Status of Cisco (*Coregonus artedi*) in Lake Superior during 1970-2006 and Management and Research Considerations

A report of the Lake Superior Technical Committee

Lake Superior Technical Report 1

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ABSTRACT

We consolidated commercial fishery catch and effort information and fishery independent survey data on cisco (*Coregonus artedi*) in Lake Superior from 1970 to 2006 to update the 1970 Lake Herring Subcommittee Report made to the Lake Superior Committee. Cisco populations have staged a recovery in Lake Superior since the 1970s. Since 1973 lakewide yield of cisco and commercial fishing effort on Lake Superior has declined and become more restricted. During 1973-2004, the commercial yield of cisco was largest from the northwest area of Lake Superior in Ontario followed by the north shore of Minnesota, the Apostle Islands in Wisconsin, and the waters within Michigan. In many areas of Lake Superior cisco are no longer commercially fished. Advances in fish ageing techniques, application of hydroacoustic sampling, and compilation of long-term data sets have advanced our understanding of cisco ecology. Management agencies contemplating rehabilitation of cisco populations should recognize that: 1) knowledge of their ecology and population dynamics is increasing; 2) they are long-lived; 3) Great Lakes' populations are likely composed of both shallow- and deep-water spawning varieties; 4) abundant year classes can be produced from small adult stocks; 5) large variation in year-class strength is intrinsic to Great Lakes' populations; 6) despite the longevity and early maturity of cisco, stocks can be over-fished because large year classes are produced only occasionally; 7) regional environmental factors likely play a large role in reproductive success; and 8) rainbow smelt *Osmerus mordax* appears to negatively affect cisco recruitment. We recommend that the Lake Superior Committee adopt a fish community objective that aims to protect cisco stocks with sensible fishery controls to ensure sufficient biomass of adults and two or more year classes of young fish to support both fisheries and predators. We believe that cisco abundance can be increased by protecting them from over-exploitation and keeping rainbow smelt at very low levels of abundance by managing for relatively high predator abundance. Managers should consider establishing a fixed exploitation rate of 10-15% on adult female cisco when setting harvest limits on commercial fishery yields from Lake Superior. Our synthesis has pointed out the inadequacies of many past survey designs at sampling cisco, and directed us to survey designs that include night sampling with hydroacoustic gear and midwater trawls throughout the lake, bottom trawling during the spring to index year-class strength, and sampling a sufficient proportion of the water column to account for vertical distribution of cisco.

Uncoordinated surveys across agencies, studies that isolate single life-stages, and lack of appropriate sampling strategies lead us to a fragmented view of cisco ecology, consequently, there is an overwhelming need to develop an overarching research framework to better understand cisco population dynamics and ecology within the context of managing them in a sustainable fashion.

INTRODUCTION

Cisco, formally known as lake herring, (*Coregonus artedi*) were the primary prey of lean lake trout (*Salvelinus namaycush*) in Lake Superior prior to the invasion of the lake by rainbow smelt (*Osmerus mordax*) and the collapse of lake trout populations (Dryer et al. 1965; Lawrie and Rahrer 1973). Numerous stocks of cisco supported a very large commercial fishery that produced yields of 8.6 million kg from Lake Superior in the mid-1940s (Fig. 1) (Baldwin et al. 1979). Thereafter, commercial fishery yield of cisco began to decline and by 1970 the yield was lower than anytime in the previous 60 years. Cisco were such a vital link in both the human and lake trout food chain that their collapse in Lake Superior in the 1970s altered predator-prey dynamics and changed the structure of commercial fisheries on the lake (Lawrie and Rahrer 1973; Bronte et al. 2003).

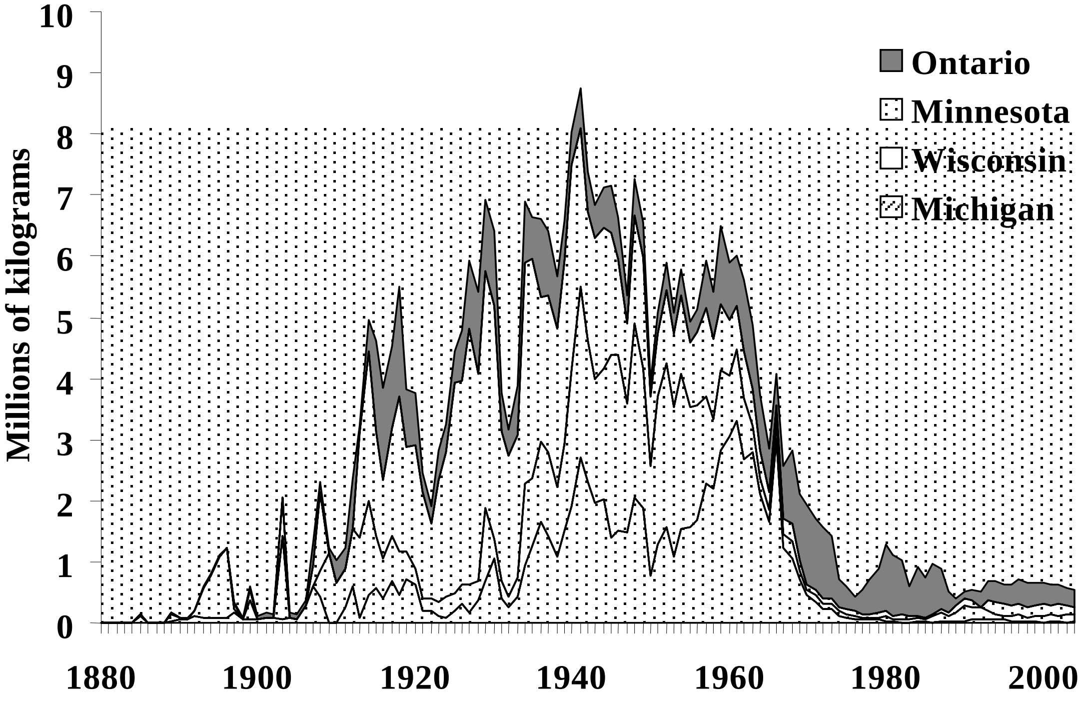

Fig. 1. *Commercial fishery yields of cisco from political jurisdiction of Lake Superior, 1880-2004.*

To address the severe decline in cisco stocks, the Lake Superior Herring Subcommittee was created and charged in 1973 by the Lake Superior Committee to compile and analyze data on cisco stocks from each jurisdiction and to publish a summary of their findings (Wright 1973). The committee's general conclusions were that:

- Heavily exploited stocks of cisco were declining and immediate action must be taken to halt the decline;
- Exploitation by the commercial fisheries was the major factor causing the decline;
- Rainbow smelt, and to a lesser extent bloaters (*Coregonus hoyi*) were contributing to the decline through replacement rather than displacement, and that additional information on the interaction between these species should be collected;
- Stock identification was not adequate and should be pursued; and
- Catch statistics should be reported from smaller areas than statistical districts to document "fishing up" of individual herring stocks.

Most management agencies took immediate steps to protect cisco populations and halt the declines in abundance after the Committee's report. These management actions severely limited commercial fishery effort and harvest (see Historic and Present-Day Management section), but recovery of the population lagged these management actions until abundant year classes were produced in the mid to late 1980s.

Cisco stocks have largely been rehabilitated in Lake Superior but they are likely still below historic levels of abundance (Bronte et al. 2003), although current abundance is probably underestimated because of sampling biases associated with the bottom gear used by Bronte et al. (2003) to estimate abundance (Stockwell et al. 2006, 2007). Several factors have been hypothesized to limit full recovery of cisco including sequential overfishing of discrete stocks (Selgeby 1982), predation and/or competition with rainbow smelt and deepwater chubs (*Coregonus* spp.) (Anderson and Smith 1971a; Swenson 1978; Cox and Kitchell 2004).

Populations of siscowet lake trout appear to have fully recovered in Lake Superior and populations of the lean lake trout are approaching full recovery lakewide (Bronte et al. 2003; Wilberg et al. 2003; Sitar et al. 2007). A consequence of the recovery of these two morphotypes has been a decline in their growth rate and diversification of their diet (Sitar and He 2006; Ray

2004; Ray et al. 2007). In many areas of Lake Superior rainbow smelt continue to be the dominant prey of lake trout and other predatory fish even though smelt abundance has declined from pre-1980 levels and cisco abundance has increased (Conner et al. 1993; Bronte et al. 2003; Ray 2004; Ray et al. 2007). This selection for rainbow smelt is even more striking given estimates of cisco abundance over the last 30 years are likely very conservative (Stockwell et al. 2006). Recent studies of lake trout food habits (Ray et al. 2007) suggest that their increasing abundance is placing a higher predatory demand on the prey fish community of Lake Superior, and this continued predation pressure may shift prey species to one dominated by native coregonines (including cisco). The Lake Superior Technical Committee believes that lake trout populations in Lake Superior will require abundant populations of cisco of all sizes to optimize their growth (Mason et al. 1998) and sustain their recovery because it cannot be accomplished on a diet of an invasive species like rainbow smelt.

Our intent is to update the 1973 subcommittee report and provide a template on which to base management recommendations to fishery agencies on Lake Superior that will promote continued recovery of cisco populations. In addition, we want to provide a thorough understanding of cisco population dynamics in Lake Superior for fishery managers on other Great Lakes where cisco populations remain severely reduced. Biologists and managers from the other Great Lakes are now just realizing the value of restored cisco populations to the stability of prey fish and predator stocks (Fitzsimons and O'Gorman 2006; Mohr and Ebener 2005). Thus this report should provide a valuable reference on cisco dynamics in the Great Lakes.

BIOLOGY OF THE SPECIES

Habitat and distribution

Ciscos have a wide distribution in North America and can be found in the north central and eastern United States and in most of Canada (Scott and Crossman 1998). They occur throughout the Great Lakes with the largest remaining populations found in Lake Superior and Lake Huron (Bronte et al. 2003; Mohr and Ebener 2005). Cisco can be found in many inland lakes in Canada and some river systems while it is limited to a few inland lakes in the northern United States.

Cisco is basically a lake species but it may also occur in large rivers in the Hudson Bay region (Dymond 1933). It is pelagic and usually forms large schools in mid-water with a bathymetric distribution of 18-53 m in Lake Superior (Dryer 1966), but data from Koelz (1929) and more recent surveys in Lake Superior show that cisco are commonly captured at depths up to 100 m and occasionally as deep as 200 m using bottom-set gill nets (Selgeby and Hoff 1996; Gorman and Todd 2005).

Recent application of hydroacoustic technology in combination with midwater trawls indicates cisco are even more broadly distributed across pelagic waters of both nearshore and offshore areas of Lake Superior than bottom trawl or bottom-set gill net surveys suggest. Cisco dominated density estimates using hydroacoustic gear and midwater trawls in the Apostle Islands and in nearshore and offshore waters of the western arm of Lake Superior during 1996 and 1997 (Johnson et al. 2004; Mason et al. 2005). A second hydroacoustic and midwater trawl survey found that cisco occupied the upper 25-35 m of the pelagic zone in deep (>150 m) offshore areas of Lake Superior >100 km from shore during 2003 and 2004 (Hrabik et al. 2006). A third study that compared night hydroacoustic and midwater trawl density estimates with day bottom trawls during the spring found bottom trawl sampling underestimated cisco densities by over an order of magnitude, and that nearshore and offshore biomass densities were equivalent when using the former sampling strategy (Stockwell et al. 2006, 2007).

In the spring and early summer cisco become distributed throughout the water column of Lake Superior as the surface water warms (Fry 1937; Dryer and Beil 1964). Cahn (1927) reported that cisco avoided temperatures above 17°C and Rudstram et al. (1987) reported that neither age 1+ or older cisco were caught in the water column above 10 m where water temperature exceeded 15°C. Ciscos are typically randomly distributed between the surface and about 53 m and adults are not extensive travelers (VanOosten 1929; Smith and VanOosten 1940; Smith 1956; Dryer 1966).

Stockwell et al. (2006) hypothesized that cisco undergo an ontogenic shift in habitat use. Fish of 1-2 years of age are typically demersal during the day and thus susceptible to bottom trawling in nearshore areas. As cisco mature, they adopt a more pelagic existence and are not as susceptible to day bottom trawling. For example, most cisco captured during spring cross-contour bottom trawl surveys in 2004 from the Apostle Islands were ages 1-2 and 75-175 mm long with very few fish >225 mm long (Fig. 2A). In spring 2005, Stockwell et al. (2006) found

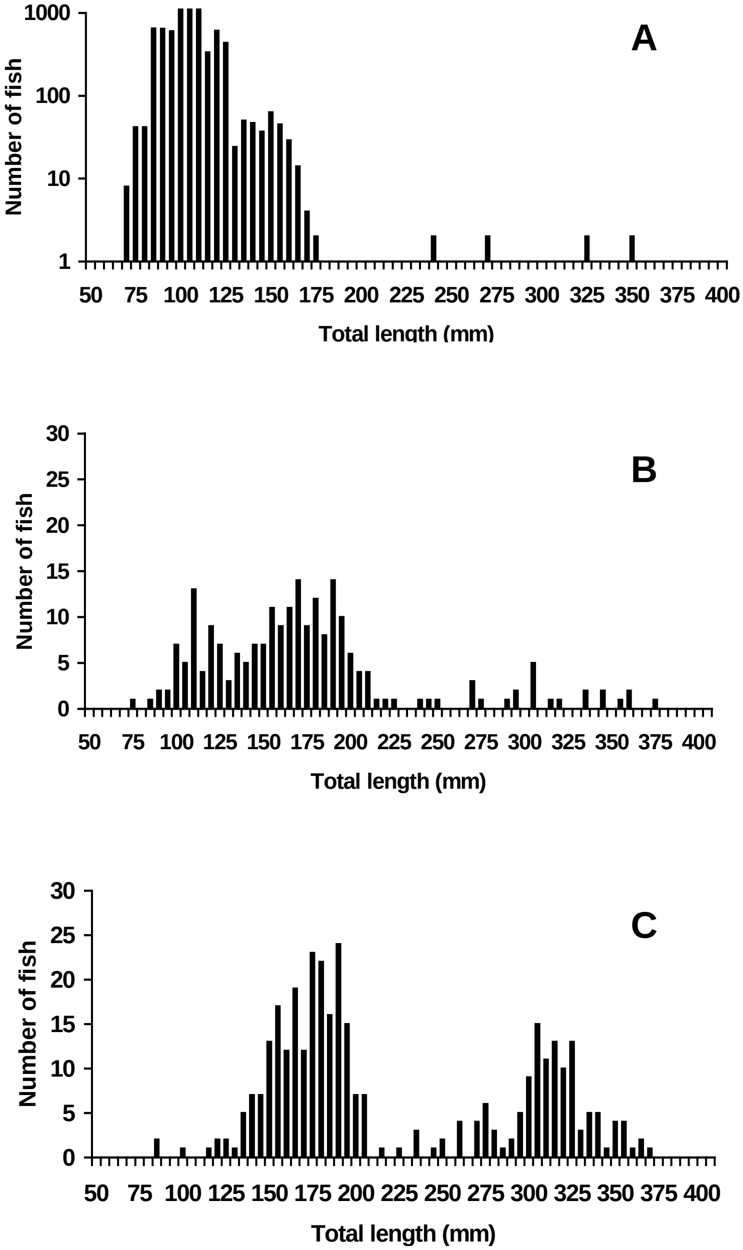

Fig. 2. *Length-frequency distributions of cisco collected during day bottom trawl surveys in spring (A) and summer (B) and midwater trawls (C) during summer in the Apostle Islands region of Lake Superior in 2004. Spring bottom trawl data represents a composite catch from 10 cross-contour trawl sites, summer bottom and midwater trawl data represents composite catch data from on-contour samples from 30, 60 and 120 m depths. Note the scale on A is logarithmic whereas B and C are linear.*

similar length-frequency distributions for day bottom trawls as in 2004, but also found relatively large catches of adult cisco at night using midwater trawls. During summer 2004, cisco up to 200 mm total length (TL) were common in on-contour bottom trawls during the day in the Apostle Islands (Fig. 2B), but fish > 225 mm TL were much more common at night using midwater trawls (Fig. 2C). The decline in catch of cisco < 140 mm TL in night midwater trawls (Fig. 2C) and bottom trawls (data not shown) in summer 2004 compared to day bottom trawls (Fig. 2B) suggests this size-class of cisco may exhibit an onshore (< 30 m bathymetric depth) migration at night (Stockwell et al. 2007). Mason et al. (2005) suggest diel vertical migration may take cisco greater than 100 m during the day, making them not susceptible to spring survey bottom trawls. However, Stockwell et al. (2007) did not capture any cisco in day bottom trawls at any depths greater than 100 m. An alternative explanation is that cisco remain demersal during the day but better evade capture by bottom trawls as they grow, and captures at night using midwater trawls are a result of diel vertical migration (Hrabik et al. 2006a). Efforts to critically test these ideas are hampered by apparent evasion of midwater trawls by schooling fish during daylight hours.

Juvenile cisco (<1 yr old) are likely to use relatively shallow nursery habitat in nearshore areas where temperatures and food resources are conducive to rapid growth, although young-of-the-year (YOY) cisco have been captured in offshore waters in August 2003 during larval sampling by the U.S. Geological Survey-Great Lakes Science Center (USGS-GLSC) and July 2004 during acoustic surveys. The upper lethal temperature for young-of-year cisco is 26^{o}C and 20^{o}C for adults. Lower lethal temperature approaches 0˚C for YOY and adult cisco (Edsall and Colby 1970). McCormick et al. (1971) determined temperatures of 13-18^{o}C were most suitable for sustained production of larval cisco, as indicated by instantaneous rates of growth, mortality, and net biomass gain. They found linear instantaneous growth rate of cisco at water temperatures of 3-16^{o}C. Laboratory studies have demonstrated that age-0 cisco require temperatures of ≥15^{o}C for more than 90 days to attain sufficient size for over-winter survival (Edsall and DeSorcie 2002). Pangle et al. (2005) concluded that mortality due to rapid cooling events do not appear to contribute to the recruitment variability observed for juvenile cisco in Lake Superior based on their laboratory study.

Spawning

In Lake Superior large schools of cisco begin to form in October and spawning occurs during the last two weeks of November to early December (Dryer and Beil 1964; Peck 1975; Goodyear et al. 1981; Yule et al. 2006a,b). The majority of known cisco spawning sites are located in western Lake Superior from the Apostle Islands west to Duluth/Superior and north through Black Bay in Ontario waters (Goodyear et al. 1981). Other spawning sites include areas northeast of Ontonagon, Michigan along the west side of the Keweenaw Peninsula, in lower Keweenaw Bay, near Marquette, and in Whitefish Bay. Goodyear et al. (1981) did not report cisco spawning along the eastern and northeastern portion of Ontario waters of Lake Superior although some spawning stocks probably exist there.

Cisco become sexually mature at a small size but age at first maturity is variable. During the 1950s and 1960s in Lake Superior the youngest mature fish were two years old and all cisco three years old and greater were mature with males maturing earlier than females (Dryer and Beil 1964). Fish ages from Dryer and Beil (1964), however, were determined from scales, and thus may under-represent the adult cisco age-structure (Schreiner and Schram 2000). All female cisco smaller than 250 mm total length (TL) were immature and all > 250 mm TL were mature in the Apostle Islands in 2004 based on a limited number of midwater trawl samples (Yule et al. 2006a). Spawning occurs at 4-5^{o}C and peaks at 3^{o}C (Cahn 1927). Ripe and spent female ciscos were captured in the Apostle Islands on 30 November and 1 December 2004 (Yule et al. 2006a). Spawning can occur in shallow water (Pritchard 1931; Smith 1956) or in much deeper water and even pelagically 9-28 m below the surface in water 64 m deep (Dryer and Beil 1964). Yule et al. (2006a) reported that the highest concentration of adult cisco in the Apostle Islands was located above 20 m over a soft bottom where depths ranged from 15-35 m. In addition, Yule et al. (2006a) reported that males were more benthic-oriented and females more pelagic in the Apostle Islands in 2004.

Egg size ranges from 1.8-2.1 mm in diameter and the larger females usually produce the greater number of eggs (Smith 1956; Dryer and Beil 1964). On average 300 mm TL female cisco from Lake Superior produced fewer eggs (6,000) than a similar size female from Lake Ontario (22,000) or Lake Erie (29,000) (Stone 1938; Scott 1951; Dryer and Beil 1964). Dextrase et al. (1986) reported that fecundity of cisco in Black Bay ranged from 5,050 eggs per female of 250 mm total length to 44,811 eggs per female of 430 mm.

Present-day cisco may be more fecund than populations that existed prior to 1960. Dryer and Beil (1964) reported that female cisco produced 29.7 eggs·g^{-1} of female body weight in Lake Superior. Dextrase et al. (1986) reported relative fecundity of 45.9 eggs.g^{-1} of body weight in 1981 and 39.7 eggs·g^{-1} in 1985 from Black Bay, and Yule et al. (2006a) reported 46.5 eggs·g^{-1} of female body mass in the Apostle Islands in 2004. This apparent change in fecundity may be fostered by changes in population density of cisco. Bowen et al. (1991) found that density-related changes in age at maturation, sex ratio of recruits, growth, and fecundity at very low densities result in cisco spawning populations in Lake Superior that are made up of many older late maturing females and few young males, and egg production is increased by a factor of five.

Eggs are deposited on the bottom without any substrate preference and abandoned by the parents (Smith 1956; Dryer and Beil 1964). Development of the eggs proceeds slowly and hatching occurs early in the spring. Colby and Brooke (1970) reported that it took cisco eggs 92 days to hatch at 5.6^{o}C, 106 days at 5.0^{o}C, and 236 days at 0.5^{o}C.

Early life history

Cisco hatch in late April and early May (Pritchard 1930; John and Hasler 1956; Anderson and Smith 1971a; Oyadomari 2005). Larvae are roughly 10 mm TL at hatch and take 1-2 days to reach swim-up (John and Hasler 1956; Hinrichs and Booke 1975). In testing a series of incubation thermal regimes that covered all of the possibilities reasonable for Lake Superior, John and Hasler (1956) produced no more than a 7-day difference in hatching dates, suggesting that the actual hatching date on Lake Superior should not be highly variable among spawning stocks.

Cisco larvae feed before the yolk sac is absorbed (Kowalchyk 1996; Selgeby et al. 1994) but could survive 20 days of starvation post hatch (John and Hassler 1956). They feed mainly on copepod nauplii and copepodites (Anderson and Smith 1971a; Savino et al. 1994; Selgeby et al. 1994). Feeding may begin from the day of hatch (John and Hasler 1956; Selgeby et al. 1994) to one (Pritchard 1930) or three (Savino and Hudson 1995) weeks after hatch. The yolk sac is completely absorbed at about 25 to 30 days after hatch when larvae are about 13 mm in total length (Oyadomari 2005).

Cisco larvae spend their early stages of development swimming and feeding near the surface (Anderson and Smith 1971a; Selgeby et al. 1978; Hatch and Underhill 1988), and are nearly indistinguishable from other larval coregonids, except lake whitefish (*Coregonus clupeaformis*) (John and Hasler 1956). They are found in significant numbers at the surface in May and June (Anderson and Smith 1971a; Hatch and Underhill 1988; Oyadomari and Auer 2004). Oyadomari and Auer (2004) found that in April and May cisco larvae were generally more abundant and slightly larger inshore near the 10 m contour than further offshore, although observations in other lakes indicate that densities may be even greater in waters less than 2 m (Pritchard 1930; Faber 1970; Clady 1976). Densities may also be greater in areas of riverine influence (Hatch and Underhill 1988; Oyadomari 2005). Oyadomari (2005) determined that inshore larvae were larger because they were older, but they also grew at a faster rate than larvae caught in offshore waters that were < 8 ^{o}C. In addition, a dense patch of young larvae was also encountered from 7 to at least 13 km offshore, suggesting that larvae may disperse to offshore regions before settling along the coast (Oyadomari 2005). Based on the distribution of larvae of different hatch dates, dispersal appears to be driven by the general counterclockwise circulation in Lake Superior (Oyadomari 2005).

By the end of June larvae are rarely encountered inshore because it appears they move into deeper waters (Faber 1970; Clady 1976; Hatch and Underhill 1988; Oyadomari and Auer 2004) when they are 15–20 mm in length (Pritchard 1930; Oyadomari and Auer 2004). These inferences are contrary to expectations that YOY cisco require water temperatures of ≥ 15^{o}C for more than 90 days to attain sufficient size for over-winter survival (Edsall and DeSorcie 2002). An alternative explanation is that once ciscos exceed 15-20 mm TL they no longer recruit to the same gear used to sample them when they first emerge. Thus, the appearance of larval movement to deeper waters might simply reflect gear avoidance. Young-of-year cisco have been caught using midwater trawls with 13-mm stretch measure at the cod-end in July and August of 2003 and 2004, and are caught as yearlings in spring bottom trawl assessments in Lake Superior (Bronte et al. 2003; Hoff and Gorman 2007).

Population structure

Few studies have been able to actually discriminate stocks of cisco in Lake Superior although there is evidence for multiple stocks based on historic growth and year-class composition (Dryer and Beil 1964), temporal and spatial fishing patterns of the commercial fishery (Wright 1973), elemental analysis of otoliths, parasites, and whole-body morphometrics. Selgeby (1982) presented indirect evidence for the existence of discrete spawning stocks of cisco in the Apostle Islands based upon how the commercial fishery sequentially overfished individual stocks. Bronte et al. (1996) were able to provide further evidence to support the existence of multiple stocks based on significant differences in trace elemental profiles in the otoliths of cisco from geographically separated spawning concentrations in Lake Superior. Bronte et al. (1996) found substantial overlap in cisco populations from western Lake Superior. Hoff et al. (1997a) concluded that cisco from Minnesota and Wisconsin waters of western Lake Superior did not mix because of significant differences in abundance of parasites in fish from the two jurisdictions.

Differences in abundance suggest that discrete spawning stocks of cisco are found in the Black and Thunder Bays in northwest Ontario waters of Lake Superior (Fig. 3). Stocks of cisco in Black Bay were severely overfished by the 1980s and this population has yet to recover (Dextrase et al. 1986). On the other hand, a commercial fishery continues to exploit a very abundant population of cisco in adjacent Thunder Bay. If these were not separate stocks of cisco that segregated each spawning season, there should have been a continual degradation of the Thunder Bay population, but this has not occurred. These studies along with anecdotal evidence suggest that discrete stocks of cisco exist in Lake Superior at Black Bay, Thunder Bay, Grand Marais, Two Harbors, Duluth-Superior, Cornucopia, Sand Island, Stockton Island, Eagle Harbor, Keweenaw Bay, Munising, and Whitefish Bay (Fig. 3) (Bronte et al. 1996; Hoff 2004a).

Two forms or ecological variants of cisco were reported from Wisconsin (King and Swanson 1972); an early-spawning reef form found along shallow rocky shoreline areas, and a deepwater form that spawned later at bottom depths of 80 m and deeper. Genetic analysis of the two cisco forms revealed no differences (Wisconsin Dept. of Natural Resources, 141 South 3rd Street, Bayfield, Wisconsin, 54814, unpublished data). A shallow and deepwater spawning form of cisco has also been reported in Michigan waters (Peck 1975).

Allozyme analysis of cisco, kiyi (*C. kiyi*), bloater, and shortjaw cisco (*C. zenithicus*) collected from five sites in Michigan waters of Lake Superior found differences among species and collection sites (Todd 1981). However, the levels of diversity observed were insufficient to determine the number of genetic stocks and the boundaries of the stocks.

