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Information in support of a Recovery Potential Assessment of Northern Madtom (*Noturus stigmosus*) in Canada

L'information à l'appui de l'évaluation du potentiel de rétablissement du chat-fou du nord (*Noturus stigmosus*) au Canada

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ABSTRACT

In April 1993, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) placed Northern Madtom (*Noturus stigmosus*) in the Data Deficient category. The species was re-examined in April 1998 and designated as Special Concern. In November 2002, Northern Madtom was uplisted to Endangered based on the existing 1998 status report with an addendum. The reason given for this designation was that, “This species has a very restricted Canadian range (two extant locations), which is impacted by deterioration in water quality and potential negative interactions with an exotic species. One population (Sydenham River) has been lost since 1975”. 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 Canadian distribution of Northern Madtom is restricted to Ontario, where it is known only from the Detroit River, St. Clair River, Lake St. Clair, and two tributaries of Lake St. Clair, the Thames River and the Sydenham River. It is likely extirpated from the Sydenham River. The Recovery Potential Assessment (RPA) provides information and scientific advice needed to fulfill various requirements of SARA including permitting activities that would otherwise violate SARA prohibitions and the development of recovery strategies. This Research Document describes the current state of knowledge of the biology, ecology, distribution, population trends, habitat requirements, and threats of Northern Madtom. Mitigation measures and alternative activities related to the identified threats, that can be used to protect the species, are also presented. This information may be used to inform the development of recovery documents and for assessing SARA Section 73 permits.

RÉSUMÉ

En avril 1993, le Comité sur la situation des espèces en péril au Canada (COSEPAC) a classé le chat-fou du Nord (*Noturus stigmosus*) dans la catégorie « Données insuffisantes ». En avril 1998, le COSEPAC a réévalué l'espèce et l'a désignée comme « préoccupante ». En novembre 2002, le chat-fou du Nord a été classé dans la catégorie « en voie de disparition » compte tenu du rapport de situation de 1998 accompagné d'un addendum. La raison invoquée pour cette désignation était que « L'aire de répartition de cette espèce est très limitée au Canada (elle est présente dans deux endroits), et subit les effets de la dégradation de la qualité de l'eau et des interactions négatives potentielles avec une espèce exotique. Une population (celle de la rivière Sydenham) a disparu depuis 1975. » Après la désignation par le COSEPAC, le chat-fou du Nord a été inscrit sur l'Annexe 1 de la Loi sur les espèces en péril (LEP) lorsque cette loi a été promulguée en juin 2003. Au Canada, le chat-fou du Nord est présent uniquement en Ontario, où il a été observé seulement dans la rivière Detroit, la rivière Sainte-Claire et le lac Sainte-Claire, ainsi que dans deux affluents de celui-ci, les rivières Thames et Sydenham. Il a probablement disparu de la rivière Sydenham. L'évaluation du potentiel de rétablissement (EPR) fournit l'information et les conseils scientifiques nécessaires pour se conformer aux exigences de la LEP, notamment l'autorisation d'activités qui seraient normalement contraires aux interdictions prévues dans la LEP et l'élaboration de stratégies de rétablissement. Le présent document de recherche fournit une description de l'état actuel de la biologie, de l'écologie, de la distribution, des tendances démographiques, des besoins en matière d'habitat et des menaces relatives au chat-fou du Nord. Des mesures d'atténuation et des activités alternatives associées aux menaces déterminées, qui peuvent être utilisées dans le but de protéger l'espèce, sont également présentées. Ces renseignements peuvent servir à éclairer l'élaboration de documents sur le rétablissement et à évaluer les permis délivrés en vertu de l'article 73 de la LEP.

SPECIES INFORMATION

Scientific Name – *Noturus stigmosus* (Taylor, 1969)
Common Name – Northern Madtom
Current COSEWIC Status & Year of Designation – Endangered (2002)
COSEWIC Reason for Designation[1] – This species has a very restricted Canadian range (two extant locations), which is impacted by deterioration in water quality and potential negative interactions with exotic species. One population (Sydenham River) has been lost since 1975.
SARA Schedule – Endangered; Schedule 1
Ontario *Endangered Species Act* – Endangered
Range in Canada – Ontario

BACKGROUND

Northern Madtom (*Noturus stigmosus*) is a small, benthic ictalurid catfish (Figure 1). The species possesses poison glands associated with the pectoral spines (Scott and Crossman 1973). Like all madtoms, Northern Madtom is negatively phototactic and seeks shelter during the day if light penetration reaches the substrate. As a result, foraging activity is nocturnal, with barbels and other sensory organs along the body used to locate prey (Keast 1985). The maximum total length (TL) globally and in Canada is 132 mm (Holm *et al.* 2009). 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. The posterior edge of the pectoral spine strongly serrated. Based on measurements done by Erling Holm at the Royal Ontario Museum, the distance from the notch between adipose and caudal fins to the origin of the dorsal fin is 1.6-1.7 times greater than the distance from the notch to the end of 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. This description is a compilation of diagnostic characters based on observations of Royal Ontario Museum specimens and observations made by Trautman (1981), Page and Burr (1991), Etnier and Starnes (1993), and Holm *et al.* (2009).

