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Information in support of a recovery potential assessment of River Darter, *Percina shumardi* (Great Lakes-Upper St. Lawrence populations) in Ontario

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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

In May 2016, a meeting of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) recommended that River Darter, *Percina shumardi* (Great Lakes-Upper St. Lawrence populations, designatable unit [DU] 3) be designated Endangered. The reason given for this designation is "*This is a small-bodied species that inhabits medium to large rivers and shorelines of larger lakes. It has a very restricted distribution, occurs at few locations, and is exposed to high risk of threats from shoreline hardening, exotic species such as Round Goby, dams and water management, dredging, nutrients and effluents from urban waste, spills, and agriculture*" (COSEWIC 2016, p. iii). The species was previously assessed as a single unit in April 1989 and was designated Not at Risk (Dalton 1989).

The Recovery Potential Assessment (RPA) provides information and scientific advice needed to fulfill various requirements of the *Species at Risk Act* (SARA) including informing both scientific and socioeconomic elements of the listing decision and permitting activities that would otherwise violate SARA prohibitions and the development of recovery strategies. This Research Document describes the current state of knowledge of the biology, ecology, distribution, population trends, habitat requirements, and threats to River Darter (Great Lakes-Upper St. Lawrence populations). Mitigation measures and alternative activities related to identified threats, which can be used to protect the species, are also presented. The information contained in the RPA and this document may be used to inform the development of recovery documents and for assessing permits, agreements, and related conditions, as per sections 73, 74, 75, 77, 78 and 83(4) of the SARA. It may also be used to prepare for the reporting requirements of SARA s.55. The scientific information also serves as advice to the Minister of Fisheries and Oceans Canada (DFO) regarding the listing of the species under the SARA and is used when analyzing the socio-economic impacts of adding the species to the list as well as during subsequent consultations, where applicable. This assessment considers the available scientific data pertaining to the recovery of River Darter (Great Lakes-Upper St. Lawrence populations) in Ontario. The advice generated via this process will update and/or consolidate any existing advice regarding River Darter (Great Lakes-Upper St. Lawrence populations).

SPECIES INFORMATION

Scientific Name – *Percina shumardi*

Common Name – River Darter (Great Lakes-Upper St. Lawrence populations)

Current COSEWIC Status (Year of Designation) – Endangered (2016)

COSEWIC Reason for Designation – "*This is a small-bodied species that inhabits medium to large rivers and shorelines of larger lakes. It has a very restricted distribution, occurs at few locations, and is exposed to high risk of threats from shoreline hardening, exotic species such as Round Goby, dams and water management, dredging, nutrients and effluents from urban waste, spills, and agriculture*" (COSEWIC 2016).

Canada *Species at Risk Act* – No Schedule, No Status

Ontario *Endangered Species Act* – Endangered (2017)

General Status Ranks – S3 (Vulnerable; Ontario), N5 (Secure; Canada) (CESC 2016)

BACKGROUND

River Darter (*Percina shumardi*) belongs to the Percidae family and is distributed from the Texas coast on the Gulf of Mexico north to the Nelson River near Hudson Bay in Manitoba and east from the Saskatchewan River in Saskatchewan to the Lake St. Clair watershed in Ontario (Scott and Crossman 1973, Stewart and Watkinson 2004, Page and Burr 2011, COSEWIC 2016). COSEWIC (2016) recognizes three designatable units (DU) (see COSEWIC Guidelines for Recognizing Designatable Units) of River Darter as follows:

- DU 1 – Saskatchewan-Nelson River populations
- DU 2 – Southern Hudson Bay-James Bay populations
- DU 3 – Great Lakes-Upper St. Lawrence populations

Designatable Units 1 and 2 were assessed as Not at Risk in May 2016. Due to its restricted distribution and exposure to several threats, River Darter in DU 3 was assessed as Endangered (COSEWIC 2016). This document provides biological information to be used in evaluating the potential for recovery of the Great Lakes-Upper St. Lawrence populations of River Darter.

