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Information in support of a Recovery Potential Assessment of Black Redhorse (*Moxostoma duquesnei*) in Canada

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

Black Redhorse is at the northern edge of its range in Canada. It is considered imperiled in several Great Lakes states including Illinois, New York, and Wisconsin. Black Redhorse was assessed as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in April 1988 and re-assessed and confirmed in May 2005. In 2015 this species was again assessed as Threatened, owing to the limited extent of occurrence and area of occupancy. Black Redhorse is found only in a few rivers in southwestern Ontario, and is threatened by habitat degradation due to the cumulative impacts of pollution from urban wastewater and agriculture and alterations to flow regimes. Black Redhorse is currently listed as Threatened under Schedule 1 of the Species at Risk Act (SARA). 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 on the biology, ecology, distribution, population trends, habitat requirements, and threats of Black Redhorse. Mitigation measures and alternative activities related to the identified threats, that can be used to protect the species, are presented. Information contained in the RPA and this document may be used in the development of recovery strategies and action plans.

INTRODUCTION

Black Redhorse (*Moxostoma duquesnei*) is one of seven redhorse species (genus *Moxostoma*) found in Canada (Scott and Crossman 1998). This large member of the Catostomidae family has a wide but disjunct range and is found in the Mississippi and Great Lakes drainages in eastern North America. In Canada, Black Redhorse is found in tributaries of Lake Erie, Lake St. Clair, Lake Ontario, and Lake Huron.

Black Redhorse was first assessed as Threatened in Canada by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1988 (Parker and Kott 1988). The status was re-examined and confirmed by COSEWIC in May 2005 (COSEWIC 2005) and in May 2015 (COSEWIC 2015). Black Redhorse has a limited extent of occurrence and area of occupancy in Canada and inhabits only a few rivers in southern Ontario. The main threats to the species in Canada include pollution and changes to water quality, and quantity, due to agricultural practices, urbanization, and dams. The effects of climate change and extreme weather events are also potential threats.

Black Redhorse is listed as Threatened in Ontario under the *Endangered Species Act*, thus, the species and its habitat are also protected under provincial legislation. Black Redhorse was listed as Threatened under Schedule 1 of the *Species at Risk Act* (SARA) in August 2019. A Recovery Potential Assessment (RPA) process has been developed by Fisheries and Oceans Canada (DFO) Science to provide background information and scientific advice needed to fulfill various requirements of SARA. This research document provides the current state of knowledge of the species including its biology, distribution, population trends, habitat requirements, threats and mitigation measures related to the identified threats, which will be used to inform the development of recovery documents and for assessing SARA Section 73 permit applications.

BIOLOGY, ABUNDANCE, DISTRIBUTION AND LIFE HISTORY PARAMETERS

ELEMENT 1: SUMMARIZE THE BIOLOGY OF BLACK REDHORSE

Species Description

Redhorse suckers (*Moxostoma* spp.) typically have large bodies and occupy the benthic reaches of rivers and large streams (Jenkins and Burkhead 1994). This species is characterized by having a slightly deep body (Figure 1), and a long rounded snout (39.6–49.8% of head length) that overhangs the mouth (Scott and Crossman 1998, Holm et al. 2010). The lower lip is covered with plicae with no transverse grooves, and the angle of the posterior edge of the lower lip is greater than 90° (120° - 170°) when the mouth is closed (Scott and Crossman 1998, Holm et al. 2010). There are club-shaped pharyngeal teeth. The scales are large, usually 44–47 lateral scales and there are 12–13 circumpeduncular scales (Scott and Crossman 1998). The caudal fin is moderately forked (Page and Burr 2011). At a given age, females are larger than males (Reid 2006b).

Black Redhorse has an olive-brown to grey back, the sides are pale silver with blueish tints, and the ventral surface is silver to milky white. The scales may have dark edges. The lower fins are often pale red and the caudal and dorsal fins are slate grey (Scott and Crossman 1998, Holm et al. 2010). The spawning male has longitudinal black stripes with colour ranging from orange to pink along their flanks (Page and Burr 2011). Males have small nuptial tubercles on their snout, anal, and caudal fins (Jenkins and Burkhead 1994, Page and Burr 2011).

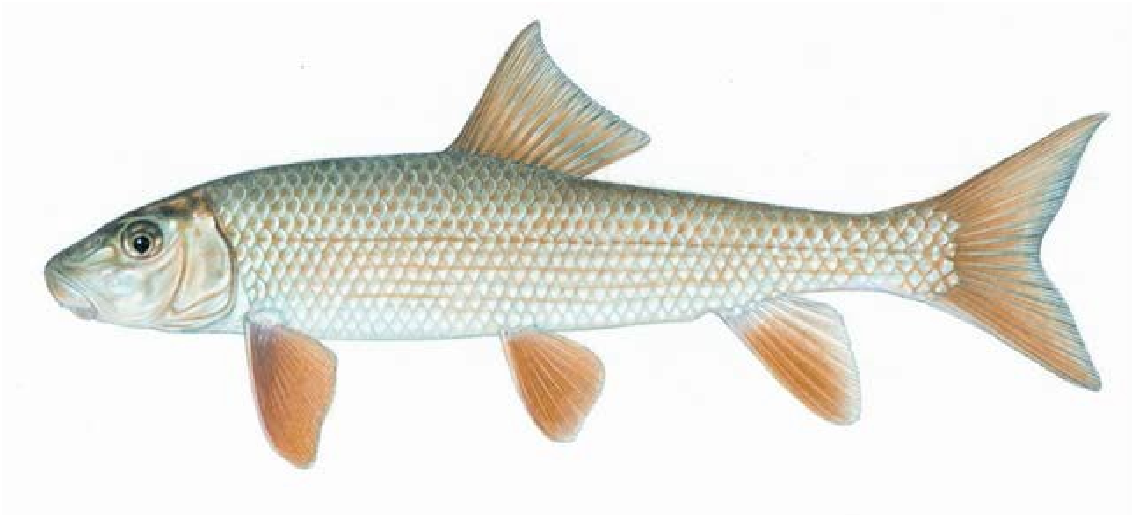

Figure 1. Black Redhorse, Moxostoma duquesnei. *Illustration by Joe Tomelleri, reproduced with permission.*

Black Redhorse differs from the six other redhorse species in Canada by the following characters: Black Redhorse has a slate-grey caudal fin, whereas River Redhorse (*M. carinatum*), Shorthead Redhorse (*M. macrolepidotum*) and Greater Redhorse (*M. valenciennesi*) have red caudal fins. Copper Redhorse (*M. hubbsi*) has 15–16 rows of scales around the narrowest part of the caudal peduncle versus 12–13 in the Black Redhorse. Black Redhorse is difficult to distinguish from the other two species of grey-tailed redhorses and a suite of characters needs to be examined (Scott and Crossman 1998). It can be distinguished from Silver Redhorse (*M. anisurum*), which has the ridges of both lips broken by transverse grooves, the posterior edge of the lower lip forming an acute angle (about 90°), a straight to slightly convex dorsal fin margin, and dorsal rays usually 14–16 (versus 12–14 in the Black Redhorse). Black Redhorse can be distinguished from the very similar Golden Redhorse (*M. erythrurum*) primarily by the larger non-overlapping lateral scale count of 44–47 (versus 40–42 for Golden Redhorse) and the scales in front of the dorsal fin are more uniformly dark with posterior margins only slightly darker than the centers, while the same scales in Golden Redhorse have obviously darker posterior margins relative to their centers (Scott and Crossman 1998). It should be noted that colour differences may be faint or absent in juveniles making identification at early life stages difficult.

Black Redhorse is sexually dimorphic during spawning. Males become more boldly coloured with a greenish-black back and sides and an orange to pink lateral stripe along the length of the body. Males have pronounced tubercles on their anal and caudal fins (Jenkins and Burkhead 1994). Females show little, or no, spawning colouration (Kwak and Skelly 1992). There is discrepancy in the literature regarding the presence of tubercles, with Kwak and Skelly (1992) reporting females with no nuptial tubercles, and Scott and Crossman (1998) reporting females with minute tubercles.

Taxonomy

Black Redhorse is one of seven species in the *Moxostoma* genus that is endemic to North America. The redhorse genus contains larger, laterally compressed species in the Catostomidae family that have three chambers in their swim bladders, rather than two (Scott and Crossman 1998). There are 17 extant *Moxostoma* species in North America and one extinct species (Harelip Sucker, *Moxostoma lacerum*; Page and Burr 2011).

Physiology

Black Redhorse has a more streamlined shape and more elongated, narrow caudle peduncle than other *Moxostoma* species, suggesting that it has a greater swimming ability and tolerance for swifter currents than other species in the genus (Clark 2004).

In Ontario, Black Redhorse is at its most northerly range. Individuals from the Grand River were found to grow more slowly, mature at a larger size, attain a longer maximum length, live longer, and have lower adult mortality rates (Reid 2009) than those found further south. The maximum published length is 658 mm total length (TL) (Coker et al. 2001) and weight is 3200 g (Howlett 1999). The Ontario record length is 543 mm TL and average length is 400 mm TL (Holm et al. 2010). Length-frequency data for 536 Black Redhorse captured in several localities in Ontario from 2002–2015 shows a range from 60 to 520 mm TL, with 140–180 mm the most abundant size class (Figure 2; Reid 2009).

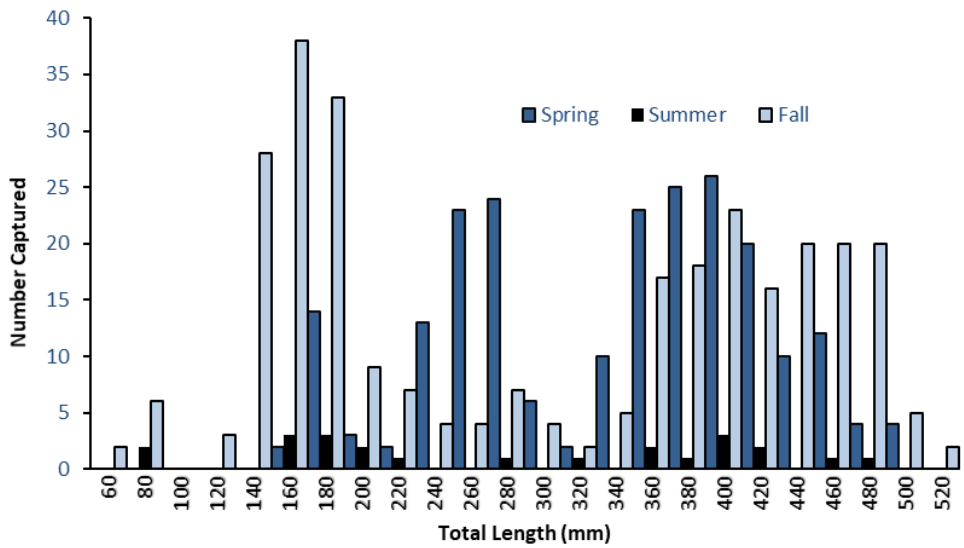

Figure 2. Length-frequency histogram for 536 Black Redhorse from several localities in Ontario captured by backpack electrofisher. Dark bars represent collections from May-June 2002–2009, in the Grand River, n = 232 (Reid 2009). Light bars represent fall collections from September-October 2002–2009 in the Grand River, n = 290 (Reid 2009). Black bars are from several collection sites in summer (2012–2015), n = 14 (DFO unpublished data).

Feeding and Diet

Adult Black Redhorse are generally bottom feeders, using the grazing-and-picking foraging method (Coker et al. 2001). Adults feed on crustaceans and aquatic insects. Redhorse less than 65 mm in length are primarily planktivorous (Bowman 1970). Juveniles (approximately 100–400 mm; Young and Koops 2014) consume benthic invertebrates such as chironomids, emphemeroptera and tricoptera (Meyer 1962, Bowman 1970).

Special Significance

Black Redhorse is a benthic feeding species that is important for the transfer of energy from the benthic to the pelagic food web, where it is prey for large piscivores (COSEWIC 2015). Black Redhorse is also intolerant of poor water quality and siltation (Scott and Crossman 1998), thus, the species may be a useful environmental indicator, as its presence requires a healthy aquatic ecosystem.