Northern Madtom underwent a recent taxonomic revision, in which Thomas and Burr (2004) determined that the allopatric populations occurring in the Coastal Plain streams of Mississippi and Tennessee were not Northern Madtom, but actually a new species, Piebald Madtom (*Noturus gladiator*).

The Canadian distribution of Northern Madtom is restricted to Ontario, where it is known only from the Detroit River, St. Clair River, Lake St. Clair, and two tributaries of Lake St. Clair, the Thames River and the Sydenham River. It is likely extirpated from the Sydenham River.

Northern Madtom feed on aquatic macroinvertebrates, including mayflies, caddisflies, and chironomids. Small fishes and crustaceans are also eaten. While Northern Madtom are

[1] http://www.cosewic.gc.ca/eng/sct5/index_e.cfm

generally opportunistic feeders, in Pennsylvania, Tzilkowski and Stauffer (2004) found that they preferentially selected blackflies and stoneflies, and avoided midges and riffle beetles. All other prey items were consumed in the same proportion to their relative abundance in the stream. In the St. Clair River, French and Jude (2001) found that at 3 m depth, Northern Madtom fed heavily on mayfly nymphs (*Hexagenia*; Ephemeridae and *Baetisca*; Baetiscidae). At 5 and 7 m depths, large Northern Madtom added brachycentrid caddisflies, amphipod crustaceans and fishes to their diet. Fish species that were consumed by Northern Madtom included Round Goby, an unidentified minnow, and other Northern Madtom (French and Jude 2001).

Five madtom species occur in Canada. In Ontario, the distributions of three madtoms (Stonecat, *N. flavus*; Tadpole Madtom, *N. gyrinus*; and Brindled Madtom, *N. miurus*) overlap with that of Northern Madtom, although several distinctive characteristics help to decrease the chance of errors in identification. Stonecat and Tadpole Madtom 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.

Primary sources of human-induced mortality and aggregate harm for Northern Madtom in Ontario include siltation and excessive turbidity, nutrient loading, invasive species[2], toxic compounds, habitat loss and degradation, and climate change. Many of these are related to the agricultural and urban land uses that dominate the local landscape. Negative interactions with invasive species, such as the Round Goby (*Neogobius melanostomus*), are speculated to be impacting Northern Madtom through competition for nest cavities and food resources (Poos *et al*. 2010).

A meeting of the COSEWIC in April 1993 resulted in placement of Northern Madtom in the Data Deficient category. The species was re-examined in April 1998 and designated as Special Concern. In November 2002, Northern Madtom was uplisted to Endangered based on the existing 1998 status report with an addendum. The reason given for this designation was that, "This species has a very restricted Canadian range (two extant locations, Thames River and Detroit River/Lake St. Clair), which is impacted by deterioration in water quality and potential negative interactions with an exotic species. One population (Sydenham River) has been lost since 1975". While not listed federally in the United States, Northern Madtom is currently designated as Endangered in Michigan, Ohio, and Pennsylvania, all of which share border waters with Canada. 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. A Recovery Potential Assessment (RPA) process has been developed by Fisheries and Oceans Canada (DFO) to provide information and scientific advice needed to fulfill SARA requirements, including the development of recovery strategies and authorizations to carry out activities that would otherwise violate SARA (DFO 2007a, b). This document provides background information on Northern Madtom to inform the RPA. In May 2012, COSEWIC completed a reassessment of Northern Madtom based on an update status report and concluded that its status should remain as Endangered.

[2] For the purposes of this report, invasive species is defined as any species, indigenous or non-indigenous, that might have a negative effect on Northern Madtom.

Figure 1. Northern Madtom (Noturus stigmosus)*. Illustration by Joe Tomelleri, reproduced with permission.*

CURRENT STATUS

In Canada, the current and historic distribution of Northern Madtom is limited to two distinct areas of the Great Lakes basin: Lake Erie drainage; and, Lake St. Clair drainage (Figure 2). In the Lake St. Clair drainage, historic records exist from the Sydenham River, 1929 (ROM 6675) and 1975 (NMC 75-1623) and Lake St. Clair, 1963 (Trautman 1981). Despite several sampling events, Northern Madtom has not been collected from the Sydenham River since 1975, and it most likely has been extirpated. In Lake St. Clair, three juveniles were seined at the mouth of Belle River approximately 19 kilometres east of the Detroit River in 1996 (Holm and Mandrak 2001). Also in 1996, MacInnis (1998) observed approximately 50 Northern Madtom guarding egg clutches near the source of the Detroit River. In 1999, a specimen was captured off Walpole Island (ROM 72038). In 2007, one individual was found dead on the south shore of Lake St. Clair near the outlet of Pike Creek (ROM, unpubl. data).