Recent genetic analysis has confirmed the presence of multiple genetic stocks of cisco in the upper Great Lakes, including different areas of Lake Superior. Researchers from Michigan State University and the USGS-GLSC have described spatial genetic structuring for several forage fish species including cisco. Cisco (N=565) were analyzed from 13 locations, of which two were outside the Lake Superior basin (Drummond Island in northern Lake Huron, and from Lake Michigan's eastern shore in the vicinity of Charlevoix, MI. The researchers used 6 microsatellite loci and 403 base pairs of mitochondrial DNA (mtDNA) control region sequence to characterize 16 to 20 samples from each location. Even though sampling was conducted during non-spawning times of the year, genetic data revealed that populations of cisco from Lake Superior are not panmictic (i.e., part of a single randomly mating population), but rather are genetically differentiated across the basin (K Scribner, Dept. of Fisheries and Wildlife, Michigan State University, 13 Natural Resources Building, East Lansing, Michigan 48824, personal communications). Significant differences in microsatellite allele frequency were observed among populations within Lake Superior (Fst=0.014, $P<0.01$), between the 2 locales in Lakes Michigan and Huron (Fst=0.044, $P<0.01$), and most notably between basins (Fst=0.069, P,0.01). Inter-population and inter-basin differences were larger for mtDNA. Within Lake Superior, pair-wise estimates of differences in allele and haplotype frequency were most pronounced between samples collected in the extreme eastern and western portions of the basin and between samples from embayments along the north-west portion of the basin.

Using a landscape-genetic approach, researchers used inter-location variation in hydrology, geology, and environmental variables including bathometry, currents, productivity, and spring and fall temperatures to predict inter-location variance in allele frequency. Preliminary analysis revealed that geographic distance, currents, and differences in fall temperature were predictive of inter-location genetic variation.

Lake Superior and Lake Huron represent a fundamental area of genetic discordance for the cisco, likely reflecting long-term separation. For example, samples from Lake Superior, including a location from Whitefish Bay in the far eastern portion of the lake, were clearly differentiated from the Lake Huron site. Data contrast a previous genetic study to delineate spawning stocks of cisco in Lake Superior that was largely unsuccessful (Todd 1981). Future sampling during spawning may yet provide sharper contrasts among possible spawning stocks.

Food habits

Cisco is primarily a plankton feeder but adults also consume a variety of aquatic insects, crustaceans, fish eggs, and small fish (Dryer and Beil 1964; Anderson and Smith 1971b). Larval ciscos require light to feed and may begin to feed the day they hatch (John and Hasler 1956). The crustaceans *Mysis* and *Diporeia* spp., copepods, and immature aquatic insects (mayflies and caddisflies) were important food items of adult cisco in Lake Superior (Dryer and Beil 1964). During spawning cisco will eat their own eggs and eggs of other fish species (Pritchard 1931; Dryer and Beil 1964). Selgeby et al. (1994) reported cisco larvae began feeding one day after hatching in the Apostle Islands and Black Bay areas of Lake Superior in 1974. In addition, 97% of 14-mm TL cisco had food in their stomachs indicating that larvae did not pass through a critical feeding period in 1974 because endogenous feeding overlapped with exogenous feeding. The diet of cisco larvae in the Apostle Islands and Black Bay was made up of ten different zooplankton species and an unknown species of rotifer during May through July of 1974, but the diet was dominated by immature copepods. Rotifers were an important food of larval cisco in Black Bay in 1974 (Selgeby et al. 1994). Small cisco of 9-13 mm TL ate mainly copepod nauplii, but at >14 mm TL cisco larvae switched to eating primarily copepod copepodites (Selgeby et al. 1994).

In the St. Marys River downstream of Lake Superior larval cisco consumed mainly calanoid or cyclopoid copepods and showed a preference for *Diacyclops thomasi* and an avoidance of nauplii (Savino et al. 1994). Larval cisco averaged 11.5 (n = 5), 11.6 (n =41) and 14.6 (n = 34) mm TL on three different dates (J. Savino, U.S. Geological Survey, Great Lakes Science Center, 1451 Green Road, Ann Arbor, Michigan 48105, personal communication) and were thus in the size range examined by Selgeby et al. (1994). The reason for the differences in prey consumption between the St. Marys River and prey consumption described in Selgeby et al. (1994) is not apparent but may be related to food availability in each environment.

Adult ciscos consume mainly zooplankton. Cisco of 250 mm TL and larger from western Lake Superior ate mainly primarily copepods, followed by cladocerans, fish eggs, mysids, and insects (Anderson and Smith 1971b). Link et al. (1995) reported that adult cisco consumed primarily crustacean zooplankton during the winter of 1994 in Chequamegon Bay, Lake Superior and showed no evidence of piscivory. Adult cisco actively selected for *Diaptomus sicilis* and

Limnocalanus macrurus when smaller-sized zooplankton was more abundant (Link et al. 1995). *Diaptomus sicilis* and *Daphnia galeata mendotae,* and ostracods occurred most frequently in the diet of pelagic cisco in the western basin of Lake Superior in August 1996 and July 1997 and both D. *sicilis* and D. *mendotae* were actively selected (Johnson et al. 2004). Hrabik et al. (1998) reported adult cisco in Sparkling Lake, Wisconsin ate zooplankton, aquatic stages of insects, and small fishes, but zooplankton were the most prevalent diet item. One study reported that cisco ate fishes and 84% of adult cisco (N = 31) consumed YOY rainbow smelt during the winters of 1993-1995 in Chequamegon Bay, Lake Superior (Hoff et al. 1997b). Milne et al. (2005) reported that cisco stomachs were more full during the day than at night in Lake Opeongo, Ontario, and they hypothesized that schooling behavior allows cisco to feed more efficiently during the day because they spend less time looking for predators.

HISTORIC AND PRESENT-DAY MANAGEMENT

Many of the jurisdictions charged with cisco management implemented dramatic changes to the fishery in the early 1970s based on the recommendations made by the Lake Herring Subcommittee. These changes and other favorable events to be discussed later allowed cisco stocks to begin a recovery that started in the early 1980s and continues to the present time. Commercial fisheries redeveloped after the recovery, but due to fishery regulation changes yields of cisco were much more limited than the historical fisheries. Two major changes in the contemporary cisco fishery include the entry of tribal fisheries, and the emphasis in most jurisdictions on the late-fall fishery that targets spawning cisco to supply the growing fish roe market.

Management units

The 1973 subcommittee report organized commercial fishery yield and effort information by statistical districts (Smith et al. 1961; Wright 1973). Since then, the technical committee has modified the statistical district boundaries in U.S. waters by reducing the size of some districts and by having the boundaries follow the 10-minute statistical grid lines (see Appendix A). Ontario created special management units when they modernized the fishery in 1984 and implemented individual transferable quota for the commercial fishery. For the purposes of this report we used the current lake trout management units (Hansen 1986) as the spatial scale for reporting commercial fishery yield and effort statistics, results from agency surveys, and biological information (Fig. 3).

Tribal fisheries

Several federal court decisions reaffirmed treaty-reserved fishing rights in Lake Superior and led to the creation of a limited tribal commercial fishery for cisco. Ciscos are legal commercial fish species for all tribal fisheries on Lake Superior, but very few tribal fishermen actively pursue cisco. Thus, regulations governing tribal cisco harvests are minimal for the most part.

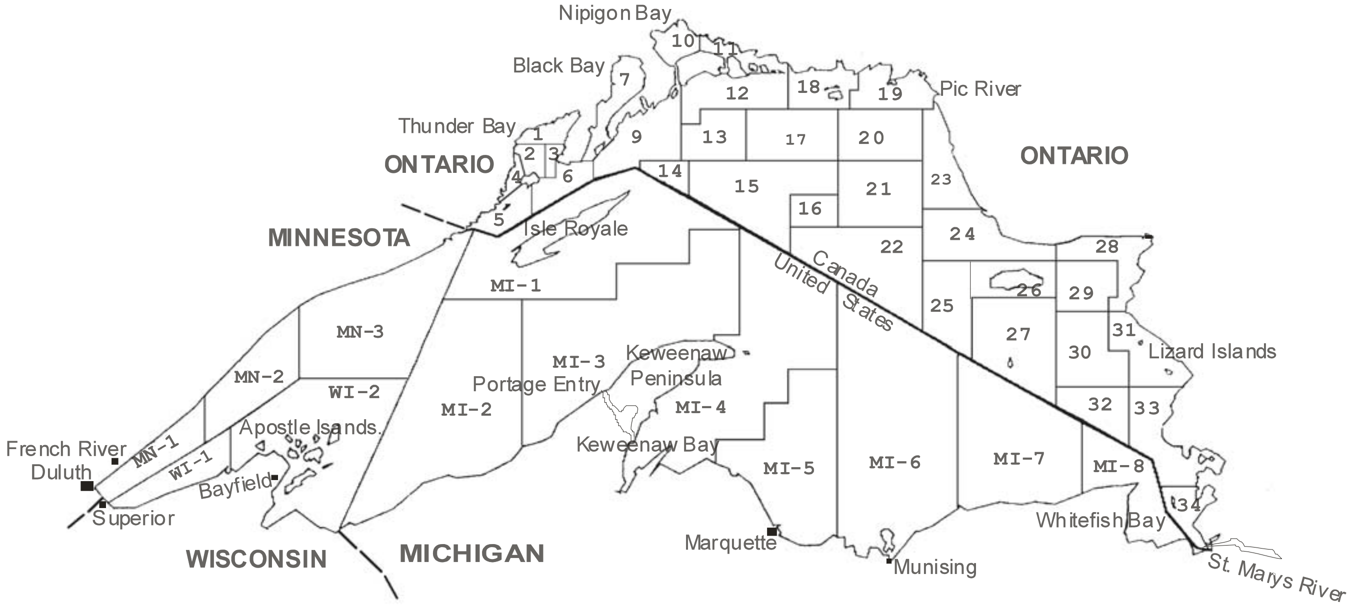

Fig. 3. *Management units in Lake Superior used for compilation of commercial fishery catch and effort statistics and locations referenced in the text.*

Chippewa/Ottawa Resource Authority

The Chippewa/Ottawa Resource Authority (CORA) was formed in 1981 to govern commercial and subsistence fishing activities by members of the tribes that were signatory to the treaty of 1836 in the U.S. (Brown et al. 1999; Chiarappa and Szylvain 2003). Although CORA member tribes reached negotiated settlements with the state of Michigan over treaty fishing rights and resource allocation in 1985 and 2000, regulations specifically designed to protect cisco did not change since the initial regulations were developed in 1981. Commercial fishers are required to complete daily catch reports submitted monthly that include effort, targeted catch, and total catch for all areas fished. CORA commercial fishery regulations to protect cisco are:

- Commercial fishing for cisco is prohibited during the period 12:00 noon November 15 through 12:00 noon December 15, and possession of more than 400 lb round weight of cisco during this time is prohibited.
- Gill net fishing is prohibited in waters west of Grand Island to Marquette, Michigan.
- Only gill nets of 63.5 to 76.2 mm (2.5 to 3.0 inch) stretched mesh are legal gear.
- Commercial fishing is prohibited in the St. Marys River east of a line extending from Point Aux Pins, Ontario to Brush Point, Michigan.

Keweenaw Bay Indian Community

The Keweenaw Bay Indian Community (KBIC) first implemented quota management of cisco in 1990. The quotas were assigned based on historical harvest levels in central Michigan waters and determined once every five years. The quotas were never exceeded. Starting in 2000 and continuing through 2004, cisco quotas were calculated for each lake trout management unit based on USGS-GLSC bottom trawl biomass estimates averaged over several years (MI-2 1981-1999, MI-3 and MI-4 1980-1999, MI-5 1985-1999). Each average density estimate from USGS-GLSC trawl stations within a given management unit was multiplied by the number of hectares of water less than 73 m deep in each management unit to estimate total biomass of cisco. KBIC chose to use a constant exploitation rate policy of 30% of the estimated biomass in each management unit as their method for setting harvest limits. The recommended annual harvest limits for the 2000-2004 period were: 29,000 kg in MI-2, 14,900 kg in MI-3, 173,000 kg in

MI-4, and 4,700 kg in MI-5 (Keweenaw Bay Indian Community 2000). Results from Stockwell et al. (2006) indicate biomass estimates of adult cisco are likely grossly under-estimated by the USGS-GLSC bottom trawl survey and thus quotas for KBIC are likely very conservative. The KBIC annual harvest of cisco from these four management units has not exceeded 18,100 kg (8% of harvest quota) during 1984-2004. Fishermen are required to complete daily catch reports submitted bi-monthly that include effort, targeted catch, and total catch for all areas fished.

Limitations on the amount of small-mesh gill net effort were also established for each management unit. The effort limitation is estimated by dividing the harvest quota for each management unit by the current catch per unit effort (CPUE) of 72 $\text{kg}\cdot 305\ \text{m}^{-1}$ of gill net of cisco. Current effort limits are 122.3 km in MI-2, 62.9 km in MI-3, 730.7 km in MI-4, and 19.9 km in MI-5. The effort quotas are adjusted annually as CPUE changes to ensure that the total maximum harvest of 221,400 kg is not exceeded.

Red Cliff and Bad River Bands of Lake Superior Chippewas

The Red Cliff and Bad River Bands of Lake Superior Chippewas currently manage their commercial fisheries in compliance with the 2005 State-Tribal Lake Superior Agreement in Wisconsin waters of Lake Superior and in compliance with an inter-tribal agreement established in 1990 in Michigan waters of the 1842 ceded territory of Lake Superior. Fishers from both Bands are permitted to fish 60.3 to 76.2 mm (2.375 to 3.0 inch) stretch mesh for cisco throughout the year. In Wisconsin waters there is no daily effort restriction, while there is a daily effort restriction of 3,658 m (12,000 ft) of gill net in Michigan waters. Targeted fishing for cisco is permitted in a small portion of the Devil's Island Refuge, Wisconsin, from 15 November through 15 January. Fishermen are required to complete daily catch reports submitted bi-monthly that include effort, targeted catch, and total catch for all areas fished.

Grand Portage Band

Historically, the Grand Portage area supported a large cisco fishery with catches from both Isle Royale and areas along Minnesota's North Shore. Grand Portage Island served as a shipping hub for cisco and other commercial species that were delivered via boat to Duluth. During this period there was no regulation of the cisco fishery, but catch reports were filed in both Minnesota and Michigan based on where the fish were harvested.

No catch quotas currently exist for Band members fishing cisco within Grand Portage Reservation waters. Regulations for the cisco fishery are specified in the current Grand Portage Reservation Tribal Council Hunting, Fishing and Trapping Codes established in 1997. Gill net mesh size cannot be less than 38.1 mm (1.5 inch) stretch, and gill nets cannot exceed 610 m in length. The total number of gill nets allowed per band member is not regulated. To assist in restoration of commercially harvested fish, no gill nets can be set in Pigeon Bay nor can gill nets be set within 305 m (1,000 ft) of any stream mouth. Over the past several years, no Band member has set commercial gill nets for cisco.

Currently, six non-Band members are allowed to fish cisco within reservation waters and they must follow Minnesota DNR regulations. Most of their cisco catch is shipped to Grand Marais, MN for roe processing, while small quantities of cisco are sold locally.

State and provincial fisheries

Ontario

Historically, most of the commercial cisco yield in Ontario came from Black and Thunder Bays in northwestern Lake Superior, but the total yield from Ontario was consistently much lower than in U.S. waters. In Ontario, total cisco harvest has exceeded 1.4 million kg only three times since 1879 and the Ontario record harvest made up only 16% of the record U.S. harvest of 8.1 million kg in 1941 (Rahrer and Elsey 1972). Early commercial operators used mainly gill nets to harvest cisco, however, during 1967-1975 trawling was the predominant method of capture in Black Bay, Ontario (Dextrase et al. 1986). Since the early 1980s the cisco fishery in Ontario has been exclusively a fall fishery using floating gill nets to target pre-spawning cisco for the roe market. The commercial cisco harvest from Ontario waters made up 52% of the lakewide yield during 2000-2004.

Cisco catch quotas were introduced in Black Bay in 1972, and in all other Ontario waters in 1984. In eastern Ontario from Otterhead to Whitefish Bay cisco catches peaked at 0.4 million kg in the early 1970’s, declined to less than 50,000 kg by the early 1980’s and have fluctuated near the 50,000 kg level for the last two decades. In western Ontario waters of Thunder Bay to Otterhead annual harvests were relatively stable until the mid 1980s when sharply declining catch rates led to a closure of the Black Bay fishery and a 60% reduction in the catch quota in Thunder Bay in 1989. By 1997 Thunder Bay quotas were increased to approximately 50% of pre-1989 levels where they remain today. In 1997 cisco quotas in Black Bay were restored to 20% of pre-1989 levels, however, declining CPUE and a continuing movement of the fishery to the extreme south end of Black Bay led to a 60% reduction in the 1997 catch quota in 2001. The 2004 harvest quotas were 52,000 kg in Black Bay and 173,000 kg in Thunder Bay. Black and Thunder bays and waters adjacent to these two bays currently make up 92% of the commercial cisco harvest from Ontario, but they make up <5% of the surface area in Ontario waters of Lake Superior.

Michigan

Historically, there were many areas where ciscos were harvested in Michigan and the most productive fisheries were found in the central and to a lesser extent the eastern portions of Michigan. The average harvest was 1.9 million kg during 1941-1946, but by 1971 the harvest declined to 0.318 million kg (Wright 1973). Commercial operators extended their season for cisco starting in the 1950s to fill the void left by declining catches of lake trout and whitefish. Keweenaw Bay was historically the most productive and heavily exploited area for cisco in Michigan. In Michigan most cisco fisheries used gill nets with mesh sizes of 63.5 to 76.2 mm (2.5 to 3.0 in) and targeted the late-fall spawning period when stocks were most abundant near shore (Peck and Wright 1972). Sequential exploitation of discrete stocks occurred along the central Michigan shoreline during 1940-1960. Both fishing effort and cisco abundance had declined by the late 1960s.

Michigan curtailed all targeted commercial fishing for cisco in 1974 in an attempt to stop the decline in abundance (Brege and Kevern 1978) by listing them as a protected species and restricting commercial sales to only incidental catches. In 1973, total yield of cisco was 0.227 million kg by 47 active commercial licenses and since then commercial yield and the total number of active commercial licenses has steadily declined. The 1985 Consent Decree between Michigan and CORA (Chiarappa and Szylvain 2003) accelerated the reduction of state-commercial licenses. During 1998-2003 annual commercial yield of cisco declined to less than 1,400 $kg \cdot y^{-1}$ with only eight remaining active commercial licenses. This yield was by-catch in the commercial chub (bloater, kiyi, and shortjaw) fishery. Based on the current status of cisco populations, Michigan has no plan to expand or promote targeted commercial harvest of cisco.

Minnesota

In Minnesota, ciscos have historically been the major species harvested by the commercial fishery. The cisco fishery began in about 1875 and continued to increase in intensity through the 1960s (Wright 1973). Total harvest averaged over 2.7 million kg during 1920-1940. From 1940 to 1970 the yield decreased by about 50% every ten years, and by 1970 the yield had further declined to less than 0.114 million kg (Hassinger and Kuechenmeister 1972). Trends in commercial fishery catch rate were monitored beginning in 1950 and showed a continual decline through 1972 in all waters.

Two fisheries for cisco emerged in Minnesota. Ciscos were captured from skiffs using suspended gill nets fished along the north shore and larger tugs fished the shallow western arm with bottom-set gill nets near Duluth. Mesh sizes fished in both fisheries ranged from 57.1 to 69.9 mm (2.25 to 2.75 in) stretched mesh. Most of the commercial effort for cisco was targeted at spawning fish, however, starting in the early 1960s some operators began fishing cisco during other periods of the year.

To stop the decline of cisco, Minnesota imposed severe restrictions on the commercial fishery. A spawning closure for cisco was implemented in 1973 and ran from 1 November through 31 December. In 1974 the closure was reduced to the month of November only, allowing a small amount of harvest in December. Gill net mesh sizes were restricted to 57.1 to 69.9 mm stretched mesh and all gill nets had to be set at least 400 m from shore. Bottom-set gill nets had to be fished deeper than 73 m (40 fathoms). In 1978, a limited entry program began that restricted the total amount of gear that could be licensed in Minnesota to 36,600 m (120,000 ft) for chub and 30,500 m (100,000 ft) for cisco. The spawning closure was the most effective regulation for reducing harvest and continued through 2005.

In 2006, the cisco harvest policy in Minnesota was changed from an unlimited harvest, with a November spawning season closure, to a management unit-specific total allowable catch (TAC) harvest policy. The TAC is calculated as 10% of the estimated 95% lower confidence limit of cisco spawning stock biomass >305 mm TL. Harvestable biomass is estimated by averaging the most recent three years of hydroacoustic biomass estimates in Minnesota waters (Schreiner et al. 2006).

Wisconsin

Commercial harvest of cisco in Wisconsin declined dramatically from an average yield of over 2.3 million kg during 1945-1956 to only 0.079 million kg in 1970. Cisco yield declined first in the western arm, which supported the largest historical fishery, followed by declines in and around the Apostle Islands (Wright 1973; Selgeby 1982). The fishery occurred mainly on spawning aggregations in November and December using bottom-set gill nets.

Although restrictive regulations for commercial cisco harvest in Wisconsin were not immediately implemented as in other jurisdictions, a variety of changes were made to protect and allow for the recovery of cisco stocks. Currently, Wisconsin has no quota or effort limits. During the 1990s the fishery changed from mainly bottom-set gill nets to floating gill nets. Commercial operators are required to fish gill nets at least 3.7 m (2 fathoms) below the surface. Typically, floating gill nets are suspended 4-5 m under the surface of the water and are set to capture pre-spawn females for the roe market. The cisco commercial fishing season is open year-round, except for within specific refuges and restricted use areas. There are also a variety of regulations that describe different mesh sizes and heights of gill nets allowed when set at various depths. These regulations are very localized and too numerous to mention in this report. Trawling for cisco is not allowed in Wisconsin. There are no regulation changes being considered at this time.

SOURCES OF DATA

The following information in this report was obtained from nearly every agency with jurisdiction on Lake Superior. Commercial fishery yield and effort statistics compiled by each agency were combined into a GIS database by staff from the Great Lakes Indian Fish and Wildlife Commission. Agency survey data and the biological data for individual cisco caught during these surveys were shared among agencies, and staff from the Wisconsin, Michigan, and Minnesota Dept. of Natural Resources compiled and analyzed the data. Acoustic survey information was gathered by staff from USGS-GLSC, Minnesota Dept. of Natural Resources, University of Minnesota, and summarized by a graduate student at the University of Minnesota – Duluth. Other data in this report were obtained during monitoring of commercial fishery harvests (Table 1).

Table 1. *Sources of cisco data used in this report. Agency acronyms are as follows: GLIFWC = Great Lakes Indian Fish and Wildlife Commission; MiDNR = Michigan Dept. of Natural Resources; KBIC = Keweenaw Bay Indian Community; MnDNR = Minnesota Dept. of Natural Resources; WiDNR = Wisconsin Dept. of Natural Resources; USGS = U.S. Geological Survey Great Lakes Science Center; OMNR = Ontario Ministry of Natural Resources; CORA = Chippewa Ottawa Resource Authority; and RCFD = Red Cliff Fisheries Dept.*

	Fishery catch/effort		Age composition				Survey data	
Agency	comml	recrl	scales	otolith	Maturity	Fecundity	incid.	target
GLIFWC	X		X	X				
MiDNR	X	X	X	X	X		X	
KBIC	X		X				X	
MnDNR	X		X	X			X	X
WiDNR	X	X	X	X			X	X
USGS			X	X		X	X	X
OMNR	X		X	X	X	X		X
CORA	X		X		X		X	
RCFD	X		X				X	

FISHERY YIELD AND EFFORT

Commercial fishery before 1970

The cisco commercial fishery on Lake Superior follows the same pattern of development, growth, and subsequent decline as many fisheries throughout the Great Lakes and the world. The fishery developed and yield increased during the 1800s and 1900s as gear and product transportation technologies advanced (Brown et al. 1999). Harvest peaked during World War II possibly due to an increased demand for Great Lakes fish in the absence of marine fish products.

Historical records from Lake Superior show that the commercial yield of cisco increased from 900 kg in 1884 to a peak of 8.7 million kg in 1941, with yields of more than 2.3 million kg annually during 1923-1968 (Fig. 1). Following this peak, harvest declined to less than 1.4 million kg annually after 1973 and to 0.430 million kg by 1976. Since 1976, the annual yield of cisco from Lake Superior has ranged between 0.408 and 1.3 million kg (Fig. 1).

Large annual yields in excess of 1.6 million kg appear to have occurred sequentially by jurisdiction, first in Minnesota, followed by Ontario, Michigan, and Wisconsin. Afterward, yield peaked and then declined to less than 0.9 million kg in each jurisdiction. Cisco yield declined to

0.9 million kg and remained less than that in 1960 in Minnesota, 1963 in Wisconsin, 1969 in Michigan, and 1981 in Ontario.

In Minnesota, yield of cisco first exceeded 1.6 million kg in 1913. During 1914-1923 the yield ranged between 1.2 and 2.5 million kg annually and during 1924-1941 yield remained above 2.3 million kg annually. After 1940, although high, the Minnesota yield of cisco began to decline, while harvest in Wisconsin and Michigan increased to 2.6 and 1.9 million kg, respectively.

In Ontario waters cisco harvests exceeded 1.6 million kg in 1918, then declined to 0.272 million kg in 1922. Harvest averaged 0.8 million kg annually during 1923-1972. From 1973 to 2003 annual harvests averaged 0.5 million kg. The yield of cisco from Ontario waters never exceeded 1.8 million kg throughout the entire time period (Fig. 1).

Yield of cisco from Michigan waters exceeded 1.6 million kg in 1936 – four years earlier than in Wisconsin. The yield averaged 1.4 million kg during 1937-1939, and remained above 1.8 million kg during 1940-1944. Harvests fluctuated between 0.77 and 2.0 million kg during 1945-1956, and then increased to all time highs of between 3.1 million and 3.3 million kg in 1960, 1961, and 1966. The yield of cisco from Michigan declined to less than 0.45 million kg by 1970.

The commercial cisco yield from Wisconsin waters exceeded 1.6 million kg in 1940 when the yield was 2.2 million kg. Fishery yield remained above 1.8 million kg during 1940-1956 after which time it began to decline. By 1962, the annual commercial yield of cisco from Wisconsin waters fell below 1.0 million kg annually.

Commercial fishery after 1970

Since 1973 lakewide yield of cisco and commercial fishing effort on Lake Superior has declined and become more restricted. In Ontario, the cisco fishery is concentrated in the area from Black Bay to Nipigon Bay and Whitefish Bay, whereas the areas between Nipigon and Whitefish Bay are no longer fished (Fig. 4 and 5). Thunder Bay is the only area in Ontario waters that has retained a substantial commercial fishery for cisco during 1973-2003. In Minnesota, commercial fishery catch and effort data has been available in electronic form by statistical grid only since 1983 and this information illustrates that fishery yield and effort has remained fairly stable and is focused near Grand Marais, Silver Bay, and Two Harbors. Yield of cisco from Wisconsin waters has paralleled changes in fishing effort and is focused in the Apostle Islands. In Michigan, the yield of cisco shifted from offshore waters around the Keweenaw Peninsula, Marquette, and Grand Marais to nearshore waters of Whitefish Bay and Keweenaw Bay to Marquette.

Yield

In 2000, 94% of the commercial harvest of cisco from the Great Lakes came from Lake Superior (Kinnunen 2003). During 1973-2003, the commercial yield of cisco was largest from the northwest area of Lake Superior in Ontario followed by the north shore of Minnesota, the Apostle Islands in Wisconsin, and the waters within Michigan (Fig. 6; Appendix B). In Ontario, harvests were concentrated near Black Bay where a cumulative total of 7.5 million kg of cisco were harvested during 1973-2003. An additional 1.2 million kg of cisco was harvested from adjacent units. In Thunder Bay, 4.7 million kg of cisco were harvested during 1973-2003 with most of this yield coming from the inner portion of the bay.