BIOLOGY, ABUNDANCE, AND DISTRIBUTION

BIOLOGY

Much of the information below is summarized from COSEWIC (2016).

Morphological Description

River Darter is a small elongate fish (Figure 1) with a short rounded snout, a moderately sized terminal mouth (Scott and Crossman 1973, Stewart and Watkinson 2004), and large eyes that are positioned high on the head and close together (Kuehne and Barbour 1983). They reach a maximum total length of 94 mm in Canada (D. Watkinson unpublished in COSEWIC 2016). Scales are ctenoid and are usually found on the cheeks and the operculum with the breast typically scaleless (Scott and Crossman 1973, Becker 1983). There are 46–62 lateral line scales (Holm et al. 2009). Colour varies from light brown to dark olive with seven to eight faint saddles on the back and 8–15 indistinct short vertical bars on the sides (Kuehne and Barbour 1983, Holm et al. 2009). Breeding males are typically darker in colour (Scott and Crossman 1973, Smith 1979) and they may exhibit nuptial tubercles on the caudal, anal, and pelvic fins and on the vent and head along the infraorbital and preopercular mandibular canals (Kuehne and Barbour 1983). Spawning males also develop an enlarged anal fin which reaches nearly to the caudal fin (Figure 1; Scott and Crossman 1973). An obvious dark spot on the upper anterior and lower posterior corners of the spiny dorsal fin distinguishes River Darter from Channel Darter (*Percina copelandi*) and Blackside Darter (*P. maculata*) (Stewart and Watkinson 2004, Holm et al. 2009).

Figure 1. River Darter (male) collected from Bird River, Manitoba. Photo: Doug Watkinson, Fisheries and Oceans Canada (DFO) (COSEWIC 2016).

Life Cycle

River Darter live to a maximum of age 3 (Thomas 1970) or 4 (Smith 1979) in the USA and reach maturity as early as age 1. River Darter collected in 2014 from DUs 1 and 2 in Manitoba and northwestern Ontario had a maximum age of 4 years and reached sexual maturity at age 1. These River Darters were found to exhibit slow growth rates, growing approximately 10 mm/year in length (Pratt et al. 2015).

Reproduction

In Canada, River Darter spawn from May to early July (Balesic 1971) with their reproductive cycle being determined by photoperiod and temperature (Hubbs 1985). They spawn mainly in rivers, but ripe individuals have also been collected in lakes (Balesic 1971). In the Assiniboine River, Manitoba ripe individuals have been collected between June 22 and 24 at a water temperature of 24°C (D. Watkinson unpublished in COSEWIC 2016). Generally males arrive at the spawning sites before females (Holm et al. 2009). Spawning behaviour has been described by Dalton (1990). Females partially bury themselves in sand or gravel substrate. The male rests on top of the female and holds her in place with his pelvic fins. They vibrate and eggs are deposited one at a time and fertilized. Spawning occurs several times with different partners over several weeks. River Darter do not guard their eggs and young. In a laboratory study, Balesic (1971) observed that eggs were adhesive and hatched nine days post-fertilization at a water temperature range of 19–21°C. Larvae were swimming within several hours of hatching and were 5–6.5 mm in length.

River Darter have been found to hybridize with Logperch (*Percina caprodes*) (Trautman 1981).

Feeding and Diet

Feeding occurs mainly during the day (Thomas 1970) and the River Darter diet includes a wide variety of prey items (Balesic 1971). In an Illinois study, stomach contents consisted of dipterans, trichopterans, ephemeropterans, crustaceans, and fish eggs (Thomas 1970). A study in Manitoba found the same diet items as the Illinois study with the addition of corixids and fishes (Balesic 1971). Gastropods have been found to be an important prey item for River Darter in Alabama (nearly 100% of the diet in October; Haag and Warren 2006), Tennessee (Starnes 1977), and Manitoba (Balesic 1971). A study in Ontario and Manitoba (DUs 1 and 2) found common prey items among sample sites included chironomids, caddisflies, and mayflies in June. These same items were still present in the diet in September and October, but at this time zooplankton and gastropods were also important components of the diet (Pratt et al. 2016). Dominant prey varied between study sites and seasons, likely due to differences in prey availability (COSEWIC 2016).

