populations. Apparently, the lake and its biological community had undergone significant degradation during the early to middle parts of the 20th century resulting in very turbid water and low colonization by rooted vascular plants and benthic macro-algae. Beginning in the 1980s climate variation and pollution abatement led to environmental changes in Lake St. Clair causing the water to become relatively clear. These changes probably allowed expansion of the plant community which occurred concurrently with significant climatic (drought), environmental (lowered water level), and biological changes (zebra mussel invasion) making it difficult to assign causality to any one. Climate change models for the Great Lakes have predicted that water supply will change enough to lower the lake levels significantly. According to Mortsch et al (2006) climate change models predict that the water level in Lake St. Clair will drop as much as 1.0 m by 2050. Because Lake St. Clair only has an average depth of 4.6 m, it will be particularly affected by such estimated drops in the water level. In some places, considering accuracy of current elevation data, water could recede from the current shoreline by 2 km or more, and the lake's surface area could be reduced by 20 percent.

By 1995, the USGS survey indicated that plants had re-colonized large areas of the lake. Our hydroacoustic surveys from 2003 through 2007 have clearly shown that submerged plants had colonized most of the lake quite possibly at the level observed in the late 1800s. The water level in Lake St. Clair has varied over six feet since continuous record keeping in 1918. Water level was very low in the mid-1960s and rose to all time high levels in the period 1972 through most of the 1990s during which time the plant community apparently recovered. It does not appear the water depth was limiting plant growth.

Aquatic macrophytes are an essential habitat component of lake ecosystems and contribute many benefits to aquatic habitats and biological communities (Wetzel 1975). Natural plant species composition and distribution within lakes are influenced by lake size and depth, wave energy, water currents, ice-scour, bottom slope, sediment composition, and water chemistry and clarity (O'Neal and Soulliere 2006). The massive surface area available for colonization, especially among submersed macrophytes, can result in very high contributions of attached littoral algae to the total primary productivity. When this productivity is coupled with the very high rates prevalent among the emergent macrophytes, the littoral primary productivity can form a major input of organic matter to lake systems. Submerged plants in the littoral zone provide diverse habitats for aquatic invertebrates, and their components are highly important in the overall production and regulation of the lake ecosystem (Wetzel 1975). Even though little herbivory by invertebrates and fish occurs on living submerged plants in Lake St. Clair, the subsequent dead plant material (detritus) supports a major food web for them. In addition, the slow metabolism of detritus provides an inherent ecosystem stability that energetically dampens otherwise short-lived and volatile fluctuations at higher trophic levels (Wetzel 1995).

A study of the invertebrate community inhabiting submerged plants was conducted in Lake St. Clair by Brown et al. (1988). Above ground plant surface area was found to be twice the bottom area occupied by the plants which essentially tripled the total surface available for attachment. Both the abundance and species richness of invertebrates were strongly related to macrophyte species richness reflecting the response of the invertebrates to the structural heterogeneity in taxonomically mixed stands. Vertically heterogeneous stands with an understory of muskgrass and overstory of vascular macrophytes were likely to contain more invertebrates than stands with only one macrophyte taxon. The bottom substrate and topography of Lake St. Clair provides very little physical diversity so aquatic plants provide most of the habitat diversity and structural complexity. Additional habitat diversity provided by plants strengthens this aquatic ecosystem against disturbance which should allow adaptation to long-term change. We found that Lake St. Clair had an average plant coverage of 61.7% and volume of water column in the submerged plant canopy of 11.7% during the period from 2003 through 2007 (Table 16). Generally, conditions for game fish deteriorate when the percentage of a deep water lake that is covered by submerged aquatic plants falls below 10% or rises above 60% (Valley et al 2004).

We found that Lake St. Clair had a wide variety of submerged plant species (22) most of which were native species (Table 15). We also found that submergent plant populations in Lake St. Clair were composed of very diverse native species complexes that vary dramatically between years. At any particular station, there was considerable variation in species biomass between years (Appendices 7-19). Individual stations had very different species mixes even though they were not separated by more than a few kilometers. Exotic species made up only 3.9% of all samples by weight and were found mainly near the mouths of rivers (Figure 28) suggesting that the rivers had degraded the aquatic environment and were possible seed sources. Madsen (1998) documented that Eurasian watermilfoil dominance was inversely proportional to cumulative native plant cover, suggesting the presence of native plants reduces the probability that invasive plants will dominate the littoral zone. Most comparative studies of plant and fish abundance conclude that intermediate vegetation levels, defined as 10-40% coverage, promote high fish species richness and are optimal for their growth and survival (Hestand and Carter 1978, Crowder and Cooper 1979, Wiley et al. 1984, Dibble et al. 1996, Minns et al. 1996, Randall et al. 1996). Cross and McInerny (2006) found that lakes with high frequency occurrences of diverse plant forms had the highest fish catch per effort of valued sport fish, while lakes with sparse monotypic plant cover had the highest catch rates of benthic omnivores such as common carp and black bullhead. Intermediate levels of structural complexity allow juvenile sunfish to forage in vegetated regions on soft-bodied organisms (Mittelbach 1981) and adults to feed in open water on zooplankton (Mittelbach 1988).

In Lake St. Clair fish species richness was highly correlated with macrophyte species richness and surface area and with associated invertebrate species richness (Poe et al. 1986). According to Eadie and Keast (1984), vegetative complexity (plant species diversity) is more important in influencing fish species diversity than the amount of vegetation. We feel that the wide variety of native plant species in Lake St. Clair has been very conducive to support of a healthy and diverse fish community.

Evaluation of Survey Methodology and Survey Performance

Index trawls.–The objectives of the June and September index trawling were to monitor the forage fish community for trends in abundance and to monitor age composition and growth for yellow perch. In general we believe the index trawl survey has been sufficient for meeting those objectives. We have considered reducing the survey to one time period per year, but young-of-year fish are not recruited to the trawl in June and yellow perch are scarce in the index trawl area during September. As a result, eliminating the June or September portion of the survey would result in a failure to meet one of the primary objectives of the survey.

Other value-added benefits of the index trawling effort include collection of contaminant samples when requested by the Michigan Department of Environmental Quality (MDEQ), collection of round gobies used for sturgeon bait in another federal aid study on the St. Clair River, collection of various fish samples for disease investigations as requested, and monitoring for new invasive aquatic species. Trawling at the index site does not provide a comprehensive picture of the Lake St. Clair fish community because many species are nearshore oriented and not sampled by trawling in the index survey area. However a comprehensive lake-wide trawl survey requires substantially increased effort distributed widely across the lake, including nearshore sampling with other gear types (small trawls, electrofishing gear, seines, fyke nets, etc.).

Trap-net survey.–The objective of the May trap net survey was to monitor trends in abundance and age composition of predatory game fish populations in Lake St. Clair, particularly smallmouth bass and walleye. The survey gear and seasonal timing have allowed us to meet the objective. Adequate numbers of smallmouth bass, walleye, muskellunge, and northern pike were collected during May sampling to provide meaningful descriptions of abundance, age distribution and growth rates for those populations. The overlap of muskellunge spawning with the survey period has provided additional opportunities for documentation of muskellunge age at maturity in Lake St. Clair. Tagging efforts for smallmouth bass and walleye have resulted in updated knowledge of movement patterns by those species within the system, as well as estimates of exploitation and survival. Increased numbers of tagged smallmouth bass and walleye could improve estimation of population parameters and better discern movement patterns, but are likely not achievable without increased effort (increased numbers of nets fished) or extending the survey period through May and into June. An extension of the survey into June would result in conflicts with field sampling scheduled for other studies, as well as resulting in increased likelihood of conflicts with recreational boaters. Public education efforts to promote tag reporting among anglers that practice catch-and-release could help reduce non-reporting of tagged smallmouth bass. Boating activity near the trap net sites becomes intense after the Memorial Day weekend in late May.

Other value-added benefits of the trap net survey effort include collection of contaminant samples when requested by MDEQ and collection of various fish samples for disease investigations when requested. In the future, trap net muskellunge catches may contribute to gamete collection efforts for the purpose of establishing a Great Lakes strain muskellunge culture program for the state. The trap net survey also has provided abundance and length frequency data for several other species such as channel catfish, freshwater drum, silver redhorse, and rock bass which are not important species in the sport fishery, but are important ecological components of the Lake St. Clair fish community and are not well sampled by the index trawl survey.

Angler diary program.–The objective of the angler diary program was to provide ongoing estimates of angler catch rates for the major fish species in the recreational boat fishery. Downward trends in angler participation in the diary program could compromise the value of the catch rates. We suggest that efforts to recruit new anglers to the program need to be intensified. To be clear, we believe an angler diary program is in no way a valid substitute for full creel surveys for monitoring trends in fish abundance, fishery participation, or fishery performance. Well designed creel surveys randomly sample anglers and provide unbiased lakewide estimates of harvest, effort, and catch rates. Those data are critical for fisheries management, but expensive to obtain on the St. Clair system. However, we believe it is worth noting that small segments of the sport fishery that are pursued by relatively few anglers, such as muskellunge or sturgeon fisheries for example, can be poorly represented in a general creel survey because they are diluted by the more popular segments of the fishery. In those cases, the angler diary program may provide a better measure of the actual targeted catch rates for the fishery. In any case, we believe the greatest value of an angler diary program may lie in the maintenance of a collaborative relationship between ardent anglers and fisheries management professionals.

Submerged aquatic plant surveys.–The objective of the submerged plant sampling was to monitor trends in populations of vascular plants and macro-algae. One way to track changes is to measure and compare percent cover of the substrate by plants. Review of literature on aquatic plant studies showed that a wide array of techniques have been used ranging from cursory visual estimation while traversing in a boat to various types of rake or hook tosses, to many types of remote sensing. The hydroacoustic survey technique (a form of remote sensing) provided an efficient and highly repeatable measure of plant cover similar in many respects to well established terrestrial plant cover estimators. Hydroacoustic sampling did not provide information on individual plant species, however, it was important to monitor species diversity and potential invasion by exotic plant species. The additional hook sampling at each hydroacoustic station provided data on plant species relative abundance and biomass which allowed tracking of changes in individual plant abundance and diversity.

Fishery Assessment and Management Recommendations

1. A lakewide creel survey should be conducted on Lake St. Clair on a regular basis to monitor changes in the sport fishery related to fish population changes. With careful interpretation, creel survey data can supplement other fish population indices and enable more advanced decision making.

2. Continue the index trawl surveys in June and September to monitor the forage fish community for trends in abundance and to monitor age composition and growth for yellow perch.

3. Continue the trap net survey in May to monitor trends in abundance and age composition of predatory game fish populations in Lake St. Clair, particularly smallmouth bass and walleye.

4. Continue to monitor trends in catch rates for selected species with a voluntary angler diary program. Increase participation in the program with increased out-reach efforts and pursue a web-based version of the program to facilitate wider public participation.

5. Continue hectare sampling with hydroacoustics and plant hook tosses in Lake St. Clair to monitor trends in plant cover and species diversity.

6. Expand inland lake plant surveys using these hydroacoustic and plant hook sampling techniques to include bass regulation study lakes and status and trends lakes. This will improve managers' ability to assess ecological condition and fishery potential.

7. Promote the trophy channel catfish fishing opportunities available in Lake St. Clair for metropolitan anglers.

8. Encourage conservative management of Lake Erie walleye stocks which are the primary component of the walleye fishery in Lake St. Clair and the connecting channels.

Acknowledgments

This study was supported by funds from the Sport Fish Restoration Act. Numerous MDNR employees were instrumental in field collections. Of the MDNR's Lake St. Clair Fisheries Research Station; boat captains Jack Hodge, and Roy Beasley operated the survey vessels and maintained the sampling gear. Ken Koster, Fisheries Research Technician, interpreted all scale and spine samples for ages. Fisheries Assistants Kevin Rathbun and Jeremy Maranowski assisted in field collections, gear maintenance, and scale sample preparation. The angler diary program was a collaborative effort with the Ontario Ministry of Natural Resources and Stan Powell was instrumental in the data management and summarization each winter. Data entry for the diary program was shared among Lake St. Clair Fisheries Research Station employees. Dr. Douglas Hunter, Oakland University, and graduate student, Sarah Cholder-Blust, were very helpful in plant field collections and data analysis. Donald W. Schloesser, U.S. Geological Survey, provided historical plant data. The Macomb County Sheriff dive team, Luke Clyburn, Kathy Trax, and divers from the Great Lakes Division of the U.S. Naval Sea Cadet Corps were instrumental in collecting plant biomass samples. Tom Kalkofen, Macomb County Health Department, and the Water Quality Board provided funding to help support 2007 field work.

Figure 1.–Lake St. Clair is part of the connecting waterway between southern Lake Huron and western Lake Erie.

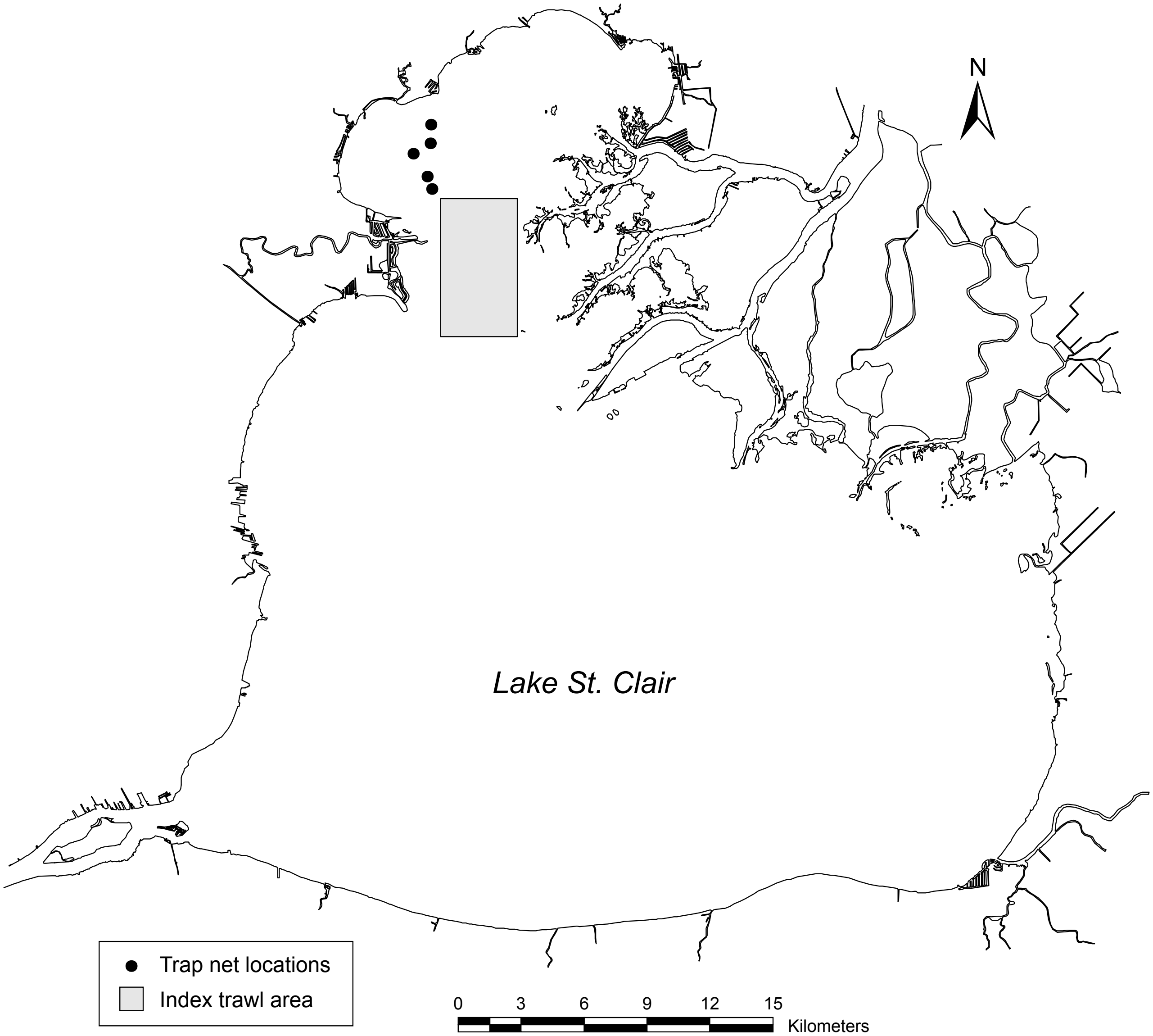

Figure 2.–Map of Lake St. Clair showing area of index trawling (shaded rectangle) and trap net locations (black circles) in Anchor Bay.

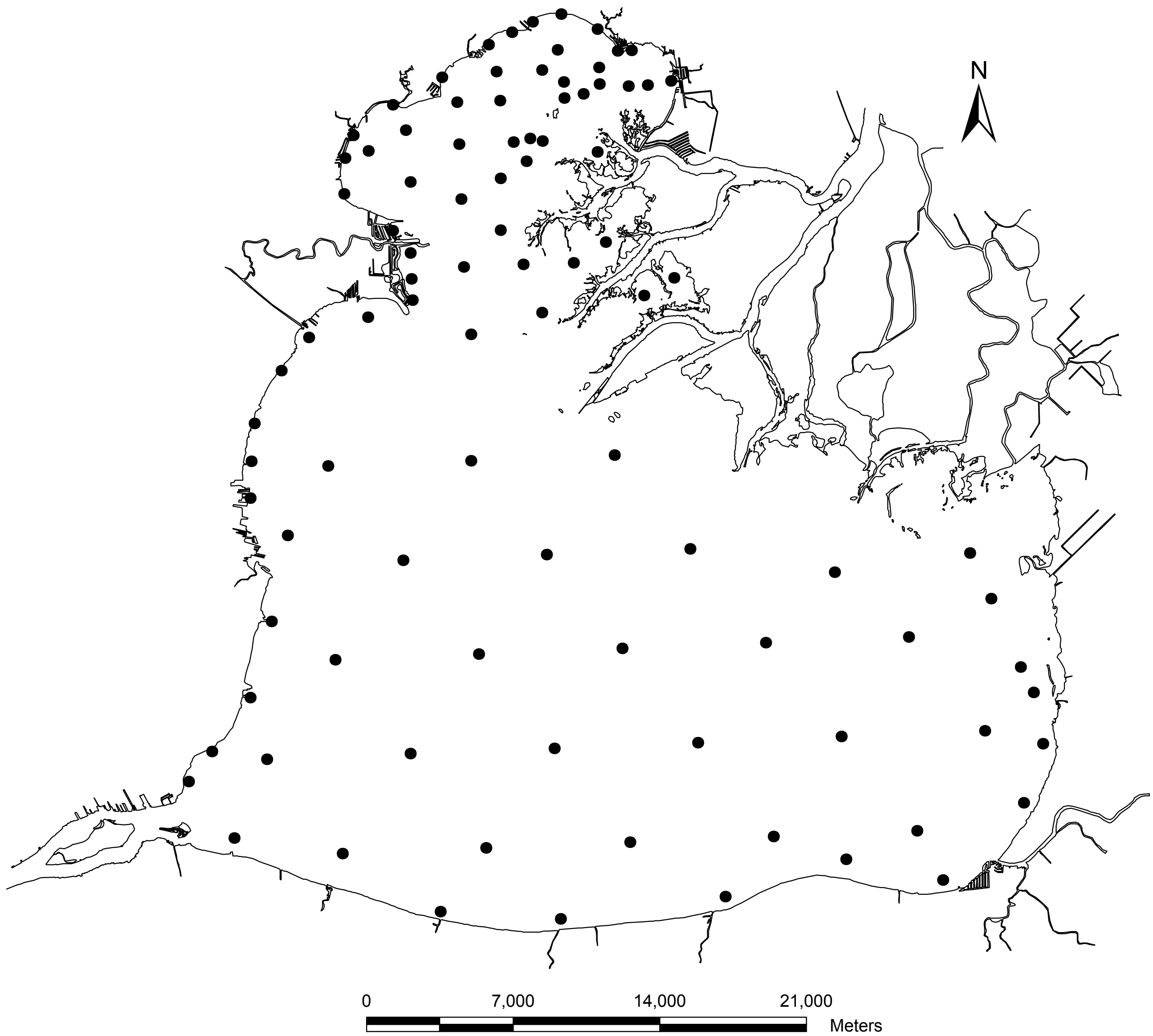

Figure 3.–Map of Lake St. Clair showing aquatic plant sampling locations based on stations established in 1978 plant survey (Schloesser and Manny 1982).

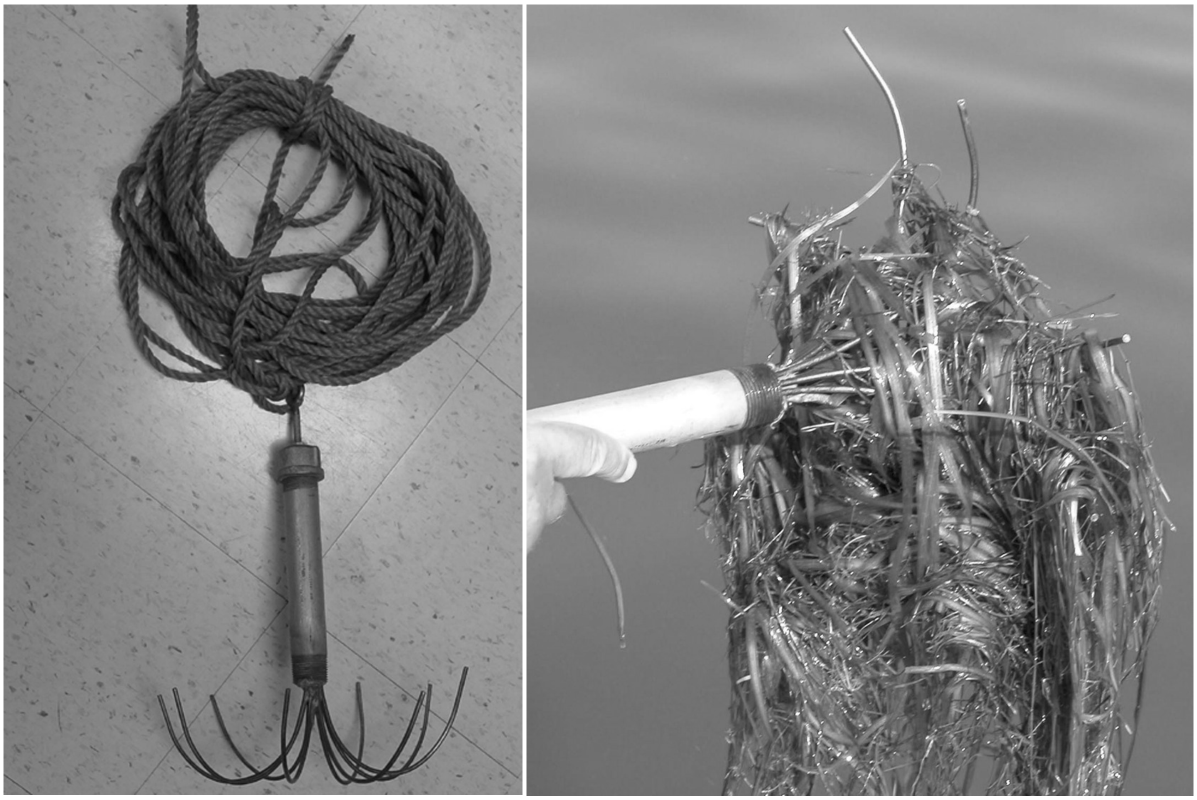

Figure 4.–Photographs of hook designed and constructed to sample submerged plants in Lake St. Clair. Hook was constructed from iron pipe filled with lead and armed with eight tines of steel drill rod.

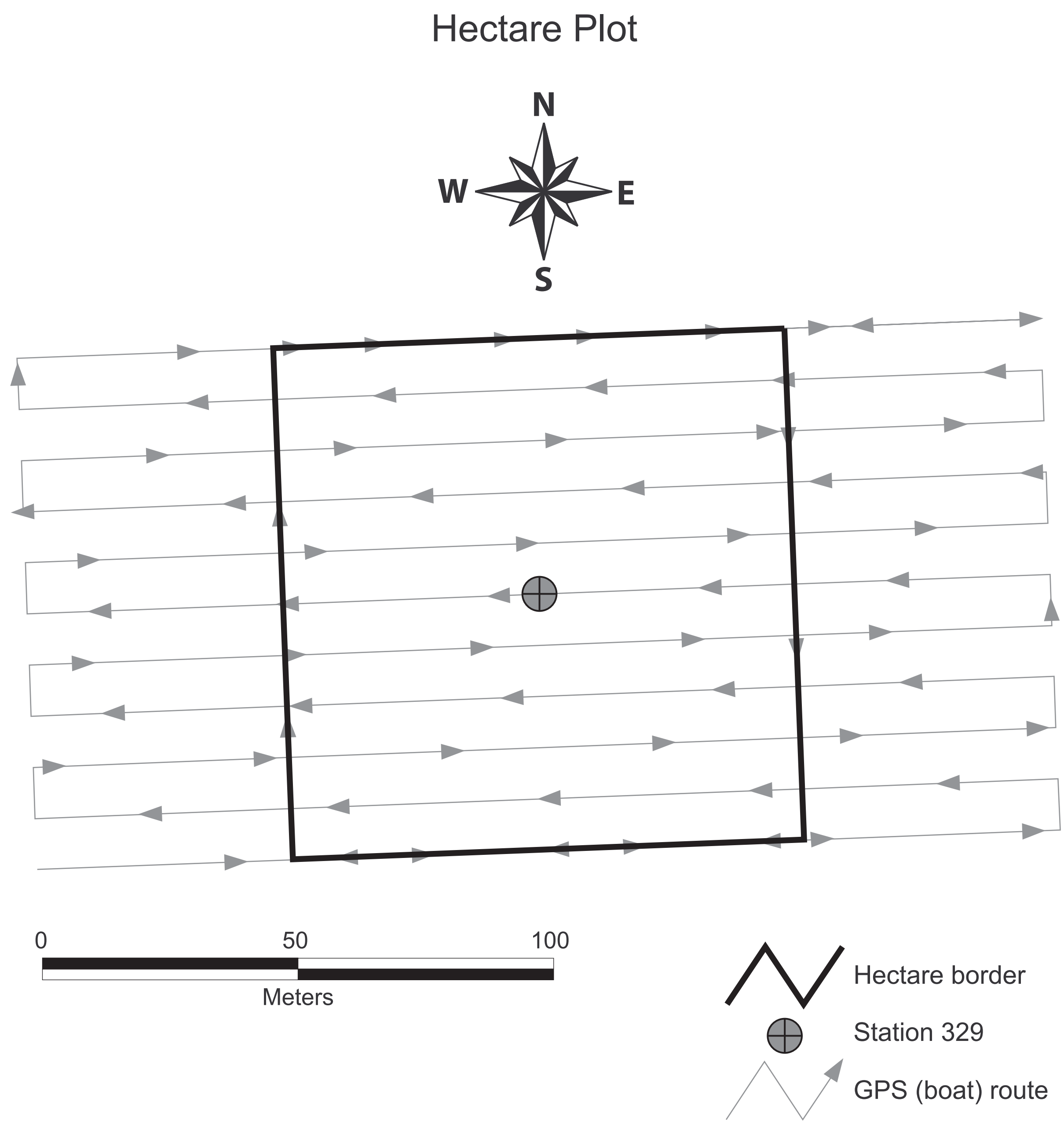

Figure 5.–Example map of hydroacoustic transects over one square hectare spaced 10 m apart and centered on station 329 in Lake St. Clair. Hydroacoustic data were post-processed and clipped to the hectare polygon. Hook tosses were generally made near the center unless plants were only observed near an edge of the square hectare.