Large-scale commercial yields of cisco also occurred in Minnesota and Wisconsin waters during 1973-2003, while yields from Michigan and other Ontario waters were minor during this time. From 1973-2003, a cumulative total of 3.4 million kg of cisco were harvested from Minnesota waters and an additional 2.0 million kg were harvested from Wisconsin waters. In Minnesota, total commercial yield of cisco was largest in MN-3 (2.4 million kg), followed by MN-2 (0.56 million kg), and lastly MN-1 (0.413 million kg). The Wisconsin commercial harvest of cisco was concentrated in the Apostle Islands area of WI-2 (1.5 million kg), followed by WI-1 (0.5 million kg). Only moderate yields of 0.05 million kg or less occurred in Whitefish Bay and Keweenaw Bay.

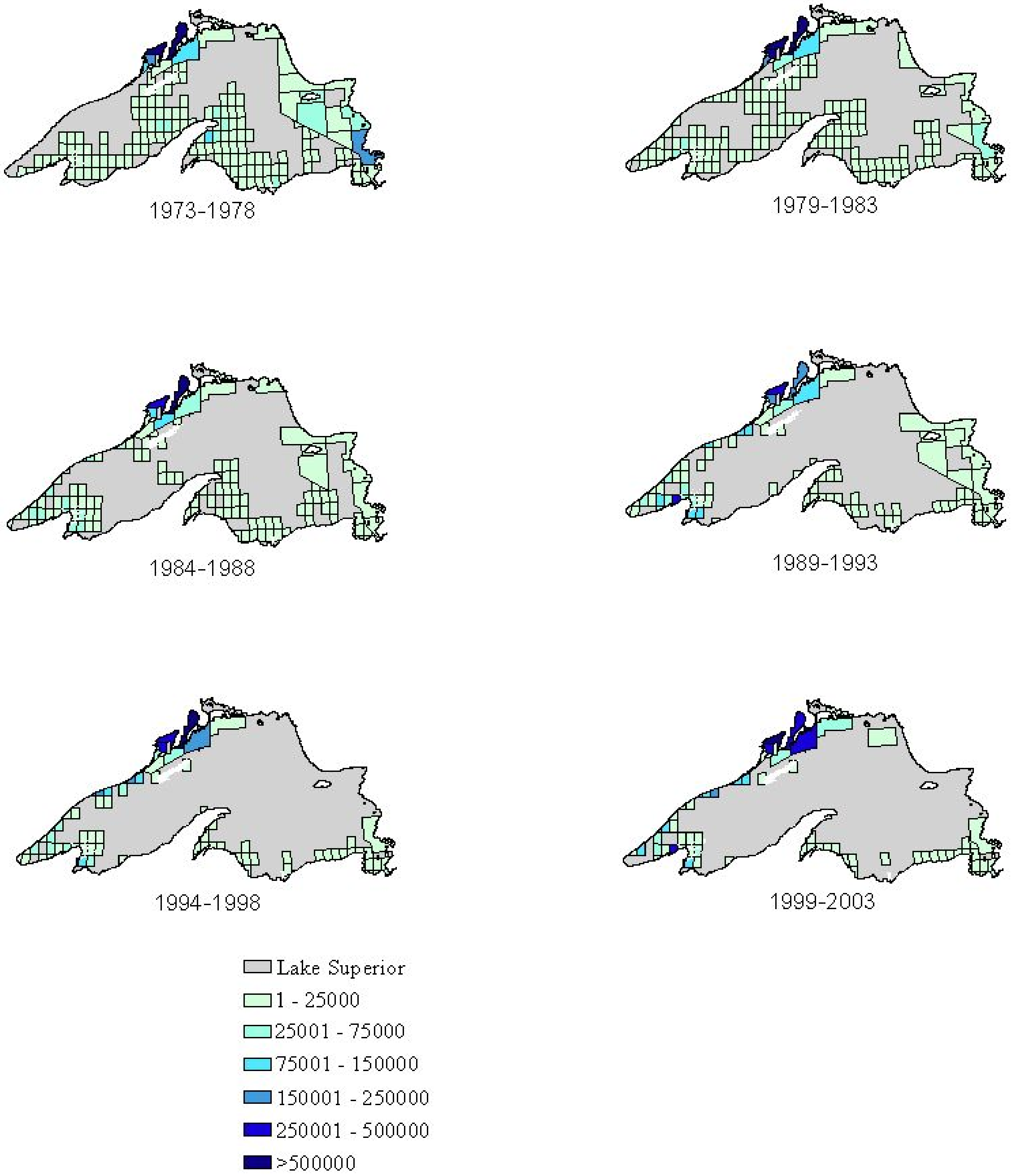
1973-1978
1979-1983
1984-1988
1989-1993
1994-1998
1999-2003

Fig. 4. *Commercial fishery yields (kg) of cisco from 10-minute by 10-minute statistical grids in U.S. waters and management units in Ontario waters of Lake Superior during five-year periods, 1973-2003.*

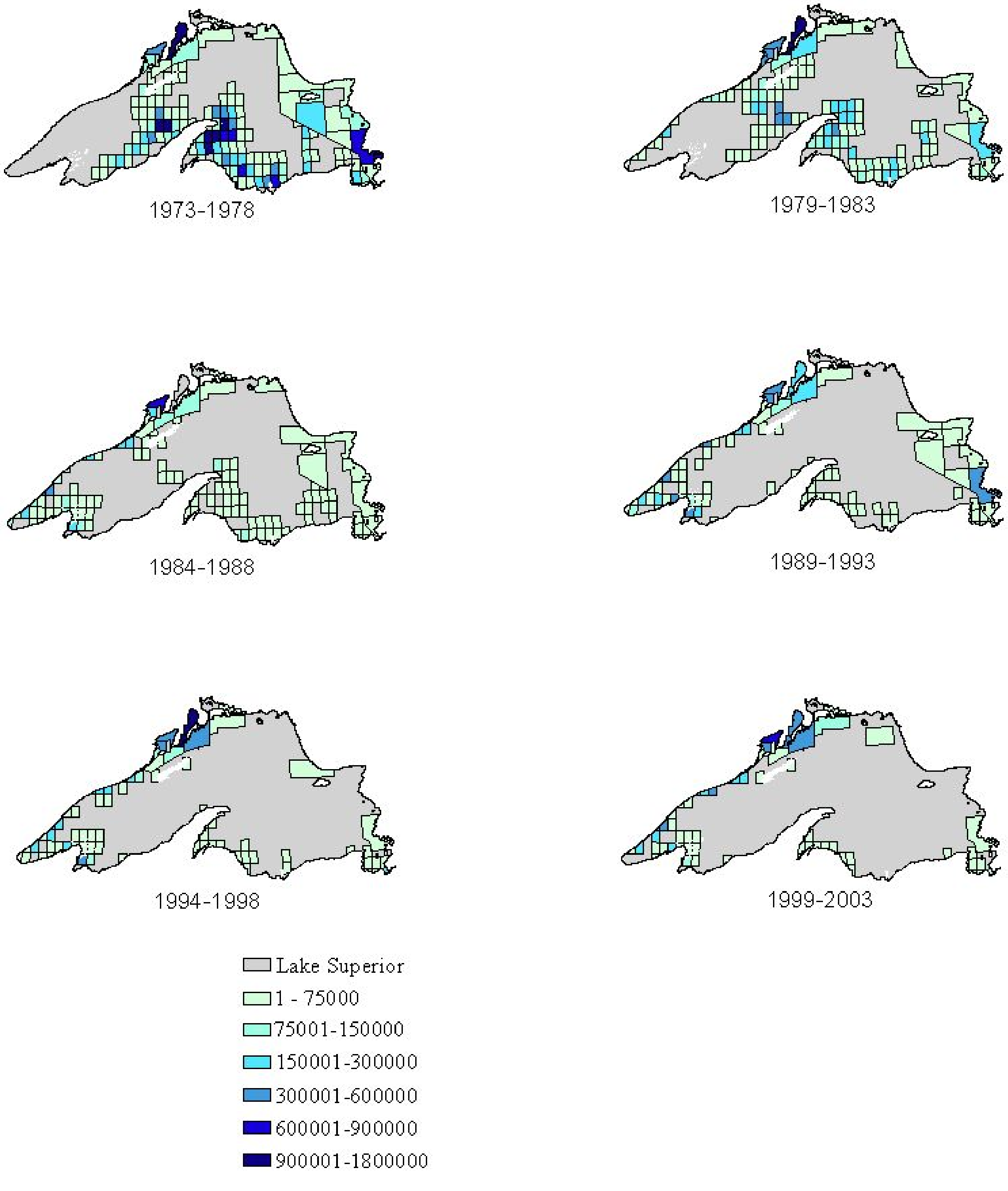

Fig. 5. *Commercial fishery small-mesh gill net effort (m) in 10-minute by 10-minute statistical grids in U.S. waters and management units in Ontario waters of Lake Superior during five-year periods, 1973-2003.*

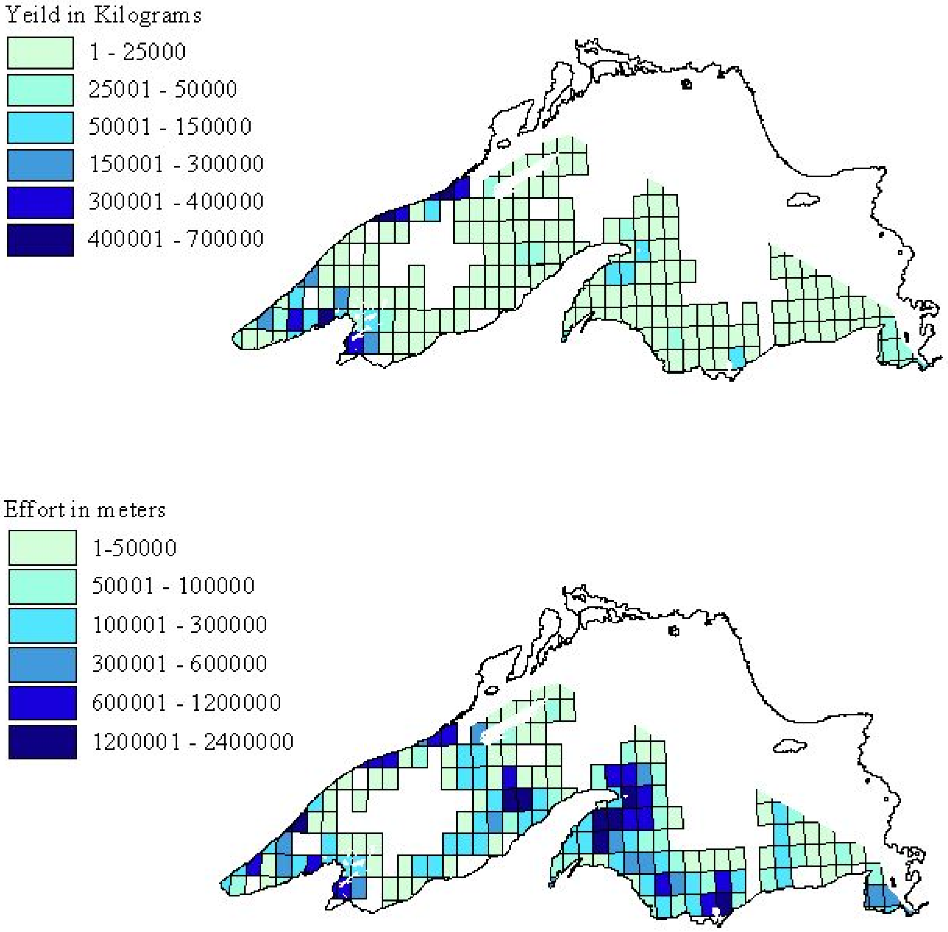

Fig. 6. *Cumulative commercial fishery yields (kg) and gill-net effort (m) in 10-minute statistical grids in U.S. waters of Lake Superior during 1973-2003. In Minnesota catch and effort information for each grid was available only for 1983-2003.*

Fishing effort

During 1973-2003, cumulative small-mesh gill net fishing effort was highest in Michigan waters followed by Minnesota waters and then Black Bay, Ontario (Fig. 6). Trawls were used to harvest cisco in Ontario waters, while small-mesh gill net effort in Michigan waters was largely targeted at chubs in the 1970s. Cumulative gill net fishing effort was 1,200 km in Keweenaw Bay (MI-4), 6,700 km on the north side of the Keweenaw Peninsula (MI-3), 3,350 km near Marquette (MI-5), and 3,400 km near Grand Island (MI-6). Much of this fishing effort in Michigan was targeted at deepwater ciscoes, thus the effort may have been distributed differently if targeted at cisco. In Minnesota, 7,800, 4,900, and 2,400 km of gill net were fished in MN-3, MN-2, and MN-1, respectively. In Black Bay 6,600 km of gill net were fished with an additional 1,600 km being fished in adjacent Ontario units 6 and 9. As previously mentioned, the small mesh gill net effort in Black Bay was paired with a significant trawl fishery. A total of 5,300 km of gill net was fished in Thunder Bay. Small-mesh gill net fishing effort in Wisconsin totaled 2,800 km around the Apostle Islands (WI-2) and 732 km in WI-1 during 1973-2003.

Catch per unit effort

During 1973-2003, average CPUE ranged from 2 kg·305 m^{-1} of gill net in Ontario management unit ON-19 to 504 kg·305 m^{-1} of gill net in Michigan management unit MI-1. In Ontario, the highest CPUE occurred in central Thunder Bay followed by Black Bay. CPUE was also high in other Ontario management units adjacent to Thunder Bay and Black Bay ranging from 236 to 281 kg·305 m^{-1} of gill net. CPUE in all other Ontario management units was less than 162 kg·305 m^{-1} of gill net. In U.S. waters the highest gill net CPUE occurred in MI-8 (310 kg·305 m^{-1}), followed by WI-1 (248 kg·305 m^{-1}), MI-6 (212 kg·305 m^{-1}) and WI-2 (155 kg·305 m^{-1}). CPUE in Minnesota is not directly comparable with that in other jurisdictions because fishing for cisco is prohibited there during November when exceptionally high catches usually occur.

Spatial distribution of yield in U. S. waters

The commercial fishery yield of cisco and the associated small-mesh gill net effort in U.S. waters of Lake Superior during 1973-2003 occurred primarily along the Minnesota shoreline, in the Apostle Islands, along the Keweenaw Peninsula, at Munising, and in Whitefish Bay (Fig. 6). Cumulative yield was greatest (>0.3 million kg) in five grids along the Minnesota shoreline and two grids in the Apostle Islands. Small-mesh gill net effort was greatest (>1,200 km) within one grid along the Minnesota shoreline, in six grids around the Keweenaw Peninsula (that may have targeted chubs) and in one grid at Munising.

Mean annual small-mesh (<88.9 mm) gill-net effort was calculated for each statistical grid during 1973-2003 in U.S. waters of Lake Superior to quantify the distribution and stability of the small-mesh gill-net fishery for cisco in a similar fashion as Wilberg et al. (2003) did for the historic lake trout fishery in Michigan waters of Lake Superior. The coefficient of variation (CV) in gill net effort was estimated for each grid and plotted for each statistical grid to show distribution and stability of the fishery through time.

Mean annual fishing effort during 1973-2003 was highest in five grids along the Minnesota shoreline and exceeded 30 km annually (Fig. 7). In Wisconsin, fishing effort along the south end of Madeline Island averaged 39.2 km annually, while fishing effort near Bark Point and Superior, Wisconsin, averaged 29.3 km and 23.0 km, respectively, each year. In Michigan, fishing effort averaged between 20 km and 30 km annually in seven offshore grids around the Keweenaw Peninsula.

The variation in gill net effort was proportional to fishing effort in Minnesota, Wisconsin, five off-shore grids east of the Keweenaw Peninsula, and in one grid outside Whitefish Bay (Fig. 7). The CV was highest in offshore grids and in nearshore grids along the west side of the Keweenaw Peninsula.

Recreational fisheries

Isolated recreational fisheries for cisco occur on Lake Superior in years when winter conditions favor formation of ice in bays around the lake. A winter fishery occasionally develops in Minnesota waters and normally lasts about one month, but there is no information on harvest levels of cisco in this fishery. An ice fishery for cisco and lake whitefish occurs in Chequamegon Bay, Wisconsin where the annual harvest of cisco has averaged 564 fish during 1997-2004. There is an ice fishery for cisco in lower Keweenaw Bay, Huron Bay, and Munising Bay in central Michigan waters of Lake Superior. In Ontario a recreational fishery targeting lake whitefish and cisco has recently developed in Nipigon Bay east to Schreiber Point, but because it is a new fishery no records of effort or harvest are available. An ice fishery for lake whitefish and cisco also occurs in the sheltered bays between Thunder Bay and Pigeon River in Ontario.

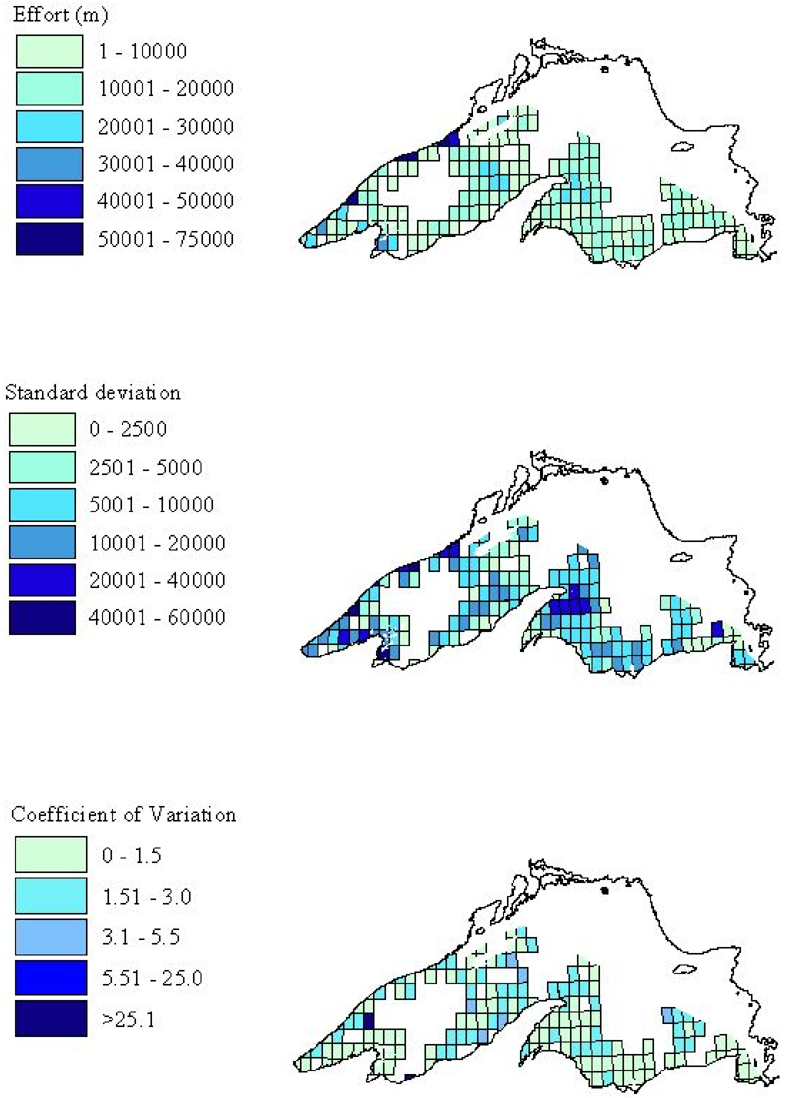

Fig. 7. *Average gill net effort (m) and its coefficient of variation in 10-minute statistical grids in U.S. waters of Lake Superior during 1973-2003***.** *In Minnesota catch and effort information for each grid was available only for 1989-2003.*

ECOLOGICAL INTERACTIONS

Predator Consumption

In addition to their importance as a commercial fish species, ciscos are also an important prey item in Lake Superior. Cisco supported most of the growth and production of lake trout prior to the invasion by rainbow smelt. Small and moderate-sized lake trout are gape-limited so small cisco probably supported the majority of their growth and production. Conversely, growth and production of large lake trout were probably dependent upon large-sized cisco because their foraging efficiency would be greatest when eating large-sized individuals (Mason et al. 1998). Historically, large lake trout were commercially fished with baited hooks in the pelagic zone of Lake Superior during the summer months when they were presumably foraging for pelagic schools of cisco (Landin 1983).

Prior to the 1960s cisco were an important prey of lake trout in Lake Superior, but since then predators have been selecting rainbow smelt over cisco and other coregonines (Ray 2004; Ray et al. 2007). Dryer et al. (1965) reported that coregonines (cisco and chubs) were present in about 50% of all lake trout ≥ 43 cm and made up 67% by volume of all food in lake trout stomachs examined from U.S. waters of Lake Superior during 1950-1953. Rainbow smelt were found in about 25% of all lake trout stomachs during the same time (Fig. 8). In 1963,

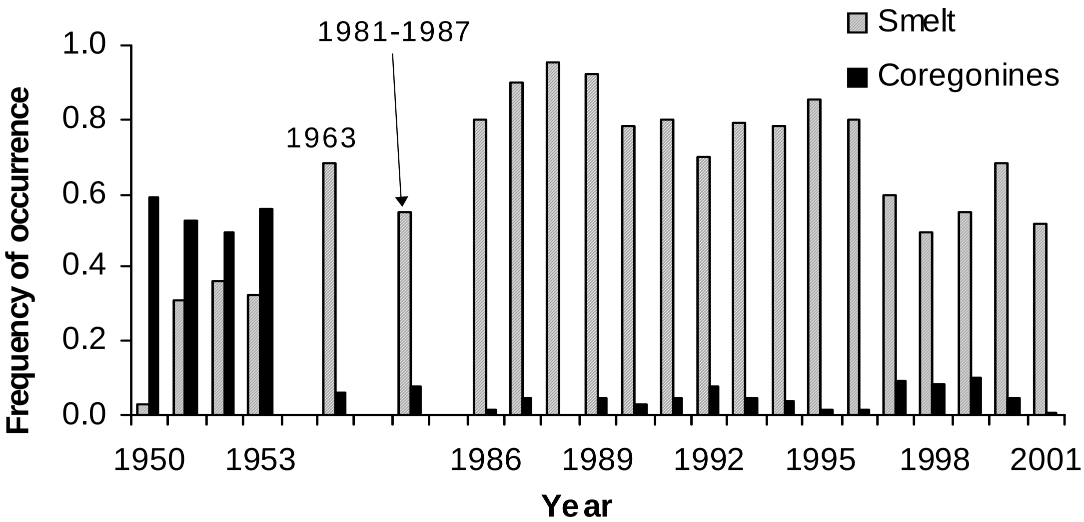

Fig. 8. *Frequency of occurrence of coregonines and rainbow smelt in the diet of lean lake trout from Lake Superior from 1952-2001 based on data assembled from Dryer et al. (1965), Conner et al. (1993), Ray (2004), and Ray et al. (2007).*

rainbow smelt were the primary prey of lake trout and coregonines were found in only 6% of lake trout stomachs, however, the 1963 lake trout samples were collected primarily in the spring when smelt make up a significant part of the lake trout diet (Conner et al. 1993; Ray 2004; Ray et al. 2007). During 1981-1987 coregonines were found in 7% and smelt 56% of inshore lake trout stomachs in the spring even though cisco were twice as abundant as smelt at the time (Conner et al. 1993). During 1986-2001 coregonines were found in 5% and smelt 75% of lake trout stomachs examined in the spring from Lake Superior (Ray 2004; Ray et al. 2007). Ray (2004) and Ray et al. (2007) reported that predators in Lake Superior positively selected rainbow smelt over cisco and other coregonines in the spring, but there was an increasing selection for coregonines by lake trout since 1986. Mason et al. (2005) and Stockwell et al. (2006) suggested cisco were even more abundant than previously thought, so selection for rainbow smelt is even more dramatic than illustrated here. We believe cisco are a larger proportion of the diet of lake trout in Lake Superior than suggested by current diet studies because rainbow smelt are always the dominant prey during spring, but not year-round, and most of our diet data is from the spring.

The composition of cisco in the diet of lake trout and other predators varies seasonally and spatially in Lake Superior. Conner et al. (1993) reported that consumption of coregonids by inshore lake trout and Chinook salmon (*Oncorhynchus tshawytcha*) was highest during the fall and winter and that coregonines made up 15% by weight of the diet of inshore lake trout from Wisconsin and Minnesota during 1981-1987. The proportion by weight of coregonines in the diet was 19% for Chinook salmon, 2% for coho salmon (*Oncorhynchus kisutch*), 20% for siscowets (*Salvelinus namaycush siscowet*), 9% for brown trout (*Salmo trutta*), and 1% for Atlantic salmon (*Salmo salar*) in Lake Superior during 1981-1987 (Conner et al. 1993). Coregonines made up 64% by weight of the diet of all sizes of burbot from the Apostle Islands region of Lake Superior during 1996-2001, but coregonines dominated the diet of large (>40 cm TL) burbot in all months (Schram et al. 2006). Negus (1995) used a bioenergetics model to estimate that salmonine predators in Minnesota waters of Lake Superior consumed 401 metric tons of coregonines in 1989 and that lean lake trout accounted for the largest proportion of that consumption, although consumption by siscowets was not addressed. Ebener (1995) also used a bioenergetics model to estimate that more coregonines were consumed than any other prey in western U.S. waters of Lake Superior, and that annual consumption of coregonines totaled

10,600 metric tons during 1984-1994. Siscowets accounted for 79% of the total coregonine consumption, followed by lean lake trout (15%) and Chinook salmon (5%) (Ebener 1995). Negus et al. (2007) estimated that predator fish consumed about 39% and 44% of the available coregonines in the western arm of Lake Superior in 2000 and 2004, respectively, according to bioenergetics simulations, and lean lake trout were the primary consumers of coregonines.

Intra-specific interactions

A mechanism that could reduce density-dependence among cisco is thermal and spatial separation by size and age. Habitat segregation by temperature could be an effective means of reducing potential competition for food and/or predation between different life stages of fishes (Brandt et al. 1980; Crowder et al. 1981). Because cisco larvae occupy a different thermal zone near the water surface (Oyadomari 2005), they may effectively isolate themselves from other size classes and thus effectively minimize intra-specific competition. Juvenile ciscos seek warmer water temperatures than adults (Pritchard 1931; Fry 1937; Anderson and Smith 1971a; Selgeby et al. 1978; Hatch and Underhill 1988). Juvenile coregonines of other species also occupy warmer waters than the adults (Reckahn 1970; Valtonen 1970; Viljanen 1983; Hamrin 1986). Food habits were also different among juvenile and adult coregonines (Reckahn 1970; Viljanen 1983) probably because of their different thermal preferences. Within pelagic systems or regions with uniform bottom type, temperature may provide the structure to a seemingly homogeneous habitat and thus a template for habitat partitioning among species and size-categories within species to segregate along temperature gradients (Brandt et al. 1980).

Inter-specific interactions

There appears to be some influence of other fish species on the dynamics of cisco in Lake Superior, but the specific pathways for these interactions are unclear. For example, Stone and Cohen (1990) used multivariate time series analysis of commercial fishery CPUE to analyze inter-and intra-specific interactions of lake trout, lake whitefish, cisco, chubs, walleye (S*ander vitreus*), and yellow perch (*Perca fluvescens*) in Lake Superior during the pre-lampricide period (1948-1958) and the post-lampricide period (1963-1973). They found that the number of inter-specific interactions increased for cisco during the post-lampricide period. They reported that during the pre-lampricide period high lake trout abundance led to low abundance of cisco with lags of one, two, and three years possibly reflecting the predator-prey relationship between lake trout and cisco. During the post-lampricide period the interactions between lake trout and cisco was not as apparent probably because rainbow smelt replaced cisco as the predominant food of lake trout. In their analysis Stone and Cohen (1990) reported that cisco exhibited the least number of inter-specific interactions among the six species analyzed during the pre-lampricide period, but that inter-specific interactions with cisco increased during the post-lampricide period. They attributed this last change to a seasonal change in the commercial fishery.

