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[Article]

Harvest and Relative Abundance of Siscowet Lake Trout in Michigan Waters of Lake Superior, 1929–1961

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Abstract.—Siscowet, a deepwater morphotype of lake trout *Salvelinus namaycush* and the top predator in Lake Superior, currently makes up most of the lake trout biomass in this lake. Anecdotal accounts indicate that siscowets made up some portion of the historical lake trout commercial fishery, but estimates of harvest and relative abundance are lacking. By using the location information provided by historical fishers on monthly catch reports and past and contemporary knowledge of the depth distribution of siscowets, we provide the first estimates of historical siscowet commercial harvest, fishing effort, and changes in relative abundance for Michigan waters of Lake Superior from 1929 to 1961. Siscowets made up about 27% of the historical yield of lake trout in Michigan waters during this period, but the composition varied greatly among management units. The relative abundance of siscowet in its principal habitat (waters deeper than 80 m) generally declined in most management units before the increase in fishing effort in the mid to late 1940s and the invasion of sea lamprey *Petromyzon marinus* during the 1950s. These factors led to the collapse of nearshore lean lake trout populations by the late 1950s. Modest levels of fishing effort (around 2,000 km annually) before sea lamprey invasion were sufficient to cause declines in siscowet and were probably related to the low production rates associated with the *k*-selected life history attributes of this deepwater morphotype.

Lake Superior had a substantial commercial fishery for lake trout *Salvelinus namaycush* until the 1950s. The fishery concentrated principally on lean lake trout—one of three principal morphotypes found in Lake Superior—occupying the nearshore area. The other types were the siscowet and the humper lake trout. These three morphotypes are similar in gross appearance (see Figure 1 in Moore and Bronte 2001) but differ in head and caudal peduncle shape, growth, fat content, water depth preference, age at maturity, mortality, diet, and spawning time and location (Eschmeyer and Phillips 1965; Khan and Qadri 1970; Lawrie and Rahrer 1973; Bronte 1993; Ray et al. 2007). Lawrie and Rahrer (1973), Burnham-Curtis (1993) and Hansen et al. (1995) provide concise descriptions of this diversity.

By 1960 the lake trout fishery collapsed from a combination of overfishing and predation by sea lamprey *Petromyzon marinus* (Hile et al. 1951; Lawrie and Rahrer 1973; Pycha and King 1975; Baldwin et al. 1979; Figure 1). Before 1950, when sea lampreys were not abundant enough to cause significant mortality, increasing commercial fishing intensity reduced lean lake trout populations in Michigan waters of Lake Superior (Hile et al. 1951; Pycha and King 1975; Wilberg et al. 2003) and probably elsewhere. Controls on sea lampreys (Smith and Tibbles 1980) and exploitation in the early 1960s and intensive stocking of hatchery-reared lake trout thereafter restored lean lake trout throughout most of Lake Superior (Hansen et al. 1995; Bronte et al. 2003; Wilberg et al. 2003; Richards et al. 2004; Sitar et al. 2007). Siscowet, a deepwater morphotype (Sweeny 1890; Khan and Qadri 1970; Lawrie and Rahrer 1973; Moore and Bronte 2001), has also recovered under these conditions of lower mortality (Bronte et al. 2003; Sitar et al. 2007). Siscowets are found principally in deep, offshore waters greater than 80 m, as consistently observed for over 100 years (Sweeny 1890; Montpetit 1897; Jordan and Evermann 1911; Eschmeyer 1955; Lawrie and Rahrer 1973; Bronte et al. 2003). Many siscowet stocks persisted after overfishing and sea lamprey predation decimated most lean lake trout populations.

Siscowet lake trout make up most of the lake trout biomass in Lake Superior at present, as was probably true historically (Ebener 1995; Bronte et al. 2003). The siscowet, with its high fat content (30–90% by weight; Eschmeyer and Phillips 1965) that makes them neutrally buoyant, is adapted for vertical migration (Crawford 1966; Eshenroder and Burnham-Curtis

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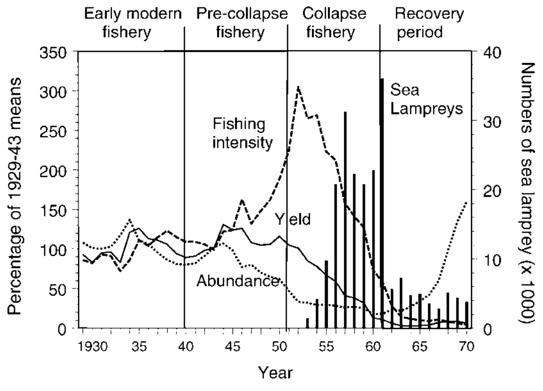

FIGURE 1.—Yield and abundance of lake trout and fishing intensity in Michigan waters of Lake Superior during four distinct periods and the number of sea lampreys captured at electrical barriers in index streams during 1953–1970. The early modern fishery prevailed from 1929 to 1939, the precollapse fishery from 1941 to 1949, the collapsed fishery from 1953 to 1961, and the recovery period after 1961. The figure is based on Figure 3 in Hansen et al. (1995).