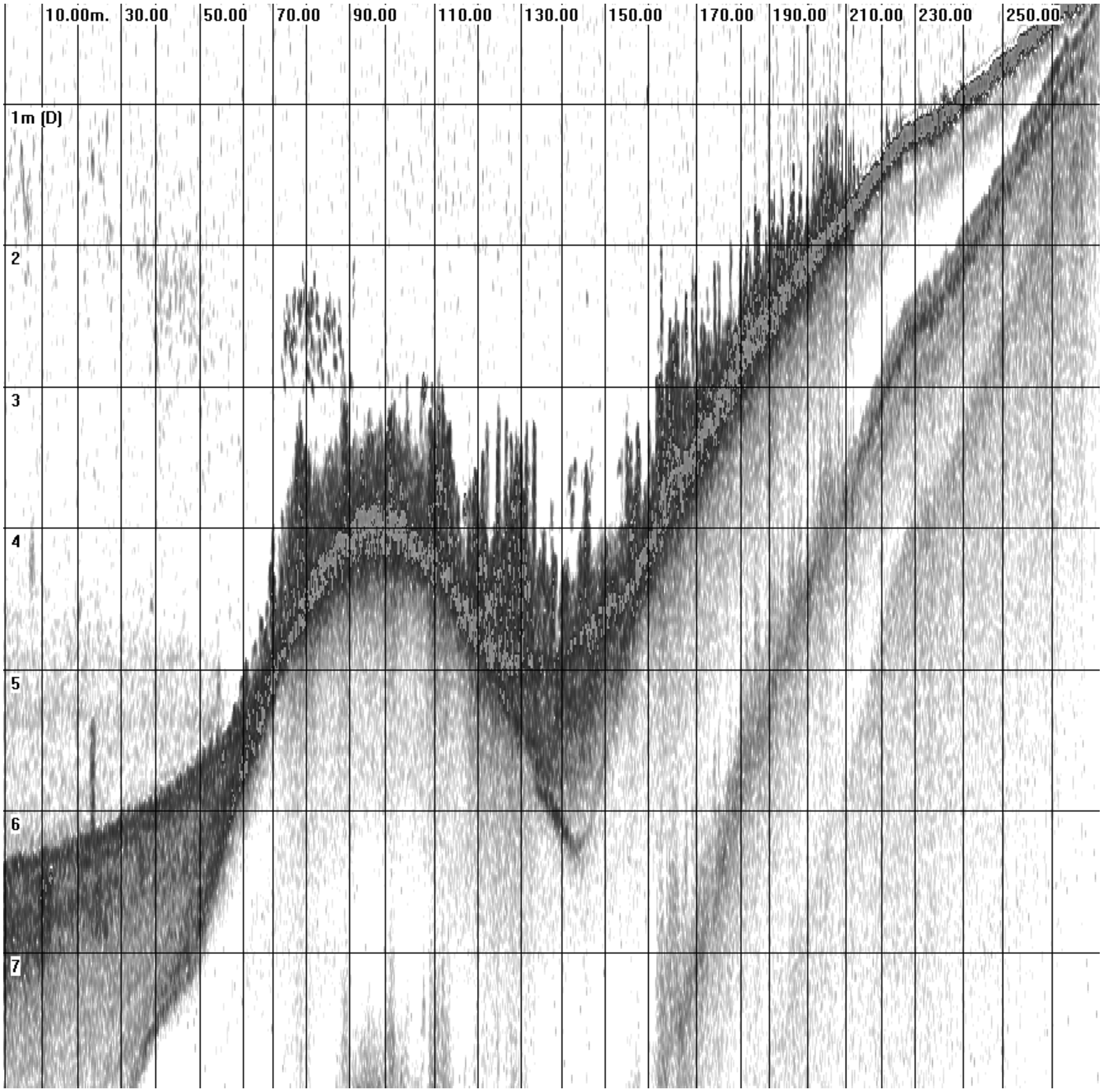

Figure 6.–Example echogram from hydroacoustic data file showing water depth, lake bottom, submerged plants, and school of fish. Plant analysis software extracts geographic position, water depth, plant height, and plant coverage from these hydroacoustic files.

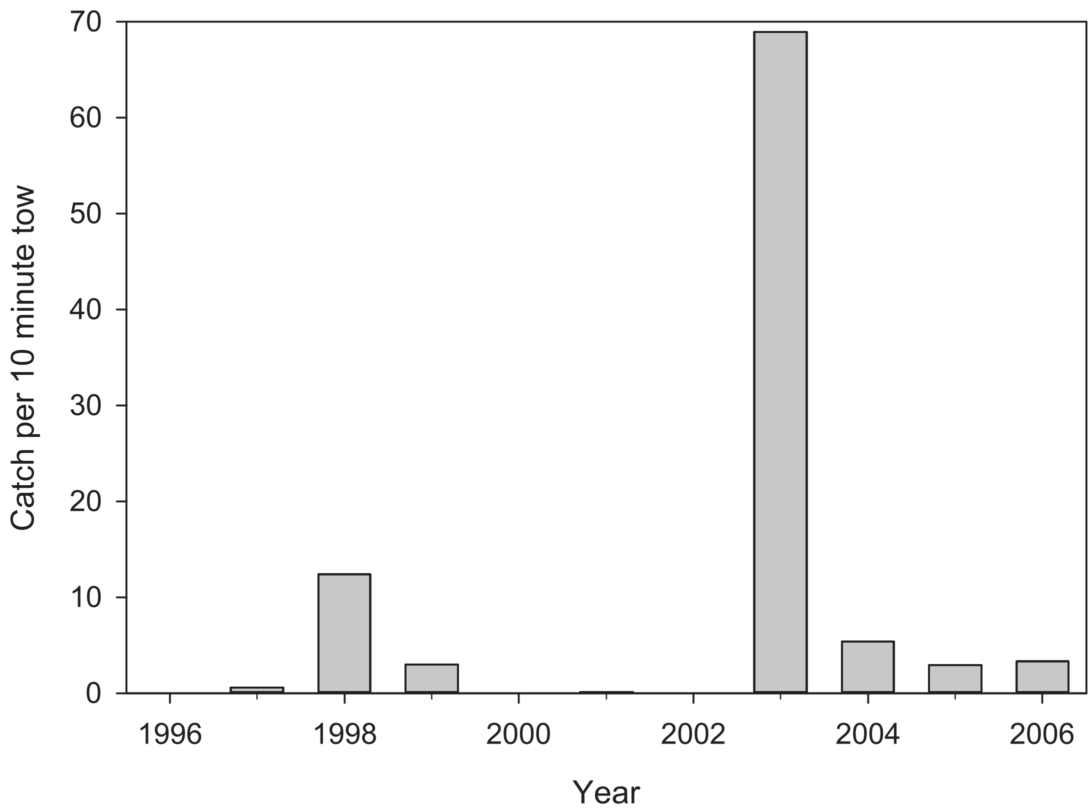

Figure 7.–Catch per 10 minute tow for age 0 yellow perch in September index trawls in Lake St. Clair from 1996 through 2006.

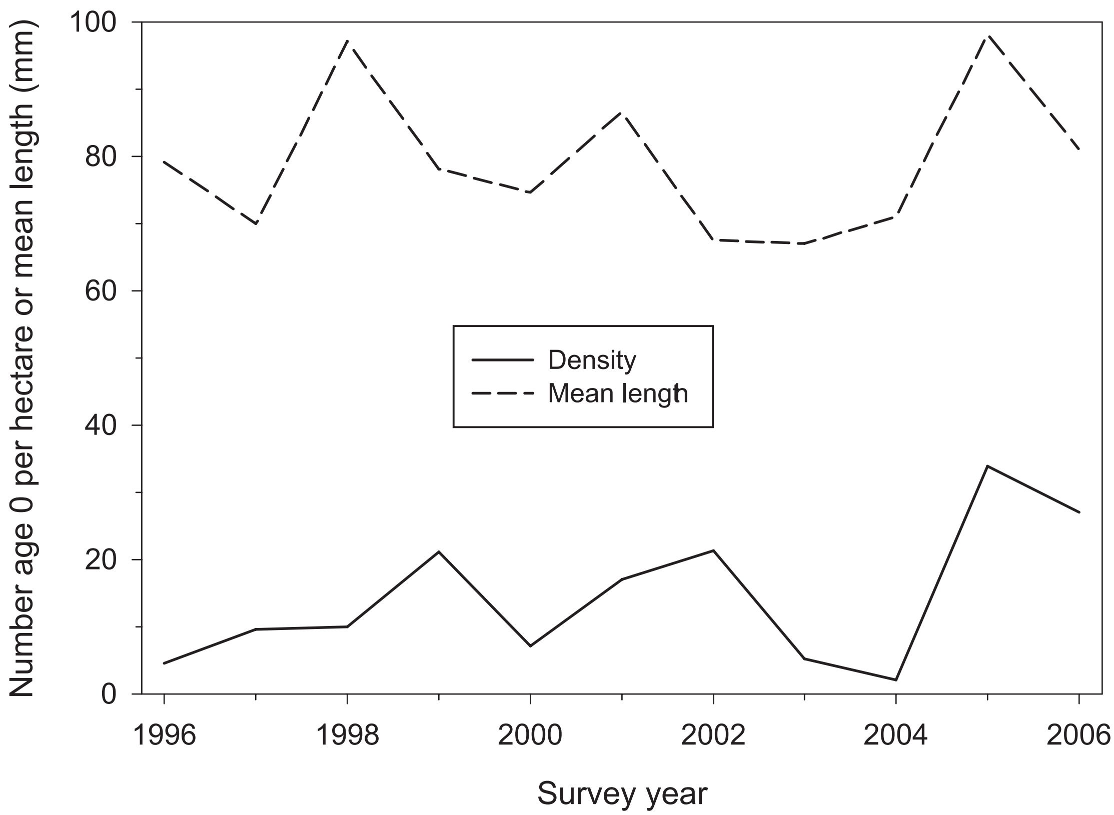

Figure 8.–Densities and mean lengths of age 0 smallmouth bass caught in September index trawls in Lake St. Clair from 1996 through 2006.

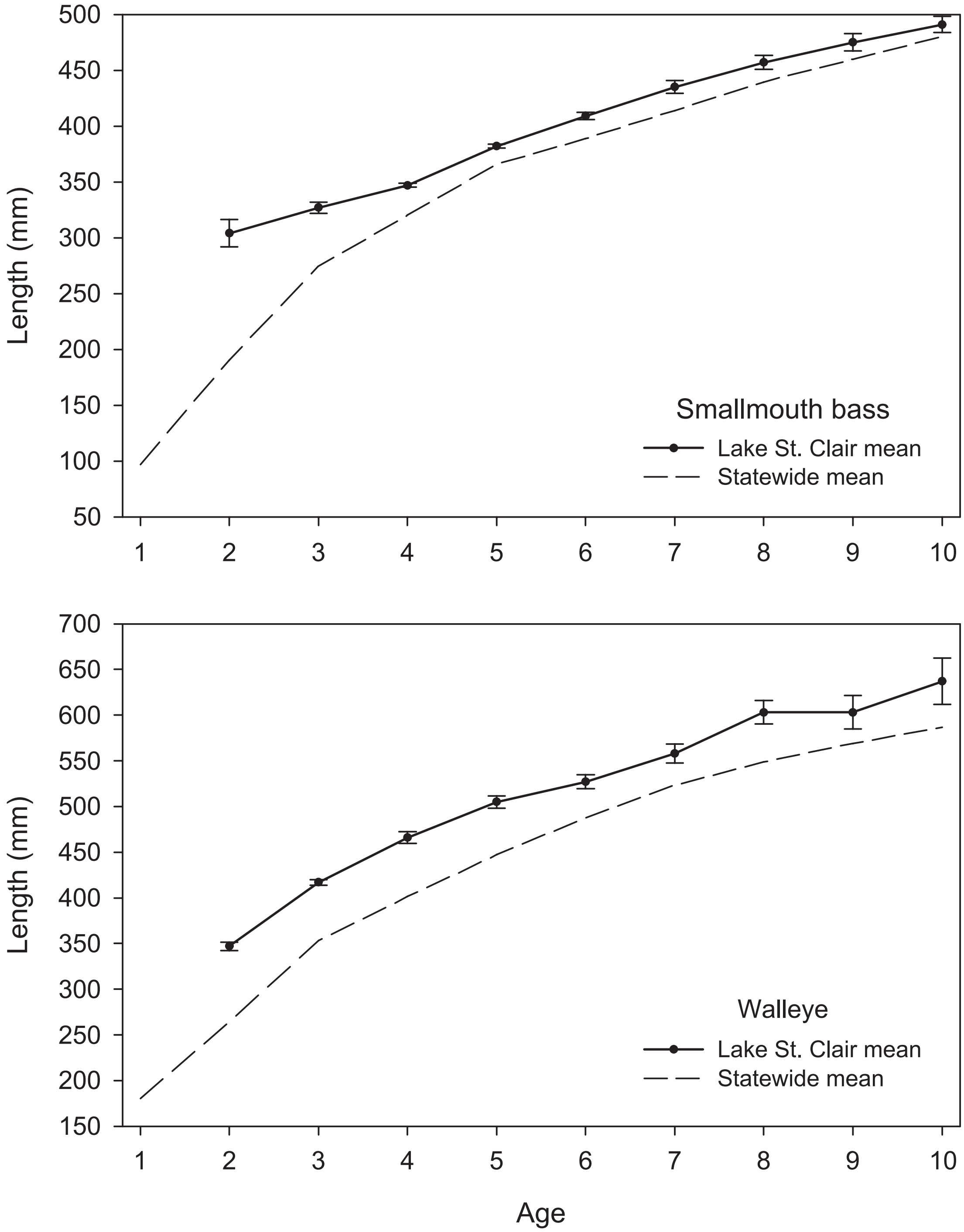

Figure 9.–Mean length at age for walleye (2002-2006) and smallmouth bass (2002-2006) in Lake St. Clair compared with Michigan statewide average lengths for May. Error bars represent 2 standard errors.

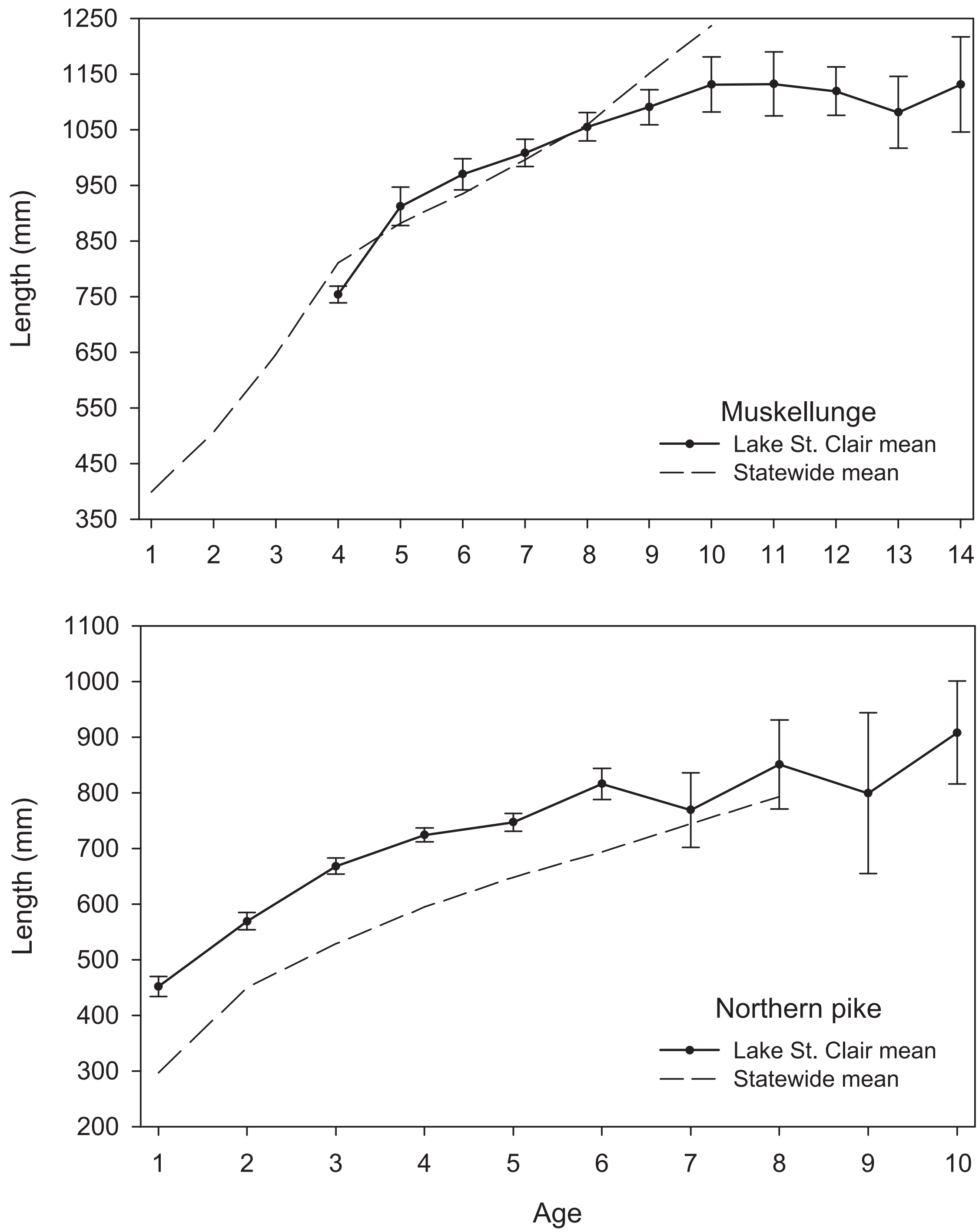

Figure 10.–Mean length at age for muskellunge (2002-2006) and northern pike (2002-2006) in Lake St. Clair compared with Michigan statewide average lengths for May. Error bars represent 2 standard errors.

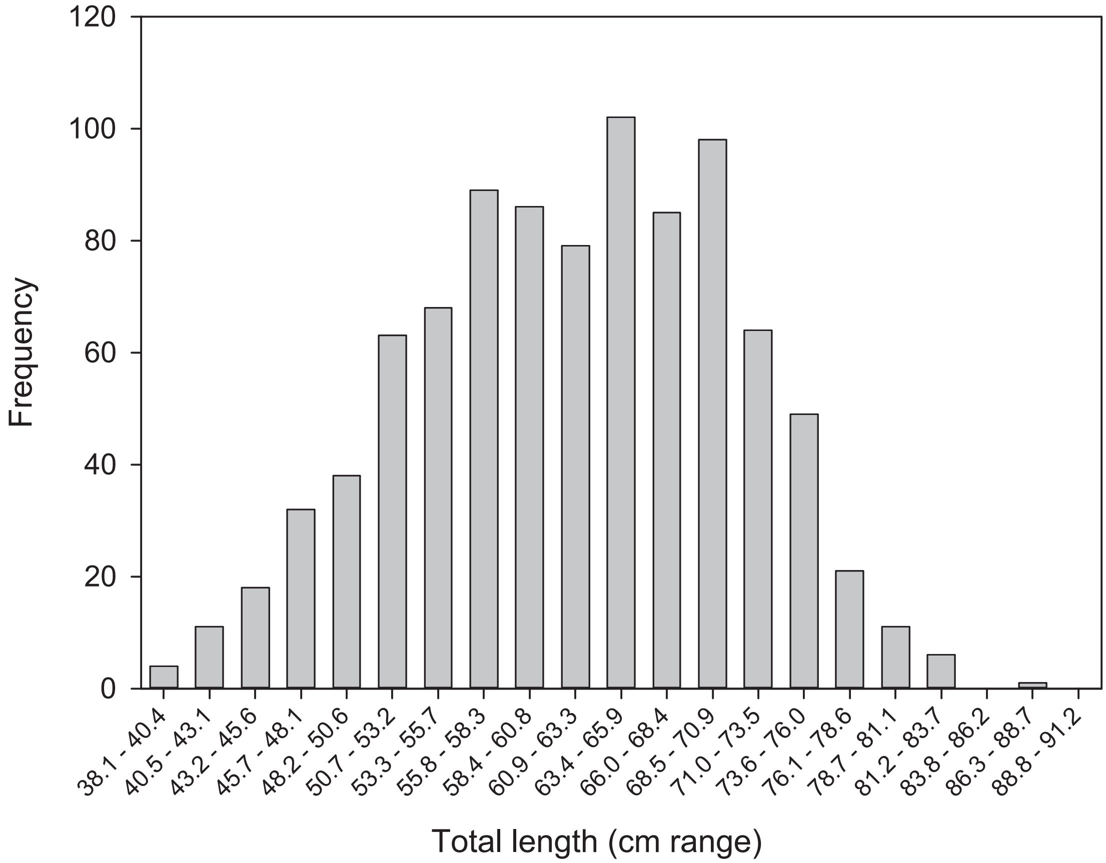

Figure 11.–Length frequency distribution for channel catfish caught in Lake St. Clair survey trap nets from 2002 to 2006 (n=925). Fish were originally tallied by inch group shown here as a centimeter range.

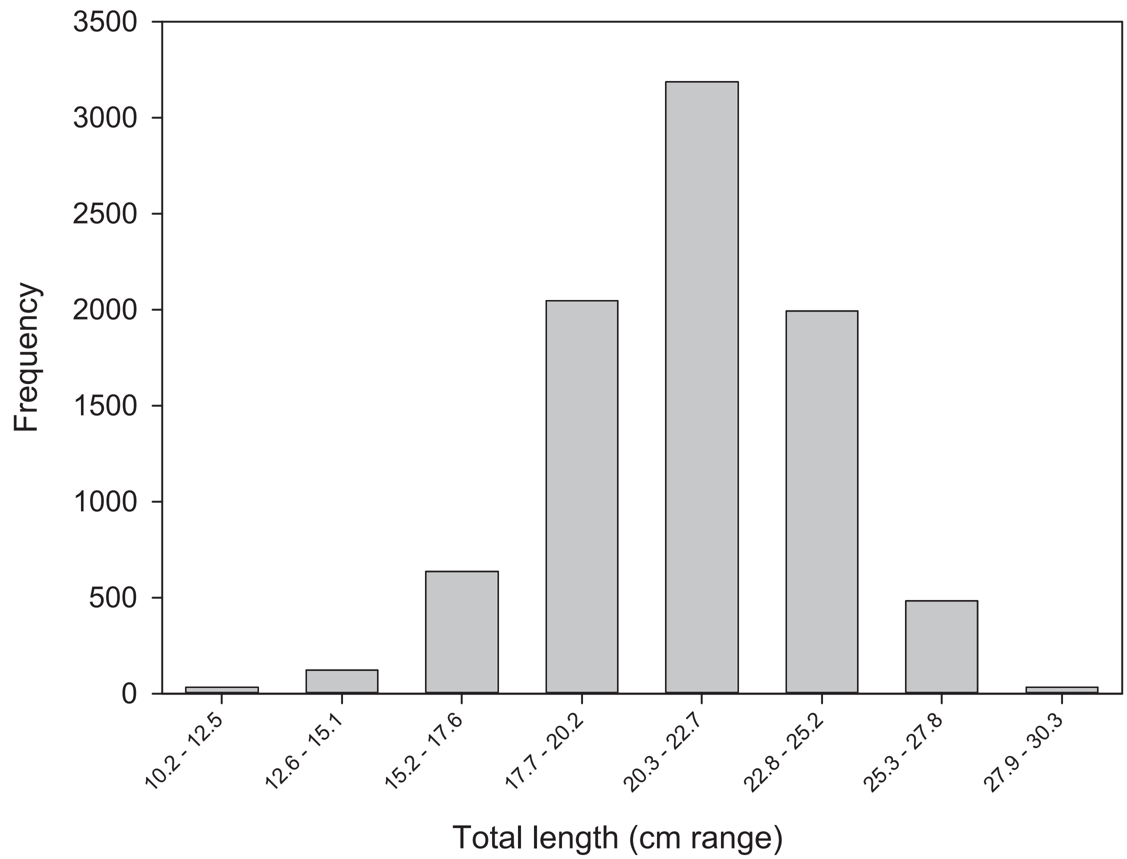

Figure 12.–Length frequency distribution for rock bass caught in Lake St. Clair survey trap nets from 2002 to 2006 (n=8,533). Fish were originally tallied by inch group shown here as a centimeter range.

