Strategy and Options for Promoting the Rehabilitation of Cisco in Lake Huron

Lake Huron Technical Committee

Great Lakes Fishery Commission

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Background

Cisco, formerly known as lake herring (*Coregonus artedi)* (See Appendix 1 for a complete listing of common and scientific names of fishes mentioned in this guide), is one of nine coregonine species that originally occurred in Lake Huron. They are a pelagic planktivore that occurred along with six deepwater cisco forms (Eshenroder and Burnham-Curtis 1999). Lake whitefish and round whitefish, two benthivorus coregonines are also wide spread throughout the lake with lake whitefish the most common.

Commercial fisheries operating in Lake Huron from 1867 to 1954 harvested enormous numbers of coregonines that averaged about 3.4 million kg annually (Baldwin and Saalfeld 1962). Cisco accounted for nearly 50% of the coregonine harvest in most years at an average of 1.65 million kg (Baldwin and Saalfeld 1962). Lake whitefish and round whitefish accounted for about 40% of the yield. The deepwater ciscos marketed collectively as 'chubs' accounted for the remainder of the annual coregonine yield. Today, with the decline of the deepwater ciscos and cisco in Lake Huron, lake whitefish has surged in abundance producing a commercial yield that approaches 4.5 million kg in some years (Mohr and Ebener 2005). Modern day yield of cisco is a fraction of its historic level amounting to about 0.02 million kg. Aside from the commercial fishery, coregonines, including cisco, formed the principle prey for key Lake Huron predators (Eshenroder and Burnham-Curtis 1999); lake trout, walleye and burbot. Today, cisco only remain in any abundance in the northern waters of Lake Huron (Figure 1) including; the St. Marys River, North Channel, and parts of Georgian Bay (Mohr and Ebener 2005; Fielder 2000).

The decline of cisco in Lake Huron is summarized by Dobiesz et al. 2005 and Eshenroder and Burnham-Cutis 1999. The decline is attributed to a combination of factors including the increase in abundance of invasive rainbow smelt and alewife, overfishing, and eutrophication (Beeton 1969; Berst and Spangler 1973; Smith 1970; Wells and McLain 1973; Christie 1974; Hartman 1988). The exact cause of modern day, on-going suppression of cisco is not fully understood, but given that overfishing and water quality issues are largely alleviated, it seems likely that on-going competition from alewife and rainbow smelt have been the central reason. Cisco may persist in the northern most reaches of Lake Huron because that area is sufficiently beyond the effective range of alewives in most years.

The Lake Huron Committee of the Great Lakes Fishery Commission developed a fish community objective (FCO) for cisco (DesJardine et al. 1995) to;

Restore lake herring (cisco) to a significant level and protect, and where possible, restore rare deepwater ciscoes.

With cisco relegated to northern most reaches of its normal range within Lake Huron, it is clearly not present in significant levels (lake wide) and is in need of further protection and rehabilitation efforts.

The case for rehabilitation

Aside from achieving the FCO, there exist numerous reasons to actively pursue rehabilitating of cisco in Lake Huron. Recovery of Great Lakes cisco was the principle subject of a workshop held in 2003 (Fitzsimons and O'Gorman 2006). Although the focus of the workshop was on cisco recovery, it was agreed that much of the benefit would stem from converting part of the prey base production away from alewives (alewife reduction) and into this native form. The principle arguments for investing in cisco rehabilitation were (adapted here specifically for Lake Huron):