1999; Henderson and Anderson 2002). This fish can therefore better use the vast expanses of deep water found in Lake Superior, as opposed to lean lake trout that are more restricted to the less abundant shallower water (<80 m; Bronte et al. 2003). Although the historical commercial fishery of the early 1800s concentrated on lake whitefish *Coregonus clupeaformis* and lean lake trout, the siscowet was differentiated from lean lake trout in accounts of the early fishery (1830–1850; Goode 1884; Nute 1926), and its prominence may be more important than previously realized. The reorganized American Fur Company initiated large-scale fisheries in U.S. waters of Lake Superior in the 1830s after fur demand dwindled. Fish were harvested and salted, then transported from fishing stations around Lake Superior to Sault Saint Marie and Detroit, Michigan (Nute 1926). One transport schooner was named the *Siskawit* (Nute 1926; mentioned but misspelled by Lawrie and Rahrer 1973), which suggests that siscowets were a prominent part of the trade. Siscowets and other fish were sold in the eastern and southern USA for rehydration and cooking by the consumer (Goode 1884; R. Tull, interview with Justin Walsted, Booth Fisheries Manager, Bayfield, Wisconsin, 1979, unpublished report to the Apostle Islands National Lakeshore). This method of preservation, distribution, and rehydration is similar to that of salted Atlantic cod *Gadus morhua* (or baccalà), which has been a part of European and New World colonial cuisines for centuries (Kurlansky 1997). Siscowet was considered inedible when fresh, but was thought superior to many fishes when preserved, reconstituted, and consumed in this manner, and commanded higher prices than lean lake trout or lake whitefish (Goode 1884). This preference for siscowet changed in the early 1900s as Old World culinary and preservation traditions diminished. Thereafter, lean lake trout brought better prices (J. Van Oosten, field notes on a trip to Upper Michigan, 1938, unpublished report, U.S. Bureau of Commercial Fisheries, Ann Arbor, Michigan), but nonetheless a siscowet fishery persisted into the 20th century.

Before the recovery of lean lake trout stocks in Lake Superior, lake trout restoration goals were based, in part, on the 1929–1943 commercial fishery production of lake trout before the sea lamprey era (Busiahn 1990), when reliable harvest figures were available. Historical production of lake trout averaged around 2×10^6 kg/year lakewide, as indicated by mandatory monthly catch reports filed by the fishermen to the management agencies (Hile et al. 1951; Baldwin et al. 1979). Unfortunately, due to the design of the catch report, the different morphotypes of lake trout were pooled under a single reporting column (entitled "Trout or Ciscowets"[1]); hence the proportion of the historical lake trout harvest composed of siscowets was unknown. Restoration goals have been revised and have moved away from historical production as the indicator of success (Horns et al. 2003). However, knowledge of the historical harvest of siscowet is still important because it could provide managers with insights on past ecological states and allow for a more enlightened view of current conditions to aid in assessing recovery (Bronte et al. 2003).

Historical commercial catch reports for the Michigan waters of Lake Superior from 1927 to 1961 were archived on microfiche transparencies at the U.S Geological Survey's Great Lakes Science Center, Ann Arbor, Michigan, which was a laboratory of the Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service, up until the early 1970s. The "by-lift" information of the lake trout fishery was extracted from these reports and electronically archived to develop a database that was previously used to compare historical measures of the relative abundance of wild, lean lake trout with contemporary indices (Wilberg et al. 2003) and to study the dynamics of the fishing fleet in Lake Superior (Wilberg et al. 2004). By

[1] This is one of many spellings of this term, including "siskawitz" (Goode 1884), "siskawaite" (Nute 1926), and "siskiwit" (Sweeny 1890), and of place names on NOAA Lake Superior navigation charts 14966 and 14968. The word is of Ojibwa (Chippewa) origin and means "that which cooks itself" (Goode 1884), referring to the large amounts of intramuscular fat that melted when the fish was exposed to fire.

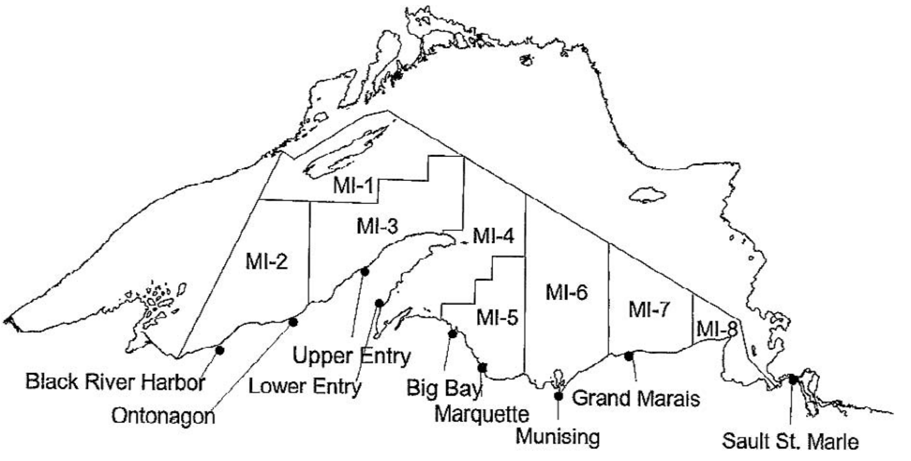

FIGURE 2.—Lake trout management units and major commercial fishing ports in Michigan waters of Lake Superior during 1929–1961.

using the location information provided by fishers on the catch reports and knowledge of the depth distribution of the siscowet, we were able to partition estimates of siscowet harvest from the historical production of lake trout. Our first objective was to estimate the harvest of siscowet in the historical lake trout fishery in Michigan waters from 1929 to 1961. Our second objective was to develop the first measures of historical siscowet relative abundance, and examine temporal trends in response to key changes in fishing and sea lamprey abundance. Although it is well accepted that overfishing combined with sea lamprey predation was the cause of the decline of lean lake trout stocks in Lake Superior (Hile et al. 1951; Lawrie and Rahrer 1973; Pycha and King 1975; Smith and Tibbles 1980; Hansen et al. 1995), the effects of both mortality sources on siscowet have not been investigated.