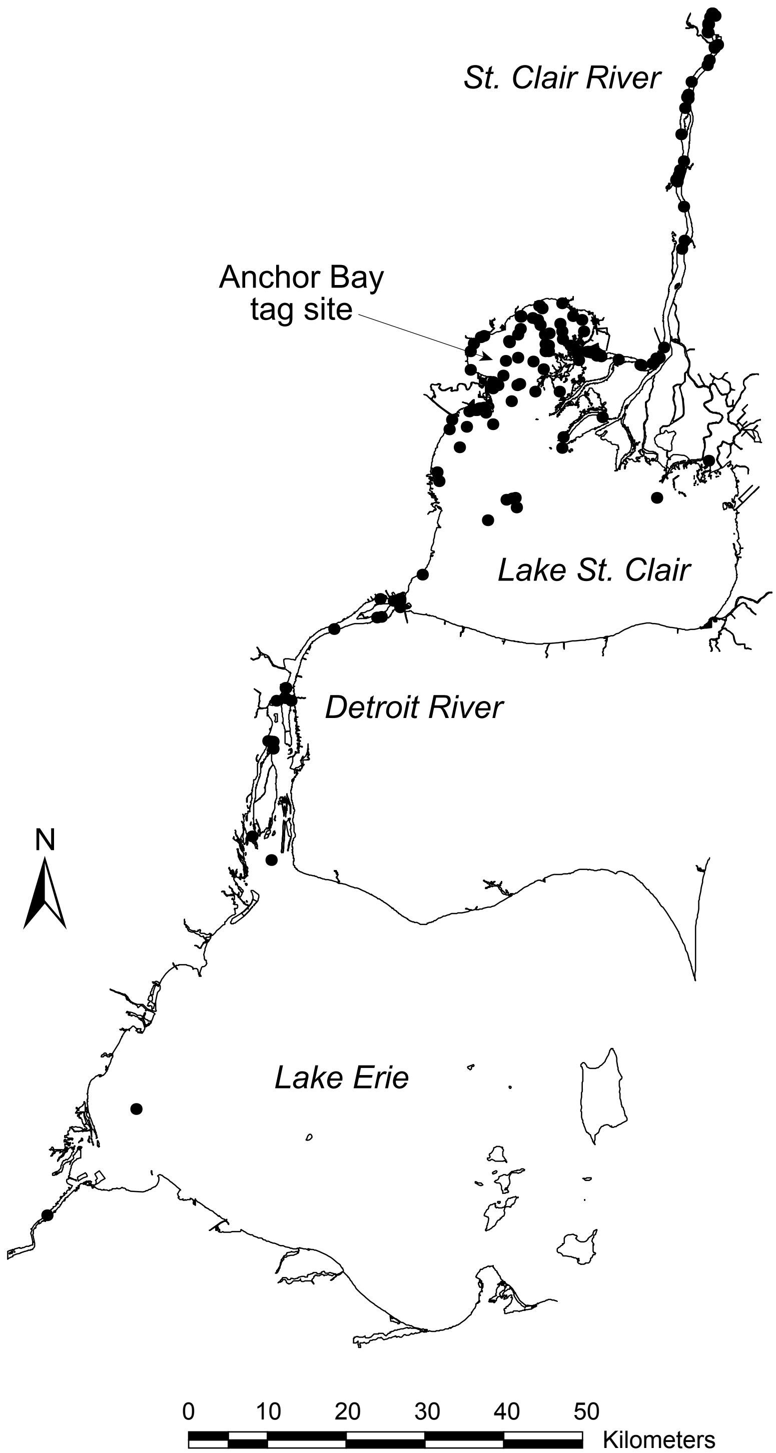

Figure 13.–Map of the geographical distribution of 143 tag recoveries from walleyes caught by anglers and commercial fishermen during 2002–2006. All walleyes were tagged at the Lake St. Clair, Anchor Bay trap-net station during spring.

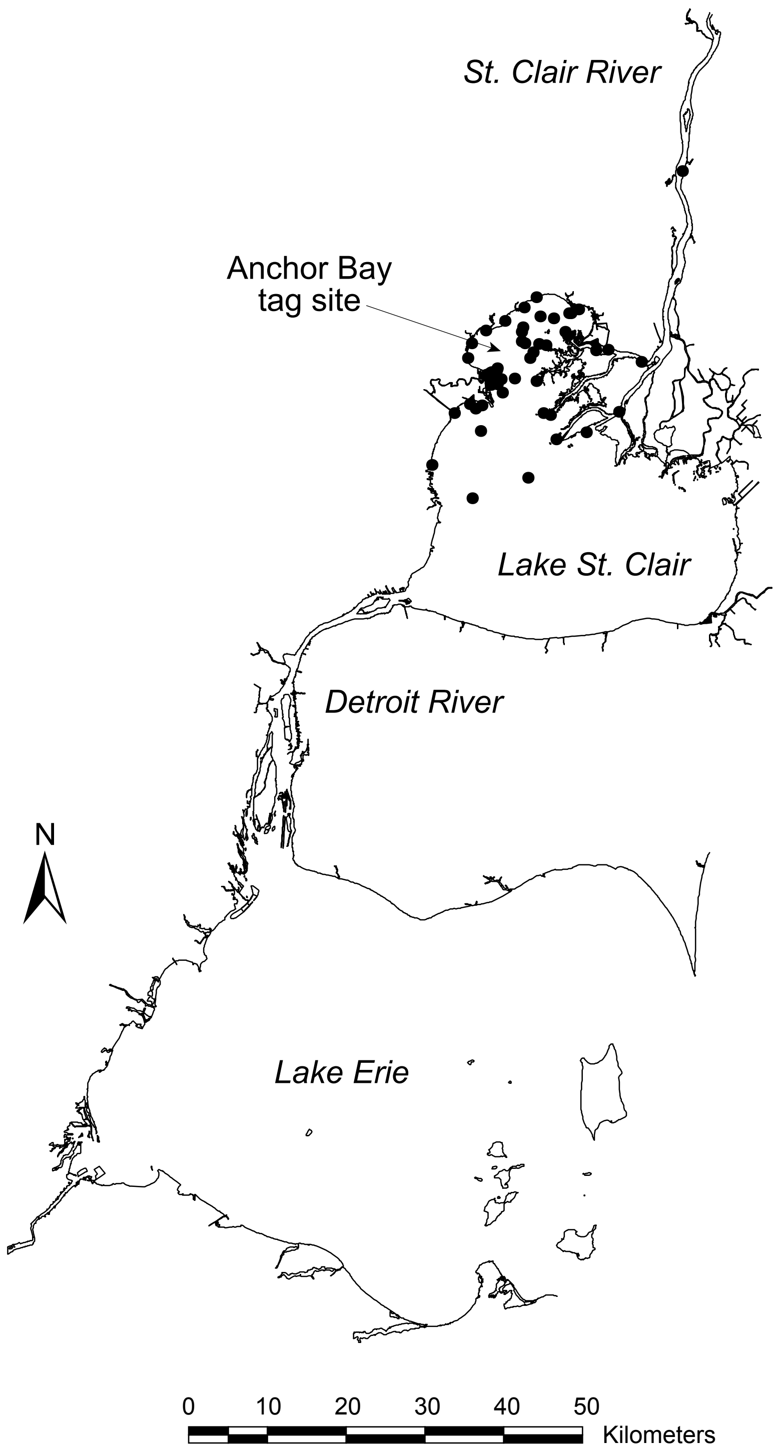

Figure 14.–Map of the geographical distribution of 54 tag recoveries from smallmouth bass caught by anglers during 2002–2006. All smallmouth bass were tagged at the Lake St. Clair, Anchor Bay trap-net station during spring.

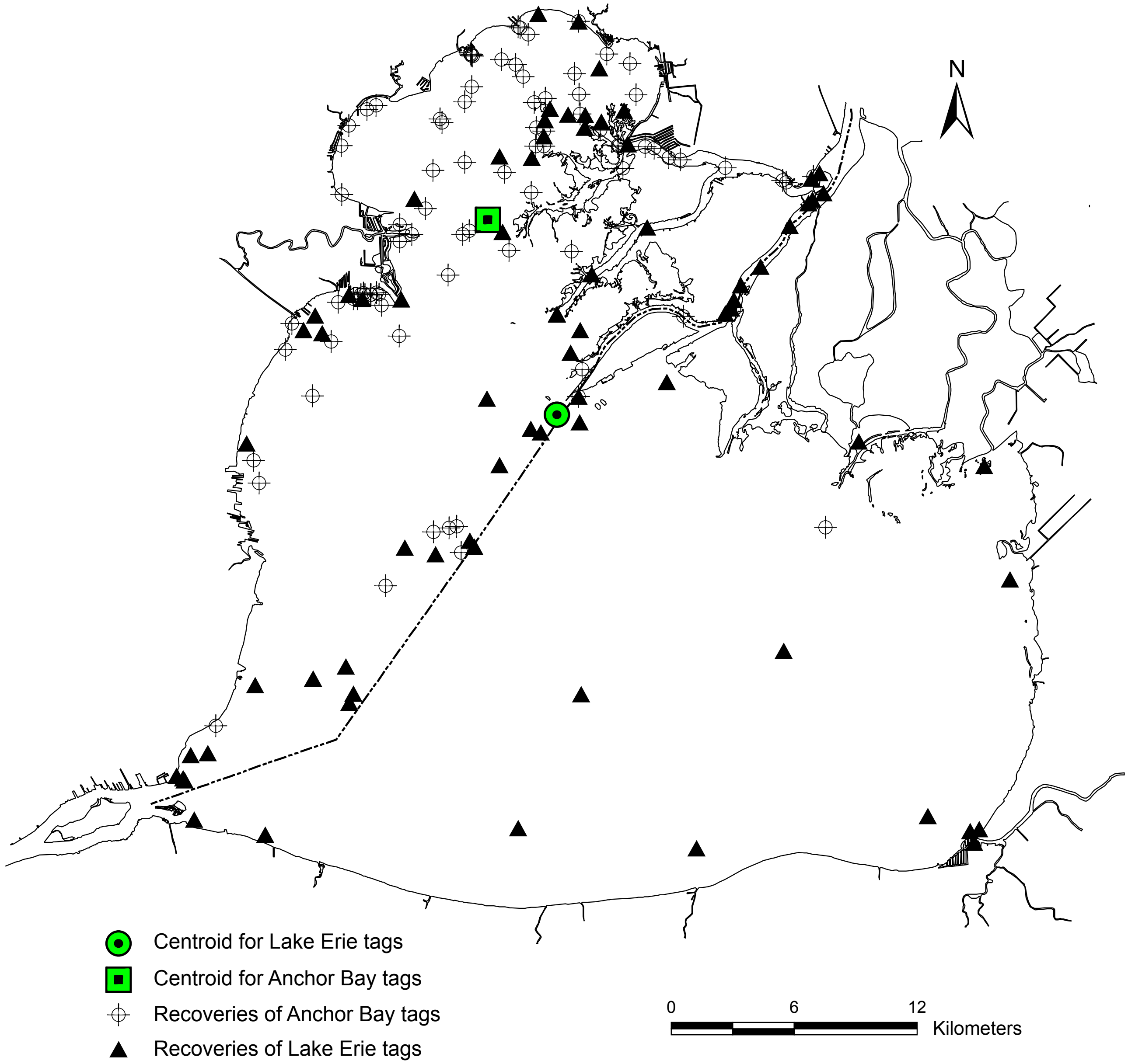

Figure 15.–Map of the geographical distribution within Lake St. Clair for 85 walleye tag recoveries from fish tagged in Anchor Bay and 74 walleyes tagged at two Michigan sites in Lake Erie. All fish were captured by anglers during period from 2002 through 2006.

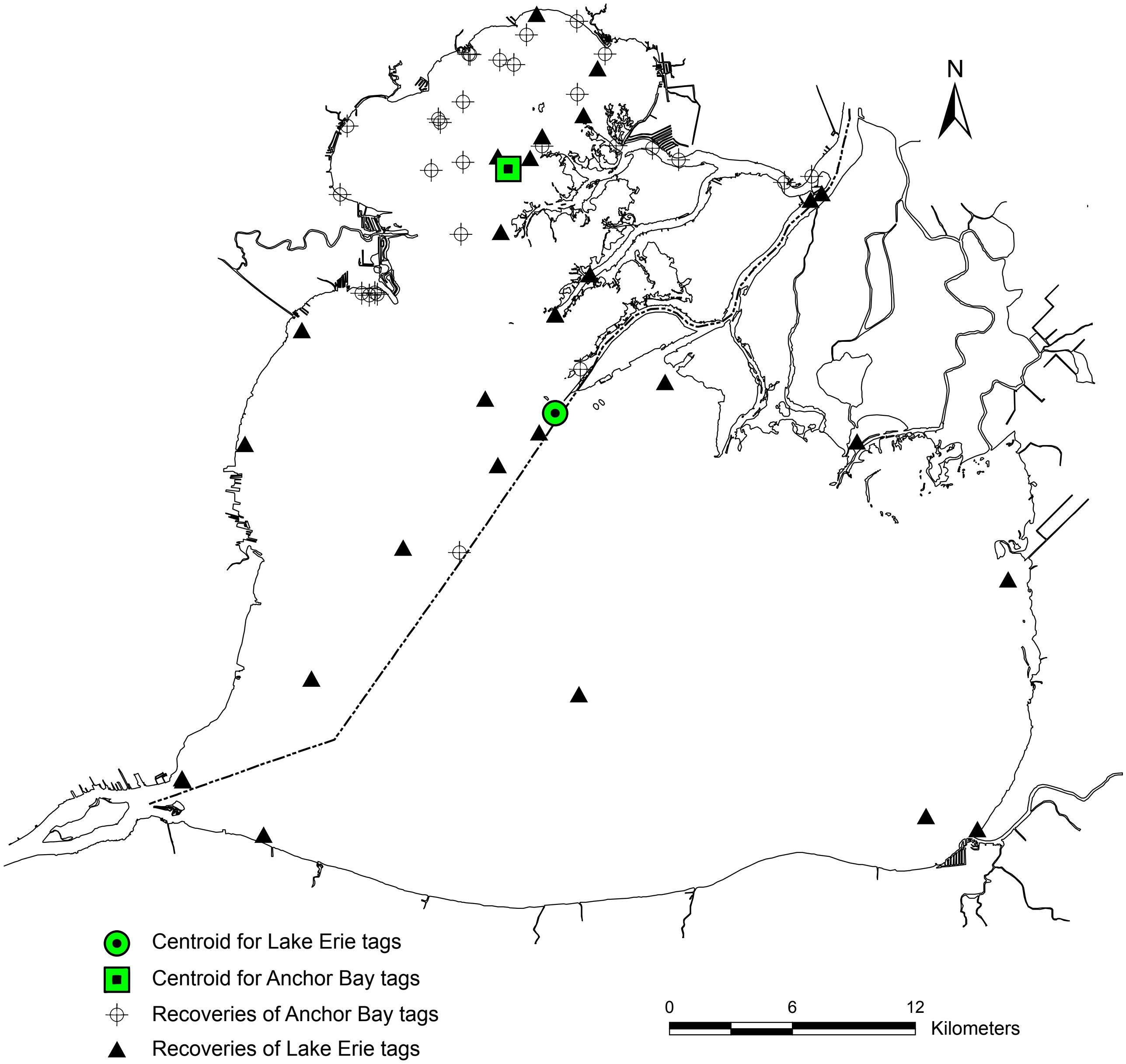

Figure 16.–Map of the geographical distribution within Lake St. Clair for 28 walleye tag recoveries from fish tagged in Anchor Bay and 28 walleyes tagged at two Michigan sites in Lake Erie. All fish were tagged at least one year prior to being captured by anglers during period from 2002 through 2006.

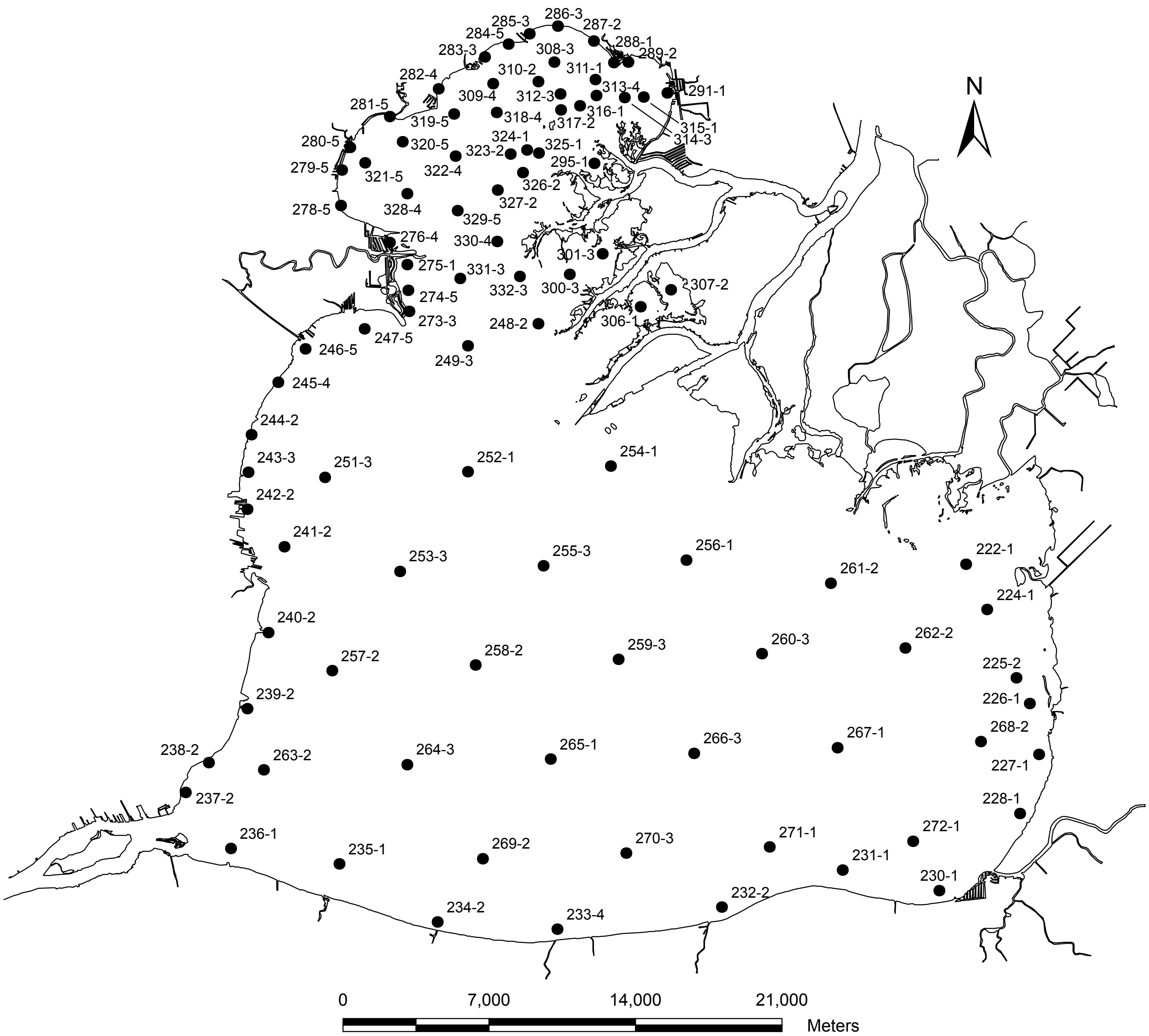

Figure 17.–Map of 96 submerged plant sampling stations in Lake St. Clair which included hook tosses and hydroacoustic transects over one square hectare spaced 10 m apart. The stations are labeled with identification number and number of sampling events (once per year 2003-2007) which ranged from 1 to 5 depending upon weather and availability of survey time.

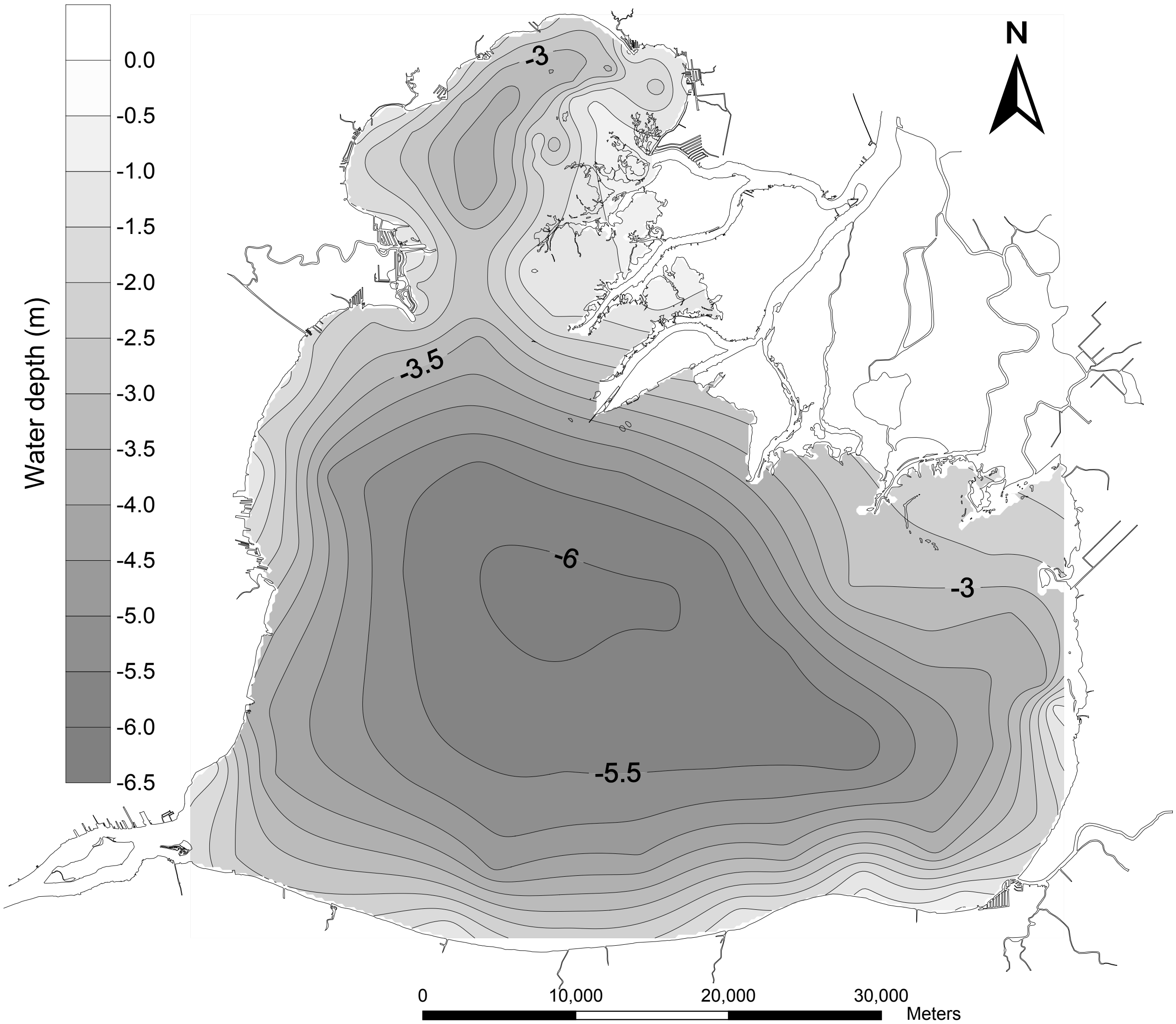

Figure 18.–Lake St. Clair map of generalized water depth (m) extracted from hydroacoustic data files where water surface is considered to be zero elevation.

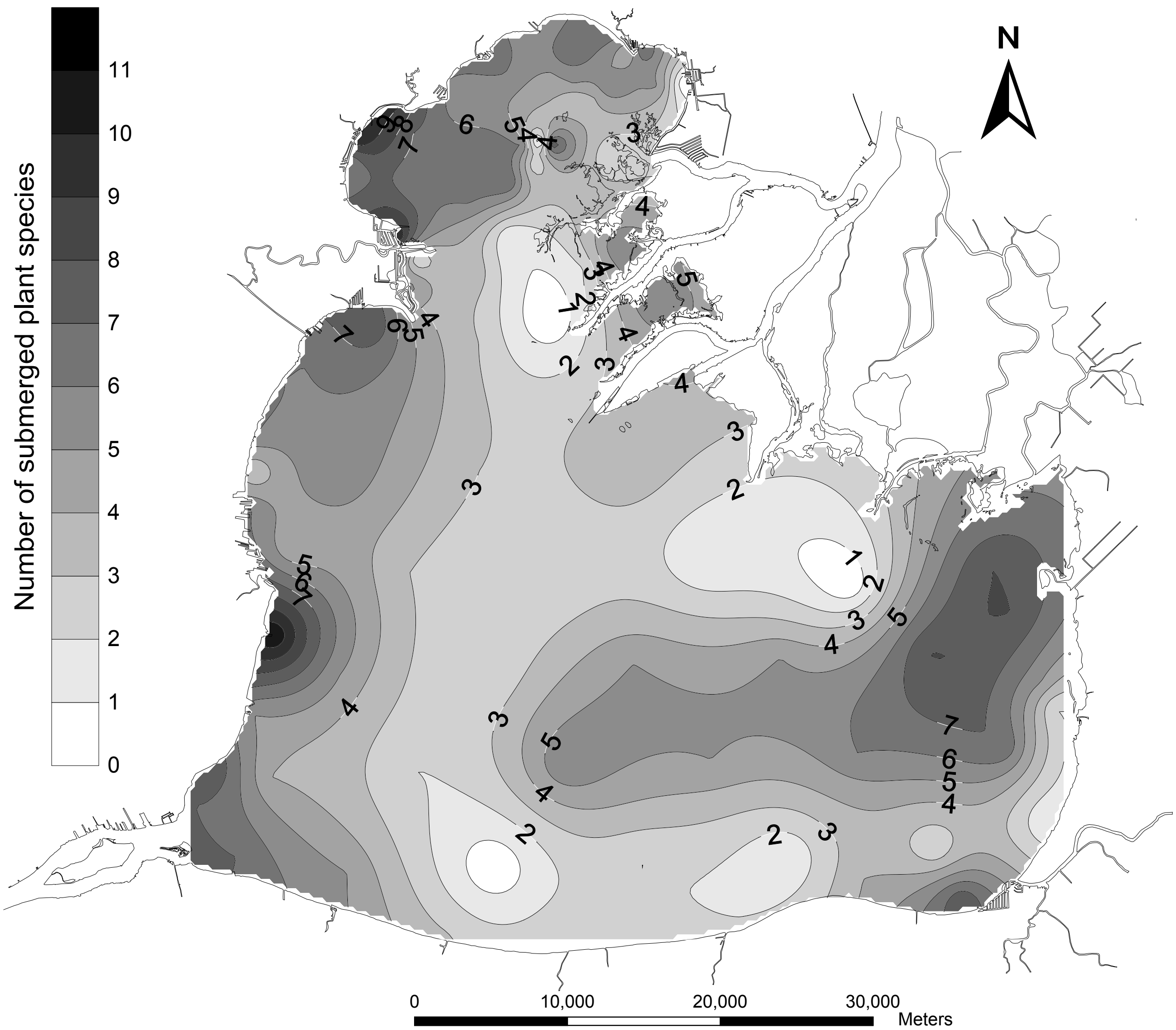

Figure 19.–Contour map of the number of submerged plant species from hook tosses at 95 stations in Lake St. Clair. Number of tosses at a station ranged from 1 to 8 depending upon sampling effectiveness.