The role of various non-indigenous species in the collapse of cisco in Lake Superior and other lakes has been an ongoing debate for decades. Anderson and Smith (1971a) estimated that rainbow smelt consumed 17% of the larval cisco produced in Nipigon Bay, Lake Superior but cisco recruitment in Nipigon Bay remained good. Selgeby et al. (1978) found that larval cisco were regularly consumed by adult rainbow smelt in Black Bay, Lake Superior, but they concluded that consumption was not sufficient to affect cisco recruitment. Selgeby et al. (1978) did note that the mean length of cisco larvae eaten by rainbow smelt was less than that of the larval cisco population as a whole. Larval cisco could be vulnerable to rainbow smelt predation for longer periods of time in areas of sub-optimal growth (Kinnunen 1997; Pangle et al. 2004). Swenson (1978) concluded that rainbow smelt predation on larval cisco contributed to the decline of cisco in western Lake Superior. Crowder (1980) hypothesized that predation by rainbow smelt and alewife (*Alosa pseudoharengus*) was the primary cause of the collapse of various Great Lakes fishes including cisco. Evans and Loftus (1987) concluded that introductions of rainbow smelt into inland lakes in Ontario had significant effects on indigenous species abundance and fish community structure. More recently, Johnson et al. (2004) found that both rainbow smelt and cisco actively selected for large zooplankton but that diet overlap was low in the pelagic waters of the western basin of Lake Superior in 1996 and 1997. *Mysis* was important in the diet of rainbow smelt, and smelt selected larger zooplankton than cisco and larger individuals within a taxa (Johnson et al. 2004). Based on the work of Johnson et al. (2004) it appears that substantial resource partitioning is occurring between rainbow smelt and cisco in western Lake Superior, so there is no competition between the two species.

The effects of rainbow smelt on cisco in small inland lakes may be greater than in the Great Lakes. Loftus and Hulsman (1986) reported that cisco larvae made up 24% of the diet of rainbow smelt in Twelve Mile Lake, a small inland lake located east of Georgian Bay, Lake

Huron. They also concluded that predation by adult rainbow smelt on larval cisco can be intense in these small lakes because there may be no segregation between coregonid larvae and adult rainbow smelt in early spring, but smelt predation on coregonines may be less intense in the Great Lakes because of the large area where larvae can avoid predation. Latta (1995) concluded that in four inland lakes in Michigan predation and/or competition from rainbow smelt and alewife caused the extirpation of cisco. Krueger and Hrabik (2005) reported that as rainbow smelt populations declined in three Wisconsin lakes due to walleye predation cisco populations increased.

Overlap in bathymetric or thermal habitats between cisco and other species may increase the potential for inter-specific competition. Hrabik et al. (1998) reported that predation on cisco larvae by rainbow smelt caused the extirpation of cisco in Sparkling Lake, Wisconsin because young cisco and adult rainbow smelt occupied very similar thermal habitats. Ciscos occupy nearly all depths and thermal habitats in Lake Superior during the year (Selgeby and Hoff 1996). Cisco were most commonly caught at bottom depths of 15-65 m and 5-25 m in spring and summer, respectively, in Lake Superior during 1958-1975 and other species commonly caught at these depths included lake whitefish, rainbow smelt, and lake trout (Selgeby and Hoff 1996). These observations were based on bottom trawls and bottom-set gill nets.

There has also been mixed conclusions as to interspecific effects of non-indigenous and indigenous fish species on cisco. Selgeby et al. (1994) found no competitive interactions between larval smelt and larval cisco in the Apostle Islands and Black Bay in 1974. Their conclusions were based on diets of both species and estimates of zooplankton composition and density. Henderson and Fry (1987) concluded that there was no evidence that abundance of cisco and other indigenous species were affected significantly by interspecific effects, particularly from alewife or rainbow smelt in South Bay, Lake Huron. Conversely, Davis and Todd (1998) concluded that diet similarities of lake whitefish and cisco could make them competitors for food in the Great Lakes. Davis and Todd reasoned that lake whitefish probably had the advantage because they are initially larger than cisco that would allow them to eat larger food items. In Sparkling Lake, Wisconsin rainbow smelt and cisco used similar thermally defined areas, but this did not reduce feeding success of the cisco. Instead, it increased predation on young cisco by rainbow smelt (Hrabik et al. 1998). In Lake Simcoe, Ontario cisco abundance did increase when lake whitefish density was low, but after lake trout abundance increased due to stocking, cisco, rainbow smelt, and yellow perch abundance declined due to predation and lake whitefish recruitment increased at a low level (Evans and Waring 1987). Hoff (2004b) reported that cisco recruitment in the Apostle Islands showed no negative effects from rainbow smelt abundance, biomass, or recruitment. In comparison, Cox and Kitchell (2004) concluded that a strong rainbow smelt predation effect on cisco was primarily responsible for the lack of compensatory cisco recruitment in Lake Superior after lake trout populations declined in the 1960s based on their ecosystem simulation of the Lake Superior fish community during 1929-1998. Cox and Kitchell (2004) also concluded that there was a strong predation effect of lake trout on rainbow smelt which in turn exerted a positive influence on cisco recruitment. Selgeby (1998) documented predation of cisco eggs by ruffe (*Gymnocephalus cernuus*) in December of 1993 and 1994 off the Duluth/Superior Harbor and he pointed out that predation by ruffe on eggs of cisco might be a substantial new sources of over-winter mortality. We don't believe that ruffe predation on cisco eggs is currently significant on a lakewide basis.

There is evidence that sea lamprey predation may be a source of mortality in cisco and increased cisco populations may benefit sea lamprey in Lake Superior. During 2002-2003 19% of 438 parasitic-phase sea lampreys collected from Lake Superior by sport and commercial fisheries were attached to cisco. Weight of 96% of the sea lampreys ranged from 2 to 16 g, but several lampreys weighed from 180 to 322 g. These large sea lampreys certainly would have killed the host cisco, but the smaller sea lampreys may not. The majority of the small lamprey had recently metamorphosed and they were collected from the Black and Thunder Bay areas of Lake Superior during November and December while cisco were aggregating for spawning. Young et al. (1996) found a significant positive correlation between parasitic-phase sea lamprey abundance and bloater biomass, and lake trout and Chinook salmon stocking rates, and concluded that the increase in sea lamprey abundance in northern Lake Huron could be attributed to improved survival of recently metamorphosed sea lamprey resulting from greater prey availability. Substantial increases in cisco abundance in Lake Superior may counteract sea lamprey control efforts if the conclusion by Young et al. (1996) is correct.

ABUNDANCE

Bottom trawl surveys

Year-class strength of cisco was highly erratic over the 27-year assessment record, with the strongest year-classes appearing in 1984, 1988-1990, 1998, and most recently in 2003 (Fig. 9). Prior to the appearance of the 1984 year-class, indices of cisco biomass in Lake Superior were very low (Hoff 2004b). The recruitment of strong year-classes over the 1978-2004 period resulted in substantial increases in population biomass, especially following the 1984 and 1988-1990 year-classes.

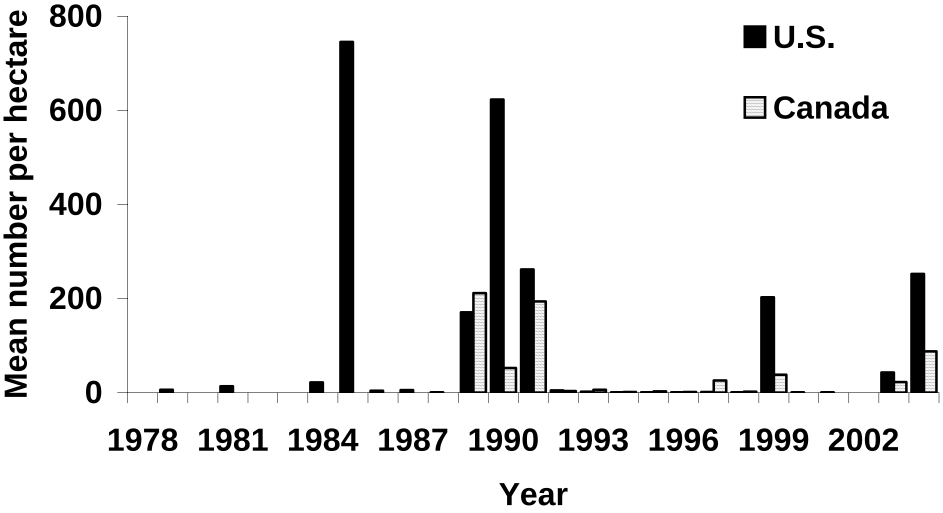

Fig. 9. *Relative abundance of age-1 cisco captured during lakewide spring bottom trawl surveys in Lake Superior during 1978-2004. Data from Ontario only covers 1989-2003.*

Indices of biomass density of cisco in Lake Superior were obtained from bottom trawl sampling conducted annually in May and June during 1978-2004 by USGS-GLSC. Cisco biomass was expressed as the arithmetic mean weight of the catch in the area swept by the trawl ($kg \cdot ha^{-1}$). Year-class strength is expressed as the arithmetic mean abundance of yearling fishes in the area swept by the trawl ($number \cdot ha^{-1}$).

Cisco biomass in U.S. waters of Lake Superior was very low during 1978-1984 averaging <0.6 $kg \cdot ha^{-1}$, but increased during 1985-1986 to > 6.5 $kg \cdot ha^{-1}$ as the result of recruitment of a large, 1984 year-class (Fig. 9 and 10). Biomass peaked in 1990, exceeding 14 $kg \cdot ha^{-1}$, then declined steadily after 1994 to 0.7 $kg \cdot ha^{-1}$ during 1996-1998. Biomass recovered partially to 3.8

kg·ha^{-1} in 1999 following recruitment of a strong 1998 year-class, and declined until 2004, when the strong 2003 year-class increased biomass to 2.4 kg·ha^{-1}. In Ontario waters, trends in annual cisco biomass (1989-2004) were similar but lower compared to that in U.S. waters. Mean biomass in Ontario waters during 1998-2000 was 46% lower than that measured during the previous nine years.

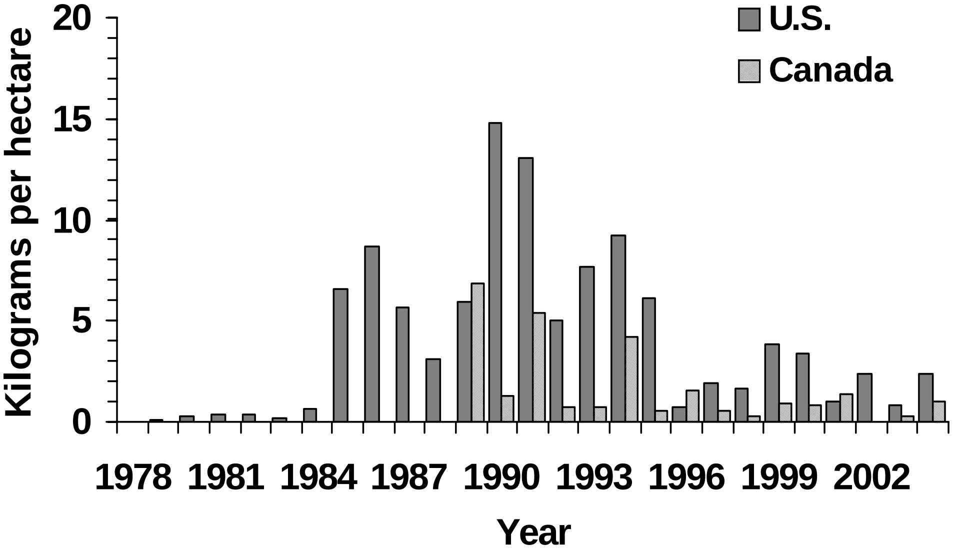

Fig. 10. *Index of lake-wide cisco biomass in Lake Superior derived from annual spring bottom trawl surveys conducted by the U.S. Geological Survey – Great Lake Science Center during 1978-2004. Data from Ontario only covers 1989-2003.*

Dynamics of cisco biomass varied across jurisdictions (Fig. 11). In Wisconsin waters where biomass was consistently higher cisco mean biomass increased as much as 20-fold between 1978-1984 and 1985-1995. The lowest biomass measured in Wisconsin waters since 1985 was observed in 1996, and then biomass increased more than five-fold from 1998 to 2000 as a result of recruitment of the strong 1998 year-class. In Michigan waters, cisco recovery followed the Wisconsin pattern through the mid-1990s, but afterwards biomass declined quickly and has remained <1 kg·ha^{-1}. Unlike in Wisconsin waters, a strong 1998 year class did not appear in Michigan waters to offset declining biomass. In Minnesota waters, biomass estimates from bottom trawls have been much lower than in any other jurisdiction, but the lake-wide pattern of increased biomass and subsequent declines following strong year-classes was observed. Patterns in cisco biomass were similar in western (Thunder Bay to Otterhead Point) and eastern (Otterhead Point to Whitefish Bay) Ontario waters up through 1996. Thereafter, cisco biomass in eastern Ontario remained at low levels until a noticeable increase in 2004 due to recruitment of the strong 2003 year-class.

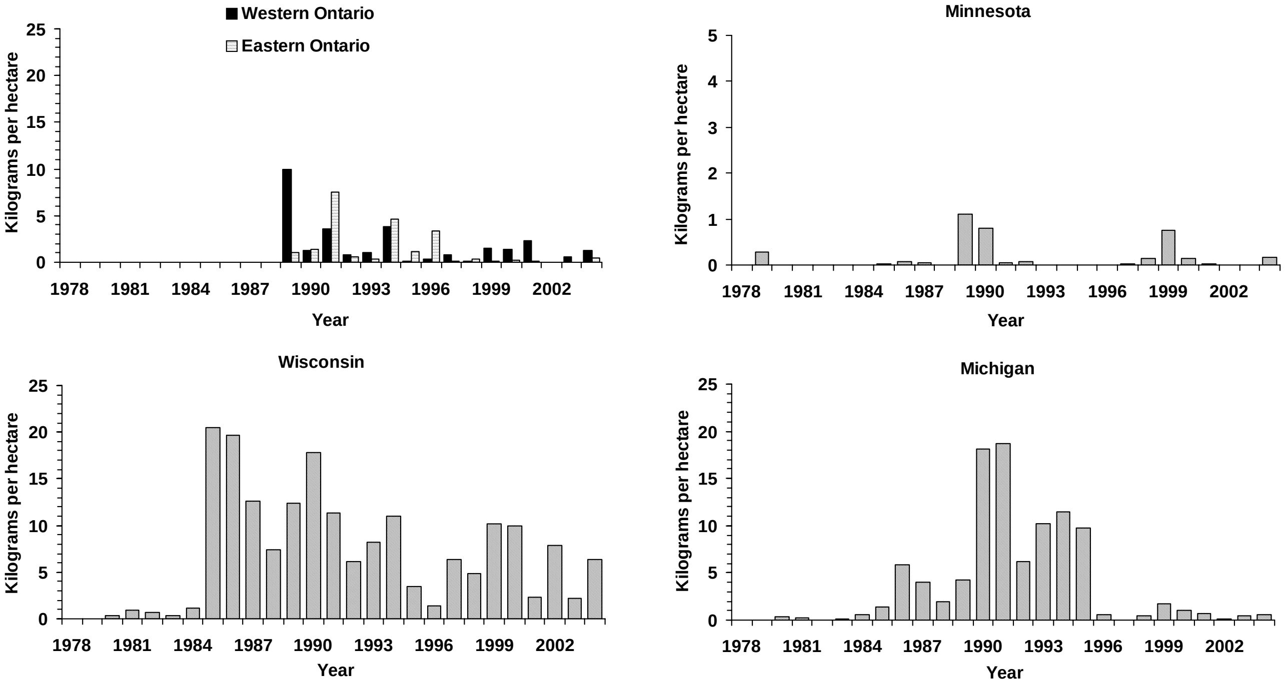

Fig. 11. *Index of cisco biomass by political jurisdiction in Lake Superior derived from annual spring bottom trawl surveys conducted by the U.S. Geological Survey, Lake Superior Biological Station, 1978-2004.*

Gill net surveys

Relative abundance indices for cisco were estimated using agency survey CPUE to assess temporal trends within management units. Overall, there have been few surveys that specifically target cisco. Generally, most agencies collect cisco as by-catch in summer lake trout gill net surveys. Although these surveys use graded-mesh bottom-set gill nets at fixed sampling stations, these gill nets generally catch cisco during the summer months. Minnesota, Ontario, and Wisconsin fishery agencies conduct fall cisco surveys using bottom-set and suspended gill nets, however, the spatial and temporal coverage is very limited. We caution the reader about making comparisons of CPUE between jurisdictions because of the variation in survey gears deployed by each agency (Table 2), however, comparing the temporal trends across jurisdictions may be informative. Misidentification of small chubs and cisco may pose a problem in catch statistics from these surveys, and all other gill-net and trawl surveys, though it is uncertain how this would be resolved for past data.

Table 2. *Basic features of summer lake trout surveys and fall cisco surveys conducted by fisheries agencies on Lake Superior. Summer surveys use bottom-set gill nets and fall surveys use suspended and bottom-set gill nets. Agency acronyms are as described in Table 1.*

Survey	Agency	Year survey began	Set Type	Mesh sizes (in)
Summer	KBIC	1995	Bottom	2.0, 2.5, 3.0
	MiDNR	1985	Bottom	2.0, 2.25, 2.5, 2.75, 3.0, 3.5
	MnDNR	1970	Bottom	1.5, 1.75, 2.0, 2.25, 2.5 (some years 0.75, 1.0, 1.25)
	WiDNR	1970	Bottom	1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0
Fall	MnDNR	1996	Suspended	1.0, 1.5, 2.0, 2.5, 3.0
	OMNR	1997	Suspended	1.5, 2.0, 2.5
	WiDNR	1980	Bottom	1.5, 2.0, 2.5, 3.0

The most spatially and temporally comprehensive dataset on cisco relative abundance comes from summer lake trout surveys. With the exception of MI-1 (Isle Royale) and MI-8 (Michigan waters of Whitefish Bay), these surveys have been conducted in all management units in U.S. waters since the mid-1980s and back to 1970 in Wisconsin and Minnesota (Table 2). No summer surveys were conducted in Ontario waters. The average depth fished during summer surveys was 46 m in Michigan (range: 15-105 m), 45 m in Minnesota (range: 36-57 m), and 34 m in Wisconsin (range: 18-61 m).

Fall spawning cisco surveys have been limited in spatial and temporal coverage. In Minnesota, fall sampling was limited to MN-1 beginning in 1996. In Wisconsin, fall cisco surveys were only conducted in WI-2 with one gill net-gang set per year at a single sampling station starting in 1980. In Ontario, fall surveys were conducted only in western waters around

Thunder and Black Bays and near St. Ignace Island at the head of Nipigon Bay (ON-1, ON-2, ON-3, ON-6, ON-7, ON-9, ON-12) starting in 1997. The average depth of fall cisco survey bottom-set gill nets in Wisconsin was 44 m (range: 37-51 m). In Minnesota, gill nets were suspended at depths of 7.6 m over bottom depths ranging from 38 to 57 m. Essentially all of the Ontario fall survey nets were suspended gill nets fished on average 2.7 m over bottom depths ranging from 10 to 58 m.

Summer gill net surveys

Trends in overall cisco abundance correspond to large fluctuations in cohort strength. This pattern is apparent when reviewing the catch data by individual mesh sizes. The overall trends in cisco abundance in the summer lake trout surveys were similar across jurisdictions as abundance peaked in the early to mid 1990s then declined (Fig. 12). In the summer surveys in Minnesota waters, geometric mean CPUE (GMCPUE) of cisco peaked during the early 1990s with the highest abundance in MN-1 and MN-3. By 1993, cisco abundance declined to low levels in all management units in Minnesota. In Wisconsin, cisco abundance was low during the 1970s and steadily increased until it peaked during the early 1990s. Thereafter, cisco abundance progressively declined. In western Michigan waters, cisco relative abundance peaked in 1996 and subsequently declined to mid-1980 levels (Fig. 12). In Michigan waters east of Keweenaw Bay, GMCPUE of cisco was lower and trends were not as steep than in the west side. In eastern Michigan waters, cisco GMCPUE increased from the mid-1980s and declined after 1999.

Fall gill net surveys

Interpretation of trends in spawning cisco abundance from the fall surveys is difficult because of how little sampling has been done. In MN-1, high fall cisco abundance was observed in 1998 and 2002 (Fig. 13). Corresponding to the trend observed in the summer survey in WI-2, fall cisco abundance increased between 1980 and the mid-1990s. In ON-1 and ON-2 in Thunder Bay, there was a general decline in abundance of spawning cisco between 1997 and 2003, with the exception of high abundance observed in 2000. A similar trend was observed in ON-7 of inner Black Bay. In ON-12, spawning cisco relative abundance has been declining since 1999.

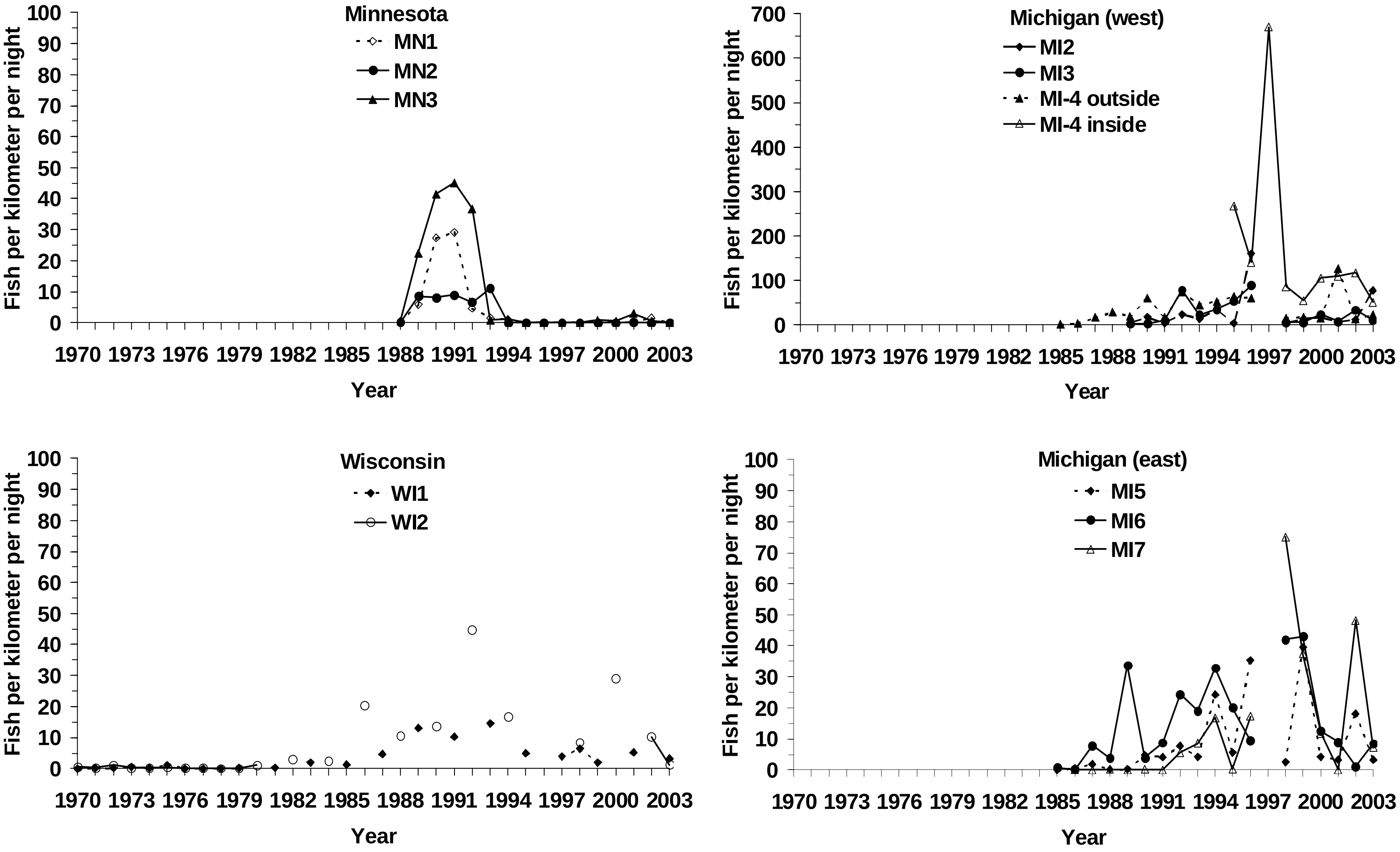

Fig. 12. *Geometric mean catch per unit effort (fish per km per night) of cisco caught during summer bottom-set gill net surveys in U.S. waters of Lake Superior, 1970-2003.*

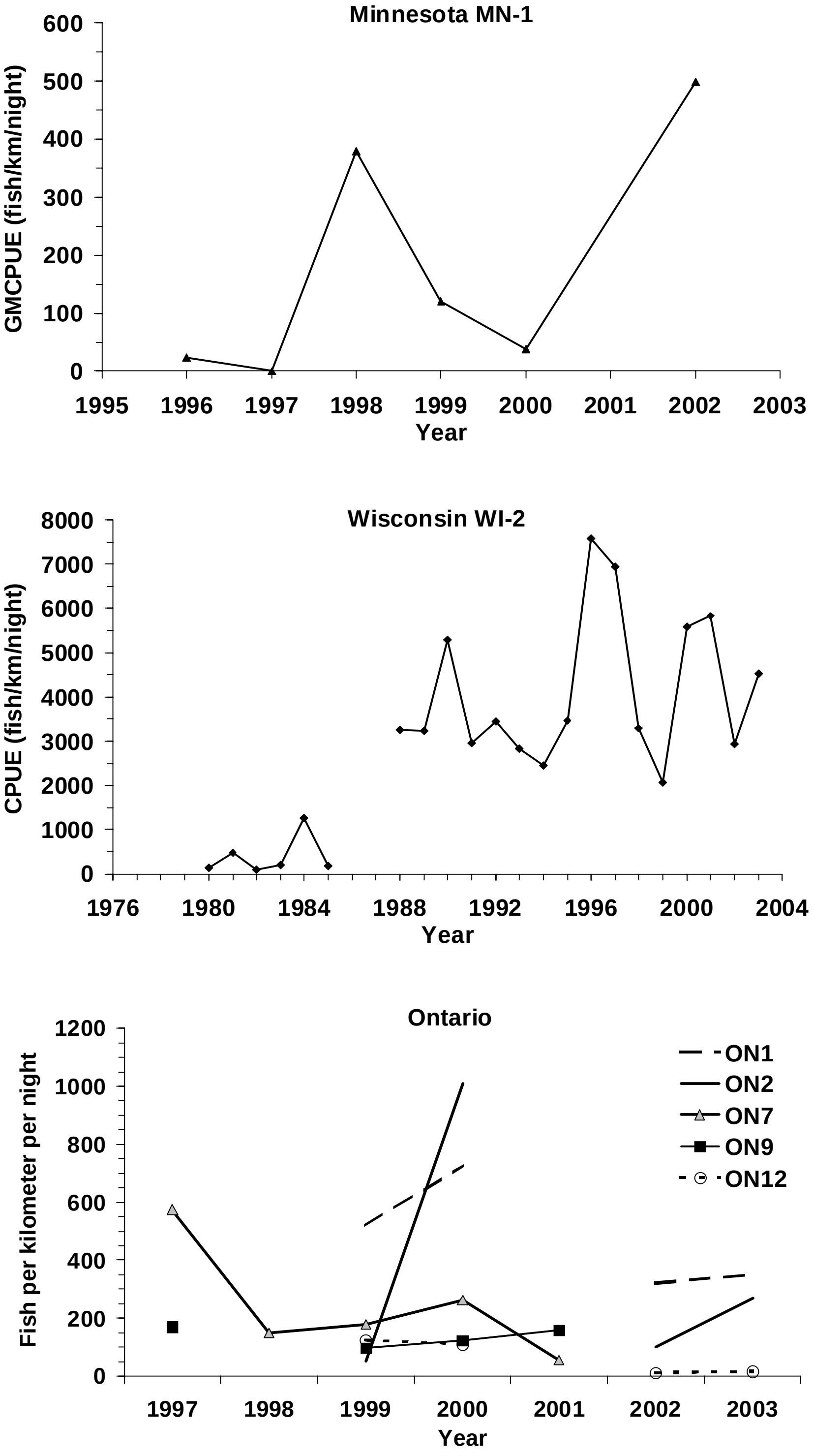

Fig. 13. *Geometric mean catch per unit effort (fish per km per night) of adult spawning cisco caught during fall surveys conducted in Minnesota, Wisconsin, and western Ontario management unit of Lake Superior during 1976-2004. Survey data in Ontario were based on multi-mesh suspended gill nets attached to commercial fishery gill-net gangs.*

Acoustic and midwater trawl surveys

Four hydroacoustic and midwater trawl surveys were conducted on Lake Superior to assess pelagic forage fish abundance since 1996. The first survey was conducted in the nearshore and offshore areas of the western arm of Lake Superior from Duluth-Superior north to Grand Marais, Minnesota and east through the Apostle Islands in July and August 1996 and 1997 (Johnson et al. 2004; Mason et al. 2005). A second survey was conducted during 2003 and 2004 to assess pelagic forage fish biomass between Grand Portage, Minnesota and Sault Ste. Marie, Ontario as part of a larger lakewide effort to be finished in 2006 (Fig. 14). During these two surveys 120-kHz (1996-1997, 2003) and 70-kHz (2004) split beam acoustic systems were used to estimate pelagic fish target strength, density, and biomass. Sampling effort during the lakewide survey was conducted in four depth strata; 0-100 m, 100-200 m, 200-300 m and >300 m in maximum depth. A total of 1,500 km of acoustic transects were made in 2003 and 2004 as part of the lakewide survey. In all surveys transect locations, acoustic information and trawl locations were georeferenced using a differential GPS. Calibrations of the echosounder were performed using a tungsten carbide reference sphere (Foote et al. 1987; Foote 1990).