Methods

The commercial catch reporting system in Michigan began in 1926 but was initially voluntary. Mandatory compliance was required beginning in 1927, and by 1929 the catch and effort data supplied by commercial fishers were deemed reliable (Hile 1962). Fishing locations, especially those beyond 5 km from port, were rarely recorded as recognizable site names, but rather indicated as course (compass bearing) and travel duration from the port of origin; this navigation procedure is known as "dead reckoning." For this study, fishing locations were approximated by running the reported courses from major fishing ports, as recorded on the catch reports across the Michigan shoreline and from seasonal fishing camps on Isle Royale (Figure 2). This was done on National Oceanic and Atmospheric Administration navigational bathymetry charts at an assumed cruising speed of 14.8 km/h, which was the average for most fishing vessels of the era. At the end of each course, fishing depth and the lake trout management unit (Figure 2) was determined for each net lift.

The database contained only information from major fishing operations from odd-numbered years during 1929–1959 and from 1960 and 1961; these years were selected to maximize the temporal coverage of data that could be entered under time and budget constraints. Major operators were defined as those who fished at least 10 times/month and in most months of each year. The database contains information from 71,308 lifts of large-mesh (114–152-mm [stretch measure]) gill nets, which accounts for 76% of the large-mesh gill-net effort in Michigan waters and 64% of the total lake trout catch during 1929–1961. Therefore, these data adequately represent most of the fishery. Estimates of siscowet catches (kg) were partitioned from the total lake trout catch using the estimated fishing depth and the known depth distribution of these morphotypes from historical accounts and current depth distribution data. All historical accounts from the 1800s indicated that siscowets occupied deep water, although catches were a mixture of lean lake trout, siscowet, and half-breeds (i.e., a putative intermediate of lean and siscowet lake trout; Lawrie and Rahrer 1973) at certain depths and times of the year (Van Oosten 1938). Exact bathymetric distributions for historical populations are unknown, so we relied on current knowledge of the bathymetric distribution of lean lake trout and siscowet from standardized lake trout gill-net surveys conducted by the Michigan Department of Natural Resources in

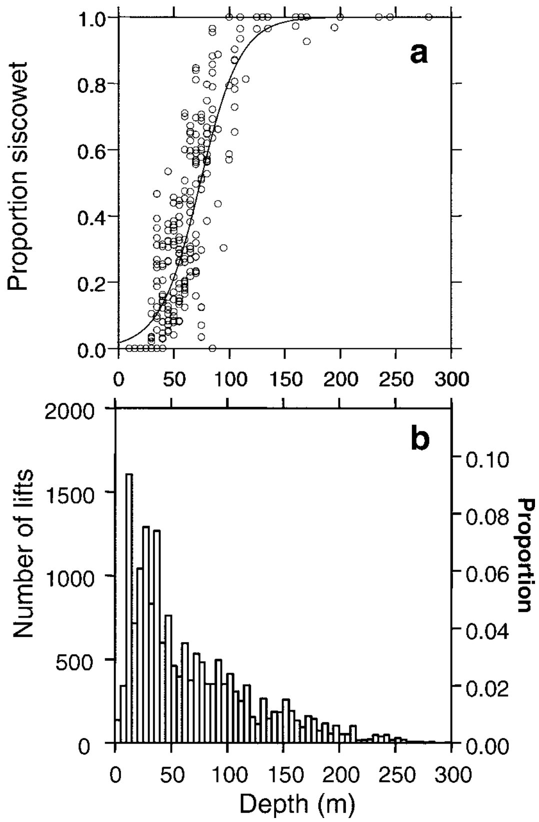

FIGURE 3.—**(a)** Relationship between siscowet as a proportion of all lake trout captured and depth (m) in gill-net surveys and **(b)** the depth frequency distribution of gill-net lifts, by number and proportion, in the commercial fishery for lake trout in Michigan waters of Lake Superior from 1929 to 1961.

Lake Superior from 1998 to 2006. We fit a logistic function to individual survey proportional catch of siscowets to the depth of net (Figure 3a). The proportion of siscowets in a net lift (P_{sis}) was

$$P_{sis} = \frac{1}{1 + e^{[-0.055(D \cdot 4.048)]}},$$

where D is the depth of the net ($r^2 = 0.91$). We applied this model to historical commercial harvest data and estimated the proportion of siscowets harvested in each lift by solving for P_{sis} using the estimated fishing depths of each of lift. This approach assumes that the proportion of siscowets in a net lift is a function of depth and assumes that population densities of siscowet and lean lake trout have tracked each other over time (i.e., the proportion of siscowets at a given depth did not change significantly over time).

