RECOVERY POTENTIAL ASSESSMENT OF NORTHERN MADTOM (*Noturus stigmosus*) IN CANADA

*Northern Madtom (*Noturus stigmosus*)*
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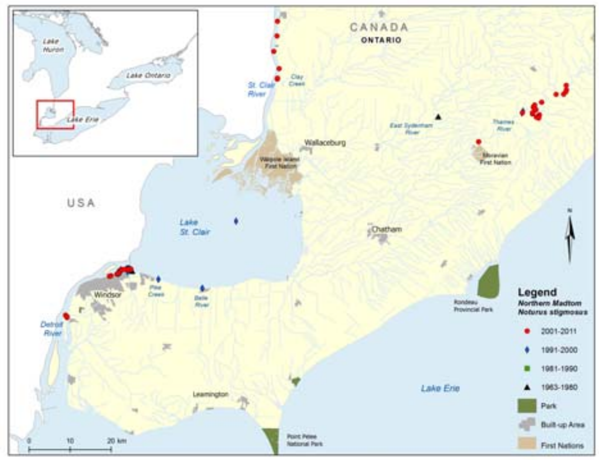

Figure 1. Distribution of Northern Madtom in Canada.

Context

*The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) first assessed the status of Northern Madtom (*Noturus stigmosus*) in April 1993. They considered the species to be Data Deficient. They re-examined the species in April 1998 and designated it as Special Concern. In November 2002, it was re-assessed and uplisted to Endangered. Subsequent to the COSEWIC designation, Northern Madtom was listed on Schedule 1 of the* Species at Risk Act *(SARA) when the Act was proclaimed in June 2003. The reason given for the designation was that the Northern Madtom has a very restricted Canadian range (two extant locations) and one population in the Sydenham River has been lost since 1975. The species is impacted by deterioration in water quality and potential negative interactions with an exotic species*

Fisheries and Oceans Canada (DFO) Science was asked to undertake a Recovery Potential Assessment (RPA) to gather scientific information to support decision-making with regards to SARA agreements and permits. A Science advisory meeting was held on March 19, 2012 to conduct the RPA. During the meeting, participants discussed the best available information for Northern Madtom on a range of topics related to species biology, population and distribution, habitat requirements, threats to survival or recovery, potential mitigation measures and allowable harm.

SUMMARY

- The current Northern Madtom distribution is limited to four distinct locations in Canada: St. Clair River, Lake St. Clair, Thames River and Detroit River.
- One historic location in the Sydenham River is likely extirpated.
- Adults occupy a wide range of habitats with clear to turbid water of large creeks to big rivers, with moderate to swift current, and lakes. Little is known about young-of-the-year and juvenile habitat.
- Northern Madtom occupy residences (cavity nests) during the breeding and rearing parts of its life cycle. Spawning takes place in cavities and males guard the young in the nest until about one month after hatch. Spawning season begins with water temperature at approximately 23°C and nests are occupied for a month post-hatch (June to September) in Canada. It is uncertain when Northern Madtom start building nests.
- To achieve ~97% probability of persistence in 100 years, the Minimum viable populations ranges from 74,000 or 2.7 million adult Northern Madtom with a 5 or 10% chance of catastrophic decline (50%) per generation, respectively. They would require a minimum of 59.7 ha of optimal river habitat or 314.7 ha of suitable lake habitat. Extinction risk is elevated and recovery is delayed exponentially if optimal habitat is less than this. Habitat restrictions result in reduced probabilities of persistence and ability to recover.
- There are insufficient data to determine recovery times however recovery times can be reduced by increasing fecundity rate or survival rate of subadults.
- The greatest threats to the survival and recovery of Northern Madtom in Canada are invasive species and climate change then siltation, nutrient loadings, habitat loss, and increases in turbidity.
- Population growth rate is very sensitive to perturbations of fecundity at any stage and survival of juveniles in the first year.
- There are insufficient data to determine allowable harm. Population trajectories are unknown as are vital rates for Canadian populations. Scientific research to address the lack of population data should be allowed.
- There remain numerous sources of uncertainty related to Northern Madtom biology, ecology, life history, young-of-the-year and juvenile habitat requirements, population abundance estimates, population structure, and species distribution. A thorough understanding of the numerous threats affecting the Northern Madtom populations is also lacking.