- The existing prey fish community lacks diversity. Open water predators have subsisted principally on alewives and rainbow smelt. A lack of diversity in diet includes several perils. They include nutritional deficiency from an unvaried diet (see thiamine deficiency below) and the vulnerability of alewives and rainbow smelt to die-offs that have characterized their populations in the four lower Great Lakes (Van Oosten 1944; Greenwood 1970; Colby 1971) . Establishing and maintaining a diverse prey fish community is another FCO developed by the Lake Huron Committee.
- Alewives in the Great Lakes are rich in thiaminase, an enzyme that reduces thiamine in predators that consume them (Fitzsimons et al. 1998; Tillitt et al. 2000). A lack of thiamine has been tied to early mortality syndrome (EMS) in lake trout and other species (Fitzsimons et al. 1999; Ketola et al. 2000). This has lead to speculation that lake trout are not recovered in Lake Huron partly due to diets consisting primarily of alewives. Conversely, cisco are very low in thiaminase and diversifying the diet of piscivorus predators through the inclusion of cisco could minimize the prevalence of EMS and contribute positively to lake trout rehabilitation.
- Cisco are well adapted to the Great Lakes climate and environment (Eshenroder and Burnham-Curtis 1999). Lake Huron is fully within their native range. Alewives, on the other hand, are at the northern limit of their range and can experience poor over-winter survival in some years (Snyder and Hennessey 2003), leading to wide fluctuations in abundance. Wide and sudden fluctuations in prey fish abundance increase the probability of an unbalanced predator/prey relationship in Lake Huron.
- Cisco achieve a larger overall body size than alewives and rainbow smelt. A large bodied prey item is essential to allow for efficient and energetically advantageous feeding by many Great Lakes piscivorus predators including lake trout (Mason et al. 1998). Recent analysis of lake trout growth parameters indicate that their current maximum growth is below the level necessary to allow for efficient gamete production and reproduction (J. He, Michigan Department of Natural Resources, Alpena Fisheries Research Station, unpublished data).
- By rehabilitating cisco to at least part of the pelagic open water niche in Lake Huron, the predacious effects of alewives could be minimized. Alewives are efficient predators on newly hatched fish fry and their predation has been identified as one of the factors limiting the production of lake trout (Krueger et al. 1995) and percids (walleye and yellow perch) (Mason and Brandt 1996; Fielder and Baker 2004; Bunnell et al. 2006).
- Cisco are sought by both commercial fisheries and recreational anglers on Lake Huron, consequently their rehabilitation may convert much of the prey fish biomass from the unpalatable forms like alewife to a more desirable form.

Opportunity for rehabilitation

The ability of cisco to regain the open water pelagic niche in Lake Huron will partly depend upon the suppression of smelt and alewives (DesJardine et al. 1995; Stockwell et al. In Prep.). Such suppression may occur in several forms. Predation by piscivorus predators in Lake Huron includes Chinook salmon, burbot, lake trout, and walleye. Succession of planktivorous species in the Great Lakes is usually driven by predation (Eshenroder and Burnham-Curtis 1999). Over-winter mortality or post-spawning die-offs of alewives and rainbow smelt may also create years of low abundance. Years of high predator abundance in combination with high natural alewife and smelt mortality may produce the lowest periods of abundance for these two species.

Alewives and rainbow smelt have been reduced or are declining throughout much of the Great Lakes including Lake Huron (Madenjian et al. 2002; Mills et al. 2003; Bronte et al. 2003; Argyle 2005; O'Gorman et al. 2007). Most recently, adult alewives have been in low abundance for more than one consecutive year, an unusual occurrence in Lake Huron (J. Schaeffer, USGS Great Lakes Science Center, Ann Arbor, personal communication). These periods of low alewife and rainbow smelt abundance create windows of opportunity to promote the rehabilitation of native prey fish. It is during these occurrences that cisco may be able to expand their existing distribution and/or survive reintroduction.

Possible negative consequences of cisco rehabilitation

While there is little, if any scientific literature that describes negative impacts from rehabilitation of native species, there are several potential negative consequences of cisco rehabilitation in Lake Huron that might be considered.