Physiology and Adaptability

Very little is known of River Darter physiology and adaptability (COSEWIC 2016). Research has shown that as current speed increases, River Darter release gases from their swim bladders which increases their density and allows for greater frictional contact with the substrate, thereby decreasing the energy required to maintain their position in the water (Gee 1983).

Dispersal and Migration

In Canada, upstream spawning migrations occur in May to July. Larval River Darter observed in the laboratory were found to have swimming positions near the top of the water column. This suggests that larval dispersal may occur in rivers in a downstream direction because the surface water velocities would generally be higher than the swimming speed of the larvae (Balesic 1971).

HISTORIC AND CURRENT ABUNDANCE AND TRENDS

Abundance data for DU 3 are only available from the Thames and Sydenham rivers (Table 1; COSEWIC 2016). Fifty collections using a mini-Missouri trawl captured only three River Darter. The mini-Missouri trawl is the optimal gear for collecting River Darter (COSEWIC 2016).

The trajectory for abundance cannot be evaluated for this DU other than that River Darter continue to be rare. Only a few specimens have been captured since the last COSEWIC status report was written (1989) with low catch per unit effort (Table 1; COSEWIC 2016). An additional eight specimens were captured in the Thames River in June 2015 and July 2016 (DFO unpublished data). This is the case despite an extensive search effort, particularly since 2005 (Table 2). Over 1,000 sites within the range of River Darter in DU 3 have been sampled using a variety of gear.

Table 1. Summary of DFO non-targeted sampling in DU 3 between 1995 and 2014 (excerpted from COSEWIC 2016).

Waterbody	Number of Collections	Gear	Effort (hauls)	Number of Fish	Catch per Unit Effort (fish/haul)
Thames River	26	mini-Missouri trawl	26	1	0.04
Sydenham River	24	mini-Missouri trawl	24	2	0.08

Table 2. Summary of surveys in the known range of River Darter in DU 3 (excerpted from COSEWIC 2016).

Waterbody / Watershed	Survey Description (years of survey effort)
Lake St. Clair watershed	▪ Nearshore fish community survey, Ontario Ministry of Natural Resources (OMNR) (2005, 2007) a ▪ Fish community survey, Michigan Department of Natural Resources (1996–2001) b ▪ Essex-Erie targeted sampling for fishes at risk, DFO (2007) a, c ▪ Fall trap-net survey, OMNR (1974–2007, annual) e ▪ Young-of-the-year index series survey, OMNR (annual) a ▪ Benthic fish community survey, DFO (2010) b ▪ Multi-gear sampling, DFO (Edwards and Mandrak 2006) a, d, e, f, g, h,j ▪ Fish survey, DFO (Marson and Mandrak 2009) a, d, f, j ▪ Poos et al. (2007) a, e ▪ Poos et al. (2008) a, e, h, j ▪ OMNR, Reid and Hogg (2014) a ▪ Species at Risk sampling, DFO (Mandrak et al. 2006) a, e ▪ Round Goby distribution survey, DFO (2015, 2016)
Detroit River	▪ Fish-habitat associations of the Detroit River, DFO and University of Windsor (2003–2004) a, d ▪ Coastal wetlands of Detroit River, DFO and University of Guelph (2004–2005) ▪ Fish community surveys, DFO and OMNR (2003, 2004) d ▪ Benthic fish community survey, DFO (2009, 2010) b
Lake Erie	▪ Interagency trawling survey in western basin, OMNR (1988–2010, annual) b ▪ Coastal wetlands along Lake Erie (2004–2005) e ▪ Nearshore beach seining surveys, OMNR and DFO (2005–2006) (Reid and Mandrak 2008) a ▪ Nearshore seine survey, west and west-central basins, OMNR (2007) a

Gear type: a – seine net; b – trawl; c – trap net; d – boat electrofishing; e – backpack electrofishing; f – fyke net; g – minnow trap; h – Windermere trap; j – gill net

HISTORIC AND CURRENT DISTRIBUTION AND TRENDS

River Darter are distributed from the Texas coast on the Gulf of Mexico north to the Nelson River near Hudson Bay in northern Manitoba (Scott and Crossman 1973, Stewart and Watkinson 2004, Page and Burr 2011, COSEWIC 2016) and to the Saskatchewan River in Saskatchewan and the Lake St. Clair watershed in Ontario to the east.