BACKGROUND

In April 1993, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) placed Northern Madtom in the Data Deficient category. The species was re-examined in April 1998 and designated as Special Concern. In November 2002, it was uplisted to Endangered based on the existing 1998 status report with an addendum (COSEWIC 2002). In May 2012, COSEWIC completed a reassessment of Northern Madtom based on an updated status report and concluded that its status should remain as Endangered. Northern Madtom is currently listed as Endangered on Schedule 1 of the *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 Northern Madtom populations in Canada, and is a summary of a Canadian Science Advisory Secretariat peer-review meeting that occurred on 19 March 2012 via WebEx/Teleconference. Two research documents, one providing background information on the species biology, habitat preferences, current status, threats and mitigations and alternatives (McCulloch and Mandrak 2012), and the other on allowable harm, population-based recovery targets, and habitat targets, provide an in-depth account of the information summarized below. The proceedings report summarizes the key discussions of the meeting (DFO 2012). Technical details and the full list of cited material are included in the two research documents. This Science Advisory Report summarizes the main conclusions and advice from the science peer review.

Species Description and Identification

Northern Madtom (*Noturus stigmosus*) is a small, benthic ictalurid catfish. The species possesses poison glands associated with the pectoral spines. The maximum total length (TL) globally and in Canada is 132 mm. The overall colour pattern is mottled with three irregular dark saddles on the back located at the front of the dorsal fin, behind the dorsal fin, and at the adipose fin. The dorsal and adipose fins of Northern Madtom have pale distal margins. There are three or four irregular crescent-shaped bars on the caudal fin; the middle bar usually extending across the upper and lower caudal rays and touching the caudal peduncle. Two pale spots about three-quarters the diameter of the eye are usually present just anterior to the dorsal fin. The adipose fin has a high rear edge, and it is nearly free from the caudal fin. In spawning males, the head flattens, dark pigment diffuses, and conspicuous swellings develop behind the eyes, on the nape, and on the lips and cheeks. The distributions of three madtoms overlap with that of Northern Madtom, although several distinctive characteristics help to decrease the chance of errors in identification. Stonecat (*Noturus flavus*) and Tadpole Madtom (*Noturus gyrinus*) are both unmottled and have weak serrations on the posterior edge of the pectoral fin spines. Brindled Madtom has a low adipose fin continuous with the caudal fin, a dark blotch at the tip of the dorsal fin, and a dark bar which extends to the extreme upper edge of the adipose fin.

ASSESSMENT

Current Species Status

Lake St. Clair Drainage

Historic records exist from the Sydenham River, 1929 and 1975 and Lake St. Clair, 1963. Despite several sampling events, Northern Madtom has not been collected from the Sydenham River since 1975, and it likely has been extirpated. In Lake St. Clair, 55 Northern Madtom, including approximately 50 males guarding egg clutches near the source of the Detroit River, have been collected.

More recent first records exist for the Thames (1991) and St. Clair River (2003). Thirty-one Northern Madtom have been recorded from the Thames River, with the majority of the sites located in, or near, the Big Bend Conservation Area. Seven Northern Madtom have been recorded from the middle section on the Canadian side of the St. Clair River.

Lake Erie Drainage

Northern Madtom was first collected on the Canadian side of the Detroit River in 1994. A total of 118 Northern Madtom have been collected between the outlet of Lake St. Clair and Fighting Island, with the majority of the records coming near Peche Island and Belle Isle.

Population Status

To assess the Population Status of Northern Madtom populations in Canada, 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 and Mandrak (2012) for detailed methods used in the Population Status assessment.