- Cisco may provide some competition with lake whitefish. Consequences might be lower lake whitefish abundance in the face of increasing cisco abundance. Commercial fishermen generally prize lake whitefish more so than cisco as whitefish command a greater market value. The likelihood of cisco and lake whitefish competition, however, is not great since they typically occupy different niches, with cisco demonstrating a more pelagic existence and lake whitefish a more benthic existence. Historically, the harvest of lake whitefish was much lower than it is today. However, the combined harvest of lake whitefish and cisco was the same in the early 1900s as the lake whitefish harvest alone is today. In theory, total coregonid harvest could still remain unchanged. Re-allocation of some of the coregonine production potential away from lake whitefish would not be inconsistent with current management objectives. On-the-other-hand, certainly whitefish were very abundant in Lake Huron at the time of European settlement (Spangler and Peters 1995) as were cisco, so negative impacts of cisco on lake whitefish is largely unsubstantiated.
- The degree to which Chinook salmon can or will consume a native coregonine like cisco is not completely clear (Eshenroder and Burnham-Curtis 1999). Chinook salmon in Lake Superior regularly include cisco in their diet (Conner et al. 1993). The emergence of record size Chinook salmon in the Minnesota and Wisconsin waters of Lake Superior in the late 1980s was partially credited to the rehabilitation of cisco. It is therefore believed that this is a minimal risk and that Chinook salmon should also benefit from cisco rehabilitation.
- If part of cisco rehabilitation is to include artificial propagation and stocking then potential negative consequences inherent with culture practices may occur. These include disease importation or transfer, reduction of genetic fitness, cost and expense of allocating hatchery resources. These risks can be eliminated or minimized through the use of best-practices that will be addressed in the subsequent sections.

Rehabilitation goal

In an effort to define rehabilitation goals, it is useful to examine lessons learned from monitoring resurgence of cisco in Lake Superior during 1970-2005 (Stockwell et al. in preparation).

- Large variations in cisco year-class strength are intrinsic to Great Lakes' populations;
- Cisco are long-lived (20+ years);

- Lakewide, there will be many discrete spawning stocks that may or may not be separated by substantial geographic distances;
- Multiple forms exist, including shallow- and deep-spawning varieties;
- Abundant year classes can be produced from small adult stock sizes;
- There is a danger of over-fishing populations because large year classes are produced only occasionally;
- Environmental factors play a large role in determining reproductive success;
- Rainbow smelt negatively affect cisco recruitment;
- Scientific knowledge of their population dynamics is limited but increasing.
- Abundance of adult cisco should be assessed using midwater trawls and acoustics, while abundance of age-1 cisco can be assessed using bottom trawls (Stockwell et al. 2006).

The Coregonine FCO calls for rehabilitation of cisco to a “significant level” without defining what constitutes significant. Presumably this implies that cisco would be a common component of the lake’s prey base, but stops short of calling for dominance. It is unclear to what degree cisco can ‘share’ the pelagic planktivore niche with the non-native forms.

Cisco do co-exist with rainbow smelt in Lake Superior. It is possible that cisco can either co-exist with these other species, or even achieve dominance in Lake Huron, if first brought back to a base level of abundance in areas of good habitat and in the presence of abundant native predator populations. Good nursery habitat is areas of large bays with substantial amounts of warm water for larval growth and development based upon the Lake Superior experience (Stockwell et al. in preparation). This base-level of abundance would then be the platform from which cisco could come to a self sustained equilibrium in the face of interspecific competition.

This guide offers specific objectives organized as strategies and options to help restore cisco to a base level that will then test the ability of this species to carve out its place in the Lake Huron fish community. The abundance that cisco ultimately attains will be a function of larger ecological forces.

