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The Fish Community and Fishery of Elk and Skegemog Lakes, Antrim, Kalkaska, and Grand Traverse counties, Michigan in 2008-09

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Michigan Department of Natural Resources
Fisheries Report 19, 2017

The Fish Community and Fishery of Elk and Skegemog Lakes, Antrim, Kalkaska, and Grand Traverse Counties, Michigan in 2008-09

Patrick A. Hanchin

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Introduction

From April 2008 through March 2009, the Michigan Department of Natural Resources (DNR), Fisheries Division surveyed fish populations and angler catch and effort in Elk and Skegemog lakes, the two lower lakes in the Antrim Chain of Lakes occurring in Antrim, Kalkaska, and Grand Traverse counties, Michigan. This work was part of the Large Lakes Program, which is the assessment and monitoring program for fish communities and fisheries in Michigan's largest inland lakes (Clark et al. 2004). The Large Lakes Program has three primary objectives: (1) to produce indices of abundance and estimates of annual harvest and fishing effort for four target species—Walleye *Sander vitreus*, Northern Pike *Esox lucius*, Smallmouth Bass *Micropterus dolomieu*, and Muskellunge *Esox masquinongy*; (2) to produce growth and mortality statistics to evaluate the effects of fishing on these species; and (3) to evaluate the suitability of various abundance and exploitation rate estimators for use in large lakes. For this report, I quantified abundance, growth, mortality, size structure, angler effort, and exploitation for Walleye, Northern Pike, and Smallmouth Bass to evaluate the current status of the populations. In addition, a preliminary investigation into the movement and seasonal distribution of Muskellunge was initiated to increase our understanding of their patterns in these lakes. Throughout, I compare current findings to historic information and to other lakes surveyed in the Large Lakes Program. This was the twentieth survey conducted under the protocols of the Large Lakes Program. The sample size for each comparison varies throughout the report because some statistics could not be estimated for a water body or species.

Study Area

Elk and Skegemog lakes are located in Antrim, Kalkaska, and Grand Traverse counties, Michigan in the Elk River watershed. Elk and Skegemog lakes are the lower two lakes in the Antrim chain, also known as the "Chain of Lakes", which flows for approximately 50 miles from the headwaters of the Intermediate river to East Grand Traverse Bay of Lake Michigan. Elk and Skegemog lakes have a combined surface area of approximately 10,961 acres (Breck 2004), with Elk Lake comprising approximately 8,195 acres and Skegemog Lake approximately 2,766 acres. The lakes are separated into two distinct basins and are connected by the "narrows", which is a shallow (<6 ft) area approximately ⅓ mile wide (Figure 1). The main tributaries to Elk and Skegemog lakes are the Torch River, and Vargason, Desmond, Barker, Battle, and Williamsburg creeks (Figure 1). In 1891, the lake level of Elk and Skegemog lakes was raised approximately two feet by the installation of a dam on the Elk River in the city of Elk Rapids (DNR Fisheries Division, unpublished data). The existing dam in Elk Rapids was built in 1915 for power generation and to facilitate the movement of vessels and logs in the Antrim chain. The dam is constructed of concrete, brick, and earth and is approximately 300 feet wide with 10 feet of head. There is no upstream fish passage from Lake Michigan over the Elk Rapids Dam.

Elk and Skegemog lakes have approximately 35 miles of shoreline. Elk Lake is highly developed with private residences, while Skegemog Lake has only about one half of its shoreline developed with private residences. Over seven miles of shoreline on Skegemog Lake and the Torch River are within the Skegemog Lake Wildlife Area, a 3,300-acre, state-owned preserve that is largely conifer swamp with a floating bog/sedge mat shoreline. The only urban areas in the vicinity of Elk and Skegemog lakes are Kewadin and Elk Rapids, each of which has a population of less than 2,000.

Elk and Skegemog lakes differ in depth, abundance of aquatic vegetation, and amount of large woody debris. Elk Lake is deeper, with mean and maximum depths of 69 and 179 ft, respectively (Figure 2). Skegemog Lake has mean and maximum depths of 11 and 30 ft, respectively (Figure 3). Littoral areas (<15 ft) in Elk Lake represent 25% of the lake area whereas in Skegemog Lake they represent 76%. Most littoral areas in Elk Lake have sandy substrate with some gravel and cobble, and where the littoral areas transition to deeper water, clay and marl become more prevalent. The bottom substrates in the deepest waters of Elk Lake are almost entirely clay (DNR Fisheries Division, unpublished data). Substrate in littoral areas of Skegemog Lake is also largely sand and sparse gravel, but organic sediments are prevalent. Skegemog Lake has abundant aquatic vegetation, while aquatic vegetation is sparse in Elk Lake, with the exceptions of small areas near Kewadin, Spencer Bay, and around the narrows. In addition to abundant vegetation, the northeastern portion of Skegemog Lake around the Torch River has an extensive area of standing dead timber and submerged woody debris, much of which is remaining from the original change in water level from the construction of the Elk Rapids Dam. Elk Lake has a small area of standing dead timber and submerged woody debris in the vicinity of Elk Rapids and Kewadin. Given the lack of structure in Elk Lake, brush shelters have been installed with help from angler groups and the lake association on several occasions in the 1940s, 1950s, 1970s, and 1990s, though evaluations of their effectiveness have not been conducted.

The Elk River watershed is within the Northern Lower Peninsula ecoregion (Eagle et al. 2005) where it covers 503 square miles (U'Ren 2005). Forest types include northern hardwoods, early successional aspen, pine systems, and lowland conifers. The geology of the region consists of Paleozoic bedrock that was completely glaciated during the Late Wisconsinan period (Eagle et al. 2005). Glaciation resulted in diverse topography with extensive outwash plains and large moraines. The majority of soils are sands, loamy sands and sandy loams (Eagle et al. 2005). Land cover in the Elk River watershed is primarily forest (47%), agricultural land (18%), and grassland (17%), with the remainder being water (11%), urban area (5%), and wetlands (2%; U'Ren 2005). In the immediate vicinity of Elk and Skegemog lakes, agricultural land is most common. Specifically, orchards are common in the watershed and they accounted for 4,500 acres of the Elk River watershed in 1984 (Anonymous 1984). There were 87 dairy, beef, hog, and poultry operations present in the watershed in 1984 (Anonymous 1984) and 93 in 1999 (Anonymous 1999). Soil erosion and agricultural pollution were problematic in the past (Anonymous 1984), though conservation efforts have alleviated many of the problems. The number of growing degree days (area-weighted average) for Elk and Skegemog lakes are 2,182 and 2,136, respectively (Breck 2004). For comparison, growing degree days in Michigan range from about 1,800 to 2,600 (Schneider et al. 2007). Ice cover on Skegemog Lake generally occurs from early December to early April, while ice cover on Elk Lake generally occurs from mid-January to early April.

Several limnological evaluations have been conducted on Elk and Skegemog lakes over the years (Everhart et al. 1971, Lape and Curry 1967), but water quality was described most recently in the 2008 Water Quality Monitoring Report published by the Tipp of the Mitt Watershed Council (Anonymous 2008). The report showed that surface pH levels in Elk and Skegemog lakes (taken soon after ice out) ranged from 7.6 to 8.4, dissolved oxygen ranged from 9.1 to 13.5 mg/L, and total phosphorous was around 1.0 µg/L. Everhart et al. (1971) described the alkalinity in the Antrim Chain of Lakes as resulting from large limestone deposits which make up the ancient river beds carved post glaciation.

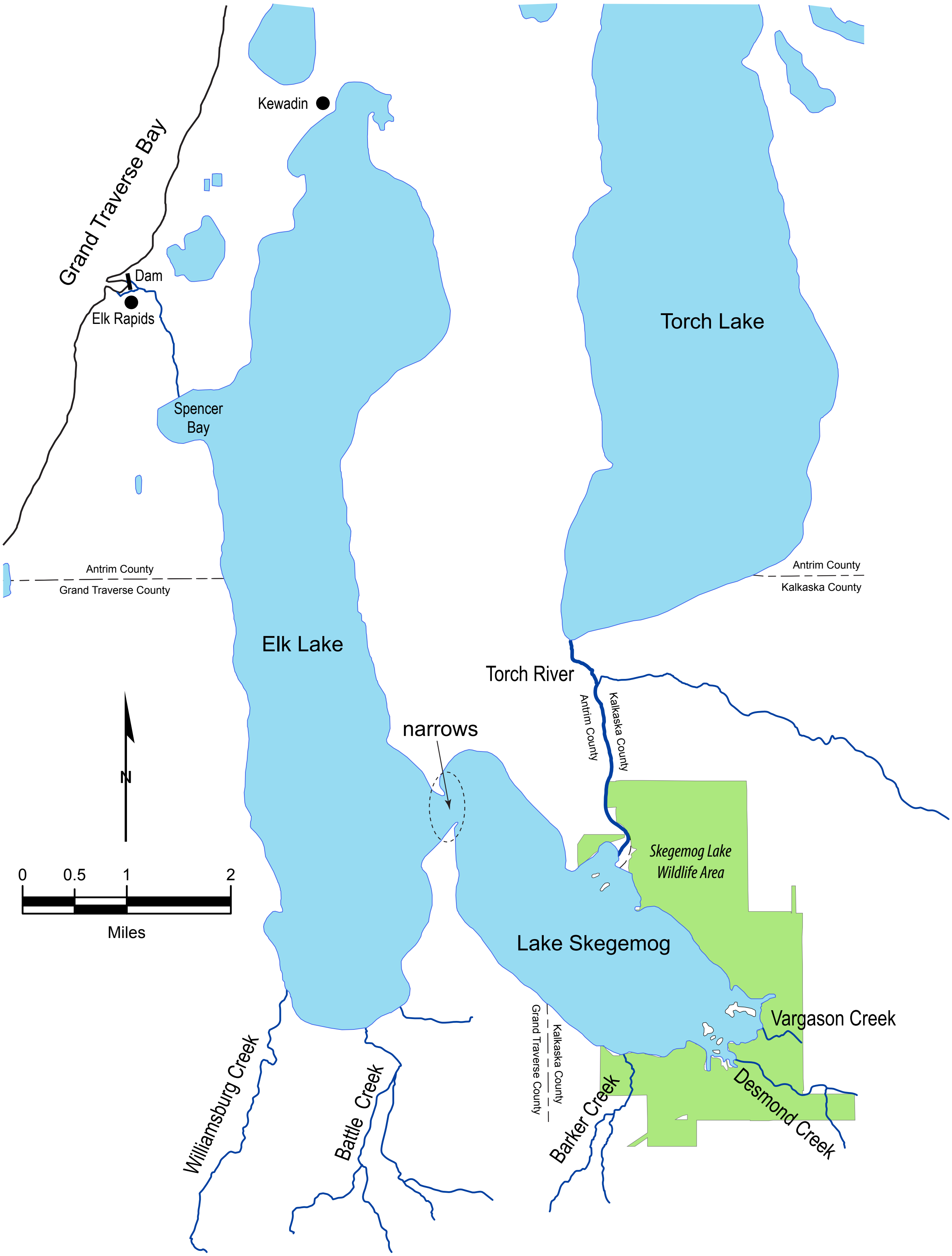

Figure 1.–Map of Elk and Skegemog lakes, Antrim, Kalkaska, and Grand Traverse counties, Michigan.

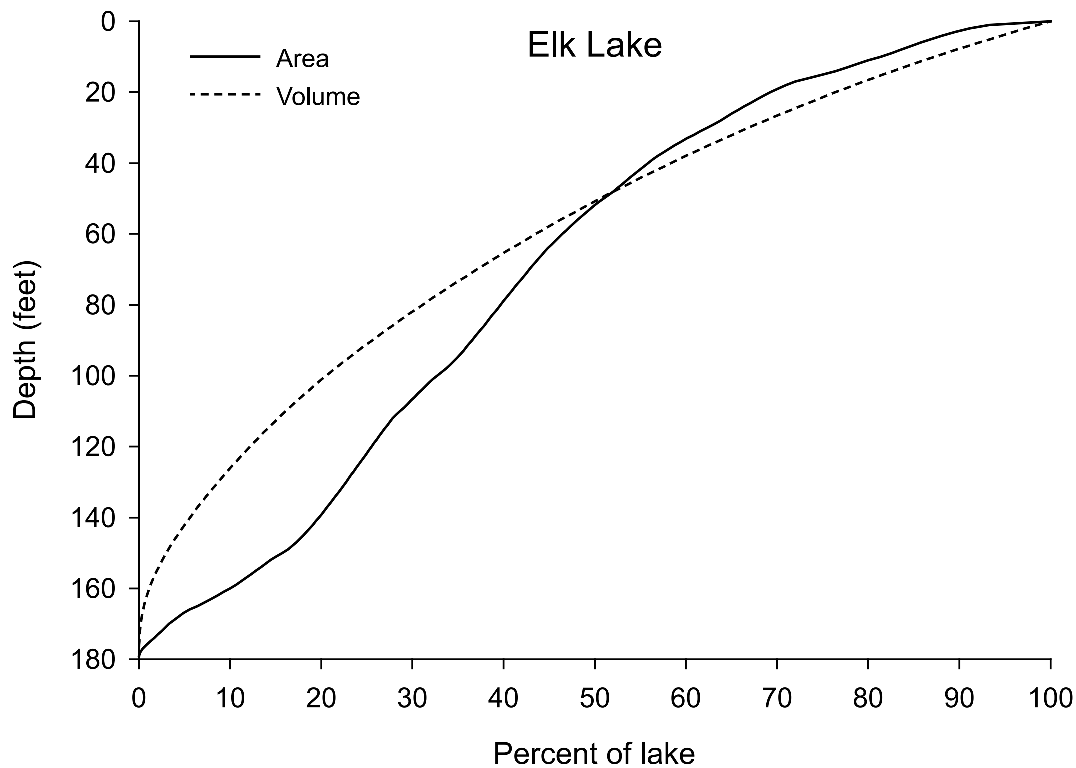

Figure 2.–Percent of lake surface area and volume equal to or greater than a given depth for Elk Lake. Data taken from DNR Digital Water Atlas (Breck 2004).

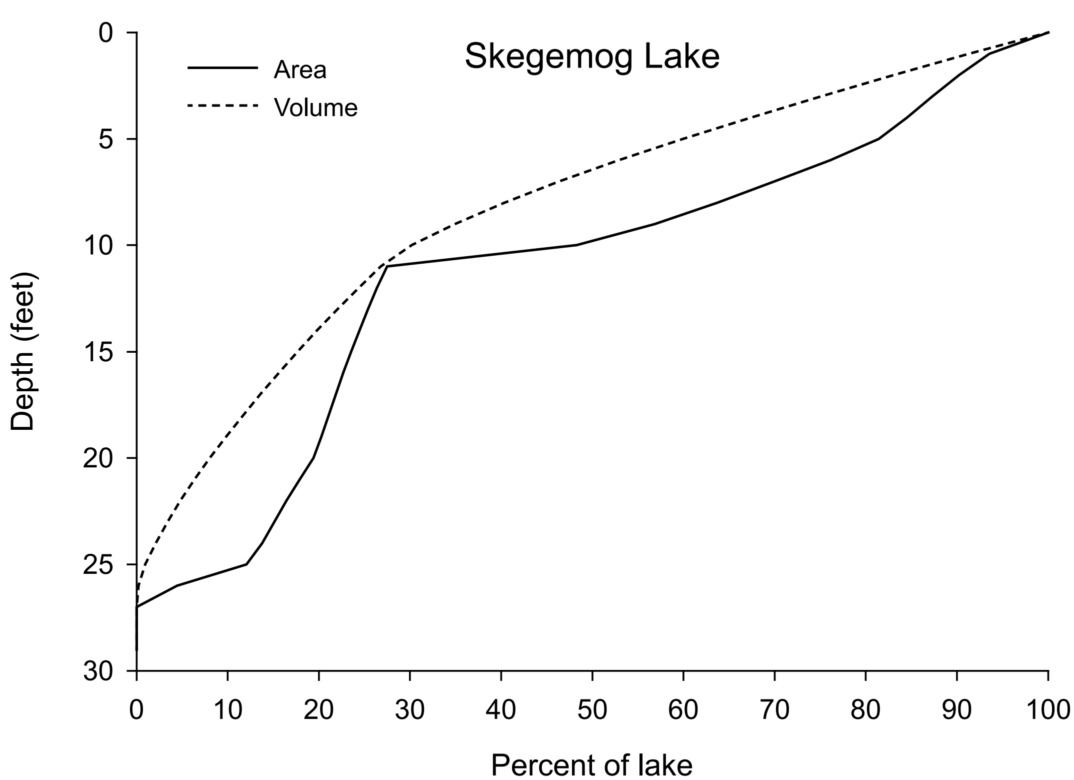

Figure 3.–Percent of lake surface area and volume equal to or greater than a given depth for Skegemog Lake. Data taken from DNR Digital Water Atlas (Breck 2004).

All water quality measurements in Elk and Skegemog lakes indicate excellent water quality. Both Elk Lake and Lake Skegemog are considered oligotrophic based on trophic state indices (TSI) of 26 and 37, respectively; however, Skegemog is near the threshold (TSI = 39) for mesotrophy. Generally, the productivity of lakes in the lower Antrim chain is lower than those in the upper chain (Krol 1971), and this is largely due to the large volume and depth of the lake basins. One noticeable trend in the water quality of Elk and Skegemog lakes is that of decreasing chlorophyll-a, and increasing water clarity since the early 1990s. These trends are likely a result of the zebra mussel introduction, and perhaps improvements made to septic systems around the lake. Although Lake Skegemog rarely stratifies thermally, the thermocline on Elk Lake normally occurs between 40 and 70 feet.

The fish community of Elk and Skegemog lakes is diverse relative to many other lakes in the area, which supports a coldwater community in addition to common cool/warmwater species. Families of fish known to currently exist include, but are not limited to*, Amiidae, Catostomidae, Centrarchidae, Cottidae, Cyprinidae, Esocidae, Gadidae, Gasterosteidae, Ictaluridae, Lepisosteidae, Osmeridae, Percidae, Salmonidae (including subfamily Coregoninae), and Umbridae*. A few of the tributaries have resident salmonid populations and some support steelhead, Brown Trout, and sucker runs. Other species that may inhabit the Elk River watershed are listed in the Skegemog Lake Wildlife Area Management Plan (Anonymous 2002). Elk and Skegemog lakes produce large fish of numerous species and there have been thirty-five State of Michigan Master Angler awards reported from 2000 to 2010, including 12 Smallmouth Bass, 10 Rock Bass, 8 Muskellunge, 3 Channel Catfish, 1 Longnose Gar, and 1 Chinook Salmon. The catch of a Chinook Salmon in Elk Lake is questionable since Chinook Salmon can not migrate into Elk Lake from Lake Michigan and they were never stocked into the lake.

The history of fisheries management on Elk and Skegemog lakes has largely consisted of fish stocking with a few statewide regulation changes over the years. Laarman (1976) provided a list of early (1894 to 1973) fish stocking efforts in Elk Lake, which included a variety of species and life stages. Given the deepwater habitat in Elk Lake and its once unimpeded connection to Grand Traverse Bay of Lake Michigan, the fish community in Elk and Skegemog lakes historically would have been similar to that of Grand Traverse Bay. Although the original fish community almost certainly contained naturally-reproducing populations of deepwater species such as Lake Trout, Lake Whitefish, and Cisco, biologists in the infancy of fisheries management often stocked fish without a thorough understanding of the fish community or population dynamics of a lake. Lake Trout were stocked in Elk Lake as early as 1894 and stocking continued throughout the 1900s (Laarman 1976). The most likely source of gametes for Lake Trout stocked into Elk Lake was Lake Michigan in the vicinity of Charlevoix. In 1956 natural reproduction of Lake Trout was documented via the presence of young fish and absence of recent stocking, but biologists still recommended annual stocking of Lake Trout and Rainbow Trout since Elk Lake was "good trout water." Additional recommendations included the encouragement of winter spearing of Northern Pike and Muskellunge in order to alleviate predation on the stocked trout. In the 1960s and 1970s, biologists thought a lack of Lake Trout reproduction in nearby Torch Lake (another lake in the lower Antrim chain) may have been due to high levels of DDT interfering with reproductive success (Patulski 1971). Lake Trout stocking in Elk Lake stopped in 1965 and managers concentrated efforts on stocking splake and Rainbow Trout which both had poor survival. Lake Trout stocking resumed in 1976 with marked fish; however, fall gill-net surveys in 1979 and 1983 resulted in very few Lake Trout with fin clips so biologists again started to question the effectiveness of stocking Lake Trout. Ultimately in 1984, Lake Trout stocking was discontinued due to their poor survival and evidence of natural reproduction. Further evidence of naturally-reproducing Lake Trout was obtained in 1990 when a fall gill-net survey found many recent year classes of Lake Trout despite the discontinuation of stocking.

With the realization that Lake Trout were reproducing naturally, fish stocking efforts in Elk Lake switched to Rainbow Trout in 1980 and Brown Trout in 1985 and both achieved moderate success, based on angler reports. Brown Trout stocking continued through 2000 and Rainbow Trout stocking continued through 2008 (Table 1). The most recent evaluation of stocked Rainbow Trout involved a comparison of the Eagle Lake inland form to the potamodromous Michigan steelhead strain (Nuhfer 2008). While sample sizes were relatively low (N = 42), 95% of Rainbow Trout collected in surveys from 2005 to 2008 were of wild origin, thus indicating that the population is largely sustained by natural reproduction. The locations where successful spawning of brown and Rainbow Trout takes place in Elk and Skegemog lakes are not entirely known, though undoubtedly a considerable portion takes place in the Rapid and Torch rivers, and some of the smaller tributaries such as Williamsburg and Battle creeks. Despite potential lapses in the natural reproduction of trout species and the variable contributions of stocked fish, Elk and Skegemog lakes currently contain naturally-reproducing populations of Lake Trout, Rainbow Trout, and Brown Trout, as well as other coldwater species such as Lake Whitefish, Cisco, and Burbot. Currently, there are no fish being stocked in Elk and Skegemog lakes, though Atlantic Salmon are being stocked annually in Torch Lake.

Table 1.–Number and size of fish stocked in Elk and Skegemog lakes 1990 through 2008.

