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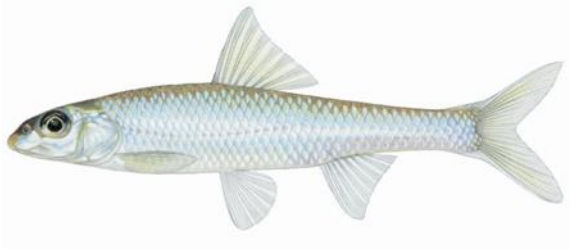
Central and Arctic Region
Canadian Science Advisory Secretariat
Science Advisory Report 2013/019

RECOVERY POTENTIAL ASSESSMENT OF SILVER CHUB (*Macrhybopsis storeriana*) IN ONTARIO



*Silver Chub (*Macrhybopsis storeriana*). Illustration by Joe Tomelleri, reproduced with permission.*

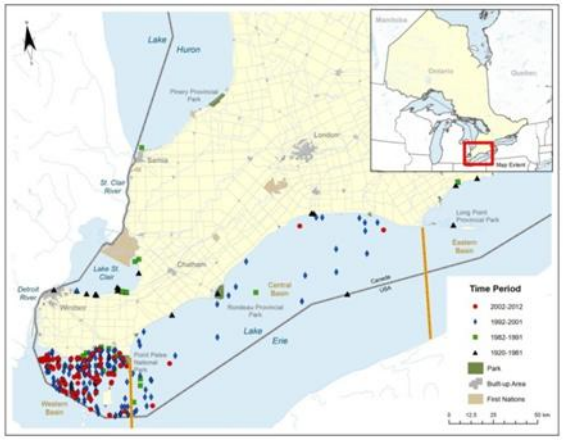


Figure 1. Distribution of Silver Chub in Ontario

Context:

In April 1985, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed Silver Chub (Macrhybopsis storeriana) *as Special Concern. The species was re-examined and the status confirmed in May 2001. In 2012, COSEWIC separated the populations into two separate designatable units (DUs): 1) the Saskatchewan - Nelson River DU; and 2) the Great Lakes - Upper St. Lawrence DU. The Saskatchewan - Nelson River DU was not considered to be at risk, while the Great Lakes-Upper St. Lawrence DU was reassessed from Special Concern to Endangered in May 2012. The reason given for this designation was "This is a small bodied fish species native to the middle Great Lakes that has declined substantially in abundance over the previous three generations. The species is assessed as at a high risk of extinction from several threats including habitat degradation, exotic species interactions and climate change". No schedule or status has yet been assigned to the Great Lakes – Upper St. Lawrence DU of Silver Chub under the federal Species at Risk Act. The distribution of the Great Lakes-Upper St. Lawrence populations is restricted to Ontario, where it is known only from lakes Erie and St. Clair, and the extreme southern portion of Lake Huron.*

A species Recovery Potential Assessment (RPA) process has been developed by Fisheries and Oceans Canada (DFO) Science to provide the information and scientific advice required to meet the various requirements of the SARA, such as the authorization to carry out activities that would otherwise violate the SARA as well as the development of recovery strategies. The scientific information also serves as advice to the Minister of DFO regarding the listing of the species under SARA and is used when analyzing the socio-economic impacts of adding the species to the list as well as during subsequent consultations, where applicable. This assessment considers the scientific data available with which to assess the recovery potential of Silver Chub in Ontario.

SUMMARY

- In Ontario, Silver Chub is limited to Lake Erie, Lake St. Clair, and the extreme southern portion of Lake Huron. It may also occur in connecting rivers (i.e., St. Clair and Detroit rivers). It has not been collected in Lake Huron and Lake St. Clair since 1983 and 1994, respectively. The majority of the Lake Erie occurrences have originated from the western basin.
- Silver Chub occurs in water temperatures up to 25.9°C and spawns when water temperature is between 19°C and 23°C. Silver Chub has been recorded from a wide range of water depths (2.3-24 m) and turbidity levels (0-4.5 m Secchi depth). Silver Chub occupy areas with clean gravel, sand, and silt bottoms.
- Adult Silver Chub fed primarily on *Hexagenia* mayfly nymphs prior to invasion of Round Goby (*Neogobius melanostomus*), then switched to a diet composed mainly of dreissenid mussels.
- To achieve ~99% probability of persistence, given a 15% per generation chance of catastrophic (50%) decline, requires ~444,000 adult Silver Chub and at least 84 km^2 of suitable habitat.
- Current available habitat in the Western Basin of Lake Erie is estimated at 3000+ km^2. The quality of this habitat (suitability for Silver Chub) is unknown.
- The greatest threats to the survival and persistence of Silver Chub in Ontario are anthropogenic in origin such as nutrient loading, turbidity and sediment loading, contaminants and toxic substances, and habitat removal and alteration. Furthermore, the presence of numerous invasive species may pose a threat to the survival and persistence of the Silver Chub in Ontario. The threats may not always act independently on Silver Chub populations; rather, one threat may directly affect another, or the interaction between two threats may introduce an interaction effect.
- The growth rate of a growing Silver Chub population is most sensitive to changes in the survival of immature individuals. Stable or Declining populations are most sensitive to changes in cumulative adult survival, and are more sensitive than growing populations to changes in fecundity of older individuals.
- Current population abundance in Canada is estimated at ~662,000 (266,000 – 1,620,000 95% confidence). This mean abundance (but not the lower confidence bound) exceeds the recommended recovery target (MVP).
- Silver Chub in the Western Basin of Lake Erie has been in decline, on average, since 2000, at a mean rate of 20% annual decline. More recently population trajectory is highly uncertain; the average growth rate from 2007 to 2012 was 4% annual growth with a large 95% confidence interval of 31% annual decline to 55% annual growth.
- At the current abundance (mean estimate of 622,000), the expected time to extirpation of a population declining at a rate of 20% annually is 58 years (36 – 95 years, 95% confidence).
- To avoid a decrease in population growth rate larger than 1%, transient harm (one-time removal of individuals) should not exceed 23.5% reduction in YOY abundance, or 15% reduction in adult abundance, or 8.5% reduction in total abundance within a seven-year period.

- Assuming a population growth rate of 4% annually, chronic harm (long-term reductions to vital rates) should not exceed 3% of YOY survival *or* 2% of adult survival *or* 3% of fecundity.
- A number of key sources of uncertainty exist for this species related to population life history, distribution and structure, habitat preferences, and factors limiting their existence. Resolving these sources of uncertainty would greatly enhance our understanding of Silver Chub in Ontario. Specifically, stage-dependent survival rates are not known (and were based on allometries for this report). Fecundity estimates are out of date (1950s) and may no longer be accurate.