Commercial catch and effort statistics were summarized annually according to historical fishery statistical districts (Hile 1962) and previously analyzed (Hile et al. 1951) to describe the changes in the fishery and populations. Tabular summaries of these data by Jensen and Buettner (1976) were used to partition total lake trout catches from statistical districts into the current lake trout management units (Figure 2) using annual lake trout catch totals and the estimated annual proportion of siscowets in lifts that contributed to the lake trout harvest from 1929 to 1961. Siscowet harvest for even-numbered years lacking lift-specific catch and effort information were estimated by multiplying the total lake trout harvest for that year by the average percentage of the total harvest composed of siscowets in the years before and after.

We developed a time series of historical siscowet relative abundance from the estimated biomass of siscowets in each historical net lift. We restricted the data set to gill-net lifts from water depths 80 m and deeper, the principal habitat for siscowet, which would provide the most reliable index of siscowet relative abundance. We used catch per unit of effort (CPUE; kilograms of siscowets per kilometer of net lifted) as the relative abundance index. Fishery effort was corrected for the number of nights the nets fished (standardized to 1 night) and the gill-net twine material used (as per Wilberg et al. 2003). We then calculated the arithmetic mean CPUE across all lifts within a year by each management unit. Our rationale was based on contemporary lake trout gill-net survey catches, which indicate that siscowets composed most of the lake trout caught at depths 80 m and deeper (Figure 3a), a finding that is consistent with historical accounts of siscowet depth preference since the 1880s. Furthermore, examination of the depth distribution of the historical lake trout fishery indicated that most of the lean lake trout fishery occurred at depths less than 80 m (Figure 3b). Inclusion of all lifts in the index of relative abundance would have resulted in extremely low siscowet CPUEs and would dampen our detection of changes in siscowet population density.

To investigate the impact of commercial fishing and sea lamprey predation on siscowet, we compared the average CPUE of siscowets among three separate periods (Figure 1): (1) 1929–1939, the early modern fishery with no sea lampreys and stable fishing intensity (similar to Hansen et al. 1995); (2) 1941–1949, the precollapse fishery with very few sea lampreys and increasing fishing intensity; and (3) 1953–1961, the collapsed fishery with declining fishing intensity and sea lamprey populations increasing greatly before control in the early 1960s (Smith and Tibbles 1980). We used analysis of variance (ANOVA) and Bonferroni-adjusted post hoc tests to identify

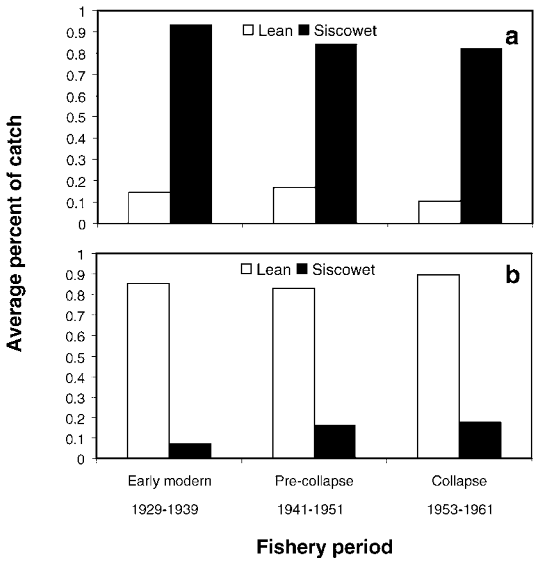

FIGURE 4.—Estimated average proportions of siscowets and lean lake trout captured in commercial gill nets in **(a)** waters 80 m deep and deeper and **(b)** waters less than 80 m during three commercial fishery periods in Michigan waters of Lake Superior.

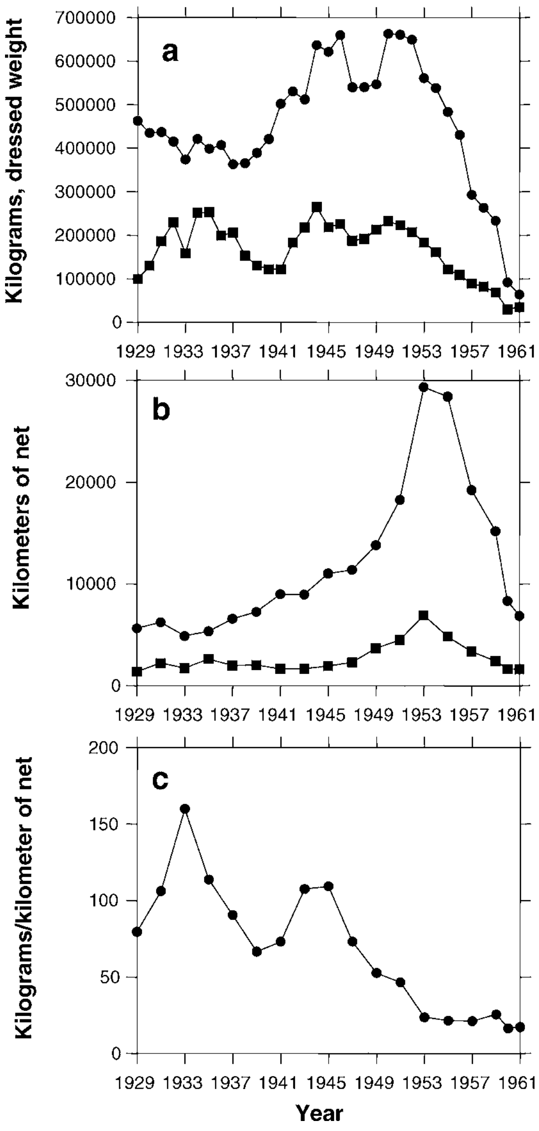

FIGURE 5.—**(a)** Estimated annual harvests in kilograms, **(b)** effort for lean lake trout (circles) and siscowet lake trout (squares), and **(c)** catch per unit effort of siscowet in waters 80 m and deeper in Michigan waters of Lake Superior, 1929–1961.