Year	Species	Number	Average size (in)
1990	Rainbow Trout	30,000	6.8
	Brown Trout	30,000	6.0
	Muskellunge	150	11.2
1991	Rainbow Trout	24,210	7.0
	Brown Trout	30,000	5.9
1992	Rainbow Trout	30,000	6.5
	Brown Trout	29,300	6.6
1993	Rainbow Trout	24,896	6.6
	Brown Trout	29,700	7.1
	Brown Trout	1,028	13.5
1994	Rainbow Trout	35,395	6.9
	Brown Trout	30,725	6.1
	Muskellunge	4,280	10.8
1995	Rainbow Trout	33,298	5.3
	Brown Trout	38,923	7.4
1996	Rainbow Trout	36,093	7.2
	Brown Trout	28,822	6.7
1997	Rainbow Trout	32,100	6.8
	Brown Trout	36,093	6.2
1998	Rainbow Trout	29,310	7.1
1999	Rainbow Trout	29,400	6.5
2000	Rainbow Trout	38,700	6.4
	Brown Trout	21,263	6.4
2001	Rainbow Trout	31,000	7.4
2002	Rainbow Trout	43,000	7.0
2003	Rainbow Trout	34,560	6.5
2004	Rainbow Trout	42,980	7.4
2005	Rainbow Trout	43,000	7.5
2006	Rainbow Trout	33,594	7.8
2007	Rainbow Trout	37,418	7.6
2008	Rainbow Trout	42,000	7.2

Contrary to the coldwater fish community, the warmwater fish community in Elk and Skegemog lakes has not been managed as intensively. All of the warmwater fish species reproduce naturally, though the Walleye population may have resulted from an upstream lake that is occasionally stocked. The Muskellunge population is supported by natural reproduction, and stocking has been only used on two occasions to supplement the population (Table 1). Of the warmwater species, the most attention has been paid to Muskellunge. While there is limited standardized data about the population in Elk and Skegemog lakes, some history of the species can be gleaned through a combination of available survey data and anecdotal information provided by the public. In May of 1971, a trap- and fyke-net survey on Skegemog Lake caught 13 Muskellunge in 78 net lifts (CPUE of 0.17 fish per net lift). Muskellunge populations have also been assessed using night spot-lighting in the Torch River. Williams (1954) conducted multiple nights of spot-lighting in 1945, 1951, 1952, and 1953. He reported a maximum of 24, 25, 19, and 13 Muskellunge observations per night in each of the years. The number of Muskellunge observed per hour varied throughout the progression of the spawning period and was also affected by water clarity; however, the yearly averages based on observations occurring during the main spawning period (May 15 to June 15) on nights with good clarity were 7.6, 7.7, and 3.4, respectively for 1951, 1952, and 1953. In 1961, the Elk-Skegemog Lake Association called for protection of Muskellunge during the spawning season since people were taking them “off the beds”. Biologists and landowners were also concerned over the dredging and filling of shoreline to improve properties and called for the identification of musky spawning areas. Lake spawning sites were apparently never documented as most Muskellunge were thought to spawn in the Torch River. Although spawning habitat in Skegemog Lake and the Torch River was likely lost due to riparian development in the 1950s and 1960s, a major success was the establishment of the Skegemog Lake Wildlife Area (Anonymous 2002), which was the culmination of a grassroots effort launched by local residents and the Michigan chapter of the Nature Conservancy in 1972. In 1978, biologists observed 2.8 Muskellunge per hour in the Torch River and concluded that abundance appeared to be lower than average (DNR, unpublished data). However, since they were near the range observed from 1951 to 53, they concluded that more observations were needed. Spot-lighting again occurred on the Torch River May 14 and 21 of 1980, and 20 Muskellunge were observed in 4 hours (5.0 fish per hour). The spawning population was assumed to be near the same level as during the 1950s.

Methods

Fish populations in Elk and Skegemog lakes were sampled with trap nets, fyke nets, and an electrofishing boat from April 2 to 25, 2008. Trap nets were 8 ft x 6 ft x 3 ft with 2-inch stretch mesh and 70- to 150-ft leads, and fyke nets were 6 ft x 4 ft with 3/4-inch stretch mesh and 70- to 150-ft leads. A Smith-Root® boat equipped with boom-mounted electrodes (DC) was used for electrofishing. Nets were located to target Walleye and Northern Pike (nonrandomly), though efforts were also made for broad coverage around the lakes. Duration of net sets ranged from 1–3 nights, but most were 1 night. Latitude and longitude were recorded for all net locations using handheld global positioning systems (GPS). In addition to the spring survey, a standardized (Wehrly et al., in press) survey was conducted June 2–6, 2008 using fyke nets, trap nets, 125-ft experimental gill nets (25-ft panels of 1.5-, 2.0-, 2.5-, 3.0, and 4.0-inch mesh), 500-ft Great Lakes gill nets (50-ft panels of 1.5- to 6.0-inch mesh), seines, and electrofishing gear.

Fish Community Composition

The status of the overall fish community was described in terms of species present, catch per unit effort (CPUE), and percentages by number. Mean CPUE in trap and fyke nets was calculated as an indicator of relative abundance, using the number of fish per net night (including recaptures for target species since they were tagged) for all net lifts that were determined to have fished effectively (i.e., without wave-induced rolling or human disturbance). Fish were categorized into three feeding guilds: (1) species that are primarily piscivores; (2) species that are primarily pelagic planktivores and/or insectivores; and (3) species that are primarily benthivores, and percentages in each were calculated. Of the species collected, Walleye, Northern Pike, Smallmouth Bass, Largemouth Bass, Muskellunge, Longnose Gar, Lake Trout, Brown Trout, and Atlantic Salmon were classified as piscivores; Rock Bass, Yellow Perch, Rainbow Trout, Bluegill, Pumpkinseed, Brook Trout, and Cisco were classified as pelagic planktivores-insectivores; and White Sucker, Brown and Black bullheads, Lake Whitefish, and Creek Chub, were classified as benthivores.

Size Structure and Sex Ratio

Total lengths of all Walleyes, Northern Pike, Smallmouth Bass, and Muskellunge were measured to the nearest 0.1 inch. For other fish, lengths were measured to the nearest 0.1 inch for subsamples of up to 200 fish per work crew. Crews ensured that lengths were taken over the course of the survey to account for any temporal trends in the size structure of fish collected. Size-structure and sex ratio data for target species only included fish on their initial capture occasion. Walleyes and Northern Pike with flowing gametes were identified as male or female; fish with no flowing gametes were identified as unknown gender. The gender of Smallmouth Bass could not be accurately determined due to the timing of the survey. Muskellunge with flowing gametes were identified accordingly, or identification was made using the recommendations of Lebeau and Pageau (1989).

Abundance

The abundance of legal-sized Walleyes, Northern Pike, and Smallmouth Bass was estimated using mark-and-recapture methods. Walleyes (≥15 inches), Northern Pike (≥24 inches), and Smallmouth Bass (≥14 inches) were fitted with monel-metal jaw tags. Some of the Muskellunge captured were fitted with either a jaw tag or a surgically-implanted acoustic transmitter (Sonotronics® model #CT-05-36-I), though abundance estimates were not a primary goal for Muskellunge since we expected very low catches. The use of the acoustic transmitters was part of a pilot study to assess the seasonal movement and distribution of Muskellunge in the lower Antrim chain (Diana et al. 2014). We followed the procedures of Anderson et al. (1997) and used a clove oil concentration of 25 mg/L to anesthetize Muskellunge since it was effective on other large-bodied fish such as Sockeye Salmon (Woody et al. 2002), Chinook Salmon, and White Sturgeon (Taylor and Roberts 1999). No specific tagging goal was set for Walleye, Northern Pike or Smallmouth Bass, but rather crews tagged as many as possible in April until the Walleye spawning season was nearing completion. To assess tag loss, tagged fish were double-marked by clipping the anterior 3 spines/fin rays of the dorsal fin. Our goal was to apply reward ($10) and nonreward tags in an approximate 1:1 ratio, though low catches of target species necessitated the more frequent use of reward tags to ensure for adequate sample size of exploitation estimates.

Initial tag loss was assessed during the marking period as the proportion of recaptured fish of legal size without tags. This tag loss was largely caused by entanglement with nets, and thus was not used to adjust estimates of abundance or exploitation. Newman and Hoff (1998) reported similar netting-induced tag loss. All fish that lost tags during netting recapture were retagged, and were accounted for in the total number of marked fish at large.

Two different methods for estimating abundance from mark-and-recapture data were used, one derived from marked-unmarked ratios during the spring survey (multiple census) and the other derived from marked-unmarked ratios from the angler survey (single census). For the multiple-census estimate, the Schumacher-Eschmeyer formula for daily recaptures during the tagging operation was used (Ricker 1975):

$$N_1 = \frac{\sum_{d=1}^{n} C_d M_d^{\,2}}{\sum_{d=1}^{n} R_d M_d}$$

N_1 = multiple-census population estimate (number of legal-sized fish);
C_d = total number of fish caught during day *d;*
R_d = number of recaptures during day *d;*
M_d = number of marked fish available for recapture at start of day *d;*
d = day (ranging from d_1 to d_n).

The variance formula was,

$$Var(N_1) = \frac{\sum_{d=1}^{n}\left(\frac{R_d^{\,2}}{C_d}\right) - \left[\frac{\left(\sum_{d=1}^{n} R_d M_d\right)^2}{\sum_{d=1}^{n} C_d M_d^{\,2}}\right]}{m-1},$$

where *m* = number of days in which fish were actually caught.

The variance of $1/N_1$ was used since it is more symmetrically distributed than the variance of N_1; thus, it is better for calculating confidence limits (Ricker 1975). The formula for the variance of $1/N_1$ is:

$$\frac{Var(N_1)}{\sum_{d=1}^{n} C_d M_d^{\,2}}.$$

The minimum number of recaptures necessary for an unbiased estimate was set a priori at four. Asymmetrical 95% confidence intervals were computed as:

$$\frac{1}{\frac{1}{N_1} \pm t(\sigma)}$$

where t = Student's T value for m -1 degrees of freedom; σ = standard error of $1/N_1$ (calculated as the square root of the variance of $1/N_1$).

The multiple-census method was used to estimate the abundance of both legal-sized and adult Walleyes and Northern Pike, and legal-sized Smallmouth Bass. Adult fish were defined as those greater than legal size, or less than legal size, but of identifiable sex by the discharge of gametes. In order to account for unequal effort between Elk Lake and Lake Skegemog (Ricker 1975), multiple-census estimates were made by lake, where possible, which were then summed.

For the single-census estimates, Elk Lake and Lake Skegemog were pooled for a single estimate due to the fact that the recapture sample consisted of fish observed in the companion angler survey, and extensive movement occurred among locations during the angling season. The minimum number of recaptures necessary for an unbiased estimate was set a priori at three, and the Chapman modification of the Petersen method was used to generate population estimates (with variance) using the following formulas from Ricker (1975):

$$N_2 = \frac{(M+1)(C+1)}{R+1}, \; Var(N_2) = \frac{{N_2}^2(C-R)}{(C+1)(R+2)},$$

N_2 = single-census population estimate (numbers of legal-sized fish);
M = number of fish caught, marked and released in first sample;
C = total number of fish caught in second sample (unmarked + recaptures);
R = number of recaptures in second sample.

Asymmetrical 95% confidence limits were calculated using values from the Poisson distribution for the 95% confidence limits on the number of recaptured fish (R), which were substituted into the equation for N above (Ricker 1975). The numbers of adult Walleyes and Northern Pike (with variance) were estimated from the single-census estimates by dividing the estimates for legal-sized fish by the proportion of legal-sized fish on the spawning grounds, using the formulas:

$$N_a = \frac{N_{leg} + N_{sub}}{N_{leg}} \times N_2, \; Var(N_a) = \left(\frac{N_{leg} + N_{sub}}{N_{leg}}\right)^2 \times Var(N_2),$$

N_a = estimated number of adult Walleyes or Northern Pike;
N_{sub} = number of sublegal and mature fish (<15 inches for Walleye, or <24 inches for Northern Pike) caught;
N_{leg} = number of legal-sized fish caught;
N_2 = single-census estimate of legal-sized Walleye or Northern Pike.

For the single-census estimates, fish that recruited to legal size during the course of the year were accounted for based on the estimated weighted average monthly growth for fish of slightly sublegal size. That is, because estimates were for the abundance of legal-sized fish at time of marking (spring) and growth of fish occurred during the recapture period, it was necessary to reduce the number of unmarked fish used in the formula by the estimated number that recruited to legal size during the recapture period. For example, to make this adjustment for Walleye the annual growth of slightly sublegal fish (i.e., 14.0–14.9-inch fish) was determined from mean length-at-age data. This value was then divided by the length of the growing season in months (6) and rounded to the nearest 0.1 inch. This average monthly growth was used as the criteria to remove unmarked fish that were observed in the angler survey. The largest size of a sublegal Walleye at tagging was 14.9 inches; thus, an average monthly growth of 0.2 inches would result in all unmarked fish 15.1 inches or larger caught during the first full month (June) after tagging to be subtracted from the total number of fish caught in second sample (C). Adjustments were made for each month of the creel survey resulting in a final ratio of marked to unmarked fish. This final ratio was used to make the single-census population estimate. I calculated the coefficient of variation (CV) for each abundance estimate (single- and multiple-census) as the standard deviation divided by the point estimate and considered estimates with a CV less than or equal to 0.40 to be reliable (Hansen et al. 2000).

The population estimates for Walleye were compared to the predicted abundance from three regression equations, one developed from Wisconsin lakes (Hansen and Hennessy 2006), and two from Michigan lakes (DNR Fisheries Division, unpublished data). These equations predict legal-sized or adult Walleye abundance based on lake size and were derived from historic abundance estimates made in each state over the past 20–25 years. The following equation for adult Walleyes in Michigan was based on 31 abundance estimates:

$$\ln(N) = 0.2388 + 1.0645 \times \ln(A),\ R^2 = 0.80, P < 0.0001,$$

where N is the estimated number of adult Walleyes and A is the surface area of the lake in acres. The equation for adult Walleyes in 1842-Treaty-ceded territory of Wisconsin lakes in which stocking is the primary recruitment source was based on 135 estimates:

$$\ln(N) = 01.0987 + 0.8831 \times \ln(A),\ R^2 = 0.61, P < 0.0001,$$

and finally, the equation for legal-sized Walleyes in Michigan was based on 33 estimates:

$$\ln(N) = 0.4155 + 0.9992 \times \ln(A), R^2 = 0.81, P < 0.0001.$$

Growth

Dorsal spines were used to age Walleye and Smallmouth Bass and dorsal fin rays were used to age Northern Pike and Muskellunge because they provided a good combination of ease of collection in the field and accuracy and precision of age estimates. Although otoliths have been shown to be the most accurate and precise ageing structure for older Walleye (Heidinger and Clodfelter 1987; Kocovsky and Carline 2000; Isermann et al. 2003; Donabauer 2010) and otoliths or cleithra for Northern Pike (Casselman 1974; Harrison and Hadley 1979), collecting these structures would have required killing the fish, which would greatly reduce the number of marked fish at large. Additionally, since there is not consensus on the accuracy and precision of spines versus scales (Belanger and Hogler 1982; Campbell and Babaluk 1979; Erickson 1983; Kocovsky and Carline 2000; Isermann et al. 2003), spines were chosen since they likely provide more accurate ages for the oldest fish in the populations. Accurate ages for older fish were important since one goal was to estimate annual mortality. Studies have demonstrated that fin rays are a valid aging structure for a number of species (Skidmore and Glass 1953; Ambrose 1983), including Northern Pike (Casselman 1996), but no comparisons have been made to statistically compare accuracy and precision of fin rays to other aging structures for Northern Pike. Sample size goals were 20 male and 20 female fish per inch group for Walleye and Northern Pike and 20 Smallmouth Bass per inch group.

Dorsal spines and fin rays were prepared by sectioning samples using a table-mounted high-speed rotary cutting tool. Sections approximately 0.02-inches thick were cut as close to the proximal end of the spine or ray as possible. Sections were examined at 40x–80x magnification with transmitted light and were photographed with a digital camera. The digital image was archived for multiple readers. Two technicians independently aged samples, and ages were considered final when independent estimates were in agreement. Samples in dispute were aged by a third technician. Disputed ages were considered final when the third technician agreed with one of the first two. Samples were discarded if three technicians disagreed on age, though occasionally an average age was used when ages assigned to older fish (age ≥ 10) were within ±10% of each other.

After a final age was identified for all samples, age-length keys (Devries and Frie 1996) were constructed and weighted mean lengths-at-age were calculated. Mean growth indices were calculated by comparing the data to Michigan state averages derived using spines/fin rays (DNR Fisheries Division, unpublished data). The mean growth index is the average of deviations (by age group) between the observed mean lengths and statewide seasonal average lengths. Due to the low sample size of Muskellunge collected during the spring survey, we also used aging structures collected from angler harvest through the time of report writing, and combined all lakes in the lower Antrim chain for analysis.

Angler Survey

Fishing harvest seasons during this survey were April 26, 2008–March 15, 2009 for Walleye and Northern Pike, and May 24 through December 31, 2008 for smallmouth and Largemouth Bass. Minimum size limits were 15 inches for Walleye, 24 inches for Northern Pike, 14 inches for smallmouth and Largemouth Bass, and 42 inches for Muskellunge. Daily bag limit was five fish in any combination of Walleye, Northern Pike, Smallmouth Bass, or Largemouth Bass, and one for Muskellunge. Harvest was permitted all year for other species present and no minimum size limits were imposed. The daily bag limit for Yellow Perch was 50. The daily bag limit for "sunfish", including black crappie, Bluegill, Pumpkinseed, and Rock Bass was 25 in any combination. The daily bag limit for Lake Whitefish and lake herring was 12 in combination. Direct contact angler surveys were conducted during the open-water period – April 26 to October 31, 2008 and January 13 to March 16, 2009, as described below.

Field methods

An aerial-roving design was used for the open-water period and a progressive-roving design was used for the ice-cover period (Lockwood 2000b). A clerk working from a boat or snowmobile conducted angler interviews and made boat or ice angler/shanty counts. Aerial counts of fishing boats were made once per day during the open-water period, and ground progressive counts of open-ice anglers and occupied shanties were made once per day during the ice-cover period. Both weekend days and three randomly-determined weekdays were selected for counting and interviewing with the exception of state holidays, which were not sampled. One of two shifts was randomly selected each sample day, with hours varying according to the daylight hours. Elk and Skegemog lakes were each sampled once per day. Starting location within a section and direction of travel were randomized for both counting and interviewing. Two possible count orders were used for the aerial survey during the open-water period: marker 1 to marker 9 or marker 9 to marker 1 (Figure 4, Table 2). The counting path for the ice-cover period used access sites for starting locations (Figure 5). Minimum fishing time prior to interviewing (incomplete-trip interview) was 1 h (Lockwood 2004; Clark et al. 2004). All roving interview data were collected by individual angler to avoid party size bias (Lockwood 1997), though the number of anglers in each party was recorded on one interview form for each party. While this survey was designed to collect roving interviews, completed-trip interviews were noted. Interview information collected included date; fishing mode; start time of fishing trip; interview time; species targeted; bait used; number of fish harvested by species; number of fish caught and released by species; length of harvested Walleye, Northern Pike, and Smallmouth Bass; and applicable tag numbers.

Table 2.–Coordinates (degrees and minutes) for the flight path markers used in the aerial survey during the open-water period on Elk and Skegemog lakes.

Marker	Latitude	Longitude
1	44° 55.70' N	85° 22.27' W
2	44° 53.88' N	85° 22.27' W
3	44° 52.63' N	85° 23.12' W
4	44° 50.98' N	85° 22.81' W
5	44° 49.22' N	85° 22.30' W
6	44° 47.82' N	85° 22.13' W
7	44° 47.68' N	85° 17.83' W
8	44° 48.65' N	85° 19.74' W
9	44° 50.14' N	85° 20.86' W

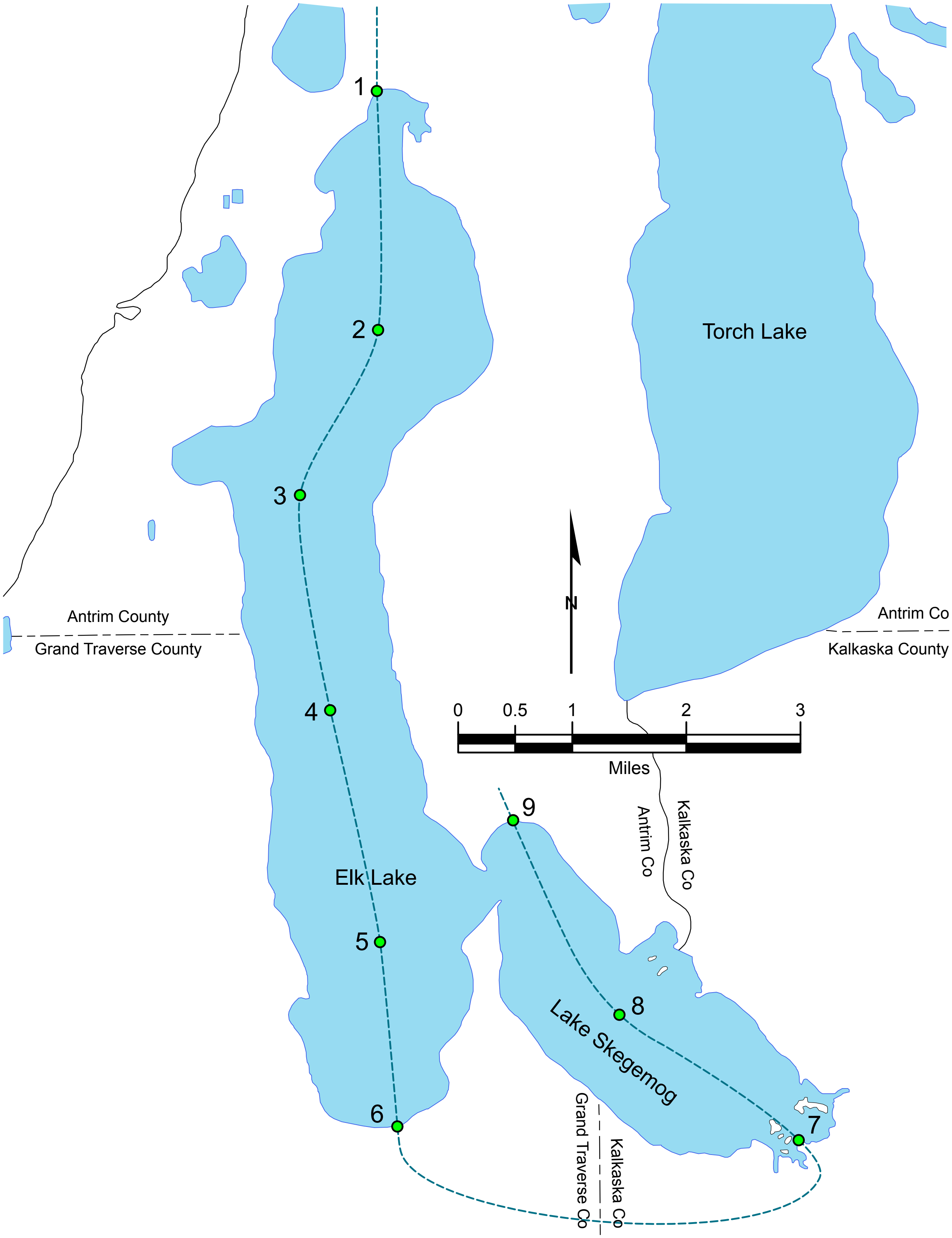

Figure 4.–Counting path and associated way points for the open-water portion of the angler survey of Elk and Skegemog lakes.