In DU 3, River Darter are distributed in the Lake St. Clair watershed (Figure 2; Table 3). The extent of occurrence (EOO; area included in a polygon without concave angles that encompasses the geographic distribution of all known populations of a wildlife species, COSEWIC Definitions and Abbreviations) has declined from a pre-2005 EOO of 2,224 km^2 to 907 km^2 in the most recent decade. The discrete index area of occupancy (IAO; actual area occupied within the EOO calculated using a 2×2 km grid) has declined from a pre-2005 IAO of 64 km^2 to 16 km^2 post-2005 and the continuous IAO has declined from 1,228 km^2 to 336 km^2 over the same period. Due to the high amount of sampling conducted in this DU, the actual IAO is likely closer to the discrete than the continuous estimate (COSEWIC 2016). This indicates a trend of decreasing distribution in DU 3.

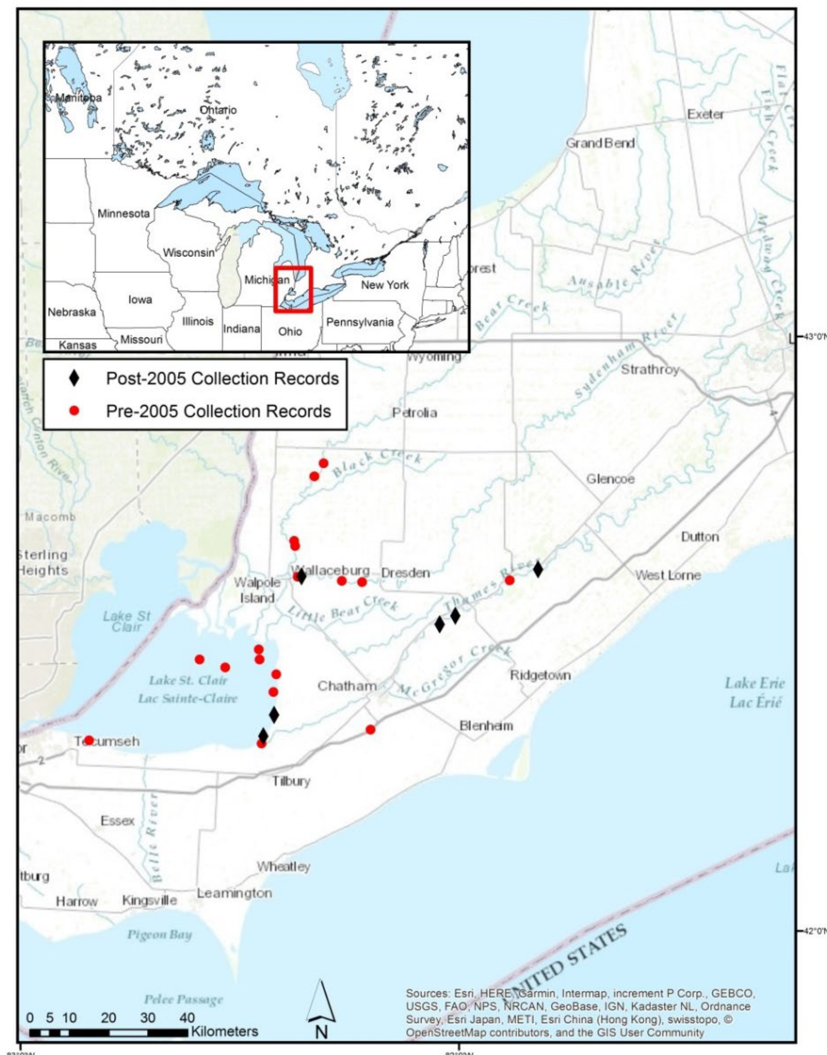

Figure 2. The distribution of River Darter in DU 3 (Great Lakes-Upper St. Lawrence populations). Pre-2005 (red circles) and post-2005 (black diamonds) occurrences are distinguished.