Northern Madtom was first collected in the Thames River 1991 near Wardsville. A juvenile specimen was captured in August 1997 at the same site. In 2003 and 2005, two Northern Madtom were captured below Wardsville at Littlejohn Road. This represents the downstream-most site for the species in the Thames River. Between 2003 and 2010, Northern Madtom were collected at 27 sites on the Thames River between Littlejohn Road and Tate Corners (Edwards and Mandrak 2006; M. Finch, pers. comm. 2010; A. Dextrase, pers. comm. 2010). The majority of sites are located in, or near, the Big Bend Conservation Area. Sampling in the lower Thames River in 2010 failed to collect Northern Madtom. Northern Madtom was first collected on the Canadian side of the St. Clair River by DFO in 2003, downstream of the Lambton Generating Station at the confluence of Clay Creek. In 2010, 6 individuals were collected between Stag Island and Clay Creek (J. Barnucz, pers. comm. 2010). On the United States of the river, 155 Northern Madtom were collected in 1994 adjacent to Algonac State Park, Algonac, Michigan (French and Jude 2001). Fourteen Northern Madtom were collected close to Algonac in 2010 (M. Thomas, pers. comm. 2010).

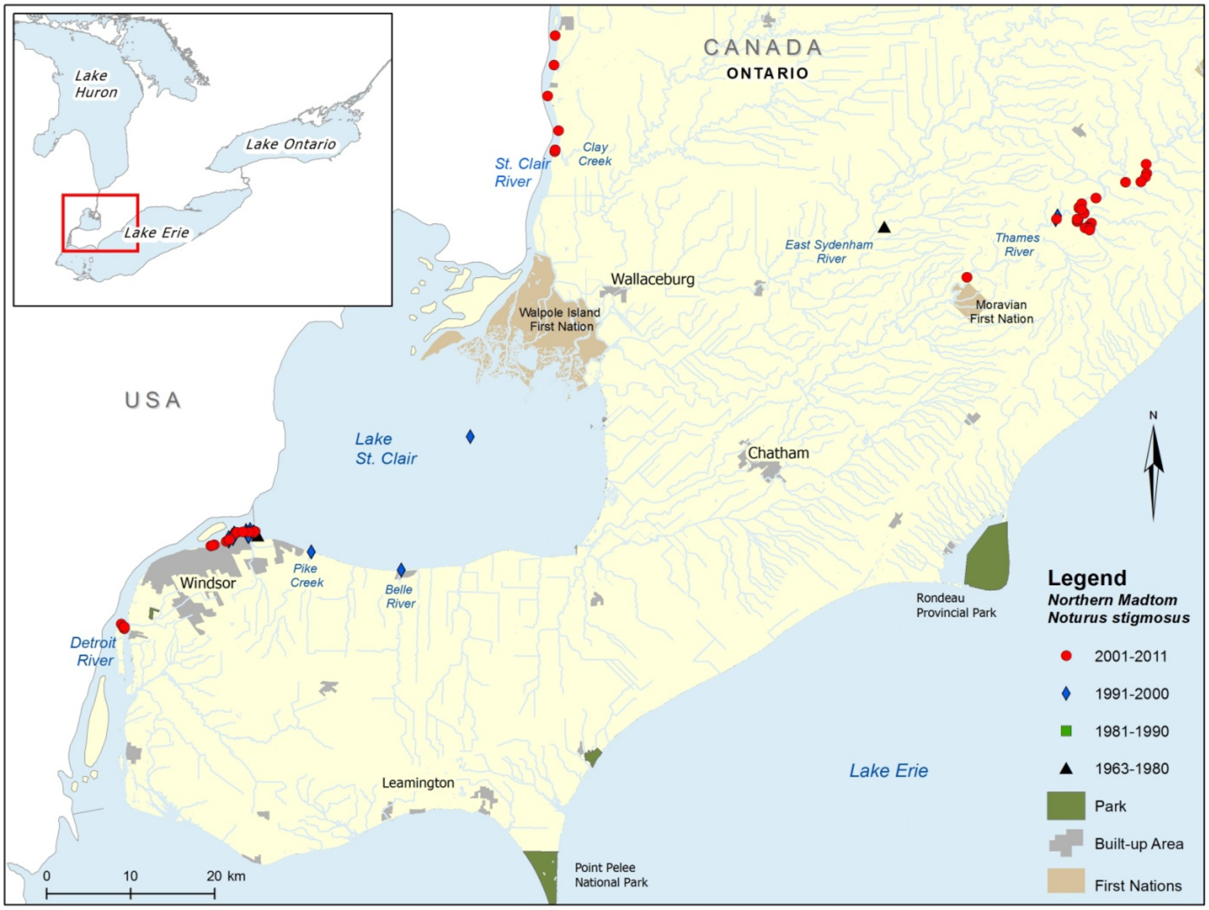

Figure 2. Distribution of Northern Madtom in Canada.