Measuring success

Achievement of base-level abundance can be indicated by several means. Since large scale recovery of cisco has not been accomplished previously, it is difficult to formulate expectations. Instead initial emphasis is focused on simply establishing a measurable population where none currently exist. This can be monitored through a variety of existing survey and assessment practices. Specifically, base-level rehabilitation will be deemed complete when:

- Catch-per-unit-effort of cisco 250 mm and larger averages 10 fish per tow in midwater trawl surveys conducted in the open waters of Lake Huron as part of the regular hydroacoustic survey. This goal represent less than one-half of the adult cisco abundance measured in midwater trawls catches and acoustic surveys in the Apostle Islands by Yule et al. (2007) and Stockwell et al. (2006).
- Cisco occur in a measurable abundance (mean >0) in the annual MDNR Saginaw Bay trawl and gillnet fish community survey, providing for both adult assessment as well as an indicator of recruitment.
- Cisco occur in a measurable abundance (mean >0) in the annual MDNR Thunder Bay summer trawl survey, serving as an indicator of recruitment.
- Catch-per-unit-of-effort greater than 4 fish/net in the annual OMNR index assessment survey in Ontario waters of the main basin.

- Cisco are a measurable component of lake trout diet in all basins. Ray et al. (2007) suggests that lake trout, especially lean forms will prefer rainbow smelt over coregonines when available. Still coregonines are a regular component of the diet (Figure2). Measuring frequency of occurrence of cisco in the diet is one currently conducted assessment technique that can supplement others to indicate presence/absence at least at higher densities.

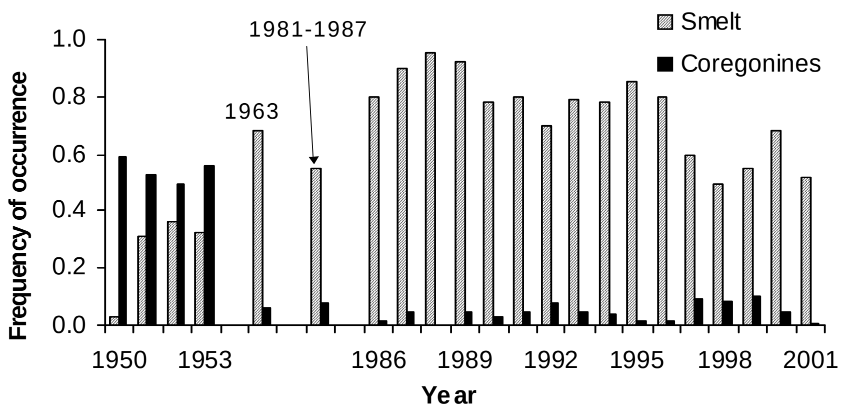

Figure 2. Frequency of occurrence of cisco in the diet of lean lake trout in Lake Superior, 1950-2001. Data from Ray et al. 2007.

- Cisco spawning aggregations is documented at reintroduction sites (see strategy 1 below).

Other indicators of progress would include the presence of cisco in the sport and commercial catch in basins of Lake Huron outside where they presently occur.

Strategies and Options

Listed below are a suite of strategies and options that should be considered by management agencies across Lake Huron. While each strategy can be pursued independently, the potential for success will be maximized by simultaneously implementing multiple strategies. Included are research needs that will likely facilitate the strategy.

1. Reintroduce cisco to locations where they are presently not found. The lack of spawning stocks of cisco was deemed the single largest impediment to rehabilitation for the Great Lakes (Fitzsimons and O'Goreman 2006). Like many salmonids, cisco are thought to exhibit a fairly high degree of fidelity to spawning and hatching location. Consequently, remnant populations of cisco currently subsisting within Lake Huron are very slow to colonize new areas. One hypothesis is that because cisco are generalists in their spawning habitat preferences, that they simply tend to spawn where other ciscos are congregated, thus the spawning aggregation its self is the spawning habitat (R. Eshenroder, personal communication). This would account for why ciscos have been slow to colonize new areas. By reintroducing cisco to areas where they currently do not exist, spawning adults will hopefully be able to take advantage of periods when non-native planktivores like alewives are in low abundance.

