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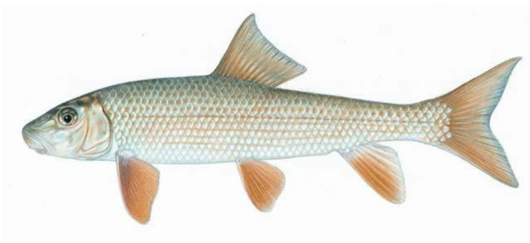
Central and Arctic Region

Canadian Science Advisory Secretariat
Science Advisory Report 2022/038

RECOVERY POTENTIAL ASSESSMENT OF BLACK REDHORSE (*MOXOSTOMA DUQUESNEI*) IN CANADA



*Black Redhorse (*Moxostoma duquesnei*)*
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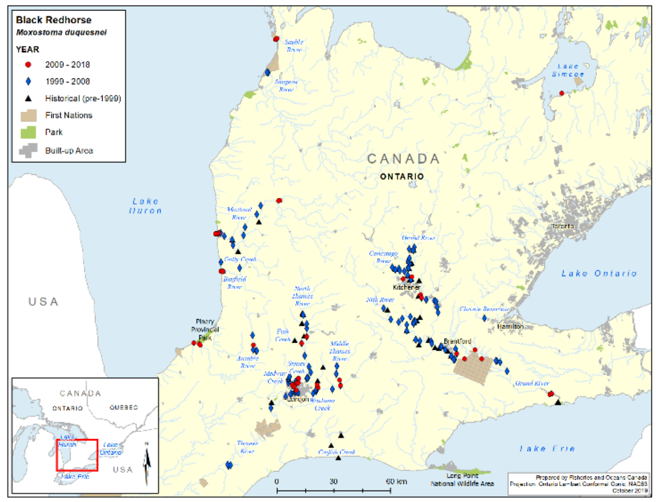

Figure 1. Distribution of Black Redhorse in Canada.

Context:

*The Black Redhorse (*Moxostoma duquesnei*) is one of seven redhorse species found in Canada and has been found in tributaries of lakes Erie, St. Clair, Ontario and Huron. It was first assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1988 as Threatened, was re-assessed as Threatened in 2005 and again in 2015. It was subsequently listed as Threatened under Schedule 1 of the* Species at Risk Act *in August 2019 owing to its limited extent of occurrence and area of occupancy, and the cumulative impacts of threats from urban wastewater and agricultural pollution and alterations to flow regimes across its range.*

A Recovery Potential Assessment process developed by Fisheries and Oceans Canada (DFO) was undertaken for Black Redhorse in 2016 in support of the SARA listing decision. This RPA summarizes information up to 2016 on the distribution, abundance, population trends, habitat requirements of, and threats to (and potential mitigations for) Black Redhorse in Canada, and identifies suitable recovery targets. This information may be used to develop a recovery strategy and action plan, and provide scientific advice needed to meet various requirements of SARA, including decisions related to the issuance of permits and authorizations.

*This Science Advisory Report is generated from the December 15, 2016 regional peer review meeting on the Recovery Potential Assessment of Black Redhorse (*Moxostoma duquesnei*). Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule](#) as they become available.*