In the Lake Erie drainage, Northern Madtom has been collected on the Canadian side of the Detroit River between the outlet of Lake St. Clair and Fighting Island. The first record was a single specimen collected in 1994 near the first capture site in Lake St. Clair (ROM 68328). Northern Madtom has been collected in the area around Peche Island in 1996 (11 individuals), 2008 (69 individuals), 2009 (eight individuals), 2010 (two individuals), and 2011 (three individuals) (J. Barnucz, pers. comm. 2010; B. Manny, pers. comm. 2010). In 2009, seven Northern Madtom were found near Fighting Island. One Northern Madtom was found in this area in each of 2010 and 2011 (B. Manny, pers. comm. 2010). In September 2011, 15 Northern Madtom were captured at four near shore sites south of Belle Isle in the Fleming Channel (J. Barnucz, pers. comm. 2011). On the United States side of the river, Northern Madtom was first collected in 1903 (University of Michigan Museum of Zoology; UMMZ 132009). In 1937, it was collected at the junction of Lake St. Clair and the Detroit River at the foot of Alter Road, Windmill Point. In 1978, it was reported on the impingement screen of the downtown Detroit coal-fired plant (Latta 2005). Between 2003 and 2008, a total of 205 Northern Madtom were captured near Belle Isle. In 2008, twenty Northern Madtom were captured near Conner Creek (B. Manny, pers. comm. 2012).

POPULATION STATUS

To assess the population status of Northern Madtom populations in Ontario, each population was ranked in terms of its abundance (Relative Abundance Index) and trajectory (Population Trajectory) (Table 1).

The Relative Abundance Index was assigned as Extirpated, Low, Medium, High or Unknown. Sampling parameters, such as gear used, area sampled, sampling effort, and whether the study was targeting Northern Madtom, were considered. The number of individual Northern Madtom caught during each sampling period was then considered when assigning the Relative Abundance Index. The Relative Abundance Index is a relative parameter in that the values assigned to each population are relative to the most abundant population. In the case of Northern Madtom, all populations were assigned an Abundance Index relative to the Detroit River population (Lake Erie drainage).

The Population Trajectory was assessed as Decreasing, Stable, Increasing, or Unknown for each population based on the best available information about the current trajectory of the population. The number of individuals caught over time for each population was considered. Trends over time were classified as Increasing (an increase in abundance over time), Decreasing (a decrease in abundance over time), and Stable (no change in abundance over time). If insufficient information was available to identify the trajectory, the Population Trajectory was listed as Unknown. Certainty has been associated with the Relative Abundance Index, and Population Trajectory rankings and is listed as: 1=quantitative analysis; 2=CPUE or standardized sampling; 3=expert opinion (Table 1).

Table 1. Relative Abundance Index and Population Trajectory of each Northern Madtom population in Canada. Certainty has been associated with the Relative Abundance Index, and Population Trajectory rankings and is listed as: 1=quantitative analysis; 2=CPUE or standardized sampling; 3=expert opinion.

Population	Relative Abundance Index	Certainty	Population Trajectory	Certainty
Lake St. Clair drainage				
St. Clair River	Low[3]	3	Unknown	3
Lake St. Clair	Low	2	Unknown	3
Thames River	Medium	3	Unknown	3
Sydenham River	Likely Extirpated	3	Not Applicable	
Lake Erie drainage				
Detroit River	Medium	2	Unknown	3

[3] Abundance could be higher; sampling is limited.

The Relative Abundance Index and Population Trajectory values were then combined in the Population Status matrix (Table 2) to determine the Population Status for each population. Each Population Status is subsequently ranked as Poor, Fair, Good, Unknown or Not applicable. 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).

Table 2. The Population Status Matrix combines the Relative Abundance Index and Population Trajectory rankings to establish the Population Status for each Northern Madtom population in Ontario. The resulting Population Status has been categorized as Extirpated, Poor, Fair, Good, or Unknown.

		Population Trajectory			
		Increasing	**Stable**	**Decreasing**	**Unknown**
Relative Abundance Index	**Low**	Poor	Poor	Poor	Poor
	Medium	Fair	Fair	Poor	Poor
	High	Good	Good	Fair	Fair
	Unknown	Unknown	Unknown	Unknown	Unknown
	Extirpated	Extirpated	Extirpated	Extirpated	Extirpated