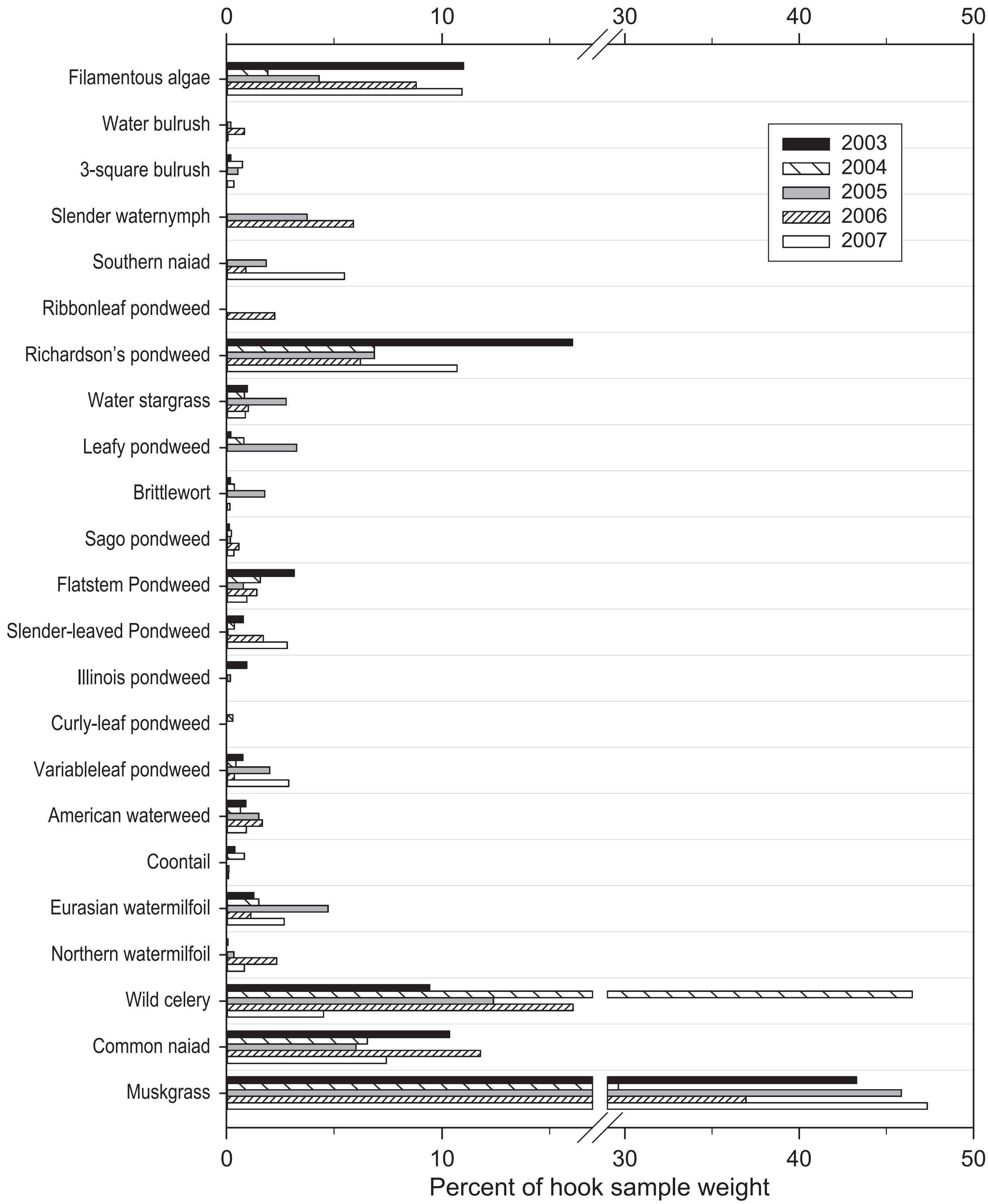

Figure 20.–Species distribution of submerged plants during five year period from 2003 to 2007. Species contributions were calculated as percent of total wet weight of plants captured in all hook tosses each year.

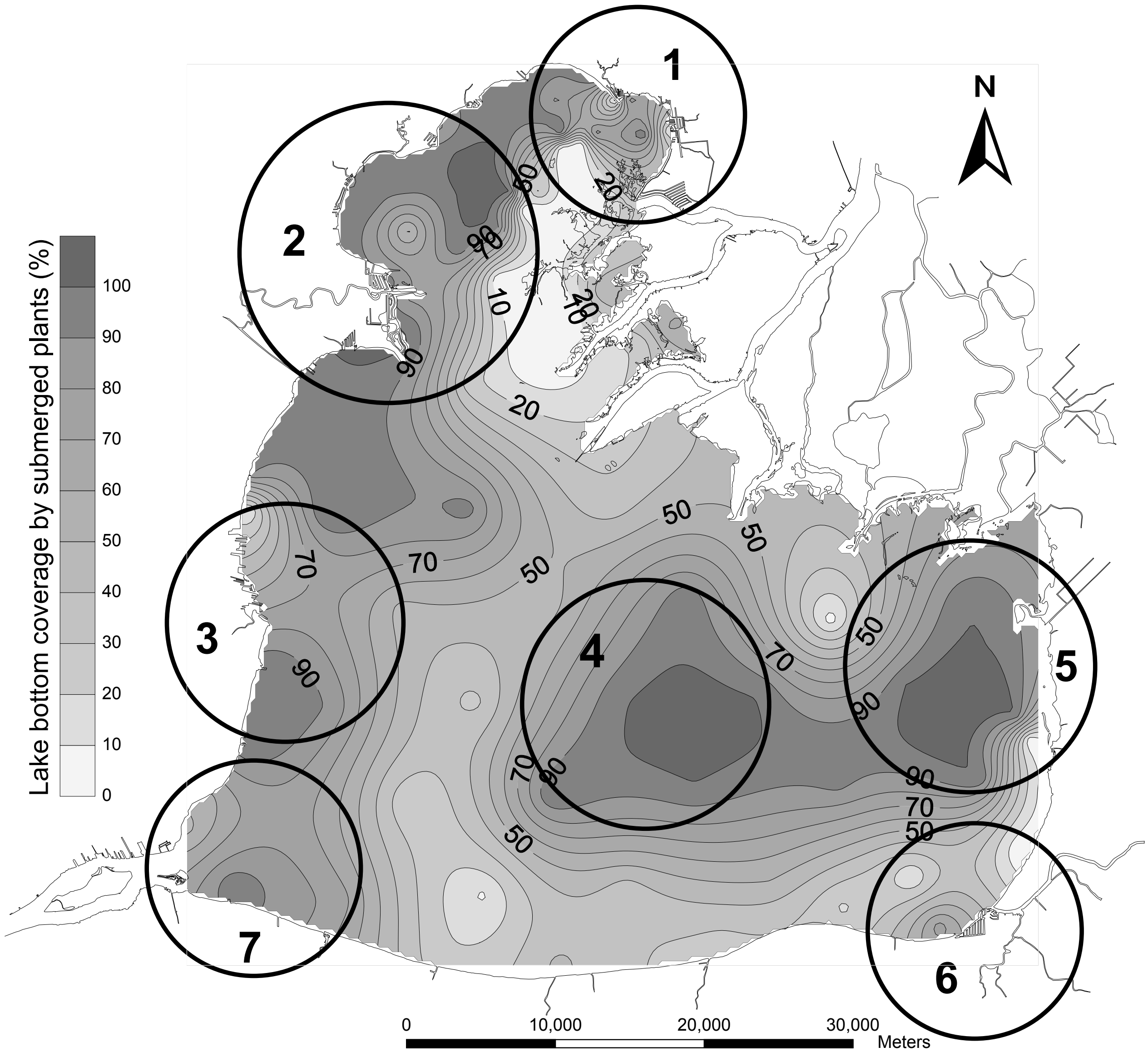

Figure 21.–Contour map of lake bottom coverage (%) by submerged plants estimated from hydroacoustic sampling at 95 square hectare stations in Lake St. Clair during 2003 through 2007. Number of surveys at a station ranged from 1 to 4 depending upon weather and availability of sampling time. Areas of densest plant growth are circled and numbered from 1-7.

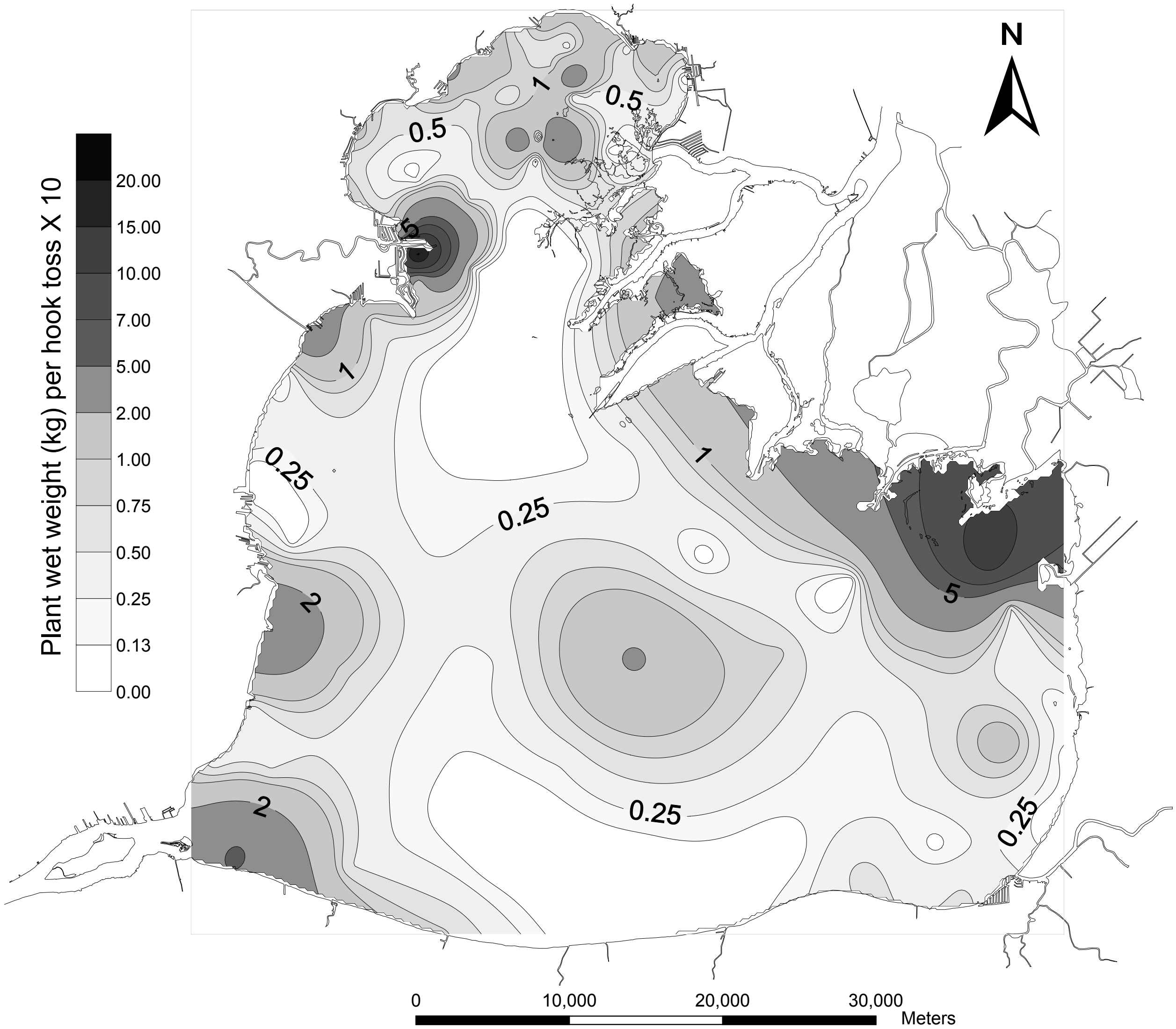

Figure 22.–Contour map of submerged plant wet weight (kg) per hook toss at 95 stations in Lake St. Clair during 2003 through 2007. Number of tosses at a station ranged from 1 to 8 depending upon sampling effectiveness and wet weight values were multiplied by 10 to improve the display.

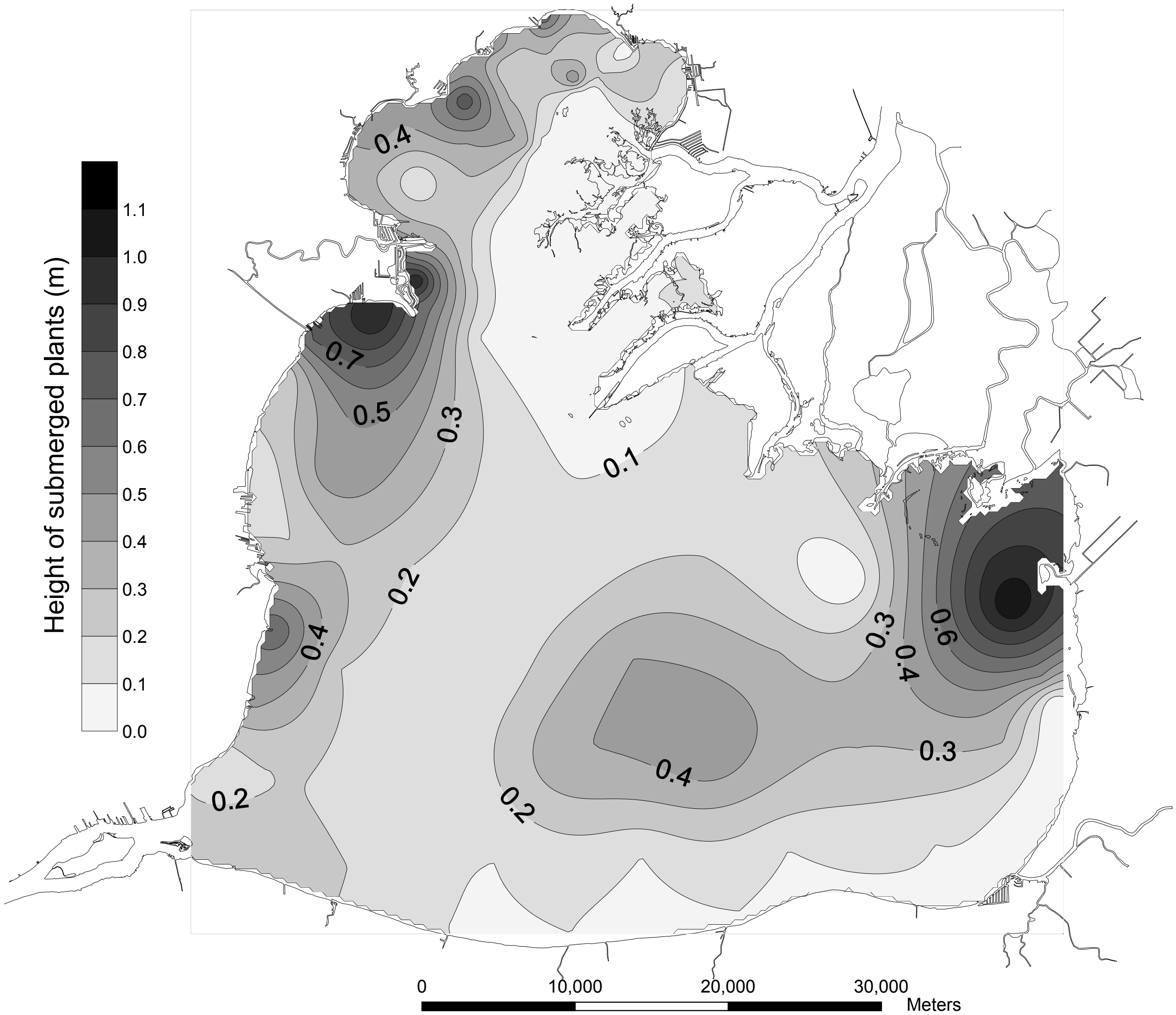

Figure 23.–Contour map of the mean height (m) of submerged plant species from hydroacoustic sampling at 95 square hectare stations in Lake St. Clair during 2003 through 2007. Number of surveys at a station ranged from 1 to 4 depending upon weather and availability of sampling time.

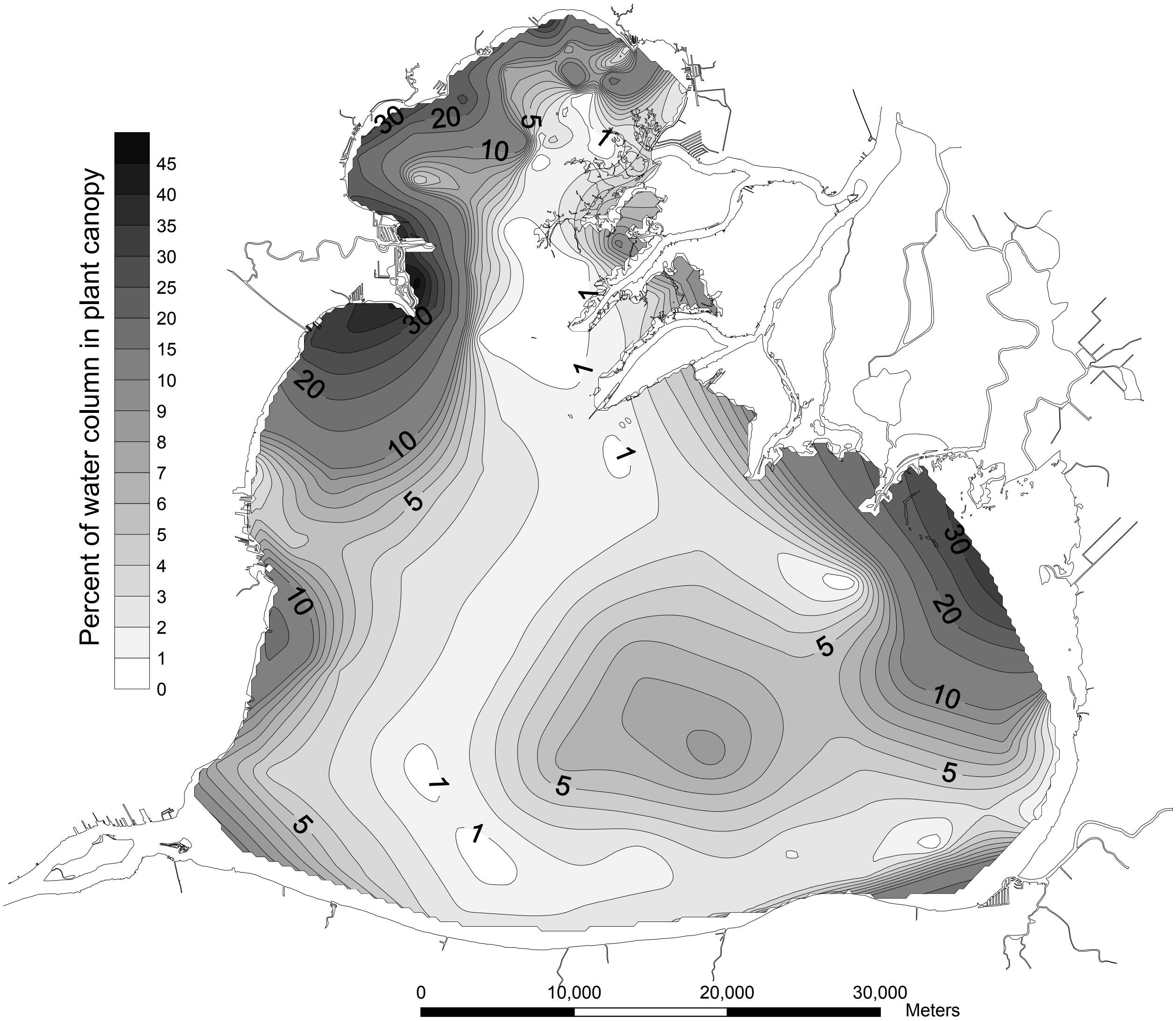

Figure 24.–Contour map of percent of the water column (plant canopy volume) within submerged plant canopy estimated from hydroacoustic sampling at 95 square hectare stations in Lake St. Clair during 2003 through 2007. Number of surveys at a station ranged from 1 to 4 depending upon weather and availability of sampling time.

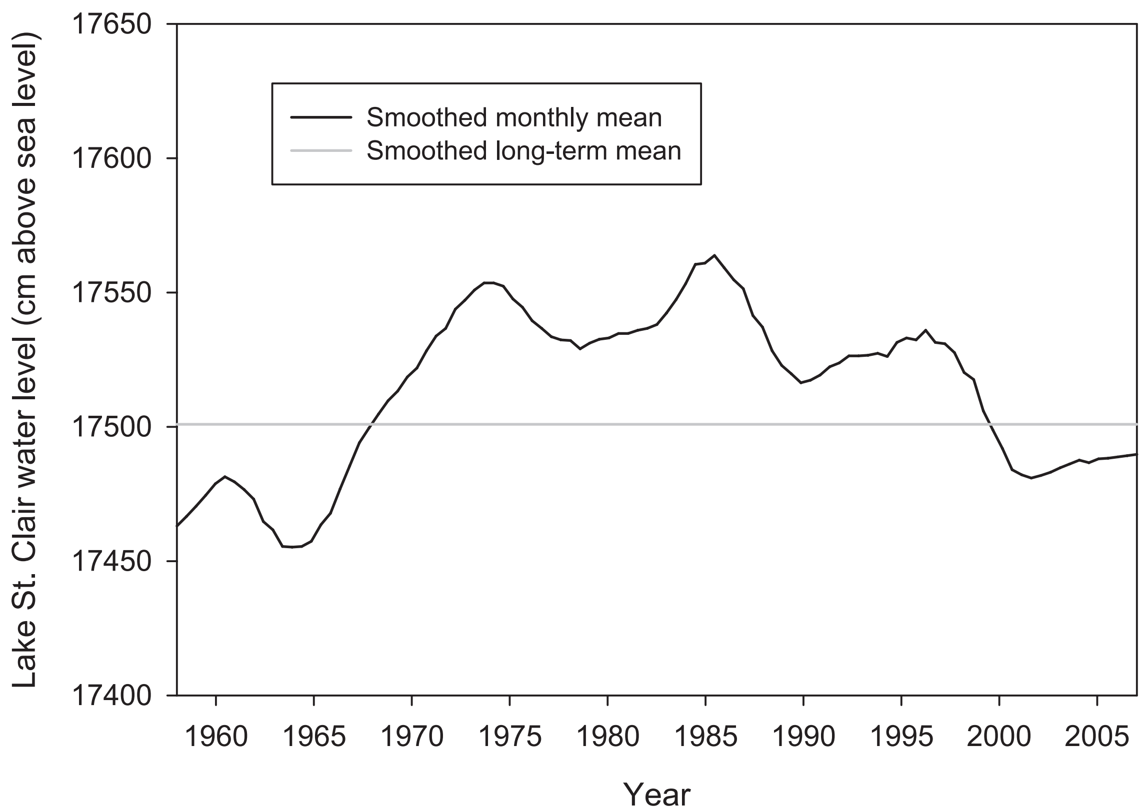

Figure 25.–Long-term monthly means and observed mean monthly water levels for Lake St. Clair from 1958 to 2007. Data from US Army Corps of Engineers.

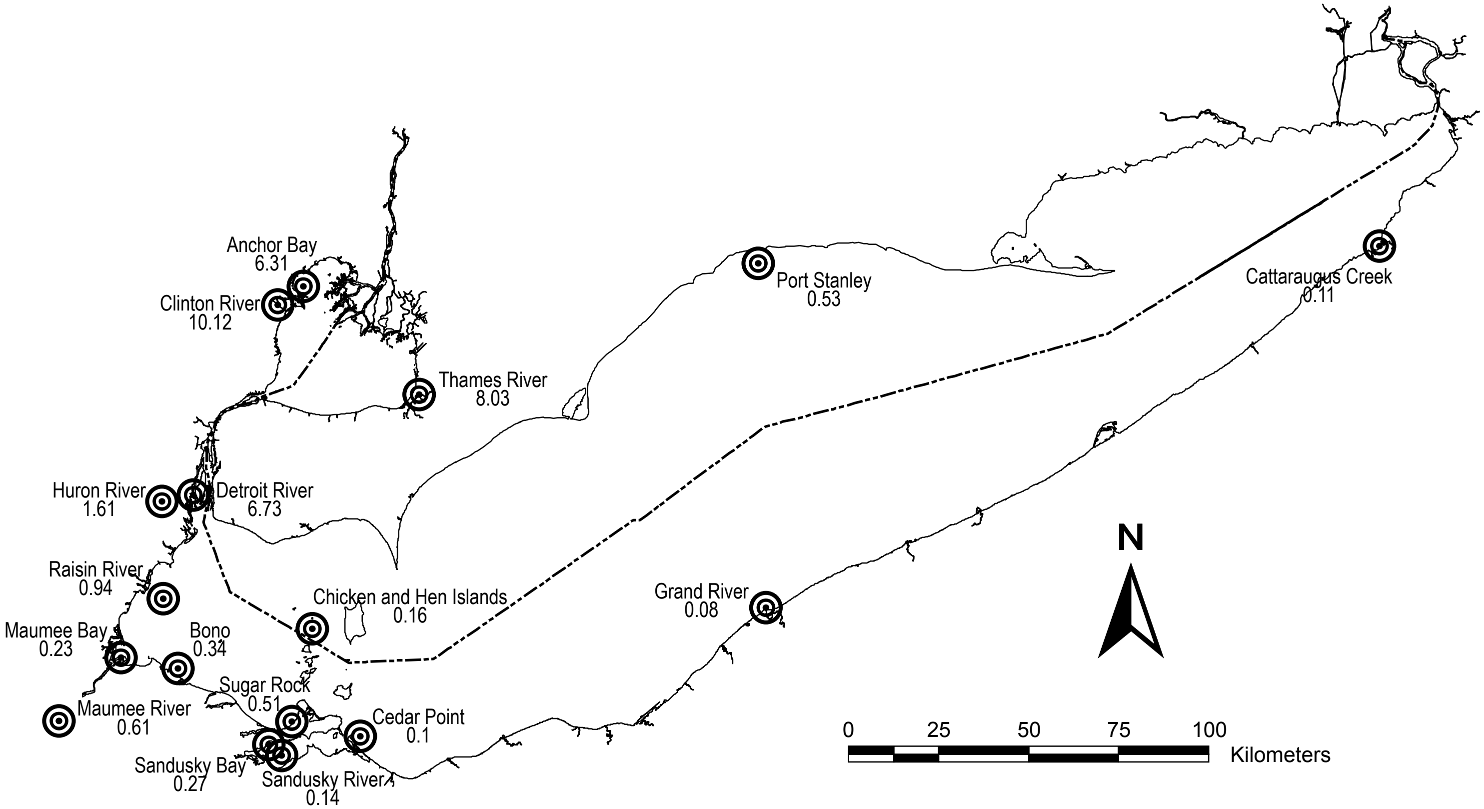

Figure 26.–Map of multi-agency walleye tagging locations that have produced angler recaptures in Lake St. Clair. Numbers show the tag recovery rate within Lake St. Clair.