August 2022

Canada

SUMMARY

- The current distribution of Black Redhorse in Canada is limited to southwestern Ontario, including tributaries of Lake Erie (Grand River and tributaries), Lake Huron (Ausable River, Bayfield River, Maitland River, Saugeen River, Sauble River and Gully Creek), and Lake St. Clair (Thames River and tributaries). Most populations are considered to be in poor status.
- Black Redhorse generally occupies cool, clear streams over clean pebble, gravel and cobble substrates in 0.6–2.5 m of depth with medium to fast flow and gradients of 1.2–1.5 m/km. Juveniles may occupy shallower runs, riffles or pools with reduced flow compared to adults. Spawning occurs in late spring in shallow riffles with cobble substrates, when water temperatures are between 15 and 21 °C.
- The greatest threats to Black Redhorse in Canada are pollution from urban wastewater and agriculture, and natural systems modifications, such as dams and water withdrawals, that result in altered flow regimes and groundwater disruptions. Additional threats include impacts from climate change related to increased temperatures and changes to flow, invasive species, indirect impacts from recreational fishing (including incidental bait harvest), and recreational vehicle and vessel use in streams.
- To achieve persistence, the minimum viable population size for Black Redhorse is estimated to be 1,700 adults (ages 4+) and 3,900 juveniles (ages 1–3), assuming the probability of catastrophe (50% decline) is 0.15 per generation, with an extinction threshold of 50 adults. The minimum area for population viability was estimated to be 14.5 ha of good quality, suitable habitat. Black Redhorse occupies approximately 554 linear river kilometer segments in Ontario; although suitable habitat has not been quantified, there is likely sufficient area to support populations of Black Redhorse in each of the occupied watersheds.
- Modelled recovery projections that incorporate a 20% increase to both juvenile and young-of-year survival resulted in recovery targets being reached within 29–119 years. If a 20% increase in survival of young adults was included, recovery targets were reached in 17–40 years. Increasing fecundity further reduced time to recovery to 11–37 years.
- Black Redhorse populations are most sensitive to perturbations in annual survival of juveniles and early adults; therefore, harm to these life stages should be minimized. Reductions of juvenile survival greater than 64% when populations are at maximum growth rate are likely to result in population decline; allowable harm to juveniles would be lower with a lower population growth rate, and zero if the population was not growing.
- There remains uncertainty around population sizes and trends, availability of suitable habitat, the association with groundwater seepages, and impacts of threats related to water quality.

BACKGROUND

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 2005 (COSEWIC 2005) and again in May 2015 (COSEWIC 2015). Fisheries and Oceans Canada (DFO) has developed a Recovery Potential Assessment (RPA) process to provide information and scientific advice related to current population status and trends, threats to survival and recovery, and feasibility of recovery. This advice is needed to fulfill various requirements of the *Species at Risk Act* (SARA), including development of recovery documents and assessing SARA Section 73 permit applications. An initial RPA for Black Redhorse was conducted December 7, 2007; however, the species was not listed on Schedule 1 of SARA at this time. Subsequent to the initial RPA meeting, a Pre-COSEWIC Assessment of Black Redhorse peer-review meeting (DFO 2014a) occurred on November 12, 2013, which focused on presenting population modelling in support of the upcoming reassessment of the species. Results included a sensitivity analysis and determination of recovery targets for population abundance and required habitat. A second RPA was held December 15, 2016 where updated information related to habitat, population status and trajectory, threats, recovery targets and allowable harm were presented and peer-reviewed (Young and Koops 2014, Bouvier et al. 2021).

Black Redhorse is relatively large-bodied sucker that occupies rivers and large streams in the Mississippi and Great Lakes drainages. In Canada, it is found only in southwestern Ontario in watersheds of Lake Erie, Lake St. Clair, and Lake Huron (Figure 1). It has a slightly deep body that is olive-brown to grey on the back and silver to milky white on the ventral surface. The tail is grey. There are 44–47 lateral line scales and 12–13 circumpeduncular scales. It has a long rounded snout that overhangs the mouth, and a lower lip with plicae not broken by transverse grooves. Females are generally larger than males at a given age; they are sexually dimorphic during spawning, with males displaying spawning colouration and developing nuptial tubercles on their snout, and anal and caudal fins (Scott and Crossman 1998, Holm et al. 2010). At its northern range edge in Ontario, it appears to grow slower, mature later, and reach a longer maximum size and older age than populations further south (Reid 2009). The Ontario record is 543 mm total length (TL) with an average of 400 mm TL (Holm et al. 2010), and a range of 60–520 mm TL measured from 536 specimens across its Ontario distribution (Reid 2009). It may reach a maximum age of 16 in Ontario (Reid 2009). It is a benthic feeder, consuming crustaceans and aquatic insects as an adult, smaller benthic invertebrates as a juvenile (100–400 mm TL), and is planktivorous below 65 mm TL (Bowman 1970, Coker et al. 2001). Detailed information regarding its biology, life history and distribution is found in Bouvier et al. (2021).

ASSESSMENT

Current Status and Trends

There is a poor understanding of Black Redhorse population abundance and trends due to a lack of standardized sampling through time. There are currently no available estimates of population size in any of the Canadian tributaries where the species is found.