Reintroduction would be best achieved by utilizing brood sources presently found in Lake Huron. This would minimize any genetic consequences. Modern day cisco in the main basin of Lake Huron, however, are thought to have hybridized with bloaters due to the severe disruption of the cisco community beginning in the 1940s (Todd and Stedman 1989). Unhybridized forms, however, are believed to persist in the St. Marys River, Les Cheneaux Islands region, and North Channel of Lake Huron providing viable sources of brood for gamete harvesting. The St. Marys River stocks of cisco may exhibit marsh spawning characteristics which were believed to be a trait of Saginaw Bay stocks as well (Van Oosten 1929), making them a desirable source for reintroduction.

Cisco could be re-introduced in outer Saginaw Bay and Thunder Bay because these two areas were historically identified as principle spawning grounds (Organ et al. 1979) and both locations provide ideal spawning and nursery habitat. Remnant stocks persist in Ontario waters and reintroduction is not necessary to promote recolonization at this point in time. Thunder Bay would provide for a source population in central Lake Huron while Saginaw Bay would provide for a source population for both central and southern Lake Huron and the bay itself. Ultimately rehabilitation of Saginaw Bay cisco would be pivotal to achieving the FCO as that location was the principal source of cisco stocks to the historic fishery, however, reintroduction in Thunder Bay may prove to be a more achievable objective in the near term due to its smaller size, fewer fish required for stocking, and an overall lower abundance of predators than Saginaw Bay.

In Saginaw Bay, cisco historically achieved maturity between age 3 and 4 (Van Oosten 1929). In Lake Superior, cisco also mature between age 3 and 4, and strong year classes of cisco were produced sporadically in 1978, 1980, 1984, 1988-1990, 1998, 2002, and 2003 (Stockwell et al. in preparation). Thus, any reintroduction effort in Lake Huron would have a greater opportunity for success (achieving natural reproduction) if large stocking events were pulsed sporadically to imitate wild population dynamics and reproduction.

In Lake Superior, strong cisco year classes are regarded to be between 5 to 900 age-1 cisco per hectare of trawlable area . Assuming a first year mortality rate of 50%, age-0 densities may range from 10 to 1800/ha. At an intermediate value of 40/ha, a total of 857,000 would be needed for stocking in Thunder Bay and 11.4 million in Saginaw Bay to fully replicate a strong year class. While it may prove impossible to achieve these densities with stocked fish, through homing, it may be possible to establish spawning aggregations in specific stocking sites with lower numbers.

Although Todd (1986) concluded that a coregonine stocking program was impractical, that author evaluated the concept principally from the idea of maintenance stocking using newly hatched fry. Todd (1986) recommended limiting coregonine stocking to rehabilitation efforts when and where little or no natural recruitment is occurring. This strategy, offered here, meets these criteria as it intends only to reintroduce the species to these areas from which they were extirpated and calls for using more advanced life stages for stocking. It is hoped and expected that a small background brood source could be established after six years of planting. That population would then be allowed to self sustain if possible.

Reintroduction stocking should follow a pulsed design alternating between Thunder Bay and Saginaw Bay with a minimum of 750,000 early summer fingerlings. Stocked cisco should be marked with Oxytetracycline so as to enable differentiation with wild cisco in subsequent evaluations.

2. Reduce exploitation. Fitzsimons and O'Gorman (2006) call for protection of existing cisco stocks through reduction of targeted fisheries and by-catch to promote rehabilitation. Fisheries which exist in areas where cisco populations are at base level (i.e. North Channel) should be managed as other commercial species are. It appears that unregulated cisco commercial harvest in any waters threatens this depressed species (Stockwell et al. In Prep.). There, biologists recommended that managers establish a fixed level of exploitation of 10-15% on adult female cisco when setting harvest limits on commercial fishery yields (Stockwell et al. in prep). Populations at very low abundance in most of Georgian Bay and parts of the main basin and represent the fringe of range rehabilitation. The best hope for cisco rehabilitation in these waters is to allow these stocks to increase in abundance and continue to colonize adjacent areas. In areas where cisco do not currently exist (i.e. Saginaw Bay), commercial harvest should be discouraged.