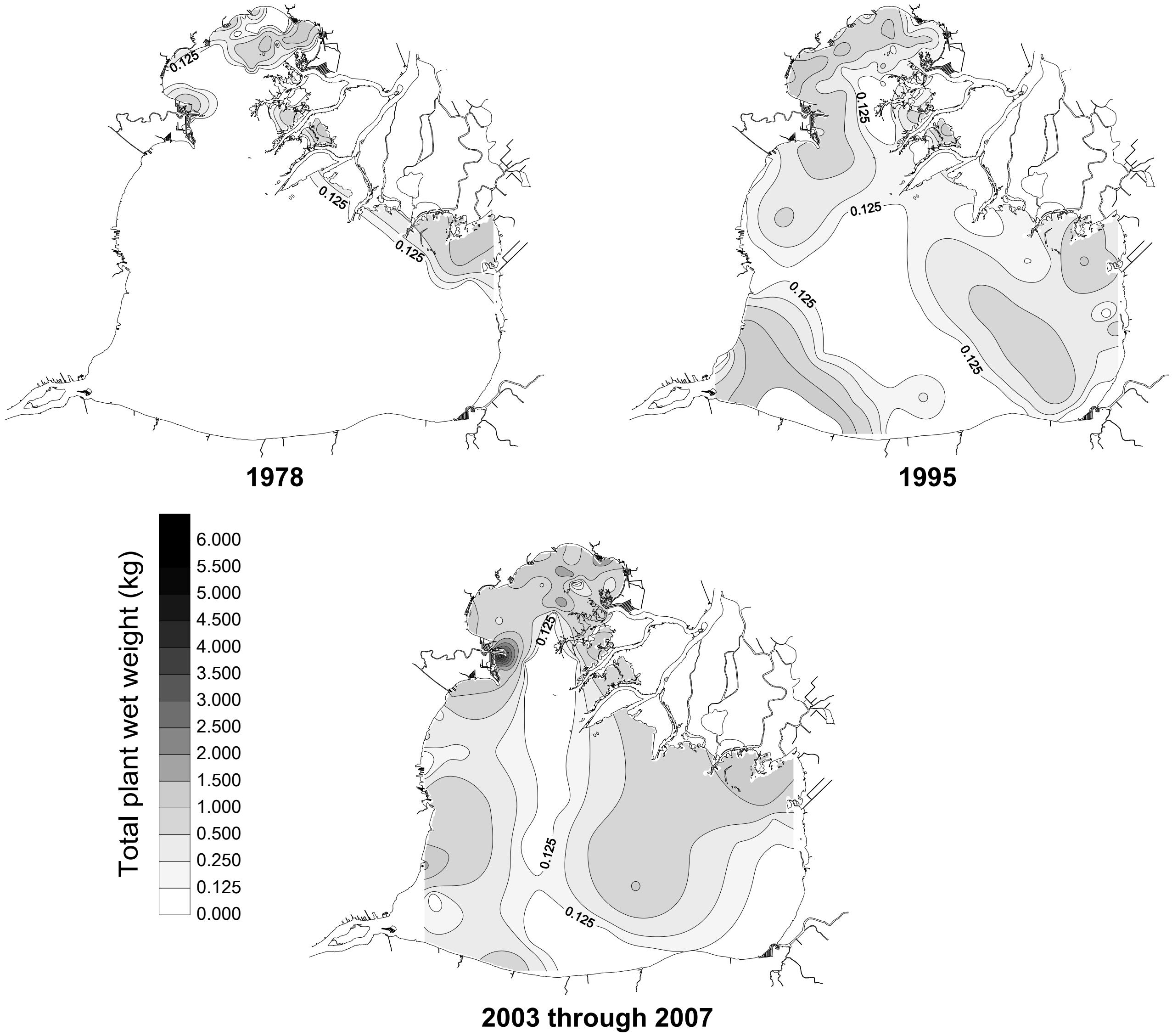

Figure 27.–Relative changes in submersed plant community, expressed as hook sample wet weight (kg), between 1978 and 2007. Weights for 1978 and 1995 were extrapolated from visual ranks collected by USGS personnel.

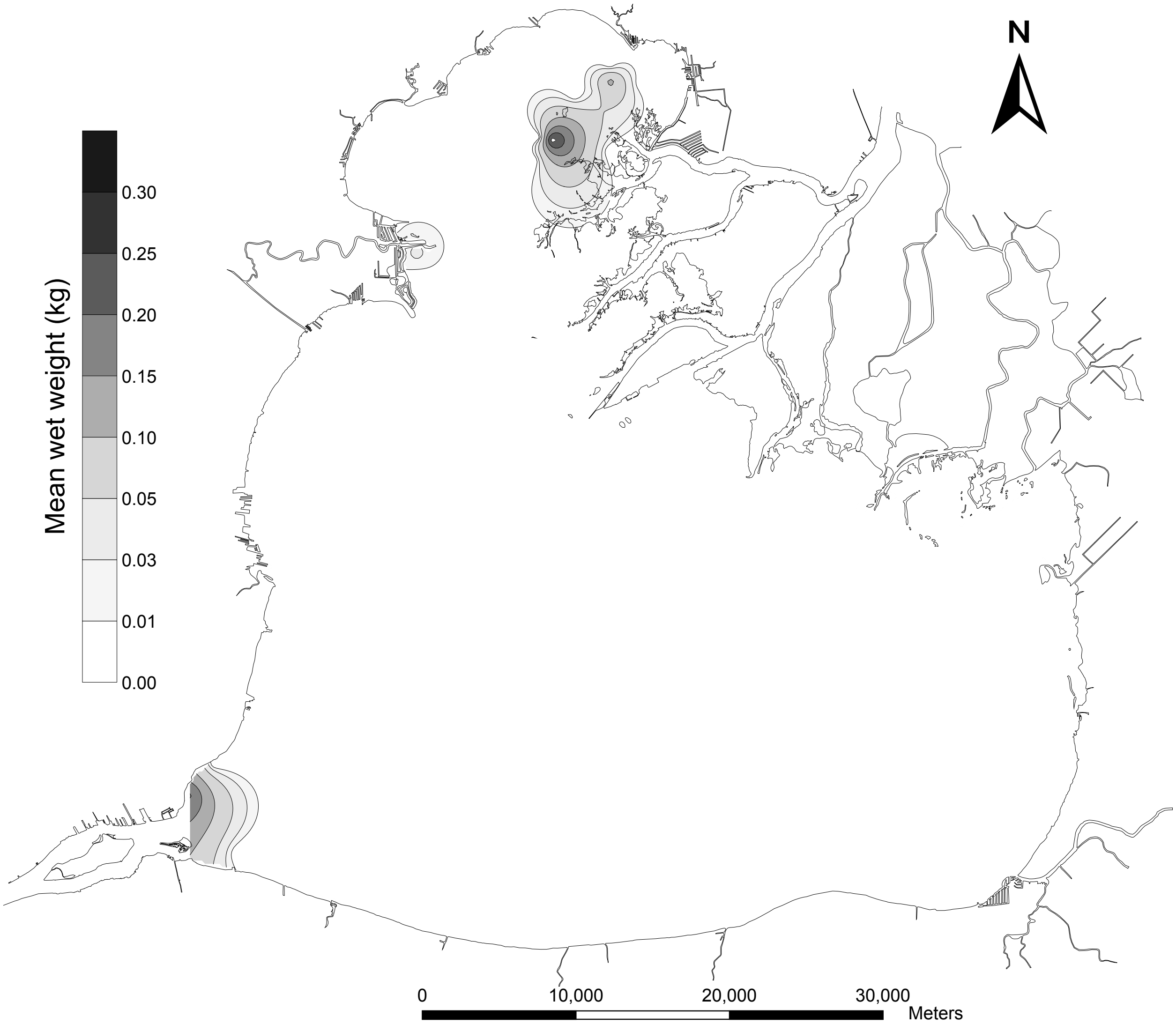

Figure 28.–Contour map of submerged exotic plant wet weight (kg) per hook toss at 95 stations in Lake St. Clair. Number of tosses at a station ranged from 1 to 8 depending upon sampling effectiveness. Two plant species were present, Eurasian watermilfoil (97% of total) and curly-leaf pondweed.

Table 1.–Mean density (number of fish caught per hectare trawled) for all fish species caught during spring (June) with 10 m headrope index trawls in Anchor Bay, Lake St. Clair, 1996–2006.

Species	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Mean
Alewife	29	11	3	2	4	3	3	0	0	0	0	5
Banded killifish	0	0	0	0	0	0	1	0	1	0	0	0
Bluegill	0	0	0	0	0	0	0	0	0	0	0	0
Bluntnose minnow	1	0	0	0	0	10	7	1	6	118	1	13
Brindled madtom	0	0	0	0	0	0	0	0	0	0	0	0
Brook silversides	0	0	0	0	0	0	0	0	0	0	0	0
Brook stickleback	0	0	0	0	0	0	0	0	0	0	0	0
Channel darter	0	1	0	0	0	0	0	0	0	0	0	0
Chinook salmon	0	0	0	0	0	0	0	1	0	0	0	0
Common carp	0	0	0	0	0	0	0	0	1	0	0	0
Common white sucker	5	4	4	0	2	1	61	2	68	22	5	16
Creek chub	0	0	0	0	0	0	0	0	0	0	0	0
Eastern sand darter	0	0	1	0	0	0	0	0	0	0	0	0
Emerald shiner	1	0	0	0	5	0	11	0	2	0	0	2
Freshwater drum	7	13	5	2	1	5	1	4	3	6	4	4
Gizzard shad	0	0	0	0	0	0	0	0	0	0	0	0
Johnny darter	22	3	7	0	0	0	0	0	3	2	0	3
Lake sturgeon	2	0	0	0	0	0	1	1	0	0	2	1
Largemouth bass	0	0	0	0	0	1	0	0	0	0	0	0
Logperch	9	76	83	8	0	2	8	0	42	6	0	21
Mimic shiner	17	26	2	0	13	20	362	0	118	45	2	55
Muskellunge	0	0	0	0	0	1	1	0	0	0	0	0
Northern pike	0	0	0	0	0	1	0	1	0	1	1	0
Shorthead redhorse	8	7	1	7	2	4	4	4	2	6	9	5
Pumpkinseed	0	1	0	0	0	2	0	0	0	0	1	0
Quillback	0	0	0	0	0	0	0	0	0	0	0	0
Rainbow smelt	593	656	4	4	4	61	0	14	53	11	6	128
Rock bass	43	18	5	1	13	30	39	18	5	10	33	19
Round goby	5	14	28	6	11	1	30	6	53	10	0	15
Silver lamprey	0	0	0	1	0	0	0	1	1	0	5	1
Silver redhorse	1	2	0	0	1	0	2	5	2	1	1	1
Smallmouth bass	0	3	1	0	1	3	4	2	2	3	4	2
Spottail shiner	178	123	8	69	935	7	5,730	211	1,777	524	769	939
Trout-perch	231	346	99	154	34	11	265	13	108	65	248	143
Walleye	5	10	1	2	1	1	1	1	0	2	12	3
White bass	0	0	0	0	0	0	0	0	0	0	1	0
White perch	1	1	0	0	13	1	1	1	2	1	2	2
Yellow perch	1,184	560	250	831	158	1,132	725	306	888	1,107	869	728

Table 2.–Mean density (number of fish caught per hectare trawled) for all fish species caught during fall (September or October) with 10 m headrope index trawls in Anchor Bay, Lake St. Clair, 1996–2006.

Species	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Mean
Alewife	28	31	12	2	3	32	12	0	0	1	1	11
Banded killifish	0	0	0	0	1	9	2	1	1	0	4	2
Bluegill	0	0	0	7	0	2	0	3	0	0	4	2
Bluntnose minnow	0	34	0	9	15	54	33	13	43	238	61	45
Brindled madtom	0	0	0	0	0	0	1	0	0	0	0	0
Brook silversides	0	0	0	2	0	1	0	10	0	0	4	2
Brook stickleback	1	0	0	0	0	0	0	0	0	0	0	0
Channel darter	0	0	0	0	0	0	0	0	0	0	0	0
Chinook salmon	0	0	0	0	0	0	0	0	0	0	0	0
Common carp	0	1	0	0	0	1	2	0	0	1	0	1
Common white sucker	1	2	0	0	1	1	8	1	1	4	6	2
Creek chub	0	0	0	0	0	1	0	0	0	0	0	0
Eastern sand darter	0	0	0	0	0	0	0	0	0	0	0	0
Emerald shiner	4	1	8	0	0	0	1	0	41	36	608	63
Freshwater drum	1	1	0	1	1	2	0	1	5	2	3	2
Gizzard shad	11	0	1	0	0	0	0	0	0	28	0	4
Johnny darter	18	4	0	0	0	0	0	7	0	0	0	3
Lake sturgeon	2	0	1	0	0	0	0	0	0	0	0	0
Largemouth bass	0	0	0	3	2	16	36	13	13	29	22	12
Logperch	32	40	21	1	5	18	6	14	38	113	34	29
Mimic shiner	268	1,095	0	30	587	10	44	507	8,909	3,072	109	1,330
Muskellunge	0	0	0	0	0	1	0	0	0	0	0	0
Northern pike	0	0	0	0	0	1	1	1	0	0	0	0
Shorthead redhorse	0	0	0	0	1	2	0	0	0	1	2	1
Pumpkinseed	0	4	0	2	0	5	5	8	1	0	5	3
Quillback	1	0	1	0	1	0	2	1	1	0	0	1
Rainbow smelt	1	17	0	0	1	0	0	4	26	0	1	5
Rock bass	18	82	1	89	93	40	41	35	25	77	67	52
Round goby	66	10	22	10	10	10	99	2	28	14	10	25
Silver lamprey	1	0	0	0	0	1	0	0	0	0	1	0
Silver redhorse	5	1	1	0	0	1	6	0	4	5	4	2
Smallmouth bass	14	11	25	11	6	23	51	7	3	41	32	20
Spottail shiner	17	487	45	200	51	879	2,407	1,068	545	2,410	2,668	980
Trout-perch	776	92	26	3	0	0	10	6	59	3	79	96
Walleye	7	1	3	1	1	0	11	0	2	9	3	3
White bass	1	0	0	0	0	0	0	0	1	0	1	0
White perch	16	12	8	0	0	0	13	8	6	146	12	20
Yellow perch	34	27	69	22	41	114	73	181	48	52	34	63

Table 3.—Density by age for yellow perch in June index trawl tows on Lake St. Clair, 1994–2006.

Year class	Total CPUE	Survey year												
		1994[a]	1995[a]	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1984	0.5	0.1	0.3	–	–	–	–	–	–	–	–	–	–	–
1985	0.2	0.2	0.0	–	–	–	–	–	–	–	–	–	–	–
1986	0.3	0.1	0.0	–	–	–	–	–	–	–	–	–	–	–
1987	1.0	0.6	0.3	0.1	–	–	–	–	–	–	–	–	–	–
1988	4.1	1.6	0.9	0.3	0.3	–	–	–	–	–	–	–	–	–
1989	10.2	3.7	2.2	1.2	0.3	–	–	–	–	–	–	–	–	–
1990	30.1	4.1	13.4	5.2	1.3	–	–	–	–	–	–	–	–	–
1991	167.9	47.0	32.1	18.7	12.9	5.3	0.6	–	–	–	–	–	–	–
1992	52.1	3.4	5.8	11.5	9.6	18.4	1.1	0.1	0.5	–	0.7	–	–	–
1993	581.3	56.3	125.8	171.4	113.7	53.7	54.3	1.5	3.3	–	1.3	–	–	–
1994	903.0	–	166.2	293.2	348.2	53.2	20.6	8.3	10.6	1.3	0.7	–	0.7	–
1995	148.1	–	–	21.4	40.7	6.7	32.2	12.3	21.1	10.4	2.7	0.6	0.0	–
1996	279.7	–	–	–	33.3	108.5	70.3	11.3	35.3	9.7	9.4	0.6	1.3	–
1997	217.7	–	–	–	–	3.8	37.6	5.5	52.8	61.3	44.4	3.6	7.9	0.8
1998	1,354.9	–	–	–	–	–	650.2	114.1	347.7	83.7	118.4	22.7	17.7	0.4
1999	102.2	–	–	–	–	–	–	4.8	25.8	17.6	24.9	22.7	3.9	2.5
2000	77.8	–	–	–	–	–	–	–	2.7	4.6	5.4	43.0	20.5	1.6
2001	308.0	–	–	–	–	–	–	–	–	131.3	89.5	50.2	25.3	11.7
2002	37.9	–	–	–	–	–	–	–	–	–	8.7	11.4	6.1	11.7
2003	1,276.7	–	–	–	–	–	–	–	–	–	–	705.3	396.6	174.8
2004	167.3	–	–	–	–	–	–	–	–	–	–	–	9.0	158.3
2005	33.6	–	–	–	–	–	–	–	–	–	–	–	–	33.6

[a]Data from previous studies.

Table 4.–Mean length at age (mm) for yellow perch from Lake St. Clair trawls in June, 1997–2006. SWavg = statewide average length at age (Schneider et al. 2000).

Age	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	SWavg
1	88	102	103	109	111	105	102	107		118	102
2	130	135	139	134	127	142	140	140	131	141	145
3	152	163	163	164	155	156	149	162	168	169	173
4	187	176	180	180	180	182	186	182	177	168	198
5	208	192	195	197	215	189	195	208	194	206	221
6	218	219	208	210	221	219	205	201	210		246
7	229	243	233	228	245	227	225	236	214		267

Table 5.–Frequency of occurrence (expressed as percent of stomachs containing each item) for non-empty smallmouth bass and walleye stomachs from trawls on Lake St. Clair, 2002 through 2006.

Diet taxa	Smallmouth bass (n=36)	Walleye (n=56)
Alewife	–	14
Gizzard shad	17	–
Emerald shiner	–	2
Spottail shiner	8	9
Unidentified shiner	–	2
Rainbow smelt	6	–
Troutperch	8	–
White bass	3	–
Smallmouth bass	6	–
Yellow perch	8	4
Johnny darter	6	–
Logperch	3	–
Brook silverside	3	–
Round goby	14	–
Unidentified fish sp.	42	77
Hexagenia sp. mayfly	–	9

Table 6.–Effort and physical data for trap net surveys in Lake St. Clair at the Anchor Bay index site, 2002–2006.

	Survey year				
Effort and physical descriptors	2002	2003	2004	2005	2006
Number of net lifts	64	50	55	34	43
Hours fished	2,748	2,839	3,080	1,773	2,371
Starting date	5/3	5/28	5/3	5/11	5/4
Ending date	5/30	6/20	5/26	5/26	5/24
Starting water temperature (°C)	9	12	8	9	13
Ending water temperature (°C)	15	16	15	13	13
Average secchi depth (m)	1.8	2.2	1.2	2.2	1.7

Table 7.–Mean catch per trap net lift for all fish species caught during spring trap net surveys in Anchor Bay, Lake St. Clair, 2002–2006.

Species	Survey year 2002	2003	2004	2005	2006
Black crappie	0.00	0.02	0.35	0.00	0.00
Bluegill	0.08	0.00	0.11	0.03	0.05
Bowfin	0.00	0.04	0.05	0.00	0.02
Brown bullhead	0.03	0.02	0.03	0.00	0.02
Channel catfish	3.81	4.14	3.92	2.50	4.33
Common carp	0.52	0.62	1.30	0.32	0.88
Freshwater drum	2.07	10.80	3.65	0.70	8.24
Gizzard shad	0.05	0.08	0.02	0.06	0.02
Golden redhorse	0.02	0.04	0.04	0.06	0.05
Lake sturgeon	0.03	0.14	0.07	0.03	0.10
Largemouth bass	0.36	0.10	0.25	0.06	0.07
Muskellunge	0.64	0.56	1.41	1.64	1.09
Northern pike	1.87	0.30	1.30	2.00	2.05
Pumpkinseed	4.96	1.54	1.12	0.05	0.52
Quillback carpsucker	0.38	0.30	0.60	0.15	0.91
Redhorse	0.00	0.00	2.85	0.00	0.00
Rock bass	49.50	32.00	33.80	12.30	35.10
Shorthead redhorse	1.84	4.08	1.53	1.44	4.00
Silver redhorse	0.50	0.66	1.29	1.26	2.98
Smallmouth bass	6.23	19.20	5.49	3.32	8.21
Walleye	3.79	3.60	2.67	5.50	5.12
White bass	0.03	0.10	0.07	0.00	0.14
White perch	0.20	0.10	0.80	0.12	2.38
White sucker	0.28	0.20	0.27	0.20	0.43
Yellow perch	4.89	1.14	5.01	0.97	1.26
Total	82.07	79.78	68.00	32.71	77.97
Net lifts	64	50	55	34	42

Table 8.–Age composition (percentage) for smallmouth bass caught in Anchor Bay assessment trap nets, 2002 to 2006.

Age	Survey year				
	2002	2003	2004	2005	2006
2	0	0	0	1	2
3	3	2	5	5	25
4	71	24	4	22	34
5	8	57	27	11	15
6	4	8	41	24	8
7	3	4	8	22	8
8	3	2	6	7	6
9	3	1	2	6	0
10	3	1	1	2	1
11	2	1	3	0	1
12	1	1	1	0	0
13	1	0	1	0	0
14	0	0	0	0	0
15	0	0	0	0	0
N	400	939	296	108	338

Table 9.–Age specific catch per net lift for smallmouth bass in Anchor Bay assessment trap net surveys, 1974–2006. Total CPUE represents the combined Age 2 through Age 13 catch per net lift values. Age 9+ is the catch per net lift for age groups 9, 10, 11, 12, and 13. Data from 1974 to 1985 is from Bryant and Smith (1988). Trap-net sampling did not occur in the years 1976, 1982, and 1986–2001.

	Survey year														
Age	1974	1975	1977	1978	1979	1980	1981	1983	1984	1985	2002	2003	2004	2005	2006
2	–	0.01	0.07	0.09	0.05	–	0.07	0.04	0.15	0.07	–	–	0.02	0.03	0.19
3	1.62	0.16	0.48	3.09	4.55	20.64	2.87	3.12	8.16	2.93	0.16	0.42	0.26	0.15	2.02
4	3.66	3.21	7.96	7.44	5.89	14.34	24.12	5.19	10.19	16.91	4.42	4.68	0.24	0.74	2.79
5	2.64	2.43	1.31	12.76	2.11	5.20	6.80	2.19	4.35	6.33	0.52	10.89	1.47	0.37	1.24
6	0.81	0.90	1.85	0.94	3.12	1.71	1.53	3.60	2.00	2.21	0.25	1.54	2.23	0.80	0.68
7	0.36	0.42	0.99	0.59	0.49	2.12	0.34	0.68	1.67	0.81	0.16	0.69	0.46	0.74	0.66
8	0.06	0.08	0.19	0.24	0.26	0.97	0.37	0.02	0.19	0.59	0.17	0.33	0.35	0.25	0.49
9	0.02	0.07	0.13	–	0.18	0.11	0.10	0.07	0.11	0.18	0.16	0.13	0.13	0.19	0.02
10	–	0.03	0.03	–	0.02	0.11	–	0.01	0.08	0.11	0.19	0.19	0.08	0.06	0.05
11	–	0.02	–	–	–	–	–	–	0.00	–	0.10	0.21	0.17	–	0.05
12	–	–	–	–	–	–	–	–	0.01	–	0.06	0.10	0.04	–	0.02
13	–	–	–	–	–	–	–	–	–	–	0.03	0.02	0.04	–	–
9+	0.02	0.12	0.16	0.00	0.20	0.22	0.10	0.08	0.20	0.29	0.54	0.65	0.46	0.25	0.14
Total CPUE	9.17	7.33	13.01	25.15	16.67	45.20	36.20	14.92	26.91	30.14	6.23	19.20	5.50	3.32	8.21
Mean age	4.44	4.86	4.69	4.56	4.43	4.02	4.27	4.58	4.24	4.47	4.87	5.12	6.09	5.88	4.62

Table 10.–Age composition (percentage) for walleye caught in Anchor Bay assessment trap nets, 2002–2006.

Age	Survey year 2002	2003	2004	2005	2006
2	3	16	0	35	2
3	33	2	34	1	73
4	6	30	5	23	3
5	23	5	16	2	8
6	18	18	5	12	1
7	3	21	14	7	4
8	9	4	10	9	2
9	3	2	7	7	2
10	1	2	5	3	1
11	1	1	4	2	3
12	0	1	0	0	2
13	0	0	1	1	1
14	0	0	0	0	0
15	0	0	0	0	0
N	243	180	147	184	214

Table 11.–Age composition (percentage) for muskellunge caught in Anchor Bay assessment trap nets, 2002–2006.

	Survey year					
Age	2002	2003	2004	2005	2006	Total
1	0	0	0	0	0	0
2	0	0	1	0	0	0
3	0	0	0	0	0	0
4	2	0	1	0	0	1
5	7	4	12	4	0	6
6	15	15	17	10	6	13
7	27	26	21	17	13	20
8	22	26	17	6	19	17
9	22	22	17	4	10	15
10	5	0	8	4	6	5
11	0	7	4	15	13	8
12	0	0	1	15	15	6
13	0	0	0	8	2	2
14	0	0	0	4	4	2
15	0	0	0	4	0	1
16	0	0	0	2	2	1
17	0	0	0	2	2	1
18	0	0	0	2	8	2
19	0	0	0	2	0	0
N	41	27	76	46	48	240

Table 12.–Age composition (percentage) for northern pike caught in Anchor Bay assessment trap nets, 2002–2006.

Age	Survey year					Total
	2002	2003	2004	2005	2006	
1	1	0	0	0	1	1
2	3	7	16	2	6	7
3	23	36	21	26	17	22
4	37	21	25	22	46	34
5	18	29	25	24	17	21
6	12	7	7	11	5	9
7	5	0	3	4	4	4
8	1	0	1	4	0	1
9	0	0	0	4	1	1
10	0	0	1	2	1	1
11	0	0	0	0	1	0
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
N	120	14	71	46	81	332

Table 13.–Walleye and smallmouth bass tag recoveries from Lake St. Clair during 2002–2006.

Year	Number tagged	Tags recovered 2002	2003	2004	2005	2006	Total	Percent recovered
Walleye								
2002	241	29	15	7	4	1	56	23.2
2003	173	–	25	6	0	1	32	18.5
2004	147	–	–	18	4	3	25	17.0
2005	166	–	–	–	7	2	9	5.4
2006	214	–	–	–	–	21	21	9.8
Total	941	29	40	31	15	28	143	15.2
Smallmouth bass								
2002	270	12	7	0	0	1	20	7.4
2003	831	–	5	2	0	1	8	1.0
2004	267	–	–	2	0	0	2	0.7
2005	97	–	–	–	1	7	8	8.2
2006	305	–	–	–	–	16	16	5.2
Total	1,770	12	12	4	1	25	54	3.1

Table 14.–Angler effort, catch, and catch rates for the Lake St. Clair sport fishing diary program 1998–2006.