Table 1. Population Status for all Northern Madtom populations in Canada, 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 drainage		
St. Clair River	Poor	3
Lake St. Clair	Poor	3
Thames River	Poor	3
Sydenham River	Likely Extirpated	3
Lake Erie drainage		
Detroit River	Poor	2

Habitat Requirements

Spawning

Both sexes of Northern Madtom come into reproductive condition in early summer and exhibit secondary sexual dimorphism at this time. Breeding seems to occur in July in most parts of its range, or when water temperature reaches 23°C. Northern Madtom likely produces only one clutch per year. Age at maturity is typically 2 years, although there is evidence for early maturation of females at 13 months. Northern Madtom is a cavity nester, with nests constructed in depressions under large rocks, logs and inside crayfish burrows, and in anthropogenic debris such as bottles, cans, and boxes. There is wide range of clutch sizes (32-160 eggs), which might be attributed to females that lay eggs in multiple nests.

Larval and Juvenile

The male guards both the eggs and young-of-year (YOY) until approximately one month post-hatch. In the Thames River, juveniles/ YOY were found in areas where water temperature was 19.5-28°C, pH was 8.03-8.47, dissolved oxygen was 6.0-10.05, depths were 0.06 to 0.90 m, and near bottom velocity was 0-0.55 m/s. Substrate was mostly sand with gravel and silt.

Adult

Adult Northern Madtom occupy a wide range of habitats, including clear to turbid water of large creeks to big rivers with moderate to swift current, and lakes. They occur on bottoms of sand, gravel, and rocks, occasionally with silt, detritus, and accumulated debris, and are sometimes associated with macrophytes. The lentic environment is usually close to a lotic source, and has a noticeable current

On the Canadian side of the Detroit River, Northern Madtom adults have been captured at depths of 1-7 m on smooth, firm bottoms often covered by macrophytes such as *Chara*. Recent targeted sampling captured Northern Madtom adults in slow run habitat in open water with substrates of mostly sand and clay. On the American side near Belle Isle, they have been collected in depths of 6-8m with limestone, sand, rock and rubble substrates, as well as hard pan clay.

Northern Madtom adults have been found in Lake St. Clair near the outlet at the Detroit River and around Belle River on sandy substrate devoid of cover. They have also been collected in areas with modest accumulations of silt and detritus and heavy growths of aquatic macrophytes. On the American side of the St. Clair River, they were collected at depths of 3-7 metres. On the Canadian side they were also found in similar depths in moderate to fast current (0.3-0.6 m/s)

In the Thames River, Northern Madtom adults have been captured in highly turbid water in moderate current where bottom consisting of sand, gravel, and rubble from areas where the substrate was free of silt and clay. Maximum depth of capture was 1.2 metres. During recent targeted sampling, Northern Madtom adults were found in moderate flows in mostly run habitat at an average depth of 1.9 m (1.6 m to 2.4 m range).

In the Detroit River, Northern Madtom adults were collected in three separate areas where habitat improvement projects were conducted. Near Belle Isle and Fighting Island, artificial reefs were constructed to improve Lake Sturgeon (*Acipenser fulvescens*) spawning habitat. Near the mouth of Conner Creek, shoreline habitat was rehabilitated as part of a project undertaken by the Detroit Water and Sewerage Department.

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, Northern Madtom occupy residences during the breeding and rearing parts of its life cycle.

Recovery Targets

Population modelling was used to determine population-based recovery targets, and conduct long-term projections of population recovery under a variety of feasible recovery strategies. It is based on a demographic approach developed by Vélez-Espino and Koops (2007, 2009a, 2009b). Where possible, life history estimates for Northern Madtom were based on data from Canadian populations in the St. Clair, Detroit and Thames rivers. However, because of the paucity of these data estimates were supplemented by life-history based allometries using the Life-History Tool in FishBase (www.fishbase.org) and included non-Canadian populations and conspecifics.