Midwater trawls were conducted in conjunction with the hydroacoustic surveys at depths of fish aggregations observed with the acoustic system. Fish data from those tows were used for species identification and to refine target strength relationships by incorporating additional species length and weight data. Using the hydroacoustic information along with the species composition from the trawls, estimates of density and biomass for cisco, rainbow smelt, and deepwater ciscoes were achieved.

The area of lake represented by each transect was used to calculate the total number of fish in the region of Lake Superior sampled in 2003 and 2004. For this, a polygon was drawn around each transect and the polygon area in hectares was calculated. Fish density (number·ha-1) was estimated for each polygon by multiplying acoustic density by the number of hectares in that polygon to calculate the total number of fish within each broadly defined area.

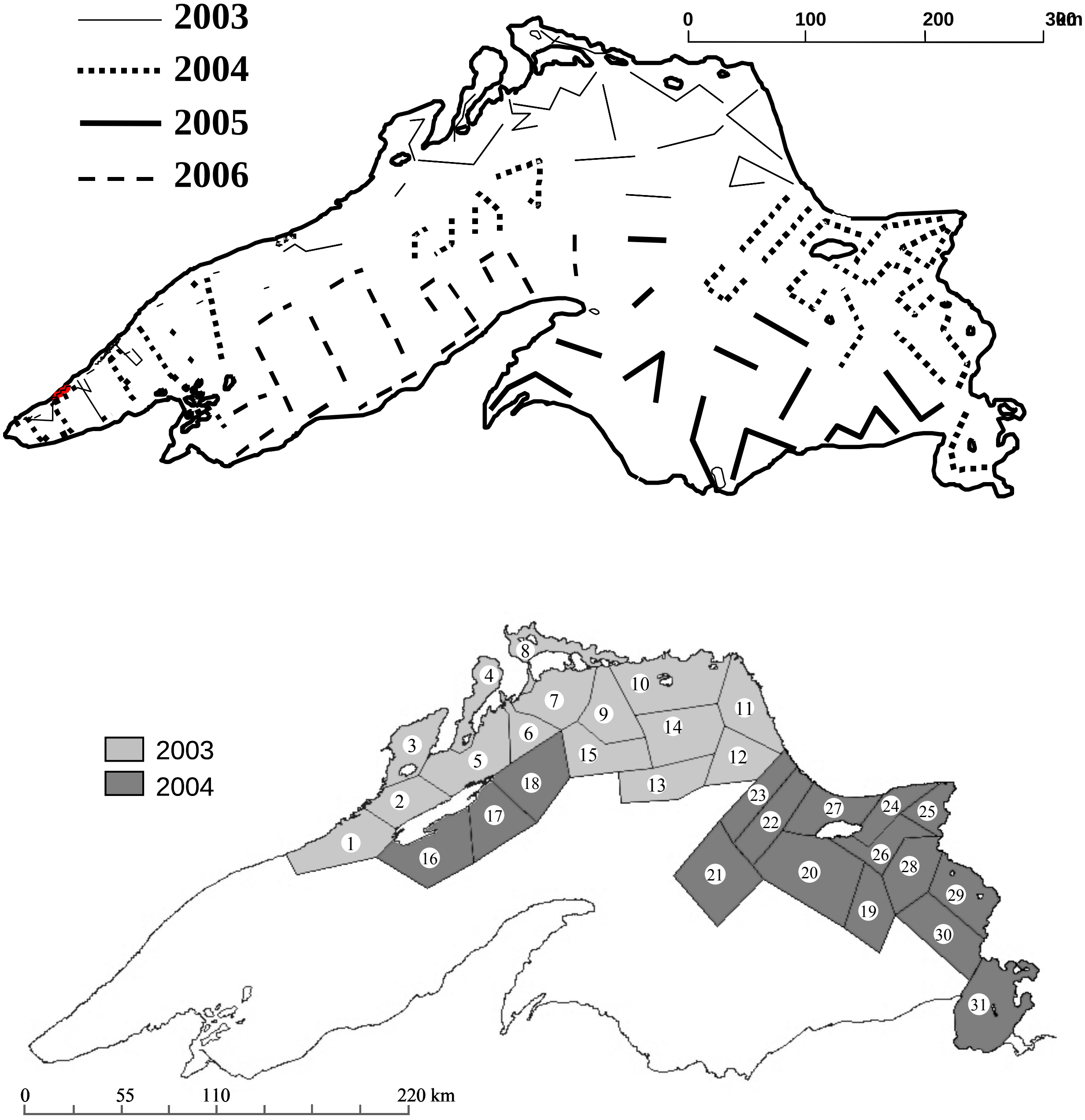

Fig. 14. *Transects sampled during the 2003 and 2004 hydroacoustic surveys on Lake Superior and proposed for 2005 and 2006 (top panel) and spatial polygons (bottom panel) used to estimate forage fish biomass in 2003 and 2004.*

The third acoustic and midwater trawl survey took place in 2003 and 2004 in Minnesota waters between Duluth and Grand Portage (Hrabik et al. 2006) at the same time as the lakewide effort. The Minnesota survey transects were conducted in waters <80 m and >80 m (Hrabik et al. 2006) using a 120 kHz split beam acoustic system during August and September. Fish species captured in the midwater trawls were classified into size classes based upon length. This study focused on assessing the importance of sample size and transects length on estimates of fish density.

The fourth survey was conducted in spring 2005 in conjunction with the USGS-GLSC bottom trawl survey to evaluate possible biases associated with sampling adult cisco using day bottom trawls (Stockwell et al. 2006). Day bottom trawls and night acoustic gear and midwater trawls were deployed at nine of the spring survey stations ("nearshore" stations) and at another nine "offshore" stations not sampled during the spring survey (bathymetric depths ranging from 95 to 325 m). Abundance and biomass densities from day bottom trawls were calculated as outlined above. A 120-kHz split beam acoustic system was used to estimate pelagic fish target strength and abundance density at night. Acoustic abundance estimates for all cisco and adults ≥ 250 mm TL were based on species and size-class compositions from concurrent midwater trawls fished in a stepped-oblique fashion. Biomass density was estimated by multiplying acoustic abundance density estimates by average weight of all cisco and adults ≥ 250 mm TL.

1996 and 1997 survey

Ciscos were the dominant prey fish captured during the 1996 and 1997 surveys in the western arm of Lake Superior. Catch rate of cisco in midwater trawls averaged 0.24 fish·1000 m^{-3} compared to 0.05 smelt·1000 m^{-3} and 0.03 deepwater chubs·1000 m^{-3} (Johnson et al. 2004; Mason et al. 2005). Coregonid biomass averaged ~10 $kg \cdot ha^{-1}$ and they made up 90% of the estimated acoustic biomass (Johnson et al. 2004; Mason et al. 2005). Given that cisco made up about three-quarters of the number of prey fish caught in the midwater trawls, cisco biomass averaged ~8.3 $kg \cdot ha^{-1}$ in the western arm during 1996 and 1997.

Ciscos were most abundant and supported the majority of biomass in the pelagic zone of each ecoregion (Duluth-Superior, Apostle Islands, and open lake). Density of cisco was 0.39

fish·1000 m^{-3} in the Apostle Islands, 0.19 fish·1000 m^{-3} at Duluth-Superior, and 0.02 fish·1000 m^{-3} in the open lake. Density of rainbow smelt and deepwater ciscoes did not exceed 0.06 fish·1000 m^{-3} and 0.05 fish·1000 m^{-3}, respectively, in any of the ecoregions (Johnson et al. 2004; Mason et al. 2005). Biomass of cisco was greatest in the Apostle Islands (~14 kg·ha^{-1}) and least in the open lake (~4 kg·ha^{-1}). Mean length and weight of cisco captured was largest in the open lake and smallest in the Apostle Islands (Johnson et al. 2004).

2003 and 2004 lakewide survey

Cisco dominated the pelagic biomass in the open water of Lake Superior and some bays during August 2003. Cisco represented approximately 26% of the prey biomass in Black Bay, 76% in Nipigon Bay, and 95% in Thunder Bay in 2003 (Table 3). Rainbow smelt represented 73% of the prey fish biomass in Black Bay and numerically they were the most abundant species in Nipigon Bay, although their smaller average size relative to coregonines decreased their contribution to the overall biomass to only 20% in Nipigon Bay. Coregonines represented the bulk of the prey fish biomass in Nipigon Bay (80%), Thunder Bay (>99%), and the open lake (>99%) (Table 3). Cisco represented 87% of fish biomass in the open lake. Kiyi represented moderate portions of prey fish biomass in the open water lake (11%) and in Thunder Bay (3%). Bloater contributed less than 3% of the overall fish biomass in Nipigon, Thunder, and Black bays and the open lake.

Coregonines dominated all areas sampled during 2004, comprising 62% of Whitefish Bay, 100% of Isle Royale, and >99% of open lake prey fish biomass (Table 3). Cisco was the most dominant prey fish by biomass in Whitefish Bay (57%) and the open lake (88%), but only made up 12% of the Isle Royale area prey fish biomass. In Whitefish Bay, 38% of the prey fish biomass was represented by rainbow smelt. Kiyi dominated the biomass at Isle Royale (86%), but kiyi contribution to Whitefish Bay and open lake areas biomass was low (6% and 9%, respectively). Bloater contributed <3% of prey fish biomass for all regions surveyed during 2004. Lean lake trout and siscowet represented 6% and 3% of the total fish biomass respectively in the open lake, although the low number of captures for these two fish resulted in large errors associated with their biomass estimates (Table 3).

Table 3. *Estimates of total biomass in metric tons of each abundant fish species within broad areas of Lake Superior sampled with acoustics and midwater trawls in 2003 and 2004. Values in parentheses indicate 95% confidence intervals about the mean estimate. See Figure 14 for sampling locations in 2003 and 2004.*

Year	Area	Cisco	Kiyi	Bloater	Rainbow smelt	Siscowet	Lean lake trout
2003	Thunder Bay	1,821.5	53.1	47.7	3.7		
		(1294.27)	(37.73)	(33.90)	(2.66)		
	Black Bay	174.1		6.5	494.8		
		(101.41)		(3.80)	(288.25)		
	Nipigon Bay	1,827.8		86.2	466.1		
		(1280.35)		(60.40)	(326.47)		
	Open Lake	20,656.9	2,560.8	654.0	0.1	3,483.6	
		(9514.01)	(937.38)	(604.59)	(0.06)	(3142.33)	
	Minnesota	2,952.2	135.1	120.3	38.5	17.2	
2004	Whitefish Bay	219.4	22.0		146.5		
		(89.68)	(9.01)		(59.86)		
	Open Lake	2,355.9	2,425.7	648.5	0.6	997.0	1,643.4
		(5882.76)	(1472.76)	(949.28)	(0.33)	(985.53)	(1150.61)
	Isle Royale	141.0	1,010.3	23.4			
		(200.17)	(976.26)	(34.74)			
	Minnesota	8,189.2	1,275.9	701.1	27.0	320.9	

2003 and 2004 Minnesota survey

The mean size of acoustic targets and the associated variability were more consistent at segment sizes of 800 m in length within a transect, and segment sizes of 800 m in length were not correlated with the nearest neighboring segments within a transect (Hrabik et al. 2006).

Consequently, Hrabik et al. (2006) estimated that a sample density of approximately 0.018 km of transects were needed in each square kilometers of the survey area in Minnesota to stabilize estimates of densities. Thus about 20 km of acoustic transects are needed in MN-1, 34 km of transects in MN-2, and 65 km of transects in MN-3 to adequately assess prey fish biomass in Minnesota waters (Hrabik et al 2006).

Fish densities in Minnesota were dominated by coregonines and fish densities were higher in waters <80 m than in waters >80 m (Hrabik et al. 2006). Spawning-sized cisco (>305 mm TL) dominated the acoustic biomass estimates in all management units in both 2003 and 2004 averaging 4.3 kg·ha^{-1} and 11 kg·ha^{-1}, respectively, throughout Minnesota waters. Large bloater and large kiyi (both >150 mm TL) also represented a large amount of the pelagic biomass in Minnesota waters in 2003 and 2004. Total pelagic fish biomass was estimated to be 3,263 metric tons in 2003 and 10,630 metric tons in 2004. Cisco made up at 90% of the total pelagic biomass in 2003 and 77% in 2004.

2005 spring survey

Day bottom trawls grossly underestimated abundance and biomass density of cisco at the spring survey stations (Stockwell et al. 2006) in 2005. Average abundance density of all cisco at the nine nearshore stations at night (124 fish·ha^{-1}) was 62 times greater than day bottom trawl estimates, and average biomass density at night (10.7 fish·ha^{-1}) was 36 times greater than day estimates. Average abundance density of adult cisco at the nine nearshore stations was significantly higher at night (21 adult fish·ha^{-1}) compared to day bottom trawls (1 adult fish·ha^{-1}; $P = 0.0119$). At the nine offshore stations, no ciscos were captured using day bottom trawls but abundance density averaged 41 adult fish·ha^{-1} at night using acoustic gear and midwater trawls. Cisco biomass density based on night acoustic gear and midwater trawling was similar in nearshore (10.7 kg·ha^{-1}) and offshore (11.9 kg·ha^{-1}) areas. Ciscos were captured with midwater trawls at stations with mean bottom depths up to 200 m. Midwater trawls fished at night captured cisco at 4 of 5 stations with mean bathymetric depths between 140 and 200 m. Day bottom trawls and night midwater trawls did not capture any cisco at the three deepest stations were the mean bathymetric depths ranged from 225 to 325 m.

AGE AND GROWTH

Age estimation

Prior to the early 1980s, all cisco were aged with scales. Following recruitment of the 1984 year-class agencies began realizing that scales were probably underestimating actual age (MacCallum 1994). The reliability of scales was evaluated by comparing ages determined from saggital otoliths and scales of 165 cisco caught in Wisconsin waters during 2003-2004. Scales were not reliable aging structures after cisco achieved four years of age, however, young fish were underrepresented in the sample (Fig. 15). Scales can be used to determine age of young fish captured in trawls, however, otoliths should be the structure used to estimate cisco age (see Schreiner and Schram 2000).

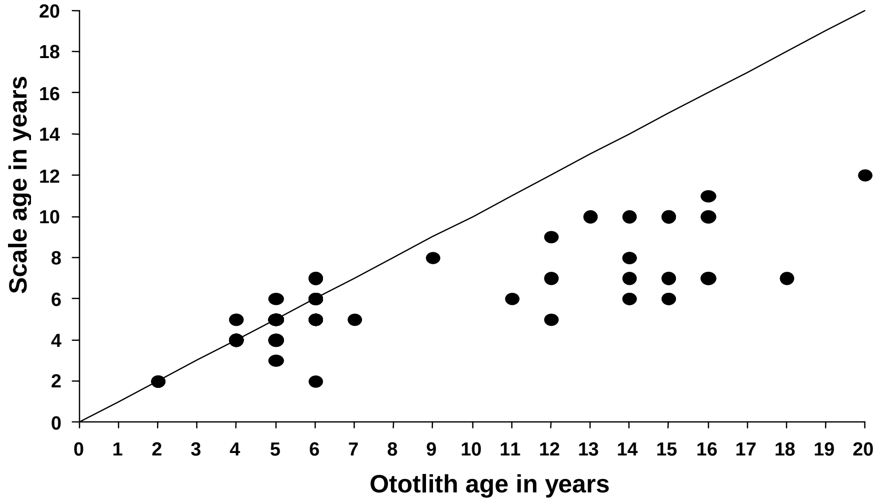

Fig. 15. *Age in years of cisco determined from both scales and otoliths for fish collected during gillnet surveys and commercial catches within the Apostle Islands (WI-2) during November/December of 2003 and 2004. Each point on the graph may represent more than one scale and otolith data set. The diagonal line represents 100% agreement between scale and otolith ages.*

Age distribution of spawning cisco

Sporadic cisco recruitment since 1980 has created age distributions of spawning fish that are greatly influenced by a few year-classes. In spawning surveys conducted by the Wisconsin Department of Natural Resources (WiDNR) around the Apostle Islands the abundant 1984, 1988, 1989, 1990, and 1998 year-classes dominated the age distribution during 1989-2004 (Table 4).

Although several cohorts were represented in some years, those strong year-classes made up the majority of the spawning population for many years. Age distribution of spawning adult cisco in Minnesota and Ontario show similar year-class dominance (Table 5). In 2003 for example, 40-64% of the spawning cisco in districts MN-1, WI-2, ON-1,ON-2,ON-7,ON-9, and ON-12 were from the 1998 year-class. Age distributions from Minnesota and Ontario, however, included more cisco from less abundant year-classes. Historically, cisco age composition may have erroneously reflected more consistent recruitment. Dryer and Beil (1964) found that age-4 cisco consistently made up 37-68% of the spawning population at Duluth, Bayfield, Portage Entry and Marquette during the 1950's. We believe that these historic age distributions may have been inaccurate because scales were used to age the fish and we know that scales dramatically underestimate age of cisco greater than four year old.

Table 4. *Percent age composition of adult, spawning cisco caught with bottom-set gill nets by the Wisconsin Dept. of Natural Resources in the Apostle Islands area of Lake Superior during November-December of 1989-2004. Percentages in bold represent the abundant 1984, 1988, 1989, 1990, and 1998 year-classes and total percent composition of these same year-classes in each year is shown in Total column.*

	Age																	
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
1989	**7.1**		4.9	21.3	**65.3**	1.3												72
1990	**0.2**	**10.5**	0.8	32.6	17.2	**37.4**	1.3											48
1991	**0.5**	**21.6**	**18.2**			6.6	**45.4**	7.1				0.3	0.3					86
1992		**3.0**	**29.9**	**9.8**	3.0	0.9	4.1	**45.0**	3.8		0.3			0.3				88
1993		2.1	**20.5**	**29.3**	**5.6**	1.9	6.4	1.3	**31.5**	0.8		0.5						87
1994			0.9	**19.8**	**30.6**	**18.2**	8.6	2.2	0.6	**15.7**	1.2	1.9						84
1995				3.4	**3.4**	**23.4**	**22.8**	20.0	13.8	3.4	**5.3**	3.4	0.9					55
1996						**9.2**	**52.7**	**16.7**	6.7		1.7	**11.7**		1.3				90
1997						2.2	**24.8**	**35.6**	**18.5**	1.5	1.5	3.7	**12.2**					91
1998					1.2		1.2	**3.6**	**64.3**	**15.5**	1.2			**11.9**	1.2			95
1999	**1.8**								**14.0**	**66.7**	**5.3**	5.3		3.5	**3.5**			91
2000		**19.4**							0.0	**8.1**	**54.8**	**9.7**	1.6			**6.5**		98
2001		4.7	**46.5**						1.2	4.7	**7.0**	**23.3**	**7.0**		3.5	1.2	**1.2**	85
2002			3.2	**54.3**	6.4	3.2		1.1	2.1	2.1	6.4	**10.6**	**4.3**	**6.4**				76
2003				13.1	**63.6**	3.0					1.0	4.0	**8.1**	**5.1**	**2.0**			79
2004		6.3		2.5	5.1	**68.4**	1.3					3.8	1.3	**11.4**				80

Table 5. *Percent age composition of adult, spawning cisco caught in gillnets during agency surveys in Minnesota, Ontario, and Wisconsin management units in November/December of 2002. Percentages in bold represent the abundant 1988-1990 and 1998 year-classes.*

	Age																			
Mgt unit	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
ON-1	0.0	**29.5**	0.3	3.4	0.6	2.8	0.0	0.0	1.1	**6.5**	**9.8**	**39.9**	2.2	0.0	1.2	2.6	0.0	0.0	0.0	0.0
ON-2	0.0	**21.1**	0.2	8.6	0.5	4.4	0.0	0.0	0.7	**3.4**	**8.8**	**47.7**	1.7	0.2	0.0	2.5	0.0	0.0	0.0	0.0
ON-7	0.3	**42.2**	0.5	0.8	1.0	12.9	0.3	0.3	0.8	**4.6**	**19.3**	**9.0**	0.3	0.5	2.3	5.1	0.0	0.0	0.0	0.0
ON-9	0.2	**36.3**	1.2	0.5	0.2	12.4	0.5	0.2	2.1	**11.2**	**22.2**	**6.3**	0.2	0.5	0.5	5.4	0.0	0.0	0.0	0.0
ON-12	0.1	**29.1**	1.7	0.8	0.4	15.6	0.9	0.3	2.0	**7.7**	**26.9**	**7.6**	0.1	0.8	0.3	4.5	1.3	0.0	0.0	0.0
MN-1	0.0	**4.9**	8.4	1.6	0.6	1.6	0.3	1.0	10.7	**21.7**	**20.1**	**8.4**	4.5	3.6	4.9	3.2	2.3	1.6	0.3	0.3
WI-2	3.2	**54.3**	6.4	3.2	0.0	1.1	2.1	2.1	6.4	**10.6**	**4.3**	**6.4**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean	0.5	**31.0**	2.7	2.4	0.5	7.3	0.6	0.6	3.4	**9.4**	**15.9**	**17.9**	1.3	0.8	1.3	3.3	0.5	0.2	0.0	0.0

Spatial variation in growth

Useful comparisons in growth between all management agencies was not possible due to lack of conformity between surveys (e.g. time of year, mesh sizes, sporadic sampling). Information on size-at-age of spawning cisco data from Minnesota, Ontario, and Wisconsin indicated that there might be spatial variability in growth. Mean length-at-age of primarily female cisco caught in suspended gill nets set in open water zones of Ontario (ON-12) and Minnesota (MN-1) was generally similar in 2003 (Table 6). Cisco from Black Bay (ON-7) and Thunder Bay (ON-1/2) were consistently smaller than in Minnesota. Furthermore, mean length-at-age of male spawning cisco from the Apostle Islands was consistently greater than that from Black Bay in 1998 and 2002 (Table 7). Mean length-at-age of spawning male cisco within the Apostle Islands were similar between the abundant 1984, 1988-1990, and 1988 year-classes (Table 8). Coffin et al. (2003) found cisco stocks in western U.S. and Canadian waters of Lake Superior grew at different rates and concluded these growth disparities were primarily due to differences in environmental factors.

Table 6. *Mean total length-at-age (mm) of primarily female spawning cisco captured in suspended gill nets from management units in Ontario and Minnesota waters of Lake Superior during November/December 2003. The standard deviations are in parentheses. Mesh sizes used in each jurisdiction are as listed in Table 2.*

	Age														
Mgt unit	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
MN-1	364 (34)	367 (16)	373 (17)				384 (36)	382 (13)	386 (24)	387 (26)	368 (23)	377 (26)		410 (26)	424 (25)
ON-1/2	322 (28)		318 (20)		355 (25)				339 (76)	319 (26)	346 (17)	357 (19)			347 (5)
ON-7	337 (21)				341 (14)			329 (30)	350 (30)	355 (23)	355 (21)				
ON-9	341 (22)	343 (18)	350 (58)		345 (16)	343 (23)			366 (23)	373 (23)	361 (10)				417 (27)
ON-12	345 (37)	335 (35)		365 (43)	350 (21)	353 (4)		410 (8)	385 (23)	383 (30)	385 (31)			396 (1)	399 (18)

Table 7. *Mean total length-at-age (mm) of spawning male cisco captured in bottom-set gill nets from Ontario and Wisconsin waters of Lake Superior during November/December of 1998 and 2002. The standard deviations are in parentheses. Wisconsin uses a maximum mesh size of 76.2 mm (3.0 in) stretch mesh and Ontario uses a maximum mesh size of 63.5 mm (2.5 in) stretched mesh (see Table 2).*

		Age												
Year	Mgt unit	3	4	5	6	7	8	9	10	11	12	13	14	15
1998	WI-2						362	366	374				380	
							(17)	(31)	(45)				(45)	
1998	ON-7	255	318	271	242	302	319	321	320	318	362	314	332	329
		(34)	(16)	(98)	(45)	(68)	(29)	(25)	(20)	(17)	(10)	(15)	(21)	(20)
2002	WI-2	257	302	284	301					363	411	384	386	
		(50)	(38)	(42)	(16)					(12)	(25)	(7)	(20)	
2002	ON-7	236	270	238	291	339			308	324	329	323	330	329
		(40)	(46)	(29)	(30)	(22)			(12)	(25)	(29)	(15)	(12)	(10)

Table 8. *Mean total length-at-age (mm) of abundant year-classes of cisco caught in bottom-set gillnets during spawning surveys in the Apostle Islands area of Lake Superior by WiDNR in November-December 1988-2004. Standard deviations are in parentheses.*

	Age (years)														
Year-class	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1984[1]			307	333	361	351	358	366	386	366	414	394	381		429
			(28)	(20)	(23)	(18)	(23)	(28)	(30)	(28)	(38)	(28)	(43)		(15)
1988	246	277	297	333	338	348	343	355	374	381	389	400	386		
	(23)	(33)	(30)	(41)	(18)	(18)	(15)	(30)	(43)	(38)	(38)	(46)	(18)		
1989	236	263	306	337	330	345	342	366	360	360	377	384	417		
	(20)	(41)	(25)	(36)	(51)	(33)	(20)	(30)	(36)	(25)	(23)	(5)	(69)		
1990		264	310		347	342	362	372	394	390	411	417	366		
		(18)	(18)		(36)	(20)	(15)	(58)	(25)	(51)	(23)	(30)	(25)		
1998	242	278	302	315	330										
	(10)	(33)	(38)	(48)	(38)										

[1] No spawning survey conducted in 1986 and 1987

Length-weight relationship

Bottom-set graded-mesh gill net survey data from Michigan waters indicated that the length-weight relationship for cisco was similar east (MI-4 and MI-5) and west (MI-2 and MI-3) of the Keweenaw Peninsula from 1996 through 2004 (Paired t-test; $t_{0.05,\,7} = 2.36$, $t = -1.07$). The slope of the length-weight relationship was similar in the eastern waters, but the slope appeared to decline from 1998 to 2003 west of the Keweenaw Peninsula (Table 9). The abundant 1998 year-class may have caused density dependent declines in weight-at-length in western waters, and the effects may be more pronounced in western waters because of lower productivity than in the eastern portion of Michigan waters. Dryer and Beil (1964) reported a slope of 3.17 for a weight-length relationship for spawning cisco caught with gill nets. Although collected in the summer using graded mesh gill nets, length-weight slopes from east and west of the Keweenaw Peninsula exceeded this value only in 1998 and 2002 during 1996-2004 (Table 9).