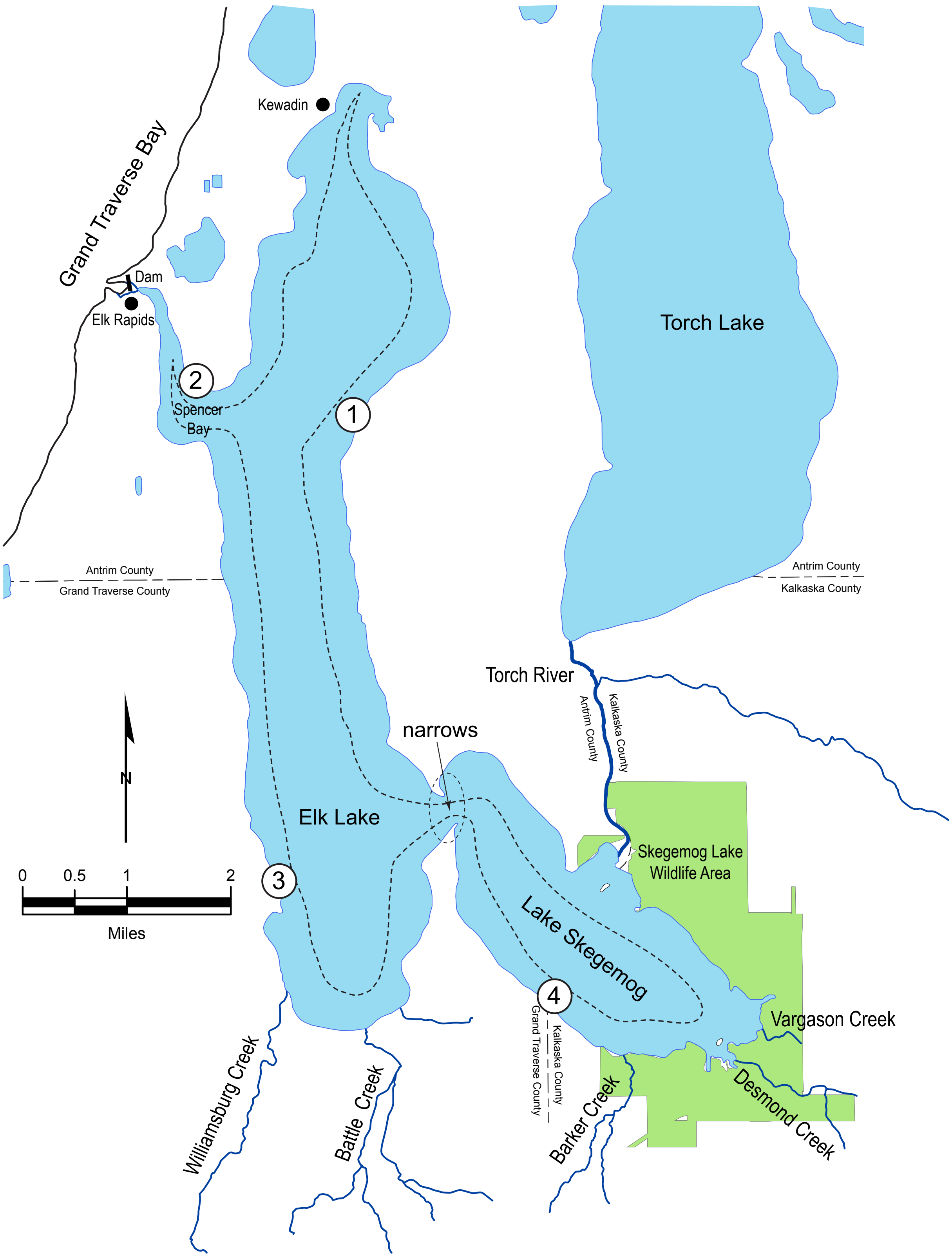

Figure 5.–Counting path and associated way points for the ice-cover portion of the angler survey of Elk and Skegemog lakes.

Estimation methods

Catch and effort estimates were made using a multiple-day method (Lockwood et al. 1999). Effort was the product of mean counts for a given period day type, days within the period, and the expansion value (the number of hours within sample days) for that period. Thus, the angling effort and catch reported are for those periods sampled; no expansions were made to include periods not sampled (e.g., 0100 to 0400 hours).

Most interviews (>80%) collected during open-water and ice-cover periods were of a single type (access or roving). However, during some shorter periods (i.e., day type within a month for a section) fewer than 80% of interviews were of a single type. When 80% or more of interviews within a time period (weekday or weekend day within a month and section) were of an interview type, the appropriate catch-rate estimator for that interview type (Lockwood et al. 1999) was used on all interviews. When less than 80% were of a single interview type, a weighted average R_w was used:

$$R_w = \frac{\left(\hat{R} \cdot n_1\right) + \left(\overline{R} \cdot n_2\right)}{\left(n_1 + n_2\right)},$$

where $\hat{R}$ is the ratio-of-means estimator for n_1 completed-trip interviews and $\overline{R}$ the mean-of-ratios estimator for n_2 incompleted-trip interviews. Estimated variance s_w^2 was calculated as:

$$s_w^2 = \frac{\left(s_{\hat{R}}^2 \cdot n_1^2\right) + \left(s_{\overline{R}}^2 \cdot n_2^2\right)}{\left(n_1 + n_2\right)^2},$$

where $s_{\hat{R}}^2$ is the estimated variance of $\hat{R}$ and $s_{\overline{R}}^2$ is the estimated variance of $\overline{R}$.

From the angler interview data collected, catch and harvest by species were estimated along with angling effort, expressed as both angler hours and angler trips. An angler trip was defined as the period an angler was at a lake (fishing site) and actively fishing. When an angler left the lake or stopped fishing for a significant period of time (e.g., an angler leaving the lake to eat lunch), the trip was considered over. Movement between fishing spots, for example, was considered part of the fishing trip. Mail or telephone surveys typically report angling effort as angler days (Pollock et al. 1994). Angler trips differ from angler days because multiple trips can be made within a day. Historically, Michigan angler creel data average 1.2 trips per angler day (DNR Fisheries Division, unpublished data).

All estimates are given with ± 2 SE, which provided statistical significance of 75 to 95% assuming a normal distribution and $N \geq 10$ (Dixon and Massey 1957). All count samples exceeded minimum sample size (10) and effort estimates approximated 95% confidence limits. Most error bounds for catch and release, and harvest estimates also approximated 95% confidence limits. However, coverage for rarely caught species is more appropriately described as 75% confidence limits due to severe departure from normality of catch rates. For Walleye, Northern Pike, and Smallmouth Bass the initial harvest estimates were expanded by adjusting for the nonsurveyed period based on the percentage of tag returns from the nonsurveyed period. Additionally, and for proper comparison with the abundance estimate, the harvest for these species was further adjusted for the percentage of sublegal fish that grew over the minimum size limit during the fishing season.

Mortality

Catch-at-age was calculated for males, females, and all fish (including males, females, and those of unknown sex), and total annual mortality rates were estimated using catch-curve analyses with assumptions described by Ricker (1975). The goal was to estimate total mortality for fish of legal size for comparison with mortality attributable to fishing. When choosing age groups to be included in the analyses, several potential problems were considered. First, an assumption of catch-curve analysis is that the mortality rate is uniform over all age groups considered to be fully recruited to the collection gear. In this survey, tagged fish were collected with types of gear (e.g., nets and electrofishing boats) different from those used in the recreational fishery. For fish smaller than the minimum size limit, mortality was natural mortality (M) + hooking mortality (H); for larger fish, mortality was $M + H$ + fishing mortality (F). Second, Walleye and Northern Pike exhibit sexual dimorphism in growth (Carlander 1969, 1997), which could lead to differences in mortality between sexes. Thus, when sufficient data were available, separate catch curves were produced for males and females to determine if annual mortality differed by sex. A catch curve was also computed for all fish that included males, females, and fish of unknown sex. Third, Walleyes and Northern Pike were collected during spawning season, so it was necessary to be sure that fish in each age group were sexually mature and represented on the spawning grounds in proportion to their true abundance in the population. Thus, only age groups of fish that were judged to be mostly mature were included in the analysis. This judgment was based on a combination of information, including relative abundance, mean size at age, and percent maturity by size.

Angler exploitation rates were estimated using three methods: (1) the percent of reward tags returned by anglers; (2) the estimated harvest divided by the multiple-census estimate of abundance; and (3) the estimated harvest divided by the single-census estimate of abundance. For Muskellunge, we also included the return of acoustic transmitters for estimates of exploitation. Probability of tag loss was calculated as the number of fish in the recapture sample that had lost tags (fin clip and no tag) divided by all fish in the recapture sample that had been tagged, including fish that had lost their tag. Standard errors were calculated assuming a binomial distribution (Zar 1999).

Using the first method, exploitation rate was estimated as the fraction of available reward tags returned by anglers, adjusted for tag loss. The tag loss adjustment was made by reducing the number of available reward tags by the percentage of tags lost over the course of the creel survey. Tagging mortality was assumed to be negligible as there was a high (near 100%) reporting rate for reward tags on fish caught by anglers. Although actual nonreporting was not assessed (for all tags, reward and nonreward), the actual number of tag returns was compared to the expected number (X) based on the ratio:

$$\frac{R}{C} = \frac{X}{H_a}$$

where R = the number of tags observed in creel, C = the number of fish observed in creel (adjusted for those that recruited to legal size over the course of the fishing season, and H_a = the total expanded harvest adjusted first for nonsurveyed period (based on percentage of tag returns from nonsurveyed period) and second for the percentage of fish that recruited to legal size over the course of the fishing season.

Additionally, individual tags observed by the creel clerks were verified to see if they were subsequently reported by anglers. This last step is also not a true estimate of nonreporting because there is the possibility that anglers believed the necessary information was obtained by the creel clerks, and further reporting to the DNR was unnecessary. Tags observed by the creel clerks that were not voluntarily reported by the angler were added to the voluntary tag returns for exploitation estimates.

Voluntary tag returns were encouraged with a monetary reward ($10) denoted on approximately 50% of the tags. Tag return forms were made available at boater access sites, at DNR offices, and from creel clerks. Additionally, tag-return information could be submitted on-line at the DNR website. All tag-return data were entered into the database so that they could be efficiently linked to and verified against data collected during the tagging operation. Letters sent to anglers contained information on the length and sex of the tagged fish, and the location and date of tagging. Return rates were calculated separately for reward and nonreward tags, unadjusted for tag loss. The reporting rate of nonreward tags relative to reward tags (λ in Pollock et al. 1991) was calculated as the fraction of nonreward tags harvested and reported divided by the fraction of reward tags harvested and reported with available tags adjusted for short-term tag loss and mortality during tagging. In addition to data on harvested fish, the release rate for legal fish was estimated from responses to a question on the tag return form asking if the fish was released. The release rate was calculated as the total number of tag returns reported as released divided by all of the tagged fish known to have been caught including voluntary returns and unreported tags observed in the creel survey.

In the second and third methods, exploitation was calculated as the adjusted harvest estimate from the angler survey (H_a from above) divided by the multiple- and single-census abundance estimates for legal-sized fish. The estimated annual harvest was adjusted for the nonsurveyed period based on the fraction of tag returns from the nonsurveyed period. Also, for proper comparison with the abundance estimates of legal fish as existed in the spring, the harvest estimate was reduced to account for fish that grew to legal size over the course of the creel survey. The reduction of harvest was based on the percentage of fish observed in the creel survey that were determined to have been sublegal at the time of the spring survey (See *Abundance* subsection of the *Methods* section). Confidence limits (95%) were calculated for these exploitation estimates assuming a normal distribution, and summing the variances of the abundance and harvest estimates.

Recruitment

Since population data for fish in Elk and Skegemog lakes were only obtained during one year, year-class strength could not be rigorously evaluated. However, I considered the relative year-class strength of adults as an index of recruitment, and used the residuals from the catch-curve regressions as indices of year-class strength (Maceina 2003). Similarly, Isermann et al. (2002) used the coefficient of determination from catch curve regressions as a quantitative index of the recruitment variability in crappie populations.

Movement

Fish movement during the spring survey was assessed in a descriptive manner by examining the location or lake where initially captured versus the location of recapture. Fish movement over the first year following tagging and through the time of report writing was also examined descriptively by comparing the initial capture location to the location of recapture by an angler. Angler tag returns were adjusted for angler effort in Elk versus Skegemog Lake using the methods similar to those described in Kanwit and Libby (2009). Returns from the lake with the lowest angler effort were adjusted upward based on the relative proportion to angler effort in the lake with the highest effort. Movement of Muskellunge was evaluated with stationary receivers placed throughout the Elk Lake, Skegemog Lake, and the Torch River, as well as with active tracking with directional hydrophones.

Results[1]

Fish Community Composition

A total of 13,810 fish comprised of 21 species were collected in the spring survey (Table 3). Total sampling effort was 172 trap-net lifts, 124 fyke-net lifts, and 2 electrofishing runs. The total catch included 82 Walleyes, 335 Northern Pike, and 512 Smallmouth Bass which made up approximately 0.6%, 2%, and 4% of the total catch, respectively. The most abundant fish species collected in order were Rock Bass, White Sucker, and Yellow Perch. The overall fish community composition was 16% benthivores, 9% piscivores, and 75% pelagic planktivores-insectivores (Table 3).

Table 3.–Fish collected from Elk and Skegemog lakes using a total sampling effort of 172 trap-net lifts, 124 fyke-net lifts, and 2 electrofishing runs (approximate distance = 2 miles per run) from April 2 to 25, 2008.

Species	Total catch [a]	Percent by number	Mean CPUE [a, b] trap-net	fyke-net	Length range (in)	Average length (in) [c]	Number measured [c]
Rock Bass	8,855	64.1	42.7	9.9	2.7–12.0	6.3	526
White Sucker	2,129	15.4	7.3	5.7	6.3–23.1	16.3	352
Yellow Perch	742	5.4	3.5	0.2	4.3–12.2	7.2	455
Smallmouth Bass	512	3.7	2.7	0.4	7.0–21.7	15.6	485
Pumpkinseed	361	2.6	1.6	0.5	3.2–9.9	6.0	361
Northern Pike	335	2.4	1.6	0.4	9.4–39.0	21.5	320
Bluegill	303	2.2	1.4	0.5	3.3–9.9	6.4	281
Largemouth Bass	169	1.2	0.7	0.3	5.9–20.2	15.1	169
Cisco	128	0.9	0.6	<0.1	4.0–12.5	7.4	104
Walleye	82	0.6	0.4	<0.1	9.5–30.1	25.1	77
Brown Bullhead	63	0.5	0.3	0.1	6.3–13.5	10.8	62
Longnose Gar	60	0.4	0.2	0.2	25.0–44.0	30.5	60
Brown Trout	24	0.2	<0.1	<0.1	9.1–25.9	19.1	24
Muskellunge	15	0.1	0.1	<0.1	18.1–54.0	42.1	15
Rainbow Trout	13	0.1	<0.1	<0.1	10.3–25.6	19.1	13
Lake Whitefish	7	0.1	<0.1	0	13.5–25.2	21.5	7
Black Bullhead	7	0.1	<0.1	<0.1	10.2–13.0	11.6	7
Lake Trout	2	<0.1	<0.1	0	27.1–27.5	27.3	2
Atlantic Salmon	1	<0.1	<0.1	0	10.8	10.8	1
Creek Chub	1	<0.1	<0.1	0	8.2	8.2	1
Brook Trout	1	<0.1	0	<0.1	11.4	11.4	1

[a] Includes recaptures
[b] Number per trap-net or fyke-net night
[c] Does not include recaptures for Walleye, Northern Pike, or Smallmouth Bass.

[1] Confidence limits for estimates are provided in relevant tables, but not in the text.

Size Structure and Sex Ratio

The percentages of legal-sized Walleyes, Northern Pike, and Smallmouth Bass were 96, 40, and 75, respectively (Table 4). The population of spawning Walleyes, although small in number, exhibited a large length distribution, with peaks at 24 and 28 inches. The largest Walleye collected was 30.1 inches and 53% of all Walleyes were greater than 25 inches (memorable size; Gabelhouse 1984). The population of spawning Northern Pike was dominated by 19- to 26-inch fish, though there was also a peak in the distribution occurring from 12 to 15 inches, which were largely immature fish. Memorable-size Northern Pike (≥ 34 inches) were relatively abundant, making up 6% of the total catch. The length distribution of the Smallmouth Bass population was impressive, with a peak at 15 inches and fish up to 21.7 inches. The male:female ratio was 1.6:1 for both legal-sized and adult Walleyes. Four percent of all Walleyes were of unknown sex. There were 0.8 male Northern Pike for every female when all sizes were considered and 0.2 males per female when fish of legal size were considered. Forty-seven percent of all Northern Pike were of unknown sex. Since only 15 Muskellunge were collected in the spring survey, data collected during the spring spawning periods of 1996, 2009, and 2010 in Elk, Skegemog, and Clam lakes were combined to better describe size structure and size at maturity of the population. Clam Lake was included because it has a direct connection to Elk and Skegemog lakes and it has very similar habitat to Skegemog Lake. Overall, we collected 54 Muskellunge during spring trap-netting on these three lakes (Figure 6). The majority (94%) of Muskellunge collected during these efforts were determined to be mature. The spawning population is dominated by fish ranging from 40 to 54 inches, which comprised 80% of the mature fish. Males averaged 43.3 inches, while females averaged 47.5 inches. Males appear to mature at total lengths as low as 32 inches, but most ranged from 42 to 46 inches. Females mature at total lengths as low as 40 inches, though most (76%) were from 44 to 54 inches.

Abundance

Crews placed a total of 74 tags on legal-sized Walleyes (63 reward and 11 nonreward tags) and since no sublegal adult Walleyes were marked, the total number of adults Walleyes marked (with jaw tag or fin clip) was also 74. None of the five Walleyes recaptured during the spring netting survey died or lost their tag; thus, the effective number tagged (M) was also 74. A total of 11 Walleyes were observed in the angler and summer netting surveys and none was marked with a fin clip or tag (R = 0). The initial C was reduced by 1 (9%) to adjust for sublegal fish that grew over the minimum size limit during the fishing season (final C = 10). Due to the low number of Walleyes marked, low number of recaptures, and low CV, a single-census estimate of Walleye abundance for Elk and Skegemog lakes was not possible. Although there was no movement of Walleyes between lakes during the spring survey, the minimum number of recaptures was not reached in Elk Lake so data from both lakes were pooled for a multiple-census estimate. The estimated number of legal-sized Walleyes was 600 using the multiple-census method (Table 5). The estimate was identical when adult Walleyes were considered. The coefficient of variation was 0.31 for both of the multiple-census estimates. For Elk and Skegemog lakes, the Michigan regression equation gives an estimate of 25,365 adult Walleyes, with a 95% prediction interval (Zar 1999) of 4,820 to 133,473. The Wisconsin regression equation for stocked populations gives an estimate of 11,082 Walleyes, with a 95% prediction interval of 2,489 to 49,334 for Elk and Skegemog lakes. The Michigan regression equation for legal-sized Walleyes gives an estimate of 16,477 legal-sized Walleyes, with a 95% prediction interval of 3,478 to 78,060 for Elk and Skegemog lakes.

Table 4.–Number of fish per inch group collected from Elk and Skegemog lakes, April 2–25, 2008.

	Species																				
Inch group	Rock Bass	White Sucker	Yellow Perch	Smallmouth Bass	Pumpkinseed	Northern Pike	Bluegill	Largemouth Bass	Cisco	Walleye	Brown Bullhead	Longnose Gar	Brown Trout	Muskellunge	Rainbow Trout	Lake Whitefish	Black Bullhead	Lake Trout	Atlantic Salmon	Creek Chub	Brook Trout
2	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3	47	–	–	–	16	–	17	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4	122	–	6	–	79	–	18	–	4	–	–	–	–	–	–	–	–	–	–	–	–
5	117	–	119	–	66	–	93	1	9	–	–	–	–	–	–	–	–	–	–	–	–
6	51	1	91	–	117	–	63	–	47	–	1	–	–	–	–	–	–	–	–	–	–
7	46	4	122	1	65	–	31	1	5	–	2	–	–	–	–	–	–	–	–	–	–
8	62	10	63	2	13	–	38	8	13	–	5	–	–	–	–	–	–	–	–	1	–
9	50	22	28	3	5	2	21	5	14	1	6	–	1	–	–	–	–	–	–	–	–
10	26	14	14	9	–	1	–	–	7	1	17	–	–	–	1	–	2	–	1	–	–
11	2	10	7	17	–	6	–	2	4	1	17	–	1	–	–	–	2	–	–	–	1
12	1	15	5	34	–	21	–	6	1	–	10	–	1	–	–	–	2	–	–	–	–
13	–	10	–	54	–	19	–	35	–	–	4	–	2	–	2	1	1	–	–	–	–
14	–	15	–	69	–	23	–	25	–	–	–	–	–	–	–	–	–	–	–	–	–
15	–	11	–	89	–	19	–	13	–	–	–	–	1	–	–	–	–	–	–	–	–
16	–	30	–	78	–	8	–	20	–	–	–	–	1	–	1	–	–	–	–	–	–
17	–	66	–	43	–	2	–	27	–	–	–	–	1	–	1	–	–	–	–	–	–
18	–	60	–	41	–	3	–	15	–	1	–	–	2	1	2	–	–	–	–	–	–
19	–	43	–	24	–	16	–	9	–	–	–	–	2	–	1	–	–	–	–	–	–
20	–	23	–	18	–	10	–	2	–	1	–	–	4	–	–	–	–	–	–	–	–
21	–	13	–	3	–	17	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–
22	–	4	–	–	–	25	–	–	–	6	–	–	1	–	1	1	–	–	–	–	–
23	–	1	–	–	–	27	–	–	–	12	–	–	3	–	1	2	–	–	–	–	–
24	–	–	–	–	–	30	–	–	–	13	–	–	2	–	2	–	–	–	–	–	–
25	–	–	–	–	–	28	–	–	–	9	–	3	2	–	1	1	–	–	–	–	–
26	–	–	–	–	–	14	–	–	–	5	–	2	–	1	–	–	–	–	–	–	–
27	–	–	–	–	–	8	–	–	–	9	–	6	–	–	–	–	–	2	–	–	–
28	–	–	–	–	–	6	–	–	–	11	–	8	–	1	–	–	–	–	–	–	–

Table 4.–Continued.