Table 3. 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	3

HABITAT REQUIREMENTS

SPAWNING

Scheibly *et al.* (2008) stated that 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 (Taylor 1969; MacInnis 1998; Scheibly *et al.* 2008). Present knowledge suggests that Northern Madtom produce only one clutch per year. However, MacInnis (1998) suggested that females lay eggs in multiple nests. Age at maturity is reached at 2 years (Taylor 1969) and 60 mm SL, although Scheibly *et al.* (2008) provided 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 (Taylor 1969; Cochran 1996). MacInnis (1998) observed and video-taped nesting of 21 adult Northern Madtom in Lake St. Clair during the summer of 1996 while conducting research on the Round Goby. Northern Madtom did not use the artificial goby nests themselves, but excavated 5 cm deep cavities in sand substrates beneath the nests (MacInnis 1998). Gravid females and recently spawned eggs were observed on 24 July 1996 near Peche Island. The nests were set in gentle current on a sandy bottom surrounded by a thick bed of aquatic macrophytes (primarily *Chara*). Eggs were approximately 3 mm in diameter and clutch size was conservatively estimated to range from 32 to 160. The male guarded both the eggs and newly hatched fry and did not abandon the nest when disturbed. Larvae and juveniles about 9 mm TL were observed being guarded by males on 13 August. The temperature during this period was 23°C. Gravid females were observed as late as mid-August, suggesting a reproduction season of at least one month (MacInnis 1998).

In Kentucky, Scheibly *et al.* (2008) observed Northern Madtom nesting in cavities 4-7 cm deep under slab rocks in a raceway upstream of a large riffle in mid-July. Water temperatures were 23-25°C and velocities were 0.36-0.69 m/s. Water depth at the nests ranged from 0.26 to 0.46 m. Clutch sizes were estimated to be between 70-110 eggs. Eggs incubated in the laboratory hatched 13 days after fertilization. Hatchlings were 7.1-9.3 mm TL, and yolk sacs had been absorbed within 10 days. In Michigan, spawning takes place in mid- to late-July. Clutch sizes in Michigan ranged from 61 to 141 eggs (Taylor 1969). In Pennsylvania, mature female Northern Madtom collected in mid-June had an average oocyte diameter of 1.83 mm, and average clutch size of 98 eggs. Relative fecundity (oocytes/g of body weight) was 20.2 (Tzilkowski and Stauffer 2004).

LARVAL AND JUVENILE

There is very limited information on larval and juvenile Northern Madtom habitat requirements. MacInnis (1998) observed both larval and juvenile Northern Madtom in nests being guarded by adult males approximately one month after occupation of nests was first observed. In Kentucky, 20 mm standard length (SL) young had moved downstream from a spawning raceway into a large riffle also about one month after hatching (Scheibly *et al.* 2008).

In the Thames River, juveniles/young-of-year (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 (A. Dextrase, unpubl. data ; M. Finch, unpubl. data;).

ADULT

Northern Madtom occupies a wide range of habitats. These include clear to turbid water of large creeks to big rivers with moderate to swift current and lakes. It occurs on bottoms of sand, gravel, and rocks, occasionally with silt, detritus, and accumulated debris, and is sometimes associated with macrophytes (Taylor 1969; Smith 1979; Trautman 1981; Cooper 1983; Burr and Warren 1986; Robison and Buchanan 1988; Carman 2001). The lentic environment is usually close to a lotic source, and has a noticeable current (J. Barnucz, pers. comm. 2010).

On the Canadian side of the Detroit River, Northern Madtom has 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 in slow run habitat in open water with substrates of mostly sand and clay (DFO, unpubl. data). On the American side near Belle Isle, it has been collected in depths of 6-8 m with limestone, sand, rock and rubble substrates, as well as hard pan clay (B. Manny, pers. comm. 2010).

Northern Madtom has been found in Lake St. Clair near the outlet at the Detroit River and around Belle River on sandy substrate devoid of cover. It has also been collected in areas with modest accumulations of silt and detritus and heavy growths of aquatic macrophytes (Holm and Mandrak 1998; MacInnis 1998; Edwards *et al.* 2012).

On the American side of the St. Clair River, Northern Madtom were collected at depths of 3-7 m, from the crest of the shipping channel to along the slope of the channel (French and Jude

2001). Northern Madtom collected on the Canadian side were also found in depths of 3-7 m in moderate to fast current (0.3-0.6 m/s) (J. Barnucz, pers. comm. 2010).

In the Thames River, the two specimens captured in 2003 and 2004 were in highly turbid water (Secchi <0.2m) on a bottom consisting of sand, gravel, and rubble from areas where the substrate was free of silt and clay. Current was moderate, maximum depth of capture was 1.2m, water temperature was 23-26°C, conductivity was 666 µS/cm, and pH was 7.9 (Edwards and Mandrak 2006). The one adult captured in 2006 was found in an area where water depth was 60-70 cm, flow (bottom) was 0.1-0.2 m/s, mean substrate size was 60-80 mm, dissolved oxygen was 8-8.5 mg/L and water clarity was 6-8 cm (Dextrase, unpubl. data). During recent targeted sampling, Northern Madtom 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). Average Secchi depth was 0.29 m. Distance from shore when captured ranged from seven to 23 m. Predominant substrate types were gravel (4 sites), sand (2 sites) and cobble (1 site) (DFO, unpubl. data.).