significant differences in $\log_e$(CPUE + 1) among periods for each management unit. A significant decline in the geometric mean CPUE between the early modern fishery and the precollapse fishery could implicate commercial fishing because sea lamprey populations were not established yet. Significant declines in geometric mean CPUE from the precollapse fishery to the collapsed-fishery period would be less conclusive because both sea lampreys and fishing were acting simultaneously on siscowet populations.

Results

Our analyses indicated that most of the historical lake trout harvest in waters deeper than 79 m consisted of siscowets (Figure 4). In the shallow waters (<80 m) of Lake Superior, lean lake trout composed more than 80% of the historical lake trout harvest across all three reference periods. Siscowet harvest for Michigan waters peaked during 1932–1935 at about 240,000 kg and declined throughout the late 1930s and into the early 1940s. Harvest then increased rapidly to mid-1930s levels by 1945, followed by a second decline (Figure 5a). Siscowets made up about 5.5 million kg (27%) of the total lake trout harvest of 20.4 million kg from Michigan waters during 1929–1961 (Table 1).

The proportion of siscowets harvested in the lake trout fishery varied by management unit (Figure 2; Table 1). During 1929–1961, siscowets made up 3–62% of the historical harvest in Michigan. Units MI-1 and MI-8 had the lowest harvests, which never exceeded 10,000 kg/year. Unit MI-7 had the highest siscowet harvest—about 51% of all siscowets came from this unit during 1929–1961. Unit MI-4 had the largest harvest of all lake trout: almost 5.0 million kg, of which almost 0.8 million kg were siscowets.

Trends in the harvest of siscowet also varied by management unit (Figure 6). Harvests varied little over

TABLE 1.—Estimated total harvest of lean lake trout and siscowet and their relative proportions in the lake trout fishery by Michigan management unit and all units combined, Lake Superior, 1929–1961.

	Lean lake trout		Siscowet	
Management unit	Estimated harvest (kg)	Proportion of total	Estimated harvest (kg)	Proportion of total
MI-1	3,080,168	0.93	241,922	0.07
MI-2	836,645	0.69	368,430	0.31
MI-3	769,746	0.64	441,159	0.36
MI-4	4,141,947	0.83	819,291	0.17
MI-5	1,542,110	0.78	426,377	0.22
MI-6	1,506,725	0.82	324,787	0.18
MI-7	1,724,110	0.38	2,815, 152	0.62
MI-8	1,303,507	0.97	39,183	0.03
All units	14,904,958	0.73	5,476,301	0.27

time in most units, except in MI-4 and MI-7. Siscowet harvest in MI-4 tracked those of lean lake trout, a feature that was not apparent elsewhere. Siscowet harvest in MI-7 was highest in the early 1930s, declined later in the decade, and showed little recovery thereafter. Siscowets in MI-7 were a major portion of the harvest in the mid-1930s but were surpassed by lean lake trout during 1938–1941. As the harvest of lean lake trout began to decline in the early 1940s that of siscowet surpassed it, but both steadily declined thereafter. By 1951, siscowet harvest was declining in nearly all management units.

Fishing effort in waters 80 m or more in depth ranged between 14% and 33% of all large-mesh (114 mm or greater [stretch measure]) gill-net effort in Michigan waters during 1929–1961 (Figure 5b) and was far lower than the effort expended for lean lake trout. Total effort targeted at siscowet ranged from 1,348 km of net in 1929 to 6,908 km in 1953. Fishing effort for siscowet was relatively stable from 1929 to 1944 (when it averaged about 2,000 km), but it increased to about 6,900 km in 1953 and declined thereafter. Harvests during the 1940s and early 1950s were similar to those in the mid-1930s but required about 2.5 times the fishing effort. Average total annual fishing effort in waters 80 m and greater in the early modern fishery was lowest in most management units compared with other periods (Table 2). Fishing effort generally increased in the precollapse fishery in most units and declined during the collapse, concurrent with the collapse of the stocks.

The relative abundance (CPUE) of siscowets in water depths greater than 80 m generally declined during 1929–1961 for all Michigan waters combined (Figure 5c) and in all management units (Figure 7). Statistically significant declines in CPUE occurred from the early modern fishery to the precollapse fishery in all units except MI-2 and MI-4 and in all Michigan waters combined (all $P < 0.001$; Table 2). In all units, CPUEs were the lowest in the collapsed-fishery period.

Discussion

This analysis indicates that siscowets composed a considerable portion of the historical commercial harvest in certain management units (31–62% in MI-2, MI-3, and MI-7) but less so elsewhere ($\leq$10% in MI-1 and MI-8). In a similar analysis for Wisconsin waters of Lake Superior (Swanson et al. 1994), 13% of the historical yield of lake trout during 1929–1941 was siscowets, which is similar to that in management units MI-4, MI-5, and MI-6 in this study. Both analyses suggest that siscowets were probably part of the lake trout harvest in Minnesota and Ontario waters of Lake Superior as well.