Recovery Targets

Consistent with SARA section 73(3), demographic sustainability was used as a criterion to set recovery targets for Northern Madtom. Demographic sustainability is related to the concept of a minimum viable population (MVP; Shaffer 1981), and was defined as the minimum adult population size that results in a desired probability of persistence (see below) over 100 years (approximately 91 generations). To achieve ~97% probability of persistence in 100 years, the minimum viable populations ranges from 74,000 to 2.7 million adult Northern Madtom with a 5 or 10 % chance of catastrophic decline (50%) per generation, respectively.

Minimum Area for Population Viability

Following Vélez-Espino *et al*. (2010), the minimum area for population viability (MAPV) was estimated as a first order quantification of the amount of habitat required to support a viable population. Northern Madtom would require a minimum of 59.7 ha of optimal river habitat or 314.7 ha of optimal lake habitat (Table 2). Extinction risk is elevated and recovery is delayed exponentially if optimal habitat is less than this. Habitat restrictions result in reduced probabilities of persistence and ability to recover.

Recovery and Extinction with Habitat Limitations

When habitat restrictions and associated density dependence were incorporated into population projections, both probabilities of persistence and ability to recover were affected. A population at MVP (2.7 million adults), experiencing 10% chance of catastrophe per generation, and having available 59.7 ha of optimal habitat (MAVP), had a 95.9% probability of persistence over 100 years. This was only slightly lower than the 97% probability of persistence observed in simulations that did not include habitat restrictions or density dependence. If habitat was reduced below the MAPV level, however, extinction risk increased exponentially.

Table 2. Stable stage distribution (percentage of the population in each stage), area per individual (API), number of individuals for each life stage to support a minimum viable population (MVP) and the resulting estimate of required habitat for each stage and for the entire population (MAPV), assuming either 5% or 10% per generation probability of catastrophe.

Extinction			5% catastrophe			10% catastrophe		
Threshold (number of individuals)	Risk (%)	Age	MVP (millions)	MAPV (ha)		MVP (millions)	MAPV (ha)	
				River	Lake		River	Lake
2	3	YOY	2.1	0.1	1.0	76	3.7	36.0
		adult	0.1	1.5	1.6	2.7	56.0	278.3
		total		1.6	2.6		59.7	314.3
2	5	YOY	1.0	0.1	0.5	22.6	11.0	10.7
		adult	0.03	0.7	3.5	0.8	16.5	92.9
		total		0.8	4.0		27.5	103.6
2	10	YOY	0.4	0.02	0.2	5.9	0.3	2.8
		adult	0.01	0.3	1.3	0.2	4.3	21.5
		total		0.3	1.5		4.6	24.3
50	3	YOY	37.8	1.8	18.0	1551.4	75.4	736.9
		adult	1.3	27.6	137.4	54.8	1134.3	5640.9
		total		29.4	155.3		1209.7	6377.8
50	10	YOY	6.1	0.3	2.9	99.1	4.8	47.1
		adult	0.2	4.5	22.2	3.5	72.4	360.2
		total		4.8	25.1		77.2	407.3

Threats to Survival and Recovery

A wide variety of threats negatively impact Northern Madtom across its range. The greatest threats to the survival and persistence of Northern Madtom are related to competition from invasive species. Other threats include climate change, siltation, degradation and/or loss of habitat, excessive turbidity, nutrient loading, and addition of toxic compounds. Many of these are directly linked to agricultural and urban land uses that dominate the local landscape. It is important to note that most Northern Madtom populations are facing more than a single threat, and that the cumulative impacts of multiple threats may exacerbate their decline. It is quite difficult to quantify these interactions and; therefore, each threat is discussed independently.