BACKGROUND

In April 1985, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) recommended that Silver Chub (*Macrhybopsis storeriana*) be designated as Special Concern. This status was reconfirmed in May 2001. In 2012, COSEWIC separated the populations into two separate designatable units (DUs): 1) the Saskatchewan - Nelson River DU; and 2) the Great Lakes - Upper St. Lawrence DU. The Saskatchewan - Nelson River DU was not considered to be at risk, while the Great Lakes-Upper St. Lawrence DU was reassessed from Special Concern to Endangered in May 2012. The reason given for this designation was “This is a small bodied fish species native to the middle Great Lakes that has declined substantially in abundance over the previous three generations. The species is assessed as at a high risk of extinction from several threats including habitat degradation, exotic species interactions and climate change”. Subsequent to the original COSEWIC designation, Silver Chub was listed on Schedule 3 and then moved to Schedule 1 of the federal *Species at Risk Act* (SARA).

When COSEWIC designates an aquatic species as Threatened or Endangered and the Governor in Council decides to list it, the Minister of Fisheries and Oceans Canada (DFO) is required by the SARA to undertake a number of actions. Many of these actions require scientific information such as the current status of the population, the threats to its survival and recovery, and the feasibility of its recovery. This scientific advice is developed through a Recovery Potential Assessment (RPA). This allows for the consideration of peer-reviewed scientific analyses in subsequent SARA processes, including permitting on harm and recovery planning. This RPA focuses on the Silver Chub populations in Ontario and is a summary of the conclusions and advice from a Canadian Science Advisory Secretariat peer-review meeting that occurred on 5 March 2013 in Burlington, Ontario. Two research documents, one providing background information on the species biology, habitat preferences, current status, threats and mitigations and alternatives (McCulloch et al. 2013), and a second on allowable harm, population-based recovery targets, and habitat targets (Young and Koops 2013) provide an in-depth account of the information summarized below. Proceedings that document the activities and key discussions of the meeting are also available (DFO 2013). Please note that reference citations have been removed from the following document to minimize the length of the document. Complete reference citations are available at McCulloch et al. (2013) and Young and Koops (2013).

Species Description

Silver Chub is a stout minnow that reaches a maximum total length (TL) of 231 mm. Species in the genus *Macrhybopsis* are characterized by the following features: a barbel at the end of the maxillary (corner of upper jaw); moderate-sized subterminal mouth; and fewer than 50 lateral line scales. Silver Chub is distinguished from other species in the genus by its large eyes located on the upper half of the head, a shorter snout, silvery sides without markings, and a more anterior-oriented dorsal fin. Colouring is a pale grey-green on the back, becoming silver on

the sides and silvery white below. A faint dusky lateral band is usually present. The caudal fin is lightly pigmented except for the lower three or four rays, which are completely white and unpigmented. Silver Chub can be confused with large Spottail Shiner (*Notropis hudsonius*), Gravel Chub (*Erimystax x-punctatus*), and two *Nocomis* species (Hornyhead Chub, *N. biguttatus*; and River Chub, *N. micropogon*,). It is distinguished from Spottail Shiner by the presence of a terminal barbel; it lacks the distinct, dark, x-shaped spots that are characteristic of Gravel Chub; and, its snout projects further beyond the mouth than that of *Nocomis* spp. Additionally, *Nocomis* spp. have smaller eyes than Silver Chub and a more pigmented body that is not usually silvery. Gravel Chub has been extirpated from Ontario; therefore, the two species will not co-occur there. The two *Nocomis* species are river dwelling; therefore, the only potential overlap in distribution with Silver Chub in Ontario would be in the Detroit River, should Silver Chub use that waterbody for migration and/or spawning purposes.

Silver Chub is the only member of the genus *Macrhybopsis* in Canada, and the Great Lakes populations are lacustrine forms. It was noted that specimens from the Ohio River appeared morphologically distinct than the Lake Erie populations in that specimens from the Ohio River were more streamlined in appearance, have less body depth at the dorsal origin, and their heads are less triangular. The Great Lakes populations are geographically isolated from the majority of other Silver Chub populations, which inhabit the Mississippi drainage, and could be genetically distinct.

Growth Rate

The maximum documented age of Silver Chub is four years. Recent growth rates and historical growth rates in Lake Erie appear to be similar. Mean standard lengths for Age 0, 1, 2, 3 and 4 Silver Chub were approximately 40, 110, 140, 155, and 165 mm, respectively.

Diet

Silver Chub is a bottom feeder that uses both taste and sight to obtain its food. External taste buds are located on the head and pectoral fins. It feeds on a variety of items depending on age and available food. Historically, in Lake Erie, young fed on small crustaceans (copepods, *Daphnia*, ostracods, and *Gammarus*) and insect larvae (midges, caddisflies, and mayflies), while older individuals fed primarily on the mayfly nymph, *Hexagenia*, when available. Other items include fish eggs of approximately 1.0–1.4 mm in diameter; Zebra Mussel (*Dreissena polymorpha*), *Cypria* (an ostracod), *Oecetis* (a caddisfly), and possibly, small fishes. More recently, Silver Chub in Lake Erie fed more on dreissenid mussels, sphaeriids, Coleoptera, *Hexagenia*, and a variety of other insects. A gut content analysis on Silver Chub captured in the fall of 2010 revealed that over 90% of the fish Age 1 or older consumed dreissenid mussels. *Hexagenia* mayflies and eggs of *Daphnia* were also present in moderate numbers. While the presence of dreissenid mussels and *Daphnia* eggs was also associated with Age 0 fish, these younger fish fed more heavily on cladocerans, copepods, and ostracods.

Genetics

Genetic studies have not been conducted on Silver Chub; therefore, little is known on the genetic variability of the species. However, the Great Lakes populations differ morphologically, and may be genetically distinct from the riverine forms found throughout most of its range in the United States. These populations are also isolated from most other Silver Chub populations, which occur in the Mississippi River drainage. A genetic study should be conducted to compare the Great Lakes populations with those in the Mississippi River and Lake Winnipeg watershed.

Distribution

The distribution of Silver Chub extends from Lake Winnipeg and the southern Great Lakes basin south to the mouth of the Mississippi River. It occurs in the Mississippi River system from Minnesota south to the Gulf of Mexico. In the northern part of its range in the Mississippi basin, it extends from Nebraska to New York where it was last taken in 1928 and, in its Gulf Coast range, it extends from the Mobile Bay basin to the Lake Pontchartrain drainage. There is also an isolated population in the Brazos River drainage of Texas. Silver Chub has not been collected in the Kansas River since 1980 and it is a species of concern in the Missouri National Recreational River in Nebraska and South Dakota.

Less than 5% of the species' global distribution is currently found in Canada. In the Great Lakes basin, Silver Chub is limited to Lake Erie, Lake St. Clair, and the extreme southern portion of Lake Huron. In the Lake Winnipeg drainage, it is found in southern Lake Winnipeg and in the Assiniboine and Red River drainages of Manitoba, North Dakota, and Minnesota.