   Cisco could also be limited or prohibited from the harvest by the state and tribal commercial operations occurring in the Michigan waters of the central and southern portions of Lake Huron as well as that of the Ontario waters. This includes the management areas known as MH-2 through MH-5. This would help protect the stocked cisco proposed in the previous strategy.

   Michigan already maintains a cisco sport daily limit of 12 fish. This was enacted statewide in 1987 so as to prevent wanton waste in the St. Marys River where a relatively intense sport fishery has evolved usually during the July mayfly emergence (Fielder et al. 2002). Ontario recently established a 25 fish daily limit.

Other Issues Considered

Although concerns over spawning and nursery habitat availability were considered by Fitzsimons and O'Goreman (2006), specific efforts to improve or restore cisco habitat were not recommended. Cisco have relatively broad environmental tolerances for spawning and nursery areas (Hayes 1999; Scott and Crossman 1973). Habitat degradation has been a concern in the rehabilitation of walleye in Saginaw Bay (Fielder and Baker 2004), and it may be an impediment for cisco. The return of large borrowing mayflies to Saginaw could be a measure with which to evaluate the appropriateness of Saginaw Bay for cisco. Habitat improvement should be considered a lower priority strategy in this rehabilitation guide relative to the other strategies, although improvements to inner Saginaw Bay reef habitat and coastal wetlands would no doubt have positive benefits in the pursuit of cisco rehabilitation and are encouraged whenever and wherever possible.

Competitive prey fish removal or reduction. Fitzsimons and O'Goreman (2006) and Stockwell et al. (In Prep.) acknowledge the potential benefit of reducing competition for cisco through the reduction of prey fish species with similar trophic requirements, most notably alewives and rainbow smelt. Rainbow smelt are certainly considered an impediment to cisco recovery in Lake Superior (Stockwell et al. in prep.) Potential methodologies would include managing for high predation rates and/or active removal programs. It is noted that because Lake Huron has recently demonstrated widely fluctuating and often depressed population levels of these non-native planktivores, that actively managing for their low abundance may not be a prerequisite for successful cisco rehabilitation. Periodic windows of low alewife abundance, if they continue to occur with some regularity, may provide opportunities for cisco to regain their vacated niche.

Increasing predation rates on prey fishes is a stated goal of the walleye rehabilitation plan in Saginaw Bay (Fielder and Baker 2004). Managing for high predation rates in the main basin of Lake Huron, however, may not be consistent with other management objectives. As native predators continue to recover, resulting predation rates may likely be beyond the control of fishery managers. There is evidence that over-winter thermal conditions may regulate age-0 alewife survival and recruitment (Synder and Hennessey 2003) . Consequently, periods of low alewife abundance may be partly driven by climatic conditions.

Although no specific strategy pertaining to removal or reduction of competitive prey fishes is offered here, fishery managers would do well to recognize that periods of low alewife and rainbow smelt abundance likely constitute opportunities for native fish rehabilitation and that these periods not solely be viewed from the short-term consequences of predator growth rate and abundance.

Research needs:

Although genetic concerns are minimized by using existing northern Lake Huron source populations for culture, a comparison of historic cisco genotypes to those of modern day populations would prove insightful. While not a prerequisite for pursuing this reintroduction option, such a research project should be considered so as to optimize subsequent brood source selection.

Cisco fingerling survival would be maximized by stocking during high zooplankton abundance. Timing of zooplankton production and blooms should be examined in Saginaw Bay and Thunder Bay to help time stocking. Such zooplankton monitoring can occur in advance of reintroduction (to better understand annual production timing) and in stocked years to ensure optimal timing within seasonal variability.