Inch group	Rock Bass	White Sucker	Yellow Perch	Smallmouth Bass	Pumpkinseed	Northern Pike	Bluegill	Largemouth Bass	Cisco	Walleye	Brown Bullhead	Longnose Gar	Brown Trout	Muskellunge	Rainbow Trout	Lake Whitefish	Black Bullhead	Lake Trout	Atlantic Salmon	Creek Chub	Brook Trout
	Species																				
29	–	–	–	–	–	4	–	–	–	6	–	14	–	–	–	–	–	–	–	–	–
30	–	–	–	–	–	4	–	–	–	1	–	8	–	–	–	–	–	–	–	–	–
31	–	–	–	–	–	8	–	–	–	–	–	5	–	–	–	–	–	–	–	–	–
32	–	–	–	–	–	5	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–
33	–	–	–	–	–	3	–	–	–	–	–	5	–	–	–	–	–	–	–	–	–
34	–	–	–	–	–	4	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–
35	–	–	–	–	–	1	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–
36	–	–	–	–	–	4	–	–	–	–	–	2	–	1	–	–	–	–	–	–	–
37	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
38	–	–	–	–	–	1	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–
39	–	–	–	–	–	9	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–
40	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
41	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
42	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–
43	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–
44	–	–	–	–	–	–	–	–	–	–	–	1	–	2	–	–	–	–	–	–	–
45	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
46	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–
47	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–
48	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
49	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
50	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
51	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–
52	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–
53	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–
54	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–
Total	526	352	455	485	361	320	281	169	104	77	62	60	24	15	13	7	7	2	1	1	1

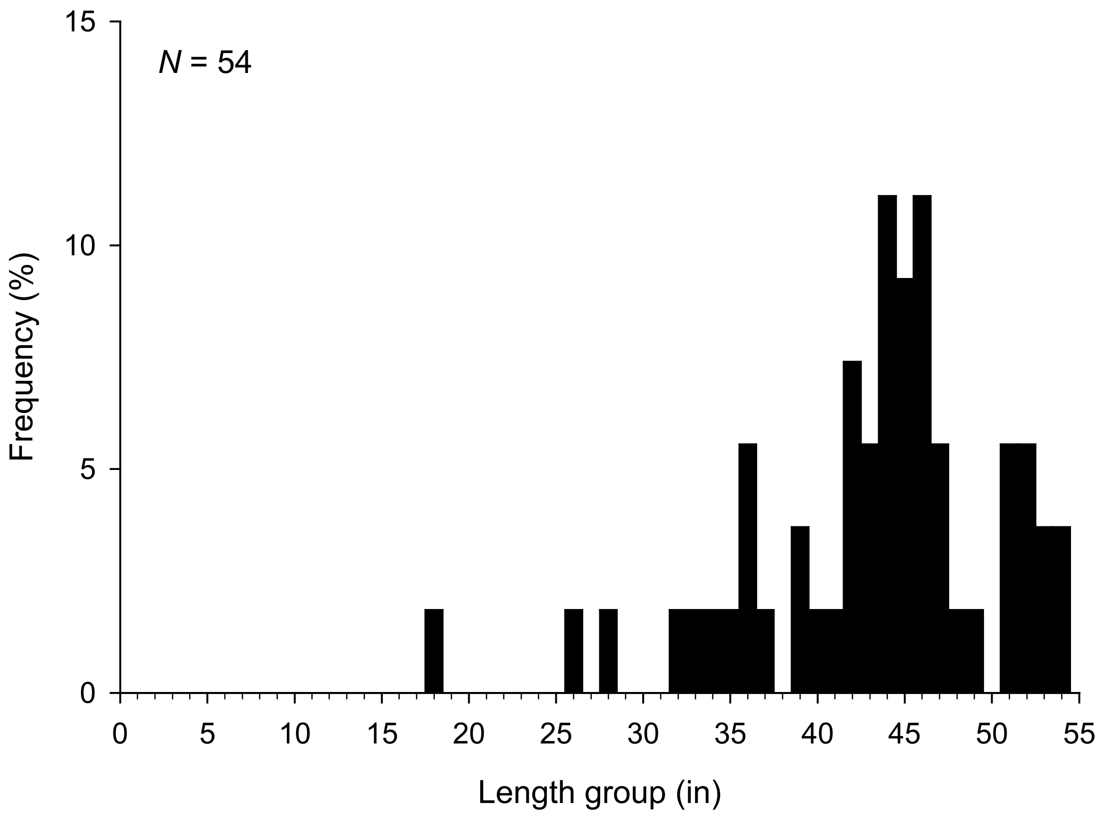

Figure 6.–Length-frequency distribution of Muskellunge collected during the spring spawning periods of 1996, 2009, and 2010 in Elk, Skegemog, and Clam lakes.

Table 5.–Estimates of abundance, angler exploitation rates, and total annual mortality rates for Elk and Skegemog lakes Walleye, Northern Pike, and Smallmouth Bass using the different methods described in text. Asymmetrical 95% confidence intervals for estimates are given in parentheses, where applicable.

Parameter	Walleye	Northern Pike	Smallmouth Bass
Number tagged	74	116	364
Total tag returns	2	14	51
Number of legal-sized[a] fish			
Multiple-census estimate	600 (354–1,951)	629 (429–1,181)	2,610 (2,078–3,507)
Single-census estimate	No estimate	416 (223–841)	2,401[b] (1,449–3,303)
Michigan model[c]	16,477 (3,478–78,060)	NA	NA
Number of adult[d] fish			
Multiple-census estimate	600 (354–1,951)	1,187 (872–1,860)	NA
Single-census estimate	No estimate	680 (365–1,375)	NA
Michigan model[e]	25,365 (4,820–133,473)	NA	NA
Wisconsin ST model[f]	11,082 (2,489–49,334)	NA	NA
Annual exploitation rates			
Based on reward tag returns	3.3%	9.1%	14.1%
Based on harvest/abundance[g]	7.6% (0%–18.7%)	24.1% (0%–54.8%)	31.4% (1.8%–61.0%)
Based on harvest/abundance[h]	No estimate	36.5% (8.1%–64.8%)	34.1% (14.9%–53.3%)
Total annual mortality rates	No estimate	34%	36%

[a] Walleye ≥ 15 inches, Northern Pike ≥ 24 inches, and Smallmouth Bass ≥ 14 inches.
[b] Summation of estimates for Elk Lake (352) and Lake Skegemog (2,049).
[c] Michigan model prediction of legal-sized Walleye abundance based on lake area, N = 33.
[d] Fish of legal size and sexually mature fish of sublegal size on spawning grounds.
[e] Michigan model of adult Walleye abundance based on lake area, N = 32.
[f] Wisconsin model of adult Walleye abundance (stocking) based on lake area, N = 135.
[g] Multiple-census estimate of legal-sized Walleye abundance.
[h] Single-census estimate of legal-sized Walleye abundance.

Crews placed a total of 119 tags on legal-sized Northern Pike in Elk and Skegemog lakes (92 reward and 27 nonreward tags) and in total marked 196 adult Northern Pike. Three of the 15 Northern Pike recaptured during the spring netting lost their tag; thus, the effective number tagged (*M*) was 116. A total of 38 Northern Pike were observed in the angler survey and summer netting survey of which 8 were marked (*R*; had a fin clip, or a tag). The initial *C* was reduced by 7 (18%) to adjust for sublegal fish that grew over the minimum size limit during the fishing season (final *C* = 31). As was the case for Walleye, the minimum number of recaptures was not reached in Elk Lake so data from both lakes were pooled for the multiple-census estimate. The estimated number of legal-sized Northern Pike was 629 (CV = 0.21) using the multiple-census method, and was 416 (CV = 0.27) using the single-census method. The estimated number of adult Northern Pike was 1,187 (CV = 0.17) using the multiple-census method and was 680 (CV = 0.27) using the single-census method (Table 5).

Crews tagged 364 (*M*) legal-sized Smallmouth Bass in Elk and Skegemog lakes (247 reward and 117 nonreward tags). None of the 25 Smallmouth Bass recaptured during the spring netting died or lost their tag. A total of 162 Smallmouth Bass were observed in the angler survey and summer (June) netting survey of which 23 were marked (*R*; had a fin clip, or a tag). The initial *C* was reduced by 22 (14%) to adjust for sublegal fish that grew over the minimum size limit during the fishing season (final *C* = 140). Although the minimum number of Smallmouth Bass recaptures was reached in both lakes during the spring survey, data from both lakes were pooled for the multiple-census estimate so it was on the same basis for comparison to the estimates for Walleye and Northern Pike. The estimated number of legal-sized Smallmouth Bass was 2,610 (CV = 0.11) using the multiple-census method (Table 5). For the single-census method, I compared estimates from pooled data to those conducted for each lake which were then summed. The estimated number of legal-sized Smallmouth Bass was 2,144 (CV = 0.18) for the pooled data, and was 2,401 (CV = 0.23) for the summed estimates. Individual estimates were 352 (CV = 0.23) for Elk Lake and 2,049 (CV = 0.27) for Skegemog Lake.

Although a population estimate for Muskellunge was not a primary goal due to the low number expected to be observed in the angler survey, a netting effort in the spring of 2009 allowed for an estimate. Eleven Muskellunge were marked (8 implanted with transmitters and 3 tagged with jaw tags) in the spring of 2008 and 9 were caught in the spring of 2009, of which one was marked. Although the minimum number of recaptures was not obtained for an unbiased estimate, the estimated number of Muskellunge on the spawning grounds in 2008 was 54, with asymmetrical 95% confidence limits of between 16 and 105, and a coefficient of variation of 0.51.

Growth and maturity

Technicians aged 76 Walleyes (Table 6), 300 Northern Pike (Table 7), and 465 Smallmouth Bass (Table 8). The overall mean growth index for Walleye was +2.8 when compared to the statewide average derived using dorsal spines, though this was only based on ages 9 and 10. Sample sizes were not large enough to compare mean lengths between males and females. For Northern Pike, the overall mean growth index was +1.5 when compared to the statewide average derived using dorsal fin rays, and female Northern Pike had higher mean lengths-at-age than males. Smallmouth Bass had higher mean lengths-at-age than the statewide average for all ages except age 9, and the mean growth index was +1.9. Technicians aged 54 Muskellunge from the Lower Antrim Chain of Lakes (Table 9). This growth analysis has some deficiencies in that fish of the same age were sampled in different years and would thus have experienced different growing conditions. Also, fish may have been collected at different times of the year and length at capture could represent several months of additional growth. Given the low sampling periodicity of the Muskellunge population and the difficulty in obtaining large sample sizes, the potential errors in the data were outweighed by the information gained. The population boasts a growth index (Casselman and Crossman 1986) of 107% and an asymptotic length for males and females combined of 53 inches. Casselman and Crossman's (1986) growth index is a relative percentage based on length-at-age data from 18 Muskellunge populations across their range. For comparison, the value for Elk and Skegemog lakes would be the 2nd highest for the populations described in Casselman and Crossman (1986). On average, male Muskellunge in the lower Antrim Chain of Lakes reach legal size between the ages of 8 and 10, while females reach legal size between the ages of 7 and 8. Male Muskellunge mature as early as age 4, but due to the low sample size it is most appropriate to consider the age at maturity to range from 4 to 8. Most females likely mature at ages 7 or 8 in the lower Antrim Chain of Lakes.

Table 6.–Weighted mean total lengths (in) at age and sample sizes for Walleyes (males and females combined) collected from Elk and Skegemog lakes, April 2–25, 2008. Standard deviation is in parentheses.

Age	State average[a]	Mean length		Number aged
1	8.3	10.0	(0.6)	2
2	12.2	11.3	(–)	1
3	14.4	–	(–)	0
4	15.8	20.5	(–)	1
5	17.2	18.3	(–)	1
6	18.7	–	(–)	0
7	19.6	22.7	(–)	1
8	20.3	–	(–)	0
9	21.2	25.4	(2.2)	7
10	21.8	25.8	(2.2)	57
11		25.3	(–)	1
12		–	(–)	0
13		28.3	(1.3)	5

[a] Statewide average calculated from dorsal spines

Table 7.–Weighted mean total lengths (in) and sample sizes by age and gender for Northern Pike collected from Elk and Skegemog lakes, April 2–25, 2008. Standard deviation is in parentheses.

	Mean length			Number aged		
Age	Males	Females	All fish[a]	Males	Females	All fish[a]
1	14.6 (0.5)	–	13.8 (1.6)	6	–	87
2	19.2 (1.1)	20.2 (–)	18.0 (2.6)	4	1	14
3	21.7 (1.8)	24.3 (1.8)	23.2 (2.2)	39	41	103
4	22.4 (1.9)	24.8 (2.4)	23.8 (2.3)	16	10	33
5	23.5 (1.8)	26.8 (2.6)	26.0 (2.9)	8	16	25
6	27.1 (2.1)	32.4 (2.0)	29.9 (3.2)	4	6	12
7	–	30.3 (2.9)	30.9 (2.6)	–	3	6
8	29.4 (3.7)	34.1 (2.9)	33.3 (3.5)	2	6	8
9	27.3 (–)	32.4 (2.4)	30.9 (3.2)	1	5	7
10	–	36.9 (3.0)	36.9 (3.0)	–	3	3
11	29.5 (–)	38.9 (–)	34.2 (6.6)	1	1	2

[a] Mean length for 'All fish' includes males, females, and fish of unknown gender.

Table 8.–Weighted mean total lengths (in) at age and sample sizes for Smallmouth Bass (males and females combined) collected from Elk and Skegemog lakes, April 2–25, 2008. Standard deviation is in parentheses.

Age	State average[a]	Mean length		Number aged
1		8.4	(2.0)	2
2	8.5	9.9	(1.3)	8
3	11.6	12.9	(1.1)	102
4	13.5	14.9	(1.0)	131
5	15.1	16.2	(0.8)	108
6	15.7	17.5	(0.9)	40
7	16.5	18.2	(0.9)	27
8	17.1	19.0	(0.9)	16
9		19.2	(0.7)	11
10		20.1	(0.7)	9
11		19.7	(1.6)	4
12		20.4	(0.5)	3
13		21.0	(0.8)	3
14		20.8	(–)	1

[a] Statewide average calculated from dorsal spines

Table 9.–Unweighted mean total lengths (in) at age and sample sizes for Muskellunge (males and females combined) collected from the lower Antrim Chain of Lakes (Lake Bellaire, Clam Lake, Torch Lake, Torch River, Elk Lake, and Skegemog Lake) from 1996 to 2011. Standard deviation is in parentheses.

Age	State average	Mean length		Number aged
2	19.9	18.1	(–)	1
3	25.4	26.2	(5.0)	3
4	31.9	34.9	(3.1)	4
5	34.7	38.1	(4.5)	4
6	36.8	36.1	(2.1)	4
7	39.2	40.4	(2.8)	6
8	41.7	44.3	(2.5)	7
9	45.3	44.9	(4.1)	8
10	48.7	48.4	(5.3)	3
11	–	47.2	(3.6)	4
12	–	50.5	(3.4)	3
13	–	–		
14	–	47.7	(3.3)	2
15	–	54.7	(–)	1
16	–	47.5	(2.2)	3
17	–	55.0	(–)	1

Angler Survey

Open-water period

The clerk interviewed 1,631 anglers during the open-water period on Elk and Skegemog lakes with most (90%) interviews consisting of incomplete fishing trips. Anglers interviewed during the open-water period came from 25 states. Most (81%) were from Michigan, though a substantial portion (14%) came from the neighboring states of Illinois, Indiana, and Ohio. Local (within 50 miles) anglers made up 39% of those interviewed. Anglers fished an estimated 41,685 hours during the open-water period and caught a total of 36,854 fish, comprising 15 species (Table 10, Appendices A and B). Although the open-water fishery on Elk and Skegemog lakes was diverse, the majority (55%) of anglers targeted bass. Other species targeted were Yellow Perch (9%), panfish (general term to describe Yellow Perch, Bluegill, Pumpkinseed, and Rock Bass; 7%), Muskellunge (5%), trout (5%), Northern Pike (2%), Bluegill (1%), and Walleye (1%), with 14% of anglers reporting that they were targeting “anything”.

Smallmouth Bass were the most numerous species caught, making up 44% of the catch by number. Anglers reported releasing 94% of all Smallmouth Bass caught. Yellow Perch were the second most frequently caught species, making up 30% of the catch by number. Anglers only caught an estimated 43 Walleyes, all of which were harvested. As opposed to total catch, total harvest during the open-water period was dominated by Yellow Perch and Rock Bass, which accounted for 67% of the total harvest. Muskellunge were not detected in the angler harvest during the open-water period, but an estimated 82 were caught and released. Of these fish, 59% were caught in Skegemog Lake and 41% were caught in Elk Lake. Monthly catch rates of Smallmouth Bass during the open-water period ranged from a low of 0.25 per hour in August to a high of 0.62 per hour in September, with an overall catch rate of 0.39 per hour. Catch rates for Northern Pike were lower than for Smallmouth Bass, averaging only 0.02 fish per hour during the open-water period. Yellow Perch catch rates averaged 0.27 fish per hour, and ranged from a low of 0.02 per hour in June to 0.54 per hour in October.

Ice-cover period

The fishery during the ice-cover period on Elk and Skegemog lakes was rather different from the open-water period. Anglers interviewed during the ice-cover period represented a much less diverse geographical distribution than during the open-water period. All of the anglers interviewed were from Michigan and most (80%) were local anglers. Most anglers used jigging or still-fishing techniques, while 16% of anglers were spearing. Yellow Perch were the most sought after species during the ice-cover period, with 57% of anglers targeting them. Muskellunge were targeted by 15% of anglers, while 11% were targeting trout, 8% were targeting Lake Whitefish, 6% were targeting panfish species, and 3% were targeting Northern Pike. Clerks interviewed 786 anglers during the ice-cover period, most (91%) of which had not completed their fishing trips. Anglers fished 12,231 hours (Table 10, Appendices C and D) and caught a total of 19,174 fish, comprising eleven species. Angler catch was dominated by panfish species, which accounted for 96% by number. In fact, the harvest rate for Yellow Perch was 6 times higher during the ice-cover period. Five Muskellunge were detected in the angler harvest. The ice-cover period is a more popular time for coldwater species angling in Elk and Skegemog lakes, and harvest of Lake Trout, Lake Whitefish, and Cisco were 118, 58, and 177, respectively.

Table 10.–Angler survey estimates for Elk and Skegemog lakes. Survey period was from April 26 to October 31, 2008 and January 13 to March 16, 2009. Catch per hour (C/H) is harvest and release rate, respectively (fish per hour). Two standard errors are given in parentheses.

	Number harvested or released by month									Open-water		Ice-cover		Annual	
Species	Apr–May	Jun	Jul	Aug	Sep	Oct	Jan	Feb	Mar	total	C/H	total	C/H	total	C/H
Harvested															
Walleye	12	9	22	0	0	0	0	0	7	43	0.001	7	0.001	50	0.001
	(24)	(17)	(44)	(0)	(0)	(0)	(0)	(0)	(12)	(53)	(0.001)	(12)	(0.001)	(54)	(0.001)
Northern Pike	31	12	9	10	0	0	27	80	18	61	0.002	125	0.010	186	0.003
	(47)	(24)	(17)	(15)	(0)	(0)	(27)	(76)	(20)	(58)	(0.001)	(83)	(0.007)	(101)	(0.007)
Largemouth Bass	0	0	0	14	7	0	0	0	0	20	<0.001	0	0	20	<0.001
	(0)	(0)	(0)	(20)	(13)	(0)	(0)	(0)	(0)	(24)	(<0.001)	(0)	(0)	(24)	(0.001)
Smallmouth Bass	113	134	183	286	189	43	0	0	0	948	0.023	0	0	948	0.018
	(109)	(107)	(146)	(177)	(111)	(37)	(0)	(0)	(0)	(300)	(0.008)	(0)	(0)	(300)	(0.008)
Yellow Perch	153	16	77	995	780	766	1,614	2,512	992	2,788	0.067	5,117	0.418	7905	0.147
	(212)	(33)	(100)	(610)	(397)	(411)	(572)	(957)	(530)	(869)	(0.022)	(1,234)	(0.101)	(1,509)	(0.103)
Bluegill	0	190	153	186	131	7	75	217	377	667	0.016	670	0.055	1,337	0.025
	(0)	(234)	(171)	(132)	(119)	(14)	(83)	(212)	(239)	(340)	(0.008)	(330)	(0.027)	(474)	(0.028)
Pumpkinseed	0	58	11	18	27	0	28	85	159	114	0.003	272	0.022	386	0.007
	(0)	(117)	(22)	(26)	(33)	(0)	(30)	(107)	(115)	(126)	(0.003)	(159)	(0.013)	(300)	(0.022)
Rock Bass	73	585	262	226	18	5	22	85	109	1,170	0.028	216	0.018	1,386	0.026
	(112)	(487)	(192)	(356)	(21)	(10)	(26)	(84)	(87)	(643)	(0.016)	(124)	(0.010)	(655)	(0.019)
Lake Trout	6	0	36	28	0	0	9	93	16	69	0.002	118	0.010	187	0.003
	(12)	(0)	(42)	(55)	(0)	(0)	(12)	(64)	(21)	(71)	(0.002)	(68)	(0.006)	(98)	(0.006)
Brown Bullhead	0	0	0	0	0	0	0	1	0	0	0	1	<0.001	1	<0.001
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(2)	(0)	(0)	(0)	(2)	(<0.001)	(2)	(0.001)
Muskellunge	0	0	0	0	0	0	5	0	0	0	0	5	<0.001	5	<0.001
	(0)	(0)	(0)	(0)	(0)	(0)	(11)	(0)	(0)	(0)	(0)	(11)	(0.001)	(11)	(0.001)
Lake Whitefish	0	0	0	0	0	0	53	5	0	0	0	58	0.005	58	0.001
	(0)	(0)	(0)	(0)	(0)	(0)	(58)	(9)	(0)	(0)	(0)	(59)	(0.005)	(59)	(0.005)
Cisco	0	0	0	0	0	0	14	85	78	0	0	177	0.015	177	0.003
	(0)	(0)	(0)	(0)	(0)	(0)	(21)	(106)	(125)	(0)	(0)	(165)	(0.014)	(165)	(0.014)
Total harvest	387	1,005	752	1,763	1,151	821	1,848	3,162	1,757	5,880	0.141	6,767	0.553	12,647	0.235
	(269)	(565)	(319)	(743)	(431)	(413)	(583)	(1,000)	(613)	(1,184)	(0.033)	(1,310)	(0.130)	(1,766)	(0.134)

Table 10.–Continued.