Table 3. River Darter collection records in DU 3 (Source: COSEWIC 2016 and DFO unpublished data). Note: ROM = Royal Ontario Museum; OMNR = Ontario Ministry of Natural Resources; DFO = Fisheries and Oceans Canada.

Database	Waterbody	Date	Latitude	Longitude
ROM	Lake St. Clair, Thames River mouth	31-Oct-73	42.316666	-82.45
OMNR	Lake St. Clair, nearshore seine	21-Jul-80	42.4033	-82.4233
OMNR	Lake St. Clair, Mitchell's Bay, trawl	5-Aug-83	42.4583	-82.5917
OMNR	Lake St. Clair, Mitchell's Bay, trawl	28-Aug-84	42.4583	-82.4550
OMNR	Lake St. Clair, Mitchell's Bay, trawl	18-Sep-84	42.4583	-82.4550
OMNR	Lake St. Clair, Mitchell's Bay, trawl	1-Oct-84	42.4450	-82.5333
ROM	Lake St. Clair, St. Lukes Bay	29-Jul-85	42.433334	-82.416664
OMNR	Lake St. Clair, Mitchell's Bay, trawl	30-Sep-85	42.4750	-82.4567
ROM	Raleigh Plains Drain, at Bloomfield Rd. and under 401 bridge	11-Aug-89	42.34	-82.20167
ROM	Thames River, Delaware Nation at Moraviantown, 150 to 600 m downstream from bridge on County Road 18	26-Jul-91	42.59111	-81.884445
OMNR	Lake St. Clair, nearshore seine	13-Jun-94	42.3217	-82.8433
ROM	Bear Creek, 1.6 km E of Waubuno above bridge	5-Aug-97	42.787777	-82.30889
ROM	Sydenham River (East), rotating bridge in Tupperville 10 to 70 m S of bridge	7-Aug-97	42.59028	-82.26722
ROM	Bear Creek, 1.8 km S of Waubuno 0 to 50 m E of bridge	7-Aug-97	42.765556	-82.329445
ROM	Bear Creek, 1.8 km S of Waubuno 70 to 35 m W of bridge	7-Aug-97	42.765556	-82.329445
ROM	Bear Creek, 1.8 km S of Waubuno 0 to 50 m E of bridge	7-Aug-97	42.765556	-82.329445
ROM	Sydenham River (East), Wallaceburg north shore at Dora Dr. downstream of reinforced bank	1-Oct-97	42.5975	-82.367775
ROM	Sydenham River, 4 km E of Tupperville	18-Jun-01	42.588333	-82.22083
ROM	North Sydenham River, off boat ramp on East River Rd. north of Lambton Line on east side of river	10-Sep-03	42.65737	-82.37566
ROM	North Sydenham River, south of Lambton Line along East River Rd. on east side of river	11-Sep-03	42.64879	-82.37357
ROM	Lake St. Clair, ~ 750 m from mouth of Thames River	10-Aug-06	42.32936	-82.44612
OMNR	Lake St. Clair, nearshore seine	4-Jul-08	42.365	-82.4217
OMNR	Lake St. Clair, nearshore seine	15-Jul-08	42.365	-82.4217
DFO	Sydenham River	20-Sep-12	42.59811667	-82.35908333
OMNR	Lake St. Clair, nearshore seine	16-Jul-13	42.365	-82.4217
DFO	Thames River	24-Jun-14 to 26-Jun-14	42.60976667	-81.8195
DFO	Thames River, between Victoria Rd. and Kent Bridge	18-Jun-15	42.53209	-82.00846
DFO	Thames River, between Victoria Rd. and Kent Bridge	19-Jun-15	42.51767	-82.04396
DFO	Thames River, 2.23 km upstream of Kent Bridge	21-Jul-16	42.51743	-82.04417