The Great Lakes have a long history of invasion by exotic species and introductions of non-native aquatic organisms. Of these, the Round Goby (*Neogobius melanostomus*) is thought to present the greatest threat to the Northern Madtom. Round Goby has been implicated in the decline of two other benthic species, Mottled Sculpin (*Cottus bairdii*) and Logperch (*Percina caprodes*) in the St. Clair River (French and Jude 2001). Similar declines of Johnny Darter (*Etheostoma nigrum*), Logperch, and Trout-perch (*Percopsis omiscomaycus*) have been observed in Lake St. Clair (Thomas and Haas 2004). As both species are cavity nesters, competition for nest sites might exist. The presence of dorsal and pectoral spines that possess venom (Scott and Crossman 1973) may protect Northern Madtom from predation by Round Goby. It is possible, however, that Round Goby could prey on Northern Madtom larvae or spawn. Potential negative impacts of the invasive Zebra Mussel (*Dreissena polymorpha*) and Quagga Mussel (*D. bugensis*) on Northern Madtom include reduction in the colonization of potential nesting cavities, as well as alteration of food web dynamics and surrounding water quality.

Potential physical habitat loss specific to Northern Madtom in Canada includes dredging the shipping corridor from the St. Clair River to Lake Erie, as well as lake and river shoreline modifications along the Detroit River and Lake St. Clair. Dredging of the shipping channels in the Detroit River has altered large areas of substrate from a complex limestone environment to homogeneous bedrock and clay habitats. Loss of habitat heterogeneity may increase predation risk, decrease availability of prey and, therefore, foraging success.

Soil deposits through agricultural tile drainage systems and overland runoff has a large influence on siltation rates. Sediment input, and streambank and shoreline erosion, increases when channelization and loss of riparian zones occur. While increases in turbidity might not affect feeding activity patterns, as the Northern Madtom is nocturnally active and so does not require light to forage, decreased primary productivity due to reduction in light penetration might reduce available food sources. Deposition of sediment can cover coarse substrates, and might affect the species' ability to nest in cavities

Nutrient loading is a primary threat affecting species at risk in the Sydenham and Thames rivers, and in Lake St. Clair. Habitat quality can be adversely affected by increased nutrient loading. Phosphorus and nitrogen levels can increase due to agricultural fertilization and manure use practices. Effluents from sewage treatment plants and faulty septic systems can also increase nutrient loadings. Adverse effects to the aquatic ecosystem include increased frequency of algal blooms, increased growth of macrophytes, increased turbidity, and disruption of food webs.

Given the presence of Northern Madtom in the Detroit and St. Clair rivers, both of which have been designated Areas of Concern (AOC), it would appear that the species is somewhat tolerant to toxic compounds. Those compounds present in the Detroit and St. Clair rivers include PCBs, PAHs, metals, oils, and greases. In the Thames River, pollutants may include chloride and metals, as well as pesticides from both agricultural and urban areas.

Climate change models predict that several aquatic species like Northern Madtom potentially will be affected, although the extent of the effect is unknown. In the Great Lakes basin, it is expected that air and water temperatures will increase; duration of ice cover will shorten; frequency of extreme weather events will increase, diseases will spread, and predator-prey dynamics will shift. Like many species at risk in southern Ontario, Northern Madtom is at the northern edge of its global range. While cold water species may be extirpated from much of their present range if water temperatures increase, warm water species like Northern Madtom may expand northwards. However, this benefit might be offset by several factors, including decreased lake and summer stream water levels, changes in evaporation patterns and vegetation communities, and increased intensity and frequency of storms.

Threat Status

To assess the Threat Status of Northern Madtom populations in Canada, each threat was ranked in terms of the Threat Likelihood and Threat Impact on a population by-population basis (see McCulloch and Mandrak 2012 for details). The Threat Likelihood and Threat Impact for each population were combined in the Threat Status Matrix resulting in the final Threat Status for each population (Table 3). Certainty was classified for both Threat Likelihood and Threat Impact based on: 1= causative studies; 2=correlative studies; and, 3=expert opinion. Certainty associated with the Threat Status is reflective of the lowest level of certainty associated with either initial parameter.