Species	Number harvested or released by month									Open-water		Ice-cover		Annual	
	Apr–May	Jun	Jul	Aug	Sep	Oct	Jan	Feb	Mar	total	C/H	total	C/H	total	C/H
Released															
Northern Pike	119	216	171	139	146	20	9	126	31	812	0.020	167	0.014	979	0.018
	(128)	(252)	(111)	(168)	(108)	(21)	(11)	(170)	(34)	(364)	(0.009)	(174)	(0.014)	(403)	(0.017)
Largemouth Bass	7	74	104	70	44	19	2	0	4	318	0.008	6	0.001	324	0.006
	(12)	(100)	(78)	(102)	(43)	(23)	(5)	(0)	(8)	(171)	(0.004)	(9)	(0.001)	(171)	(0.004)
Smallmouth Bass	1,651	2,965	3,079	1,711	4,972	897	4	5	20	15,275	0.366	29	0.002	15,304	0.284
	(1,279)	(1,353)	(1,084)	(616)	(1,842)	(444)	(7)	(11)	(29)	(2,934)	(0.082)	(32)	(0.003)	(2,934)	(0.082)
Yellow Perch	7	120	1,492	2,850	2,917	965	4,361	5,044	1,523	8,350	0.200	10,928	0.894	19,278	0.358
	(10)	(113)	(1,423)	(1,337)	(1,357)	(464)	(1,529)	(1,917)	(938)	(2,426)	(0.063)	(2,625)	(0.215)	(3,574)	(0.224)
Bluegill	0	114	639	869	447	5	46	238	636	2,075	0.050	920	0.075	2,995	0.056
	(0)	(115)	(344)	(588)	(357)	(11)	(52)	(406)	(472)	(778)	(0.012)	(625)	(0.051)	(998)	(0.055)
Pumpkinseed	0	0	0	28	34	0	7	38	101	62	0.002	147	0.012	209	0.004
	(0)	(0)	(0)	(40)	(40)	(0)	(15)	(60)	(103)	(57)	(0.001)	(120)	(0.010)	(133)	(0.010)
Rock Bass	160	1,548	1,192	685	311	22	0	24	90	3,917	0.094	114	0.009	4,031	0.075
	(152)	(1,000)	(580)	(453)	(242)	(30)	(0)	(30)	(102)	(1,274)	(0.032)	(107)	(0.009)	(1,278)	(0.034)
Rainbow Trout	0	33	0	0	0	0	0	0	0	33	0.001	0	0	33	0.001
	(0)	(66)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(66)	(0.002)	(0)	(0)	(66)	(0.002)
Lake Trout	0	0	18	0	0	0	0	12	0	18	<0.001	12	0.001	30	0.001
	(0)	(0)	(25)	(0)	(0)	(0)	(0)	(24)	(0)	(25)	(<0.001)	(24)	(0.002)	(35)	(0.002)
Channel Catfish	0	0	5	0	27	0	0	0	0	32	0.001	0	0	32	0.001
	(0)	(0)	(10)	(0)	(54)	(0)	(0)	(0)	(0)	(55)	(0.001)	(0)	(0)	(55)	(0.001)
Muskellunge	26	11	0	13	10	23	0	0	0	82	0.002	0	0	82	0.002
	(39)	(15)	(0)	(22)	(19)	(28)	(0)	(0)	(0)	(58)	(0.001)	(0)	(0)	(58)	(0.001)
Cisco	0	0	0	0	0	0	3	57	24	0	0	84	0.007	84	0.002
	(0)	(0)	(0)	(0)	(0)	(0)	(6)	(87)	(39)	(0)	(0)	(95)	(0.008)	(95)	(0.008)
Total released	1,971	5,081	6,699	6,365	8,908	1,950	4,433	5,546	2,429	30,974	0.743	12,407	1.014	43,381	0.805
	(1,295)	(1,713)	(1,917)	(1,661)	(2,332)	(644)	(1,530)	(1,970)	(1,061)	(4,111)	(0.131)	(2,711)	(0.260)	(4,924)	(0.291)
Total catch (harvested + released)	2,358	6,085	7,452	8,128	10,059	2,771	6,280	8,708	4,186	36,854	0.884	19,174	1.568	56,028	1.039
	(1,323)	(1,803)	(1,943)	(1,820)	(2,372)	(766)	(1,637)	(2,209)	(1,226)	(4,278)	(0.145)	(3,011)	(0.323)	(5,231)	(0.354)
Angler hours	5,022	8,911	8,084	8,112	8,370	3,186	4,065	5,820	2,346	41,685		12,231		53,916	
	NAN	(2,869)	(2,135)	(1,779)	(2,476)	(971)	(925)	(1,161)	(682)	(4,799)		(1,634)		(5,070)	
Angler trips	924	1,749	2,983	2,770	2,104	876	1,238	1,485	596	11,406		3,319		14,725	
	NAN	(777)	(914)	(1,278)	(886)	(412)	(381)	(392)	(209)	(2,007)		(585)		(2,091)	

Annual period

In the annual period from April 26 to October 31, 2008 and January 13 to March 16, 2009, anglers fished 53,916 hours on Elk and Skegemog lakes. Angler effort was consistent throughout the summer months, but was lower in the spring, fall, and winter months. Of the total annual fishing effort, 77% occurred during the open-water period and 23% occurred during the ice-cover period. Average daily effort was slightly higher during the open-water period (221 versus 194 angler hours per day). In total, anglers interviewed over the course of the entire creel survey came from 25 states, with Michigan making up the majority (87%) and Illinois, Indiana, and Ohio making up a substantial portion (9%). The majority (53%) of anglers were from local areas.

Yellow Perch were the predominant species caught (harvested + released), followed by Smallmouth Bass, Rock Bass, and Bluegill. Catch rates for Walleye, Northern Pike, and Smallmouth Bass were 0.001, 0.02, and 0.30 fish per hour, respectively. Catch rates were calculated with general effort, not targeted effort, and are therefore not necessarily indicative of the rate that an angler targeting one species may have experienced. Anglers released none of the Walleyes caught, 84% of Northern Pike, and 94% of Smallmouth Bass.

The total annual harvest was 12,647 fish, which was predominantly Yellow Perch (63%), Rock Bass (11%), and Bluegill (11%). There was no angler survey during November and December, because it was thought that relatively little fishing occurred during that time of year, and ice conditions were unsafe. No tag returns were reported as being caught during the nonsurveyed period so the estimated harvest for Walleye, Northern Pike, and Smallmouth Bass were not further adjusted for the nonsurveyed period. After being further adjusted for the percentage of sublegal fish that grew over the minimum size limit during the fishing season (see *Abundance* section), the total expanded harvest (H_a) for Walleye, Northern Pike, and Smallmouth Bass was 50, 152, and 819, respectively.

Mortality

Ages 4 and older were used in the catch-curve analyses to represent the legal-sized Walleye population (Figure 7; Table 11), but the catch-curve regression was not significant ($P < 0.05$). Anglers returned a total of 2 tags (both reward) from harvested Walleyes in Elk and Skegemog lakes in the year following tagging (Tables 12). The creel clerk did not observe any recaptured Walleyes that had lost tags during the angler survey; thus, a tag loss rate of 5% was applied based on previous Large Lake Program surveys. The reward tag return estimate of annual exploitation of Walleye was 3.3% after adjusting for tag loss, the estimated exploitation rate for Walleye was 7.6% based on dividing harvest by the multiple-census abundance estimate, and there was no estimate based on the single-census abundance estimate (Table 5).

Ages 3 and older were used in the catch-curve analyses to represent the adult male and legal-sized female Northern Pike populations, while age 4 and older were used in the catch-curve analyses to represent the overall legal-sized Northern Pike population (Figure 8). The catch-curve regressions were all significant ($P < 0.05$) and produced total annual mortality rates of 38%, 32%, and 34% for males, females, and all Northern Pike, respectively. Anglers returned a total of 9 tags (6 reward and 3 nonreward) from harvested Northern Pike and 4 tags (3 reward and 1 nonreward) from released Northern Pike in Elk and Skegemog lakes in the year following tagging. Additionally, 1 (reward) tagged Northern Pike in the possession of an angler was observed during the creel survey that was not subsequently reported. The creel clerk did not observe any tag loss during the angler survey; thus, an annual tag loss rate of 5% was used. The reward tag return estimate of annual exploitation of Northern Pike was 9.1% after adjusting for tag loss (Table 5). Anglers actually reported reward tags at a lower rate than nonreward tags (9.9% versus 16.0%), but the number of tags voluntarily returned by anglers (13) was lower than the expected number of returns (39) based on the ratio described previously in the Methods section. Based on all tagged Northern Pike caught, the reported release rate was 28.6%. The estimated exploitation rate for Northern Pike was 24.1% when harvest is divided by the multiple-census abundance estimate, and 36.5% when dividing harvest by the single-census abundance estimate (Table 5).

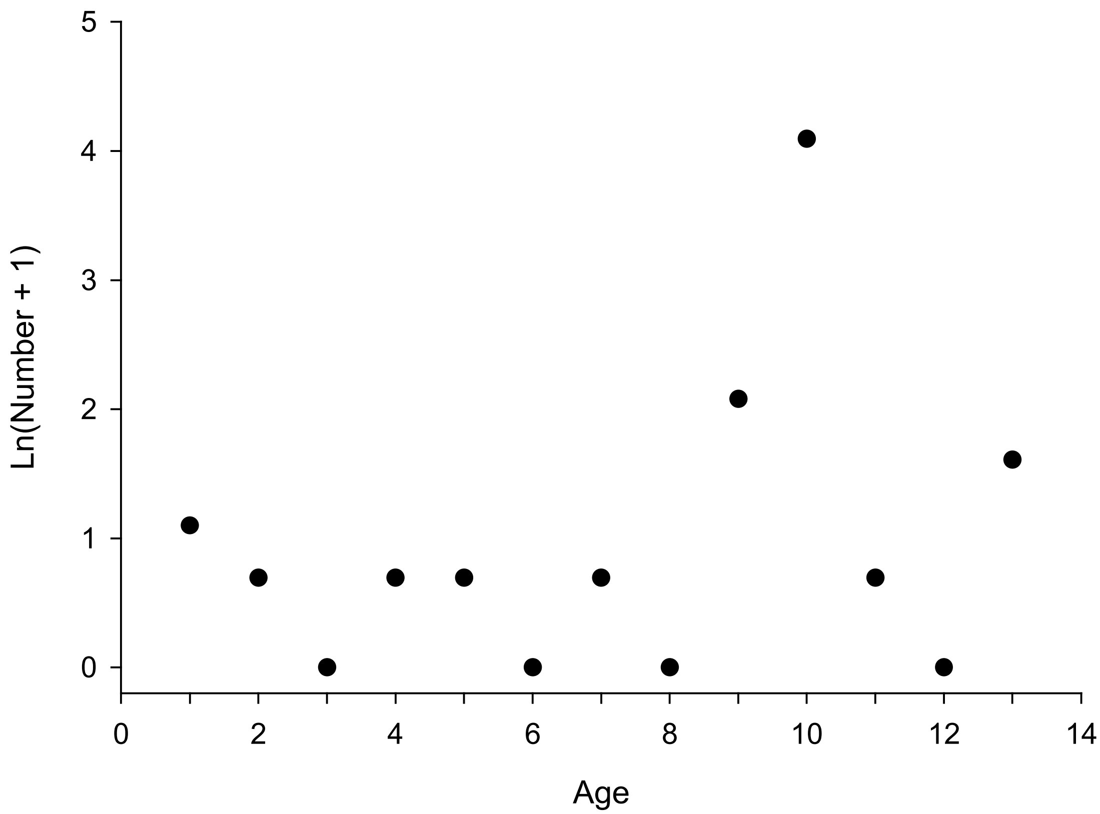

Figure 7.–Plots of observed ln(number) versus age for all (including males, females, and unknown sex) Walleyes in Elk and Skegemog lakes. There was no significant regression.

Table 11.–Catch at age estimates (apportioned by age-length key) for Walleye, Northern Pike, and Smallmouth Bass from Elk and Skegemog lakes, April 2–25, 2008.

Age	Year class	Walleye	Northern Pike			Smallmouth Bass
		All fish[a]	Males	Females	All fish[a]	All fish[a]
1	2007	2	3	–	96	2
2	2006	1	4	1	14	10
3	2005	–	37	39	108	107
4	2004	1	16	11	35	132
5	2003	1	8	19	27	110
6	2002	–	4	6	13	42
7	2001	1	–	3	7	28
8	2000	–	2	6	9	17
9	1999	7	1	5	7	12
10	1998	59	–	2	2	11
11	1997	1	1	1	2	5
12	1996	–	–	–	–	3
13	1995	4	–	–	–	4
14	1994	–	–	–	–	1
15	1993	–	–	–	–	–
16	1992	–	–	–	–	–
17	1991	–	–	–	–	–
18	1990	–	–	–	–	–
19	1989	–	–	–	–	–
20	1988	–	–	–	–	–
Total		77	76	93	320	484

Table 12.–Voluntary angler tag returns (reward and nonreward, harvested and released combined) from Walleye by month for the angling season following tagging in Elk and Skegemog lakes. Tags observed by creel clerk, but not reported by angler are also included. Percentage of total is in parentheses.

Month	Species		
	Walleye	Northern Pike	Smallmouth Bass
4	1 (50)	0 (0)	0 (0.0)
5	1 (50)	5 (35.7)	10 (21.6)
6	0 (0)	5 (35.7)	13 (25.5)
7	0 (0)	0 (0)	7 (13.7)
8	0 (0)	0 (0)	10 (21.6)
9	0 (0)	0 (0)	5 (9.8)
10	0 (0)	0 (0)	4 (7.8)
11	0 (0)	0 (0)	0 (0.0)
12	0 (0)	0 (0)	0 (0.0)
1	0 (0)	1 (7.1)	0 (0.0)
2	0 (0)	2 (14.3)	0 (0.0)
3	0 (0)	1 (7.1)	0 (0.0)
Total	2	14	51

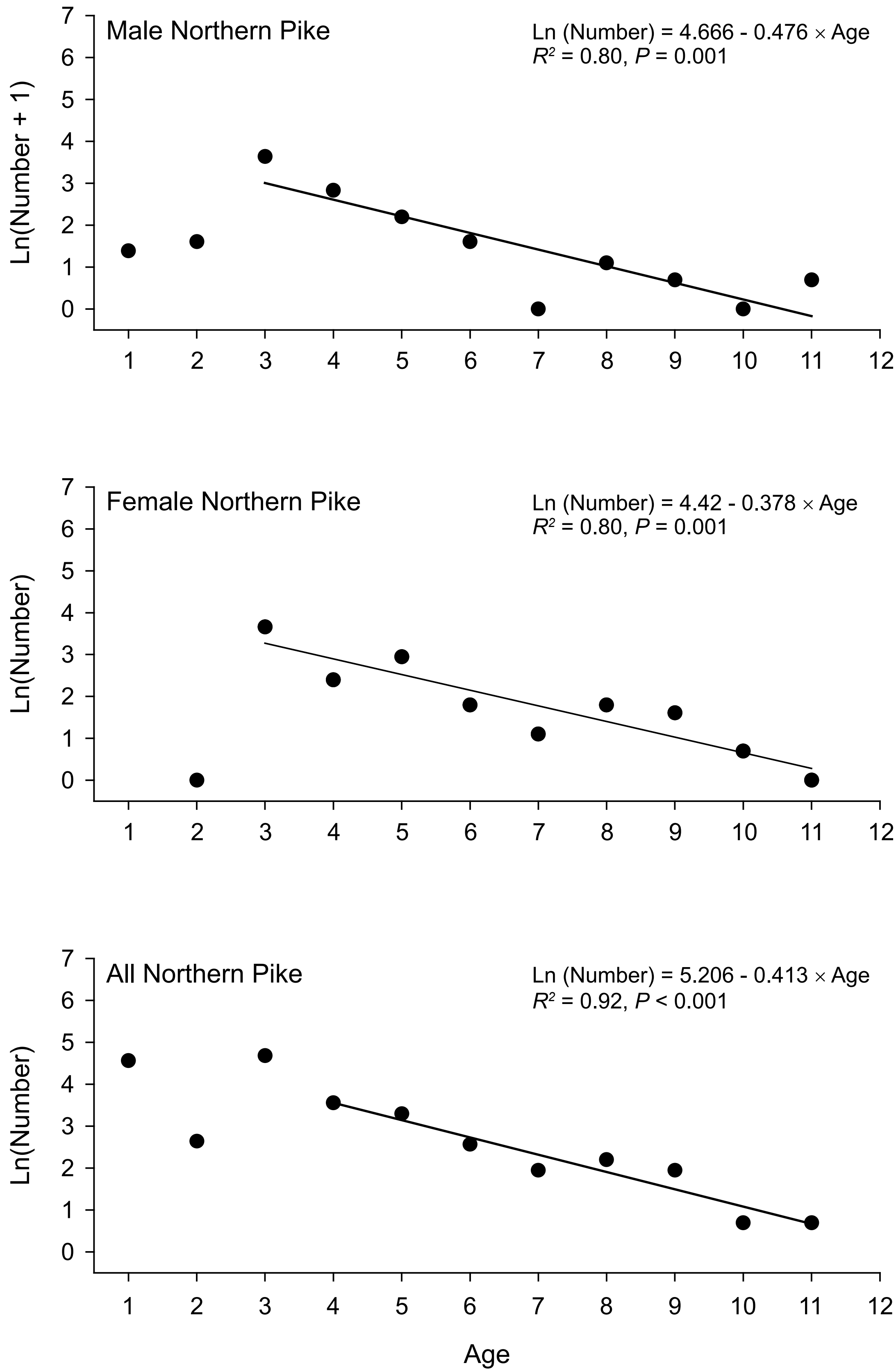

Figure 8.–Plots of observed ln(number) versus age for males, females, and all (including males, females, and unknown sex) Northern Pike in Elk and Skegemog lakes. Lines are plots of regression equations given beside each graph.

Ages 4 and older were used in the catch-curve analyses to represent the legal-sized Smallmouth Bass population (Figure 9). The catch-curve regression was significant ($P < 0.05$) and resulted in a total annual mortality rate of 36%. Anglers returned a total of 40 tags (32 reward and 8 nonreward) from harvested Smallmouth Bass, and 9 tags (4 reward and 5 nonreward) from released Smallmouth Bass in Elk and Skegemog lakes in the year following tagging. The creel clerk also observed 2 tags (1 reward and 1 nonreward) in the possession of anglers that were not subsequently reported. None of the twelve recaptured Smallmouth Bass observed in the angler survey had lost their tags. The reward tag return estimate of annual exploitation of Smallmouth Bass was 14.1% after adjusting for tag loss (Table 5). Anglers reported reward tags at a higher rate than nonreward tags (14.6% versus 11.1%). The number of tags voluntarily returned by anglers (49) was much lower than the expected number of returns (135) derived from observations in the angler survey. Incorporating all tagged Smallmouth Bass known to be caught, the reported release rate was 17.6%. Exploitation rates based on dividing harvest by the multiple- and single-census abundance estimates were similar at 31.4% and 34.1%, respectively.

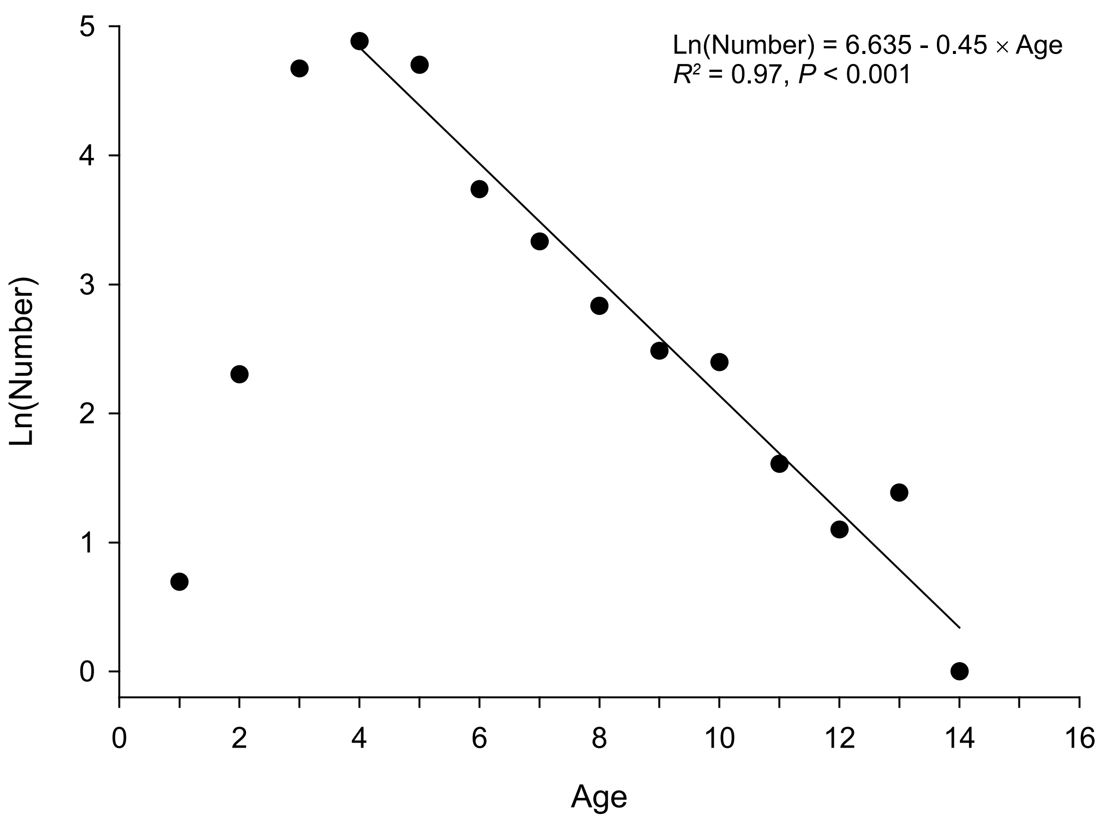

Figure 9.–Plots of observed ln(number) versus age for Smallmouth Bass in Elk and Skegemog lakes. Line is plot of regression equation given beside graph.

A catch curve regression was not possible for Muskellunge given small sample sizes collected in the spring of 2008. However, a regression was run using all of the Muskellunge samples collected from fish in the lower Antrim chain to date in order to get a broad approximation of mortality. Age-8 and older fish were used since age 8 was the first year in which the mean length was greater than legal size. The regression was significant ($P < 0.05$) and resulted in a total annual mortality estimate of 18% (Figure 10). Total annual mortality was also estimated at 25% based on the maximum observed age of 17 in Elk and Skegemog lakes (Casselman et al. 1996). Anglers returned a total of 4 tags (all nonreward) from harvested Muskellunge in the first year following tagging for an estimated exploitation of 36.4%. One fish was harvested during the open-water period and three were harvested during the ice-cover period using spears. Thus, the angling exploitation was 9% and spearing exploitation was 27% during the 2008-09 angling season. At the start of the 2009-10 angling season, there were 10 legal-sized tagged Muskellunge at large in Elk and Skegemog lakes. Seven tagged muskies remained from year one (6 with acoustic tags and 1 with a jaw tag) and 3 more legal-sized muskies were implanted with acoustic tags in the spring of 2009 in Skegemog Lake. Anglers did not return any tags from harvested Muskellunge during the 2009 open-water season or during the ice-cover spearing season, so the estimated exploitation for the 2009-10 angling season was 0%. The two-year average for annual exploitation of Muskellunge was 18.2%. Although an exploitation estimate for the third year following tagging is measured with significant uncertainty, we do know that another fish implanted with an acoustic tag was harvested in the winter of 2011. Given that there were ten tagged fish remaining from 2008 and 2009 and one sublegal fish that would have recruited to legal size by the spring of 2010, the minimum exploitation in the third year was 9.1%. Exploitation based on dividing the harvest estimate by the abundance estimate in 2008 was 9.3%.

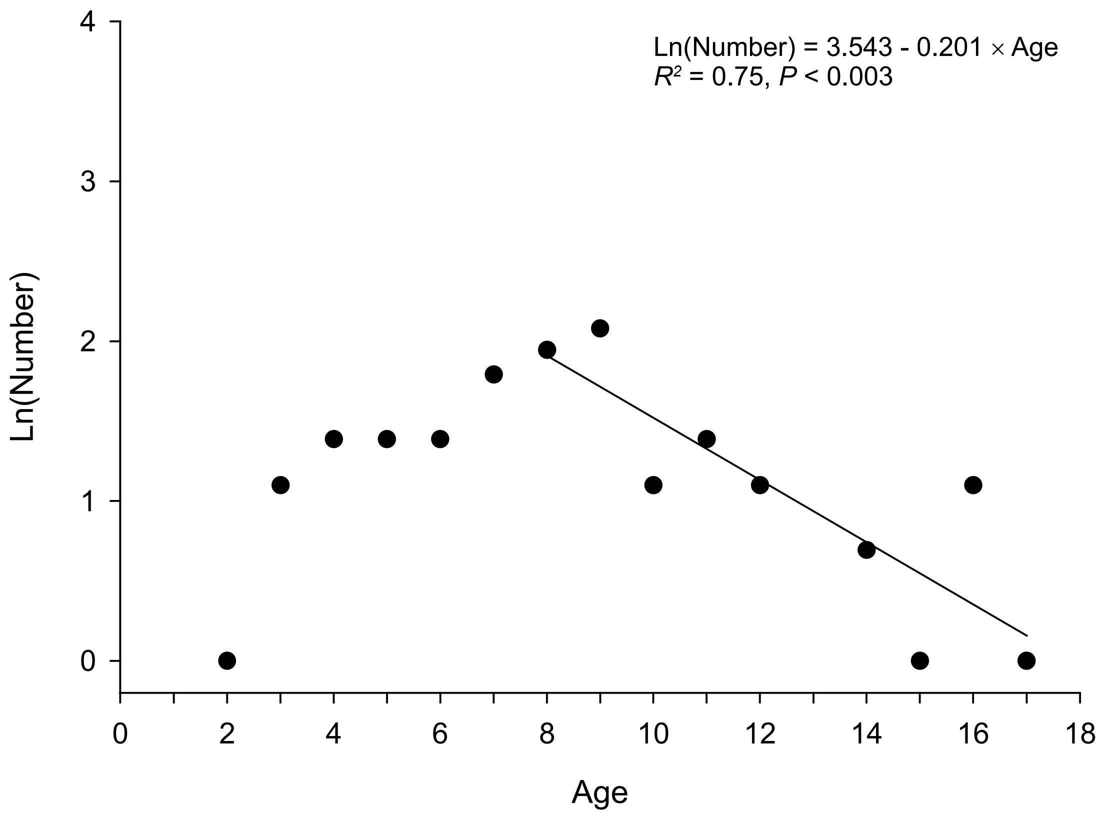

Figure 10.–Plots of observed ln(number) versus age for Muskellunge collected during the spring spawning periods of 1996, 2009, and 2010 in Elk, Skegemog, and Clam lakes. Line is plot of regression equation given beside graph.