Although patterns were mixed across management units, it appears that low to modest fishing effort during the early modern fishery and precollapse fishery was concurrent with declines in siscowet CPUE. Siscowet CPUE was declining (mid-1940s and beyond) before sea lamprey populations were abundant enough (mid-1950s) to exert significant mortality on these populations. Ecosystem modeling suggests that a 10-fold increase from low fishing mortality on siscowet would produce sharp declines in siscowet biomass (Kitchell et al. 2000); this may be consistent with the historical decline reported here, as exploitation was greater then as compared with now. This has implications for any planned increase in the harvest of siscowet. Siscowet lake trout contain very high levels of omega-3 fatty acid (Wang et al. 1990), which has human health benefits. Commercial interest in the use of siscowet as a source for fish oil has increased, and any resulting fishery would have to be monitored and closely managed to prevent overharvest, if conservation is the objective.

The apparent sensitivity of historical populations of siscowet to overfishing is related to their slower

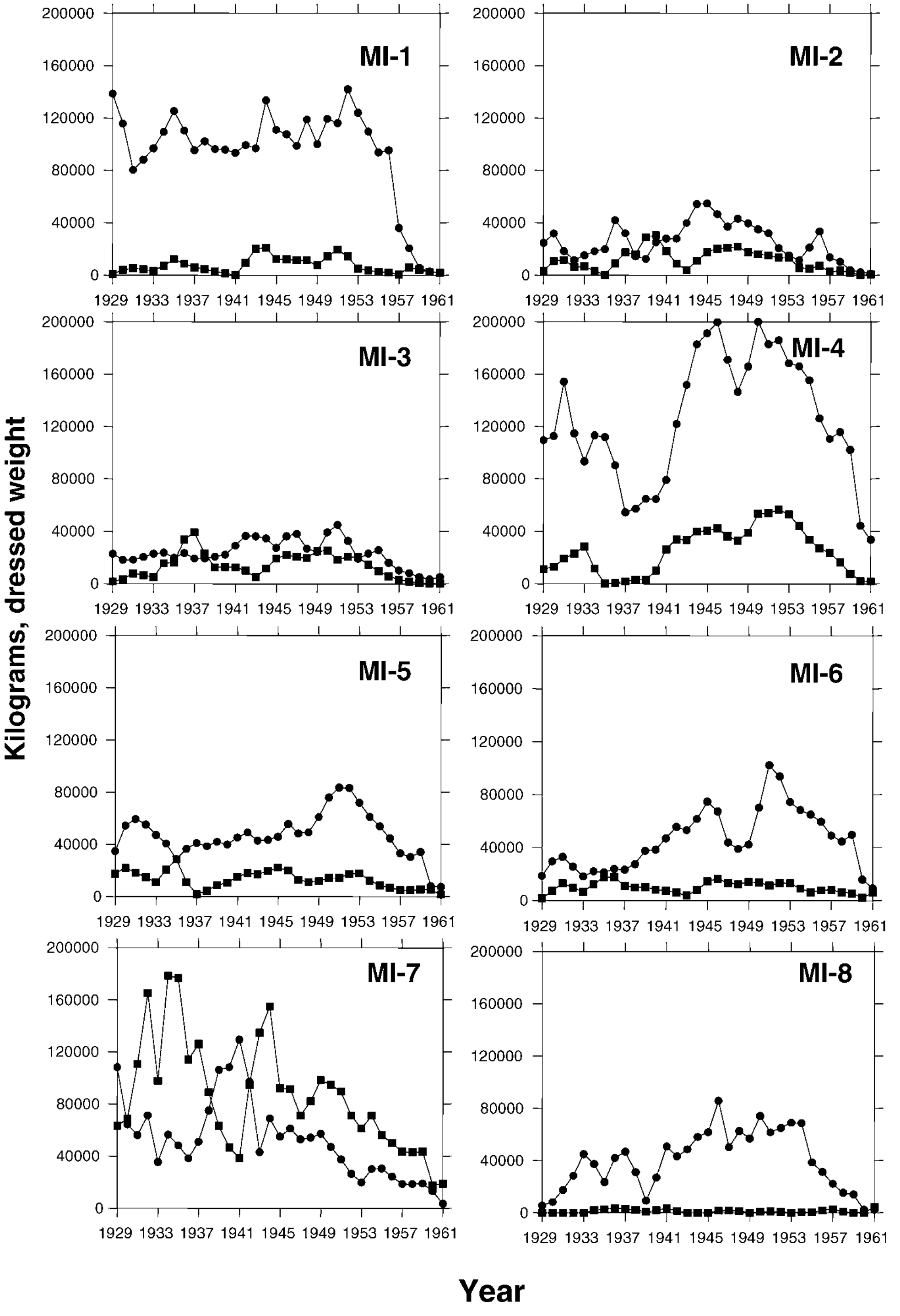

FIGURE 6.—Annual harvests (kg) of lean lake trout (circles) and siscowet (squares) as estimated from the total lake trout harvest reported by commercial gillnetters for eight lake trout management units in Michigan waters of Lake Superior, 1929–1961.