ELEMENT 2: EVALUATE THE RECENT SPECIES TRAJECTORY FOR ABUNDANCE, DISTRIBUTION, AND NUMBER OF POPULATIONS

Distribution

Black Redhorse has a wide, but disjunct distribution in the Mississippi and Great Lakes drainages of eastern North America (Figure 3). It is found from Alabama and Mississippi in the south, to Ontario and Michigan in the north, and from New York in the east, to Oklahoma and Minnesota in the west. In the Mississippi drainage, the distribution east of the Mississippi River is continuous, but to the west it is disjunct (Lee et al. 1980, Page and Burr 2011). In the Great Lakes basin, disjunct populations are found in Ontario, Michigan, and Wisconsin (Lee et al. 1980, Page and Burr 2011).

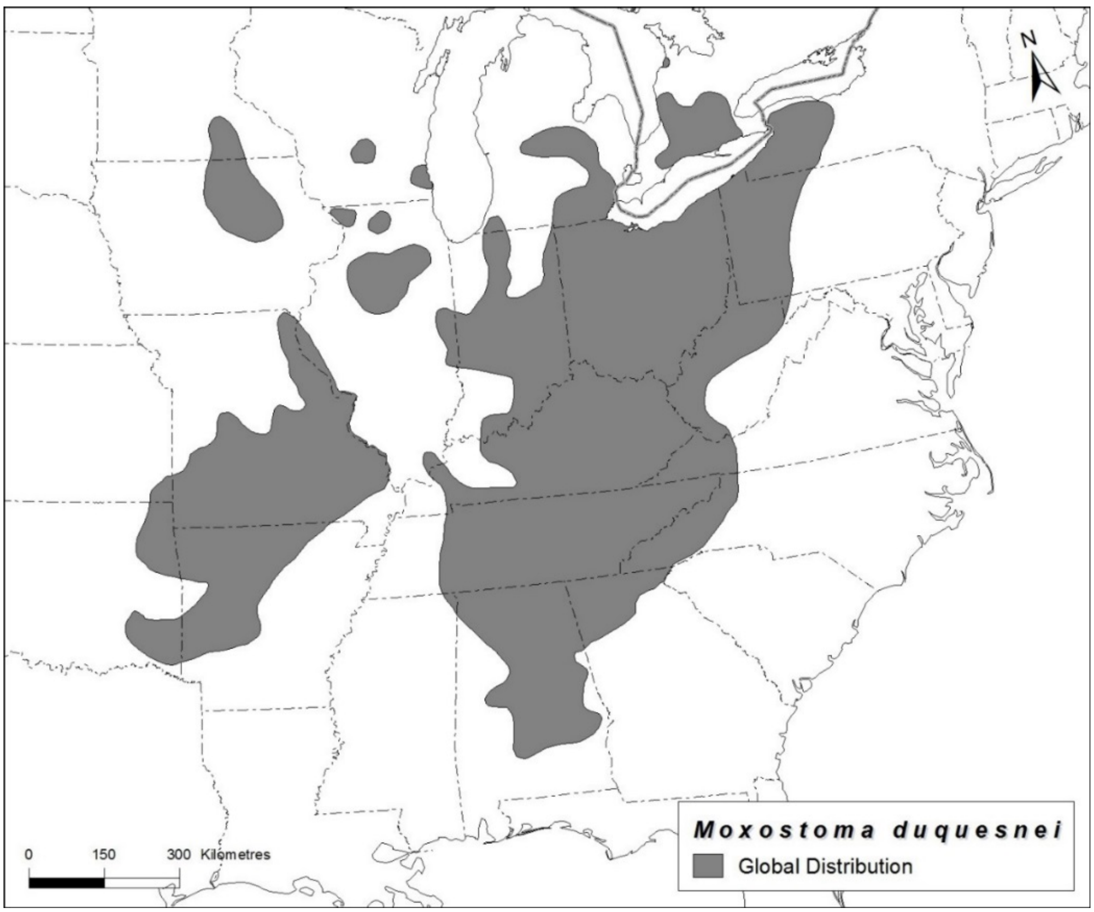

Figure 3. Global distribution of Black Redhorse, Moxostoma duquesnei. *Modified from Page and Burr (1991).*

The Black Redhorse range in Canada is limited to southwestern Ontario, where it has been found in tributaries of Lake Erie, Lake St. Clair, Lake Huron, and Lake Ontario (Figure 4). In the Lake Erie drainage, Black Redhorse is found in one watershed, the Grand River and its tributaries (e.g., Conestogo River, Nith River, Big Creek and Mount Pleasant Creek). The watershed in the Lake St. Clair drainage where Black Redhorse resides is the Thames River and its tributaries (e.g., Fish Creek, Wye Creek, Flat Creek, Medway Creek, Waubuno Creek, and Fanshawe Lake). In the Lake Huron drainage, there are records of Black Redhorse from six tributaries: Ausable River, Bayfield River, Maitland River, Saugeen River, Sauble River, and

Gully Creek. Black Redhorse was found in Catfish Creek (Lake Erie drainage) until 1938; however, this population is now believed to be extirpated (COSEWIC 2015). In the Lake Ontario drainage, one individual was found in Christie Reservoir in 1998, and another was discovered dead in a trap net in Lake Simcoe in 2011 (T. Langley, Lake Simcoe Fisheries Assessment Unit, unpublished data). However, no other individuals have been collected at these localities in subsequent sampling efforts. These two records are considered to be introductions, likely as baitfish.

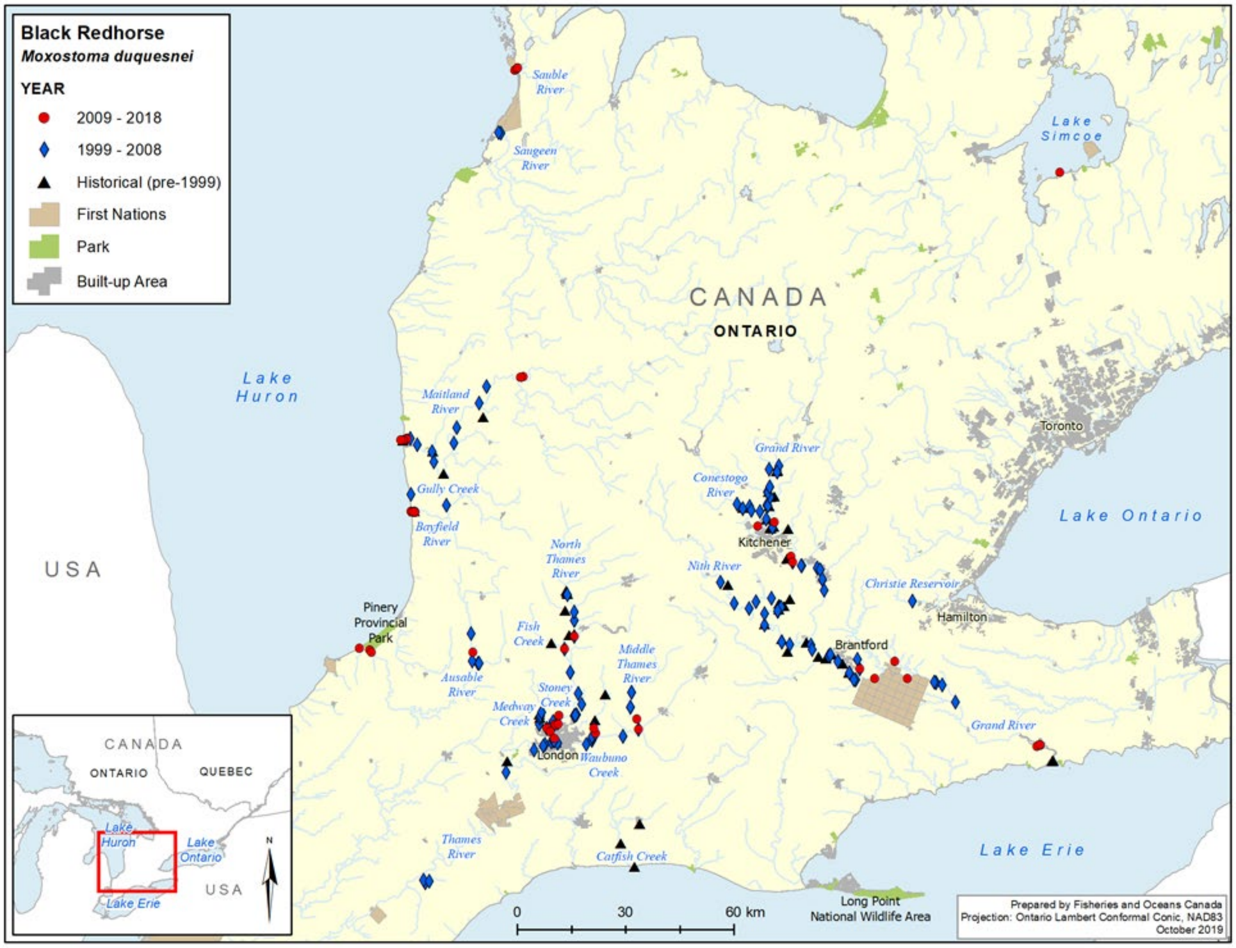

Figure 4. Canadian distribution of Black Redhorse, Moxostoma duquesnei.

ABUNDANCE

There are currently no available estimates of the population size for Black Redhorse in any of the Canadian watersheds where the species is found.

CURRENT STATUS

Studies targeting Black Redhorse have not occurred in the Canadian range for this species, thus, fluctuations and trends related to Black Redhorse populations are difficult to accurately assess due to lack of consistent monitoring through time. Problems with accurately identifying the species, gear selectivity, and non-standardized data collection have also hindered accurate assessment of population fluctuations.

LAKE ERIE DRAINAGE

The first record of Black Redhorse from the Grand River watershed was from 1927 when a single individual was vouchered from Mud Creek (originally Cedar Creek (ROMUM089075). Black Redhorse was not recorded again in this watershed until 1975 when three individuals were captured in Brantford Township just upstream from Brant Conservation Area. Black Redhorse was consistently reported from the Grand River watershed from 1976 to 1982 with records from the Grand River (1978–1982), Hunsburger Creek (1977), Nith River (1976–1977,1979, 1981), and Cox Creek (1980). A single individual was recorded from Laurel Creek in 1991; however, this is the only recorded individual from this creek. Black Redhorse reappeared in fish collections in 1997, with individuals recorded for the first time in the Conestogo River.

Targeted sampling for redhorses in the Grand River watershed occurred between 2001 and 2003, which yielded the capture of 107 Black Redhorse from 98 sites (S. Reid, Ministry of Natural Resources and Forestry (MNRF), unpublished data, Mandrak et al. 2006). More recently, Black Redhorse has been recorded in the central Grand River, but the area is fragmented by four large dams that lack suitable passage for benthic species, indicating that five disjunct populations likely occur (Reid 2006a). Although Black Redhorse was present in collections downstream of the Mannheim and Dunnville weirs, none were collected upstream over a three-year period, indicating that fishway designs at these two weirs may be sub-optimal for passing Black Redhorse (Reid 2006a). From 2004 – 2018, Black Redhorse has been captured both above and below the dam at Paris. In total, Black Redhorse collections have occurred throughout a 160 km stretch from downstream of Inverhaugh to York. In the Grand River watershed, it appears that the Black Redhorse population is stable.

Black Redhorse also occurs in the lower reaches of two major tributaries, the Conestogo River and Nith River. In the Conestogo River, it has been found in a 25 km section from its confluence with the Grand River at Conestogo to Wallenstein. Of 19 sites sampled in 2002 and 2003, six individuals were captured (DFO unpublished data). In the Nith River, Black Redhorse has been recorded along an 86 km reach from the confluence with the Grand River in Paris, upstream to New Hamburg. In 1997, four individuals at two sites were captured. In 2002–2003, 43 sites were sampled, with 14 sites having a total of 20 individuals. The Nith River was again sampled in 2005 and 2009, with one and four individuals captured respectively. Recent collections have verified the presence of Black Redhorse in lower portions of the Grand River watershed in 2007 at Mount Pleasant Creek, and at two sites where it was not previously collected (i.e., Big Creek in 2010 and Forwell Creek in 2010). Surveys in the Speed River and upstream of Inverhaugh in the Grand River did not detect Black Redhorse (Reid 2004, Reid et al. 2008a).