HABITAT AND RESIDENCE REQUIREMENTS

HABITAT REQUIREMENTS

Typically collected in medium to large rivers or nearshore areas of lakes (Balesic 1971, Stewart and Watkinson 2004, COSEWIC 2016), River Darter generally occur in deeper, moderate-velocity water over a variety of substrates (Thomas 1970, Pfleiger 1971, Scott and Crossman 1973, Becker 1983, Kuehne and Barbour 1983, COSEWIC 2016). This species tolerates turbid waters (Balesic 1971, Pfleiger 1971, Cooper 1983, Sanders and Yoder 1989, COSEWIC 2016). Little is known about spawning and feeding habitat, but clean gravel and cobble substrates may be important features. Adults and juveniles appear to occupy the same habitat as they are often collected together during sampling (COSEWIC 2016).

Specific habitat information is limited for River Darter in DU 3. Information is available in Mandrak (2018) for one site in the Sydenham River and three sites in the Thames River at which 11 River Darter were captured between 2012 and 2016 (sampling occurred in the months of June and September). These specimens were caught at a mean: water temperature of 22.2 ± 2.6°C (range: 19.6–26.5°C); conductivity of 565.4 ± 138.8 μs (range: 327.0–686.5 μs); dissolved oxygen of 7.01 ± 0.79 mg/L (range: 6.15–7.77 mg/L); pH of 8.65 ± 0.31 (range: 8.25–9.05); secchi tube of 0.20 ± 0.20 m (range: 0.07–0.60 m); turbidity of 86.94 ± 37.36 NTU (range: 61.80–151.80 NTU); stream width of 45.67 ± 1.13 m (range: 44.00–47.50 m); bank slope of 41.67 ± 2.64% (range: 5.00–80.00%); channel cover of 2.50 ± 2.64% (range: 0.00–5.00%); average depth of 2.32 ± 0.99 m (range: 1.10–3.53 m); and average water velocity of 0.41 ± 0.36 m/sec (range: 0.02–0.98 m/sec). The dominant substrate at capture locations was clay in the Sydenham River and gravel and cobble in the Thames River. The maximum depth at which a specimen has been collected is 15 m (single specimen collected with a beam trawl in Lake Winnipeg [D. Watkinson unpublished data cited in COSEWIC 2016]). In DUs 1 and 2 in June and September 2014, River Darter were collected at depths ranging from 2.0–5.0 m, temperatures ranging from 8.52–15.63°C, pH ranging from 7.10–8.10, turbidity ranging from 0.4–6.3 NTUs, and dissolved oxygen ranging from 9.02–10.54 mg/L (Pratt et al. 2015).

Functions, Features, and Attributes

A description of the functions, features, and attributes associated with River Darter habitat is presented in Table 4. The habitat required for each life stage has been assigned a function that corresponds to a biological requirement of River Darter. In addition to the habitat function, features have been assigned for 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 which describe how the features support the function for each life stage. This information is provided to guide any future identification of critical habitat for this species. Habitat attributes associated with current records may differ from optimal habitat as River Darter in DU 3 may be occupying sub-optimal habitat where optimal habitat is not available. Furthermore, the habitat information for DU 3 represents only three locations at which 11 River Darter were captured over a period of four years.

Table 4. Summary of the essential functions, features and attributes for each life stage of River Darter. This information is provided to guide the future identification of critical habitat.