Lake Erie Drainage

Black Redhorse was first detected in the Grand River watershed in 1927 in Mud Creek, but was not detected again until 1975. It has been consistently reported in this watershed since that time during targeted sampling efforts and as incidental captures. Detections have occurred in the main stem of the Grand River (a 160 km stretch from downstream of Inverhaugh to York), the lower reaches of the Conestogo and Nith rivers (tributaries of the Grand River) and their tributaries (Hunsburger and Cox creeks). A single detection occurred in Laurel Creek in 1991. It is believed to be extirpated from Catfish Creek, as it has not been detected since 1938. The distribution of Black Redhorse is somewhat fragmented in the Grand River resulting from four dams that lack suitable passage for benthic species; this may have impacted population structure. Despite the presence of dams, the population in the Grand River appears to be stable.

Lake St. Clair Drainage

In the Thames River watershed, Black Redhorse 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, and Wye Creek), as well as Fanshawe Lake (man-made lake resulting from the Fanshawe Dam on the North Thames River). There have been singular records of the species from both Fish Creek (1972) and Flat Creek (1997) and it is unknown if it still occupies these tributaries. Black Redhorse has not been detected in Fanshawe Lake proper since 1998, despite fish surveys. There are two dams on the Thames River that lack fish passage that may have impacted population structure.

Lake Huron Drainage

In the Lake Huron drainage, Black Redhorse has been recorded form the Sauble River, Saugeen River, Maitland River, Gully Creek, Bayfield River and Ausable River. It was first detected in the Sauble River in 1958, but was not detected again until 2014; it has subsequently been detected in the lower reaches. It was detected at two sites on the Saugeen River in 2006. Black Redhorse is known from a 63 km stretch of the Maitland River from the mouth at Lake Huron to Wingham. It has been consistently captured in the lower reaches in recent years, but sampling events have been sporadic in the mid and upper reaches (including in tributaries Belgrave Creek, Blyth Brook and Bridgewater Creek) and have not resulted in captures, except at Wingham in 2016. A juvenile Black Redhorse was detected in Gully Creek approximately 1 km from the mouth at Lake Huron. No other records from Gully Creek exist; however, the lower reaches have not been well-sampled. Black Redhorse was first detected in the Bayfield River in 1982 but was not detected in this system again until 2014. Since then, several records exist from the lower reaches (~ 1.5 km from the mouth at Lake Huron). One specimen was recorded from the outlet to Tricks Creek in 2003. In the Ausable River, Black Redhorse is known from an 8 km stretch, with most recent detections occurring in the lower 4 km. One specimen was recorded from the Little Ausable River near Maguire Road in 2002. A dead specimen was found in a trap net in Lake Simcoe in 2011, but this record is thought to be a likely introduction.

Lake Ontario Drainage

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

Population Assessment

To assess the population status, each population was ranked in terms of abundance (Relative Abundance Index; Extirpated, Low, Medium, High, or Unknown) and trajectory (Trajectory; Increasing, Decreasing, Stable, or Unknown) (Table 1). Relative abundance for populations was assessed against the Grand River population, as it is the largest and best studied in Canada. The population assessment considered sampling effort, gear used, area sampled, and whether the study was targeting Black Redhorse. Refer to Bouvier et al. (2021) for detailed methods used to assess the Population Status.

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. 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.

Table 1. 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

Habitat Requirements

A total of 554 kilometers of river segments in Ontario contain Black Redhorse records; however, the availability of suitable habitat within these segments has not been quantified. Black Redhorse habitat, in general, consists of well-oxygenated, relatively eutrophic waters with an average July temperature of 20 °C (Parker 1989) and a mean depth of 1.5 m (range: 0.6–2.5 m; DFO unpublished data). It is reported from streams with gradients ranging 1.2–1.5 m/km and was negatively correlated with high-gradient habitats (Parker and Kott 1980, Reid 2006). The average water velocity in several southwestern Ontario streams where Black Redhorse was found was 0.29 m/s (range 0.0–1.1 m/s; DFO unpublished data). The more streamlined, fusiform body shape and elongated and narrow caudal peduncle of the Black Redhorse compared to other redhorse species suggests it may be better adapted to higher flow habitats (Clark 2004). The substrate typically consists of clean, coarse, bed material (e.g., gravel and cobble, but occasionally boulders, sand, silt and clay) with stable channels and well-developed riffles (Reid 2006, DFO unpublished data). Adults are rarely associated with aquatic vegetation.