TABLE 2.—Results of analysis of variance of mean catch per unit effort (CPUE [$\log_e$\{catch (kg)/km of net\}]) of siscowets in the commercial fishery in three fishery periods by management unit and all Michigan waters of Lake Superior combined. Within rows, values with the same letter are not significantly different. Values in parentheses are average annual fishing effort (kilometers of gill net). In the early modern and precollapse fisheries, only fishing affected the population, whereas both fishing and sea lamprey predation were acting on populations during the collapsed fishery period.

				CPUE		
Management unit	*F*	df	*P*	Early modern fishery (1929–1939)	Precollapse fishery (1941–1951)	Collapsed fishery (1953–1961)
MI-1	259.3	2, 878	<0.001	4.01 (20) a	4.34 (155) b	2.95 (141) c
MI-2	58.2	2, 515	<0.001	3.81 (113) a	3.86 (109) a	3.00 (61) b
MI-3	120.6	2, 1,177	<0.001	3.89 (62) a	3.54 (314) b	2.69 (234) a
MI-4	764.5	2, 2,041	<0.001	4.01 (41) a	3.97 (473) a	2.73 (860) b
MI-5	726.9	2, 1,245	<0.001	4.60 (147) a	3.98 (264) b	2.44 (524) c
MI-6	99.7	2, 523	<0.001	4.38 (119) a	4.04 (182) b	3.29 (228) c
MI-7	417.3	2, 2,528	<0.001	4.45 (657) a	3.96 (792) b	3.24 (936) c
MI-8	78.8	2, 100	<0.001	4.64 (23) a	4.07 (31) b	2.22 (104) c
All units	2411.4	2, 9,028	<0.001	4.31 (1,981) a	3.93 (2,604) b	2.80 (3,451) c

growth, lower production to biomass ratio (*P*/*B*), later age at maturity, and lower fecundity compared with lean lake trout from Lake Superior. Lean lake trout populations declined during the same historical period (Wilberg et al. 2003) but under higher levels of fishing effort and harvest (Figure 4). Estimates of the Brody growth coefficient (*k*) for siscowet range (0.053–0.080) are less than those for lean lake trout (0.14; Kitchell et al. 2000; Miller and Schram 2000). Adult siscowets were the major component of the harvest; their *P*/*B* ratios were estimated at 0.25, which is 39% lower than that of lean lake trout (0.41; Kitchell et al. 2000). Reported ages at first maturity are age 8 for siscowet, compared with age 5 for lean lake trout (Kitchell et al. 2000), and most siscowets reach maturity at well beyond age 10. Siscowet fecundity (1,025 eggs/kg) is about 28% lower than for lean lake trout (1,424 eggs/kg; Carlander 1970; Peck 1988). Density-dependent declines in growth have occurred for lean lake trout in Michigan waters of Lake Superior (Sitar and He 2006) and density dependence probably affects siscowet similarly (Bronte et al. 2003); hence, the growth rates and fecundity of siscowet may be even lower in recent times as populations recovered. These population characteristics greatly limit sustainable yield and make overfishing of siscowet a real possibility.

Contemporary commercial catch data indicated that Lake Superior siscowet populations have increased greatly since the 1950s (Figure 8; Bronte et al. 2003). Along with the restoration of lean lake trout (Hansen et al. 1995), the recovery of siscowet populations is an important milestone in the return of Lake Superior to a less perturbed, more natural, and perhaps an ancestral state (Bronte et al. 2003). Controls on exploitation after lake trout stocks declined and reductions in sea lampreys certainly enhanced the recovery. However, some controversy has arisen regarding the resurgence of siscowet. These fish are now much more conspicuous to biologists, anglers, and commercial fishers in nearshore areas (Bronte et al. 2003) where lean lake trout, lake whitefish, and Pacific salmon *Oncorhynchus* spp. are normally captured. Because the abundance of both lean lake trout and siscowets is historically high and the two species are closely related both phylogenetically and ecologically and exhibit some bathymetric overlap, the two forms should exhibit increased mixing that might lead to the misperception that siscowets are encroaching on or invading nearshore waters. Some sport fishers complain that siscowet bycatch is becoming a nuisance and interfere with the targeting of other salmonines. Perceptions among user groups are that siscowets are "taking over" the lake and that reductions are required to protect forage for salmonines targeted by the fisheries. This has led to specific concerns over the effect siscowet predation is having on cisco *Coregonus artedi* and rainbow smelt *Osmerus mordax* populations and lean lake trout restoration (Kitchell et al. 2000). However, recent studies have found little dietary overlap and minor levels of trophic competition between siscowets and lean lake trout (Harvey and Kitchell 2000; Harvey et al. 2003; Ray et al. 2007). Ecosystem modeling suggests that a reduction in siscowet biomass would result in a significant increase in bloater *Coregonus hoyi*, kiyi *C. kiyi*, and burbot *Lota lota* (Kitchell et al. 2000), which are at low or declining abundances (Bronte et al. 2003). Rainbow smelt would not be affected because they are a small component of the diet of siscowets. It is unlikely that siscowets have negatively affected lean lake trout populations because both lean and siscowet lake trout recovered simultaneously (Bronte et al. 2003) and wild populations of lean lake trout have