Historically Black Redhorse was found in Catfish Creek in 1922 (ROMUM085887), 1926 (ROMRMC01975), 1937 (ROMRMC09637), and 1938 (ROMRMC10364) but is now believed to be extirpated (COSEWIC 2015).

LAKE ST. CLAIR DRAINAGE

Black Redhorse is present in the Thames River watershed. It occupies the three branches of the Upper Thames River (North Thames, Middle Thames, and Lower Thames) and has been recorded from six tributaries (Fish Creek, Flat Creek, Medway Creek, Stoney Creek, Waubuno Creek, Wye Creek) as well as Fanshawe Lake, a small man-made lake formed by the Fanshawe Dam on the North Thames River north of London. There have only been singular records from both Fish Creek (1972) and Flat Creek (1997), and it is unknown if Black Redhorse still occupies these tributaries.

Black Redhorse is distributed along a 192 km stretch from St. Mary's in the North Thames, and Thamesford in the Middle Thames, to Big Bend Conservation Area (Wardsville), in the Lower

Thames. However, the last record in the Lower Thames River at this location was in 2003 (DFO unpublished data).

There are two large dams in the Thames River that lack fish passage, potentially causing fragmentation, and resulting in disjunct populations. The majority of Black Redhorse have been collected in the Upper Thames River and its tributaries including, Medway, Stoney, Waubuno, and Wye creeks. In Medway Creek, it is found along a 5 km stretch from Medway Road to its confluence with the Upper Thames River, with records from 1975, 2000, 2004–2012 (excluding 2009–2011); however, the species has not been recorded from this area since 2012. In Waubuno Creek, it is found along a 5.4 km stretch from its confluence to just upstream of Trafalgar Street. Black Redhorse has been recently recorded in Waubuno Creek (2002, 2005, 2007–2009, 2012); however, the number of individuals collected over this period of time is quite low (n = 15). Black Redhorse also occupies a 4 km stretch of Stoney Creek with records from 2002, 2004, and 2012. In 2012, a single Black Redhorse was detected from one site in Wye Creek, a small tributary to the north of Fanshawe Lake. Additional sampling has occurred in the vicinity of this capture (2013–2014, 2017–2018) but no additional detections occurred.

Nine Black Redhorse have been recorded from two sites in Fanshawe Lake in 1998. Fish surveys have occurred in Fanshawe Lake subsequent to this first detection in 1998 (2003, 2014, and 2015); however, no additional Black Redhorse have been detected.

LAKE HURON DRAINAGE

In the Lake Huron drainage, Black Redhorse has been recorded from the Sauble River, Saugeen River, Maitland River, Gully Creek, Bayfield River, and Ausable River. It was first detected in the Sauble River in 1958 when two specimens were reportedly collected by the Ontario Department of Planning and Development, and deposited in the Royal Ontario Museum (ROM) (ROM Accession No. RMA0446). The specimens were identified in 1969 by Dr. W. Beamish, University of Guelph, and subsequently discarded by the Royal Ontario Museum (E. Holm, ROM, pers. comm.). Additional sampling on the Sauble River failed to reveal any individuals until 2014 when three were caught near the river mouth (Marson et al. 2016). Black Redhorse has also been recorded from subsequent sampling efforts of DFO's Asian Carp Program in 2016 (Colm et al. 2018) and 2017 (Colm et al. 2019).

In 2006, six Black Redhorse were captured from two sites in the Saugeen River just 18 km south of the Sauble River (Marson et al. 2009).

In the Maitland River, Black Redhorse has been found within a 63 km reach from its confluence with Lake Huron to Wingham in the North Maitland River. Black Redhorse has been consistently recorded at the mouth of the Maitland River by the Asian Carp Program (2014–2018). Although historically detected throughout the Maitland River (1982, 1999, 2002), including Belgrave Creek (1973, 2002), Blyth Brook (1999), and Bridgewater Creek (1998), the species has not been detected in this reach of the Maitland River since 2002. Black Redhorse has only been recorded from the North Maitland River from two sites at Wingham (2016).

In 2003, a juvenile Black Redhorse was captured in Gully Creek approximately one km upstream from Lake Huron. This represents the only record of this species occupying this creek; however, the lower reach of Gully Creek has not been well-sampled. Additional sampling in this area is required to determine the ongoing occurrence of Black Redhorse in Gully Creek.

Black Redhorse was first detected in the Bayfield River in 1982 (ROMRMC43037). Despite a long period where the species was not detected, Black Redhorse has been consistently recorded in sampling efforts by the Asian Carp Program (2014, 2016–2018). These efforts are focused on the mouth of the Bayfield; and therefore, all recent Black Redhorse records from this system have been attributed to sites within the first 1.5 km of the river, from the confluence with Lake Huron to the area surrounding the bridge at Highway 21. The only outlier is a Black Redhorse that was recorded from the outlet to Tricks Creek in 2003, which is the only Black Redhorse record from this area.

Black Redhorse was first collected in the Little Ausable River at one site near Maguire Road in 2002 (DFO unpublished data). Subsequent sampling resulted in Black Redhorse from the main Ausable River channel in 2007–2009, along a total river reach of 8 km. More recently, monitoring efforts by the Asian Carp Program have recorded the presence of Black Redhorse within a 4 km stretch of the Ausable River from the confluence to the bridge at Highway 21. Black Redhorse was detected by these efforts in 2015, and 2017–2018.

A single, dead Black Redhorse was recorded in Lake Simcoe by the Lake Simcoe Fisheries Assessment Unit (T. Langley, Lake Simcoe Fisheries Assessment Unit, unpublished data) in 2011.

LAKE ONTARIO DRAINAGE

Black Redhorse was collected at a single site in Christie Reservoir, a waterbody that drains into western Lake Ontario, in 1998; however, no other specimens have been collected in subsequent sampling efforts in the Lake Ontario drainage. Due to the separation between established populations this record is considered to be an introduction, likely as baitfish.

POPULATION ASSESSMENT

To assess the population status of Black Redhorse populations in Canada, 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. The evaluation of relative abundance considered gear used, area sampled, sampling effort, and whether the study was targeting Black Redhorse. The number of individual Black Redhorse 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 Black Redhorse, all populations were assigned an abundance index relative to the Grand River population. Grand River was chosen as the benchmark as it is the largest and most studied of the Ontario populations, and was assigned a “medium”. Catch-data from populations sampled using different gear types were assumed to be comparable when assigning the relative abundance index.

The population trajectory was assessed as Decreasing, Stable, Increasing, or Unknown for each population based on the best available knowledge 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), or Stable (no change in abundance over time). If insufficient information was available to inform the population trajectory, the population was listed as Unknown.

Table 1. Relative abundance index and population trajectory of each Black Redhorse 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
Grand River	Medium	2	Stable	3
Catfish Creek	Extirpated	3	Not applicable	-
Thames River	Low	2	Decreasing	3
Sauble River	Low	2	Unknown	3
Saugeen River	Unknown	3	Unknown	3
Maitland River	Low	2	Unknown	3
Gully Creek	Unknown	3	Unknown	3
Bayfield River	Low	2	Unknown	3
Ausable River	Low	2	Unknown	3

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. Population Status was subsequently ranked as Poor, Fair, Good, Unknown or Not applicable (Table 3).

Table 2. The Population Status Matrix combines the relative abundance index and population trajectory rankings to establish the Population Status for each Black Redhorse population in Canada. 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 of all Black Redhorse 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
Grand River	Fair	3
Catfish Creek	Extirpated	3
Thames River	Poor	3
Sauble River	Poor	3
Saugeen River	Unknown	3
Maitland River	Poor	3
Gully Creek	Unknown	3
Bayfield River	Poor	3
Ausable River	Poor	3

The size of the Canadian Black Redhorse population is currently unknown. The highest abundances in Canada are found in the Grand River and consistent detections of Black Redhorse in this system indicates that the species is well-established at this location. Lower abundances but consistent detections in the Thames River, and several Lake Huron tributaries, also likely indicate reproducing populations at these locations. Additional surveys are required at all locations to determine the population abundance, and long-term monitoring would be required to determine population trajectory through time.

ELEMENT 3: ESTIMATE THE CURRENT OR RECENT LIFE-HISTORY PARAMETERS FOR BLACK REDHORSE

Life History Parameters

Survival rates of Black Redhorse populations in Ontario are unknown. However, survival rates are available from two rivers in Missouri (Table 4). Mortality estimates from the Grand River indicate that adult mortality is lower there than in the Muskegon River, Michigan (Reid 2009) although mean annual air temperature is comparable between the two localities.

Table 4. Survival rates of Black Redhorse populations from Niangua and Big Piney rivers, Missouri (Bowman 1959).

Age Class	Niangua River	Big Piney River
5	0.49	0.68
6	0.48	0.49
7	0.33	0.03
8	0.03	0.02
9	0.02	0.01
10	0.01	-

In Ontario, estimates of growth and survival for Black Redhorse were based on a von Bertalanffy growth curve fitted to age-at-length data from Reid (2009; Figure 5). Hatch length was overestimated by the fitted curve to be 40 mm, much larger than the observed mean length of emergence of 8.8 mm (COSEWIC 2015). Therefore, the curve was forced to pass through 8.8 mm at age 0 to allow a more meaningful representation of first year growth. Separate male and female growth models were not derived (Reid 2009).

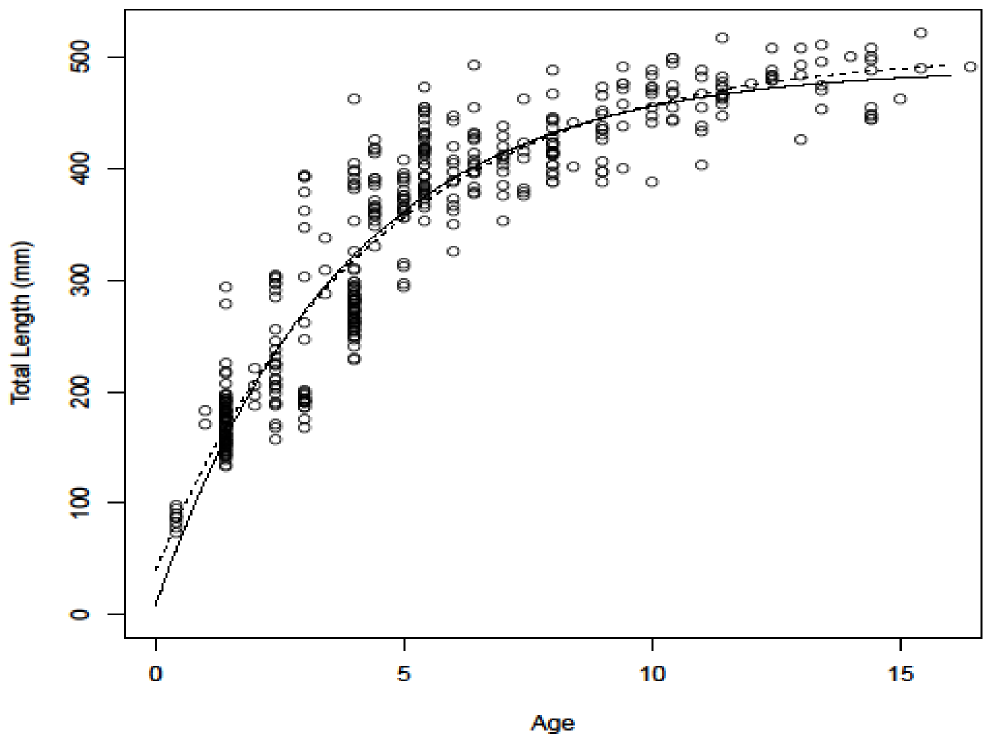

Figure 5. Size-at-age of Black Redhorse from the Grand River, Ontario (Reid 2009) with fitted von Bertalanffy Growth curves either forced (solid) or not forced (dashed) to pass through a hatch size of 8.8 mm (Reid 2009).