In the Licking River, Kentucky, Scheibly (2003) found that moderate current averaging 0.50 m /s was preferred.

In the Detroit River, Northern Madtom 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 spawning habitat. Near the mouth of Conner Creek, shoreline habitat was rehabilitated as part of a combined sewer outflow disinfection basin project undertaken by the Detroit Water and Sewerage Department. Northern Madtom had been collected near Belle Isle prior to the reef construction, but were captured in lower numbers (B. Manny, pers. comm. 2012).

Trawling nets used to target Northern Madtom in Canadian waters have been deployed to a maximum depth of 7 m. Madtom have been collected at this depth, but it is unknown as to whether they occupy deeper areas in the Detroit and St. Clair rivers, and Lake St. Clair.

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. Northern Madtom is a cavity nester, with nests located in depressions under large rocks, logs and inside crayfish burrows, and in anthropogenic debris such as bottles, cans, and boxes (Taylor 1969; Cochran 1996). Northern Madtom were observed to excavate 5 cm deep crevices beneath artificial Round Goby nests in Lake St. Clair (MacInnis 1998). Parental guarding is conducted by males until YOY are approximately one month of age, at which time both males and young they leave the nest (MacInnis 1998; Scheibly *et al.* 2008).

THREATS

A wide variety of threats negatively impact Northern Madtom across its range. Several threats to Northern Madtom in Canada have been identified by Edwards *et al.* (2012). The greatest threats to the survival and persistence of Northern Madtom are related to competition from invasive species. Other threats include climate change, siltation, nutrient loading, the degradation and/or loss of habitat, excessive turbidity, and addition of toxic compounds. Many of these are directly tied to the 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.

INVASIVE SPECIES

The Great Lakes have a long history of invasion by exotic species and introductions of non-native aquatic organisms. Of these, the Round Goby is thought to present the greatest threat to Northern Madtom. Since its first detection in the St. Clair River in 1990 and successful reproduction within one year (Jude *et al.* 1992), 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). While the Round Goby is a mussel specialist, Carman *et al.* (2006) showed that diet is similar to native benthic fishes when mussels are absent from a waterbody. French and Jude (2001) found significant diet overlap between Round Goby and Northern Madtom at 3 m depth in the St. Clair River. However, nocturnal foraging by Northern Madtom might reduce temporal competition for food. As both species are cavity nesters, competition for nest sites might exist. However, MacInnis and Corkum (2000) found that spawning seasons of the two species barely overlapped, with Round Goby spawning earlier in the year. French and Jude (2001) found that large Northern Madtom preyed on Round Goby YOY, but that the reverse was not observed. 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.

During recent sampling targeted at Northern Madtom in the Detroit River, Roundy Goby was captured in 4 of the 5 trawls that produced Northern Madtom and, in those trawls, the goby to madtom ratio ranged from 3:1 to 15:1 (DFO, unpubl. data). While the Northern Madtom population in the Thames River has not yet had to co-exist with Round Goby, considerable upstream movement of gobies to new areas of the river was documented in 2006 (Poos *et al.* 2010). Roundy Goby has also been confirmed in the Sydenham River, just downstream of the recorded occurrence of Northern Madtom at the town of Florence (Poos *et al.* 2010).

Potential negative impacts of the exotic 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 (Edwards *et al.* 2012). Increased populations of these mussels could, however, reduce diet overlap between Round Goby and Northern Madtom.

CLIMATE CHANGE

Climate change models predict that several aquatic species like Northern Madtom potentially will be affected. 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 (Lemmen and Warren 2004). Like many species at risk in southern Ontario, Northern Madtom is at the northern edge of its global range. While coldwater species may be extirpated from much of their present range if water temperatures increase, warmwater species like Northern Madtom may expand northwards (Chu *et al.* 2005). 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 (EERT 2008).

SILTATION AND TURBIDITY

Siltation and turbidity are also potential threats to Northern Madtom in Canada. Bailey and Yates (2003) stated that direct soil deposits through agricultural tile drainage systems and overland runoff has the largest influence on siltation rates. Additionally, the level of sediment input, as well as the rate of streambank and shoreline erosion, increases when channelization and loss of riparian zones occurs (Bailey and Yates 2003). This loss can occur through ploughing or livestock grazing to the edge of a watercourse (Bailey and Yates 2003). While increases in turbidity might not affect feeding activity patterns, as 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 (Dextrase *et al*. 2003).

NUTRIENT LOADING

Nutrient loading has been identified as a primary threat affecting species at risk in the Sydenham and Thames rivers (Staton *et al.* 2003; Taylor *et al.* 2004; Nelson 2006), and in Lake St. Clair (EERT 2008). 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 loading (Edwards *et al.* 2012). Adverse effects to the aquatic ecosystem include increased frequency of algal blooms, increased growth of macrophytes, increased turbidity, and disruption of food webs (Bailey and Yates 2003).