Evaluation of rehabilitation efforts

On Lake Superior a combination of bottom trawling in combination with night midwater trawling and acoustic sampling was deemed the best strategy for assessing cisco abundance. Bottom trawling will adequately sampling age-1 and some age-2 cisco, but abundance of adult cisco can only be surveyed with midwater trawls and acoustic (Stockwell et al. 2006; Yule et al. 2006). The recent addition of a Lake Huron wide hydroacoustic and midwater trawl survey by the USGS' Great Lakes Science Center will serve as a important evaluation component. This annual survey will help determine the presence/absence of juvenile and adult cisco in the pelagic waters of Lake Huron adjacent to these introduction locations. The Michigan DNR annual Saginaw Bay survey will allow for assessing the prevalence of cisco (both adults and juveniles) in the Saginaw Bay fish community. The inclusion of suspended gill nets in standard index programs would aid in assessing cisco populations, especially in areas where populations are known to exist. Lake trout diet is annually assessed across the Michigan waters of Lake Huron by the Michigan DNR, OMNR, USGS Great Lakes Science Center, the U.S. Fish & Wildlife Service and Chippewa/Ottawa Resource Authority. These surveys can help assess any expansion of the cisco population.

An inter-agency cisco occurrence database should be developed and maintained by one volunteer Lake Huron agency. The database should include documented encounters with confirmed cisco collections or sightings in Lake Huron. The database should include all sources including survey collections, commercial landings, and sport catch. Data records should also be geo-referenced for spatial analysis. The database could be designed to reflect multiple encounters in single instances. The objective would be to provide a documented expression of range by year.

Summary of primary rehabilitation strategies

- Reintroduce cisco to selected areas in the Michigan waters of Lake Huron's main basin by stocking fingerlings.
    - Utilize a local extant Lake Huron cisco brood source.
    - Develop a multi-agency partnership in the propagation of the cisco.
    - Biannually pulse stock a minimum of 750,000 early summer fingerlings in Thunder Bay and Saginaw Bay (alternating years) over a period of at least 6 years (minimum of three stockings each).
- Limit exploitation on existing cisco stocks to no more than 10-15% on adult females
    - Close or limit commercial harvest of ciscos in areas of the main basin where base line populations have not been achieved.
    - Manage for sustainable fisheries in areas where base-line populations have been achieved and sustainable harvest levels can be determined.

Summary of evaluation and research needs

- Use existing surveys to assess the status and trends of cisco and their rehabilitation.
    - Use of hydroacoustic and midwater trawling in offshore areas of Lake Huron as the primary survey method for assessing adult cisco abundance.
    - Use the MDNR & USFWS (Thunder Bay and Saginaw Bay) and USGS main basin fall trawling surveys and the OMNR annual index community surveys to monitor expansion of cisco to other areas of Lake Huron
        - Incorporate suspended gill net sampling into existing bottom set surveys to assess abundance of ciscoes
    - Use the annual lake trout surveys performed by the MDNR, USFWS, and OMNR to assess the range of cisco in lake trout stomachs.
    - Establish and maintain an inter-agency cisco spatial distribution database.
- Compare and contrast modern day cisco genotypes with historic genotypes through genetic analysis of extant populations and historic scale collections.
- Document and monitor spring and early summer zooplankton production and thermal regimes in Saginaw and Thunder Bays so as to optimize timing of cisco stocking.
- Mark all stocked Cisco with oxytetracycline and include vertebrae collections and subsequent origin determination of any collected specimens as part of the evaluation process.

Time frame and adaptive management

The concept of adaptive management is premised on the acknowledgement of uncertainty as to the outcome of efforts. This uncertainty is embraced and the guide proceeds based on on-going assessment which provides feedback to decision makers to gauge progress, make changes to the strategies if necessary, and to declare a conclusion to rehabilitation when appropriate. The reintroduction experiment is premised on a 6 year strategy although continued evaluation beyond that may be required to fully assess any benefits.