The growth rate of juvenile Black Redhorse was determined to be 80 mm/year (Reid 2009). Length-weight equations from a number of studies are presented in Table 5 and von Bertalanffy growth equations have been determined for several populations (Table 6).

Table 5. Summary of length-weight equations developed for Black Redhorse populations. Form of length-weight equation: log (weight g) = b +mlog(length mm).

b	m	Waterbody/Sex/Life Stage	Source
-4.58	2.94	Niangua River	Bowman (1970)
-4.59	2.95	Big Piney River	Bowman (1970)
-5.7475	3.363	Immature fish	Smith (1977)
-4.748	2.9554	Mature male	Smith (1977)
-4.6607	2.9227	Mature female	Smith (1977)
-5.39	3.158	Grand River	Reid (MNRF, unpublished data)

Table 6. Summary of von Bertalanffy growth equations developed for Black Redhorse. Form of von Bertalanffy equation: Lt = L∞ [1-e-k(t-t0)].

L_∞	k	T_0	Comment	Source
385.4	0.39	-0.48	James River	Howlett (1999) Howlett 1999
369.3	0.39	0.30	Bull Creek	Howlett (1999) Howlett 1999
378.3	0.34	-0.29	Swan Creek	Howlett (1999)
426.4	0.45	-0.34	Elk River	Howlett (1999)
490.9	0.26	-0.75	Grand River	Reid (MNRF, unpublished data)

HABITAT AND RESIDENCE REQUIREMENTS

ELEMENT 4: DESCRIBE THE HABITAT PROPERTIES THAT BLACK REDHORSE NEEDS FOR SUCCESSFUL COMPLETION OF ALL LIFE-HISTORY STAGES. DESCRIBE THE FUNCTION(S), FEATURE(S), AND ATTRIBUTE(S) OF THE HABITAT, AND QUANTIFY BY HOW MUCH THE BIOLOGICAL FUNCTION(S) THAT SPECIFIC HABITAT FEATURE(S) PROVIDES VARIES WITH THE STATE OR AMOUNT OF HABITAT, INCLUDING CARRYING CAPACITY LIMITS, IF ANY

In spring, Black Redhorse migrates upstream to suitable spawning habitat, seeking shallow riffles (Jenkins 1970). Spawning behavior and habitat was described by Kwak and Skelly (1992) for Black Redhorse in Illinois. In that study, riffle areas used for spawning had a relatively steep gradient causing high velocity and turbulence. Spawning occurred in water temperatures from 15 to 21 ºC and spawning substrate ranged from fine gravel to large cobble, with small cobble being used most often (48% of locations surveyed) (Kwak and Skelly 1992). Spawning depth ranged from 0.12–0.37 m (mean = 0.22 m), while bottom water velocities ranged from 0.04 to 0.66 m/s (mean = 0.31 m/s). It was noted that Black Redhorse spawned in slightly deeper, swifter water, and over coarser substrate than the Golden Redhorse (Becker 1983, Kwak and Skelly 1992). Extremely high flow rates cause Black Redhorse to abandon previously utilized spawning shoals (Bowman 1970). Table 7 summarizes the habitat utilization of different life history stages of Black Redhorse in Canada.

Table 7. Summary of habitat utilization across different life history stages of Black Redhorse in south-western Ontario.

Age Class	Average Distance from Shore (m)	Average Depth (m)	Flow (m/s)	Substrate Type/ Habitat Type	Macrophyte Cover	Source
Egg	0.8	0.2-0.3	Flow Data Unavailable	gravel/cobble/pebble	none	Bunt et al. (2013)
YOY	1.37	0.22	0.03	gravel/pebble/silt over sediment (minimal to none)	swamp loosestrife	Bunt et al. (2013)
Juvenile	3.07	0.83-2.0	0.08	sand/cobble/ pebble/silt over sediment	vegetated littoral zones	Bunt et al. (2013)
	-	0.61	0.06	-	-	Brown (1984)
Adult	n/a	2.0-5.0 (Over-wintering habitat)	Flow Data Unavailable	sand/cobble/ gravel	n/a	Biotactic (unpublished data), N. Mandrak and J. Casselman (unpublished data)

Young-of-the-year (YOY or 0+) Black Redhorse were found in shallow pools and slackened current in the Thames and Nith rivers in Ontario (Parker 1989). In the Grand River, YOY were most commonly observed among beds of swamp loosestrife (*Decodon verticullatus*) in relatively quiet waters. Recent field work showed that in summer, juvenile Black Redhorse occupied vegetated littoral zones, 0.8–2.0 m deep, along the edges of pools and runs downstream of riffles (Bunt et al. 2013, S. Reid, MNRF, unpublished data). At night, young Black Redhorse was found in areas with very little flow (Bunt et al. 2013). Juveniles also utilized low gradient habitat, with reduced flow, clean pebble, gravel, and cobble substrate of a heterogeneous composition, with a mixture of sand and silt (Bunt et al. 2013). This habitat is similar to that of the age 0+ Copper Redhorse and River Redhorse (Bunt et al. 2013). During the summer, large juveniles (approx. 150 mm) have been observed to feed alone along the bottom of sandy pools (Bowman 1970). Immature Black Redhorse have been captured in shallow pools below riffles (Parker and Kott 1980). In the Grand River, approximately 35% of Black Redhorse collection sites contained both juveniles and adults (S. Reid, MNRF, unpublished. data). In the Grand River, Black Redhorse larvae occupied runs in 41% of observations, both riffles and pools in 23% of observations, and backwaters in 13% of observations (Bunt et al. 2013). It was found that habitat utilization by larvae and juvenile Black Redhorse was not proportional to habitat availability (Figure 6).

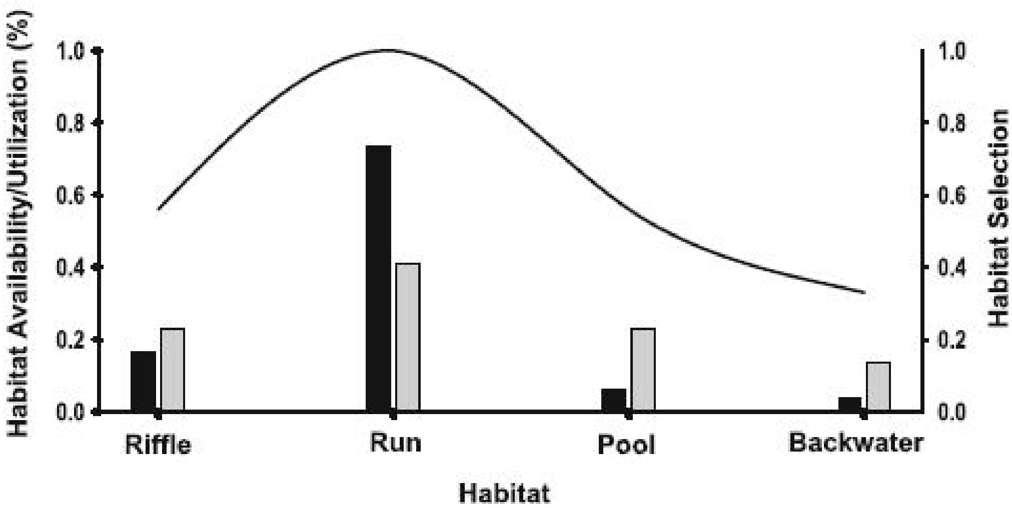

Figure 6. General lotic habitat availability (black bars), larval/juvenile Black Redhorse habitat utilization (grey bars) and the calculated habitat selection curve; taken from Bunt et al. (2013) with permission.

In a study of habitat utilization of young Redhorse in the Grand River, hundreds of juveniles were found 30 m downstream of groundwater flows during the day. These groundwater flows were approximately 10°C cooler than the surrounding river temperature (Bunt et al. 2013). Cool groundwater mixed with, and aerated by, warmer water of the Grand River would have a higher DO saturation point and hence would have more oxygen than the surrounding waters. The persistence of YOY Black Redhorse at these groundwater seepages indicates that this species may have a groundwater preference (Bunt et al. 2013). Groundwater upwellings may create microhabitats that provide refuge from unfavourable thermal conditions or poor water quality (Hayashi and Rosenberry 2002, Bunt et al. 2013). Groundwater may modify the water quality to allow sensitive species, such as Black Redhorse, to inhabit degraded environments. It has been determined that the protection of 0+ Black Redhorse habitat is critical for its conservation and enhancement (Vélez-Espino and Koops 2009). More recent modelling indicates that juvenile survival is critical to the sustainability of viable Black Redhorse populations (Young and Koops 2014).

Upstream movement of juvenile Black Redhorse has been observed in early November when the water temperature was 5 °C (Bunt et al. 2013). These movements were presumably to reach over-wintering habitat and may help explain life-stage specific patterns of movement to seasonally appropriate areas.

Black Redhorse, in general, associate with well oxygenated and relatively eutrophic water with July water temperature averaging approximately 20 ºC (Parker 1989). In a study of various redhorse species, 77 sites in Indiana were surveyed and showed that sites where Black Redhorse occurred were characterized by greater depth (mean = 0.61 m vs. 0.31 m) and slower current (mean = 0.06 m/s vs. 0.49 m/s) compared to sites where Black Redhorse was absent (Brown 1984). Reid (2006a) determined that Black Redhorse presence was negatively correlated with habitat containing high gradients, as well as small and large upstream drainage areas (i.e., cumulative catchment size upstream of the site). It has been reported in streams with gradients ranging from 1.2–1.5 m/km (Parker and Kott 1980). Based on collections in 1997, Black Redhorse are generally found in pools in the summer and over-winters in deeper pools (Bowman 1970). Average depth in several south-western Ontario streams where Black Redhorse was found was 1.5 m (range 0.6–2.1 m; DFO unpublished data).

In one section of the Grand River between Paris and Brantford, mean water velocity was 0.22 m/s and 1.69 m deep in areas where Black Redhorse was found (Clark 2004). Black Redhorse was seldom found in slower velocities, and may have been limited to faster moving habitats (Clark 2004). However, these data should be treated cautiously, due to the small sample size (n = 4). Average water velocity in several south-western Ontario streams where Black Redhorse was found was 0.29 m/s (range 0.0–1.1 m/s) in sampling conducted by DFO between 2010–2015 (DFO unpublished data). There are several morphometric differences in body shape of the Black Redhorse that distinguish it from other Redhorse species including the more streamlined, fusiform shape, with elongated and narrow caudal peduncle in the Black Redhorse. This suggests greater swimming potential allowing for utilization of areas with higher water velocities, and indicates that this species appears to be more adapted to high flow habitats (Clark 2004).

Stream width is considered to be an important factor in determining the presence of redhorse species. Black Redhorse was only captured at sites in the Grand River that were greater than 22 m wide (Reid 2006a). Average stream width in several south-western Ontario streams where Black Redhorse was detected by DFO sampling was 96.1 m (range 46–219 m; DFO unpublished data).

Substrate was found to consist of rubble, gravel, sand, boulders and silt (Holm and Boehm 1998). Reid (2006a) suggested that suitable habitat for Black Redhorse includes clean coarse bed material (gravel and cobble), stable channels, and well developed riffles. Adult Black Redhorse is rarely associated with submerged aquatic vegetation. Substrate type at locations where Black Redhorse adults were captured by DFO in south-western Ontario streams between 2010 and 2015 was mainly clay, sand, or cobble (Figure 7; DFO unpublished data).