ASSESSMENT

Current Species Status

In Ontario, Silver Chub was historically collected along most of the north shore of Lake Erie and the south and east shores of Lake St. Clair (Figure 1). Most of the records for Lake Erie were collected prior to 1960 and since 1990; whereas, the Lake St. Clair records were collected in the 1970s and 1980s. Since 1980, Silver Chub has been collected primarily in the western and central basins of Lake Erie with a few occurrences in Lake St. Clair and a single occurrence in Lake Huron. The increase in records from the western basin of Lake Erie in the 1990s is likely a reflection of the species' recovery since the 1980s. However, the spatial extent of records has decreased in the last 10 years based on ongoing standardized sampling, leading to a 64% decline in both Extent of Occurrence (EO) (7639.42 km² for 2001-2010 records) and the Index of Area of Occupancy (IAO) (296 km², if only Canadian portion of grids are included; 2001-2010 records) (COSEWIC 2012).

Lake Erie – Western Basin

In 2012, a total of 70 bottom trawls (37 in Canadian waters) were conducted by the U.S. Geological Survey (USGS) in late spring (June 18-19) and fall (September 14-17 and October 9, 11) (P. Kocovsky, USGS, unpubl. data). In June, three of 19 trawls in Canadian waters produced 49 Silver Chub for a catch rate of 8.70 fish/hectare. Forty-five Silver Chub (29, 16) were captured from two sites south of Willow Beach and Ambassador Beach. In the fall, 13 Silver Chub, including six young-of-the-year (YOY), were captured from five of the 18 trawls for a catch rate of 2.33 fish/hectare. The combined catch rate in Canadian waters for 2012 was 5.53 fish/hectare, which is similar to recent sampling efforts.

In 2011 and 2012, nearshore electrofishing and trapnetting was conducted by a University of Toledo graduate student and the Ohio Environmental Protection Agency. A total of 143 sites were sampled by electrofishing (68 day and 75 night events). This sampling covered over 66 kilometres of nearshore habitat. No Silver Chub were captured. In six trapnet nights with approximate soak times of 14 hours, three Silver Chub were captured at one site on May 25, 2011. All Silver Chub captured were determined to be Age 3.

The standardized Interagency Trawl Index data, collected by the Ontario Ministry of Natural Resources (OMNR) and Ohio Division of Wildlife (ODW) are completed annually in the western basin of Lake Erie to provide fishery harvest and effort information, as well as gain baseline

stock assessment data for important sport, commercial and forage fish (ODW 2013). A total of 74 bottom trawls were completed in 2012, yielding the capture of 37 Silver Chub from 12 sites.

The most recent data from the Partnership Index Gill Net Index Program (OMNR and commercial fishing agencies) show a slight decrease in the mean catch per gear in 2012 [0.14 fish/multi-mesh gang (mmg); four fish total]. This follows five consecutive years where values were below one fish/mmg. It should be noted that gillnetting is not the effective means of capturing Silver Chub as the mesh size configuration has been selected to minimize the capture of smaller forage species.

Silver Chub has also been recorded during the 2004 yearling Walleye (*Sander vitreus*) gillnet survey. A total of 235 Silver Chub were recorded from surveys conducted from July 12 to October 27, 2004 (M. Belore, OMNR, unpubl. data). During this survey, all nets were fished on the bottom overnight. Silver Chub was most often caught in mesh sizes 51 mm and smaller (M. Belore, OMNR, unpubl. data). This survey has not been repeated since 2004.

In Lake Erie, a dramatic decline in the Silver Chub began in the late 1940s. Scott and Crossman (1973) reported the last known record of Silver Chub as caught in 1960. However, Silver Chub began appearing in OMNR midwater trawls and bottom gillnets in 1967.

The standardized Interagency Trawl Index data exhibit a steady rise from 3.6 fish/hectare in 1988 to 25.9 fish/hectare in 1994. Numbers increased dramatically to 106 fish/hectare in 1996 and 125 fish/hectare in 1999, and then declined precipitously to less than seven fish/hectare since 2005. There had been a decline of 71% for 10 years, but an increase of 26% over the next five years. Surveys completed in 2012 yielded 1.76 fish/hectare.

Additional trawling of the western basin occurred from 2004 to 2012 (P. Kocovsky, USGS, unpubl. data. Relatively few Age-0 individuals have been recorded from this program with the greatest Age-0 catch rate observed in 2012 with a mean Silver Chub catch per hectare of 1.50. A greater catch rate was observed for adult Silver Chub with higher catch rates recorded during spring sampling for all years except in 2006.

A similar pattern, but with lower mean values, for yearling and adult Silver Chub was exhibited by additional trawling in the Ohio waters of the western basin in August and September to October (fall sampling) each year between 1990 and 2012. Trawling in the Ohio waters confirmed very low adult numbers in the west-central basin (Ohio District 2) and virtually no individuals in the east-central basin (Ohio District 3). The mean trend across basins is a 99% decline over the last five and 10 years. YOY data for the same trawls indicated large catches in 1996, 1998, and 1999, but virtually no catches since then.

Data from the Partnership Index Gill Net Index Program are available for Canadian populations in the western of Lake Erie from 1990 to 2012. The mean catch per gear increased from 1.1 fish/mmg in 1990 to 13.86 fish/mmg in 1993, dropping again until 1999 with a second peak of 8.41 fish/mmg. Mean catch of Silver Chub subsequently decreased to less than 1 fish/mmg in 2007 and has remained at this low level since 2007. The 2012 mean Silver Chub catch for the western basin of Lake Erie was 0.14 fish/mmg. The western basin has experienced a 93% decline in Silver Chub catch over the last 10 years.

Lake Erie – Central Basin

Despite considerable sampling effort, catch rates from the Partnership Index Gill Net Index Program remained low for 2012 (0.03 fish/mmg; one Silver Chub recorded). Mean Silver Chub catch per gear has never reached levels greater than 0.89 fish/mmg. This small peak occurred in 2003.

Lake Erie – Eastern Basin

A single Silver Chub was recorded from the eastern basin of Lake Erie in 2001 by the Partnership Index Gill Net Index Program. Silver Chub have not been since this 2001 capture.

Lake St. Clair

Recent sampling has failed to collect Silver Chub in Lake St. Clair. The Michigan Department of Natural Resources conducted annual bottom trawl surveys in Lake St. Clair (including the Canadian side) between 1996 and 2001 and did not catch any Silver Chub, despite using mesh sizes effective at detecting Silver Chub.