Year	Trips seeking	Effort (rod-hours)	Number caught	Number kept	Catch per rod-hour	% released
			Walleye			
1998	510	5,599	2,481	1,947	0.44	22
1999	625	5,850	2,610	2,239	0.44	14
2000	444	4,672	1,753	1,646	0.37	6
2001	342	4,051	1,893	1,681	0.47	11
2002	425	4,475	1,357	1,298	0.30	4
2003	543	5,533	2,536	2,280	0.46	10
2004	393	3,740	1,048	862	0.28	18
2005	526	4,845	4,036	1,906	0.83	53
2006	436	4,204	2,373	2,046	0.56	14
			Yellow perch			
1998	305	3,520	7,134	5,048	2.03	29
1999	226	2,087	6,142	3,654	2.94	41
2000	235	2,892	10,436	5,660	3.61	46
2001	164	2,047	5,862	4,350	2.86	26
2002	412	4,658	12,841	9,091	2.87	29
2003	335	3,829	9,694	6,149	2.53	37
2004	293	3,917	7,910	5,119	2.02	35
2005	232	2,798	8,470	4,141	3.03	51
2006	231	2,456	13,261	6,785	5.40	49
			Smallmouth bass			
1998	127	1,248	495	94	0.40	81
1999	222	1,841	1,112	204	0.60	82
2000	190	1,126	1,484	126	1.22	92
2001	74	512	280	48	0.55	83
2002	153	1,207	954	110	0.79	88
2003	179	1,586	1,466	135	0.92	91
2004	126	999	845	54	0.84	94
2005	82	556	286	41	0.52	86
2006	84	828	564	72	0.68	87
			Muskellunge			
1998	383	11,336	1,075	8	0.094	99
1999	318	9,370	645	5	0.069	99
2000	269	8,874	749	16	0.084	98
2001	241	7,248	851	2	0.117	100
2002	156	3,953	277	4	0.070	99
2003	141	3,731	341	10	0.091	97
2004	114	2,510	236	1	0.094	100
2005	109	2,468	209	0	0.085	100
2006	89	1,838	130	0	0.071	100

Table 15.–Common and scientific names of submerged aquatic plants observed in hook samples from 96 stations in Lake St. Clair with species wet weight (kg) sampled and percent of total weight from 2003 to 2007.

Common name	Scientific name	Wet weight	Percent
Muskgrass	*Chara sp.*	59.680	41.44
Common naiad	*Najas flexilis*	11.224	7.79
Wild celery	*Vallisneria americana*	24.392	16.94
Northern watermilfoil	*Myriophyllum sibiricum*	1.233	0.86
Eurasian watermilfoil	*Myriophylum spicatum*	3.841	2.67
Coontail	*Ceratophyllum demersum*	0.296	0.21
American waterweed	*Elodea canadensis*	1.688	1.17
Variableleaf pondweed	*Potamogeton gramineus*	2.401	1.67
Curly-leaf pondweed	*Potamogeton crispus*	0.100	0.07
Illinois pondweed	*Potamogeton illinoensis*	0.070	0.05
Leafy pondweed	*Potamogeton foliosus*	2.012	1.40
Flatstem Pondweed	*Potamogeton zosteriformis*	1.598	1.11
Sago pondweed	*Potamogeton pectinatus*	0.469	0.33
Brittlewort	*Nitella sp.*	0.847	0.59
Slender-leaved pondweed	*Potamogeton filiformis*	1.443	1.00
Water stargrass	*Heteranthera dubia*	1.993	1.38
Richardson's pondweed	*Potamogeton richardsonii*	11.572	8.03
Ribbonleaf pondweed	*Potamogeton epihydrus*	0.670	0.47
Southern naiad	*Najas guadalupensis*	3.655	2.54
Slender waternymph	*Najas gracillima*	3.170	2.20
3-square bulrush	*Scirpus americana*	0.570	0.40
Water bulrush	*Scirpus subterminalis*	0.360	0.25
Unidentified filamentous algae		10.160	7.05
Decaying plant material		0.582	0.40

Table 16.–Station summary of data on submerged plant community in Lake St. Clair collected during five year period from 2003 through 2007.

Plant variable	Survey year 2003	2004	2005	2006	2007	Overall
Summary of plant hook sampling						
Mean Secchi depth (m)	2.10	1.76	1.48	2.13	2.59	1.95
Mean number of hook tosses	5.23	4.43	3.27	3.70	4.29	4.15
Mean number of plant species	4.16	5.83	4.82	4.95	4.88	4.87
Mean wet weight (kg)	0.67	0.91	0.68	0.70	0.66	0.70
Mean wet weight per species	0.15	0.20	0.16	0.13	0.12	0.15
Mean wet weight per hook toss	0.18	0.32	0.32	0.35	0.22	0.27
Number of stations sampled	44	30	55	43	75	247
Summary of hydroacoustic data from EcoSAV software						
Mean depth (m)	-2.59	-2.41	-2.54	-2.58	-2.97	-2.66
Mean plant height (m)	0.12	0.51	0.32	0.36	0.24	0.29
Mean plant cover (%)	22.59	82.79	65.79	68.67	68.31	61.74
Mean plant canopy volume (%)	2.85	22.56	13.47	14.69	8.89	11.70
Number of reports in EcoSAV files	22,387	16,182	31,504	23,634	37,156	130,863

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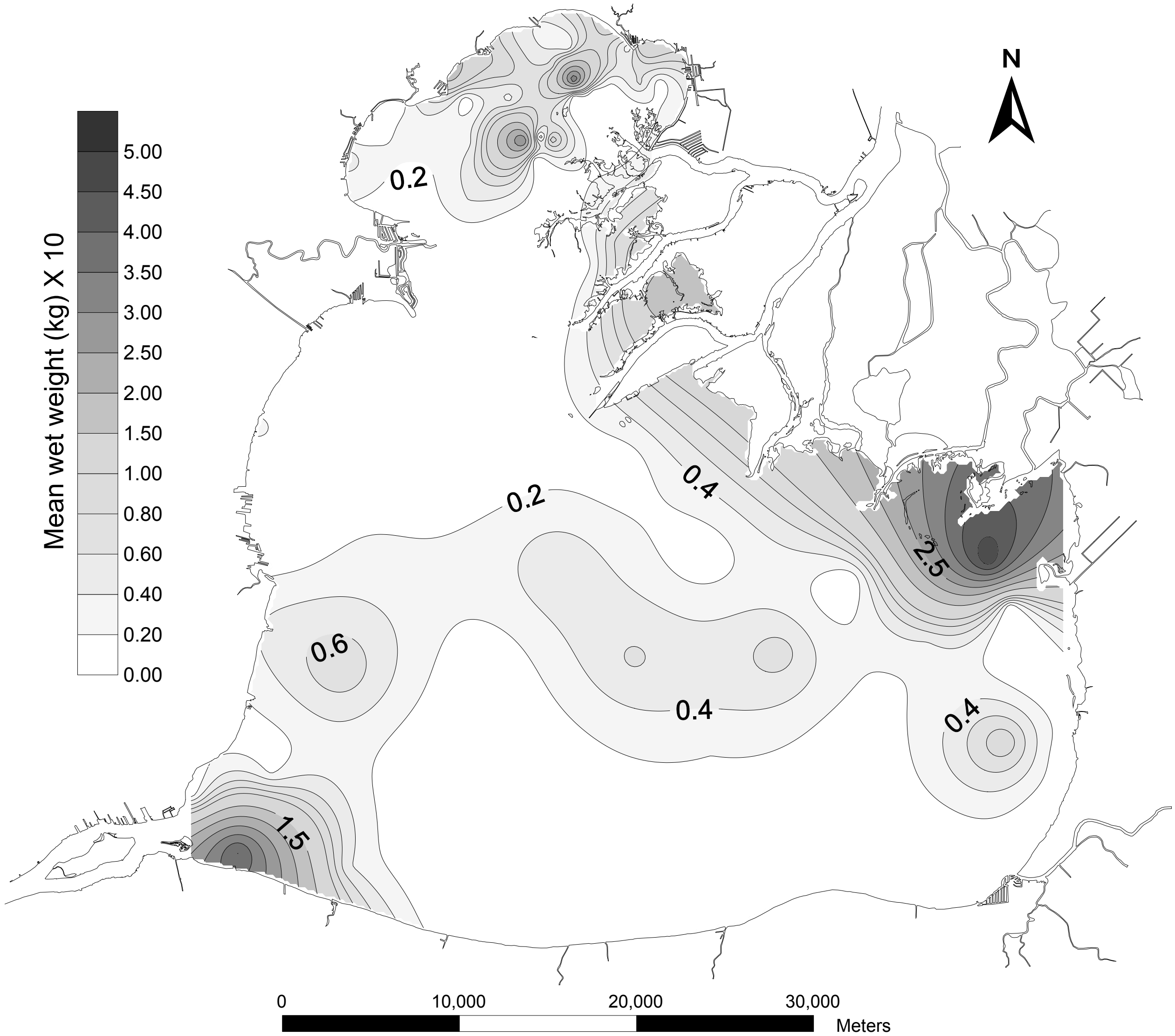
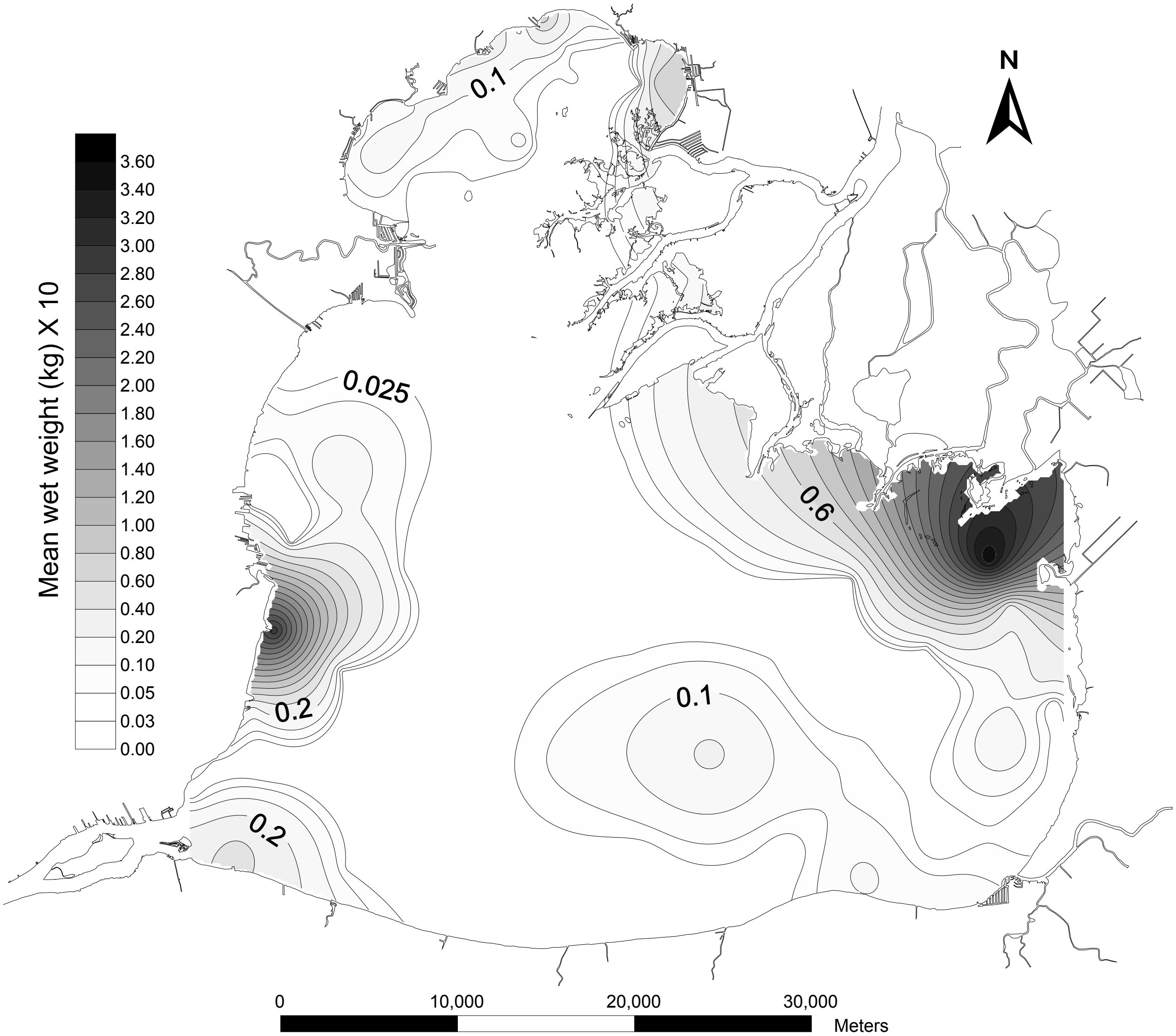
Appendix 1.─Common and scientific names of fishes and aquatic organisms mentioned in this report, with indication of gear of capture for those species caught during the Lake St. Clair trap-net and trawl surveys from 2002 to 2006.

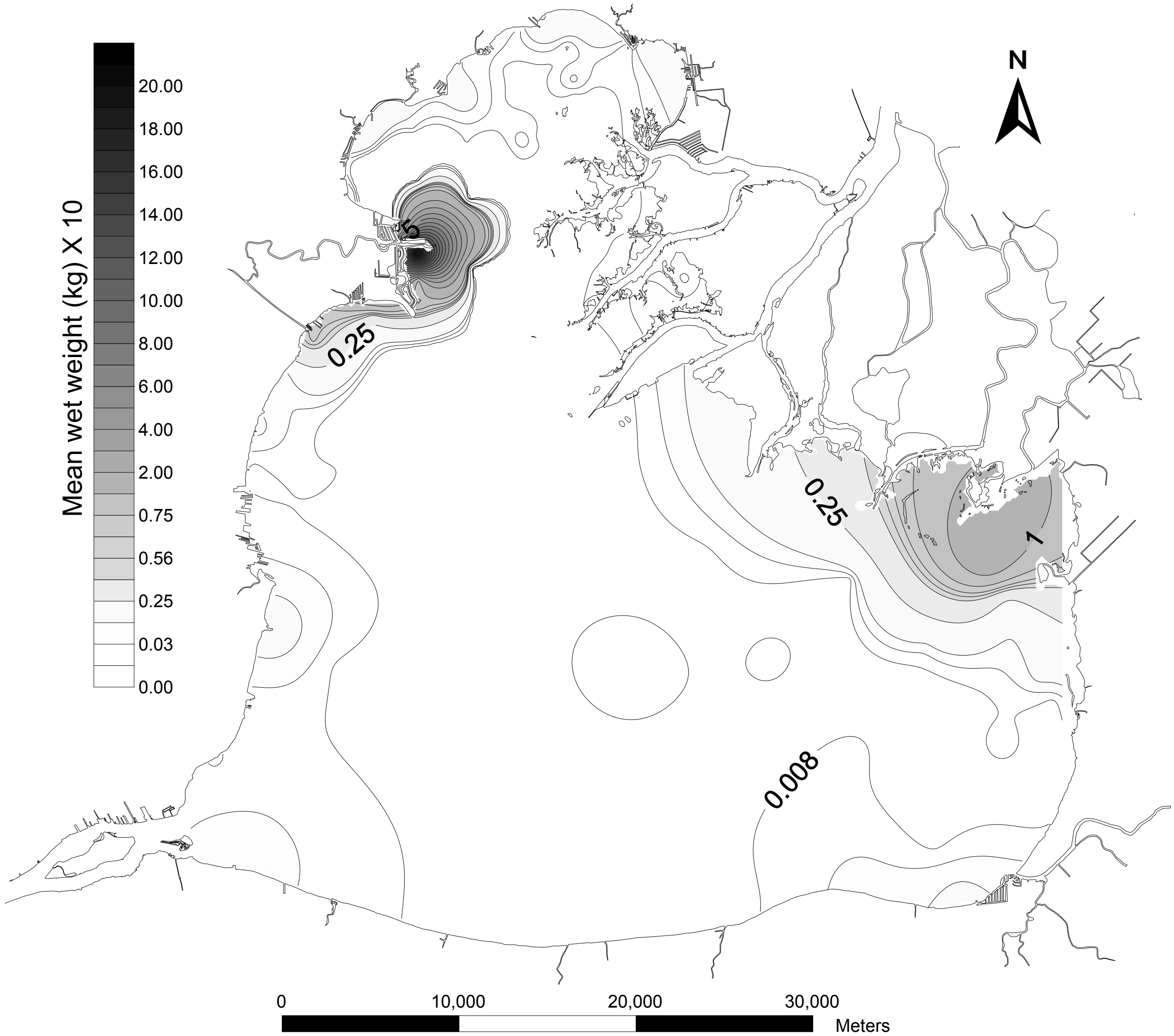
Common name	Scientific name	Trap-net	Trawl
Alewife	*Alosa pseudoharengus*		X
Banded killifish	*Fundulus diaphanus*		X
Black crappie	*Pomoxis nigromaculatus*	X	
Bluegill	*Lepomis macrochirus*	X	X
Bluntnose minnow	*Pimephales notatus*		X
Bowfin	*Amia calva*	X	
Brindled madtom	*Noturus miurus*		X
Brook silversides	*Labidesthes sicculus*		X
Brook stickleback	*Culaea inconstans*		
Brown bullhead	*Ameiurus nebulosus*	X	
Channel catfish	*Ameiurus punctatus*	X	
Channel darter	*Percina copelandi*		
Common carp	*Cyprinus carpio*	X	X
Creek chub	*Semotilus atromaculatus*		
Eastern sand darter	*Ammocrypta pellucida*		
Emerald shiner	*Notropis atherinoides*		X
Freshwater drum	*Aplodinotus grunniens*	X	X
Gizzard shad	*Dorosoma cepedianum*	X	X
Golden redhorse	*Moxostoma erythrurum*	X	
Johnny darter	*Etheostoma nigrum*		X
Lake sturgeon	*Acipenser fulvescens*	X	X
Largemouth bass	*Micropterus salmoides*	X	X
Logperch	*Percina caproides*		X
Mimic shiner	*Notropis volucellus*		X
Muskellunge	*Esox masquinongy*	X	X
Northern pike	*Esox lucius*		X
Pumpkinseed	*Lepomis gibbosus*	X	X
Quagga mussel	*Dreissena rostriformis bugensis*		
Quillback carpsucker	*Carpiodes cyprinus*	X	X
Rainbow smelt	*Osmerus mordax*		X
Rock bass	*Ambloplites rupestris*	X	X
Round goby	*Neogobius melanostomus*		X
Ruff	*Gymnocephalus cernuus*		
Shorthead redhorse	*Moxostoma macrolepidotum*	X	X
Silver lamprey	*Icthyomyzon uniscuspis*		X
Silver redhorse	*Moxostoma anisurum*	X	X
Smallmouth bass	*Micropterus dolomieu*	X	X
Spiny water flea	*Bythotrephes cederstroemi*		
Spottail shiner	*Notropis hudsonius*		X
Trout-perch	*Percopsis omiscomaycus*		X
Tubenose goby	*Proterorhinus marmoratus*		
Walleye	*Sander vitreus*	X	X
White bass	*Morone chrysops*	X	X
White perch	*Morone americana*	X	X
White sucker	*Catostomus commersoni*	X	X
Yellow perch	*Perca flavescens*	X	X
Zebra mussel	*Dreissena polymorpha*		



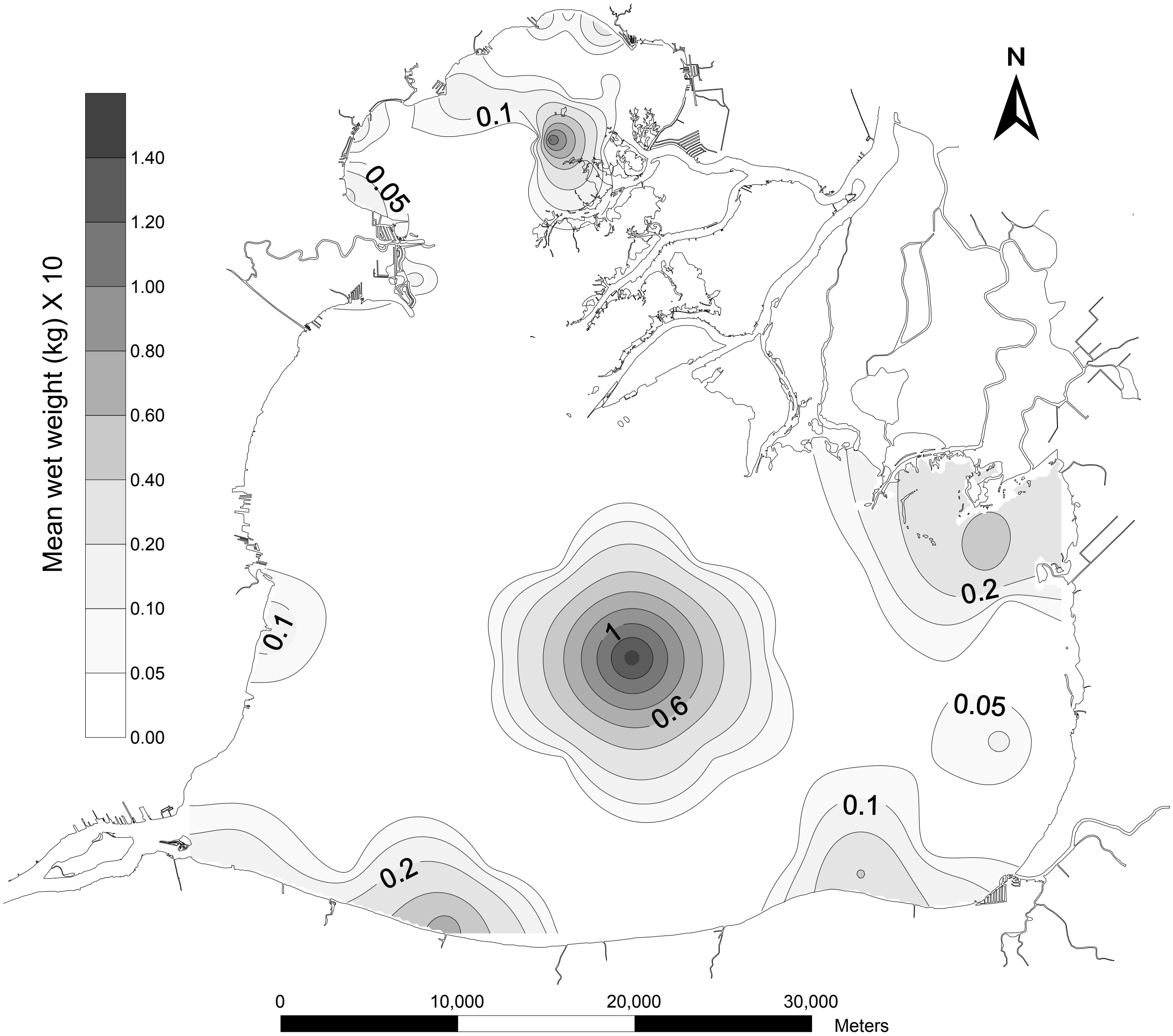
Appendix 2.–Contour map of muskgrass wet weight (kg) per hook toss multiplied by 10 at 95 stations in Lake St. Clair during 2003 through 2007. Number of tosses at a station ranged from 1 to 8 depending upon sampling effectiveness.



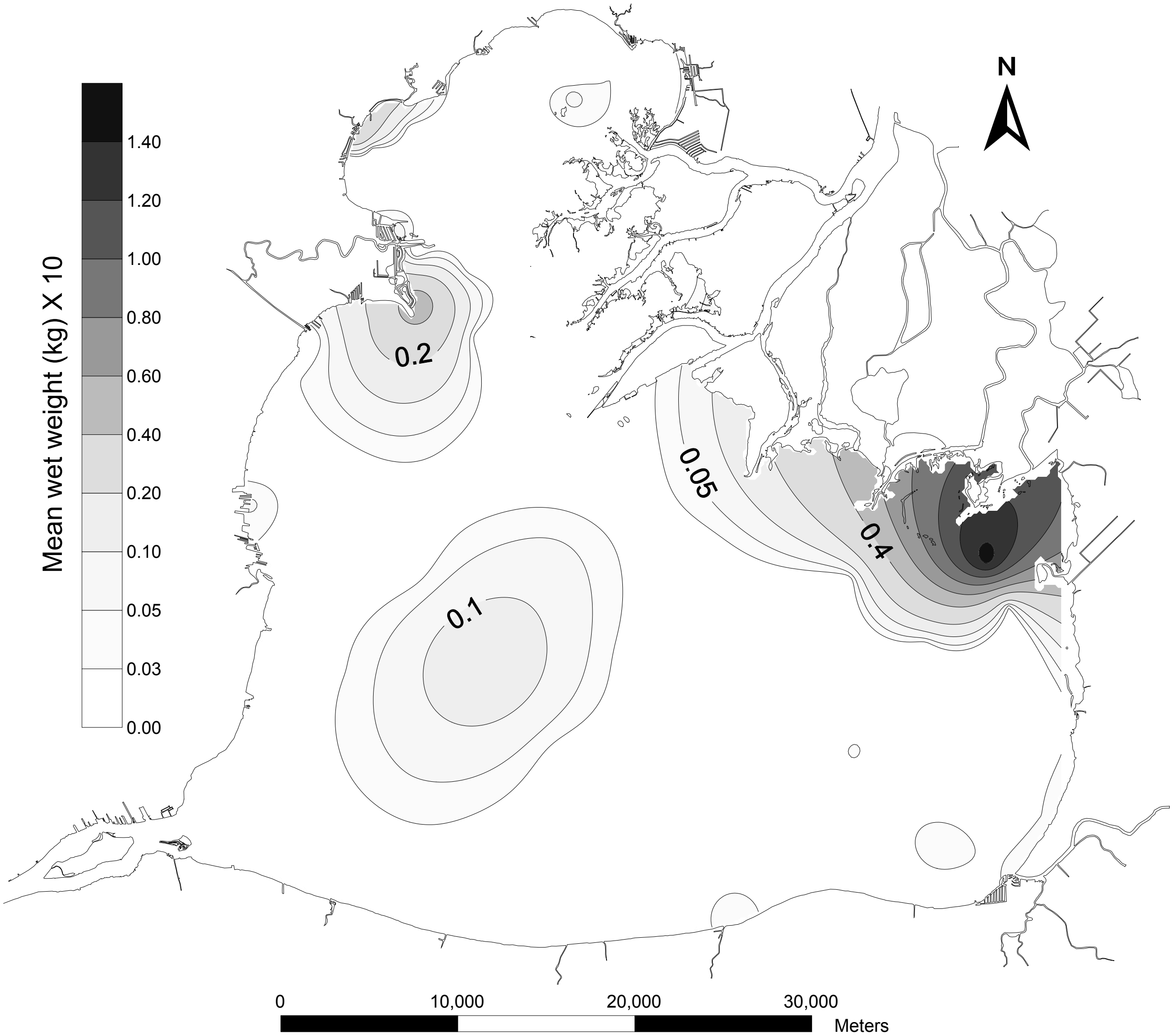
Appendix 3.–Contour map of common naiad wet weight (kg) per hook toss multiplied by 10 at 95 stations in Lake St. Clair during 2003 through 2007. Number of tosses at a station ranged from 1 to 8 depending upon sampling effectiveness.