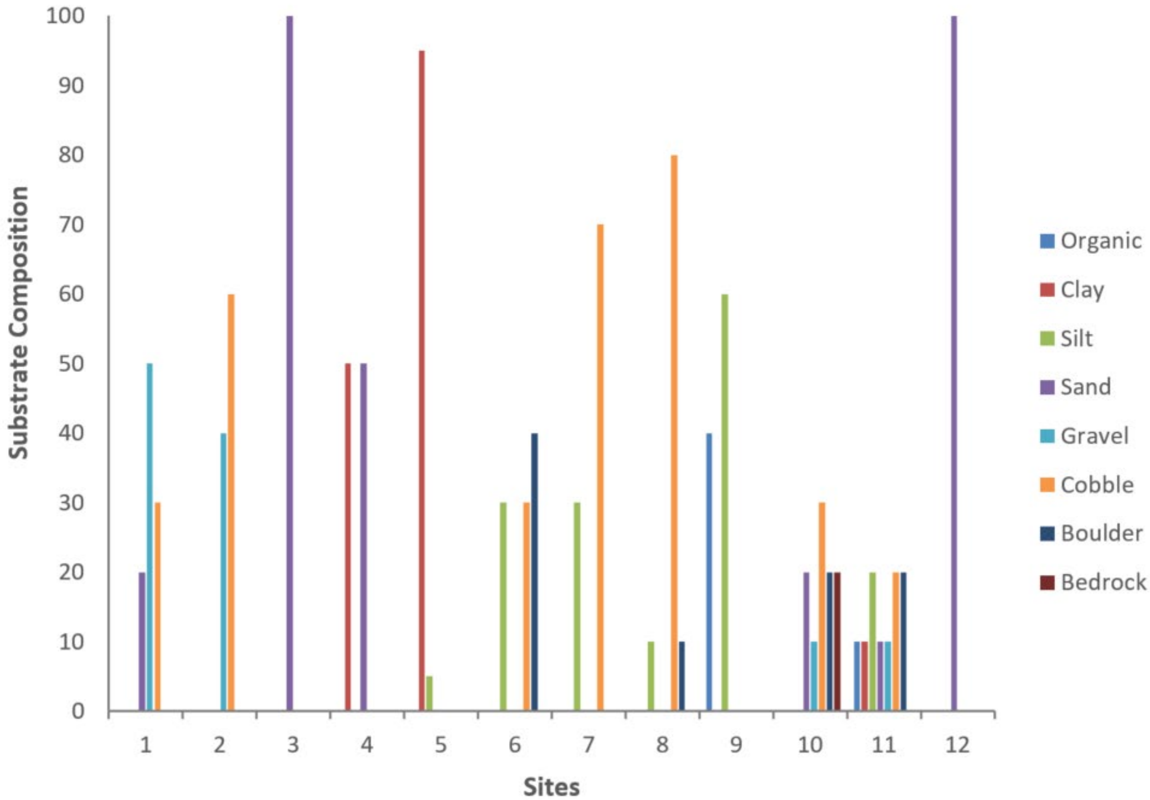

Figure 7. Substrate composition (%) at 12 sites where Black Redhorse, Moxostoma duquesnei*, occurred between 2010–2015 in south-western Ontario (DFO unpublished data).*

Functions, Features and Attributes

A description of the functions, features, and attributes associated with Black Redhorse habitat can be found in Table 8. The habitat required for each life stage has been assigned a life history function that corresponds to a biological requirement of Black Redhorse. For example, individuals in the spawn to juvenile life stage require habitat for nursery and spawning purposes. In addition to the life history function, a habitat 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 life history function for each life stage. Optimal habitat attributes from the literature for each life stage have been combined with habitat attributes from current records to show the maximum range in habitat attributes within which Black Redhorse may be found (see Table 8, 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 Black Redhorse may be occupying sub-optimal habitat in areas where optimal habitat is no longer available.

Table 8. Summary of the essential functions, features, and attributes for each life stage of Black Redhorse. Habitat attributes from published literature, and those recorded during recent Black Redhorse captures, have been used to determine the habitat attributes required for the delineation of critical habitat.

			Habitat Attributes		
Life Stage	**Function**	**Feature(s)**	**Scientific Literature**	**Current Records**	**For Identification of Critical Habitat**
Spawning (occurs in late spring)	Spawning	Spawns in shallow riffles (0.12-0.37 m) over cobble substrate	• Spawning occurs when water temperature reaches 13°C (Holm et al. 2010) • Present in shallow riffles with relatively steep gradient • Bottom water velocity mean value 0.31 m/s (Kwan and Skelly 1992)	-	• Shallow riffles with cobble substrate, mean depth: 0.22 m.
Egg to juvenile	Nursery Feeding Cover	Shallow runs, riffles and pools with aquatic vegetation Preference for groundwater seepages	• Edges of pools and runs, downstream of riffles: 0.8–2.0 m deep (Bunt et al. 2013)	• Low gradient with slow to moderate flow; clean pebble/gravel/ cobble substrate (S. Reid, MNRF, unpublished data)	• Shallow pools, slow to moderate flow with gravel to cobble (occasionally sand) substrate
Adult (from Age 1 [onset of sexual maturity])	Feeding Cover	Streams with gradient 1.2–1.5m/km	• 0.1–1.8 m deep (Holm and Boehm 1998) • 77 sites surveyed in Indiana showed mean depth of 0.61 m (Brown 1984)	• Between 2010–2015, individuals were caught in depths from 0.6–2.5 m. (average 1.5 m) at various locations in its range (DFO unpublished data)	• 0.6–2.5m depth, with stream gradient of 1.2–1.5 m/km

ELEMENT 5: PROVIDE INFORMATION ON THE SPATIAL EXTENT OF THE AREAS IN BLACK REDHORSE DISTRIBUTION THAT ARE LIKELY TO HAVE THESE HABITAT PROPERTIES

The spatial extent of the areas that are likely to have the habitat properties outlined in Element 4, have not yet been defined for the entirety of the 554 km of river segments containing records of this species in Canada. Within the area of the Grand River that was sampled by Bunt et al. (2013), approximately 72.4% of the river area was classified as run, 18.8% riffle, 6.8% pool, and 2% backwater areas. The habitat utilization by larval and juvenile Black Redhorse was not proportional to the habitat availability within this sample area (Bunt et al. 2013). A disproportionately high number of observations of larval Black Redhorse were found in backwater areas (13.6%), pools (22.7%), and riffles (22.7%) despite these habitat types being proportionately less available (Bunt et al. 2013), suggesting that the area that is available and suitable to the species is smaller than the total area of river that makes up their distribution. Additionally, it was shown that juvenile Black Redhorse were concentrated in areas with groundwater discharge into the river system (Bunt et al. 2013); however, future research is required to determine the spatial extent of the availability of this habitat feature throughout the watersheds occupied by Black Redhorse.

ELEMENT 6: QUANTIFY THE PRESENCE AND EXTENT OF SPATIAL CONFIGURATION CONSTRAINTS, IF ANY, SUCH AS CONNECTIVITY, BARRIERS TO ACCESS, ETC.

There are seven dams in the river systems occupied by Black Redhorse in Canada that do not facilitate the passage of warmwater, benthic species: four in the Grand River; two in the Thames River; and, one in the Maitland River at Wingham. Additionally, the Springbank dam on the Thames River is currently non-operational but may be brought into service in the future. These dams may cause fragmentation of the populations and act as barriers to gene flow, however, Reid et al. (2008b) showed that dams had little effect on the population genetic structure of Black Redhorse in the Grand River, indicating that the dams may not constitute complete barriers to gene flow. Large impoundments and multiple dams in close proximity, however, would likely have negative impacts on the movement and distribution of Black Redhorse.

ELEMENT 7: EVALUATE TO WHAT EXTENT THE CONCEPT OF RESIDENCE APPLIES TO THE SPECIES, AND IF SO, DESCRIBE THE SPECIES' 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 (DFO 2010). In the context of the above narrative description of habitat requirements during spawn-to-hatch, YOY, juvenile and adult life stages, Black Redhorse does not occupy residences.

THREATS AND LIMITING FACTORS TO THE SURVIVAL AND RECOVERY

ELEMENT 8: ASSESS AND PRIORITIZE THE THREATS TO THE SURVIVAL AND RECOVERY OF THE BLACK REDHORSE

Threat Categories

A wide variety of threats negatively impact Black Redhorse across the Canadian range. The greatest threats to the survival and persistence of Black Redhorse in Canada are related to habitat alteration and degradation due to pollution resulting from municipal and agricultural sources. Climate change and severe weather resulting in droughts or storms and flooding also constitute threats to the species in Canada. Threats have been categorized based on the IUCN IUCN (2014) classification system, and ranked following the methods and terminology outlined by (DFO 2014). The following threat descriptions emphasize the principal threats to Black Redhorse in Canada.

Pollution (9.1 Household sewage & urban waste water, 9.3 Agricultural & forestry effluents)

The two largest populations of Black Redhorse in Canada are found in the Grand River and Thames River, where pollution from urban growth, impoundment of riverine habitats, and agricultural activities threaten remaining populations.

The majority of Canadian research on Black Redhorse has been conducted in the Grand River. The species is largely distributed along the central and lower portions of the river, where land use is primarily agriculture (79%) and woodland (17%) (Reid et al. 2008a). Major urban centers in the central part of the watershed overlap with known locations of Black Redhorse populations. In addition, human population growth in the Grand River basin has been projected to increase by 30% over the next 20 years, which will negatively impact this species (Portt et al. 2003). Specifically, impacts will include impairment of habitat and water quality resulting from changes in land use that affect run-off, increased water abstraction, and increased wastewater discharge. Habitat quality in the upper Thames River watershed is also adversely affected by urban and rural land use. Anthropogenic pollution that would negatively affect Black Redhorse includes wastewater effluent, acute spills, poor drainage practices, run-off, road salt inputs, and siltation from stream bank alteration (Reid and Mandrak 2006). Much of the forest cover in the watershed has been cleared, resulting in increased water temperature, increased siltation events, and decreases in water quality.

Endocrine disruptors have not been reported to impact Black Redhorse specifically (Blazer et al. 2014). However, for other catostomid species, extensive impacts on the male reproductive system, such as the presence of testicular oocytes and elevated levels of plasma vitellogenin, have been found to be related to exposure to municipal wastewater treatment effluent (Blazer et al. 2014) and other sources of pollution, such as mills (Munkittrick et al. 1991, Keme 1998). There is a growing body of literature indicating the negative endocrinological effects of urban pollution on fishes including Redhorse suckers (Maltais and Roy 2014) and endocrine disruptors are present in the Grand River (Tetreault et al. 2011) in areas occupied by a range of age classes of Black Redhorse. Effluent from the Kitchener Wastewater Treatment Plant has been shown to cause reproductive changes in fishes (Tetreault et al. 2011) and other aquatic organisms such as mussels (Gillis et al. 2014). The facility is being upgraded with a scheduled completion date of 2022, however, it is not known if the upgrades will minimize this threat through reductions in concentrations of estrogenic compounds and other pharmaceutical or personal care products (Gillis et al. 2014). It is highly likely that similar chronic chemical and hormonal threats are present throughout the species' range; however, further research is required for this to be fully substantiated. Additional research on the population-wide effects of de-masculinisation and potential negative impacts on sex ratios and reproduction of Black Redhorse are warranted.

Climate change & severe weather (11.2 Droughts, 11.4 Storms & flooding)

It has been predicted that climate change will have several effects on aquatic ecosystems including increases in water and air temperature, decreases in water levels, shortening of the duration of ice cover, increases in the frequency of extreme weather events, emergence of diseases, and shifts in predator-prey dynamics (Lemmen and Warren 2004). A climate change vulnerability report in Ontario identified Black Redhorse as being highly vulnerable to the impacts of climate change (Brinker et al. 2018). Under the climate scenario modeled, its range and or abundance could decline significantly by 2050, as an increase in temperature of 2.85–3.16 °C is expected across 98% of its range, and a climate moisture deficit of 38.87–56.86 is expected across 97% of its range. The dispersal capacity of Black Redhorse to seek out more suitable habitat in response to climate changes may be limited by the presence of barriers, both natural (i.e., absence of connecting waterways with suitable flow and substrate conditions) and anthropogenic (e.g., dams). Black Redhorse in Ontario has experienced a small degree of temperature variation in recent decades which may make it poorly suited to adapt to future temperature variability. Additionally, thermally suitable habitat may become restricted with increasing temperatures. Black Redhorse is also susceptible to drought and decreases in water levels that lead to a reduction in flow and groundwater inputs that the species relies on. Additionally, storms and flooding may also impact Black Redhorse by altering flow regimes and siltation patterns. It must be noted that droughts and floods have occurred in the past and there is no evidence to suggest that it has been detrimental to the species. Extreme events resulting from climate change may, however, have severe and unpredictable acute impacts on water quality and habitat availability (Grand River Watershed Water Management Plan 2014).