Silver Chub was first collected in Lake St. Clair in 1968. By 1975, abundance began to increase in the lake based on the OMNR index trawling data for the period 1968–1984. Dramatic increases were recorded between 1981 and 1984 (approximately 60–200 individuals/trawl-hour), the last years of the index trawling program. An OMNR beach seine study conducted in Lake St. Clair in 1979 to 1981 and 1990 to 1996 documented high numbers of Silver Chub in 1979 and moderate numbers in 1980, 1981, and 1990. During 1991 to 1996, only a single individual was recorded (in 1994). OMNR beach seine surveys in 2005, 2007-2012, and trawling in 2010 failed to detect any Silver Chub.

The OMNR have completed several beach seine surveys of Lake St. Clair at eight sites in 1990-1996, 2005, 2007-2012 (with an additional nine sites in 2007 sampled with a combination of seining and boat electrofishing). These surveys resulted in the capture of 21 Silver Chub from three sites in 1990, and one additional individual in 1994. Silver Chub have not been recorded from Lake St. Clair since 1994.

Lake Huron

Silver Chub was collected at one location in 1983 at the extreme southern end of the lake near Sarnia, Ontario. Two individuals were taken by commercial trapnet. No other Silver Chub have been collected in Lake Huron.

Population Status Assessment

To assess the Population Status of Silver Chub populations in Ontario, each population was ranked in terms of its abundance (Relative Abundance Index) and trajectory (Population Trajectory). The level of certainty was associated with each assignment (1=quantitative analysis; 2=CPUE or standardized sampling; 3=expert opinion). The Relative Abundance Index and Population Trajectory values were combined in the Population Status matrix to determine the Population Status for each population. Each Population Status was subsequently ranked as Poor, Fair, Good, Unknown, or Extirpated (Table 1). The Certainty assigned to each Population Status is reflective of the lowest level of certainty associated with either initial parameter. Refer to McCulloch et al. (2013) for detailed methods used for the assessment of Population Status.

Table 1. Population Status for all Silver Chub populations in Ontario, resulting from an analysis of both the Relative Abundance Index and Population Trajectory. Certainty assigned to each Population Status is reflective of the lowest level of certainty associated with either initial parameter (Relative Abundance Index, or Population Trajectory).

Population	Population Status	Certainty
Lake St. Clair	Poor	2
Lake Erie – western basin	Poor	2
Lake Erie – central basin	Poor	2
Lake Erie – eastern basin	Poor	2
Lake Huron	Unknown	3

Habitat Requirements

Spawning

Presently, Silver Chub likely spawns in open-water lentic habitat. Historical spawning was been observed over clean gravel substrates in tributaries of Lake Erie. In Ohio, Silver Chub spawns in late May or early June, possibly in open water, when water temperature reaches 21°C. In Canada, spawning occurs in spring or early summer (May to July) at temperatures of 19–23°C. Fecundity can be as high as 12 311 eggs.

Larval and Juvenile

There is very limited information available on habitat preferences of larval and juvenile Silver Chub. In the western basin of Lake Erie, juvenile Silver Chub were captured at water depths ranging between 7.6 and 9.8 m. Larval and juvenile Silver Chub have been collected in equal numbers in surface and bottom sampling and their abundance was higher in backwaters than the main channel of the upper Mississippi River.

Adult

In Ontario, Silver Chub is found in large lakes but may also occur in connecting rivers (i.e., St. Clair and Detroit rivers). In the western basin of Lake Erie in 2012, Silver Chub were captured in water temperatures ranging from 9.6°C to 25.9°C and water depths ranging from 2.3 to 24 m.

Silver Chub CPUE across various depths was explored to determine the relationship between depth and Silver Chub presence and abundance using the interagency bottom trawling conducted in August and early September from 1987 to 2012. CPUE was highest for trawls at depths of 6.1-7.0 m, followed by 2.1-3.0 m. There is substantial variation in the catch data; therefore, Silver Chub depth preference cannot be determined.

Silver Chub CPUE was also explored across various Secchi depths to determine possible relationship between Silver Chub abundance and turbidity. Data were taken from the interagency bottom trawling conducted in August and early September of each year. While CPUE was highest for trawls at Secchi depths of 2.6 to 3.0 m, Silver Chub was captured in a low proportion of the trawls, with large numbers at a few sites influencing the CPUE. When Secchi depth was recorded to be between 0.6 and 1.5 m, both CPUE and the proportion of trawls with Silver Chub were noticeably higher than at other Secchi depths.

Silver Chub have been found over clean gravel, sand, and silt bottoms in Lake Erie. In the United States bordering Lake Erie, Silver Chub has been found in stream mouths with fine gravel or sand bottoms.

Function, Features and Attributes

A description of the functions, features, and attributes associated with Silver Chub habitat is found in Table 2. Please see McCulloch et al. (2013) for definitions of functions, features and attributes. The habitat required for each life stage has been assigned a function that corresponds to a biological requirement of Silver Chub. For example, individuals in the spawn-to-juvenile life stage require habitat for nursery and spawning purposes. In addition to the habitat function, a feature has been assigned to each life stage. A feature is considered to be the structural component of the habitat necessary for the survival or recovery of the species. Habitat attributes have also been provided, describing how the features support the function for each life stage. Optimal habitat attributes from the literature for each life stage have been combined with habitat attributes from current records (records from 2001 to present) to show the maximum range in habitat attributes within which Silver Chub may be found (see Table 2, and references therein). This information is provided to guide any future identification of critical habitat for this species. It should be noted that habitat attributes associated with current records may differ from optimal habitat attributes as Silver Chub may be occupying sub-optimal habitat in areas where optimal habitat is no longer available.

Residence

Residence is defined in SARA as a, “dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating”. Residence is interpreted by DFO as being constructed by the organism. In the context of the above narrative description of habitat requirements during larval, juvenile, and adult life stages, Silver Chub do not occupy residences.

Table 2. Summary of the essential functions, features and attributes for each life stage of Silver Chub. Habitat attributes from published literature, and habitat attributes recorded during recent Silver Chub surveys captured have been combined to derive the habitat attributes required for the delineation of critical habitat (see text for a detailed description of categories).