Black Redhorse migrates upstream to suitable spawning habitat, seeking shallow (0.12–0.37 m) riffles with generally steep gradients (and bottom velocities of 0.04–0.66 m/s) and hard substrates ranging from fine gravel to large cobble (most frequently small cobble) (Jenkins 1970, Kwak and Skelly 1992). Spawning occurs in water temperatures from 15–21 °C (Kwak and Skelly 1992). Extremely high flow rates may cause Black Redhorse to abandon previously utilized spawning shoals (Bowman 1970). Young-of-the-year (YOY) Black Redhorse have been found in shallow pools with slackened current in Ontario. One study found larvae occupied runs in 41% of observations, both pools and riffles in 23%, and backwaters in 13%, but this utilization was not proportional to the availability of those habitat types (Bunt et al. 2013). YOY have been found concentrated around groundwater seepages that contain cooler (by 10 °C), well-oxygenated water compared to the main stem of the river. These microhabitats likely provide refuge that allow them to persist in otherwise degraded environments (Hayashi and Rosenberry 2002, Bunt et al. 2013); however, further research is needed to confirm this association. Juveniles occupy (sometimes vegetated) edges of pools and runs with reduced flow, and clean pebble to cobble substrates with depths of 0.8–2.0 m. Upstream movement of juvenile Black Redhorse has been observed in early November (water temperature of 5 °C), possibly to seek over-wintering habitats.

Functions, Features, and Attributes

The functions, features and attributes of Black Redhorse habitat are described in Table 2. The habitat required for each life stage has been assigned a life history function that corresponds to a biological requirement of the species. A feature is considered to be the structural component of the habitat necessary for the survival or recovery of the species. The habitat attributes describe how the habitat features support the life history function. 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 2. 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.

Life Stage	Function	Feature(s)	Habitat Attributes		
			Scientific Literature	Current Records	For Identification of Critical Habitat
Spawning (occurs in late spring)	Spawning	Spawns in shallow riffles (0.12–0.37m) 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 (Kwak 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[1], 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 1.2–1.5 m/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

[1] Ministry of Natural Resources and Forestry

Threats

The greatest threats to the survival and persistence of Black Redhorse in Canada are related to habitat alteration and degradation due to pollution 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.

Pollution

Major (and growing) urban centres and agriculture in the watersheds that contain Black Redhorse have resulted in land use changes that affect run-off, including road salt inputs and siltation from stream bank alteration, lead to increased water abstraction, increased wastewater discharge, impacts from acute spills, and poor drainage practices. Endocrine disruptors commonly found in municipal wastewater treatment effluent (and other sources) have been found to negatively impact male reproductive systems in other catostomid species in general (Blazer et al. 2014), and other fish species in the Grand River watershed (Tetreault et al. 2011). Further research is required on hormonal threats across the species range, the population-wide effects of de-masculinisation and potential negative impacts on sex ratios and reproduction of Black Redhorse.

Climate Change and Severe Weather

A climate change vulnerability report in Ontario identified Black Redhorse as being highly vulnerable to the impacts of climate change (Brinker et al. 2018). 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. 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, leading to acute impacts on water quality and habitat availability (Grand River Conservation Authority 2014).

Invasive and Other Problematic Species and Genes

Non-native piscivores (Brown Trout [*Salmo trutta*] and Rainbow Trout [*Oncorhynchus mykiss*]) may predate on juvenile and young adult Black Redhorse and compete with adults for benthic prey. The invasive Round Goby (*Neogobius melanostomus*) is an aggressive benthic feeder that may compete with Black Redhorse and predate upon eggs and larvae. Zebra Mussel (*Dreissena polymorpha*) and Asian carp species are also potential invaders that would pose a threat should they become established in tributaries occupied by Black Redhorse (COSEWIC 2015).

Biological Resource Use

Incidental capture and bycatch mortality during recreational angling or baitfish harvest is a potential threat to Black Redhorse, although there is no targeted recreational fishery or baitfish harvest.