A weight-length relationship (g and mm) was also developed for 138 male and female spawning cisco captured in statistical grid 1409 using a midwater trawl on 30 November and 1 December 1, 2004 (Yule et al. 2006a). The slope of this relationship was 3.16 and the intercept was –12.7. These values are very similar to those from Michigan waters during 1996-2004.

Table 9. *Number of cisco and their length range used to estimate the intercept and slope of length-weight equations for cisco caught in bottom-set gillnet surveys in Michigan waters east and west of the Keweenaw Peninsula during July-September of 1996-2004.*

	Number of fish		Length range (mm)		Intercept		Slope	
Year	east	west	east	west	east	west	east	west
1996	392	225	201-500	224-488	-4.98	-4.45	2.93	2.71
1998	226	92	208-521	210-479	-5.55	-6.10	3.17	3.39
1999	394	97	124-485	141-506	-5.21	-5.42	3.03	3.10
2000	173	126	133-667	165-503	-5.20	-5.54	3.02	3.15
2001	215	86	171-481	175-488	-5.21	-5.14	3.03	2.99
2002	277	161	189-512	201-450	-5.60	-4.92	3.18	2.90
2003	159	228	172-517	125-418	-5.40	-4.55	3.10	2.75
2004	285	148	146-541	207-447	-5.43	-5.08	3.12	2.97

STOCK AND RECRUITMENT

Recruitment of cisco following population recovery that began in the late 1970s appears to be more variable than was indicated from variation in historic yield (Hoff 2004b). Year-class strengths varied by more than 4,000-fold over the 27-year assessment record, with the strongest year-classes appearing in 1984, 1988-1990, 1998, and most recently in 2003. The minimum interval between abundant year-classes was four years and the maximum was seven years. Highly variable recruitment of age-1 cisco and decreasing susceptibility to bottom trawls as they mature are responsible for the high variation in biomass over the 27-year bottom trawl time series. Bronte et al. (2003) reported that some of the weakest year classes of cisco were produced under the highest stock sizes, suggesting density-dependent compensation in stock-recruitment. Bronte et al. (2003) also suggested that density-independent factors such as weather was important in determining recruitment of cisco in Lake Superior.

Over-winter survival may be important in regulating cisco recruitment in Lake Superior. Kinnunen (1997) suggested that annual and regional differences in growth and year-class strength of cisco stocks in Lake Superior appear to affect size-dependent winter survival, which is supported by Hoff's (2004b) finding that extended winter periods negatively affect recruitment. Laboratory studies by Pangle et al. (2004) confirmed that increased survival of age-0 cisco under winter-like conditions is associated with larger body size and greater lipid content as expected.

Appearance of strong year-classes appears to be synchronized among discrete cisco populations distributed over hundreds of kilometers in Lake Superior. Dryer and Beil (1964) found strong correlation in the strength of year-classes from the western arm, Apostle Islands, and Keweenaw Bay regions during 1946-1955. In addition, year-class strengths of bloater appear to be largely correlated with that of cisco in Lake Superior during 1978-2004 (O'Gorman et al. 2005). Cross-lake comparisons show concordance in the appearance of strong year-classes of cisco and bloater in lakes Michigan and Superior between 1978 and 1990, and more recently in 2003 for lakes Huron and Superior (O'Gorman et al. 2005). Concordance in the appearance of strong year-classes of ciscoes over large geographic regions suggests that ciscoes share similar early life history requirements and age-1 recruitment is similarly influenced by variation in regional climatic factors and phenology.

Variation in sex ratios of Lake Superior cisco and Lake Michigan bloater populations has been hypothesized to limit recruitment and regulate population size (Brown et al. 1987; Bowen et al. 1991). Both Lake Superior cisco and Lake Michigan bloater populations share the feature of increasing female dominance with increasing age, which has been attributed to differential mortality of males vs. females (Brown et al. 1987; TeWinkel et al. 2002) and may be instrumental in driving population cycles (Madenjian et al. 2002). Following the recruitment and maturation of strong year-classes of bloater, males become increasingly rare as the population ages, numbers dwindle, and recruitment failures continue. Rice et al. (1987) found no relationship between bloater egg deposition rate and recruitment to age-1 in Lake Michigan; 2.5 times as many larval bloater recruited from an adult spawner stock that was only 53% as large as the previous year. Variation in the sex ratios of Lake Superior cisco populations has been related to delayed maturation of females in relation to population density but not differential mortality of the sexes (Bowen et al. 1991). Further, Bowen et al. (1991) hypothesized that variation in recruitment was largely responsible for observed variation in population density and the subsequent influence on sex ratio.

Both biotic and abiotic factors have been surmised to regulate recruitment of cisco. Hoff (2004b) reported that a number of biotic and abiotic factors including cisco adult stock size, lake trout abundance, slimy sculpin (*Cottus cognatus*) biomass, the interaction of mean daily wind speed in April and cisco stock size, and mean air temperature in April explained 93% of the variation in cisco recruitment in the Apostle Islands during 1984-1998. Lake trout abundance, slimy sculpin biomass and hypothesized adult cisco cannibalism all negatively affected cisco recruitment in Hoff's model. Adult stock size explained only 35% of the variation in recruitment (Hoff 2004b). Hoff proposed that wind speed in April reduced the hypothesized effect of cannibalism, while recruitment was positively related to spring air temperatures, however, precision estimates for adult (Yule et al. 2006a) and yearling (Stockwell et al. 2006) cisco data used in Hoff (2004b) were lower than recommended for stock-recruit analysis (Walters and Ludwig 1981). Additionally, Stockwell et al. (2006) demonstrated that day bottom trawls are ineffective for assessing adult cisco. As such, Hoff's (2004b) search for factors other than adult stock to explain cisco recruitment was likely premature and may be misleading (Walters and Ludwig 1981).

A lakewide stock-recruitment model was developed as part of a broader effort to develop an ecosystem level simulation model of the Lake Superior fish community (Cox and Kitchell 2004). The lakewide stock-recruitment model showed a normal density-dependent response of cisco recruitment to adult stock size during 1929-1970 (S. Cox, Simon Fraser University, 8888 University Drive, Burnaby, British Columbia, Canada, V5A 1S6, personal communication). Thereafter, the stock-recruitment relationship was depensatory and the shape of the relation changed. From 1971-1998 adult stock size that was similar to stock sizes during 1929-1970 produced substantially fewer recruits and in many years very few age-1 cisco were produced regardless of the adult stock size. However, data used to develop this stock-recruitment relationship was partially based on the USGS-GLSC spring bottom trawl survey. Day bottom trawls appear to be ineffective for assessing adult cisco stocks (Stockwell et al. 2006). As stated previously, Cox and Kitchell (2004) argued that predation on cisco by lake trout and rainbow smelt both were driving cisco recruitment to age-1. The extent to which the findings of Stockwell et al. (2006) would significantly alter the conclusions of Cox and Kitchell (2004) is unknown and warrants further study.

MANAGEMENT CONSIDERATIONS

Based upon the information described in previous sections of this report, we recommend that fishery agencies contemplating development of strategies for managing cisco in Lake Superior, and the other Great Lakes, must begin with the recognition that:

- Scientific knowledge of cisco population dynamics and ecology is increasing;
- Cisco are long-lived (20+ years);
- Multiple forms exist, including those than spawn in both shallow and deep water;
- Abundant year classes can be produced from small adult stock sizes;
- Large variation in cisco year-class strength is intrinsic to Great Lakes' populations;
- Despite the longevity and early maturity of cisco, there is a danger of over-fishing populations because large year classes are produced only occasionally;
- Regional environmental factors likely play a large role in determining reproductive success; and

- Rainbow smelt likely have a negative affect on cisco recruitment.

Large variations in year class strength of cisco appear to be a common trait of the species. Hartman (1973) reported that commercial yields of cisco from Lake Erie fluctuated violently from the time the statistics first became available in about 1880 and that various other scientists attributed these large oscillations to eutrophication or increases in pollution, but Scott (1951) concluded that periods of abundance of cisco in Lake Erie were mainly due to the presence of exceptionally strong year classes, like that of the 1944. Scott (1951) also pointed out that the strong 1944 year class was produced from a small adult stock, and that factors other than the size of spawning stocks was clearly important in determining year class success in Lake Erie.

We recommend that management agencies on Lake Superior adopt a fish community objective that aims to protect cisco stocks with sensible fishery controls to ensure sufficient biomass of large- (>300 mm TL) and small-sized (<150 mm TL) cisco to support both fisheries and predators. Historically, cisco was the dominant prey fish in Lake Superior and we believe that complete rehabilitation of their populations is essential for achieving many fish community objectives. Lake Superior is a self-regulating system, for the most part, that is closely approaching a restored state (Kitchell et al. 2000). Fishery agencies can, with some reasonable level of precision, estimate consumption of cisco by predators (Negus 1995; Kitchell et al. 2000; Negus et al. 2007). Options to control predator consumption are limited because survival of hatchery-reared fish is poor (Schreiner et al. 2007) and stocking has only a minimal effect on predator population dynamics in Lake Superior (Negus et al. 2007). Increasing or decreasing sport and commercial fishery harvests or sea lamprey control are potential options for increasing or decreasing predator demand on cisco. Establishing a fish community objective that tries to allocate cisco to predators and fisheries would be, in practice, a great challenge. However, managing for trends in predator consumption (and thus availability to commercial fisheries) is plausible. For example, Kitchell et al. (2000) simulated six different management scenarios for Lake Superior and the only scenario where cisco experienced sustained increases in abundance occurred when rainbow smelt collapsed due to lake trout predation.

We believe that cisco abundance can be increased by protecting them from over-exploitation and keeping rainbow smelt at very low levels of abundance by managing for relatively high predator abundance. Managers should consider establishing a fixed level of exploitation of 10-

15% on adult female cisco when setting harvest limits on commercial fishery yields from Lake Superior. Previous exploitation rate estimates of 28-90% reported by Selgeby (1982) were likely overestimated because of errors associated with reliance on scale ageing (Yule et al. 2008). Exploitation rates of 2-9% reported by Yule et al. (2006a,b, 2008) are not excessive and highly unlikely to harm spawning populations. Schreiner et al. (2006) recommended a harvest management policy for cisco in Minnesota waters of Lake Superior based on harvesting 10% of the estimated 95% lower confidence limit of spawning stock biomass of cisco $\geq$ 305 mm TL as determined by hydroacoustic surveys. For comparison, the lake sturgeon rehabilitation plan for Lake Superior states that exploitation rates should be maintained at or near 5% to protect self-sustaining populations (Auer 2003). Lake whitefish in Lake Superior have been able to sustain annual exploitation rates of 20-30% ($F = 0.22\text{-}0.36\ y^{-1}$) over the last two decades (see Woldt et al. 2006) and thus can likely sustain higher exploitation rates. Current exploitation rates of wild lake trout in Lake Superior are generally less than 10% and maximum allowable exploitation rates are roughly 20% based on a 45% limit to total annual mortality (Woldt et al. 2006). Given these estimates of exploitation on other species a target exploitation rate of 10-15% on large (>250 mm TL) female cisco seems appropriate.

To be an effective harvest management policy, a fixed level of exploitation requires annual estimates of stock size (Hilborn and Walters 1992). Therefore, recent development of hydroacoustic techniques in combination with bottom and mid-water trawl surveys to estimate cisco abundance and biomass in Lake Superior (Mason et al. 2005; Hrabik et al. 2006; Yule et al. 2006a,b; Stockwell et al. 2006) will greatly benefit management.

Future Survey Considerations

Our findings indicate that adult ciscos are not adequately sampled in bottom trawls and thus data from spring bottom trawl assessments provide a biased picture of the age-structure, abundance, and biomass of cisco populations in Lake Superior. However, the long-term data series derived from the USGS-GLSC spring bottom trawl surveys appears to be the best method for monitoring recruitment of yearlings, although this method appears to suffer from poor precision (Stockwell et al. 2006). Evaluation of age structures from the 2005 comparison of day bottom trawls and night acoustic gear and midwater trawls should identify the age to which survival can reliably be estimated using data from the day bottom trawl survey.

In contrast to bottom trawls, summer gill net surveys are biased towards larger adult fish so they can provide a relative measure of adult age structure (age 3+). Relative abundance of cisco in summer gill-net surveys has been variable, but generally abundance followed of that in the bottom trawl surveys. This overall trend corresponds to the increase in lake trout abundance (Wilberg et al. 2003; Bronte et al. 2003), and indicates the possibility that predation may be a factor influencing the decline in cisco abundance observed in the 1990s (Cox and Kitchell 2004), but the decline in abundance may also indicate that large cisco are not vulnerable to mesh sizes used in the summer gill net surveys. No lake-wide inference could be made from the fall gill-net surveys because of the limited sampling. However, in a few management units, fall cisco abundance follows the pattern observed in the summer surveys. Data from small-mesh gill-net surveys may be particularly useful in understanding population dynamics of cisco if future surveys are structured differently than they are currently.

In general, cisco relative abundance has not been well quantified because there has not been a comprehensive targeted survey. Bottom-set gill nets are not the proper gear to effectively index cisco abundance because they are pelagic. It may be more logical to use suspended multi-mesh gill nets to sample cisco to better index relative abundance and collect growth and age data. It appears that midwater trawling at night may be adequate to collect sufficient growth and age data. Furthermore, the sampling design needs to be standardized and provide adequate spatial coverage. Acoustics coupled with trawling may be better than gill nets for indexing cisco relative abundance. If target strengths for cisco can be differentiated from other deepwater cisco, then acoustic estimates of abundance may be the most efficient method to assess abundance.

Our synthesis has directed us to some obvious survey designs that other agencies should consider if and when they embark on evaluating the status of cisco and its rehabilitation in the Great Lakes.

- Surveys to measure adult cisco population parameters (e.g. abundance, growth, mortality) require night sampling with hydroacoustics and midwater trawls (Hrabik et al. 2006; Stockwell et al. 2006;) or suspended gill nets as used on inland lakes in Ontario (see Milne et al. 2005).
- Sampling during non-spawning times will require a survey design that considers the entire lake. Performing hydroacoustic surveys during the spawning period provides an opportunity to sample populations while they are aggregated, thus providing a measure of actual spawner

abundance and also permits direct estimates of exploitation rates on the fishing grounds (Yule et al. 2006a,b). However, on large bodies of water like Lake Superior with spatially distant spawning stocks this option becomes logistically impractical given the short period of time the fish spawn and limited budgets for sampling at the end of the year.

- Bottom trawling during the spring to sample age-1 cisco appears effective for indexing year-class strength, although we do not know if night sampling with acoustics would provide better precision and/or be closer to actual abundances. A comparison of these two gears after a large reproductive event would provide insight to this question. Additionally, it is not apparent at what rate a cohort switches to a pelagic lifestyle as it grows and how this affects its vulnerability to day bottom trawl sampling.
- Future efforts to measure population attributes such as sex ratios will require attention to cisco dynamic patterns in vertical distribution. Temporal monitoring during the course of the spawning season and/or use of multiple sampling gears will be required to adequately represent spawning populations.
- Fishery agencies should routinely sample cisco in commercial fishery harvests. Biological attributes and commercial fishery catch-at-age information will be invaluable for constructing stock assessment models and projecting harvest limits. The OMNR sampling program conducted in Black Bay during October and November of 1997-2001 is a good model for this proposed work and is outlined below.
    1. Collect length, weight, sex, maturity, sea lamprey marking information and scale and otolith samples from the first 50 cisco caught per gang during monitoring of commercial fishery harvests.
    2. Record fishing effort and catch in weight of cisco for each gang of commercial gill nets from which biological samples were collected.
    3. Attach standard monofilament or multifilament graded-mesh gill nets of 38, 51, 64, 75, 89, and 102 mm (1.5 to 4.0 in) stretched mesh to the middle or end of several gangs of commercial fishery gill nets.
    4. Panel sizes of each graded-mesh gill net should be either 30 or 91 m long,
    5. Record the number of cisco caught in each panel of the graded-mesh gill nets, and collect standard biological data (length, weight, sex, etc) from the first 20 cisco caught in each panel.

- A standardized fishery-independent gill net survey targeting spawning concentrations of cisco should be implemented by each political jurisdiction in each management unit (see Figure 2). These fishery-independent surveys will be very useful in stock assessment modeling efforts (NRC 1998) and provide indices of abundance in areas where hydroacoustic surveys can't be conducted each year. If no commercial fisheries exist in a management unit the graded-mesh gill nets described above should be fished in a consistent manner each year; i.e. bottom-set or pelagically.
- We believe the historic age distributions reported for Lake Superior (Dryer and Beil 1964) are inaccurate. Historic age distribution reported for other Great Lakes might also be biased if ciscos were aged with scales (Van Oosten 1929; Pritchard 1931; Stone 1938; Smith 1956). Fishery agencies should continue to routinely collect both scales and otoliths from cisco, and otoliths should be used as the structure for aging on sizes of fish that roughly correspond to age 4 and older.

RESEARCH PRIORITIES

It is evident that despite many monitoring and research efforts since the original subcommittee report in 1973, there is an overwhelming need to develop an overarching research framework to better understand cisco population dynamics and ecology within the context of managing them in a sustainable fashion. Uncoordinated and non-targeted surveys across agencies, studies that isolate single life-stages, and lack of appropriate sampling strategies lead us to a fragmented view of cisco ecology. For example, we are just learning that day bottom trawls are inappropriate for assessing adult cisco, and there is still no general agreement on the impact of rainbow smelt on cisco recruitment dynamics. As such, we propose a coordinated research framework that attempts to link multiple life-stages to better understand impediments in cisco population dynamics. Intrinsic to this approach is a need for: 1) long-term monitoring of the Lake Superior community to assess the importance of temporal variation in biotic and abiotic factors; and 2) recognition that spatial variability is likely an important component to cisco dynamics and needs to be specifically incorporated into future research efforts.

EARLY LIFE HISTORY AND RECRUITMENT

The large-scale synchrony in year-class strength suggests that cisco recruitment is influenced by large-scale weather patterns (Dryer and Beil 1964; O'Gorman et al. 2005), however, it is unknown what specific aspects of weather affect recruitment. Surface water temperature explained differences in recruitment better than annual differences (Kinnunen 1997). Prevailing wind-generated currents may transport larvae away from spawning areas (Oyadomari 2005), and such dispersal is hypothesized to reduce predation mortality (Hoff 2004b). It is unknown how much migration occurs among stocks, and if migration occurs predominately during early life-stages. The extent of such migration could be studied by detecting shifts in otolith microchemistry associated with early life, a method used to distinguish adults from various regions of the lake (Bronte et al. 1996). We don't know at what size or age larval cisco seek out preferred temperatures versus being pushed there by currents. It would be important to know where recruits originate because stocks may differ in their contributions to lake-wide recruitment, and such a difference may not be detectable in the stocks themselves if larval transport is a common phenomenon in Lake Superior. It is possible that specific, localized stocks are producing the majority of recruits for extensive regions of the lake.

Because of demographic differences between sexes (Bowen et al. 1991) and egg resorption following spawning failure (Arnold 1981), stock size based on past day bottom trawl surveys may not be a reliable indicator of reproductive output. Reproductive success could be measured with egg surveys as by Yule et al. (2006a,b), and egg abundances could be correlated to recruitment success within different regions. It may be important to more closely manage stocks with high reproductive success, especially with the growing roe fishery.

Reproductive success also depends on the survival of larvae. The environmental conditions larvae encounter can influence their survival, but it is not known how much survival varies among different regions of the lake, or if particular regions should be valued as productive nursery grounds. Previous studies have identified several factors that influence early life survival and recruitment (Hoff 2004b), but it is clear that well-constructed, hypothesis driven, field research will be necessary to understand the magnitude and direction of interspecific effects on cisco in Lake Superior. Diet and prey selection studies conducted by Selgeby et al. (1978) and Selgeby et al. (1994) did a good job of evaluating competition between larval cisco and rainbow smelt in two areas of Lake Superior, but these studies were not spatially extensive and only reviewed competition within the first three months of life. There are several studies that clearly show adult rainbow smelt consume larval cisco but the conclusion that these effects were not important is questionable. Expanding diet studies of rainbow smelt across a broader spatial scale and across years may help elucidate the effects of rainbow-smelt predation on cisco recruitment.

ADULT ABUNDANCE

It is obvious that a coordinated, multiple gears, sampling strategy will be required to properly assess adult cisco populations. Bottom trawls can be used to assess age-1 cisco and a combination of mid-water trawl and hydroacoustic sampling is effective for assessing biomass of large adult cisco. We recommend that research be conducted to identify the size and age at which cisco become pelagic, and thus less vulnerable to bottom trawls, for understanding gear selectivity and recruitment to the adult population. Studies like that of Yule et al. (2006a,b) to estimate abundance of spawning cisco using multiple gears should be expanded to all other areas of Lake Superior. These estimates of spawning biomass will be necessary for estimating appropriate harvest limits for each cisco stock where fisheries occur; i.e. Apostle Islands, western arm, Black Bay, Thunder Bay, Nipigon Bay, Keweenaw Bay, and Whitefish Bay. Estimates should be made of cisco spawning biomass in unfished areas where we suspect there are stocks, but there is little or no data to evaluate population status such as eastern Ontario waters from Lizard Islands to Pic River.

While we believe our recommended exploitation rate of 10-15% on adult female cisco is sustainable, future research efforts should attempt to refine a long-term level of harvest than can be sustained by Lake Superior cisco in the face of highly variable reproduction, global climate change, rainbow smelt populations, and potentially new invasive species. Global climate change may increase the volume of Lake Superior water that is thermally usable by larval cisco, or it may cause a shift in the spatial areas that are consistently conducive to high larval survival. While all of the new invasive species to Lake Superior since the 1970s (Dryer et al. 2007) appear to have little influence on cisco dynamics, rapidly expanding global economies will likely lead to more invasive species entering Lake Superior. These new invasive species, in combination with warming waters and declining lake levels due to global climate change, may negatively affect cisco in Lake Superior, potentially reducing allowable harvest levels for cisco. Long-term sustainable harvest levels for cisco should be estimated for each of the recognizable stocks in Lake Superior because we suspect productivity varies among these stocks.

We really don't understand the dynamics of cisco reproduction despite nearly a century of research on the species. Substrates over which adults deposit eggs have not been studied and substrate influence on reproduction remains obscure. There appears to be a density-dependent effect of adult stock size on reproductive success (Bronte et al. 2003), consequently, increased exploitation of adult stocks could increase recruitment and abundance of small-sized cisco. In many stocks females predominate in the adult population and this may be a mechanism to reduce reproductive success, or it may simply be a consequence of higher mortality on males. Energy content of female cisco ovaries and their fecundity may be negatively affected by population abundance and not by changes in the food web as with lake whitefish populations (Kratzer et al. 2007).

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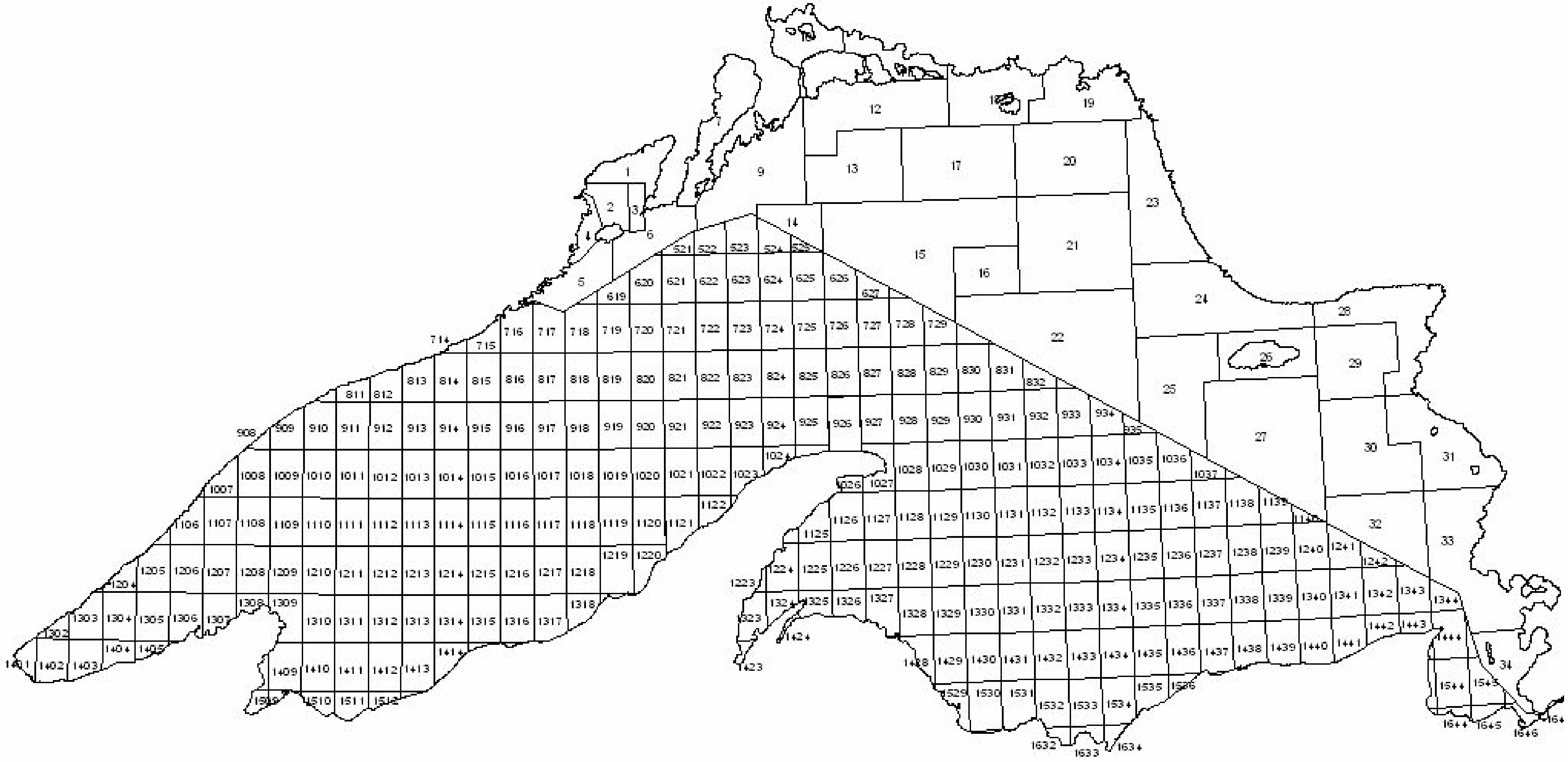
Appendix A

Map of Lake Superior showing 10-minute by 10-minute statistical grids in U.S. waters and management units in Ontario. Map taken from Chiriboga (2001).



Appendix B

Commercial fishery small-mesh gill net effort (m) and yield (kg) of cisco from statistical grids (521-1646) in U.S. waters and management units (1-33) in Ontario waters of Lake Superior, 1973-2003.