			Habitat Attributes		
Life Stage	**Function**	**Feature(s)**	**Scientific Literature**	**Current Records**	**For Identification of Critical Habitat**
Spawning (spawning likely occurs late May through to July)	Spawning	Nearshore and open water of large lakes.	• Spawning thought to occur when water temperatures are between 19-23°C (Holm et al. 2010) • Nearshore in Lake Erie (Kinney 1954) • Clean gravel substrates in tributaries to Lake Erie (historically) (Goodyear et al. 1982)		• Spawning thought to occur when water temperatures are between 19-23°C.
Egg to juvenile	Nursery Feeding Cover	Nearshore and open water of large lakes.	• Unknown	• YOY were captured in trawls with adult fish in water ranging in depth from 7.6-9.8 m (P. Kocovsky, USGS, unpubl. data)	• Same features as adult habitat.
Adult (from Age 1 [onset of sexual maturity])	Feeding Cover	Large lakes and connecting rivers.	**Water depth** • In 1995, it was captured at depths of 7.6–12 m in Lake Erie (Schwier et al. 1995a, b) but it has been reported from as deep as 20 m (Kinney 1954)	• In the western basin of Lake Erie, caught at depths from 3.1 to 10.4 m, with nearly 40% of the fish caught at 5.8 m. (P. Kocovsky, USGS, unpubl. data) • In the partnership gill net surveys, Silver Chub have been recorded between 4 and 24 m (average depth = 10.5 m) (OMNR 2013a) • In the western basin interagency bottom trawls, Silver Chub was caught at depths from 2.3 to 13.7 m	• 2.3 to 24 m water depth

Life Stage	Function	Feature(s)	Habitat Attributes		
			Scientific Literature	Current Records	For Identification of Critical Habitat
				(average depth = 8.2 m) (ODW 2013; OMNR 2013a)	
			Turbidity		
			• Occur in a wide range of turbidity levels. • Quite tolerant of silty turbid streams (Robison and Buchanan 1992)	• In Lake Erie captured where Secchi depths ranged from 0.25 to 2 m. Close to 40% of the fish were captured where Secchi depth was 0.25 m (P. Kocovsky, USGS, unpubl. data). • In the partnership gill net surveys, Silver Chub was caught when Secchi was recorded between 0.25 and 6.5 m (OMNR 2013a) • In the western basin interagency bottom trawls, Silver Chub was caught at Secchi depths from 0.2 to 4.5 m (OMNR 2013a)	• Wide range of turbidity levels, from 0.25 to 6.5 m
			Substrate		
			• Favoured lentic substrates are clean gravel and sand (Trautman 1981), silt (Kinney 1954). In stream mouths, found over fine gravel or sand bottoms (Werner 2004).		• Favoured lentic substrates are clean gravel and sand, silt. In stream mouths, found over fine gravel or sand bottoms.

Recovery Modelling

Population Trajectory

Population trajectory of Silver Chub was estimated based on a time series of annual trawling data from the Western Basin of Lake Erie between 1988 and 2012 (ODW 2013; OMNR 2013a) (Figure 2). The average annual population growth rate (λ) between 2000 and 2012 was λ=0.8 (95% confidence interval: 0.72 – 0.90), or 20% annual decline. From 2007 to 2012, the average rate was λ=1.04 (4% annual growth), but the uncertainty around this estimate is large (95% confidence: 31% annual decline to 55% annual growth).

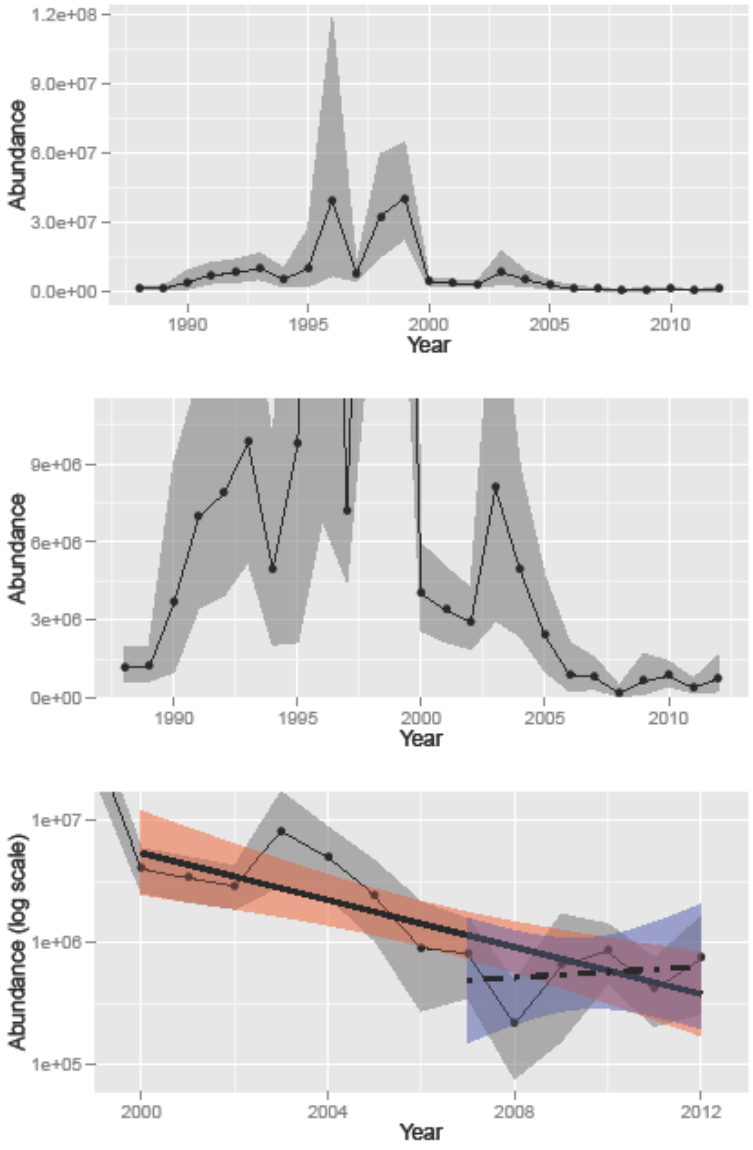


Figure 2. Abundance of Silver Chub in the Western basin of Lake Erie from 1988 – 2012 (top panel). Abundance with high range (boom years) excluded (middle panel). Logged abundance from 2000 – 2012 with lines of best fit from 2000 – 2012 (solid) and from 2007-2012 (dashed) showing trends of long-term decline and more recent slight growth, respectively, with 95% confidence for fit (red and blue shaded, respectively) (bottom panel). Abundances based on geometric mean fish per hectare with 95% quasi Poisson confidence intervals (grey shaded).

Population Sensitivity

The assessment of population sensitivity involves perturbation analyses of population projection matrices and includes a stochastic element. Outputs of the analyses include calculation of a population growth rate and its sensitivity to changes in vital rates (survival and fecundity). See Young and Koops (2013) for complete details of the model and results. Sensitivity of the Silver Chub model depends on assumptions regarding population growth rate. The growth rate of a growing Silver Chub population is most sensitive to changes in the survival of immature individuals. Stable or Declining populations are most sensitive to changes in cumulative adult survival, and are more sensitive than growing populations to changes in fecundity of older individuals (Figure 3).