Recruitment

Walleye in Elk and Skegemog lakes exhibited variable year-class strength, while Northern Pike and Smallmouth Bass had more consistent recruitment. Walleye were represented by 9 year classes with ages ranging from 1 to 13. A regression could not be completed on the catch at age data due to the lack of any decrease in catch at age. The majority (77%) of Walleye collected were from the 1998 year class (age-10) and other year classes were poorly represented. Walleye were not stocked in Elk or Skegemog lakes in 1998, though they were stocked in Lake Bellaire (an upstream lake in the Antrim chain) in 1997 and 1999. Northern Pike were represented by 11 year classes (ages 1–11) and the R^2 from the catch curve regression was 0.92. Smallmouth Bass were represented by fourteen year classes (ages 1 through 14) and had an R^2 of 0.97. Muskellunge collected from the lower Antrim chain ranged from 2 to 17 years old (Table 9) and represented year classes ranging from 1986 to 2006.

Movement

Based on recaptures during the spring survey, the majority of Walleyes and Northern Pike were recaptured in the same general location where they were tagged. The only Walleye recaptures (N = 5) occurred in Skegemog Lake, which is where they were tagged. For Northern Pike tagged in Skegemog Lake (N = 12 recaptures), 92% were recaptured there and the remaining 8% were recaptured in Elk Lake. No Northern Pike tagged in Elk Lake were recaptured during the spring survey. For Smallmouth Bass tagged in Skegemog Lake (N = 22 recaptures), 64% were recaptured there and the remaining 36% were recaptured in Elk Lake. For those tagged in Elk Lake (N = 2 recaptures), 50% were recaptured in Elk Lake and 50% in Lake Skegemog.

Based on angler tag returns (unadjusted for angler effort) received through the time this report was written, the majority of Walleyes, Northern Pike, and Smallmouth Bass tagged in Elk and Skegemog lakes remained in their lake of origin; however, limited movement was detected that generally went from Skegemog Lake into Elk Lake. Walleyes tagged in Skegemog Lake (83%) were generally recaptured there, with 17% (a single fish) of the returns coming from Elk Lake (Table 13). Similarly, the majority (82%) of Skegemog Lake Northern Pike were recaptured in Skegemog Lake with 18% (3 fish) being recaptured in Elk Lake (Table 14). Angler tag returns depicted greater exchange of Smallmouth Bass between Elk and Skegemog lakes than for Walleye or Northern Pike (Table 15). Although the majority (58%) of Smallmouth Bass tagged in Skegemog Lake were also recaptured there, 33% were recaptured in Elk Lake, 4% were recaptured in Torch Lake or the Torch River, and 5% were recaptured in other locations near Elk Rapids (2 from the Elk River upstream of the dam, and 1 from East Grand Traverse Bay).

Table 13.–Recapture locations of Walleye tagged in Elk and Skegemog lakes based on angler tag returns (reward and nonreward, harvested and released) received through the time of report writing (October 2010). Percent of total recaptured fish is in parentheses.

	Recapture location			
Tagging location	Lake Skegemog	Elk Lake	Torch Lake/River	Other
Lake Skegemog	5 (83.3)	1 (16.7)	0 (0)	0 (0)
Elk Lake	1 (100)	0 (0)	0 (0)	0 (0)

Table 14.–Recapture locations of Northern Pike tagged in Elk and Skegemog lakes based on angler tag returns (reward and nonreward, harvested and released) received through the time of report writing (October 2010). Percent of total recaptured fish is in parentheses.

	Recapture location			
Tagging location	Lake Skegemog	Elk Lake	Torch Lake/River	Other
Lake Skegemog	14 (82.4)	3 (17.6)	0 (0)	0 (0)
Elk Lake	1 (100)	0 (0)	0 (0)	0 (0)

Table 15.–Recapture locations of Smallmouth Bass tagged in Elk and Skegemog lakes based on angler tag returns (reward and nonreward, harvested and released) received through the time of report writing (October 2010). Percent of total recaptured fish is in parentheses.

	Recapture location			
Tagging location	Lake Skegemog	Elk Lake	Torch Lake/River	Other
Lake Skegemog	32 (58.2)	18 (32.7)	2 (3.6)	3 (5.5)
Elk Lake	1 (6.7)	14 (93.3)	0 (0)	0 (0)

Since Skegemog Lake had the higher angler effort, tag returns caught in Elk Lake were adjusted (for angler effort) upward by a factor of 2.18 in order to obtain secondary estimates of movement. These adjustments resulted in minor changes to the percentages of Walleyes and Northern Pike remaining in their lake of origin, but resulted in significant changes for Smallmouth Bass. Of Walleyes tagged in Skegemog Lake, the adjusted estimates were 71% remaining in Skegemog Lake, with 29% (two fish) of the returns coming from Elk Lake. Similarly, the majority (67%) of Skegemog Lake Northern Pike were estimated to be recaptured in Skegemog Lake, and 33% were predicted to be recaptured in Elk Lake. For Smallmouth Bass, the effort adjustment resulted in the majority (51%) of recaptures of Smallmouth Bass tagged in Skegemog Lake from Elk Lake (51%) with the rest coming from Skegemog Lake (42%) and other locations (7%). The effort-adjusted tag returns likely provide the best estimates of fish movement in Elk and Skegemog lakes from 2008–2011.

Muskellunge moved into the Torch River to spawn in early May and remained there through late May and in some cases early June. Water temperature in the Torch River generally ranged from 50°F when Muskellunge first showed up in the river to around 65°F when they emigrated from the river. Most fish then remained in Skegemog Lake during June and started moving into Elk Lake in late June and early July. Fish that moved into Elk Lake remained there throughout the fall and returned to Skegemog Lake sometime over the winter or during the early spring. The results of the Muskellunge movement and seasonal distribution study can be found in Diana et al. (2014).

Discussion

Fish Community Composition

Past fisheries surveys conducted on Elk and Skegemog lakes have used a variety of gear types and have been conducted in different seasons, making effective comparisons of the fish community composition difficult. Additionally, surveys have generally been directed at certain species, rather than the fish community as a whole. Besides some changes with stocked salmonids, the overall fish community in Elk Lake today is similar to that described by Laarman (1976) and the fish community in Skegemog Lake has also likely remained relatively unchanged. Atlantic Salmon, a relatively new species to the fish community, are occasionally caught in Elk and Skegemog lakes since they are stocked in Torch Lake; however, their presence is limited since natural reproduction has never been documented. Also, according to some vague records smelt were stocked in Elk Lake around 1960, but they apparently did not establish. There is, however, a smelt population in Lake Bellaire, which due to its connection, could occasionally result in smelt showing up in Elk and Skegemog lakes. Some minnow species that have been collected in the past have not been collected recently (Appendix E), though recent surveys using small-mesh seines have not been extensive. Overall, the 2008 survey showed a diverse and well-balanced fish community in Elk and Skegemog lakes.

Of the four target species, Muskellunge is the only one with enough historical data to which comparisons can be made. As is often the case with Muskellunge, there is limited standardized data about the population in Elk and Skegemog lakes. Although the 2008 survey occurred slightly earlier (April 2–25) than previous trap- and fyke-net surveys, we collected a total of 15 Muskellunge (CPUE of 0.14 fish per trap-net lift and 0.06 fish per fyke-net lift) in Skegemog Lake. From a simple comparison, the relative abundance of Muskellunge in Skegemog Lake appears similar to what it was in 1975. Night spot-lighting from recent surveys reveals a similar trend. Over several nights between May 21 and June 9, 2009, a single spot-lighter observed on average 1.8 Muskellunge per hour (including all nights), with the highest number observed being 2.9 per hour on June 9 (J. Molenhouse, personal communication). These observations are probably lower than previous ones since there was only a single spot-lighter, who surveyed the entire river from Skegemog Lake to Torch Lake, and did so at a slower pace than the other observations. The maximum number of Muskellunge observed in a single night in 2009 was 13, which is similar to what was observed in other years. Finally, in a single night in 2011, two spotters observed 12 Muskellunge in 2 hours (6 per hour; DNR, unpublished data). The number of spawning Muskellunge observed during night spot-lighting is largely affected by the progression of the spawning period, water temperature, and the clarity of the water; thus, differences may not indicate true variability in the spawning population. Overall, the Torch River spot-lighting data, while variable, suggest that the abundance of spawning Muskellunge has probably not changed appreciably since the 1950s.

Size structure, growth, and maturity

There have been no spring surveys conducted on Elk and Skegemog lakes to use for proper comparison of size structure among the target species. The best surveys for comparison were conducted in May of 1971 and 1996 on Skegemog Lake. The number of Walleyes collected was too low for any comparisons since there were not any collected in 1971 and only one collected in 1996. However, from comparisons to other Walleye populations in large lakes, it is apparent that the Walleye population in Elk and Skegemog lakes has relatively high size structure. The percentage of Walleyes that were legal size (96%) was well above the median (73%) and mean (72%) for 21 populations surveyed under the Large Lakes program. The high size structure is likely a result of the low Walleye density and abundant prey. Northern Pike size structure has varied with the percentages of legal-sized Northern Pike being 11, 70, and 40 in 1971, 1996, and 2008, respectively. Similar to Walleye, the size structure of Northern Pike is relatively high compared to other large lakes surveyed in Michigan. The percentage of Northern Pike that were legal size (40%) was above the median (24%) and mean (28%) for 20 populations surveyed under the Large Lakes program. Smallmouth Bass size structure was similar to that from most other large lakes surveyed in northern Michigan. The percentage of Smallmouth Bass that were legal size (75%) was slightly above the median (72%) and mean (65%) for 18 populations surveyed under the Large Lakes program. The size structure of Smallmouth Bass appears to have increased over time as percentages of legal-sized fish were 28 inches 1971, 47 inches 1996, and 75 inches 2008. The relatively high size structure of Walleye, Northern Pike, and Smallmouth Bass in Elk and Skegemog lakes is largely a reflection of the growth exhibited by these species. Mean lengths-at-age for all species were well above the statewide averages and growth indices ranged from +1.5 to +2.8.

Similar to the other cool/warmwater species, Muskellunge in Elk and Skegemog lakes have high size structure, and recent increases are likely the result of changes to the minimum size limit. In 1996, 56% of the Muskellunge caught in a trap-net survey of Lake Skegemog were of legal size (42 inches), with average and maximum sizes of 41.4 and 51.5 inches, respectively. In 2008, 73% of the Muskellunge in our trap-net survey were of legal size, and mean and maximum lengths were 42.1 and 54.0 inches, respectively. The data from 1996 is actually reflective of the population under the 30-inch minimum size limit since the regulation changed to 42 inches in 1995, and its effects had not been realized yet in the spring of 1996. Growth does not appear to have changed appreciably over the past several decades, hence providing additional support for the positive influence of the size regulation on size structure. Mean lengths in 1956 for age 1, 2, and 8 Muskellunge harvested from Elk Lake were 15.6, 21.0, and 46.0 inches, while the lengths for age 5 and 8 Muskellunge harvested from Elk Lake in 1959 were 36.4 and 48.5 inches (N = 1 for each age). These values are similar to those estimated recently (Table 9) and there is not a positive trend in mean lengths at age to suggest that improvements in size structure were the result of improvements in growth. Thus, any changes in size structure are likely a result of the higher size limit. In other management scenarios, increased minimum size limits for Muskellunge have resulted in higher size structure (MacLennan 1995; Cornelius and Margenau 1999; Casselman 2007).

Given the size structure of the Muskellunge population, it is clear that there is high growth potential. In fact, the growth index based on ages 5 through 10 would rank second highest of the 18 studies reported by Casselman and Crossman (1986). The high growth potential of the population is also supported by the large size of males. The largest male collected in the recent study was 48.5 inches, which was captured in Clam Lake in 2010. Casselman et al. (1996) reported that less than 5% of male Muskellunge collected from Ontario water bodies exceeded 48 inches. In fact, 55% (N = 11) of males collected during the spawning period in the lower Antrim chain exceeded 42 inches. While overall Muskellunge growth is good, it does slow appreciably as fish age. A 42.5-inch male Muskellunge harvested in Skegemog Lake in March of 2011 had been tagged in May of 2008 when it was 41.0 inches; thus, it grew 1.5 inches in 2 years and 10 months. The superior growth of Muskellunge in Elk and Skegemog lakes likely results from the abundant prey base, adequate thermal refuge, and low population density.

Abundance

One of the initial goals of the Large Lakes Program was to compare different methods for estimating the abundance of Walleye, Northern Pike, and Smallmouth Bass. The results from Elk and Skegemog lakes were not consistent with the trend that has been observed in previous surveys (Clark et al. 2004; Hanchin et al. 2005a, b, c; Hanchin and Kramer 2007; Hanchin and Cwalinski 2011). That is, the multiple-census estimates for both Northern Pike and Smallmouth Bass were actually higher than the single-census estimates. The multiple-census estimates also compared better to the independently-derived exploitation estimates, which was inconsistent with past trends. At least for Northern Pike, the reason that the population estimates did not follow the trend observed in other Large Lake Program surveys is likely low sample size. We only tagged 116 Northern Pike and observed only 31 in the recapture sample. Thus, given the relatively consistent trend that we have observed in previous surveys, it is likely that for Elk and Skegemog lakes the multiple-census estimates are biased low and the single-census estimates even more so. Multiple-census estimates made during the onshore spawning migration of species such as Walleye and Northern Pike are likely biased low due to size selectivity and unequal vulnerability of fish to nearshore netting (Pierce 1997). Essentially, the method samples the behavioral pattern of onshore migrations and thus violates the assumption of equal catchability of all individuals. Additionally, multiple-census methods used during onshore migrations have the potential problem of incomplete mixing, which is not a problem with the single-census method since it allows sufficient time for marked fish to fully mix with unmarked fish. In a comparison of surveys conducted similarly to ours, Pierce (1997) concluded that recapturing fish at a later time with a second gear type resulted in estimates that were more valid.

The multiple-census estimates for Walleye abundance were both significantly lower than the predictions from the various regression equations, indicating that the Walleye population in Elk and Skegemog lakes is rather different than the populations used to derive the equations. The primary reason for the difference most likely is that Elk and Skegemog lakes have very little Walleye spawning habitat. While Walleye are probably native to the entire Antrim Chain of Lakes, the connection to Lake Michigan has been lost; thus, Walleye cannot enter the system from Lake Michigan. The existing Walleye population is probably remnant, or it has been established by Walleyes emigrating from Lake Bellaire. Given the small size of the Walleye population in Elk and Skegemog lakes, it would not be appropriate to use any of the regression equations as a surrogate for an empirical population estimate as long as the stocking and/or recruitment patterns in Elk and Skegemog lakes do not change to any large degree.

The current population density of Walleye in Elk and Skegemog lakes was well below average compared to other Walleye lakes in Michigan. The multiple-census estimate for 15-inch-and-larger Walleye was 0.05 per acre, which is the lowest density observed in the Large Lakes Program to date. Density of legal-sized Walleyes estimated recently for twenty-one large lakes in Michigan has averaged 1.9 fish per acre (range = 0.1 to 4.6 fish per acre), though the median (1.6 fish per acre) is a better measure of central tendency for these data (DNR unpublished data). Population density of adult Walleyes (0.05 fish per acre) was also well below the average (3.1 fish per acre) and median (2.4 fish per acre) from 21 populations surveyed in the Large Lakes Program.

Abundance estimates for Northern Pike were successful, and the multiple-census estimates were considered more accurate than the single-census estimates. The multiple-census estimate for legal-sized Northern Pike converts to a density of 0.06 per acre, which is below the average (0.18) and median (0.09) estimated recently in the Large Lakes Program. The density of adult Northern Pike (0.11 per acre) was even further below the average (0.87) and median (0.46) estimated recently in the Large Lakes Program. However, the density of Northern Pike in Skegemog Lake is probably much higher than in Elk Lake. In fact, 94% of the Northern Pike (same percentage for both legal-sized and adult) were caught in Skegemog Lake. Thus, the true density of legal-sized Northern Pike in Skegemog Lake is closer to 0.21 fish per acre, which is actually above the Large Lakes Program average. The density of adult Northern Pike in Skegemog Lake converts to 0.40 fish per acre, which is slightly below the program average. The higher Northern Pike density observed in Skegemog Lake as compared to Elk Lake is primarily a result of the abundant spawning habitat and aquatic vegetation.

Although unbiased estimates of Muskellunge population size were not obtained, based on their relative abundance and recapture ratio, the population appears to be rather small. Even if the upper 95 confidence limit from the population estimate is used, the density of adult Muskellunge would only convert to a density of 0.01 fish per acre for Elk and Skegemog lakes, or 0.04 fish per acre if the assumption is made that the majority occupy Skegemog Lake. A similar population estimate based on netting was conducted during 2009 and 2010 in Clam Lake (lower Antrim chain) that resulted in an estimated 12 adult Muskellunge, which converted to a density of 0.03 fish per acre. In Clam Lake, 5 Muskellunge were marked in 2009, and 4 of the 9 fish captured in 2010 were marked from the previous year. The low sample sizes, yet high recapture rates suggest that the spawning populations in the lower Antrim chain are relatively small. By comparison, the density of Muskellunge greater than or equal to 30 inches in 8 Wisconsin lakes which were supported by stocking was 0.33 per acre (Hanson 1986).

Angler Survey

Summary

The fishery of Elk and Skegemog lakes is dominated by Smallmouth Bass and Yellow Perch, with a minor coldwater component of the fishery adding some diversity. The Smallmouth Bass fishery is largely catch and release. Anglers travel great distances to target Smallmouth Bass in Elk and Skegemog lakes, and it is not uncommon to see several Illinois and Indiana trailers at the boat launch during the summer. Yellow Perch are targeted all year, but the winter fishery is much better and more anglers target them during the winter. A fishery exists for Muskellunge, though the effort directed towards them is relatively low. In fact, during the open-water period 50% of the Muskellunge that were caught and released were caught by anglers targeting bass. Spear fishers accounted for approximately 60% of the overall effort targeted towards Muskellunge. The coldwater species are targeted by relatively few anglers. This may, in part, be due to the fact that better fishing for Lake Trout and whitefish is readily available in the nearby Lake Michigan ports of Traverse City, Elk Rapids, and Charlevoix.

Historical comparisons

There have not been any other comprehensive creel surveys conducted on Elk and Skegemog lakes, though some surveys have been conducted using different methods and over shorter durations. Species composition in the angler catch appears to be similar to past surveys. The earliest information on angler catch came from general creel surveys conducted by conservation officers. For Elk Lake, the angler catch showed similar species compositions from 1928 to 1964 (Laarman 1976). Yellow Perch or Rock Bass always comprised the highest percentage, followed by Smallmouth Bass or Lake Trout. During the period from 1946 to 1951, Muskellunge comprised 6.9% of the catch by number, when they usually comprised only 0.3 to 0.5% in other periods. It is unknown whether this was a true reflection of higher abundance or if there was a seasonal bias present such as would occur if the majority of angler interviews occurred during the winter. Alternatively, with the end of World War II in 1945, the higher effort may have resulted from some post-war phenomenon such as a substantial increase in the popularity of recreational fishing. On Skegemog Lake, a general creel survey conducted by conservation officers from 1940 to 1949 resulted in species catch compositions that were 91% panfish species, 3% Northern Pike, 3% black bass, and <1% Muskellunge. If the species composition in the catch represents angler harvest, species compositions did not differ substantially from those observed from 2008-09. However, if the historic survey data actually represented angler catch, then it would appear that black bass have either increased in abundance, or at least increased in importance to anglers.

A roving creel survey directed at Lake Trout and whitefish anglers was conducted on Elk Lake during three consecutive weekends in the winter of 1964. It is difficult to compare these data to values for 2008-09, but an estimated 0.137 pounds of Lake Trout were caught per angler hour and 0.245 pounds whitefish per angler hour. Using length-weight regressions (Schneider et al. 2000b), these values roughly convert to catch rates of 0.05 Lake Trout per hour (for 20-inch Lake Trout) and 0.12 whitefish per hour (for 18-inch whitefish). A rough targeted catch rate of 0.08 fish per hour can be calculated for the 2008-09 data by averaging the individual catch (harvest + release) of Lake Trout per hour for those anglers targeting trout. This could not be done for whitefish because few anglers indicated they were targeting whitefish. While the methods used to derive the catch rates differ and certain assumptions were made, it does appear that angler catch rates for Lake Trout were similar between the two periods. It is interesting to note that all Lake Trout observed in the 1964 angler catch were wild (no clips from recent stocking). At the time anglers thought fishing was degenerating to a point where it would not be worth doing any longer.

A mail survey conducted on Elk Lake in 1970 and 1973 resulted in an estimated 8,120 and 22,770 angler days, respectively. To compare these estimates with 2008-09, the current average number of trips per day (1.2 trip/day; DNR Fisheries Division, unpublished data) and the average length of a completed trip (4.1 h/trip for the annual period) from the 2008-09 angler survey were multiplied to estimate the average length of an angler day ($1.2 \times 4.1 = 4.9$ angler hours). Thus, the 1970 and 1973 estimates equate to around 39,788 and 111,573 hours of fishing effort, respectively, for an average of 75,681 hours. These estimates are much higher than the 2008-09 estimate of 16,969 total angler hours for Elk Lake (Appendices B and D). Possible explanations include that effort has decreased dramatically, that the two methods are too different to be directly comparable, or both. Given the potential differences in angling effort, it may not be of much value to compare the angler catch (assumed to be harvest) estimated from these mail surveys. None the less, angler catch in 1970 on Elk Lake was 11,470 Yellow Perch, 420 black bass, 750 Northern Pike, and 1,400 suckers (Laarman 1976). One distinction that can be made is the existence of suckers in the angler catch, which were absent from the angler catch in the 2008-09 survey.