Table 3. Threat Status for all Northern Madtom populations in Canada, resulting from an analysis of both the Threat Likelihood and Threat Impact. The number in brackets refers to the level of certainty assigned

to each Threat Level, which reflects the lowest level of certainty associated with either initial parameter (Threat Likelihood, or Threat Impact). Certainty has been classified as: 1=causative studies; 2=correlative studies; and 3=expert opinion.

	Lake Erie Drainage	Lake St. Clair Drainage			
Threats	**Detroit River**	**Thames River**	**St. Clair River**	**Lake St. Clair**	**Sydenham River**
Invasive species	High (3)	High (3)	High (3)	High (3)	High (3)
Climate change	Unknown (3)	High (2)	Unknown (3)	High (2)	High (2)
Siltation	Low (3)	High (3)	Low (3)	Medium (3)	High (3)
Turbidity	Low (3)	Medium (3)	Low (3)	Low (3)	Medium (3)
Nutrient loading	Medium (3)	Medium (3)	Low (3)	Medium (3)	Medium (3)
Physical habitat loss	Medium (3)	Low (3)	Medium (3)	Medium (3)	Low (3)
Contaminants and toxic substances	Low (3)	Low (3)	High (3)	Low (3)	Low (3)

Allowable Harm

Allowable harm for Northern Madtom was not investigated due to data limitations, despite the modelled population's demographics exhibiting positive growth. This species is extremely rare throughout its range and the estimated vital rates, which were based to a large extent on non-Canadian populations and on conspecifics, do not necessarily reflect the Canadian population of Northern Madtom. Scientific research to address the lack of population data should be allowed.

Population Sensitivity

Based on the elasticities of the mean vital rates of the Northern Madtom life cycle, population growth rate is very sensitive to perturbations of both fecundity (*f*) and survival in the first year. A growing population of Northern Madtom is relatively insensitive to changes in adult survival. Further, the importance of these two vital rates does not change when the population is declining, growing or in an equilibrium state. Elasticities for these rates are only just under 1, and so a proportional change in either rate will affect the growth rate in nearly the same proportion. Juvenile survival and fecundity are always the most important vital rates to the population growth rate, regardless of the state of the population. Harm to fecundity and juvenile survival should be minimized to avoid jeopardizing the survival and future recovery of Canadian populations. In scenarios where the population is not growing (i.e., at equilibrium and declining states), there is less disparity between the relative importance of juvenile and adult survival rates. There is a great deal of uncertainty about the significance of the proportion of reproducing age-1 fish as the confidence intervals are very wide, especially for a population in decline.

Mitigations and Alternatives

Numerous threats affecting Northern Madtom populations are related to habitat loss or degradation. Habitat-related threats to Northern Madtom have been linked to the Pathways of Effects developed by DFO Fish Habitat Management (FHM) (Table 4). DFO FHM has developed guidance on generic mitigation measures for 19 Pathways of Effects for the protection of aquatic species at risk in the Ontario Great Lakes Area (Coker *et al.* 2010). This guidance should be referred to when considering mitigation and alternative strategies. Additional mitigation and alternative measures specific to exotic species are listed below.

Table 4. Threats to Northern Madtom populations in Canada and the Pathways of Effect associated with each threat. See Appendix I for a key to the Pathways. 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.

Threats	Pathways
Turbidity and siltation	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 15, 16, 18
Nutrient loading	1, 4, 7, 8, 11, 12, 13, 14, 15, 16
Contaminants and toxic substances	1, 4, 5 ,6 ,7 ,11 ,12 ,13 ,14, 15, 16 ,18

Invasive Species

As discussed in the Threats section, Round Goby introduction and establishment could have negative effects on Northern Madtom populations.

Alternatives

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

Mitigation

- Establish “Safe Harbours” in areas known to have suitable Northern Madtom habitat.
- Watershed monitoring for invasive species that may negatively affect Northern Madtom populations, or negatively affect Northern Madtom preferred habitat.
- Develop plan to address potential risks, impacts, and proposed actions if monitoring detects the arrival or establishment of an exotic species.
- Introduce a public awareness campaign and encourage the use of existing exotic species reporting systems.