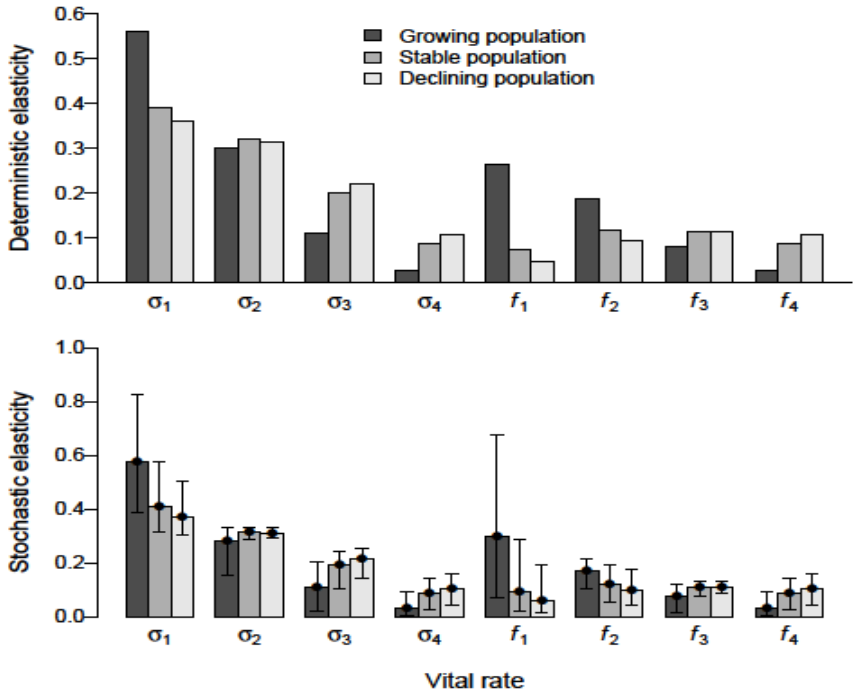


Figure 3. Results of the deterministic (upper panel) and stochastic (lower panel) perturbation analysis showing elasticities (ε_v) of vital rates for Silver Chub: annual survival probability from age j-1 to age j (σ_j) and fecundity at age j (f_j). Results for a growing, stable, or declining population are compared. Stochastic results include associated bootstrapped 95% confidence interval. Exact values listed in Table 3 in Young and Koops (2013).

Allowable Harm

For the purpose of the recovery potential assessment modelling, the following definitions are used:

- Allowable harm is defined as harm to the population that will not jeopardize population recovery or survival.
- Chronic harm refers to a negative alteration to a vital rate that reduces a population growth rate over the long term.
- Transient harm refers to a one-time removal of individuals that reduces the mean population growth rate temporarily over a specific time-frame.

Using the current estimated population growth rate, allowable chronic harm is determined such that said harm to the vital rate(s) of Silver Chub does not cause population decline. Allowable transient harm is defined as an acceptable temporary change in growth rate resulting from one-time removals of individuals over 10 years or 3 generations, whichever is shorter (7 years for Silver Chub). The allowable removal rate is determined by simulating removal of individuals (stochastically) and measuring the resulting change in population growth rate.

If the Silver Chub population is growing at a rate of λ=1.04, to avoid population decline, chronic harm should not exceed 3% of YOY survival *or* 2% of adult survival *or* 3% of fecundity. Figure 4 shows the effect of transient harm on the population growth of a stable or slow growing Silver Chub population. One-time removals of individuals in the amount of 23.5% reduction in YOY abundance, or 15% reduction in adult abundance, or 8.5% reduction in total abundance within a seven-year period result in a 1% change in mean population growth rate of a stable population. To avoid this change, allowable transient harm should not exceed these rates. See Table 4 in Young and Koops (2013) for examples of removal rates resulting in 1%, 2%, or 4% changes in growth rate for a slow growing population and for removal numbers based on current population abundance
estimates.

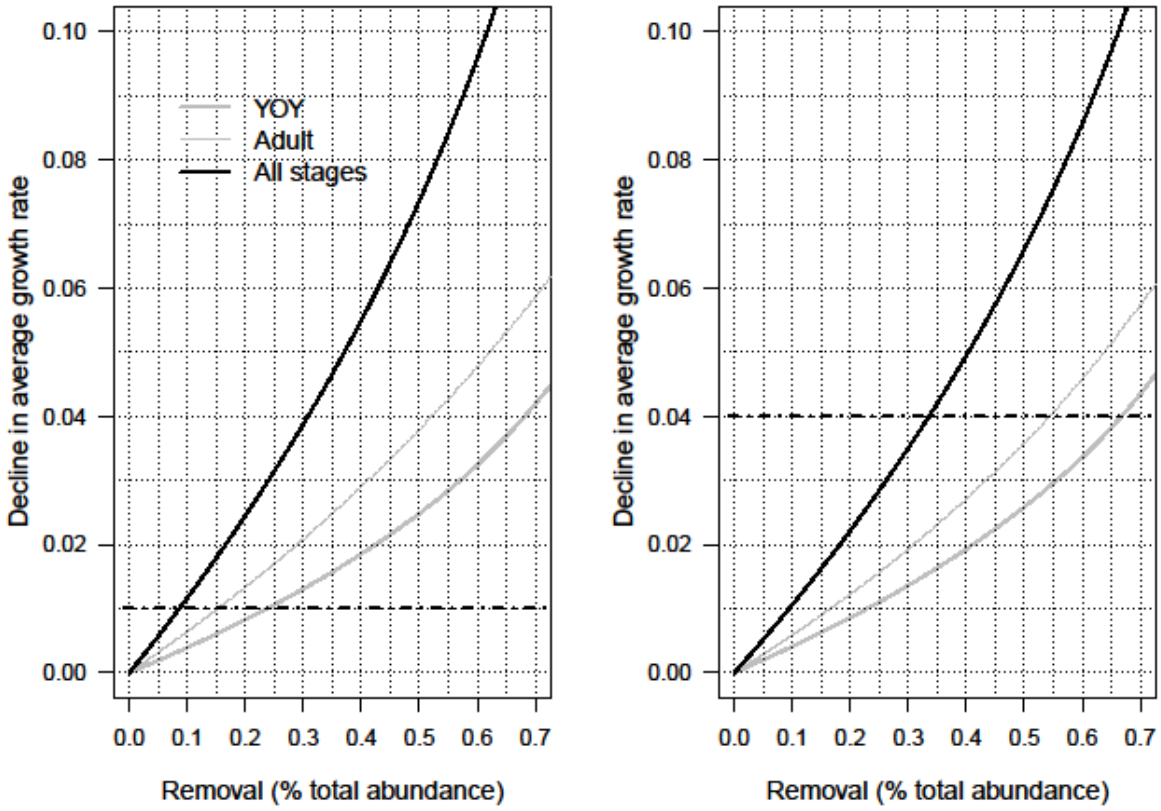


Figure 4. Decline in average population growth rate of a stable population (left) or a population growing at a rate of λ=1.04 (right) over 7 years, as a function of the percent of individuals removed from the population in one of 7 years. Results for removal of YOY only, adults only, or all stages are compared. Values shown are the lower confidence bounds only. See Young and Koops (2013) for mean values

Science Advice on Allowable Harm

Each element of allowable harm advice is independent and assumes no additional sources of harm. If there is harm from multiple sources, allowable harm should be reduced.