Year	Grid	Meters	Kilograms
1973	1	64,740	80,213
1973	2	14,630	46,607
1973	6	5,212	3,529
1973	7	114,026	124,227
1973	9	13,899	14,438
1973	24	3,200	685
1973	26	39,319	14,022
1973	27	38,405	7,327
1973	33	233,355	64,550
1973	522	60	1,046
1973	718	283	4,074
1973	719	13,350	642
1973	927	133,624	9,437
1973	1019	56,998	1,423
1973	1020	392,186	12,702
1973	1021	143,317	6,255
1973	1022	17,435	114
1973	1027	914	1
1973	1028	386,272	17,292
1973	1118	22,860	48
1973	1119	132,771	507
1973	1122	22,264	10,085
1973	1125	89,866	3,070
1973	1126	189,046	57,644
1973	1127	439,489	21,602
1973	1128	60,960	1,819
1973	1138	7,315	503
1973	1224	3,658	59
1973	1225	9,815	43
1973	1226	257,068	4,217
1973	1227	58,735	8,353
1973	1327	3,691	1,962
1973	1328	33,668	4,196
1973	1428	5	136
1973	1429	16,459	120
1973	1430	322,576	7,480
1973	1431	47,549	534
1973	1435	10,973	147
1973	1444	12,426	1,659
1973	1445	151	4,464
1973	1529	2,978	6,045
1973	1530	79	4,428
1973	1532	62,362	2,987
1973	1533	30,489	705
1973	1534	348,150	18,103
1973	1535	22,860	528
1973	1544	34,658	6,254
1973	1545	102,346	3,130
1973	1644	3,048	9

Year	Grid	Meters	Kilograms
1973	1645	3,419	2,134
1974	1	74,524	124,801
1974	2	23,500	25,530
1974	4	29,627	30,598
1974	7	122,959	180,900
1974	9	14,539	8,839
1974	23	4,115	587
1974	25	1,463	49
1974	26	13,716	4,349
1974	27	66,934	20,253
1974	31	4,572	9,548
1974	33	159,563	46,272
1974	34	17,191	6,293
1974	619	8,992	522
1974	622	743	259
1974	718	10,205	1,452
1974	823	9,754	14
1974	917	5,486	5
1974	920	24,384	50
1974	927	177,516	5,250
1974	928	80,467	6,243
1974	929	84,125	6,393
1974	1019	4,877	2
1974	1020	300,655	9,122
1974	1021	131,491	2,544
1974	1022	7,925	30
1974	1028	106,070	2,109
1974	1029	160,934	2,398
1974	1118	136,825	2,225
1974	1119	177,576	1,274
1974	1122	99,097	2,158
1974	1125	3,671	372
1974	1126	378,728	15,780
1974	1127	204,521	8,506
1974	1128	223,114	5,158
1974	1224	3,658	68
1974	1225	65,380	1,805
1974	1226	295,382	4,192
1974	1227	94,000	3,739
1974	1228	3,658	86
1974	1314	5,486	45
1974	1315	27,432	268
1974	1325	914	1
1974	1328	62,179	3,636
1974	1330	14,630	274
1974	1412	14	14
1974	1428	5,121	254
1974	1430	197,328	3,961
1974	1431	32,187	910
1974	1434	103,022	227
1974	1435	15,240	42
1974	1444	82	978

Year	Grid	Meters	Kilograms
1974	1529	2,415	4,049
1974	1532	92,903	2,933
1974	1533	91,280	1,900
1974	1534	111,130	4,172
1974	1535	42,672	550
1974	1544	18,963	12,911
1974	1545	38,405	281
1974	1644	24,384	108
1974	1645	11	316
1974	1646	2,012	3
1975	1	58,613	111,181
1975	2	10,013	9,895
1975	4	3,658	13,271
1975	6	1,097	1,490
1975	7	138,641	175,645
1975	9	10,150	5,820
1975	26	17,374	3,507
1975	27	29,261	2,770
1975	28	914	274
1975	31	23,134	19,920
1975	33	53,812	25,968
1975	522	21	84
1975	622	52	503
1975	719	2,560	118
1975	720	2,957	129
1975	828	3,658	465
1975	917	18,044	179
1975	920	51,938	347
1975	926	20,117	1,927
1975	927	99,182	5,762
1975	928	109,789	3,649
1975	929	18,288	898
1975	1019	8,412	116
1975	1020	146,456	5,392
1975	1021	163,647	7,095
1975	1022	49,256	1,641
1975	1023	24,750	142
1975	1024	9,754	71
1975	1027	41,148	787
1975	1028	353,416	6,001
1975	1029	189,464	2,772
1975	1117	17,800	36
1975	1118	31,882	68
1975	1119	68,153	234
1975	1121	69,190	287
1975	1122	31,394	300
1975	1125	2,743	127
1975	1126	196,901	4,844
1975	1127	256,946	14,634
1975	1128	245,059	2,958
1975	1129	3,658	34
1975	1216	36,637	114

Year	Grid	Meters	Kilograms
1975	1217	105,888	381
1975	1225	39,380	1,259
1975	1226	266,700	5,286
1975	1227	3,658	9
1975	1313	4,877	7
1975	1314	86,868	323
1975	1315	80,162	367
1975	1327	29,261	372
1975	1328	30,114	670
1975	1329	110,947	376
1975	1342	58,979	4,764
1975	1343	9,144	224
1975	1413	4,877	5
1975	1429	46,817	1,230
1975	1430	109,362	2,439
1975	1431	29,261	34
1975	1432	28,529	81
1975	1433	16,825	42
1975	1434	145,847	371
1975	1442	12,802	607
1975	1530	14,630	495
1975	1531	30,724	80
1975	1532	32,431	1,203
1975	1533	42,672	984
1975	1534	111,343	1,981
1975	1535	4,572	11
1975	1544	4,334	1,785
1976	1	47,423	43,431
1976	7	132,186	142,493
1976	26	6,858	4,222
1976	27	16,459	6,014
1976	30	3,200	689
1976	31	67,940	23,189
1976	33	26,426	8,632
1976	34	366	21
1976	622	1,120	377
1976	718	4,901	125
1976	719	1,951	86
1976	720	1,221	104
1976	817	4,877	16
1976	818	19,507	95
1976	819	9,754	49
1976	820	4,877	20
1976	830	25,603	63
1976	917	9,754	41
1976	920	108,814	1,354
1976	921	19,507	155
1976	922	14,630	76
1976	923	10,973	40
1976	926	25,603	368
1976	927	21,488	2,207
1976	928	106,070	1,323

Year	Grid	Meters	Kilograms
1976	929	32,918	1,031
1976	930	43,891	314
1976	1020	222,443	2,561
1976	1021	226,375	2,634
1976	1023	25,603	313
1976	1024	13,411	114
1976	1028	304,983	6,382
1976	1029	7,315	885
1976	1030	43,891	312
1976	1119	60,930	205
1976	1120	4,877	17
1976	1121	14,630	138
1976	1122	11,460	62
1976	1125	27,432	440
1976	1126	134,630	3,920
1976	1127	122,225	5,596
1976	1128	51,816	1,471
1976	1129	188,366	1,489
1976	1138	75,834	277
1976	1216	37,490	119
1976	1217	55,352	151
1976	1218	10,973	31
1976	1225	12,344	247
1976	1226	192,481	2,288
1976	1228	24,384	170
1976	1238	32,918	92
1976	1314	9,754	22
1976	1315	41,758	459
1976	1327	22,068	100
1976	1328	81,991	833
1976	1329	11,582	68
1976	1330	85,588	424
1976	1331	29,992	60
1976	1332	35,052	411
1976	1333	2,134	1
1976	1334	2,134	1
1976	1335	2,134	2
1976	1430	67,300	2,199
1976	1431	80,467	1,050
1976	1432	7,315	82
1976	1435	57,912	169
1976	1438	85,954	1,243
1976	1444	13,289	1,130
1976	1530	3,658	15
1976	1532	8,778	95
1976	1533	172,883	1,198
1976	1534	51,206	1,080
1976	1535	914	0
1976	1544	97,688	496
1977	1	58,382	81,916
1977	2	12,527	14,269
1977	4	15,911	14,728

Year	Grid	Meters	Kilograms
1977	6	8,595	5,455
1977	7	192,536	240,040
1977	19	457	2
1977	24	1,829	289
1977	26	11,887	862
1977	27	22,860	2,478
1977	28	914	31
1977	31	16,116	3,975
1977	32	2,926	1,048
1977	33	83,210	18,208
1977	522	4,877	35
1977	523	14,630	35
1977	621	24,384	68
1977	622	4,877	18
1977	718	84,940	1,612
1977	719	701	54
1977	720	209	211
1977	721	9,754	39
1977	819	4,877	22
1977	828	69,494	294
1977	918	4,877	49
1977	920	80,467	1,091
1977	921	9,754	21
1977	923	19,507	30
1977	927	40,234	3,010
1977	928	21,946	176
1977	929	40,234	213
1977	1018	9,754	26
1977	1019	42,977	2,543
1977	1020	181,356	5,813
1977	1021	156,972	5,691
1977	1022	7,010	45
1977	1023	4,877	31
1977	1024	4,877	50
1977	1028	176,723	6,705
1977	1029	95,707	576
1977	1037	3,658	49
1977	1119	32,614	466
1977	1120	32,309	137
1977	1121	65,837	291
1977	1125	18,288	456
1977	1126	145,176	3,736
1977	1127	211,470	15,670
1977	1129	209,459	1,787
1977	1130	8,839	311
1977	1131	36,576	231
1977	1138	14,630	106
1977	1139	15,240	112
1977	1216	43,891	138
1977	1217	62,179	153
1977	1218	54,864	123
1977	1225	3,658	64

Year	Grid	Meters	Kilograms
1977	1226	108,814	1,665
1977	1227	39,624	1,204
1977	1228	4,877	45
1977	1230	16,459	287
1977	1238	10,973	69
1977	1314	9,754	113
1977	1315	29,261	191
1977	1316	3,658	20
1977	1327	40,965	340
1977	1328	112,532	1,848
1977	1330	35,113	220
1977	1331	8,778	29
1977	1338	29,261	113
1977	1429	29,261	1,379
1977	1430	74,249	1,767
1977	1431	46,086	606
1977	1432	20,422	425
1977	1433	12,314	282
1977	1434	61,570	269
1977	1438	91,440	396
1977	1444	4,877	121
1977	1531	3,658	44
1977	1533	48,768	359
1977	1534	78,334	796
1977	1535	16,154	34
1977	1544	110,439	631
1977	1644	10,973	39
1978	1	55,762	79,823
1978	2	38,862	61,155
1978	4	33,741	20,882
1978	6	14,173	6,316
1978	7	199,751	308,103
1978	9	48,006	64,218
1978	11	1,372	66
1978	12	25,329	1,960
1978	26	12,802	1,229
1978	28	3,018	29
1978	31	20,062	12,431
1978	33	43,983	13,053
1978	522	9,761	575
1978	523	11,582	32
1978	622	9,144	73
1978	623	21,336	103
1978	718	19,434	2,270
1978	719	19,507	667
1978	720	4,877	39
1978	721	9,754	75
1978	729	21,946	173
1978	818	6,858	9
1978	823	7,315	20
1978	829	10,973	103
1978	917	39,014	175

Year	Grid	Meters	Kilograms
1978	918	4,877	17
1978	919	24,384	1,290
1978	920	145,694	4,403
1978	923	4,877	15
1978	926	14,630	334
1978	927	80,467	2,040
1978	928	31,699	983
1978	929	14,630	19
1978	1020	128,321	973
1978	1021	230,429	4,497
1978	1022	49,835	284
1978	1023	10,973	216
1978	1027	99,792	3,726
1978	1028	201,412	6,526
1978	1029	106,619	845
1978	1108		27
1978	1109		425
1978	1110		531
1978	1113		651
1978	1117	4,267	9
1978	1118	12,192	32
1978	1119	78,029	160
1978	1120	36,576	73
1978	1122	3,048	22
1978	1125	3,658	61
1978	1126	100,249	2,006
1978	1127	101,620	5,542
1978	1128	29,261	258
1978	1129	225,308	1,899
1978	1138	54,864	228
1978	1208		6,133
1978	1209		582
1978	1210		476
1978	1211		1,156
1978	1213		191
1978	1216	21,946	116
1978	1217	63,398	176
1978	1218	30,480	53
1978	1225	60,808	708
1978	1226	128,016	1,002
1978	1227	46,025	2,338
1978	1228	69,616	328
1978	1229	14,630	84
1978	1238	54,864	200
1978	1305		859
1978	1306		351
1978	1307		6,193
1978	1308		860
1978	1309		74
1978	1310		645
1978	1311		1,010
1978	1312		11

Year	Grid	Meters	Kilograms
1978	1314	4,267	58
1978	1315	51,206	350
1978	1316	15,850	37
1978	1328	9,510	107
1978	1329	104,973	1,496
1978	1330	37,308	290
1978	1331	11,339	331
1978	1332	2,926	20
1978	1338	62,179	186
1978	1339	47,549	134
1978	1342	3,505	10
1978	1403		590
1978	1404		47
1978	1405		26
1978	1409		2,206
1978	1410		200
1978	1411		984
1978	1429	16,459	951
1978	1430	49,012	1,834
1978	1431	46,086	601
1978	1434	102,413	298
1978	1444	12,741	263
1978	1445	3,505	7
1978	1530	7,315	20
1978	1531	6,584	23
1978	1532	52,669	1,612
1978	1533	35,814	321
1978	1534	153,924	1,296
1978	1535	914	1
1978	1544	23,470	56
1978	1644	5,486	26
1979	1	107,413	129,571
1979	2	42,794	61,855
1979	4	163,266	78,787
1979	6	6,584	5,810
1979	7	249,585	407,263
1979	9	183	63
1979	23	5,029	1,435
1979	31	24,104	10,317
1979	33	64,099	22,914
1979	522	22	1,282
1979	523	12,192	530
1979	622	28,110	327
1979	718	69,205	847
1979	719	24,384	223
1979	721	14,630	98
1979	818	2,743	11
1979	819	5,486	23
1979	917	114,605	811
1979	918	64,922	357
1979	920	332,842	2,701
1979	927	76,810	657

Year	Grid	Meters	Kilograms
1979	928	113,386	958
1979	929	95,098	317
1979	930	20,726	156
1979	1020	111,557	1,832
1979	1021	179,832	2,817
1979	1022	6,706	21
1979	1027	3,658	459
1979	1028	121,310	4,521
1979	1029	124,358	1,434
1979	1030	17,678	291
1979	1109		10
1979	1110		219
1979	1113		1,996
1979	1119	4,877	5
1979	1120	4,877	41
1979	1125	2,743	14
1979	1126	55,565	1,875
1979	1127	230,673	6,376
1979	1128	14,630	153
1979	1129	27,432	383
1979	1138	58,522	434
1979	1208		8,543
1979	1209		322
1979	1210		758
1979	1211		584
1979	1212		226
1979	1213		0
1979	1225	2,743	50
1979	1226	53,950	1,294
1979	1227	39,014	957
1979	1228	31,699	482
1979	1238	58,522	355
1979	1305		99
1979	1306		29
1979	1307		14,325
1979	1308		7,278
1979	1309		87
1979	1311		1,640
1979	1312		21
1979	1316	14,630	16
1979	1329	98,328	1,701
1979	1404		22
1979	1405		69
1979	1409		2,388
1979	1410		49
1979	1411		1,448
1979	1429	26,335	1,222
1979	1430	14,996	255
1979	1431	38,039	1,284
1979	1432	18,288	269
1979	1434	94,122	263
1979	1435	18,288	41

Year	Grid	Meters	Kilograms
1979	1437	18,288	150
1979	1438	36,576	336
1979	1530	20,483	787
1979	1532	17,556	1,372
1979	1533	130,302	2,399
1979	1534	83,058	1,815
1979	1544	16,764	91
1979	1545	91,440	240
1979	1644	12,131	57
1980	1	167,107	194,820
1980	2	158,923	201,041
1980	4	61,448	81,517
1980	6	3,475	1,215
1980	7	347,179	597,996
1980	9	549	1,422
1980	23	1,829	3,402
1980	28	1,372	113
1980	31	5,121	699
1980	33	75,895	12,227
1980	34	5,578	56
1980	523	4,877	20
1980	620	4,877	24
1980	623	12,802	113
1980	718	27,222	93
1980	719	10,363	54
1980	721	9,754	41
1980	817	25,603	76
1980	818	30,175	169
1980	819	2,743	7
1980	917	68,915	309
1980	918	96,926	779
1980	920	202,296	1,637
1980	926	18,288	307
1980	927	54,864	487
1980	928	69,494	961
1980	929	71,323	490
1980	1018	12,802	15
1980	1020	114,087	1,587
1980	1021	186,294	1,987
1980	1022	4,389	9
1980	1023	13,106	59
1980	1028	136,550	5,159
1980	1029	65,837	682
1980	1109		30
1980	1110		58
1980	1113		646
1980	1117	8,534	23
1980	1118	12,192	37
1980	1119	13,411	188
1980	1125	8,230	41
1980	1126	88,605	1,847
1980	1127	141,031	4,282

Year	Grid	Meters	Kilograms
1980	1128	14,630	919
1980	1130	51,206	675
1980	1137	18,288	142
1980	1138	35,357	275
1980	1207		256
1980	1208		16,195
1980	1209		3,697
1980	1210		845
1980	1211		1,057
1980	1217	4,877	29
1980	1224	2,448	51
1980	1225	14,265	277
1980	1226	27,737	209
1980	1227	17,922	331
1980	1228	36,576	559
1980	1238	54,864	594
1980	1304		388
1980	1305		317
1980	1306		40
1980	1307		24,391
1980	1308		516
1980	1309		21
1980	1310		366
1980	1311		1,735
1980	1314	4,877	27
1980	1315	24,384	121
1980	1316	4,877	33
1980	1327	3,658	68
1980	1329	80,711	1,119
1980	1335	9,144	28
1980	1338	36,576	486
1980	1339	39,624	709
1980	1403		15
1980	1405		73
1980	1409		1,555
1980	1410		28
1980	1411		2,008
1980	1429	2,926	104
1980	1431	40,965	921
1980	1432	5,822	150
1980	1433	19,020	434
1980	1434	108,387	938
1980	1435	2,286	1
1980	1530	40,965	1,160
1980	1531	8,778	202
1980	1532	5,852	334
1980	1533	74,036	1,145
1980	1534	59,954	913
1981	1	125,227	109,296
1981	2	95,829	160,974
1981	4	123,444	23,032
1981	6	28,255	10,822

Year	Grid	Meters	Kilograms
1981	7	268,318	595,151
1981	9	134,417	94,950
1981	26	5,486	1,447
1981	28	4,206	951
1981	31	10,973	1,229
1981	33	24,689	9,719
1981	522	366	203
1981	523	3,658	3
1981	524	7,315	16
1981	623	46,330	118
1981	624	26,822	98
1981	718	9,845	425
1981	720	3,353	21
1981	721	4,877	14
1981	722	8,534	16
1981	817	65,319	352
1981	818	30,389	290
1981	819	3,566	51
1981	820	9,754	65
1981	917	27,432	189
1981	918	62,789	511
1981	920	60,350	327
1981	927	2,743	166
1981	928	24,384	706
1981	929	27,432	44
1981	1020	105,156	346
1981	1021	7,925	29
1981	1022	732	11
1981	1023	4,877	14
1981	1028	35,052	1,941
1981	1029	53,340	463
1981	1126	24,140	464
1981	1127	25,969	309
1981	1128	9,754	53
1981	1139	53,645	269
1981	1207		1,320
1981	1208		6,334
1981	1209		7
1981	1210		434
1981	1211		9
1981	1224	23,409	628
1981	1225	23,317	95
1981	1226	46,086	376
1981	1227	17,252	119
1981	1228	4,877	104
1981	1238	51,206	211
1981	1239	3,658	13
1981	1304		1,877
1981	1305		1,422
1981	1306		1,509
1981	1307		70
1981	1308		3,059

Year	Grid	Meters	Kilograms
1981	1309		854
1981	1310		921
1981	1311		2,586
1981	1403		453
1981	1405		4,086
1981	1409		1,192
1981	1410		11
1981	1411		1,569
1981	1412		27
1981	1429	15,606	1,508
1981	1431	37,399	717
1981	1432	2,286	8
1981	1433	2,286	2
1981	1434	51,206	215
1981	1437	43,891	365
1981	1438	37,795	295
1981	1442	0	4
1981	1443	0	66
1981	1444	0	9
1981	1529	16,764	705
1981	1530	21,458	786
1981	1532	6,858	21
1981	1533	9,327	1,235
1981	1534	99,974	1,552
1981	1535	3,048	8
1981	1544	762	588
1981	1545	0	3
1981	1644	732	369
1981	1645	1,036	878
1981	1646	0	14
1982	1	106,619	70,211
1982	2	116,037	114,095
1982	6	30,815	21,112
1982	7	393,626	625,569
1982	9	70,866	42,163
1982	11	2,560	864
1982	12	5,121	1,119
1982	18	2,560	173
1982	26	2,286	660
1982	28	7,407	980
1982	31	14,265	784
1982	33	5,258	417
1982	718	396	65
1982	720	9,540	20
1982	816	29,261	244
1982	817	39,014	290
1982	818	24,384	105
1982	820	4,877	34
1982	916	4,877	25
1982	917	9,754	40
1982	927	19,507	518
1982	928	46,634	555

Year	Grid	Meters	Kilograms
1982	1020	63,094	582
1982	1022	457	13
1982	1028	1,829	159
1982	1029	9,144	95
1982	1125	732	14
1982	1207		1,378
1982	1208		9,620
1982	1209		888
1982	1210		1
1982	1212		1
1982	1213		1
1982	1224	39,014	479
1982	1226	14,021	419
1982	1228	18,288	492
1982	1304		1,301
1982	1305		2,380
1982	1306		1,737
1982	1307		2,218
1982	1308		9,553
1982	1309		717
1982	1310		2,369
1982	1311		2,106
1982	1329	30,724	646
1982	1405		6,635
1982	1409		313
1982	1410		1,463
1982	1411		1
1982	1434	1,524	11
1982	1443	0	59
1982	1529	15,362	1,231
1982	1530	26,335	778
1982	1531	23,409	862
1982	1533	0	422
1982	1534	0	524
1982	1544	0	93
1982	1644	0	258
1982	1645	0	15
1983	1	17,922	14,318
1983	6	9,327	6,057
1983	7	253,655	453,359
1983	9	3,658	3,187
1983	26	5,486	450
1983	28	12,984	3,948
1983	31	7,132	517
1983	32	914	85
1983	33	9,693	2,447
1983	522	4,328	1,334
1983	623	4,877	23
1983	715	12,131	1,149
1983	716	62,316	6,256
1983	718	244	179
1983	719	366	1

Year	Grid	Meters	Kilograms
1983	811	114,239	20,784
1983	812	103,518	11,982
1983	813	2,286	24
1983	814	10,851	883
1983	927	14,935	214
1983	928	27,432	393
1983	1007	35,479	1,150
1983	1020	3,658	32
1983	1021	4,572	102
1983	1106	211,522	24,927
1983	1119	22,860	202
1983	1125	1,219	18
1983	1128	21,946	3,447
1983	1204	56,967	1,380
1983	1205	15,850	194
1983	1207		884
1983	1208		627
1983	1209		658
1983	1210		193
1983	1211		1,351
1983	1212		4
1983	1213		1
1983	1218	27,432	176
1983	1224	16,276	216
1983	1225	49,378	960
1983	1226	23,165	1,247
1983	1227	3,658	14
1983	1228	14,783	345
1983	1302	26,822	325
1983	1303	36,027	1,200
1983	1304		1,533
1983	1305		7,703
1983	1306		1,712
1983	1307		565
1983	1308		706
1983	1309		91
1983	1310		4,679
1983	1311		3,773
1983	1329	23,652	971
1983	1401	9,784	5,270
1983	1405		2,422
1983	1409		286
1983	1410		31
1983	1411		177
1983	1412		54
1983	1431	17,922	322
1983	1433	11,704	1,239
1983	1529	20,483	1,144
1983	1530	11,704	635
1983	1531	5,852	379
1983	1534	2,926	346
1983	1544	0	11

Year	Grid	Meters	Kilograms
1983	1645	0	14
1984	1	72,603	34,020
1984	2	27,981	35,257
1984	6	9,830	6,362
1984	7	488,573	699,307
1984	9	30,907	12,627
1984	24	914	499
1984	26	686	686
1984	28	1,372	284
1984	31	2,515	139
1984	33	7,315	1,208
1984	522	1,494	156
1984	715	80,863	8,407
1984	716	57,138	4,873
1984	718	15,758	2,542
1984	811	74,760	7,912
1984	817	4,877	75
1984	818	29,261	313
1984	927	51,816	630
1984	928	5,486	83
1984	929	18,288	191
1984	1007	26,883	472
1984	1020	1,829	1
1984	1021	54,864	584
1984	1028	5,486	180
1984	1029	36,576	430
1984	1106	136,736	9,980
1984	1109		835
1984	1110		286
1984	1125	3,658	52
1984	1128	42,672	2,949
1984	1139	7,315	16
1984	1204	4,206	233
1984	1207		480
1984	1208		714
1984	1209		2,713
1984	1210		389
1984	1211		6,008
1984	1212		1
1984	1224	1,829	23
1984	1226	17,069	1,238
1984	1228	8,230	116
1984	1229	3,048	23
1984	1230	49,682	576
1984	1238	18,288	26
1984	1239	32,918	88
1984	1240	21,946	97
1984	1241	3,658	2
1984	1302	13,497	190
1984	1303	52,999	2,187
1984	1304		3,460
1984	1305		12,290

Year	Grid	Meters	Kilograms
1984	1306		682
1984	1307		769
1984	1308		8,476
1984	1309		3
1984	1310		5,311
1984	1311		2,838
1984	1312		107
1984	1329	21,488	170
1984	1330	28,651	111
1984	1337	18,288	244
1984	1338	21,946	364
1984	1340	7,315	516
1984	1341	10,973	1,191
1984	1401	26,554	4,808
1984	1405		2,636
1984	1409		115
1984	1410		51
1984	1411		2,700
1984	1432	13,106	205
1984	1433	1,219	14
1984	1434	16,459	63
1984	1444	0	32
1984	1529	3,353	777
1984	1530	49,012	1,575
1984	1532	7,010	130
1984	1544	0	143
1984	1644	1,097	347
1984	1645	0	37
1984	1646	0	3
1985	1	50,109	23,295
1985	2	53,127	34,377
1985	5	1,372	62
1985	6	7,315	13,777
1985	7	413,876	555,464
1985	9	28,090	13,578
1985	11	2,743	66
1985	12	3,018	73
1985	26	10,058	3,143
1985	28	8,230	3,601
1985	33	39,776	6,047
1985	522	9,418	1,060
1985	619	1,219	5
1985	715	18,288	965
1985	716	57,424	3,094
1985	718	3,383	4,039
1985	720	8,748	226
1985	810	69,190	4,686
1985	811	24,994	1,281
1985	812	2,477	61
1985	927	58,522	398
1985	1007	13,533	241
1985	1022	25,603	1,002