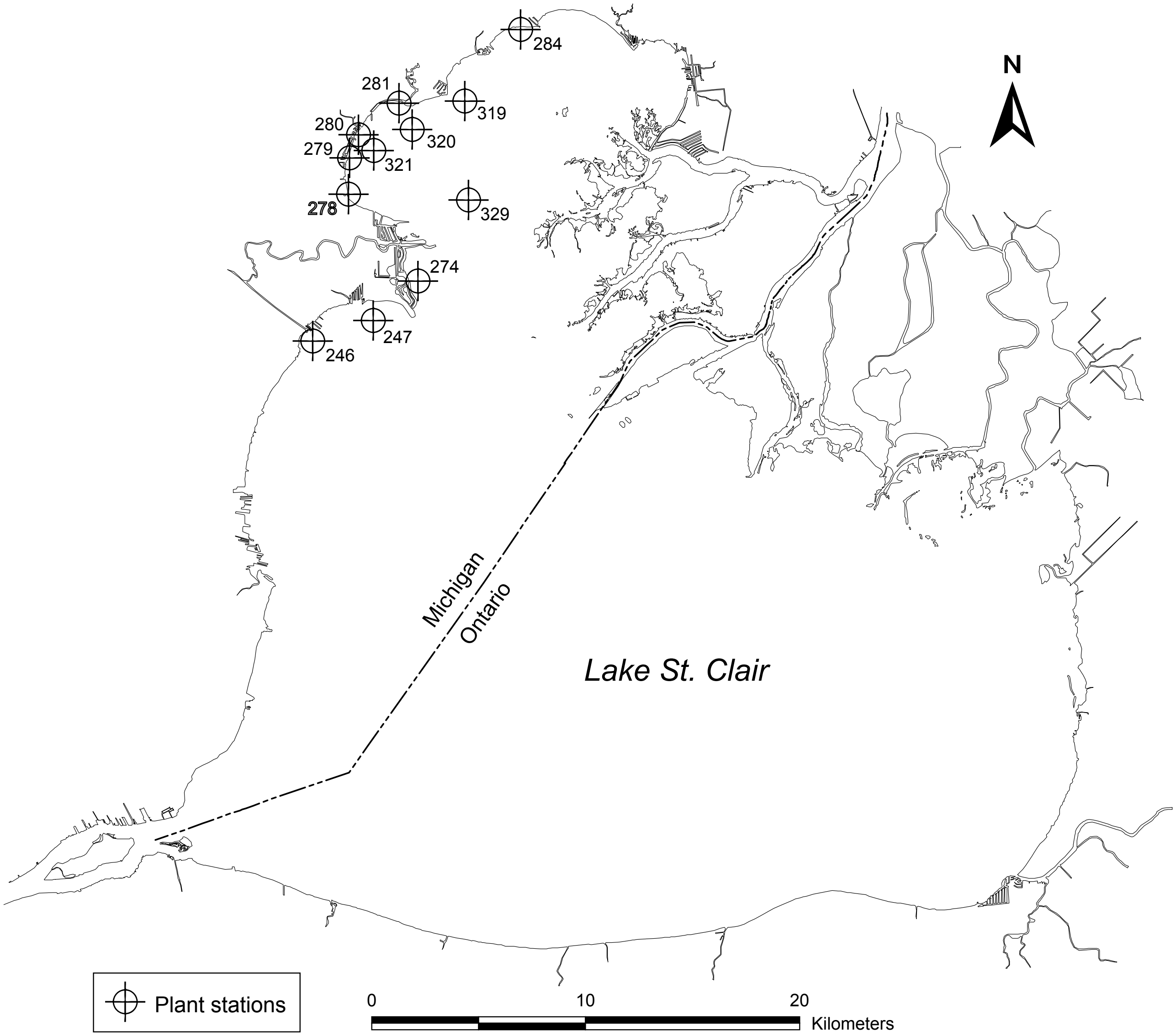
Appendix 4.–Contour map of wild celery wet weight (kg) per hook toss multiplied by 10 at 95 stations in Lake St. Clair during 2003 through 2007. Number of tosses at a station ranged from 1 to 8 depending upon sampling effectiveness.



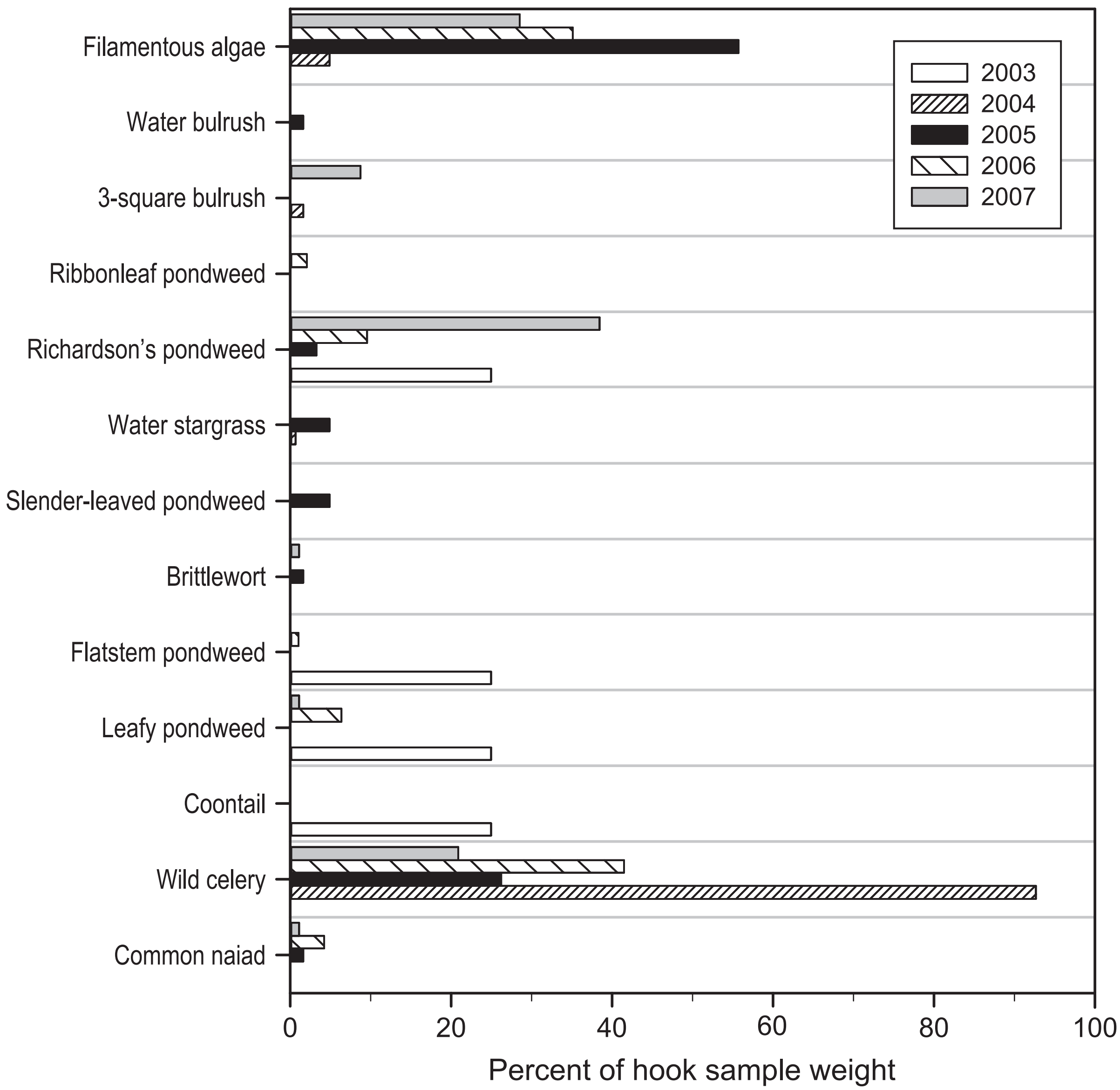
Appendix 5.–Contour map of Richardson's pondweed wet weight (kg) per hook toss multiplied by 10 at 95 stations in Lake St. Clair during 2003 through 2007. Number of tosses at a station ranged from 1 to 8 depending upon sampling effectiveness.



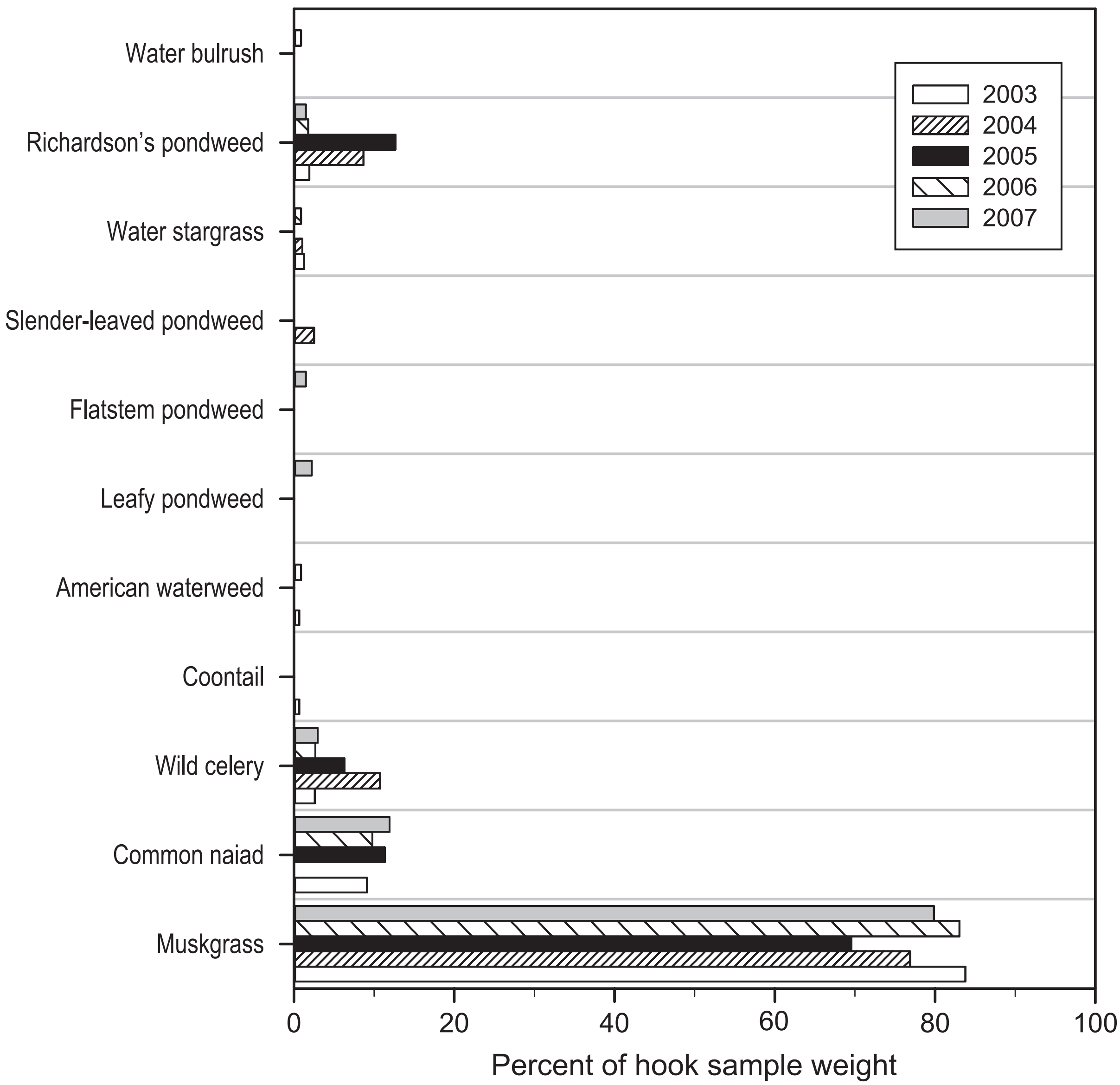
Appendix 6.–Contour map of filamentous algae wet weight (kg) per hook toss multiplied by 10 at 95 stations in Lake St. Clair during 2003 through 2007. Number of tosses at a station ranged from 1 to 8 depending upon sampling effectiveness.



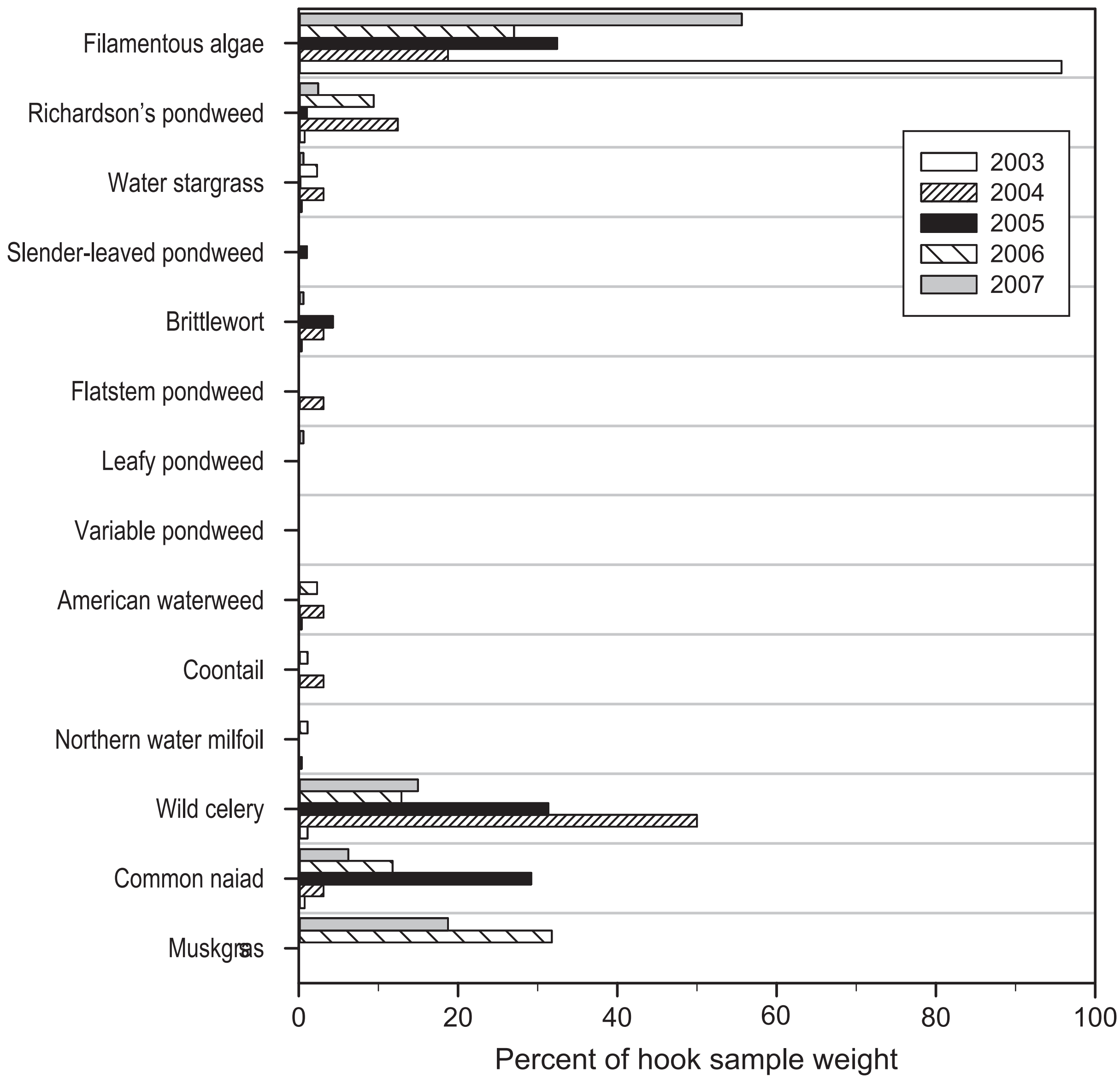
Appendix 7.–Map of Lake St. Clair showing 12 plant sampling stations that were surveyed five consecutive years from 2003 through 2007. Number of hook tosses at a station ranged from 1 to 8 depending upon sampling effectiveness.



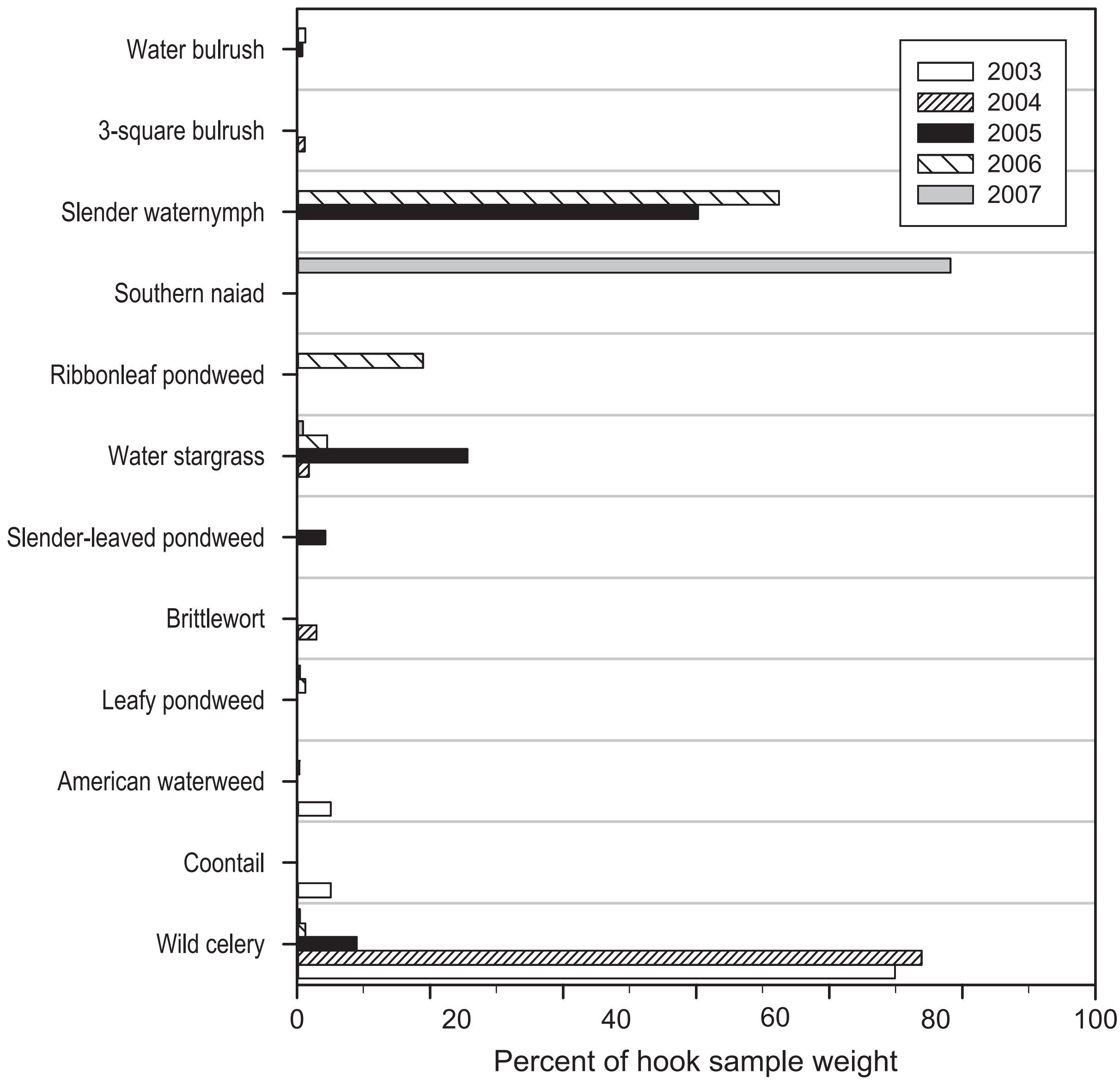
Appendix 8.–Grouped bar chart showing species distribution of submerged plants at station 247 during five year period from 2003 to 2007. Species contributions were calculated as percent of total wet weight of plants captured by hook tosses.



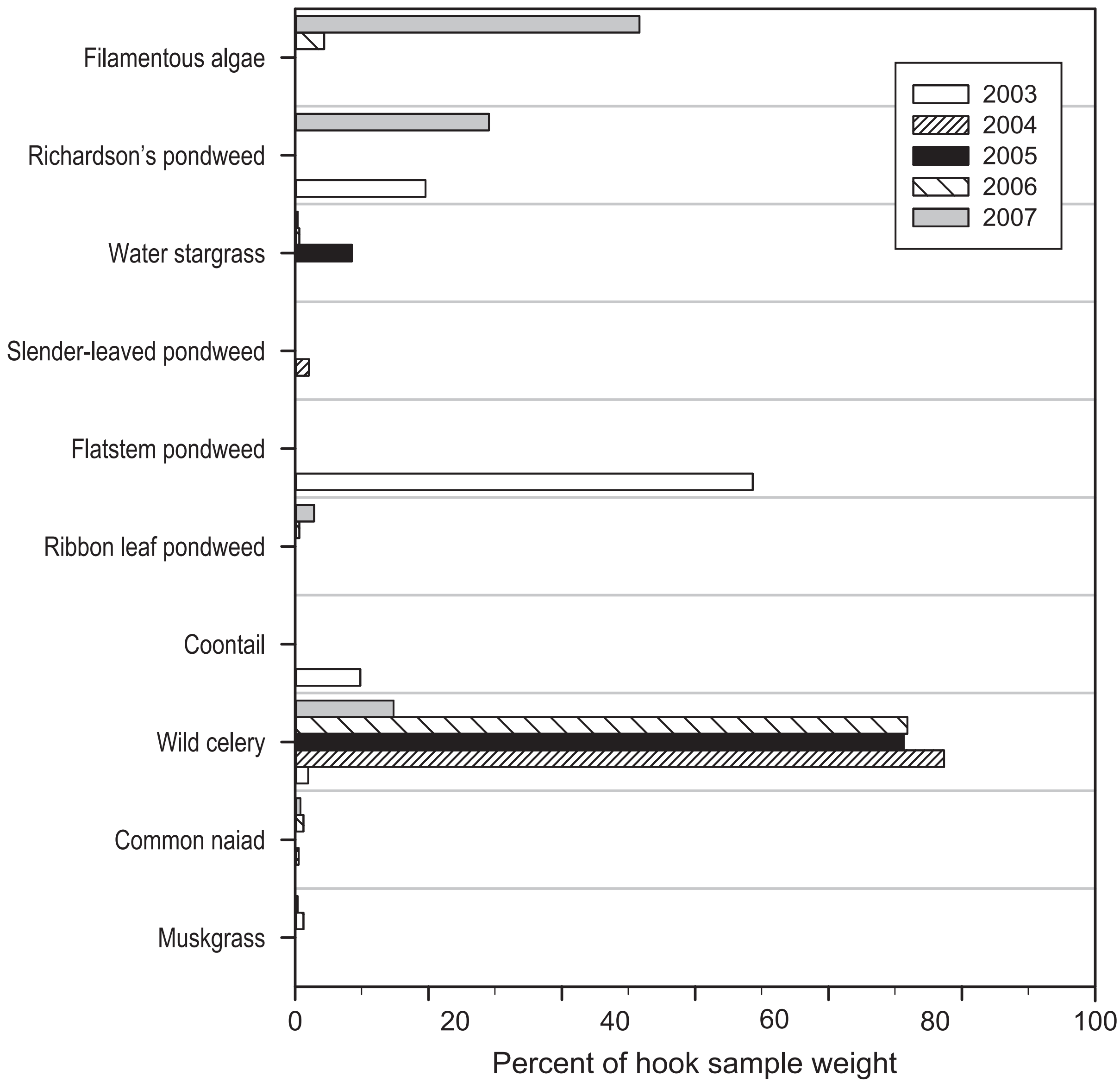
Appendix 9.–Grouped bar chart showing species distribution of submerged plants at station 279 during five year period from 2003 to 2007. Species contributions were calculated as percent of total wet weight of plants captured by hook tosses.