Invasive & other problematic species & genes (8.1 Invasive non-native/alien species)

Brown Trout (*Salmo trutta*) is a non-native piscivore that is stocked in the Grand River to provide recreational angling opportunities and poses a potential threat to Black Redhorse through direct predation of juveniles and smaller individuals, as well as competitive interactions with adults for benthic prey items. Similarly, Rainbow Trout (*Oncorhynchus mykiss*) is a non-native piscivore that is found in many of the watersheds that are occupied by Black Redhorse, particularly the Lake Huron tributaries and the Grand River. Round Goby (*Neogobius melanostomus*), native to the Ponto-Caspian region of Europe, is an invasive species that is found throughout the Great Lakes basin and is expanding into many of the tributaries, including the rivers that are occupied by Black Redhorse. Round Goby, an aggressive benthic feeding species, is a potential competitor of Black Redhorse, and may predate upon eggs and larvae. Zebra Mussel (*Dreissena polymorpha*) and the Asian carp species are also potential invaders that would pose a threat to Black Redhorse, should they become established (COSEWIC 2015).

Biological resource use (5.4 Fishing & harvesting aquatic resources)

Incidental capture and bycatch mortality during commercial baitfish harvest is a potential threat to Black Redhorse. There is no targeted commercial or recreational fishery for the species in Canada; however, incidental capture by recreational anglers is a potential threat that may impact on Black Redhorse in Canada (COSEWIC 2015). The impact of bycatch on Black

Redhorse is dependent on the likelihood of encounter rate and resulting fate of captured individuals (e.g., release unharmed vs. keep for food or bait).

Human intrusions & disturbance (6.1 Recreational activities)

Human intrusion for recreational purposes in the form of ATV operation within the stream bed poses a threat to Black Redhorse. ATV use within the stream can cause physical alteration of the streambed and increase turbidity. Impacts are expected to be slight and limited to easily accessible areas (COSEWIC 2015). Additionally, many of the watersheds are subjected to human intrusion in the form of anglers wading in streams and recreational use of canoes and kayaks. Angling and recreational paddle sports may impact Black Redhorse habitat when individuals disturb the substrate while walking in the stream or launching boats.

Natural system modifications (7.2 Dams & water management/use, 7.3 other ecosystem modifications)

Existing dams in the Thames and Grand River watershed alter flow regimes and impact impounded areas upstream of the dams. Dams also pose a barrier to fish passage when fishways become non-functional (COSEWIC 2015); however, genetic analyses indicate that the population structure of Black Redhorse is not affected by the presence of dams in the Grand River (Reid et al. 2008b). The creation of impoundments may also facilitate invasion by the Zebra Mussel (COSEWIC 2015) and Round Goby (Rabb et al. 2017).

Zebra Mussel are known to modify invaded ecosystems in a number of ways including depleting plankton resources and dissolved oxygen, increasing water clarity, and altering relative substrate composition (Dermott and Munawar 1993, Effler et al. 1996, Caraco et al. 1997). Improved water clarity could benefit the turbidity-sensitive Black Redhorse, while Zebra Mussel adhering to hard surfaces could reduce available habitat on spawning shoals or nursery areas used by Black Redhorse leading to reduced spawning and recruitment success. Additionally, reductions in the plankton community could indirectly impact the species through shifts in prey availability and other food web changes.

Withdrawal of groundwater for municipal and industrial use is another natural system modification that poses a threat to Black Redhorse since the species relies on groundwater inputs as a cold-water refuge during the summer (Bunt et al. 2013). The magnitude of the impact of natural system modifications on Black Redhorse is unknown at this time.

Other natural system modifications related to human development, such as shoreline hardening and instream structures, are also prevalent throughout the watersheds where Black Redhorse is found. These natural system modifications may alter flow regimes and sediment transport throughout the watersheds.

Threat Assessment

To assess the threat level of Black Redhorse populations in Ontario, each threat was ranked in terms of the threat Likelihood of Occurrence (LO), threat Level of Impact (LI) and Causal Certainty (CC) on a population-by-population basis. The Likelihood of Occurrence was assigned as Known, Likely, Unlikely, Remote or Unknown, and the Level of Impact was assigned as Extreme, High, Medium, Low, or Unknown (Table 10). The level of certainty associated with each threat was assessed and classified as: 1 = very high, 2 = high, 3 = medium, 4 = low, 5 = very low. The Population-Level Threat Occurrence (PTO), Threat Frequency (PTF) and Threat Extent (PTE) were also evaluated and assigned a status based on the definitions outlined in Table 9 (DFO 2014). The Likelihood of Occurrence and Level of Impact for each population were subsequently combined in the threat risk matrix (Table 11) resulting in the Population-

Level Threat Risk (PTR, Table 12). The PTR for each population was then rolled up to determine the species-level Threat Assessment based on methodology from the DFO guidance document for the completion of recovery potential assessments (DFO 2014; Table 13).

Table 9. Definition and terms used to describe likelihood of occurrence (LO), level of impact (LI), causal certainty (CC), population level threat occurrence (PTO), threat frequency (PTF) and threat extend (PTE) Information taken from (DFO 2014).

Term	Definition
Likelihood of Occurrence (LO)	
Known or very likely to occur (K)	This threat has been recorded to occur 91–100%.
Likely to occur (L)	There is a 51–90% chance that this threat is or will be occurring.
Unlikely (UL)	There is 11–50% chance that this threat is or will be occurring.
Remote (R)	There is 1–10% or less chance that this threat is or will be occurring.
Unknown (U)	There are no data or prior knowledge of this threat occurring or known to occur in the future.
Level of Impact (LI)	
Extreme (E)	Severe population decline (e.g., 71–100%) with the potential for extirpation.
High (H)	Substantial loss of population (31–70%) or threat **would jeopardize** the survival or recovery of the population.
Medium (M)	Moderate loss of population (11–30%) or threat is **likely to jeopardize** the survival or recovery of the population.
Low (L)	Little change in population (1–10%) or threat is **unlikely to jeopardize** the survival or recovery of the population.
Unknown (U)	No prior knowledge, literature or data to guide the assessment of threat severity on population.
Causal Certainty (CC)	
Very high (1)	Very strong evidence that threat is occurring and the magnitude of the impact to the population can be quantified.
High (2)	Substantial evidence of a causal link between threat and population decline or jeopardy to survival or recovery.
Medium (3)	There is some evidence linking the threat to population decline or jeopardy to survival or recovery.
Low (4)	There is a theoretical link with limited evidence that threat is leading to a population decline or jeopardy to survival or recovery.
Very low (5)	There is a plausible link with no evidence that the threat is leading to a population decline or jeopardy to survival or recovery.

Term	Definition
Population-Level Threat Occurrence (PTO)	
Historical (H)	A threat that is known to have occurred in the past and negatively impacted the population.
Current (C)	A threat that is ongoing, and is currently negatively impacting the population.
Anticipatory (A)	A threat that is anticipated to occur in the future, and will negatively impact the population.
Population-Level Threat Frequency (PTF)	
Single (S)	The threat occurs once.
Recurrent (R)	The threat occurs periodically, or repeatedly.
Continuous (C)	The threat occurs without interruption.
Population- Level Threat Extent (PTE)	
Extensive (E)	71–100% of the population is affected by the threat.
Broad (B)	31–70% of the population is affected by the threat.
Narrow (NA)	11–30% of the population is affected by the threat.
Restricted (R)	1–10% of the population is affected by the threat.

Table 10. Threat Likelihood of Occurrence (LO), Level of Impact (LI), Causal Certainty (CC), Population-Level Threat Occurrence (PTO), Threat Frequency (PTF) and Threat Extent (PTE) of each Black Redhorse population in Ontario.

	Grand River							**Thames River**							**Sauble River**						
	LO	**LI**	**CC**	**PTO**	**PTF**	**PTE**	**Ref**	**LO**	**LI**	**CC**	**PTO**	**PTF**	**PTE**	**Ref**	**LO**	**LI**	**CC**	**PTO**	**PTF**	**PTE**	**Ref**
Pollution	K	M	2	C	C	E	1,2, 3,5	K	M	3	C	C	E	1,2, 3,5	K	M	3	C	C	E	1,2, 3,5
Climate change and severe weather	K	M	2	C,A	C	E	6,7	K	M	3	C,A	C	E	6,7	K	M	3	C,A	C	E	6,7
Invasive species	K	L	5	C	C	E	6	L	L	5	C	C	B	6	K	L	5	C	C	R	6
Biological resource use	L	L	5	C	R	R	6	L	L	5	C	R	R	6	L	L	5	C	R	R	6
Human intrusion	K	L	5	C	R	E	6	K	L	5	C	R	R	6	K	L	5	C	R	R	6
Natural system modification	K	U	5	C	C	E	6	K	U	5	C	C	B	4,6	R	U	5	C	C	R	6

	Saugeen River							**Maitland River**							**Gully Creek**						
	LO	**LI**	**CC**	**PTO**	**PTF**	**PTE**	**Ref**	**LO**	**LI**	**CC**	**PTO**	**PTF**	**PTE**	**Ref**	**LO**	**LI**	**CC**	**PTO**	**PTF**	**PTE**	**Ref**
Pollution	K	M	3	C	C	E	1,2,3,5	K	M	3	C	C	E	1,2, 3,5	K	M	3	C	C	E	1,2,3,5
Climate change and severe weather	K	M	3	C,A	C	E	6,7	K	M	3	C,A	C	E	6,7	K	M	3	C,A	C	E	6,7
Invasive species	K	L	5	C	C	R	6	K	L	5	-	C	B	6	L	L	5	C	C	R	6
Biological resource use	L	L	5	C	R	R	6	L	L	5	C	R	R	6	L	L	5	C	R	R	6
Human intrusion	K	L	5	C	R	R	6	K	L	5	C	R	R	6	UL	L	5	C	R	R	6
Natural system modification	R	U	5	C	C	R	6	K	U	5	C	C	NA	6	R	U	5	C	C	R	6

	Bayfield River							Ausable River						
	LO	**LI**	**CC**	**PTO**	**PTF**	**PTE**	**Ref**	**LO**	**LI**	**CC**	**PTO**	**PTF**	**PTE**	**Ref**
Pollution	K	M	3	C	C	E	1,2,3,5	K	M	3	C	C	E	1,2,3,5
Climate change and severe weather	K	M	3	C,A	C	E	6,7	K	M	3	C,A	C	E	6,7
Invasive species	K	L	5	C	C	R	6	K	L	5	C	C	R	6
Biological resource use	L	L	5	C	R	R	6	L	L	5	C	R	R	6
Human intrusion	K	L	5	C	R	R	6	K	L	5	C	R	R	6
Natural system modification	K	U	5	C	C	R	6	K	U	5	C	C	R	6

References:
1. Portt et al. (2003)
2. Blazer et al. (2014)
3. Grand River Conservation Authority (2014)
4. Reid and Mandrak (2006)
5. Tetreault et al. (2011)
6. COSEWIC (2015)
7. Lemmen and Warren (2004)

Table 11. The Threat Level Matrix combines the Likelihood of Occurrence and Level of Impact rankings to establish the Threat Level for each Black Redhorse population in Ontario. The resulting Threat Level has been categorized low, medium, high or unknown. Reproduced from DFO (2014).

Likelihood of Occurrence	**Level of Impact**				
	Low	**Medium**	**High**	**Extreme**	**Unknown**
Known or very likely	Low	Medium	High	High	Unknown
Likely	Low	Medium	High	High	Unknown
Unlikely	Low	Medium	Medium	Medium	Unknown
Remote	Low	Low	Low	Low	Unknown
Unknown	Unknown	Unknown	Unknown	Unknown	Unknown

Table 12. Threat Level Assessment for all Black Redhorse 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.