Human Intrusion and Disturbance

ATV operation within a stream can cause physical alteration of the streambed and increase turbidity. Additionally, anglers wading in streams and recreational use of canoes and kayaks may impact Black Redhorse habitat by disturbing the substrate while walking in the stream or launching boats.

Natural Systems Modifications

Existing dams in the Thames River and Grand River watersheds alter flow regimes and impact impounded areas upstream of the dams, which likely negatively affect Black Redhorse. 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. 2008). The creation of impoundments may also facilitate invasion by the Zebra Mussel (COSEWIC 2015) and Round Goby (Rabb et al. 2017). Withdrawal of groundwater for municipal and industrial use could reduce groundwater inputs that provide a coldwater refuge during the summer months (Bunt et al. 2013). Lastly, shoreline hardening and instream structures, prevalent throughout the watersheds where Black Redhorse is found, may alter flow regimes and sediment transport.

Threat Assessment

To assess the threat level for Black Redhorse, each threat was ranked in terms of the Likelihood of Occurrence, Threat Level of Impact, and Causal Certainty on a per-population basis. Threats were rolled-up to create a species-level Threat Assessment in Table 3 (terms and definitions described in Table 4). Refer to DFO (2014b) for guidance and Bouvier et al. (2021) for detailed methodology on the Threat Assessment.

Table 3. Species-level Threat Assessment for Black Redhorse in Canada, resulting from roll-up of the population-level Threat Assessment. The highest level of risk for a given population is retained in the roll-up of Threat Risk and the associated causal certainty value is presented (1 = very high [strong evidence], 2 = high, 3 = medium, 4 = low, 5 = very low [plausible link only]). All categories of Threat Occurrence and Frequency identified in the population-level assessment are retained. The mode of the population-level Threat Extent was retained.

Threat	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Pollution	Medium (2)	Current	Continuous	Extensive
Climate change and severe weather	Medium (2)	Current, Anticipatory	Continuous	Extensive
Invasive and other problematic species and genes	Low (5)	Current	Continuous	Restricted
Biological resource use	Low (5)	Current	Recurrent	Restricted
Human intrusion and disturbance	Low (5)	Current	Recurrent	Restricted
Natural systems modifications	Unknown	Current	Continuous	Restricted

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Table 4. 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. tributaries)**	**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)	-	-	-	-	✓	-	-	-		-	-

Mitigations and Alternatives

Threats to species survival and recovery can be reduced by implementing mitigation measures to reduce or eliminate potential harmful effects resulting from works, undertakings, or activities in Black Redhorse habitat. DFO 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 (now Ontario and Prairie, and Arctic regions; Coker et al. 2010). This guidance should be referred to when considering mitigations and alternative strategies for habitat-related threats. A summary of activities reported to DFO in Black Redhorse habitat from 2011–2016 and applicable Pathways of Effects are presented in Table 4.

Mitigations and alternatives for non habitat-related threats are found below.

Invasive and other problematic species and genes

- 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.
- 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

- 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, and aligned with the protections under the *Endangered Species Act* and/or the *Species at Risk Act*.
- 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

- Provide information and education on aquatic species at risk, their habitat, and the destructive consequences of ATV operation in streams to ATV users.
- Install signage to discourage ATV use in streams in known problem areas.

Recovery Modelling

To estimate allowable harm and conduct recovery potential modelling, information on Black Redhorse vital rates was first compiled into age-structured projection matrices that incorporated environmental stochasticity and density-dependence. Refer to Young and Koops (2014) for detailed methodology.

Allowable Harm

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 ($\lambda = 1.6$) any reduction of juvenile survival by greater than 64% would cause the population growth rate to drop below $\lambda = 1$ (declining growth rate; Table 5).