The most valid historic angler survey to use for comparison to current information was an August 1996 creel survey on Elk Lake. Biologists estimated a harvest of 2,799 Yellow Perch, 1,802 Rock Bass, 1,200 Smallmouth Bass, 110 Lake Trout, 58 Rainbow Trout, 24 Cisco, and 22 unidentified salmonids. In comparison to August of 2008 on Elk Lake, anglers harvested 1,864 Yellow Perch, 260 Rock Bass, 430 Smallmouth Bass, 69 Lake Trout, no Rainbow Trout, and no Cisco. It is difficult to determine if the reduced harvest of the various species represents reduced abundance, reduced effort, or some general increase in catch and release. The percent compositions of the various species were at least similar between years. In 1996 anglers were seeking bass (37%), bass and perch (37%), trout (23%), and panfish (3%). August 2008 anglers were targeting bass (51%), panfish (25%), trout (14%), Muskellunge (8%), and Walleye (1%). Anglers were generally targeting the same species, with the addition of Muskellunge and Walleye in 2008.

Although largely observational and sometimes anecdotal in nature, there are numerous historical observations on the Muskellunge fishery in Elk and Skegemog lakes that are worth documenting. All indications are that effort directed at Muskellunge and harvest of Muskellunge were higher historically than they are today. In 1951, biologists observed two spawning Muskellunge being caught by anglers in the Torch River, and local anglers reported that around 15 were actually caught during the spawning period. Based on observations during the spawning period, a thorough canvassing of the resorts, boat liveries, restaurants, and taverns during the summer tourist season, and a winter postcard survey on spearing shacks ($N = 146$), Williams (1954) estimated that the 1952-53 Muskellunge harvest in Elk and Skegemog lakes was approximately 80 fish. The annual harvest was comprised by at least 7 Muskellunge (including a 57.5-inch female) taken from the Torch River during the spawning season, 15 taken during the summer/fall season, and 58 taken by spearing through the ice. The Muskellunge fishing season in Michigan at this time was from the last Saturday in April to March 15, the size limit was 30 inches and there was no bag limit. Thus, even if the Muskellunge population was the same as it is today, the expected harvest would be higher given the liberal regulations.

Williams (1954) realized that the spear fishery had the largest potential effect on the Muskellunge population, and he studied it thoroughly in the 1950s. In 1953 and 1954, he used postcard surveys and questionnaires to estimate harvest and effort. There were 146 spearing shacks on Elk and Skegemog lakes in 1953 targeting Muskellunge and estimated harvest was 58. This represented a large increase in effort compared to the 1920s when there was reportedly an average of only 10 spearing shacks on Elk and Skegemog lakes. Although effort was lower in the 1920s when the area was starting to develop as a recreation area, the Muskellunge population was likely in somewhat of an unexploited state, and annual Muskellunge harvest was around 300 (Williams 1954). In 1954, there were at least 101 spearing shacks observed, and spear fishers harvested between 82 and 98 Muskellunge on Elk and Skegemog lakes. Spear fishers spent an estimated 5,515 hours on Elk and Skegemog lakes in the winter of 1954, and the average trip length was 5.2 hours for Elk Lake and 5.5 hours for Skegemog Lake. In comparison, spearing effort in the winter of 2008-09 was approximately 3,000 angler hours and the average trip was

4.0 hours. The only other estimate of Muskellunge harvest was an anecdote from a local spear fisher that 50 Muskellunge were speared on Skegemog Lake in 1992 (DNR Fisheries Division, unpublished data).

Williams (1954) made a variety of estimates of the amount of time required to spear a Muskellunge, and his best estimates were between 163 and 209 hours per fish. Although this was not directly estimated in 2008-09, a rough estimate can be calculated using the total hours exerted by those spear fishers targeting Muskellunge that were interviewed, and the number of Muskellunge observed as harvested from those interviews. Using this method, it took on average 279 hours of spearing effort for the spearing community on Elk and Skegemog lakes to harvest one fish. Given the higher size limit (42 inches) in place today versus during the 1950s (30 inches), it is reasonable that it would take longer to spear a legal-sized Muskellunge. Although the average time it takes to spear a Muskellunge is rather large, some spear fishers likely experience much higher success rates. In 1993, a spear fisher reported harvesting 6 Muskellunge over 30 lbs (DNR Fisheries Division, unpublished data). Even if this spear fisher spent every day of the season (59 days) on the ice for 5 hours a day, it would calculate to 295 hours, or one fish every 49 hours. Siler and Beyerle (1986) reported an average spearing rate of 0.06 muskies (any size) per hour in Iron Lake, Michigan. This represented a rather successful harvest rate of one Muskellunge every 17 hours of spearing, which demonstrates that the fishing method can be efficient at high densities. The only historic statistics for open-water angling on Elk and Skegemog lakes directed at Muskellunge came from one angler in 1954 that caught 10 Muskellunge (32–44 inches) in 225 hours of trolling for a catch rate of approximately 0.04 per hour, or one fish every 22.5 hours. In 2008-09, anglers targeting Muskellunge in Elk and Skegemog lakes caught 0.007 Muskellunge per hour or about one Muskellunge every 140 hours.

Given the lower minimum size limit in place during the 1950s, Muskellunge harvested by spear fishers were smaller than they are today. In 1953, the average size of a Muskellunge speared on Skegemog Lake was 34 inches and the largest was 45 inches ($N = 11$). On Elk Lake the average size was 35 inches ($N = 7$). In 1954, the average size of a Muskellunge speared on Skegemog Lake was 35.5 inches ($N = 32$) and Elk 38 inches ($N = 13$). Although only one Muskellunge (45.5 inches) was observed during the current angler survey, the average size was obviously greater than 42 inches.

Comparison to other large lakes

In addition to the historic angler survey data for Elk and Skegemog lakes, comparisons with angler surveys from other large lakes are useful. An estimated 53,916 angler hours occurred on the Elk and Skegemog lakes during the 2008-09 angling season, which corresponds to 4.9 hours per acre. This is well below the mean and median values for other lakes surveyed under the Large Lakes Program (Table 16). The harvest per acre (1.2) of all fish species in Elk and Skegemog lakes was also well below the mean and slightly below the median values for other large lakes. This is largely due to the fact that angler effort was directed primarily at Smallmouth Bass, which were primarily released. Michigan lakes with a high harvest per acre generally have popular panfish fisheries that bolster the total harvest. Additionally, Elk Lake has an extensive amount of surface area that is deepwater habitat, which is not as productive as shallow-water habitat, nor is it fished as heavily.

Overall, the Walleye fishery in Elk and Skegemog lakes is unimpressive. While some anglers do target Walleye, it is a minor component of the overall fishery. The estimated annual harvest from Elk and Skegemog lakes was 0.005 Walleyes per acre, which is the lowest observed thus far in the Large Lakes Program and far below the average (0.5 per acre) and median (0.4 per acre) for the twenty one populations surveyed as part of the Large Lakes Program. The average harvest of six other large Michigan Lakes (> 1,000 acres) reported by Lockwood (2000a) was 0.63 Walleyes per acre, ranging from 0.09 for Brevoort Lake to 1.68 for Chicagon Lake. These Michigan lakes were subject to similar gears and fishing regulations, including a 15-inch minimum size limit. The lower harvest per acre of

Table 16.–Comparison of recreational fishing effort and total harvest on Elk and Skegemog lakes to estimates from other selected Michigan lakes. Lakes are listed from highest to lowest total fishing effort.

Lake and County	Size (acres)	Survey period	Fishing effort (hours)	Fish harvested (number)	 per hour	Hours fished per acre	Fish harvested per acre
Houghton Roscommon	20,075	Apr 2001–Mar 2002	499,048	386,287	0.77	24.9	19.2
Cisco Chain Gogebic, Vilas	3,987	May 2002–Feb 2003	180,262	120,412	0.67	45.2	30.2
Muskegon Muskegon	4,232	Apr 2002–Mar 2003	180,064	184,161	1.02	42.5	43.5
Burt Cheboygan	17,395	Apr 2001–Mar 2002	134,205	68,473	0.51	7.7	3.9
South Manistique Mackinac	4,133	May 2003–Mar 2004	142,686	43,654	0.31	34.5	10.6
Leelanau Leelanau	8,607	Apr 2002–Mar 2003	112,112	15,464	0.14	13.0	1.8
Gogebic Gogebic, Ontonagon	13,127	May 2005–Mar 2006	101,372	15,689	0.15	7.7	1.2
Big Manistique Luce, Mackinac	10,346	May 2003–Mar 2004	88,373	71,652	0.81	8.5	6.9
Mullett Cheboygan	16,704	May 2009–March 2010	71,240	63,136	0.89	4.3	3.8
Black Cheboygan, Presque Isle	10,113	Apr 2005 Mar 2006	59,874	18,762	0.31	5.9	1.9
Charlevoix Charlevoix	17,268	Apr 2006 Mar 2007	57,126	19,671	0.34	3.3	1.1
Crooked and Pickerel Emmet	3,434	Apr 2001–Mar 2002	55,894	13,665	0.24	16.3	4.0
Elk and Skegemog Antrim, Kalkaska, Grand Traverse	10,961	Apr 2008–Mar 2009	53,916	12,647	0.23	4.9	1.2

Table 16.–Continued.

Lake and County	Size (acres)	Survey period	Fishing effort (hours)	Fish harvested (number)	Fish harvested per hour	Hours fished per acre	Fish harvested per acre
Michigamme Reservoir Iron	6,400	May 2001–Feb 2002	52,686	10,899	0.21	8.2	1.7
Portage and Torch Houghton	13,208	May 2007–Feb 2008	42,724	6,339	0.15	3.2	0.5
Long Presque Isle, Alpena	5,342	Apr 2004–Mar 2005	34,894	7,004	0.20	6.5	1.3
Grand Presque Isle	5,822	Apr 2004–Mar 2005	33,037	10,623	0.32	5.7	1.8
Michigamme Baraga, Marquette	4,292	May–Sep 2006	26,574	4,307	0.16	6.2	1.0
Peavy Pond Iron	2,794	May 2004–Feb 2005	26,447	6,299	0.24	9.5	2.3
Bond Falls Flowage Ontonagon	2,127	May–Oct 2003	21,182	3,193	0.15	10.0	1.5
North Manistique Luce	1,709	May 2003–Mar 2004	10,614	7,603	0.72	6.2	4.4
Average			94,492	51,902	0.41	13.1	6.8
Median			57,126	15,464	0.31	7.7	1.9

Walleye in Elk and Skegemog lakes is a result of the small population and the large size of the lake. The harvest per hour (0.001) for Walleye was a small fraction of the average (0.04) and median (0.04) values from other populations surveyed under the Large Lakes Program. The catch rate of all Walleyes (harvested + released) was identical to the harvest rate since no Walleyes were released. The lack of any released Walleye is another indication of the size and nature of the Walleye population. Populations with few or no Walleyes caught and released usually have high size structure and often have little or no recruitment.

The Northern Pike fishery in Elk and Skegemog lakes was rather unimpressive as a whole, but was better in Skegemog Lake. The estimated annual harvest was 0.02 fish per acre, which was also below the average (0.07) and median (0.03) values from populations (having a 24-inch minimum size limit) sampled in the Large Lakes Program. The average harvest of seven other large Michigan lakes (>1,000 acres) reported by Lockwood (2000a) was 0.15 Northern Pike per acre, ranging from 0.002 per acre in Bond Falls Flowage to 0.65 per acre in Fletcher Pond. The lakes reported by Lockwood (2000a) were also subject to similar gears and fishing regulations, including a 24-inch minimum size limit. Elsewhere, Pierce et al. (1995) estimated harvests from 0.7 to 3.6 per acre in seven smaller Minnesota lakes, which ranged from 136 to 628 acres in size and had no minimum size limit for Northern Pike. Although the harvest per acre of Northern Pike in Elk and Skegemog lakes was below average, the value for Skegemog Lake alone (0.07) is equal to the Large Lake Program average. Just as for harvest per acre, the harvest per hour (0.003) for Northern Pike in both lakes combined was below the average (0.007) and median (0.005) values from other large lake populations, though the value for Skegemog Lake alone (0.005) was about average. Overall, the Northern Pike fishery in Elk and Skegemog lakes when viewed as whole is below average in most angling statistics, but the fishery in Skegemog Lake is similar to the average for other large lakes in Michigan.

Contrary to Walleye and Northern Pike, the Smallmouth Bass fishery in Elk and Skegemog lakes is rather impressive. The average open-water catch rate for Smallmouth Bass from nineteen populations sampled in the Large Lakes Program was 0.10 per hour (median = 0.06 per hour); the rate of 0.39 fish per hour for Elk and Skegemog lakes is about four times this average. It is, in fact, the highest catch rate observed thus far in the Large Lakes Program. Since these catch rates are calculated with general effort rather than targeted effort, the value for each lake may be biased low if Smallmouth Bass are not highly targeted among anglers. That is not the case with Elk and Skegemog lakes where 55% of open-water anglers were targeting Smallmouth Bass. The estimated annual harvest of Smallmouth Bass was 0.09 fish per acre, which was similar to the average (0.10) and median (0.09) from lakes sampled in the Large Lakes Program. The average harvest of eight large (>1,000 acres) Michigan lakes reported by Lockwood (2000a) was 0.08 Smallmouth Bass per acre, ranging from 0.03 to 0.15. The lakes reported by Lockwood (2000a) were all subject to similar gears and fishing regulations; however, the surveys did not always include the entire open-water period.

Although only a few valid statistics describing the Muskellunge fishery in Elk and Skegemog lakes were possible, the density and therefore catch per hour are relatively low. The total Muskellunge catch (all sizes) was 0.008 per acre. The average catch from 8 Wisconsin lakes was 0.9 fish per acre (Hanson 1986) though it varied widely from 0.23 to 2.09 fish per acre. While the Wisconsin lakes were more traditional Muskellunge waters, the disparity between the values does reinforce the low density and corresponding low catch rates for Elk and Skegemog lakes. Hanson (1986) estimated that it took 71 hours to catch a legal-sized (30") Muskellunge in Wisconsin lakes. Kerr et al. (2011) reported an average of one Muskellunge caught every 19 rod hours based an angler diary program in Ontario, though these values could obviously represent highly successful Muskellunge anglers. For anglers targeting Muskellunge in Elk and Skegemog lakes, the catch rate was 0.007 per hour, or about one Muskellunge every 140 hours.

Mortality

Although there was no valid estimate of adult Walleye mortality in Elk and Skegemog lakes, the exploitation rate (3.3%) was low. The average and median values from other population surveyed in the Large Lakes Program are 14.2% and 11.6%, respectively. Total mortality of Northern Pike in Elk and Skegemog lakes (34%) was below the average (49%) and median (48%) values from Northern Pike populations surveyed as part of the Large Lakes Program, and was substantially below the range (35% to 65%) for the majority of North American lakes summarized by Pierce at al. (1995). Angler exploitation of Northern Pike was not excessive as it accounted for less than one-third of total mortality. The mean and median exploitation rates for Northern Pike from Large Lake Program surveys to date are 16.3% and 15.2%, respectively. The Smallmouth Bass population in Elk and Skegemog lakes has lower annual mortality and higher exploitation than Northern Pike. The estimate of total mortality for Smallmouth Bass in Elk and Skegemog lakes (36%) is similar to those reported in the literature. Clady (1975) reported total mortality estimates of 33% for Smallmouth Bass in a Michigan lake with no fishing and 41–65% in a lake subject to simulated exploitation of 13–16%, while Bryant and Smith (1988) reported 58% total mortality of adult Smallmouth Bass from Anchor Bay of Lake St. Clair. Total mortality for Smallmouth Bass in ten populations surveyed in the Large Lakes Program has averaged 33%, with a median value of 36%, and a range of 22–45%. I caution that the exploitation estimates based on tag returns in Elk and Skegemog lakes should be viewed as minimum values. In each case, the expected number of tag returns was much higher than the actual number of tag returns. Although the expected number of returns was calculated for reward and nonreward tags (versus the tag-return estimate of exploitation only using reward tags), it does provide some evidence for nonreporting, and thus a possible underestimation of exploitation based on tag returns.

Similar to total mortality, angler exploitation (14%) of Smallmouth Bass was about average relative to other Michigan lakes. Exploitation of Smallmouth Bass in ten populations surveyed in the Large Lakes Program has averaged 13%, with a range of 4 to 21%. Latta (1975) reported a range of 9% to 33% exploitation, with an average of 19%, for a sample of Smallmouth Bass populations throughout the Great Lakes region and the northeastern United States. In Michigan, Latta (1963) reported 22% exploitation of Smallmouth Bass near Waugoshance Point in Lake Michigan, and Bryant and Smith (1988) reported a rate of 13% for Smallmouth Bass in Lake St. Clair. Although exploitation was not excessively high, Smallmouth Bass are still spawning, and in some cases have not even spawned when the harvest season opens on Elk and Skegemog lakes. Thus, if angling effort increases dramatically in the future, restrictions on harvest and exploitation will need further consideration.

It is both interesting and alarming that the species (Muskellunge) which has the highest exploitation rate on Elk and Skegemog lakes is actually the one that can probably tolerate the least amount of exploitation. Exploitation of Muskellunge in Elk and Skegemog lakes was very high during the 2008 angling season, and even though it was estimated at zero for the 2009 angling season, the two-year average still accounted for 100% of the annual mortality estimate. While these values have error associated with them, they indicate that anglers can harvest a considerable portion of the Muskellunge population in a given year. Even if the predicted annual mortality rate (Casselman et al. 1996) of 24.6% is used based on the maximum observed age (17 in Elk and Skegemog lakes), the two-year average exploitation still accounts for 74% of that prediction. Furthermore, average annual mortality rates for trophy Muskellunge populations ranged from 16% to 26% across North America and Canada (Casselman et al. 1996); thus, the exploitation rate (36%) observed in 2008 was excessive. Muskellunge exploitation has also been found to be high in other lakes in the Antrim Chain of Lakes. Muskellunge exploitation in Clam Lake was 16.7% (1 out of 6 acoustic tags returned) in 2009-10, 0% (0 out of 9 acoustic tags returned) in 2010-11, and 11.1% in 2011-12. Thus, the 2- and 3-year average exploitation estimates were 8.4% and 9.3%; however, the 0% exploitation during the second year should be interpreted with caution. First, we were unable to locate all of the remaining Muskellunge at large with telemetry gear in the spring of 2011 to verify that they were still alive. While it is feasible that fish were not located simply due to the large size (18,721 acres) of Torch Lake, which is connected to Clam Lake, it does provide some evidence that some fish did not make it through the winter spearing season. Additionally, some spear fishers made it known that they would not return tags found in harvested fish. Muskellunge exploitation has been high in other parts of the Midwest. In eight Wisconsin lakes, exploitation averaged 25.9% and ranged from 13.8–42.0% for 30-inch fish, but these lakes generally have high contributions from stocking (Hanson 1986). Hanson also found a negative relationship between exploitation and size structure and thought that exploitation rates of 25–40% were too high to meet the management goal of population quality.

The high exploitation on Muskellunge observed in Elk and Skegemog lakes likely affects both size structure and abundance to some degree. While the size structure is still very good, it could probably be even better. The effect of harvesting large, old Muskellunge on a population is such that a 2% increase in annual mortality (18% to 20%) of trophy Muskellunge is comparable to a 70% reduction in recruitment to the population (Casselman et al. 1996). Although the proportion of released muskies that were legal size is unknown, without voluntary catch and release, it is likely that angler harvest would have likely exceeded levels needed to sustain the fishery.

Recruitment

Walleye recruitment in Elk and Skegemog lakes is comprised of low-level, inconsistent natural reproduction and/or immigration from Lake Bellaire. The relative proportion of each remains unknown. Immigration from Lake Bellaire is possible given the tendency for Walleye to move downstream. Also, the majority of Walleyes collected in Elk and Skegemog lakes were from a single age group that was within one year of stocking years in Lake Bellaire, and aging error of one year is not uncommon for Walleye. Unlike Walleye, Northern Pike and Smallmouth Bass in Elk and Skegemog lakes have relatively consistent recruitment. Most of the variation in Northern Pike (R^2 = 0.92; Figure 8) and Smallmouth Bass (R^2 = 0.97; Figure 9) catch by age class was explained by annual mortality. Also, these indices of variability were above the averages for Northern Pike (0.87) and Smallmouth Bass (0.80) from other Michigan populations surveyed as part of the Large Lakes program. The consistency of recruitment for Northern Pike is expected given the abundance of flooded and submerged vegetation that exists in Skegemog Lake, and the consistency for Smallmouth Bass would suggest that spawning habitat is available and that environmental conditions have been favorable in recent years.

While little information on Muskellunge recruitment was gained during this survey, some information about the population was gained that will ultimately affect recruitment. Based on the age of maturity (4–8) of male Muskellunge in the lower Antrim chain and the number of years it takes them to reach legal size (8–10), the 42-inch minimum size limit (MSL) appears to allow the average male to potentially spawn 4–5 times before it is available for legal harvest. Female Muskellunge however, do not appear to have such protection in place. Female Muskellunge in the lower Antrim Chain of Lakes reach sexual maturity and legal size at about the same time (7–8 years); thus, the average female is not allowed protection from legal harvest prior to spawning. While low sample size, aging error, and recruitment variability could potentially affect the interpretation of age/size at maturity, it would likely not change the interpretation that the current MSL does not adequately protect female Muskellunge in the lower Antrim Chain of Lakes. This is especially relevant considering the high level of exploitation that has been observed in some years.

Muskellunge recruitment in Elk and Skegemog lakes is somewhat of a mystery. Usually only exceptionally large year classes of Muskellunge will produce the oldest, largest trophy Muskellunge (Casselman et al. 1996). Thus, given the presence of large Muskellunge in Elk and Skegemog lakes, it would follow that recruitment is high in some years. However, given the rather low density, it would also appear that recruitment must be rather low in most years. Furthermore, it is doubtful that the population could persist with low recruitment if exploitation were consistently as high as it was in 2008. Thus, it is probable that both Muskellunge recruitment and exploitation are highly variable in this system.

Movement

For the purpose of management, Elk and Skegemog lakes are considered a single system. This is a reasonable strategy given the large width of the connection between the two lakes, but the narrows are shallow, and they probably inhibit movement of fish between the two lakes to some degree. Walleye and Northern Pike were largely recaptured in the same lake in which they were tagged. However, when tag returns were adjusted for effort, movement from Skegemog Lake to Elk Lake was greater than initially estimated. Smallmouth Bass exhibited the greatest exchange between the lakes, with the direction of movement tending to be from Skegemog Lake to Elk Lake. Since we only had two capture locations for Walleye, Northern Pike, and Smallmouth Bass, we do not know exact timing of movement or distribution of the fish prior to tagging. It is quite possible that some of the Walleyes, Northern Pike, and Smallmouth Bass exhibit a pattern similar to that observed for Muskellunge of moving into the cooler waters of Elk Lake as water temperature in Skegemog Lake increases. Although this general movement pattern observed for Muskellunge was not any great surprise, it should be emphasized that the spawning population of Muskellunge in Elk and Skegemog lakes is not protected from harvest during the spawning period under the current fishing regulations. Fish spawning in the Torch River did so from early May through early June. Williams (1954) observed the same thing for Muskellunge in the Torch River, and recommended changing the season dates.