Life Stage	Function	Feature(s)	Attributes
Egg / Embryo – spawning through emergence	Spawning (May to early July) Incubation and early rearing	• Sand or gravel substrate[1] • Clean gravel and cobble substrate[2]	• Ripe individuals collected between June 22 and 24 in the Assiniboine River (Manitoba) at a water temperature of 24°C[3] • Eggs hatched nine days post-fertilization at water temperatures between 19 and 21°C in the laboratory[1]
Fry	Nursery	Unknown	Unknown
Juvenile Adult	Feeding Cover	• Medium to large rivers or nearshore areas of lakes; generally in deep, moderate velocity water over a variety of substrates[2] • Clean gravel and cobble substrates may be important[2]	• In DU 3 in the Thames and Sydenham rivers collected from four locations at[2]: ○ Water temperature: 19.6–26.5°C (mean: 22.2°C) ○ Dissolved oxygen: 6.15–7.77 mg/L (mean: 7.01 mg/L) ○ pH: 8.25–9.05 (mean: 8.65) ○ Conductivity: 327–686.5 µs (mean: 565.4 µs) ○ Secchi tube: 0.07–0.60 m (mean: 0.20 m) ○ Turbidity: 61.8–151.8 NTU (mean: 86.94 NTU) ○ Stream width: 44–47.5 m (mean: 45.67 m) ○ Average depth: 1.1–3.53 m (mean: 2.32 m) ○ Average water velocity: 0.02–0.98 m/s (mean: 0.41 m/s) ○ Bank slope: 5–80% (mean: 41.67%) ○ Channel cover: 0–5% (mean: 2.5%) ○ Dominant substrates: clay, gravel, and cobble • In DUs 1 & 2 in June and September collected at depths ranging from 2–5 m, temperatures between 8.52 and 15.63°C, pH from 7.1–8.1, turbidity from 0.4–6.3 NTUs, and dissolved oxygen from 9.02–10.54 mg/L[3]
Juvenile / Adult	Overwintering	Unknown	Unknown

[1] Dalton 1990
[2] COSEWIC 2016
[3] D. Watkinson unpublished in COSEWIC 2016
[4] Balesic 1971
[2] Mandrak 2018
[3] Pratt et al. 2015

SPATIAL EXTENT OF SUITABLE HABITAT

The spatial extent of suitable habitat for River Darter in DU 3 is unknown but was inferred to be declining by COSEWIC (2016). However, this was based on the distribution of the species. While the spatial extent of distribution records may be declining, suitable habitat is not necessarily declining.

SPATIAL CONFIGURATION CONSTRAINTS

According to Fishwerks, basin-wide habitat available in the Lake St. Clair watershed is 36,620 river km and located within this watershed are 64 impassable dams and 2,643 passable road crossings that could potentially impact River Darter. However, River Darter occur in only three systems in this watershed – Lake St. Clair and the Sydenham and Thames rivers (COSEWIC 2016).