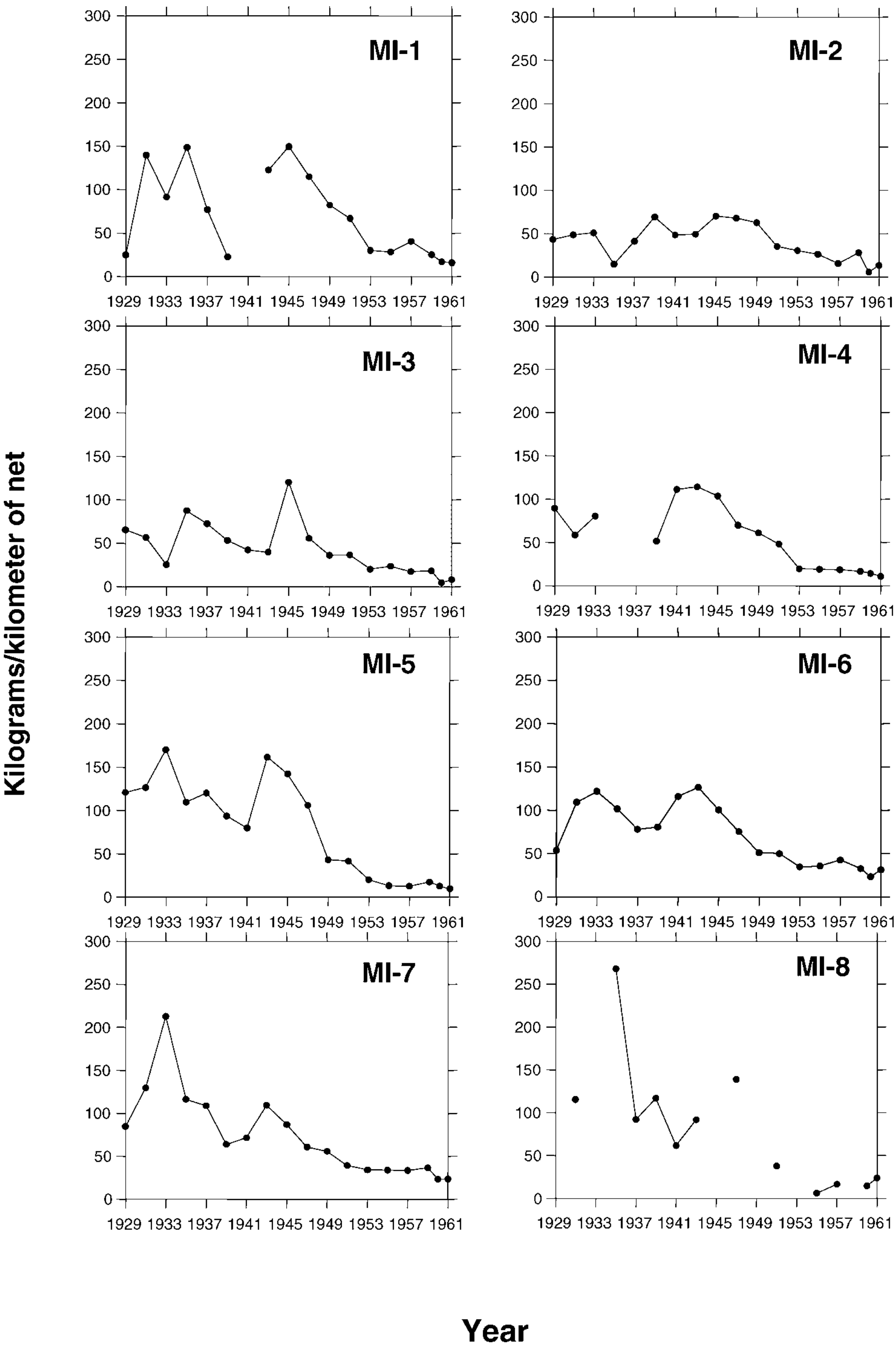

FIGURE 7.—Catch per unit of effort of siscowet in waters 80 m and deeper as estimated for the commercial fishery for lake trout for eight management units in Michigan waters of Lake Superior, 1929–1961.

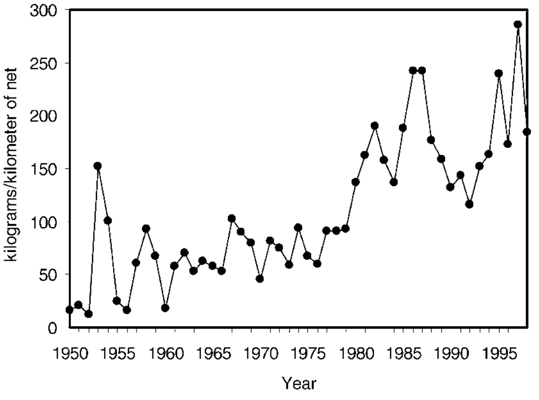

FIGURE 8.—Relative abundance (catch per unit effort) of siscowet lake trout in commercial fisheries in all jurisdictions in Lake Superior, 1950–1998 (from Bronte et al. 2003).

reached or exceeded historical levels in some areas (Wilberg et al. 2003).

Regardless of the biological impact of siscowet on lean lake trout or the ecosystem, the data presented here suggest that siscowet populations may support localized, low levels of targeted commercial fishing. Some stock structure of siscowet populations has been suggested (Bronte and Moore 2007) and could be used to manage any developing fishery. However, we recommend developing models that can quantify population size and estimate and compartmentalize mortality rates. Furthermore, in support of agency lake trout management goals and objectives, modeling simulations should be used to determine safe harvest levels based on a range of suitable biological reference points to ensure sustainability of siscowet populations, fishery exploitation, and the Lake Superior food web.

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