PHYSICAL HABITAT LOSS

Destruction of habitat is believed to be the primary threat to endangered fish species (Wilcove *et al.* 1998). Dextrase and Mandrak (2006) considered habitat loss and degradation to be the two primary threats to aquatic species at risk in Canada. Chan and Parsons (2000) stated that the greatest risk to madtom conservation is habitat destruction. Benthic fishes, including several *Noturus* species, are experiencing disproportionate rates of extirpation and imperilment because stream substrates are often the first impacted habitat type (Angermeier 1995; Warren *et al.* 1997 in Midway *et al.* 2010). The restricted distribution of many madtom species further increase their vulnerability to habitat destruction (Piller *et al.* 2004). Simon (2006) stated that habitat loss has caused the local extirpation of Northern Madtom in the Wabash River.

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 (e.g., shoreline stabilization projects, docks, marinas) along the Detroit River and Lake St. Clair (Manny 2003; Edwards *et al.* 2012). Larson (1981) stated that 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.

CONTAMINANTS AND TOXIC SUBSTANCES

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 (U.S. Environmental Protection Agency 2009). In the Thames River, pollutants may include chloride (e.g., from road salt, wastewater treatment and water softeners) and metals, as well as pesticides from both agricultural and urban areas (TRERT 2004). While still below the Environment Canada guidelines for sensitive aquatic species, chloride levels in the Thames River have shown a continual increase over the past 30 years (TRERT 2004). In the midwestern United States, Wildhaber *et al.* (2000) suggested that the closely related Neosho Madtom (*Noturus placidus*), is limited by the presence of heavy metals such as cadmium, lead and zinc.

THREAT LEVEL

To assess the Threat Level of Northern Madtom populations in Ontario, each threat was ranked in terms of the Threat Likelihood and Threat Impact on a population by population basis (Tables 4, 5). The Threat Likelihood was assigned as Known, Likely, Unlikely, or Unknown, and the Threat Impact was assigned as High, Medium, Low, or Unknown. The Threat Likelihood and Threat Impact for each population were subsequently combined in the Threat Level Matrix (Table 6) resulting in the final Threat Level for each population (Table 7). Certainty has been classified for both Threat Likelihood and Threat Impact and is based on: 1=causative studies; 2=correlative studies; and, 3=expert opinion. Certainty associated with the Threat Level is reflective of the lowest level of certainty associated with either initial parameter.

The Threat Level results were used to assess the overall effect each threat may have on Canadian Northern Madtom populations as a whole. Each threat was categorized in terms of both Spatial and Temporal Extent (Table 8). Spatial Extent was categorized as Widespread [threat is likely to affect a majority of Canadian Northern Madtom populations (i.e., threat affecting five or more populations)] or Local [threat is likely to not affect the majority of Canadian Northern Madtom populations (i.e., threat affecting less than five populations)]. Temporal Extent was categorized as Chronic (threat that is likely to have a long-lasting, or re-occurring effect on a population) or Ephemeral (threat that is likely to have a short-lived, or non-recurring effect on a population).

Table 4. Definition of terms used to describe Threat Likelihood, Threat Impact and Certainty.

Term	**Definition**
Threat Likelihood	
Known (K)	This threat has been recorded to occur at site X.
Likely (L)	There is a > 50% chance of this threat occurring at site X.
Unlikely (U)	There is a < 50% chance of this threat occurring at site X.
Unknown (UK)	There are no data or prior knowledge of this threat occurring at site X.
Threat Impact	
High (H)	Currently, the threat is jeopardizing the survival or recovery of the population. OR If the threat was to occur, it would jeopardize the survival or recovery of the population.
Medium (M)	Currently, the threat is likely jeopardizing the survival or recovery of the population. OR If threat was to occur, it would likely jeopardize the survival or recovery of the population.
Low (L)	Currently, the threat is unlikely jeopardizing the survival or recovery of the population. OR If threat was to occur, it would be unlikely to jeopardize the survival or recovery of the population.
Unknown (UK)	There is no prior knowledge, literature or data to guide the assessment of the impact if it were to occur.
Certainty	
1	Causative study
2	Correlative study
3	Expert opinion

Table 5. Threat Likelihood and Threat Impact of each Northern Madtom population in Canada. Certainty has been associated with the Threat Likelihood (TLH) and Threat Impact (TI) based on the best available data. The Threat Likelihood was assigned as Known (K), Likely (L), Unlikely (U), or Unknown (UK), and the Threat Impact was assigned as High (H), Medium (M), Low (L), or Unknown (UK). Certainty (C) has been classified and is based on: 1=causative studies; 2=correlative studies; and 3=expert opinion. References (Ref) are provided.