	Grand River	**Thames River**	**Sauble River**	**Saugeen River**	**Maitland River**
Pollution	Medium (2)	Medium (3)	Medium (3)	Medium (3)	Medium (3)
Climate change & severe weather	Medium (2)	Medium (3)	Medium (3)	Medium (3)	Medium (3)
Invasive species	Low (5)	Low (5)	Low (5)	Low (5)	Low (5)
Biological resource use	Low (5)	Low (5)	Low (5)	Low (5)	Low (5)
Human intrusion	Low (5)	Low (5)	Low (5)	Low (5)	Low (5)
Natural system modification	Unknown	Unknown	Unknown	Unknown	Unknown

	Gully Creek	**Bayfield River**	**Ausable River**
Pollution	Medium (3)	Medium (3)	Medium (3)
Climate Change & severe weather	Medium (3)	Medium (3)	Medium (3)
Invasive species	Low (5)	Low (5)	Low (5)
Biological resource use	Low (5)	Low (5)	Low (5)
Human intrusion	Low (5)	Low (5)	Low (5)
Natural system modification	Unknown	Unknown	Unknown

Table 13. Species-level Threat Assessment for Black Redhorse in Canada, resulting from roll-up of population-level Threat Assessment. The species-level Threat Extent is calculated as the mode of population-level Threat Extent.

	Species-level Threat Risk	**Species-level Threat Occurrence**	**Species-level Threat Frequency**	**Species-level Threat Extent**
Pollution	Medium (2)	C	C	E
Climate change & severe weather	Medium (2)	C,A	C	E
Invasive species	Low (5)	C	C	R
Biological resource use	Low (5)	C	R	R
Human intrusion	Low (5)	C	R	R
Natural system modification	Unknown	C	C	R

ELEMENT 9: IDENTIFY THE ACTIVITIES MOST LIKELY TO THREATEN (I.E., DAMAGE OR DESTROY) THE HABITAT PROPERTIES IDENTIFIED IN ELEMENTS 4-5 AND PROVIDE INFORMATION ON THE EXTENT AND CONSEQUENCES OF THESE ACTIVITIES

The activities most likely to threaten Black Redhorse habitat based on the threat assessment in Element 8 are municipal and agricultural practices that increase pollution, resulting in habitat degradation. Municipal and agricultural pollution has the potential to impact Black Redhorse habitat through impairment of habitat and water quality resulting from changes in land use that affect run-off, increased water abstraction, and increased wastewater discharge (Portt et al. 2003). These urban and agricultural inputs are likely to cause impaired water quality, increased nutrient inputs, and increased turbidity. Elevated nutrient levels can lead to algal blooms and, consequently, a decrease in dissolved oxygen. The majority of the locations where Black Redhorse is found in Canada are within agricultural or urban areas, thus, the extent of the potential impacts from these activities encompasses a large proportion of the species Canadian range.

Any new impoundments or reservoirs that are created in areas that support Black Redhorse populations are likely to impact the species' habitat. The magnitude of potential impact would be determined by the size of the impoundment, whether the dam design incorporates cold-water discharge, and the extent of fish passage.

ELEMENT 10: ASSESS ANY NATURAL FACTORS THAT WILL LIMIT THE SURVIVAL AND RECOVERY OF THE BLACK REDHORSE

The distribution of the Black Redhorse is likely limited by the availability of ideal habitat within its Canadian range (Parker 1989). Access to suitable habitat is affected by dams and impoundments that block movement, as well as expanses of unsuitable habitat that separate populations between watersheds. Adults associate with moderate to high gradient habitat in medium-sized warmwater streams and rivers (Bowman 1970, Page and Burr 2011). Black Redhorse does not generally associate with low gradients and turbidity as opposed to other redhorse species found within its range, and is considered intolerant of siltation (Trautman 1981, Scott and Crossman 1998). It is often more abundant in cool, swift, rocky streams than the Golden Redhorse (Jenkins and Burkhead 1994). Due to restricted spawning habitat preferences in water depth, water velocity, and substrate (Table 7; Kwak and Skelly 1992), Black Redhorse recruitment is vulnerable to changes in the flow regime. An extreme high flow event was observed by Bowman (1970) to result in the abandonment of a historically utilized spawning shoal. In the Grand River, large increases in discharge during the spawning period prevented spawning of ripe individuals of Greater Redhorse (Cooke and Bunt 1999). Black Redhorse is sensitive to poor water quality and habitat degradation (Reid 2006a), and as such, improvements, to both water quality and habitat in the Illinois and Ohio river, have recently resulted in re-establishment of stable populations of Black Redhorse (Retzer 2005, Yoder et al. 2005).

ELEMENT 11: DISCUSS THE POTENTIAL ECOLOGICAL IMPACTS OF THE THREATS IDENTIFIED IN ELEMENT 8 TO BLACK REDHORSE AND OTHER CO-OCCURRING SPECIES. LIST THE POSSIBLE BENEFITS AND DISADVANTAGES TO THE TARGET SPECIES AND OTHER CO-OCCURRING SPECIES THAT MAY OCCUR IF THE THREATS ARE ABATED. IDENTIFY EXISTING MONITORING EFFORTS FOR THE TARGET SPECIES AND OTHER CO-OCCURRING SPECIES ASSOCIATED WITH EACH OF THE THREATS, AND IDENTIFY ANY KNOWLEDGE GAPS.

The degradation of habitat quality through pollution is considered to be the greatest threat to Black Redhorse in Canada. Increased runoff from urban and agricultural sources leads to an increase in turbidity which negatively affects Black Redhorse and other species that are intolerant to siltation, such as Eastern Sand Darter (*Ammocrypta pellucida*; COSEWIC 2009) and River Redhorse (COSEWIC 2006), both of which are found in watersheds that are occupied by Black Redhorse. Increased turbidity impairs recruitment through smothering of demersal eggs by siltation and negatively affects feeding by visual predators. Reducing the influx of sediment into the watersheds that are occupied by Black Redhorse is expected to benefit benthic spawning species through increased hatching success and improved survivorship and condition of visual predators.

Exposure to urban wastewater pollution impacts the reproductive system in several benthic fishes, as well as mussel species (Tetreault et al. 2011, Gillis et al. 2014), causing feminization of males and potentially leading to altered sex ratios and reproductive impairment in the population. Improving the effectiveness of treatment for wastewater that is discharged into watersheds that are occupied by Black Redhorse is expected to restore the reproductive capacity of co-occurring fish and mussel species.

Local conservation authorities conduct yearly monitoring of the watersheds that are occupied by Black Redhorse in Ontario. These programs include monitoring of surface water quality, groundwater quality, and natural forest cover within the watershed. Despite the ongoing monitoring efforts, several knowledge gaps still exist. Baseline population data for Black Redhorse are needed, along with causative studies to evaluate the impact of exposure to contaminants on Black Redhorse populations as well as an estimation of cumulative impacts. Threshold levels for water quality parameters (e.g., nutrients, turbidity) and physiological parameters including temperature, pH, dissolved oxygen, and pollution tolerance also need to be determined.

RECOVERY TARGETS

ELEMENT 12: PROPOSE CANDIDATE ABUNDANCE AND DISTRIBUTION TARGET(S) FOR RECOVERY

Young and Koops (2014) determined Minimum Viable Population (MVP) size for Black Redhorse and the Minimum Area for Population Viability (MAPV) that is required to support these population sizes (Table 14). These recovery targets were estimated using simulations to generate a cumulative distribution function of extinction probability, where a population was said to be extinct if it was reduced to one or twenty-five adult (female) individuals. Catastrophic decline in population size, defined as a 50% reduction in abundance, was incorporated into these simulations, and occurred at a probability (P_c) of 0.10, or 0.15 per generation. Minimum area for population viability (MAPV) was estimated as the amount of habitat required to support a viable population by multiplying the MVP by an estimated area required per individual (API) for each age class.

MVP estimates for Black Redhorse are 1700 adults (ages 4+) and 3900 juveniles (ages 1–3) assuming the probability of a catastrophic (50%) decline is 0.15 per generation and an extinction threshold of 50 adults. MAPV for Black Redhorse was 14.5 ha of good quality, suitable habitat, including 3.7 ha for juveniles and 10.3 ha for adults, assuming these habitats are discrete.

Table 14. Number of individuals by stage required to support a minimum viable population (MVP), and associated hectares of habitat required, based on estimated Area per Individual. Results for an extinction threshold of 50 adults, 15% probability of catastrophe, and a timeframe of 100 years are shown. Stages shown are young of the year (YOY), Juvenile (ages 1–3), and adult (ages 4–16).

Age class	**MVP**		**MAPV (ha)**	
	Mean	**95% CI**	**Mean**	**95% CI**
YOY	5.0×10^6	(4.2×10^6–6.1×10^6)	0.5	(0.4–0.6)
Juvenile	3.9x103	(3.3×10^3–4.8×10^3)	3.7	(3.1–4.6)
Adult	1.7x103	(1.4×10^3–2.1×10^3)	10.3	(8.6–12.7)
Total	-	-	14.5	(12.2–17.8)

ELEMENT 13: PROJECT EXPECTED POPULATION TRAJECTORIES OVER A SCIENTIFICALLY REASONABLE TIME FRAME (MINIMUM OF 10 YEARS), AND TRAJECTORIES OVER TIME TO THE POTENTIAL RECOVERY TARGET(S), GIVEN CURRENT BLACK REDHORSE POPULATION DYNAMIC PARAMETERS

Currently, size and trajectory is unknown for Black Redhorse populations in Ontario.

ELEMENT 14: PROVIDE ADVICE ON THE DEGREE TO WHICH SUPPLY OF SUITABLE HABITAT MEETS THE DEMAND OF THE SPECIES BOTH AT PRESENT AND WHEN THE SPECIES REACHES THE POTENTIAL RECOVERY TARGET(S) IDENTIFIED IN ELEMENT 12

Black Redhorse occupies approximately 554 linear km of river segments in Ontario. While the amount of specific habitat types within these rivers has not been quantified, and the quality of habitat is likely to vary within this area, it is likely that the MAPV of 14.5 ha of suitable habitat is available to support Black Redhorse populations at the level of the recovery targets in each of the watersheds occupied by Black Redhorse in Canada.

ELEMENT 15: ASSESS THE PROBABILITY THAT THE POTENTIAL RECOVERY TARGET(S) CAN BE ACHIEVED UNDER CURRENT RATES OF POPULATION DYNAMIC PARAMETERS, AND HOW THAT PROBABILITY WOULD VARY WITH DIFFERENT MORTALITY (ESPECIALLY LOWER) AND PRODUCTIVITY (ESPECIALLY HIGHER) PARAMETERS

Long-term modelling projections by Vélez-Espino and Koops (2008), completed using five hypothetical recovery strategies, suggest that allowing 20% mortality on adult Black Redhorse would result in the recovery targets never being reached, despite a 20% increase in YOY survival. Projections that incorporated simultaneous increases of 20% to juvenile and YOY survival resulted in recovery targets being reached within 29–119 years (Vélez-Espino and Koops 2008), dependent on whether the upper or lower bound of population response was used. Including an increase in survival of young adults by 20% in the simulation resulted in recovery targets being reached within 17–40 years and increasing fecundity further reduced time to recovery to 11–37 years.

SCENARIOS FOR MITIGATION OF THREATS AND ALTERNATIVES TO ACTIVITIES

ELEMENT 16: DEVELOP AN INVENTORY OF FEASIBLE MITIGATION MEASURES AND REASONABLE ALTERNATIVES TO THE ACTIVITIES THAT ARE THREATS TO THE SPECIES AND ITS HABITAT (AS IDENTIFIED IN ELEMENT 8 AND 10)

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 Black Redhorse habitat. Black Redhorse has been assessed as Threatened by COSEWIC (COSEWIC 2015) and is currently listed and protected under both the *Endangered Species Act, 2007*, and the *Species at Risk Act*.

Within Black Redhorse habitat, a variety of works, undertakings, and activities have occurred in the last five years with project types including: water crossings (e.g., bridge maintenance); shoreline and streambank works (e.g., stabilization); instream works (e.g., channel maintenance); and, the placement or removal of structures in water. A review has been completed summarizing the types of work, activity, or projects that have been undertaken in habitat known to be occupied by Black Redhorse (Table 15). The DFO Program Activity Tracking for Habitat (PATH) database has been reviewed to estimate the number of projects that have occurred during a five year period from 2011 to 2016. Forty eight (48) projects were identified in Black Redhorse habitat, but these likely do not represent a complete list of projects or activities that have occurred in these areas (Table 15). Some projects occurring in proximity but not in the area of habitat may also have impacts, but were not included. Some projects may not have been reported to partner agencies or DFO if they occurred under conditions of an Operational Statement. A known bridge replacement project on Stoney Creek in London was initiated in 2016, but it was not submitted or reviewed by DFO.