Sources of Uncertainty

Despite recent targeted sampling for Northern Madtom in Canada, there remain key sources of uncertainty for this species. Occurrence, status, range, abundance, and population demographic data are lacking for the species in Canada. Information on the habitat properties needed by all life stages of Northern Madtom and where they occur is also needed to contribute to the identification of critical habitat. These baseline data are required to monitor Northern Madtom distribution and population trends as well as the success of any recovery measures. While some recent sampling in new locations has been undertaken, additional targeted sampling in areas lacking Northern Madtom records but possessing potentially suitable habitat should be conducted.

There is a lack of information on genetic relationships between populations, as well as the amount of genetic variation within populations. Genetics of Canadian populations of Northern Madtom should be compared to populations in the United States. This will help to distinguish populations, and contribute necessary information should population enhancement through relocations or captive rearing be required

There is uncertainty in the current distribution and extent of suitable Northern Madtom habitat which should be investigated and mapped. These areas should be the focus of future targeted sampling efforts for this species. Seasonal habitat needs, including home range and species movement, of all life-stages of the Northern Madtom should be determined. This will allow for a full identification of critical habitat for Northern Madtom, and will assist with the development of a habitat model. Establishment and implementation of a standardized index population and habitat monitoring program should be undertaken. This will enable an assessment of changes in range, abundance, key demographic characters and changes in habitat features, extent and health.

Variables required to inform the population modeling efforts are currently unknown for Northern Madtom populations in Canada, creating the need to use data from other non-Canadian populations. Additional studies are needed to fill in these knowledge gaps and should focus on acquiring additional information population growth rate, population structure, clutch size and fecundity. Research is needed to determine (i) survival rates, especially for young of the year, (ii) population growth rate (or rate of decline) and (iii) the frequency and extent of catastrophic events. More accurate estimates of uncertain vital rates are needed to confirm the status of Northern Madtom populations that were simulated. . In the absence of early-life survival estimates, determination the population growth rate is paramount, as it would allow an extrapolation of any missing vital rate. Research that identifies the magnitude and frequency of catastrophic events will greatly reduce the uncertainty in estimates of minimum viable population size, and thus in recommendations for the recovery. Finally, predictions from this model assume random mating and complete mixing of the population. This assumption should be considered when applying MVP targets to populations, and larger targets should be set if the assumption does not hold. A further consideration is that MVP targets assume an extinction threshold of 1 adult female. If a higher extinction threshold is likely, we suggest that a larger target be set.

Numerous threats have been identified for Northern Madtom populations in Ontario, although the severity of most of these threats is currently unknown. There is a need for more causative studies to evaluate the impact of each threat on each Northern Madtom population with greater certainty. There is a need to investigate the impacts of Round Goby and Zebra Mussel on Northern Madtom. Studies should include impacts on Northern Madtom spawning success, as well as monitoring the spread of Zebra Mussel in watersheds occupied by the Northern Madtom. This will enable an assessment of the risk posed to Northern Madtom should Zebra Mussel spread and/or increase in number in occupied areas. The impacts of physical habitat changes on the Northern Madtom should also be investigated to identify the degree to which the Northern Madtom is affected by physical habitat alterations. Investigating the impacts (lethal/sub-lethal) of pollutants in the Huron-Erie corridor, and nutrient loading in the Sydenham and Thames rivers, on Northern Madtom. will enable an assessment of risks and the identification of contaminants of concern. Finally, if the need for population supplementation is determined, relocation and captive rearing techniques should be developed and incorporated into population specific action plans as required.

SOURCES OF INFORMATION

This Science Advisory Report is from the March 19, 2012 Recovery Potential Assessment of Northern Madtom (*Noturus stigmosus*). Additional publications from this process will be posted as they become available on the Fisheries and Oceans Canada Science Advisory Schedule at www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

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