- Scientific research to advance the knowledge of population data should be allowed.

Allowable Chronic Harm

- When population trajectory is declining, there is no scope for allowable chronic harm (i.e., at the population level).
- When population trajectory is growing, chronic harm may be allowed to the levels indicated in the allowable chronic harm modelling. Any chronic harm may delay recovery.
- When population trajectory is stable and exceeds the recovery target (MVP), chronic harm may be considered that does not result in population decline.
- When population trajectory is unknown, the scope for allowable chronic harm can only be assessed once population data are collected.

Allowable Transient Harm

- When population trajectory is declining or unknown, even low levels of transient harm may compromise recovery or shorten the time to extirpation.
- When population trajectory is stable, transient harm should not exceed 23.5% of YOY *or* 15% of adults *or* 8.5% of total abundance over 7 years.
- When population trajectory is growing, transient harm at greater levels may be considered, based on the population growth rate, to the levels indicated in the allowable transient harm modelling.

Recovery Targets

Abundance Targets (MVP)

Demographic sustainability was used as a criterion to set recovery targets for Silver Chub. Demographic sustainability is related to the concept of a minimum viable population (MVP) and was defined as the minimum adult population size that results in a desired probability of persistence over 100 years (approximately 40 generations). MVP targets were chosen to optimize the benefit of reduced extinction risk and the cost of increased recovery effort, and resulted in a persistence probability of approximately 99% over 100 years. Recommended targets were estimated at 444,000 adults (ages 1+), assuming the probability of a catastrophic (50%) decline was 0.15 per generation and an extinction threshold of 50 adults.

Risk at Current Abundance

If Silver Chub in the Western Basin of Lake Erie are stable, the risk of extirpation to the current population of 662,000 (95% confidence, 266,000 – 1,619,700) is 0.57% (0.31 - 1.05%) over the next 100 years (assuming 15% per generation catastrophes and an extinction threshold of 50 adults). If Silver Chub are declining at a rate of 20% annually, expected time to extirpation for the mean estimated abundance is 58 years (95% confidence, 36 - 95 years). Time to extirpation decreases if the abundance of Silver Chub has been over-estimated.

Habitat Targets (MAPV)

Minimum area for population viability (MAPV) is a quantification of the amount of habitat required to support a viable population. Variables included in the MAPV assessment include MVP values

and area required per individual (API values). API values were estimated from an allometry for lake environments from freshwater fishes. MAPV for the recommended recovered population above was 84 km^2 of suitable Silver Chub habitat. Current available habitat is estimated at 3000+ km^2 in the Western Basin of Lake Erie. The quality of this habitat is unknown.

Threats to Survival and Recovery

A wide variety of threats negatively impact Silver Chub. Our knowledge of threat impacts on Silver Chub populations is limited to general documentation, as there is a paucity of threat-specific cause-and-effect information in the literature. Many of the greatest threats to the survival and persistence of Silver Chub in Ontario are anthropogenic in origin such as nutrient loading, turbidity and sediment loading, contaminants and toxic substances, and habitat removal and alteration. Furthermore, the presence of numerous invasive species may pose a threat to the survival and persistence of the Silver Chub in Ontario. A lesser threat that may be affecting the survival of Silver Chub is the incidental capture of this species in the commercial fishery; although, this threat may be negligible as the minimum mesh size used in the commercial fishing industry is greater than that required to successfully capture Silver Chub. It is important to note the threats may not always act independently on Silver Chub populations; rather, one threat may directly affect another, or the interaction between two threats may introduce an interaction effect on Silver Chub populations.

Threat Level Assessment

To assess the Threat Level of Silver Chub populations in Ontario, each threat was ranked in terms of the Threat Likelihood and Threat Impact on a population-by-population basis [see McCulloch et al. (2013) for complete details on classification approach]. Threat Impact categorization is location specific, in that impact categorization was assigned on a location-by-location basis. If no information was available on the Threat Impact at a specific location, a precautionary approach was used - the highest level of impact from all sites was applied. The Threat Likelihood and Threat Impact for each population were subsequently combined in the Threat Level Matrix resulting in the final Threat Level for each population (Table 3). The level of certainty associated with the Threat Impact assignment has been assessed and classified as: 1=causative studies; 2=correlative studies; and, 3=expert opinion.

Table 3. Threat Level for all Silver Chub populations in Ontario, resulting from an analysis of both the Threat Likelihood and Threat Impact. The number in brackets refers to the level of certainty associated with the Threat Impact. Certainty has been classified as: 1= causative studies; 2=correlative studies; and 3=expert opinion.

Threats	Lake St. Clair	Lake Erie Western basin	Lake Erie Central basin
Habitat removal and alteration	High (3)	High (3)	High (3)
Nutrient loading	High (3)	High (3)	High (3)
Turbidity and sediment loading	Low (3)	Low (3)	Low (3)
Contaminants and toxic substances	High (3)	High (3)	Medium (3)
Invasive species	High (3)	High (3)	High (3)
Incidental harvest	Low (2)	Low (2)	Low (2)

Mitigation and Alternatives

Threats to species survival and recovery can be reduced by implementing mitigation measures to reduce or eliminate potential harmful effects that could result from works or undertakings associated with projects, or activities in Silver Chub habitat. Currently, SARA prohibitions do not

apply to Silver Chub. In Ontario, the species is listed as Threatened under the *Endangered Species Act* (2007). Legislation exists to prevent the intentional harvest of Silver Chub as bait; however, due to its morphological similarity to other shiners, it may be inadvertently taken. A management plan for Silver Chub in Canada has been completed.

Within Silver Chub habitat, a variety of works, undertakings, and activities have occurred in the past few years (see McCulloch et al. 2013 for a complete list of works, undertakings, and activities). Research has been completed summarizing the types of work, activity, or projects that have been undertaken in habitat known to be occupied by Silver Chub (Table 4). Based on the assumption that historic and anticipated development pressures are likely to be similar, it is expected that similar types of projects will likely occur in or near Silver Chub habitat in the future. The primary project proponents were municipalities.

As indicated in the Threat Analysis, numerous threats affecting Silver Chub populations are related to habitat loss or degradation. Habitat-related threats to Silver Chub have been linked to the Pathways of Effects developed by DFO Fish Habitat Management (FHM) (Table 4). DFO FHM has developed guidance on mitigation measures for 19 Pathways of Effects for the protection of aquatic species at risk in the Central and Arctic Region (Coker et al. 2010). This guidance should be referred to when considering mitigation and alternative strategies for habitat-related threats. At the present time, we are unaware of mitigation that would apply beyond what is included in the Pathways of Effects.