Table 5. Summary of elasticities (stochastic mean and upper bound) a stable ($\lambda = 1$) and growing ($\lambda = 1.6$) population and allowable harm for Black Redhorse vital rates (εv) for a growing ($\lambda = 1.6$) 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 ($\sigma_2 - \sigma_4$)	Early Adult ($\sigma_5 - \sigma_{10}$)	Late Adult ($\sigma_{11} - \sigma_{16}$)	Early Adult (η_3- η_{10})	Late Adult (η_{11}- η_{16})
Elasticity ($\lambda = 1$)						
Stochastic mean	0.12	0.36	0.43	0.09	0.09	0.03
Elasticity ($\lambda = 1.6$)						
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 ($\lambda = 1.6$)	-1.79	-0.64	-1.14	-18.75	-1.56	-37.50

Recovery Targets

Young and Koops (2014) used demographic sustainability as a criterion to identify recovery targets. Demographic sustainability is related to the concept of minimum viable population (MVP) and was defined as the minimum adult population size that results in a desired probability of persistence over 100 years (approximately 12 generations for Black Redhorse). Recovery targets were estimated using simulations, where a population was said to be (quasi) extinct if it was reduced to 50 adults (25 females). Catastrophic decline in population size, defined as a 50% reduction in abundance, was incorporated into these simulations, and occurred at a probability of 10% or 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; estimated from allometry) for each age class.

MVP estimates for Black Redhorse are 1,700 adults (ages 4+) and 3,900 juveniles (ages 1–3) assuming the probability of a catastrophic (50%) decline is 15% per generation and an extinction threshold of 50 adults (Table 6). These abundance-based recovery targets are particularly applicable to populations that are below this threshold, and are useful for optimizing efforts and resources by selecting those populations that are in the greatest need of recovery. MVP estimates were made using a post-breeding model, and, thus, represent the maximum annual abundance for a given population. Spawning date relative to sampling date should be considered when estimating population size from catch data.

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. Suitable Black Redhorse habitat has not been quantified in any of the Canadian watersheds where the species is found, but it is likely that sufficient habitat exists to support its persistence.

Table 6. 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	3.9×10^3	(3.3×10^3 – 4.8×10^3)	3.7	(3.1 – 4.6)
Adult	1.7×10^3	(1.4×10^3 – 2.1×10^3)	10.3	(8.6 – 12.7)
Total	-	-	14.5	(12.2 – 17.8)

Vélez-Espino and Koops (2008) conducted long-term modelling projections using five hypothetical recovery strategies to determine timeframes for recovery. Projections that incorporated simultaneous increases of 20% to YOY and juvenile survival resulted in recovery targets being reached within 29–119 years. 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. These recovery timeframes are based on an earlier version of recovery targets (Vélez-Espino and Koops 2008) than what is presented above (Young and Koops 2014), but still provide appropriate guidance.

Sources of Uncertainty

There are several knowledge gaps related to the abundance and distribution of Black Redhorse in Canada. There are currently no population size estimates available for Canadian populations, thus, trends/trajectories cannot be evaluated. The species' current distribution within known watersheds is poorly understood, and mostly consists of records that are spatially and temporally sporadic. Standardized, long-term monitoring is required to resolve the distribution, abundance and trends through time. Further mapping of rivers and streams (and habitat features) to identify and quantify suitable habitat is needed for designing targeted sampling efforts and to determine whether sufficient habitat exists to achieve recovery targets.

Studies of Black Redhorse in Canada have been limited to a single watershed (i.e., Grand River), and data from other watersheds are needed to provide baseline information to facilitate recovery planning. Age and growth data from additional populations would improve population modelling projections. Studies evaluating habitat associations by life stage and associations with groundwater seepages from other populations would provide a more fulsome understanding of habitat needs and would aid in refining critical habitat.

The impact of threats to Black Redhorse are also poorly understood. 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, individually and cumulatively, on Black Redhorse physiology and productivity. The impact of barriers on population structure, in terms of both genetics and demographics, warrants further investigation.

LIST OF MEETING PARTICIPANTS

Name	Organization/Affiliation
Lynn Bouvier (Chair)	DFO, Science
Maja Cvetkovik (Rapporteur)	DFO, Science
Jason Barnucz	DFO, Science
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Adam van der Lee	DFO, Science
Dave Balint	DFO, Species at Risk
Shelly Dunn	DFO, Species at Risk
Joshua Stacey	DFO, Species at Risk
Collin Gyles	DFO, Policy and Economics
Rebecca Dolson	Ontario Ministry of Natural Resources and Forestry

SOURCES OF INFORMATION

This Science Advisory Report is from the December 15, 2016 regional peer review meeting on the Recovery Potential Assessment of Black Redhorse (*Moxostoma duquesnei*). Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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