Summary and Management Recommendations

Elk and Skegemog lakes support below-average density Walleye, Northern Pike, and Smallmouth Bass populations with high size structure and excellent growth potential. Densities of all three species are higher in Skegemog Lake, and at least for Northern Pike and Smallmouth Bass the densities are closer to the average from other large lakes surveyed in Michigan. The Walleye population results from a combination of low-level, erratic natural recruitment and possible immigration from upstream lakes in the Antrim chain. Future stocking efforts in Intermediate Lake and Lake Bellaire should include chemical marking of fingerlings so that it could be determined if the Walleye are migrating to Skegemog Lake. Fall electrofishing surveys could be conducted to document the extent of Walleye reproduction in Skegemog Lake. Finally, although the 2007 Inland Consent Decree (US vs. Michigan 2007) categorizes Skegemog Lake as a "Walleye lake system", the population estimate used for setting harvest limits for the state and tribes is inaccurate and should not be used. The population estimate used for setting harvest limits is almost 6 times higher than the estimate derived from the current study.

The creel statistics for Smallmouth Bass were average or above average. In fact, the catch rate was the highest observed thus far in the Large Lakes Program. It is no surprise that the majority of anglers fishing Elk and Skegemog lakes are targeting Smallmouth Bass. Although angler exploitation is currently about average, the fishery should be occasionally monitored as its reputation for high catch rates and large Smallmouth Bass will continue to attract interest. Particular attention should be paid to the results of an ongoing evaluation of the early catch-and-release season for Smallmouth Bass in Michigan.

Perhaps the most fascinating species in Elk and Skegemog lakes is the Muskellunge. Elk and Skegemog lakes have tremendous size structure, but relatively low density of Muskellunge. It is difficult to determine if the population has decreased in number over the past century, though anecdotes from the early 1920s suggest that a small number of spear fishers used to spear more Muskellunge than were speared by many more spear fishers during the height of spearing activity in the 1950s. Local residents have voiced concern over the condition of the Muskellunge population in Elk and Skegemog lakes on numerous occasions over the years, calling for spearing bans several times since the 1950s. Other proposals have included a closed season during spawning, reduced bag limits, and increased size limits. Biologists thought that the apparent reduction in the population observed during the 1950s likely resulted from a combination of development on the Torch River and high angler harvest. In the 1990s, numerous anglers and spear fishers were concerned about high spearing success on Muskellunge that were staging near the Torch River in February. They generally expressed concerns that the fishery was not what it used to be. One stark example came from an angler that reported catching and releasing 17 Muskellunge over 35 lbs in 1971 and only 1 in 1992. In 1992, a petition was circulated to ban spearing of Muskellunge and Northern Pike in Bellaire, Clam, Torch, Elk, and Skegemog lakes. A total of 268 anglers signed this and 70% of those attending a public meeting on the subject were in favor of a ban as was the Elk Skegemog Lake Association. A local newspaper editor (DNR Fisheries Division, unpublished data) informally surveyed 299 subscribers and 96% were in favor of spearing ban. With largely anecdotal evidence, it was difficult to confirm the perceived fish population declines. However, the number of people coming forth with similar opinions spurred further interest in evaluating Muskellunge regulations. In 1993, the MSL on Muskellunge was raised from 30 to 42 inches. Managers thought the 42-inch MSL would restrict spearing on Elk and Skegemog lakes to less than 10 fish per year, making a spearing ban unnecessary. With an estimated harvest of only 5 (upper 95% confidence limit = 16) in 2008-09, the increased size limit has apparently reduced harvest; however, exploitation, especially from spearing is still a significant source of mortality.

In the 1970s the biologist managing Elk and Skegemog lakes suggested a Muskellunge stocking program, though hatcheries were having difficulty raising Great Lakes Muskellunge and a stocking program was never initiated. The only Muskellunge stocking occurred in 1990 and 1994, which were Great Lakes strain Muskellunge received from the Wisconsin DNR. Wisconsin's Muskellunge strain originated from the Indian River chain of lakes in Cheboygan County, Michigan. Since 1990, management prescriptions for Elk and Skegemog lakes have called for stocking Great Lakes Muskellunge. This has not occurred because the DNR lacks an easily accessible brood source to raise our own Muskellunge and the number of Muskellunge that can be obtained from outside sources is small. While the Muskellunge population in Elk and Skegemog lakes could support a higher density, the concerns regarding stocking to supplement natural reproduction may outweigh the potential benefits. One must consider the health of this unique genetic strain, the inadvertent introduction of disease, the effect of hatchery fish on population dynamics, and maintenance of balanced predator-prey relationships. An alternative to stocking is to further restrict harvest in some manner to increase adult abundance. In general, slight increases in the annual mortality of adult Muskellunge are comparable to large decreases in recruitment of juveniles. Alternatively, slight reductions in annual mortality of adult fish are comparable to large increases in recruitment. Thus, it follows that if the population can be maintained and/or improved through harvest reductions that reduce mortality, it would be preferable to relying on stocking as a way to supplement recruitment.

Managers around the Great Lakes states and provinces have recognized the Great Lakes strain of Muskellunge as being very different from the other strains, especially with respect to spawning season, and have tailored regulations appropriately. Currently, the harvest season and size limit in the Antrim Chain of Lakes are some of the most lenient of the Great Lakes states and provinces that apply to Great Lakes Muskellunge populations (Kerr 2011). In light of the increasing popularity of Muskellunge fishing in other Midwestern states (Simonson and Hewett 1999, Younk and Pereira 2003), this is some cause for concern. Most other populations are protected through a combination of shorter seasons and higher size limits. For example, Ontario, Quebec, Minnesota, and New York all have seasons that begin in June, while the season on the Antrim Chain of Lakes begins in late April. Adding to this concern, in 2009, the winter spearing season in Michigan was extended from January and February to include December and March 1–15. This represents a 78% increase in the number of days potentially available for spearing, though in reality spearing on Skegemog Lake rarely occurs before January and spearing on Elk Lake almost never occurs before January because of poor ice conditions. Williams (1954) recognized that the fishing season for Muskellunge in the Antrim Chain of Lakes did not protect spawners, and recommended that the closed season be changed to Dec 1 through the 3rd Saturday in June. It is also my recommendation that a delayed opening date should be considered for the Muskellunge population in the Antrim Chain of Lakes. The simplest change would be to have at least the opening day coincide with that for the Muskellunge population in Lake St. Clair and the Detroit River (1st Saturday in June).

The size limit on the Antrim Chain of Lakes is also lower than those established for Great Lakes populations in nearby states and provinces. The MSL for the Muskellunge population in Wisconsin waters of Green Bay is 50 inches. The St. Lawrence River, which has a similar latitude and fish community, as well as similar growth and maturity as Muskellunge in the Antrim Chain of Lakes recently enacted a 48-inch MSL based on the growth potential and maturity data (Farrell et al. 2003). Given that the growth potential of muskies in Elk and Skegemog lakes compares to other world-renowned populations that have produced muskies in excess of 50–60 lbs, this population may have the capability of producing world-class Muskellunge if exploitation is reduced. The lower Antrim Chain of Lakes has produced the last two state records (current is 50 lb 8 oz) and a Muskellunge from Elk Lake reported to be 60 inches is on display at a local taxidermist's shop. Several Muskellunge greater than 50 inches are caught or speared each year, but there is the potential for many more fish to achieve this size range. The other rationale for an increased size limit is the fact that the majority of female Muskellunge mature at the same time they reach legal size; thus, there is no guarantee that an individual has had the opportunity to spawn once. Thus for Elk and Skegemog lakes, an increased size limit would align well with goal III of the Management Plan for Muskellunge in Michigan (Smith et al. 2016) to protect, maintain, and enhance Michigan's Muskellunge fisheries and associated fish assemblages and aquatic communities. Ultimately, the Muskellunge fishery in Elk and Skegemog lakes could be improved in terms of both density and size structure if exploitation were reduced. This could be achieved through a variety of regulations, such as a shortened season, reduced possession limit, or higher MSL.

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Appendix A.–Angler survey estimates for open-water period on Skegemog Lake. Survey period was from April 26 to October 31, 2008. Catch per hour (C/H) is harvest and release rate, respectively (fish per hour). Two standard errors are given in parentheses.

Species	Apr–May	Jun	Jul	Aug	Sep	Oct	Season	C/H
				Harvested				
Walleye	12	9	0	0	0	0	21	0.0008
	(24)	(17)	(0)	(0)	(0)	(0)	(30)	(0.0011)
Northern Pike	31	12	9	10	0	0	61	0.0023
	(47)	(24)	(17)	(15)	(0)	(0)	(58)	(0.0022)
Largemouth Bass	0	0	0	14	7	0	20	0.0007
	(0)	(0)	(0)	(20)	(13)	(0)	(24)	(0.0009)
Smallmouth Bass	90	128	105	55	109	32	518	0.0190
	(97)	(106)	(109)	(45)	(83)	(31)	(206)	(0.0083)
Yellow Perch	135	0	77	105	273	333	924	0.0340
	(209)	(0)	(100)	(110)	(210)	(214)	(395)	(0.0157)
Bluegill	0	190	153	173	106	7	628	0.0231
	(0)	(234)	(171)	(129)	(113)	(14)	(337)	(0.0131)
Pumpkinseed	0	58	11	18	5	0	92	0.0034
	(0)	(117)	(22)	(26)	(10)	(0)	(122)	(0.0045)
Rock Bass	67	585	194	52	6	5	910	0.0334
	(111)	(487)	(162)	(73)	(12)	(10)	(530)	(0.0204)
Lake Trout	0	0	0	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Total harvest	335	982	549	426	506	377	3,175	0.1166
	(261)	(563)	(279)	(194)	(254)	(217)	(783)	(0.0355)
				Released				
Northern Pike	119	216	162	134	146	14	792	0.0291
	(128)	(252)	(110)	(168)	(108)	(17)	(364)	(0.0143)
Largemouth Bass	7	28	94	70	44	19	262	0.0096
	(12)	(37)	(76)	(102)	(43)	(23)	(142)	(0.0055)
Smallmouth Bass	1,628	2,542	1,986	699	3,819	820	11,494	0.4223
	(1,279)	(1,310)	(849)	(384)	(1,748)	(439)	(2,733)	(0.1257)
Yellow Perch	7	29	106	509	1,066	496	2,213	0.0813
	(10)	(36)	(111)	(315)	(679)	(291)	(811)	(0.0332)
Bluegill	0	114	637	845	267	5	1,868	0.0686
	(0)	(115)	(344)	(587)	(266)	(11)	(740)	(0.0298)
Pumpkinseed	0	0	0	28	34	0	62	0.0023
	(0)	(0)	(0)	(40)	(40)	(0)	(57)	(0.0021)
Rock Bass	160	1,350	892	421	216	22	3,061	0.1125
	(152)	(978)	(502)	(404)	(184)	(30)	(1,195)	(0.0483)

Appendix A.–Continued.

Species	Apr–May	Jun	Jul	Aug	Sep	Oct	Season	C/H
Rainbow Trout	0	0	0	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Lake Trout	0	0	0	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Channel Catfish	0	0	5	0	0	0	5	0.0002
	(0)	(0)	(10)	(0)	(0)	(0)	(10)	(0.0004)
Muskellunge	26	11	0	0	0	10	46	0.0017
	(39)	(15)	(0)	(0)	(0)	(21)	(46)	(0.0017)
Total released	1,947	4,290	3,882	2,706	5,591	1,386	19,803	0.7275
	(1,295)	(1,659)	(1,058)	(892)	(1,907)	(529)	(3,203)	(0.1756)
Total catch	2,282	5,272	4,431	3,132	6,097	1,763	22,978	0.8441
	(1,321)	(1,752)	(1,095)	(913)	(1,924)	(571)	(3,297)	(0.1937)
Angler hours	4,159	6,109	5,192	4,043	5,550	2,168	27,221	
	(2,673)	(2,684)	(1,482)	(1,209)	(2,252)	(830)	(4,875)	
Angler trips	702	1,226	1,710	1,692	1,365	609	7,304	
	(501)	(663)	(563)	(984)	(648)	(338)	(1,584)	

Appendix B.–Angler survey estimates for open-water period on Elk Lake. Survey period was from April 26 to October 31, 2008. Catch per hour (C/H) is harvest and release rate, respectively (fish per hour). Two standard errors are given in parentheses.

Species	Apr–May	Jun	Jul	Aug	Sep	Oct	Season	C/H
				Harvested				
Walleye	0	0	22	0	0	0	22	0.0015
	(0)	(0)	(44)	(0)	(0)	(0)	(44)	(0.0030)
Northern Pike	0	0	0	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Largemouth Bass	0	0	0	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Smallmouth Bass	23	6	78	231	80	12	430	0.0298
	(50)	(14)	(98)	(171)	(74)	(20)	(218)	(0.0159)
Yellow Perch	18	16	0	890	507	433	1,864	0.1289
	(36)	(33)	(0)	(600)	(336)	(351)	(774)	(0.0581)
Bluegill	0	0	0	14	25	0	39	0.0027
	(0)	(0)	(0)	(28)	(36)	(0)	(45)	(0.0032)
Pumpkinseed	0	0	0	0	22	0	22	0.0015
	(0)	(0)	(0)	(0)	(31)	(0)	(31)	(0.0022)
Rock Bass	6	0	68	174	12	0	260	0.0180
	(13)	(0)	(102)	(349)	(17)	(0)	(364)	(0.0253)
Lake Trout	6	0	36	28	0	0	70	0.0048
	(12)	(0)	(42)	(55)	(0)	(0)	(71)	(0.0049)
Total harvest	53	23	203	1,337	646	445	2,707	0.1871
	(64)	(36)	(154)	(718)	(348)	(352)	(888)	(–)
				Released				
Northern Pike	0	0	9	5	0	6	20	0.0014
	(0)	(0)	(14)	(10)	(0)	(12)	(21)	(0.0015)
Largemouth Bass	0	46	10	0	0	0	56	0.0039
	(0)	(93)	(20)	(0)	(0)	(0)	(95)	(0.0066)
Smallmouth Bass	23	423	1,093	1,011	1,154	76	3,780	0.2613
	(33)	(338)	(675)	(482)	(579)	(65)	(1,069)	(0.0869)
Yellow Perch	0	90	1,386	2,341	1,851	469	6,137	0.4243
	(0)	(107)	(1,419)	(1,300)	(1,175)	(362)	(2,286)	(0.1746)
Bluegill	0	0	2	24	180	0	206	0.0142
	(0)	(0)	(5)	(35)	(238)	(0)	(240)	(0.0168)
Pumpkinseed	0	0	0	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Rock Bass	0	198	300	264	95	0	857	0.0593
	(0)	(208)	(291)	(203)	(158)	(0)	(441)	(0.0322)
Rainbow Trout	0	33	0	0	0	0	33	0.0023
	(0)	(66)	(0)	(0)	(0)	(0)	(66)	(0.0046)

Appendix B.–Continued.

Species	Apr–May	Jun	Jul	Aug	Sep	Oct	Season	C/H
Lake Trout	0	0	18	0	0	0	18	0.0012
	(0)	(0)	(25)	(0)	(0)	(0)	(25)	(0.0017)
Channel Catfish	0	0	0	0	27	0	27	0.0019
	(0)	(0)	(0)	(0)	(54)	(0)	(54)	(0.0038)
Muskellunge	0	0	0	13	10	13	36	0.0025
	(0)	(0)	(0)	(22)	(19)	(20)	(35)	(0.0025)
Total released	23	791	2,817	3,659	3,316	564	11,170	0.7723
	(33)	(427)	(1,598)	(1,402)	(1,342)	(369)	(2,577)	(–)
Total catch	76	813	3,021	4,996	3,962	1,008	13,876	0.9593
	(72)	(428)	(1,606)	(1,575)	(1,386)	(509)	(2,726)	(–)
Angler hours	863	2,802	2,892	4,069	2,820	1,018	14,464	
	(–)	(1,013)	(1,537)	(1,305)	(1,030)	(502)	(2,531)	
Angler trips	222	523	1,273	1,078	740	267	4,103	
	(–)	(405)	(720)	(816)	(605)	(234)	(1,330)	

Appendix C.–Angler survey estimates for ice-cover period on Skegemog Lake. Survey period was from January 13 to March 16, 2009. Catch per hour (C/H) is harvest and release rate, respectively (fish per hour). Two standard errors are given in parentheses.

Species	January	February	March	Season	C/H
	Harvested				
Walleye	0	0	2	2	0.0002
	(0)	(0)	(3)	(3)	(0.0003)
Northern Pike	27	78	18	123	0.0127
	(27)	(76)	(20)	(83)	(0.0085)
Yellow Perch	1,614	2,500	992	5,105	0.5249
	(572)	(956)	(530)	(1,234)	(0.1273)
Bluegill	75	217	377	670	0.0689
	(83)	(212)	(239)	(330)	(0.0340)
Pumpkinseed	28	85	159	272	0.0280
	(30)	(107)	(115)	(159)	(0.0164)
Rock Bass	22	85	109	216	0.0222
	(26)	(84)	(87)	(124)	(0.0128)
Lake Trout	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)
Brown Bullhead	0	1	0	1	0.0001
	(0)	(2)	(0)	(2)	(0.0002)
Muskellunge	5	0	0	5	0.0006
	(11)	(0)	(0)	(11)	(0.0011)
Lake Whitefish	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)
Cisco	5	0	0	5	0.0005
	(9)	(0)	(0)	(9)	(0.0010)
Total harvest	1,776	2,966	1,657	6,399	0.6579
	(580)	(992)	(599)	(1,296)	(0.1682)
	Released				
Northern Pike	9	126	31	167	0.0171
	(11)	(170)	(34)	(174)	(0.0179)
Largemouth Bass	2	0	4	6	0.0007
	(5)	(0)	(8)	(9)	(0.0009)
Smallmouth Bass	4	5	20	29	0.0030
	(7)	(11)	(29)	(32)	(0.0033)
Yellow Perch	4,354	5,021	1,523	10,898	1.1206
	(1,529)	(1,916)	(938)	(2,625)	(0.2708)
Bluegill	46	238	636	920	0.0946
	(52)	(406)	(472)	(625)	(0.0643)
Pumpkinseed	7	38	101	147	0.0151
	(15)	(60)	(103)	(120)	(0.0123)

Appendix C.–Continued.

Species	January	February	March	Season	C/H
Rock Bass	0 (0)	24 (30)	90 (102)	114 (107)	0.0118 (0.0110)
Lake Trout	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Cisco	0 (0)	11 (22)	0 (0)	11 (22)	0.0011 (0.0023)
Total released	4,423 (1,530)	5,464 (1,967)	2,405 (1,061)	12,292 (2,709)	1.2639 (0.3413)
Total catch	6,199 (1,636)	8,430 (2,203)	4,062 (1,218)	18,691 (3,003)	1.9219 (0.4304)
Angler hours	3,418 (879)	4,560 (1,087)	1,747 (590)	9,725 (1,518)	
Angler trips	969 (307)	1,027 (315)	388 (164)	2,384 (469)	

Appendix D.–Angler survey estimates for ice-cover period on Elk Lake. Survey period was from January 13 to March 16, 2009. Catch per hour (C/H) is harvest and release rate, respectively (fish per hour). Two standard errors are given in parentheses.

Species	January	February	March	Season	C/H
	Harvested				
Walleye	0	0	6	6	0.0023
	(0)	(0)	(12)	(12)	(0.0047)
Northern Pike	0	2	0	2	0.0008
	(0)	(4)	(0)	(4)	(0.0016)
Yellow Perch	0	12	0	12	0.0047
	(0)	(24)	(0)	(24)	(0.0095)
Bluegill	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)
Pumpkinseed	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)
Rock Bass	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)
Lake Trout	9	93	16	118	0.0470
	(12)	(64)	(21)	(68)	(0.0274)
Brown Bullhead	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)
Muskellunge	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)
Lake Whitefish	53	5	0	58	0.0231
	(58)	(9)	(0)	(59)	(0.0234)
Cisco	9	85	78	173	0.0689
	(19)	(106)	(125)	(165)	(0.0659)
Total harvest	72	196	100	368	0.1469
	(62)	(126)	(128)	(190)	(0.0837)
	Released				
Northern Pike	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)
Largemouth Bass	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)
Smallmouth Bass	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)
Yellow Perch	7	24	0	30	0.0121
	(13)	(48)	(0)	(49)	(0.0197)
Bluegill	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)
Pumpkinseed	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)

Appendix D.–Continued.

Species	January	February	March	Season	C/H
Rock Bass	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)
Lake Trout	0	12	0	12	0.0047
	(0)	(24)	(0)	(24)	(0.0095)
Cisco	3	46	24	73	0.0291
	(6)	(84)	(39)	(92)	(0.0369)
Total released	10	82	24	115	0.0459
	(14)	(99)	(39)	(107)	(0.0443)
Total catch	82	278	124	483	0.1928
	(64)	(160)	(133)	(218)	(0.0988)
Angler hours	647	1,260	599	2,505	
	(287)	(409)	(342)	(605)	
Angler trips	269	458	208	935	
	(226)	(232)	(131)	(349)	

Appendix E.–Fish species collected during surveys in Elk and Skegemog lakes from 1931 through 2008.

Common name	Scientific name
Species collected in spring 2008 with trap nets, fyke nets, and electrofishing gear	
Atlantic Salmon	*Salmo salar*
Black Bullhead	*Ameiurus melas*
Bluegill	*Lepomis macrochirus*
Brook Trout	*Salvelinus fontinalis*
Brown Bullhead	*Ameiurus nebulosus*
Brown Trout	*Salmo trutta*
Cisco	*Coregonus artedi*
Creek Chub	*Semotilus atromaculatus*
Lake Whitefish	*Coregonus clupeaformis*
Lake Trout	*Salvelinus namaycush*
Largemouth Bass	*Micropterus salmoides*
Longnose Gar	*Lepisosteus osseus*
Muskellunge	*Esox masquinongy*
Northern Pike	*Esox lucius*
Pumpkinseed	*Lepomis gibbosus*
Rainbow Trout	*Oncorhynchus mykiss*
Rock Bass	*Ambloplites rupestris*
Smallmouth Bass	*Micropterus dolomieu*
Walleye	*Sander vitreus*
White Sucker	*Catostomus commersonii*
Yellow Perch	*Perca flavescens*
Additional species collected in summer 2008 with trap nets, fyke nets, and gill nets	
Black Crappie	*Pomoxis nigromaculatus*
Burbot	*Lota lota*
Additional species collected in fall 1979 with gill nets	
Rainbow Smelt	*Osmerus mordax*
Additional species collected in fall 1971 with gill nets	
Splake	*Salvelinus namaycush X Salvelinus fontinalis*
Additional species collected in summer 1956 with seines	
Sand Shiner	*Notropis stramineus*
Common Shiner	*Luxilus cornutus*
Bluntnose Minnow	*Pimephales notatus*
Logperch	*Percina caprodes*
Johnny Darter	*Etheostoma nigrum*
Iowa Darter	*Etheostoma exile*
Rosyface Shiner	*Notropis rubellus*
Longear Sunfish	*Lepomis peltastes*
Central Mudminnow	*Umbra limi*
Blacknose Dace	*Rhinichthys obtusus*
Northern Redbelly Dace	*Phoxinus eos*
Ninespine Stickleback	*Pungitius pungitius*
Blackchin Shiner	*Notropis heterodon*
Mottled Sculpin	*Cottus bairdii*
Additional species collected in fall 1931 seine	
Longnose Dace	*Rhinichthys cataractae*