Additional mitigation and alternative measures, specific to Silver Chub, related to invasive species and incidental harvest are listed below.

Invasive species

Aquatic invasive species (e.g., Round Goby) introduction and establishment could have negative effects on Silver Chub populations.

Mitigation

- Physically remove non-native species from areas known to be inhabited by Silver Chub.
- Monitor for invasive species that may negatively affect Silver Chub populations directly, or negatively affect Silver Chub preferred habitat.
- Develop a plan to address potential risks, impacts, and proposed actions if monitoring detects the arrival or establishment of an invasive species.
- Introduce a public awareness campaign and encourage the use of existing invasive species reporting systems.

Alternatives

- Unauthorized
  - None.
- Authorized
  - Use only native species.
  - Follow the National Code on Introductions and Transfers of Aquatic Organisms for all aquatic organism introductions (DFO 2003).

Incidental harvest

Incidental harvest of Silver Chub through the commercial fisheries industry was recognized as a potentially low risk threat.

Table 4. Summary of works, projects and activities that have occurred during the period of January 2010 to January 2013 in areas known to be occupied by Silver Chub. Threats known to be associated with these types of works, projects, and activities have been indicated by a checkmark. The number of works, projects, and activities associated with each Silver Chub population, as determined from the project assessment analysis, has been provided. Applicable Pathways of Effects have been indicated for each threat associated with a work, project or activity (1 - Vegetation clearing; 2 – Grading; 3 –Excavation; 4 – Use of explosives; 5 – Use of industrial equipment; 6 – Cleaning or maintenance of bridges or other structures; 7 – Riparian planting; 8 – Streamside livestock grazing; 9 – Marine seismic surveys; 10 – Placement of material or structures in water; 11 – Dredging; 12 – Water extraction; 13 – Organic debris management; 14 – Wastewater management; 15 – Addition or removal of aquatic vegetation; 16 – Change in timing, duration and frequency of flow; 17 – Fish passage issues; 18 – Structure removal; 19 – Placement of marine finfish aquaculture site).

Work/Project/Activity	**Threats** (associated with work/project/activity)						**Watercourse/Waterbody** (number of works/projects/activities between Jan 2010-Jan 2013)		
	Habitat removal and alteration	**Nutrient loading**	**Turbidity and sediment loading**	**Contaminants and toxic substances**	**Invasive species**	**Incidental harvest**	**Lake St. Clair**	**Lake Erie – western basin**	**Lake Erie – central basin**
Applicable pathways of effects for threat mitigation and project alternatives	1,2,3,4, 5,7,9,10, 11,12,13, 15,18	1,4,7, 9,11, 13,14 15,19	1,3,4 5,9,10, 11,13, 16,18	1,4,5,7, 10,11, 13,14, 15,18					
Shoreline work (stabilization, breakwater repair, groynes and jetties)	✓		✓	✓			7	16	19
In–lake works (disposal of dredgate, seismic exploration)	✓	✓	✓	✓			19	1	3
Water management (stormwater management, water withdrawal)									
Structures in water (water intakes, gas pipeline installation, plug wells, lighthouse repair)	✓		✓					1	4
Commercial fishing						✓			
Invasive species introductions (accidental and intentional)					✓				

Mitigation

- Provide information and education to commercial harvesters on Silver Chub to raise awareness
- Immediate release of Silver Chub if incidentally caught, as defined under the Ontario Recreational Fishing Regulations (OMNR 2013b).
- Education through mandatory training on species at risk for commercial harvesters.

Alternatives

- Seasonal or zonal restrictions applied to commercial harvest during Silver Chub spawning season.

If Silver Chub is listed under the SARA, it is possible that alternatives in addition to mitigation may be required. However, alternatives, such as redesigning projects, have also been used as mitigation in many of the works that have taken place in the last few years. Offsetting may be required in some instances if future projects are permitted to result in the destruction of critical habitat.

Sources of Uncertainty

A number of key sources of uncertainty exist for this species related to population distribution and structure, habitat preferences, and factors limiting their existence. Resolving these sources of uncertainty would greatly enhance our understanding of Silver Chub in Ontario.

There is a need for a continuation of quantitative sampling of Silver Chub in areas where it is known to occur with the appropriate gear type to determine population size, current trajectory, and trends over time. Standardized trawling surveys should be extended to the central basin of Lake Erie where Silver Chub continues to be collected in gill net surveys. Trawling surveys should also be extended to Lake St. Clair to determine the status of the Silver Chub population in this system. These baseline data are required to monitor Silver Chub distribution and population trends as well as the success of any recovery measures implemented. Tissue samples should be collected from Silver Chub captured from the central and western basin of Lake Erie, as well as Lake St. Clair to determine the genetic structure of these populations.

The current distribution and extent of suitable Silver Chub habitat is unknown and should be investigated and mapped. These areas should be the focus of future targeted sampling efforts for this species. There is also a need to refine habitat requirements for each life stage. There is very little information available for both spawning and egg-to-juvenile habitat requirements, necessitating the inference of these requirements from other life stages. Larval surveys are needed to identify both spawning and nursery grounds. It is currently assumed that Silver Chub are open-water spawners as the rivers that were historically used for spawning are degraded and no longer suitable for spawning. This assumption should be tested.

Numerous threats have been identified for Silver Chub populations in Ontario, although the direct impacts of these threats on Silver Chub are highly speculative. There is a need for more causative studies to evaluate the impact of each threat on Silver Chub populations with greater certainty as well as an estimation of the cumulative effects of interactive threats. There is a need to determine threshold levels for water quality parameters (e.g., nutrients, turbidity) and to determine physiological parameter limits including temperature, pH, dissolved oxygen, and pollution tolerance.

SOURCES OF INFORMATION

This Science Advisory Report is from the March 5, 2013 Recovery Potential Assessment of Silver Chub (*Macrhybopsis storeriana*). Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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THIS REPORT IS AVAILABLE FROM THE:

Centre for Science Advice (CSA)
Central and Arctic Region
Fisheries and Oceans Canada
501 University Crescent
Winnipeg, Manitoba
R3T 2N6

Telephone: (204) 983-5131
E-Mail: xcna-csa-cas@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-5079 (Print)
ISSN 1919-5087 (Online)

Correct Citation for this Publication:

DFO. 2013. Recovery Potential Assessment of Silver Chub (*Macrhybopsis storeriana*) in Ontario. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/019.

Aussi disponible en français :

MPO. 2013. Évaluation du potentiel de rétablissement du méné à grandes écailles (Macrohybopsis storeriana) en Ontario. Secr. can. de consult. sci. du MPO, Avis sci. 2013/019.