Conclusion

Cisco rehabilitation will have tangible benefits for the ecosystem through a much-needed diversification of the prey fish community and a return to a dependence upon a native prey species. Benefits expected will include better growth rates for predators, less fluctuation in the overall prey biomass of the lake, better reproduction of predator species via less EMS, and conversion of the largest component of the fish community's biomass into a form that can eventually contribute to fisheries. Aside from the rehabilitation strategies laid out in this guide, management agencies would help the cause by also informing the public as to the reasoning behind, and importance ascribed to cisco rehabilitation. An informed public will be a necessary component to fully implement many of these strategies. While success is far from certain, these rehabilitation strategies constitute relatively small investments in the large scale of Great Lakes fishery management. The potential benefits are great enough, however, that such efforts are easily justified.

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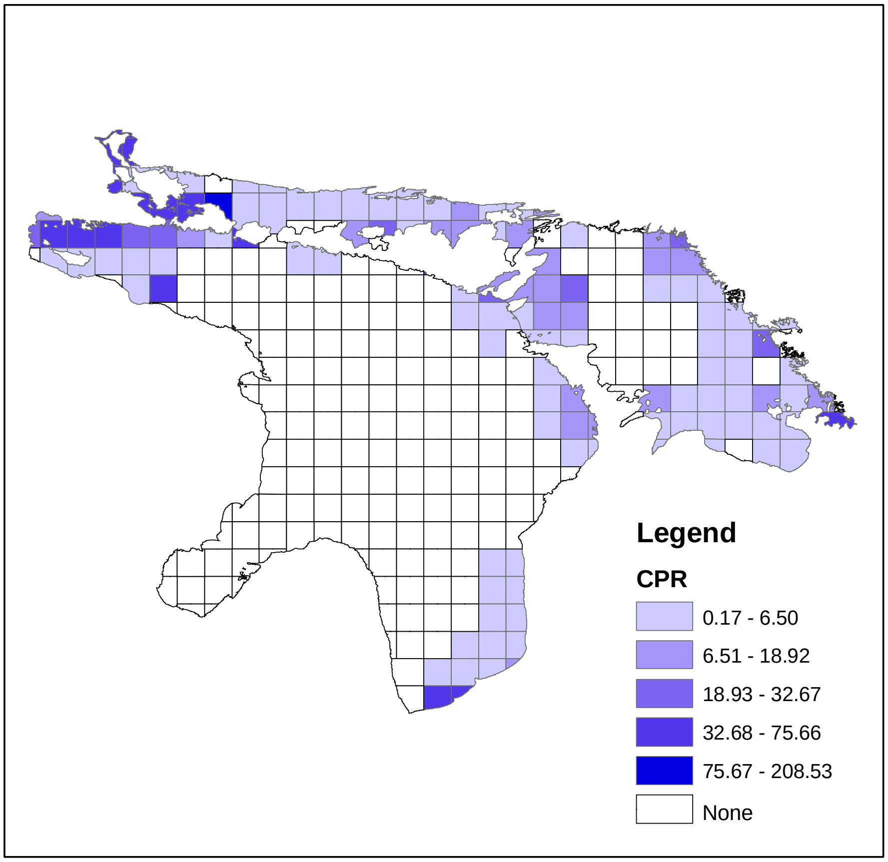
Figure 1. Cisco distribution in Lake Huron from 1974 through 2004 expressed as mean catch-per-reported record (CPR).



Appendix 1. Common and scientific names of fishes relevant to this guide.

Common name	Scientific name
Alewife	*Alosa pseudoharengus*
Bloater	*Coregonus hoyi*
Burbot	*Lota lota*
Chinook salmon	*Oncorhynchus tshawytscha*
Deepwater cisco	*Coregonus johannae*
Cisco (a.k.a. lake herring)	*Coregonus artedi*
Lake trout	*Salvelinus namaycush*
Lake whitefish	*Coregonus clupeaformis*
Rainbow smelt	*Osmerus mordax*
Round whitefish	*Prosopium cylindraceum*
Sea lamprey	*Petromyzon marinus*
Walleye	*Sander vitreus*