Only one project to replace the Caledonia bridge is to be authorized under the *Fisheries Act* and the *Species at Risk Act* since fish and mussel relocations for other SARA species are required. The remaining projects were deemed low risk to fish and fish habitat and were addressed through letters of advice with standard mitigation. Without appropriate mitigation, projects or activities occurring adjacent or close to these areas could have impacted Black Redhorse (e.g., increased turbidity or sedimentation from upstream channel works).

The most frequent project type was for bridge maintenance, dredging, drain maintenance, and bank stabilization. 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 Black Redhorse habitat in the future. The primary project proponents were provincial and municipal road or drainage departments. Activities were undertaken in the Thames River and its tributaries, the Grand River and one of its tributaries (Nith River), and the Maitland River. No known activities were undertaken in the other watersheds that are occupied by Black Redhorse during this time-frame.

Habitat-related threats to Black Redhorse have been linked to the Pathways of Effects developed by DFO Fish Habitat Management (FHM) (Table 15). 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 Black Redhorse, related to invasive species, human intrusion, and incidental harvest are listed below.

Table 15. Summary of works, projects, and activities that have occurred during the period from 2011–2016 in areas known to be occupied by Black Redhorse. 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 Black Redhorse 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 June 2011–June 2016)				
	Habitat removal and alteration	**Nutrient loading**	**Turbidity and sediment loading**	**Contaminants and toxic substances**	**Exotic species and disease**	**Incidental harvest**	**Thames River**	**Waubuno, Stoney, Wye, Oxbow, Flat creeks (Thames R. tribs)**	**Grand River**	**Nith River (Grand R. tributary)**	**Maitland River**
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, 8,11, 12,13, 14,15, 16	1,2,3,4, 5,6,7,8, 10,11, 12,13, 15,16,18	1,4,5,6, 7,11,12, 13,14, 15,16, 18	-	-	-	-	-	-	-
Water crossings (bridges, culverts, open cut crossings)	✓	-	✓	✓	-	-	1	2	9	7	2
Shoreline, streambank work (stabilization, infilling, retaining walls, riparian vegetation management)	✓	-	✓	✓	-	-	1	-	4	2	1
Instream works (channel maintenance, restoration, modifications, realignments, dredging, aquatic vegetation removal)	✓	✓	✓	✓	-	-	2	5	2	-	3
Water management (stormwater management, water withdrawal)	-	✓	✓	✓	-	-	-	-	-	-	1
Structures in water (boat launches, docks, effluent outfalls, water intakes, dams)	✓	✓	✓	✓	-	-	2	-	3	-	1
Baitfishing	-	-	-	-	-	✓	-	-	-	-	-
Invasive species introductions (accidental and intentional)	-	-	-	-	✓	-	-	-	-	-	-

Invasive and other problematic species, genes, and diseases (8.1 Invasive non-native/alien species)

Mitigation

- Removal/control of introduced species from areas inhabited by Black Redhorse.
- Monitor for introduced species that may negatively affect Black Redhorse populations or preferred habitat.
- Develop a plan to address potential risks, impacts, and proposed actions if monitoring detects the arrival or establishment of introduced species.
- Initiate a public awareness campaign and encourage the use of existing invasive species reporting systems.
- Under circumstances where barriers to fish movement (i.e., dams) are to be removed or fish passage is to be increased (i.e., creation of a fishway) the potential negative effects of introduced species moving into Black Redhorse habitat should be considered.

Alternatives

- Do not stock non-native species in areas inhabited by Black Redhorse.
- Do not enhance habitat for non-native species in areas inhabited by Black Redhorse.

Biological resource use (5.4 Fishing and harvesting aquatic resources)

Mitigation

- Provide information and education on Black Redhorse to bait harvesters and recreational anglers to raise awareness, and request voluntary avoidance of occupied Black Redhorse areas.
- Immediate release of Black Redhorse if incidentally caught, as defined under the Ontario Recreational Fishing Regulations.

Alternatives

- Prohibit the harvest of baitfish in areas where Black Redhorse is known to exist.
- Seasonal or zonal restrictions applied to harvesting/fishing during Black Redhorse spawning season.

Human intrusion and disturbance (6.1 Recreational activities)

Mitigation

- Provide information and education on aquatic species at risk, their habitat, and the destructive consequences of ATV operation in streams to ATV users.

Alternatives

- Install signage to discourage ATV use in streams in known problem areas.

ELEMENT 17: DEVELOP AN INVENTORY OF ACTIVITIES THAT COULD INCREASE THE PRODUCTIVITY OR SURVIVORSHIP PARAMETERS (AS IDENTIFIED IN ELEMENTS 3 AND 15)

The mitigation measures outlined above are consistent with the goal of increasing survivorship, by reducing threats to the species directly (e.g., invasive species, bait harvest) or indirectly by improving habitat quality (e.g., reducing threats of urban and agricultural pollution).

ELEMENT 18: IF CURRENT HABITAT SUPPLY MAY BE INSUFFICIENT TO ACHIEVE RECOVERY TARGETS (SEE ELEMENT 14), PROVIDE ADVICE ON THE FEASIBILITY OF RESTORING THE HABITAT TO HIGHER VALUES. ADVICE MUST BE PROVIDED IN THE CONTEXT OF ALL AVAILABLE OPTIONS FOR ACHIEVING ABUNDANCE AND DISTRIBUTION TARGETS.

The feasibility of rehabilitating or restoring degraded habitat features due to municipal and agricultural pollution in the watersheds that are occupied by Black Redhorse has not been assessed. However, actions to reduce agricultural and municipal pollution inputs are likely to result in increased quantity and quality of habitat. In agricultural areas, the use of best management practices is encouraged to restore a healthy riparian zone, reduce livestock access, establish manure collection systems, encourage conservation tillage, and, reduce the impact of tile drains. These practices would improve Black Redhorse habitat by reducing agricultural runoff and bank erosion, thereby limiting the input of sediments and nutrients from agricultural lands. Additionally, the improvement of urban waste water treatment systems would improve Black Redhorse habitat by reducing the input of contaminants, such as endocrine disruptors.

ELEMENT 19: ESTIMATE THE REDUCTION IN MORTALITY RATE EXPECTED BY EACH OF THE MITIGATION MEASURES OR ALTERNATIVES IN ELEMENT 16 AND THE INCREASE IN PRODUCTIVITY OR SURVIVORSHIP ASSOCIATED WITH EACH MEASURE IN ELEMENT 17

We are unable to respond to this element due to limitations in current available data.

ELEMENT 20: PROJECT EXPECTED POPULATION TRAJECTORY (AND UNCERTAINTIES) OVER A SCIENTIFICALLY REASONABLE TIME FRAME AND TO THE TIME OF REACHING RECOVERY TARGETS, GIVEN MORTALITY RATES AND PRODUCTIVITIES ASSOCIATED WITH THE SPECIFIC MEASURES IDENTIFIED FOR EXPLORATION IN ELEMENT 19. INCLUDE THOSE THAT PROVIDE AS HIGH A PROBABILITY OF SURVIVORSHIP AND RECOVERY AS POSSIBLE FOR BIOLOGICALLY REALISTIC PARAMETER VALUES.

We are unable to respond to this element due to limitations in current available data.

ELEMENT 21: RECOMMEND PARAMETER VALUES FOR POPULATION PRODUCTIVITY AND STARTING MORTALITY RATES AND, WHERE NECESSARY, SPECIALIZED FEATURES OF POPULATION MODELS THAT WOULD BE REQUIRED TO ALLOW EXPLORATION OF ADDITIONAL SCENARIOS AS PART OF THE ASSESSMENT OF ECONOMIC, SOCIAL, AND CULTURAL IMPACTS IN SUPPORT OF THE LISTING PROCESS

We are unable to respond to this element due to limitations in current available data.

ALLOWABLE HARM ASSESSMENT

ELEMENT 22: EVALUATE MAXIMUM HUMAN-INDUCED MORTALITY AND HABITAT DESTRUCTION THAT THE SPECIES CAN SUSTAIN WITHOUT JEOPARDIZING ITS SURVIVAL OR RECOVERY

Young and Koops (2014) estimated allowable chronic harm for Black Redhorse populations in Canada, assuming a positive growth rate in the absence of harm (λmax) of 1.6. Simulations indicate that to avoid jeopardizing the survival and future recovery of Black Redhorse in Canada, human-induced harm to the annual survival of juveniles and early adults should be minimized. Changes to survival of YOY and fecundity of early adults had much less influence on population growth. Changes to survival and fecundity of older adults had minimal impact. For populations growing at maximum population growth rate (λ = 1.6) any reduction of juvenile survival by greater than 64% would cause the population growth rate to drop below λ = 1 (declining growth rate; Table 16).

Table 16. Summary of elasticities (stochastic mean and upper bound) a stable (λ = 1) and growing (λ = 1.6) population and allowable harm for Black Redhorse vital rates (εv) for a growing (λ = 1.6) population. Shown are values for: first year survival (YOY), cumulative survival for juveniles (ages 1–4), and cumulative survival and fecundity for early adults (up to age 10) and late adults (age 11 and over).

	Survival				Fecundity	
	YOY (σ_1)	Juvenile (σ_2–σ_4)	Early Adult (σ_5–σ_{10})	Late Adult (σ_{11}–σ_{16})	Early Adult (η_3–η_{10})	Late Adult (η_{11}–η_{16})
Elasticity (λ = 1)						
Stochastic mean	0.12	0.36	0.43	0.09	0.09	0.03
Elasticity (λ = 1.6)						
Stochastic mean	0.19	0.54	0.26	0.01	0.18	0.00
Upper Bound	0.21	0.59	0.33	0.02	0.24	0.01
Allowable Harm (λ = 1.6)	-1.79	-0.64	-1.14	-18.75	-1.56	-37.50

Allowable harm would be lower if the population is growing at a slower rate, and is 0 if it is not growing. Allowable chronic harm for a population with a positive growth rate (λ^+) that is lower than the maximum population growth rate ($\lambda_{max} > \lambda^+ > 1$) can be approximated with Equation 1 by using the λ^+ along with the elasticities from the growing population ($\lambda = \lambda_{max}$) in Table 16.

If human activities are such that harm exceeds just one of these thresholds, the future persistence of populations is likely to be compromised. In addition, simulations suggest that recovery time can be severely delayed by any levels of harm within the maximum allowable harm suggested in Table 16 (Young and Koops 2014).

SOURCES OF UNCERTAINTY

There are several knowledge gaps related to the distribution and abundance of Black Redhorse in Canada. The species is still relatively understudied and no long-term monitoring projects are in place to determine current size or trajectory of Canadian populations. The studies that have been completed regarding the species in Canada are limited to a single watershed [Grand River; e.g., Bunt et al. (2013)] and further study in other watersheds in Canada is required to provide baseline information to facilitate recovery planning. Standardized sampling over multiple years is required to determine population size and growth rates/trajectories.

Current distribution and extent of suitable habitat is unknown for Black Redhorse; further mapping of rivers and streams in southwestern Ontario should be conducted and areas of suitable habitat should be the focus of future targeted sampling efforts for this species. There is also a need to refine habitat requirements, and comparisons of habitat use by other populations with the habitats utilized in the Grand River, for each life stage.

Bunt et al. (2013) found that Black Redhorse utilized groundwater seepage areas as a thermal refuge in the Grand River. Future research to determine the extent that this habitat type is utilized and potential impacts to Black Redhorse populations due to groundwater withdrawal is warranted.

Black Redhorse is under continuing threats to habitat quality from cumulative impacts of pollution from urban wastewater and agriculture and alterations to flow regimes. There is a need for causative studies to evaluate the impact of these threats on Black Redhorse populations as well as an estimation of cumulative impacts. Threshold levels for water quality parameters (e.g., nutrients, turbidity) and physiological parameters including temperature, pH, dissolved oxygen, and pollution tolerance also need to be determined.

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