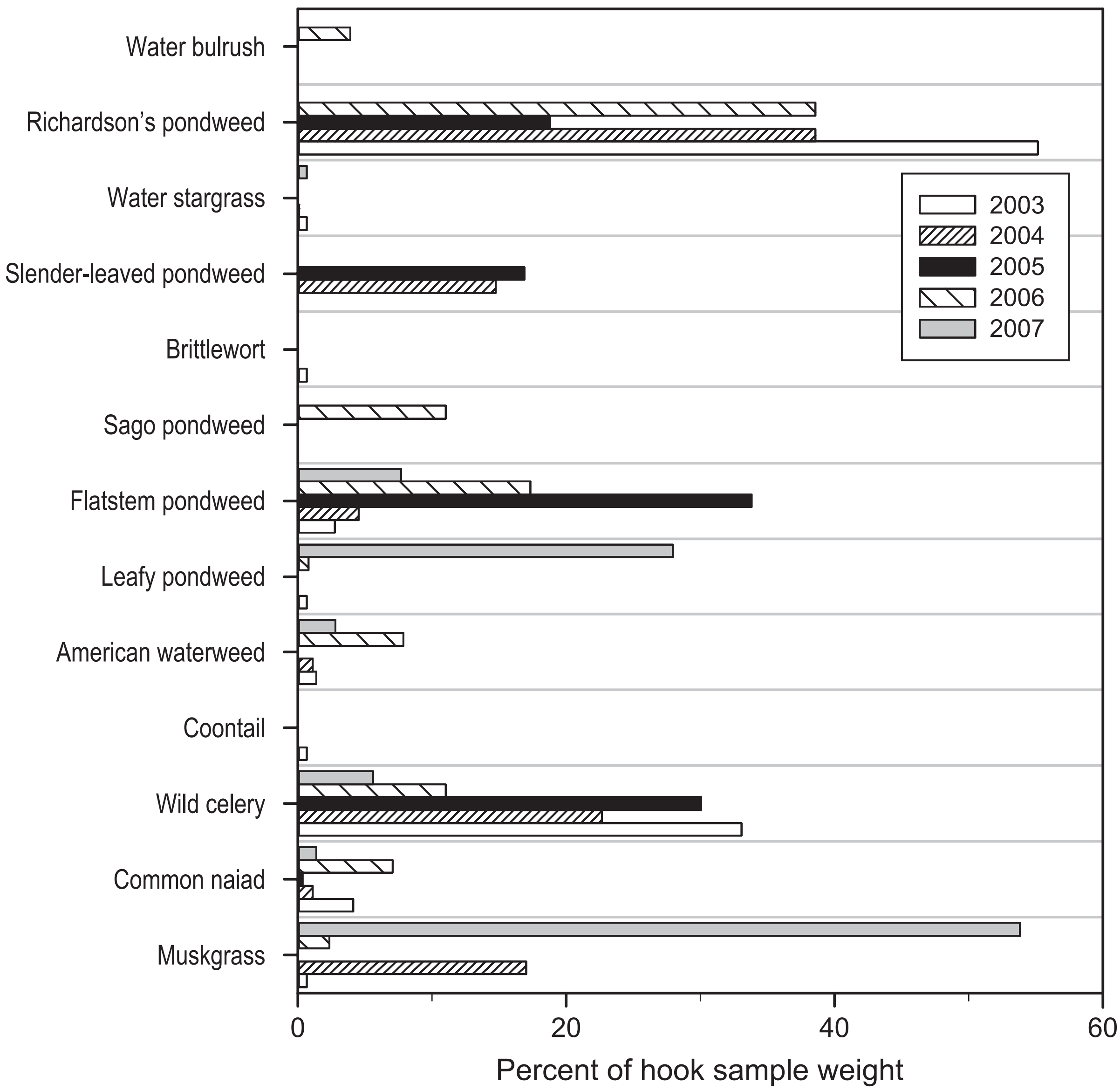
Appendix 10.–Grouped bar chart showing species distribution of submerged plants at station 281 during five year period from 2003 to 2007. Species contributions were calculated as percent of total wet weight of plants captured by hook tosses.



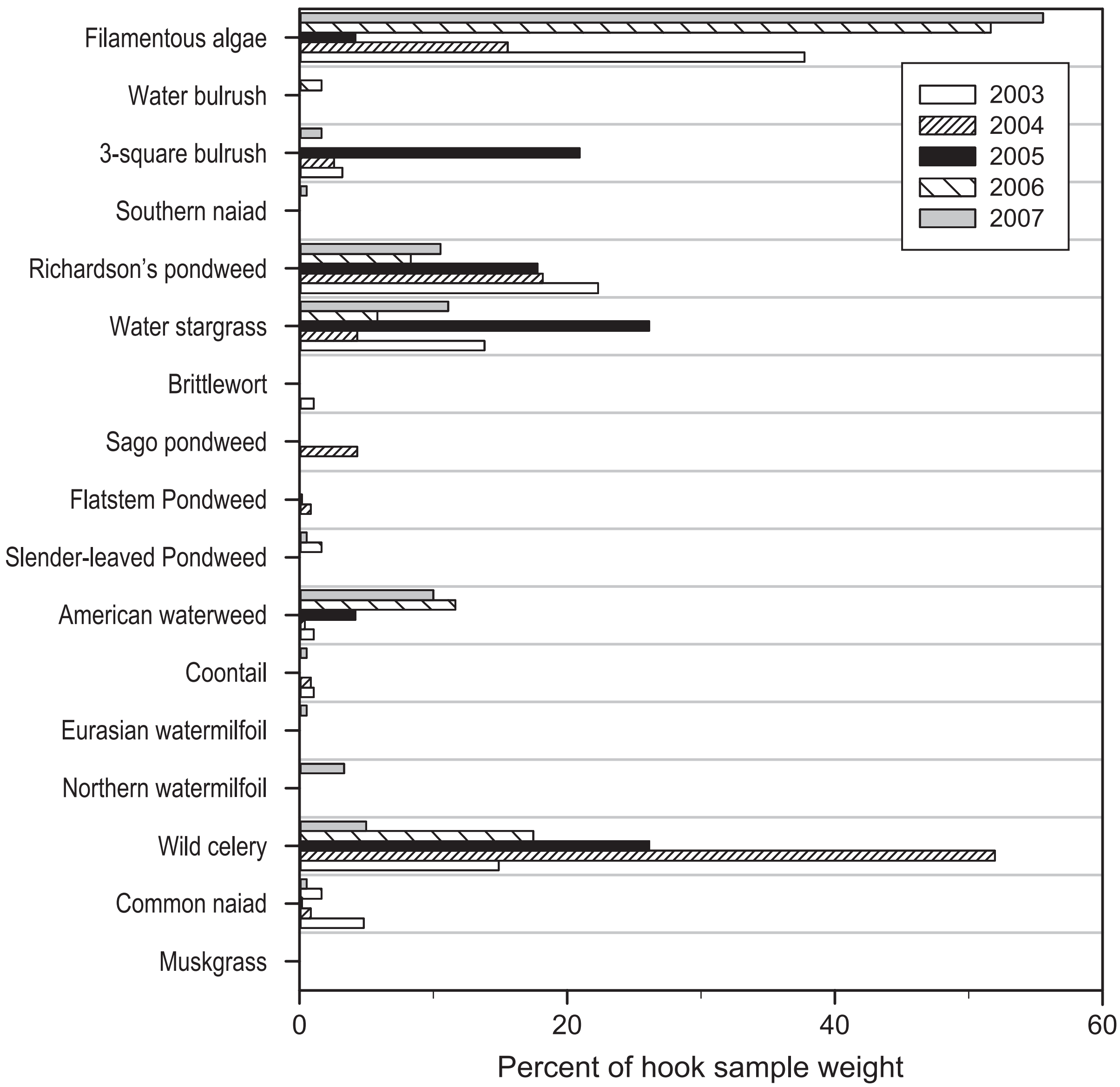
Appendix 11.–Grouped bar chart showing species distribution of submerged plants at station 246 during five year period from 2003 to 2007. Species contributions were calculated as percent of total wet weight of plants captured by hook tosses.



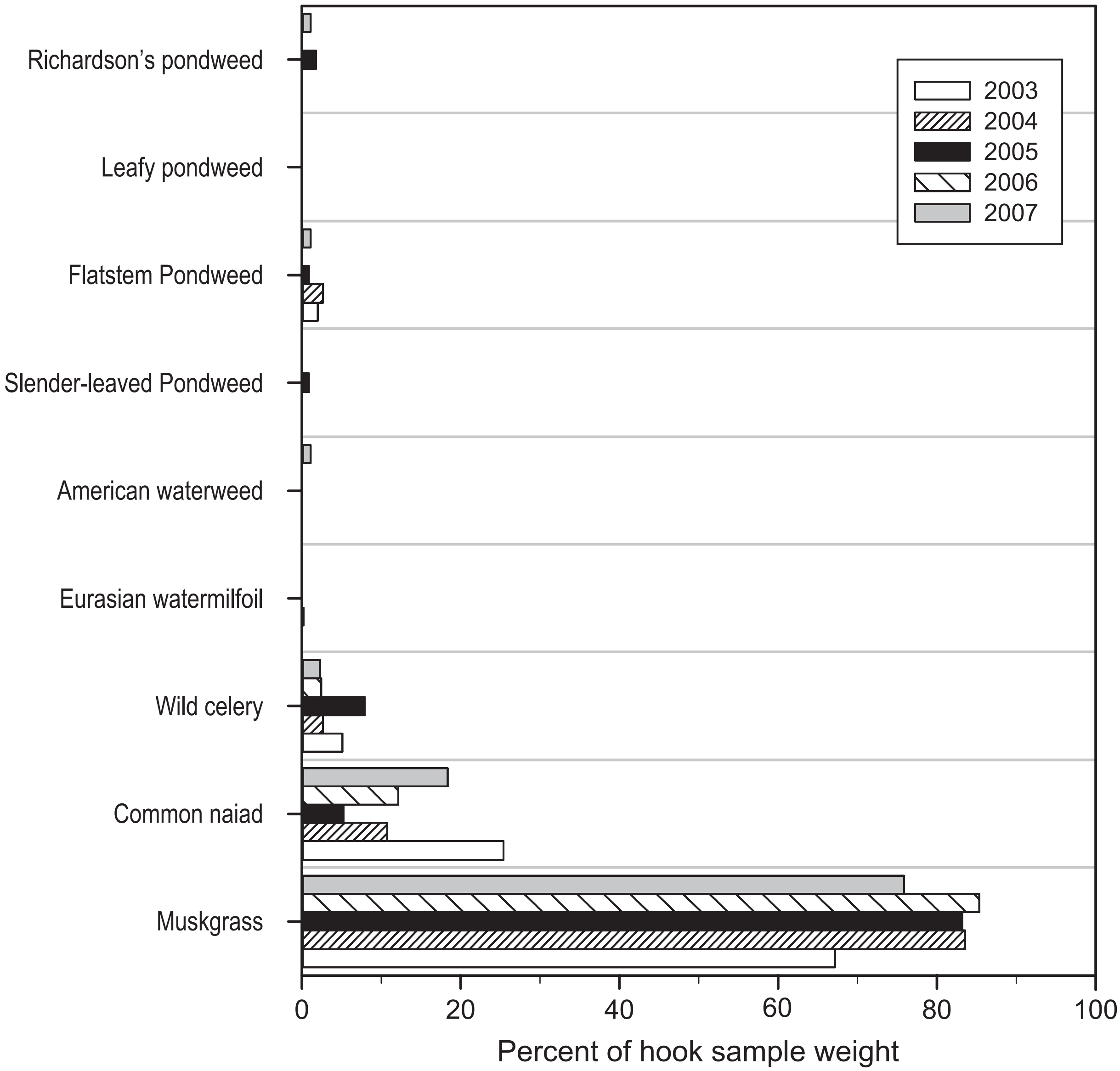
Appendix 12.–Grouped bar chart showing species distribution of submerged plants at station 274 during five year period from 2003 to 2007. Species contributions were calculated as percent of total wet weight of plants captured by hook tosses.



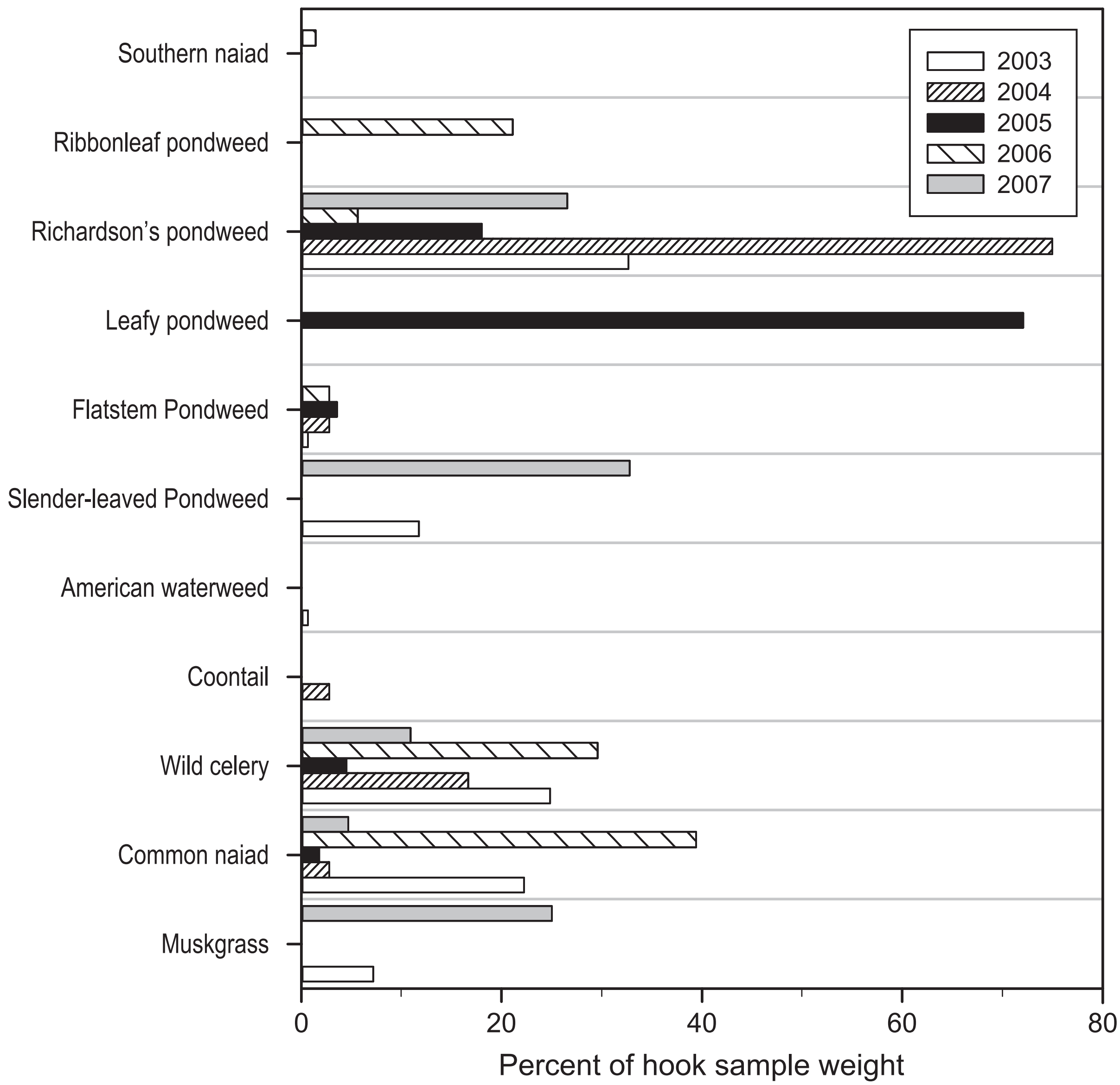
Appendix 13.–Grouped bar chart showing species distribution of submerged plants at station 278 during five year period from 2003 to 2007. Species contributions were calculated as percent of total wet weight of plants captured by hook tosses.



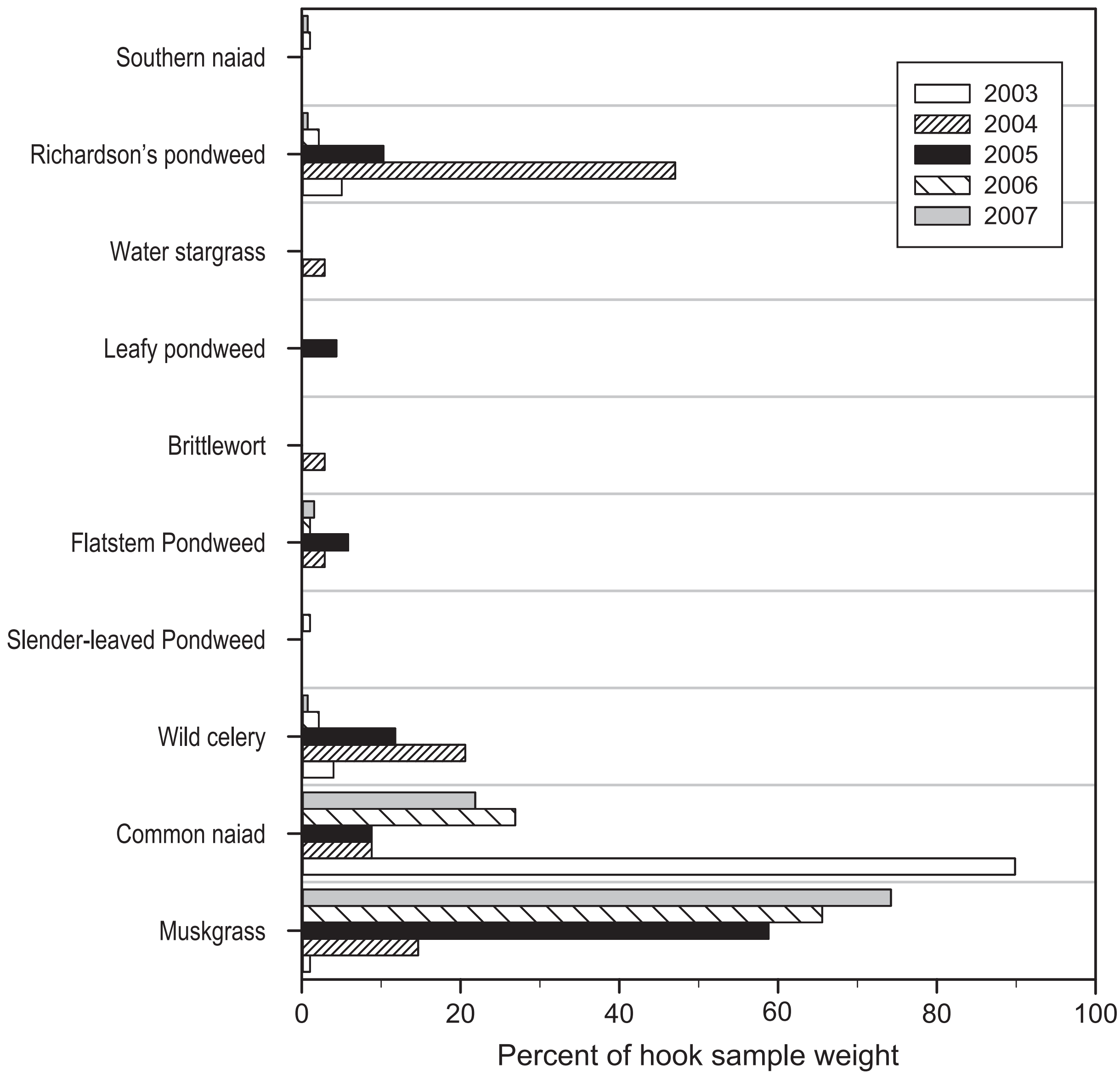
Appendix 14.–Grouped bar chart showing species distribution of submerged plants at station 280 during five year period from 2003 to 2007. Species contributions were calculated as percent of total wet weight of plants captured by hook tosses.



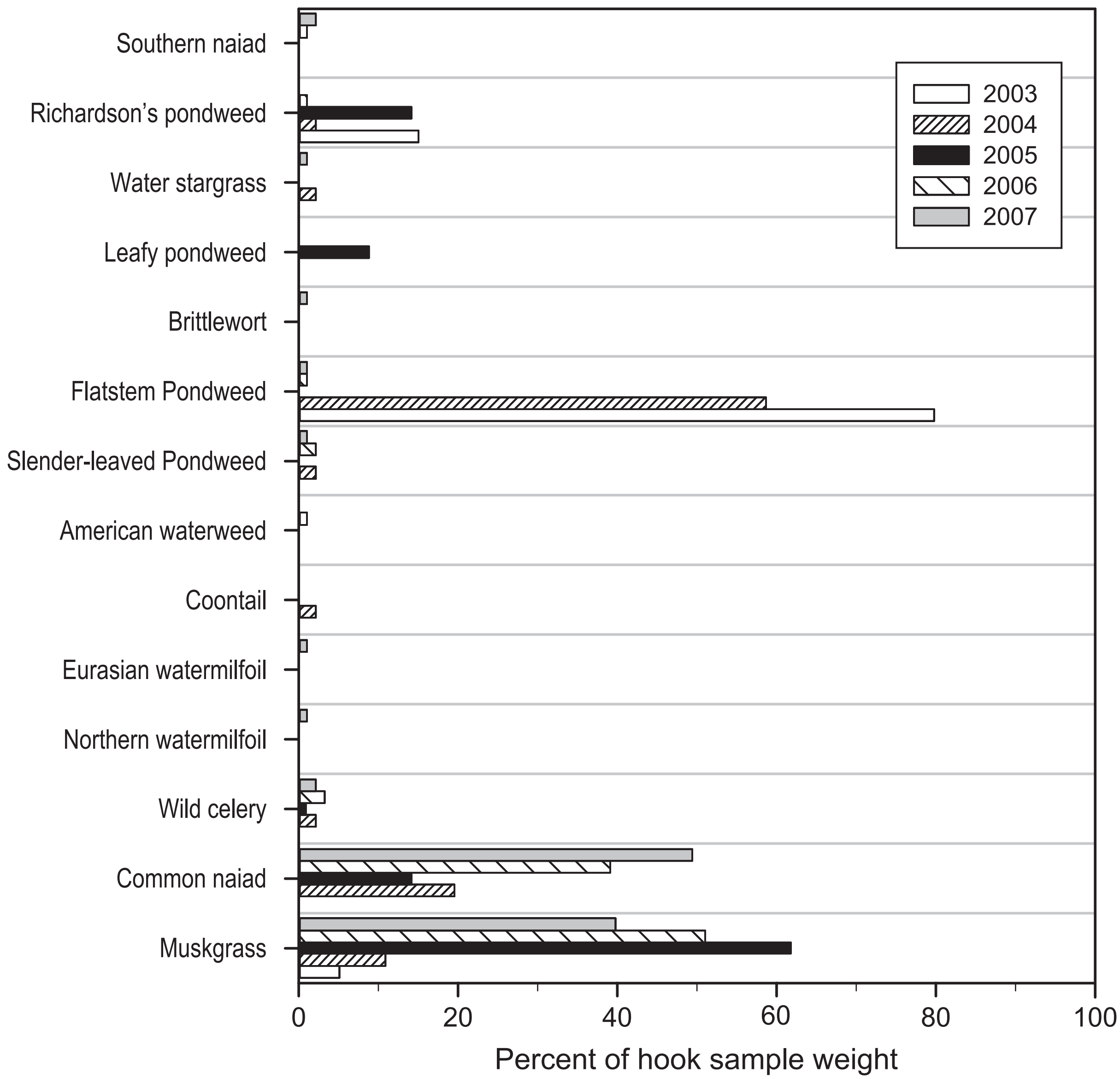
Appendix 15.–Grouped bar chart showing species distribution of submerged plants at station 284 during five year period from 2003 to 2007. Species contributions were calculated as percent of total wet weight of plants captured by hook tosses.



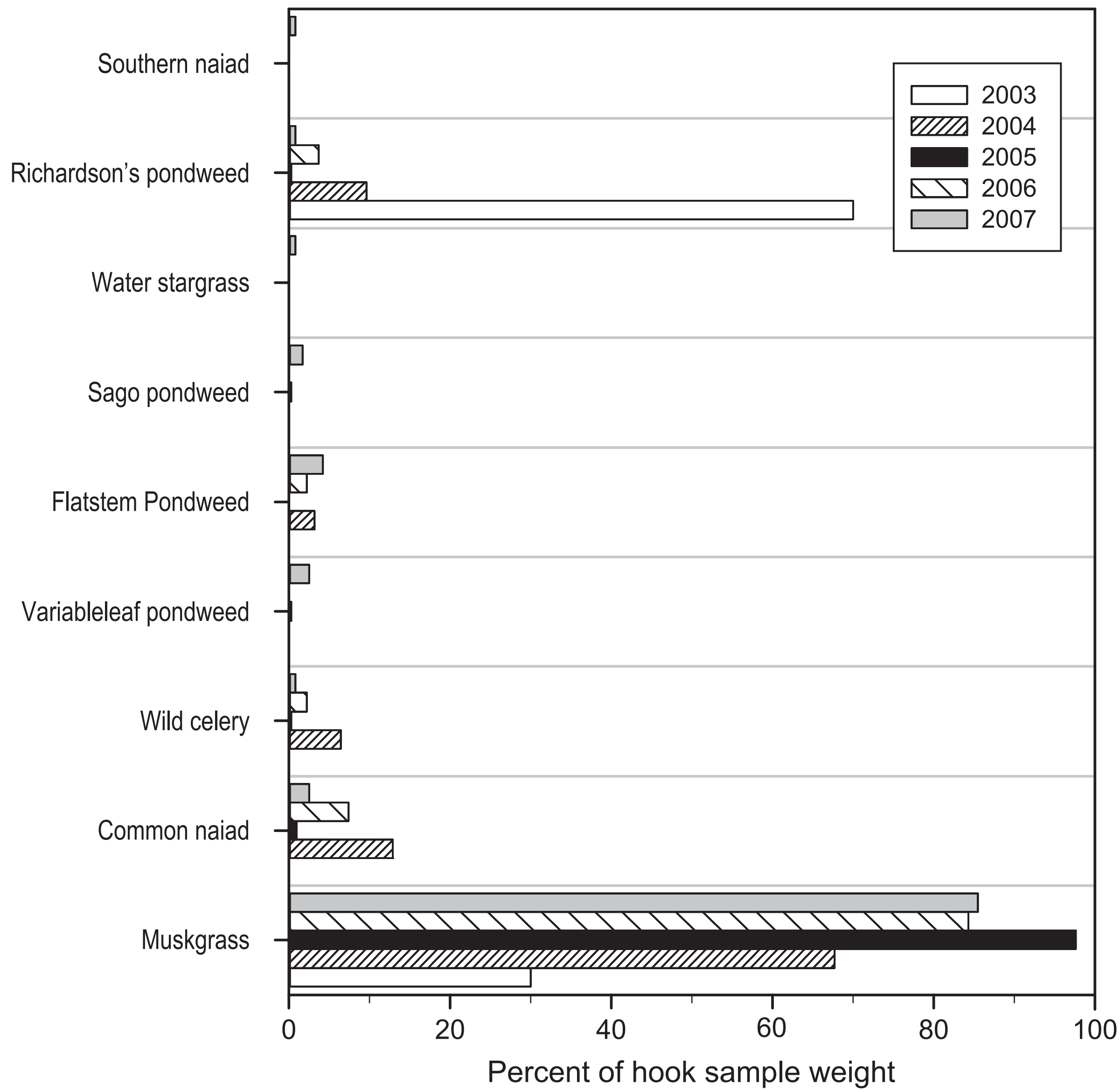
Appendix 16.–Grouped bar chart showing species distribution of submerged plants at station 319 during five year period from 2003 to 2007. Species contributions were calculated as percent of total wet weight of plants captured by hook tosses.



Appendix 17.–Grouped bar chart showing species distribution of submerged plants at station 320 during five year period from 2003 to 2007. Species contributions were calculated as percent of total wet weight of plants captured by hook tosses.



Appendix 18.–Grouped bar chart showing species distribution of submerged plants at station 321 during five year period from 2003 to 2007. Species contributions were calculated as percent of total wet weight of plants captured by hook tosses.



Appendix 19.–Grouped bar chart showing species distribution of submerged plants at station 329 during five year period from 2003 to 2007. Species contributions were calculated as percent of total wet weight of plants captured by hook tosses.