Threats	Lake Erie Drainage					Lake St. Clair Drainage																			
	Detroit River					Thames River					St. Clair River					Lake St. Clair					Sydenham River				
	TLH	C	TI	C	Ref	TLH	C	TI	C	Ref	TLH	C	TI	C	Ref	TLH	C	TI	C	Ref	TLH	C	TI	C	Ref
Invasive species	K	3	H	3	b	K	3	H	3	i,o	K	3	H	3	g	K	3	H	3	b,d	K	3	H	3	n,o
Climate change	K	3	UK	3	a,p	K	2	H	2	a	K	3	UK	3	a,p	K	2	H	2	a,p	K	2	H	2	a
Siltation	K	3	L	3	b	K	3	H	3	b	K	3	L	3	b	K	3	M	3	d,	K	3	H	3	l,m
Turbidity	K	3	L	3	b	K	3	M	3	b,o	U	3	L	3	b,o	K	3	L	3	d,o	K	3	M	3	l,m
Nutrient loading	K	3	M	3	b,j	K	3	M	3	b,c	K	3	L	3	b,k	K	3	M	3	d	K	3	M	3	l,m
Physical habitat loss	K	3	M	3	b,e,j	K	3	L	3	c,f	K	3	M	3	e,j	K	3	M	3	b	K	3	L	3	l,m
Contaminants and toxic substances	K	3	L	3	e,k	K	3	L	3	b	K	3	H	3	b,k	K	3	L	3	d	K	3	L	3	l,m

References:

a. Chu *et al.* (2005)
b. Edwards *et al.* (2012)
c. TRERT (2004)
d. EERT (2008)
e. GLIN (2012) (http://www.great-lakes.net/envt/pollution/aoc.html; Accessed February 2012)
f. Taylor *et al.* (2004)
g. French and Jude (2001)
h. Dextrase *et al.* (2003)
i. Poos *et al.* (2010)
j. Manny (2003)
k. USEPA (2009)
l. Edwards *et al.* (2007)
m. SRRT (2001)
n. St. Clair Region Conservation Authority (http://www.scrca.on.ca; Accessed 20 March 2012)
o. Northern Madtom Recovery Potential Assessment WebEx Participants (19 March 2012)
p. Mackey *et al.* (2006).

Table 6. The Threat Level Matrix combines the Threat Likelihood and Threat Impact rankings to establish the Threat Level for each Northern Madtom population in Canada. The resulting Threat Level has been categorized as Poor, Fair, Good, or Unknown.

		Threat Impact			
		Low (L)	**Medium (M)**	**High (H)**	**Unknown (UK)**
Threat Likelihood	**Known (K)**	Low	Medium	High	Unknown
	Likely (L)	Low	Medium	High	Unknown
	Unlikely (U)	Low	Low	Medium	Unknown
	Unknown (UK)	Unknown	Unknown	Unknown	Unknown

Table 7. Threat Level 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.

Threats	**Lake Erie Drainage**	**Lake St. Clair Drainage**			
	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)

Table 8. Overall effect of threats on Canadian Northern Madtom populations. Spatial extent was categorized as Widespread [threat is likely to affect a majority of Canadian Northern Madtom populations (i.e., threat affecting three or more populations)] or Local [threat is likely to not affect the majority of Canadian Northern Madtom populations (i.e., threat affecting less than two populations)]. Temporal Extent was categorized as Chronic (threat that is likely to have a long-lasting, or re-occurring effect on a population) or Ephemeral (threat that is likely to have a short-lived, or non-recurring effect on a population).

Threat	Spatial Extent	Temporal Extent
Invasive species	Widespread	Chronic
Climate change	Widespread	Chronic
Siltation	Local	Chronic
Turbidity	Widespread	Chronic
Nutrient loading	Widespread	Chronic
Physical habitat loss	Local	Chronic
Contaminants and toxic substances	Widespread	Chronic

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 9). 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 9. 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 exotic 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 (DFO, USFWS, USGS unpubl. data), there remain key sources of uncertainty for this species (Edwards *et al.* 2012). There is a need for additional quantitative sampling of Northern Madtom in areas where they are known to occur. This will help to determine occurrence, status, range, abundance, and population demographics and contribute to the identification of critical habitat. Additional sampling is also necessary for all populations with low certainty identified in the population status analysis. 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 (e.g., lower Thames River near its mouth), additional targeted sampling in areas lacking Northern Madtom records but possessing potentially suitable habitat should be conducted. New occurrences of Northern Madtom may be detected.

There is a need to examine 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 (Edwards *et al.* 2012).

The current distribution and extent of suitable Northern Madtom habitat 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 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 (Edwards *et al.* 2012).

Numerous threats have been identified for Northern Madtom populations in Ontario, although the severity of most of these threats is currently unknown. Additionally, climate change could have both positive and negative effects on Northern Madtom. 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 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. (Edwards *et al.* 2012). The impacts of physical habitat changes on Northern Madtom should also be investigated to identify the degree to which Northern Madtom is affected by physical habitat alterations (e.g., dredging, sedimentation and shoreline hardening) (Edwards *et al.* 2012). 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 for Northern Madtom (Edwards *et al.* 2012). 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 (Edwards *et al.* 2012).

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