Year	Grid	Meters	Kilograms
1985	1028	10,973	120
1985	1106	108,856	4,990
1985	1110		616
1985	1127	9,144	323
1985	1128	21,946	1,119
1985	1204	45,354	1,121
1985	1205	12,924	84
1985	1207		734
1985	1208		233
1985	1209		1,355
1985	1210		39
1985	1211		455
1985	1212		112
1985	1226	12,802	14
1985	1228	42,062	238
1985	1229	63,398	370
1985	1302	14,240	582
1985	1303	77,480	3,406
1985	1304		4,390
1985	1305		10,771
1985	1306		743
1985	1307		1,288
1985	1308		2,940
1985	1309		34
1985	1310		3,932
1985	1311		1,309
1985	1327	10,973	261
1985	1328	24,384	562
1985	1401	26,152	5,750
1985	1409		195
1985	1410		360
1985	1411		995
1985	1412		26
1985	1432	35,662	238
1985	1433	26,213	161
1985	1438	0	136
1985	1529	24,384	1,368
1985	1530	7,925	1,218
1985	1532	8,778	376
1985	1533	13,533	1,813
1985	1534	12,680	317
1985	1544	0	399
1985	1644	0	49
1985	1645	0	120
1986	1	85,771	53,437
1986	2	27,341	29,975
1986	6	31,547	30,095
1986	7	500,241	698,872
1986	9	9,601	9,045
1986	26	3,658	2,579
1986	28	2,743	1,134
1986	31	3,200	181

Year	Grid	Meters	Kilograms
1986	33	3,200	245
1986	522	6,492	1,990
1986	718	2,408	2,901
1986	720	17,983	1,241
1986	920	4,572	27
1986	927	16,459	297
1986	1020	2,743	91
1986	1109	0	887
1986	1127	2,743	104
1986	1128	2,743	86
1986	1129	3,658	9
1986	1207	0	1,219
1986	1208	34,747	20,334
1986	1209	5,486	4,205
1986	1210	0	4
1986	1211	0	1,051
1986	1212	0	138
1986	1304	0	4,876
1986	1305	41,453	14,020
1986	1306	0	73
1986	1307	0	27
1986	1308	15,850	5,290
1986	1309	0	76
1986	1310	1,219	2,926
1986	1311	0	4,245
1986	1405	3,048	919
1986	1409	70,622	11,008
1986	1410	22,951	5,328
1986	1411	0	165
1986	1423	14,508	2,169
1986	1444	0	108
1986	1530	21,580	875
1986	1531	5,121	152
1986	1534	14,143	1,838
1986	1544	0	91
1986	1644	0	52
1986	1645	0	103
1986	1646	7,681	725
1987	1	231,892	107,611
1987	2	50,566	21,103
1987	6	38,405	26,365
1987	7	737,189	499,319
1987	9	5,852	791
1987	19	9,144	95
1987	27	8,230	5,547
1987	31	3,658	73
1987	33	12,802	159
1987	34	7,315	359
1987	714	7,696	3,321
1987	715	32,004	8,308
1987	716	47,396	6,313
1987	718	4,572	3,037

Year	Grid	Meters	Kilograms
1987	720	1,067	1,127
1987	811	48,925	5,265
1987	908	2,469	125
1987	927	4,023	70
1987	1106	157,269	11,542
1987	1127	14,722	1,477
1987	1204	43,708	1,186
1987	1205	7,925	57
1987	1207	0	138
1987	1208	56,388	26,345
1987	1211	0	7,918
1987	1302	7,385	987
1987	1303	43,925	2,028
1987	1304	0	5,984
1987	1305	12,192	14,248
1987	1306	0	469
1987	1307	1,219	684
1987	1308	61,265	32,596
1987	1309	0	53
1987	1310	0	9,769
1987	1311	0	8,939
1987	1323	1,372	46
1987	1401	32,089	5,064
1987	1404	0	209
1987	1405	3,658	3,934
1987	1409	31,242	5,572
1987	1410	23,470	5,990
1987	1423	37,734	4,069
1987	1438	0	44
1987	1441	0	2
1987	1444	0	68
1987	1534	23,409	2,201
1987	1535	3,658	449
1987	1544	0	199
1987	1545	1,097	240
1987	1546	4,755	259
1987	1644	0	179
1987	1645	38,405	2,618
1987	1646	35,113	3,398
1988	1	164,409	140,355
1988	2	42,062	28,156
1988	4	11,887	6,096
1988	6	3,018	562
1988	7	308,244	121,001
1988	9	48,097	24,269
1988	26	4,115	1,580
1988	28	4,572	1,077
1988	31	5,029	1,225
1988	33	10,973	1,409
1988	715	74,585	20,571
1988	716	69,129	10,391
1988	718	7,986	4,501

Year	Grid	Meters	Kilograms
1988	811	28,721	11,743
1988	1106	172,756	9,534
1988	1127	5,944	987
1988	1128	1,981	10
1988	1204	9,327	485
1988	1205	38,405	3,512
1988	1208	8,534	4,987
1988	1211	0	231
1988	1226	20,117	5
1988	1302	6,376	1,261
1988	1303	15,179	2,547
1988	1304	0	8,927
1988	1305	7,315	13,936
1988	1306	0	1,931
1988	1307	0	969
1988	1308	2,438	6,366
1988	1309	5,364	1,867
1988	1310	0	3,473
1988	1311	0	41
1988	1324	1,506	585
1988	1401	8,291	2,071
1988	1409	91,684	14,157
1988	1410	44,958	21,019
1988	1423	43,899	5,898
1988	1431	18,288	10
1988	1441	0	6
1988	1444	914	934
1988	1533	2,926	24
1988	1534	2,926	18
1988	1544	0	591
1988	1545	0	24
1988	1546	2,926	539
1988	1644	0	126
1988	1645	0	337
1988	1646	2,469	315
1989	1	123,883	57,519
1989	2	51,664	35,201
1989	4	7,224	861
1989	6	13,716	3,819
1989	7	457	37
1989	9	13,442	26,050
1989	27	6,401	645
1989	33	146,761	4,236
1989	714	25,603	1,604
1989	715	73,640	27,188
1989	718	6,492	3,184
1989	811	79,844	30,912
1989	814	2,896	94
1989	911	26,822	4,998
1989	1010	2,743	335
1989	1026	6,340	6,319
1989	1106	142,730	24,290

Year	Grid	Meters	Kilograms
1989	1125	373	52
1989	1126	366	162
1989	1127	6,645	615
1989	1204	1,463	42
1989	1205	17,648	398
1989	1208	13,411	16,545
1989	1211	0	11
1989	1302	5,724	1,696
1989	1303	22,220	7,560
1989	1304	0	809
1989	1305	11,552	24,250
1989	1306	0	905
1989	1307	12,802	17,192
1989	1308	15,149	20,284
1989	1309	0	28
1989	1310	0	14
1989	1311	4,877	1,302
1989	1324	12,192	1,979
1989	1325	1,829	642
1989	1326	373	36
1989	1401	2,048	2,250
1989	1405	610	300
1989	1409	52,883	14,883
1989	1410	45,720	36,919
1989	1423	50,034	7,884
1989	1441	0	15
1989	1443	0	2
1989	1444	183	370
1989	1534	3,475	1,407
1989	1544	0	136
1989	1545	0	73
1989	1644	0	107
1989	1645	23,592	1,365
1989	1646	0	1
1990	0	1,829	3,550
1990	1	72,786	54,884
1990	2	61,722	28,182
1990	4	732	996
1990	5	1,097	1,570
1990	6	25,420	8,293
1990	7	1,920	1,316
1990	9	14,173	22,455
1990	24	366	361
1990	26	457	36
1990	29	3,658	78
1990	31	10,516	3,571
1990	33	53,950	5,210
1990	34	5,486	641
1990	714	24,003	4,828
1990	715	41,285	14,472
1990	716	74,219	23,173
1990	718	6,584	3,211

Year	Grid	Meters	Kilograms
1990	811	101,024	23,457
1990	1106	76,246	16,555
1990	1108	12,070	479
1990	1125	3,658	1
1990	1126	5,944	67
1990	1204	19,842	1,353
1990	1205	9,784	373
1990	1208	18,288	7,216
1990	1224	1,524	50
1990	1302	6,072	1,225
1990	1303	32,583	8,230
1990	1304		3,160
1990	1305	36,576	41,325
1990	1306	20,665	8,678
1990	1307	36,546	62,536
1990	1308		34
1990	1309	48,768	14,761
1990	1310	914	460
1990	1324	1,219	127
1990	1401	658	98
1990	1402	24,719	13,531
1990	1405	12,497	13,336
1990	1409	46,970	14,284
1990	1410	61,935	55,013
1990	1423	31,852	7,584
1990	1439	0	44
1990	1440	0	47
1990	1441	0	35
1990	1443	0	6
1990	1444	7,041	867
1990	1534	9,144	3,163
1990	1544	0	710
1990	1545	0	37
1990	1634	91	0
1990	1644	152	792
1990	1645	5,364	909
1990	1646	2,286	361
1991	0	10,973	11,037
1991	1	65,105	36,420
1991	2	63,825	40,833
1991	6	11,521	10,572
1991	7	61,311	50,803
1991	9	20,848	25,534
1991	12	3,200	3,343
1991	28	1,829	511
1991	31	37,490	7,047
1991	32	4,572	281
1991	33	79,004	5,516
1991	34	10,973	624
1991	714	52,447	20,416
1991	715	86,304	34,595
1991	716	4,267	943

Year	Grid	Meters	Kilograms
1991	718	29,566	1,945
1991	811	48,768	12,893
1991	812	31,143	9,600
1991	814	305	61
1991	1007	3,505	370
1991	1008	13,606	706
1991	1026	1,219	167
1991	1106	74,950	11,892
1991	1125	5,486	2,779
1991	1204	6,614	758
1991	1205	12,040	1,083
1991	1208	12,192	2,522
1991	1211	4,572	243
1991	1223	366	23
1991	1224	366	68
1991	1302	5,998	1,123
1991	1303	32,187	11,924
1991	1304	20,117	1,215
1991	1305	178,308	19,858
1991	1306	31,394	18,403
1991	1307	54,102	45,199
1991	1308	5,029	179
1991	1309	32,675	5,928
1991	1310	17,252	1,344
1991	1323	18,151	1,079
1991	1324	10,424	6,350
1991	1325	2,926	1,202
1991	1401	9,906	1,844
1991	1402	63,612	2,278
1991	1405	1,219	45
1991	1409	145,268	36,863
1991	1410	17,678	8,001
1991	1423	23,393	5,210
1991	1440	0	1
1991	1441	0	39
1991	1442	0	10
1991	1443	0	11
1991	1444	10,881	793
1991	1534	0	51
1991	1544	0	3,005
1991	1545	0	127
1991	1644	0	161
1991	1645	3,444	921
1991	1646	44,348	12,025
1992	1	100,584	58,214
1992	2	53,127	39,790
1992	4	8,412	10,824
1992	6	18,014	15,218
1992	7	114,867	96,655
1992	9	66,294	37,540
1992	12	6,949	3,946
1992	28	1,829	183

Year	Grid	Meters	Kilograms
1992	31	9,601	6,154
1992	32	6,858	285
1992	33	61,722	4,521
1992	34	2,743	455
1992	714	44,531	11,846
1992	715	45,354	18,506
1992	716	78,175	27,646
1992	718	3,810	4,436
1992	811	41,064	16,117
1992	812	16,154	10,714
1992	814	27,804	21,770
1992	1007	3,429	474
1992	1024	4,755	1,613
1992	1026	2,195	132
1992	1106	52,349	10,803
1992	1108	12,728	714
1992	1125	5,334	2,599
1992	1205	12,741	1,529
1992	1208	16,154	16,009
1992	1219	488	48
1992	1302	14,691	4,565
1992	1303	64,069	23,632
1992	1305	2,438	1,660
1992	1306	7,315	2,361
1992	1307	122,545	107,849
1992	1308	152	1
1992	1309	29,505	10,825
1992	1310	7,010	4,104
1992	1323	25,116	2,000
1992	1324	7,681	1,854
1992	1327	914	122
1992	1342	6,401	787
1992	1343	0	3
1992	1401	12,954	13,300
1992	1405	16,459	10,983
1992	1409	115,839	25,478
1992	1410	29,078	20,949
1992	1423	52,692	8,989
1992	1428	5,486	6,674
1992	1430	10,973	3,418
1992	1432	1,829	125
1992	1441	0	4
1992	1442	0	45
1992	1443	0	59
1992	1444	2,438	934
1992	1533	1,829	517
1992	1534	2,926	882
1992	1544	0	2,335
1992	1545	23,470	5,504
1992	1644	2,195	536
1992	1645	7,894	1,076
1992	1646	16,093	2,685

Year	Grid	Meters	Kilograms
1993	1	88,880	84,863
1993	2	71,232	71,294
1993	4	2,743	2,541
1993	6	17,374	12,275
1993	7	115,918	91,362
1993	9	47,732	32,797
1993	12	4,389	3,175
1993	24	1,372	1,433
1993	28	549	14
1993	31	1,829	1,331
1993	33	6,401	1,592
1993	714	47,421	46,686
1993	715	34,107	19,756
1993	716	32,507	25,300
1993	718	2,835	3,878
1993	720	610	307
1993	811	39,438	45,981
1993	812	10,205	1,387
1993	1007	5,105	789
1993	1024	610	200
1993	1026	3,993	775
1993	1106	46,500	8,471
1993	1107	14,082	906
1993	1122	1,006	110
1993	1125	6,706	1,159
1993	1204	640	512
1993	1205	19,349	2,219
1993	1208	1,219	431
1993	1219	640	20
1993	1302	6,133	3,543
1993	1303	30,907	12,766
1993	1304	7,766	10,966
1993	1305	34,534	20,493
1993	1306	549	41
1993	1307	97,810	31,452
1993	1308	6,096	5,170
1993	1309	10,973	3,927
1993	1310	3,109	1,312
1993	1323	4,999	1,210
1993	1324	8,047	2,629
1993	1325	3,048	1,139
1993	1329	7,315	1,549
1993	1401	7,041	1,640
1993	1405	4,328	2,667
1993	1409	97,719	28,507
1993	1410	19,263	9,292
1993	1423	43,300	9,326
1993	1429	3,658	1,003
1993	1430	1,829	176
1993	1434	21,458	8,218
1993	1440	0	22
1993	1441	0	14

Year	Grid	Meters	Kilograms
1993	1443	0	88
1993	1444	0	1,856
1993	1512	5,486	9,011
1993	1544	4,511	2,028
1993	1545	6,675	2,317
1993	1644	0	163
1993	1645	2,926	1,153
1993	1646	8,108	5,934
1994	1	81,930	86,705
1994	2	87,142	78,596
1994	4	5,486	2,903
1994	6	14,082	14,789
1994	7	150,556	119,651
1994	9	57,287	39,050
1994	12	2,835	3,425
1994	714	50,597	52,252
1994	715	37,643	34,485
1994	716	31,181	25,268
1994	718	823	210
1994	811	49,982	40,489
1994	812	15,499	1,577
1994	912	2,682	322
1994	1007	4,343	1,331
1994	1008	10,058	995
1994	1026	3,658	468
1994	1106	37,155	7,884
1994	1204	10,162	4,194
1994	1205	15,545	1,919
1994	1224	17,831	3,629
1994	1303	36,637	15,526
1994	1305	14,143	19,107
1994	1306	11,826	6,325
1994	1307	24,933	10,987
1994	1308	5,742	4,265
1994	1309	11,095	3,176
1994	1310	3,475	2,051
1994	1323	1,768	158
1994	1324	6,645	1,235
1994	1325	914	272
1994	1326	975	386
1994	1329	2,438	753
1994	1402	3,581	2,160
1994	1404	91	680
1994	1405	1,890	408
1994	1409	72,009	19,855
1994	1410	37,247	21,062
1994	1414	427	33
1994	1423	61,570	9,780
1994	1424	146	7
1994	1429	1,829	620
1994	1430	1,219	552
1994	1434	1,829	403

Year	Grid	Meters	Kilograms
1994	1440	0	3
1994	1441	0	75
1994	1442	2,286	51
1994	1443	0	370
1994	1444	0	2,547
1994	1534	21,580	12,263
1994	1544	1,829	1,807
1994	1545	18,837	2,011
1994	1546	0	11
1994	1644	0	5
1994	1645	9,936	3,298
1994	1646	45,171	3,782
1995	1	93,635	87,441
1995	2	106,528	70,631
1995	4	3,658	4,094
1995	6	14,996	14,812
1995	7	180,845	112,974
1995	9	58,064	37,334
1995	714	34,747	22,603
1995	715	67,605	55,769
1995	716	45,171	21,599
1995	718	2,027	920
1995	811	35,509	21,099
1995	812	34,503	14,683
1995	814	16,234	24,510
1995	912	12,497	4,487
1995	1007	3,200	356
1995	1008	110	5
1995	1024	1,097	55
1995	1106	30,129	5,236
1995	1205	32,918	3,854
1995	1302	12,073	2,749
1995	1303	38,880	9,952
1995	1305	7,010	8,143
1995	1306	2,438	625
1995	1307	55,931	9,219
1995	1309	2,438	411
1995	1310	15,728	4,688
1995	1323	1,219	611
1995	1325	6,462	1,630
1995	1401	2,134	1,028
1995	1405	1,707	288
1995	1409	98,709	31,002
1995	1410	41,422	12,247
1995	1414	1,524	369
1995	1423	13,960	2,445
1995	1430	2,926	1,524
1995	1441	0	79
1995	1442	15,545	2,067
1995	1443	0	73
1995	1444	6,706	2,256
1995	1534	12,680	8,314

Year	Grid	Meters	Kilograms
1995	1544	2,195	983
1995	1545	0	3
1995	1546	11,704	516
1995	1645	19,263	4,403
1995	1646	55,047	21,475
1996	1	83,393	65,547
1996	2	92,629	71,519
1996	4	21,488	17,017
1996	5	3,383	2,858
1996	6	20,483	12,838
1996	7	246,614	120,666
1996	9	80,924	41,187
1996	33	2,012	30
1996	622	1,158	193
1996	714	27,402	22,306
1996	715	48,829	41,295
1996	716	26,213	20,451
1996	718	1,387	408
1996	811	36,232	33,428
1996	812	42,962	21,173
1996	814	16,240	17,507
1996	911	671	141
1996	912	9,845	1,074
1996	1007	4,343	508
1996	1026	3,109	442
1996	1106	33,209	5,116
1996	1125	2,652	878
1996	1205	38,405	4,972
1996	1209	716	72
1996	1210	5,319	696
1996	1211	1,189	204
1996	1302	10,497	3,251
1996	1303	20,501	5,409
1996	1305	15,545	14,396
1996	1307	34,793	13,057
1996	1309	12,055	2,424
1996	1310	30,523	10,508
1996	1311	488	36
1996	1323	4,267	416
1996	1324	1,646	1,052
1996	1325	3,292	2,318
1996	1326	2,438	304
1996	1401	3,932	1,315
1996	1405	16,916	4,374
1996	1409	103,586	28,290
1996	1410	35,204	8,251
1996	1423	22,570	4,995
1996	1430	5,486	2,707
1996	1438	0	191
1996	1443	0	54
1996	1444	2,926	859
1996	1534	1,219	245

Year	Grid	Meters	Kilograms
1996	1544	0	199
1996	1545	7,132	724
1996	1546	2,560	1,434
1996	1644	0	34
1996	1645	2,164	860
1996	1646	41,910	13,229
1997	1	131,491	94,104
1997	2	85,222	85,571
1997	4	11,156	10,590
1997	6	20,391	15,157
1997	7	211,775	129,132
1997	9	48,280	40,834
1997	12	732	130
1997	622	2,377	196
1997	714	38,313	24,070
1997	715	67,772	55,698
1997	716	11,765	5,335
1997	718	533	228
1997	811	73,112	39,404
1997	812	27,914	13,816
1997	814	1,756	274
1997	911	146	14
1997	912	5,060	1,358
1997	1007	3,658	461
1997	1106	43,300	11,013
1997	1205	49,378	5,660
1997	1302	16,654	5,376
1997	1303	36,765	13,908
1997	1305	15,697	17,418
1997	1306	28,346	9,942
1997	1307	30,419	15,427
1997	1310	18,075	5,352
1997	1323	2,134	335
1997	1401	3,840	3,048
1997	1409	44,684	18,733
1997	1410	20,178	4,517
1997	1423	10,161	1,039
1997	1428	1,829	140
1997	1441	0	6
1997	1442	0	55
1997	1444	0	370
1997	1529	2,134	1,416
1997	1534	3,292	1,962
1997	1544	0	112
1997	1545	30,175	10,094
1997	1644	0	172
1997	1645	4,846	1,288
1997	1646	14,234	7,107
1998	1	84,948	101,373
1998	2	50,566	87,249
1998	4	33,650	20,328
1998	6	9,693	10,877

Year	Grid	Meters	Kilograms
1998	7	124,907	111,190
1998	9	58,613	50,396
1998	12	6,218	3,533
1998	714	23,957	16,152
1998	715	51,709	32,012
1998	716	24,890	28,939
1998	811	32,882	20,349
1998	812	71,107	55,760
1998	814	610	340
1998	1007	2,629	444
1998	1106	48,006	10,137
1998	1205	53,127	9,070
1998	1302	15,152	7,148
1998	1303	20,973	12,204
1998	1305	14,935	15,477
1998	1307	10,973	10,924
1998	1309	6,828	714
1998	1323	2,012	452
1998	1324	1,920	399
1998	1325	183	64
1998	1342	0	95
1998	1409	11,000	3,968
1998	1423	20,726	4,452
1998	1428	268	125
1998	1438	0	84
1998	1439	0	34
1998	1440	0	6
1998	1441	0	177
1998	1442	0	46
1998	1443	0	59
1998	1444	3,566	915
1998	1534	549	136
1998	1544	0	370
1998	1545	10,378	2,526
1998	1644	0	191
1998	1645	8,138	3,834
1998	1646	2,240	706
1999	1	107,351	102,602
1999	2	70,134	87,621
1999	4	18,837	10,776
1999	6	13,213	10,547
1999	7	194,584	96,053
1999	9	67,757	52,562
1999	12	5,029	1,894
1999	622	91	29
1999	714	26,609	12,004
1999	715	64,252	27,562
1999	716	77,739	31,822
1999	718	640	123
1999	811	30,632	9,065
1999	812	102,361	45,103
1999	1007	2,210	273

Year	Grid	Meters	Kilograms
1999	1106	55,428	9,907
1999	1205	50,932	5,839
1999	1208	8,595	6,001
1999	1224	1,219	61
1999	1302	6,515	2,566
1999	1303	29,453	17,718
1999	1305	19,202	14,917
1999	1307	28,773	19,599
1999	1308	1,097	186
1999	1309	1,128	71
1999	1310	914	13
1999	1326	2,195	998
1999	1409	46,787	26,304
1999	1410	6,584	2,029
1999	1423	15,697	3,270
1999	1424	610	48
1999	1428	3,658	2,625
1999	1429	610	360
1999	1437	0	116
1999	1438	0	434
1999	1439	0	237
1999	1441	137	548
1999	1443	0	96
1999	1444	0	518
1999	1544	0	764
1999	1545	0	1
1999	1644	0	136
1999	1645	1,554	1,057
1999	1646	8,961	4,011
2000	1	104,150	102,368
2000	2	63,642	90,811
2000	4	13,625	6,963
2000	6	15,819	14,724
2000	7	158,831	60,264
2000	9	99,852	52,093
2000	12	23,409	12,078
2000	714	37,765	11,243
2000	715	64,898	32,607
2000	716	71,174	41,809
2000	811	40,386	29,084
2000	812	84,710	41,940
2000	1007	686	211
2000	1106	68,463	19,100
2000	1205	36,728	5,870
2000	1208	4,511	1,463
2000	1302	5,502	1,788
2000	1303	33,866	20,496
2000	1305	9,449	8,952
2000	1307	34,869	20,277
2000	1308	244	9
2000	1323	4,206	742
2000	1325	1,554	308

Year	Grid	Meters	Kilograms
2000	1409	29,413	17,216
2000	1423	6,828	1,162
2000	1428	2,743	528
2000	1437	0	15
2000	1438	0	15
2000	1439	0	21
2000	1441	0	599
2000	1442	0	192
2000	1444	0	398
2000	1544	0	189
2000	1545	1,829	453
2000	1644	0	74
2000	1645	3,840	925
2000	1646	19,629	6,961
2001	1	115,580	99,356
2001	2	92,903	90,848
2001	6	19,568	19,223
2001	7	86,777	50,336
2001	9	65,288	51,921
2001	12	14,996	14,068
2001	714	50,582	26,051
2001	715	69,677	28,183
2001	716	25,756	11,535
2001	811	42,497	15,533
2001	812	96,134	31,265
2001	1007	1,829	297
2001	1026	8,412	413
2001	1106	86,330	20,810
2001	1205	37,948	4,365
2001	1208	914	379
2001	1209	549	479
2001	1224	914	5
2001	1302	274	3
2001	1303	39,388	22,476
2001	1305	10,668	12,484
2001	1306	15,850	6,268
2001	1307	51,328	53,716
2001	1308	2,789	799
2001	1309	3,459	1,055
2001	1310	305	103
2001	1323	4,115	863
2001	1324	610	101
2001	1326	1,463	2,206
2001	1343	0	488
2001	1409	31,577	14,961
2001	1423	12,616	2,724
2001	1424	1,097	287
2001	1428	1,814	733
2001	1429	5,578	1,599
2001	1433	0	35
2001	1437	0	133
2001	1441	0	309

Year	Grid	Meters	Kilograms
2001	1442	0	3
2001	1443	0	4
2001	1444	2,012	2,097
2001	1529	1,829	42
2001	1544	0	501
2001	1546	0	3
2001	1644	0	13
2001	1645	640	397
2001	1646	35,753	10,549
2002	1	155,631	111,668
2002	2	88,514	82,593
2002	4	8,504	5,414
2002	6	914	1,134
2002	7	74,158	36,758
2002	9	65,745	52,383
2002	12	51,572	22,553
2002	714	37,943	22,618
2002	715	32,644	23,130
2002	716	26,575	21,863
2002	811	35,591	14,351
2002	812	152,659	50,002
2002	908	32,309	1,549
2002	909	9,638	1,238
2002	1007	1,143	108
2002	1026	8,230	2,134
2002	1106	96,911	24,208
2002	1205	45,537	6,458
2002	1208	488	924
2002	1210	17,069	8,433
2002	1302	12,948	2,377
2002	1303	41,980	15,985
2002	1305	2,438	18
2002	1306	32,004	9,760
2002	1307	76,276	49,947
2002	1309	6,126	1,770
2002	1310	16,307	6,794
2002	1327	4,328	3,978
2002	1344	0	1,631
2002	1409	6,584	2,893
2002	1410	13,411	5,620
2002	1423	3,048	538
2002	1437	0	26
2002	1438	0	67
2002	1440	0	14
2002	1441	0	421
2002	1442	0	20
2002	1443	0	88
2002	1444	8,534	4,878
2002	1529	5,486	490
2002	1544	0	100
2002	1644	0	66
2002	1645	1,219	164

Year	Grid	Meters	Kilograms
2002	1646	16,154	6,374
2003	1	166,420	87,693
2003	2	131,310	76,661
2003	3	28,900	18,428
2003	6	910	1,043
2003	7	67,940	37,328
2003	9	81,470	52,446
2003	11	1,170	12
2003	12	39,410	20,811
2003	20	8,230	3,902
2003	33	4,480	8
2003	714	19,020	8,329
2003	715	26,700	21,109
2003	716	55,874	37,195
2003	811	29,367	12,800
2003	812	119,329	28,482
2003	909	15,752	1,203
2003	1007	914	21
2003	1106	82,707	9,658
2003	1107	8,656	1,672
2003	1205	62,179	7,934
2003	1208	1	340
2003	1303	55,382	14,130
2003	1305	5,040	19,051
2003	1307	33,040	106,731
2003	1308	2,092	6,804
2003	1310	5,729	35,925
2003	1405	1,461	9,662
2003	1409	4,260	27,080
2003	1414	1,463	1,089
2003	1423	7,346	888
2003	1441	0	658
2003	1442	0	13
2003	1443	0	41
2003	1444	0	733
2003	1544	3,200	453
2003	1645	0	18
2003	1646	14,707	6,446