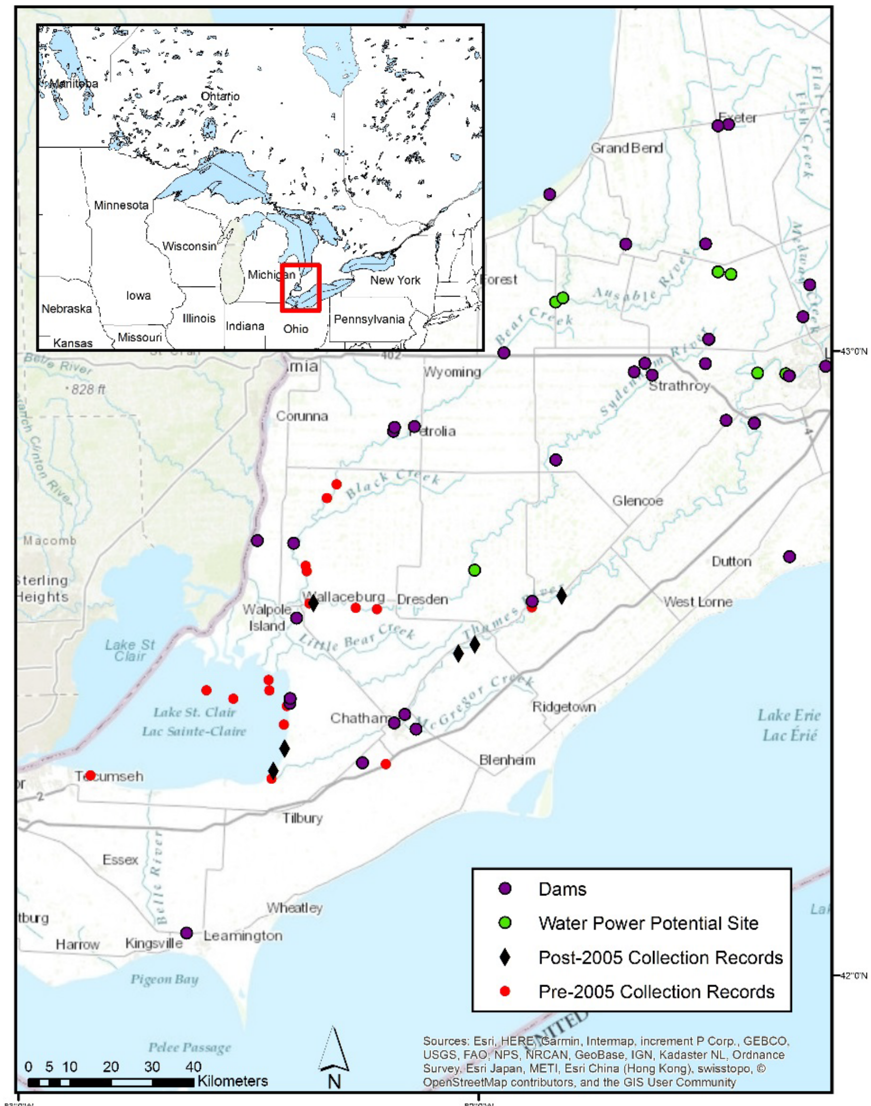

Figure 3. Location of dams and potential water power sites in the area surrounding River Darter collection records. Data obtained from Land Information Ontario.

RESIDENCE

The *Species at Risk Act* (SARA) defines a 'residence' 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*" (SARA, s. 2.1). DFO (2015) uses the following four conditions to determine when the concept of 'residence' applies to an aquatic species:

1. there is a discrete dwelling-place that has structural form and function similar to a den or nest;
2. an individual of the species has made an investment in the creation, modification or protection of the dwelling-place;
3. the dwelling-place has the functional capacity to support the successful performance of an essential life cycle process such as spawning, breeding, nursing, and rearing; and,
4. the dwelling-place is occupied by one or more individuals at one or more parts of its life cycle.

In the context of the information provided in the Reproduction section (p. 2), the concept of residence as defined by the SARA does not apply to River Darter.

THREATS AND LIMITING FACTORS TO THE SURVIVAL AND RECOVERY OF RIVER DARTER

NATURALLY OCCURRING LIMITING FACTORS

River Darter in DU 3 has a very restricted distribution and only a small number of individuals have been collected (COSEWIC 2016). Immigration (rescue effect) of individuals from the USA side of Lake St. Clair and Lake Erie may be possible, but the natural dispersal ability of the species is unknown (COSEWIC 2016), although it is suspected to be substantially less than 8 km per year (Shea et al. 2015).

ANTHROPOGENIC THREATS

DFO (2014, p. 2) defines a threat as "any human activity or process that has caused, is causing, or may cause harm, death, or behavioural changes to a wildlife species at risk, or the destruction, degradation, and/or impairment of its habitat, to the extent that population-level effects occur". Two main anthropogenic threat categories comprising six threats impacting River Darter in DU 3 have been identified. These include exotic/invasive species and habitat alteration (dredging, shoreline hardening, nutrient loading, contaminants and toxic substances, and sediment loading). These threats do not occur in isolation and may interact to have cumulative and synergistic effects.

Exotic/Invasive Species

Two exotic/invasive species may be impacting River Darter in DU 3 – Round Goby (*Neogobius melanostomus*) and Zebra Mussel (*Dreissena polymorpha*).

Round Goby

Round Goby is native to the Ponto-Caspian region of eastern Europe and was first identified in the Laurentian Great Lakes in 1990 (Jude et al. 1992, Johansson et al. 2018). This species is now found in major ports and nearshore areas of all five Great Lakes (Bronnenhuber et al. 2011) and has undergone a secondary invasion into Great Lakes tributaries (Kornis and Vander

Zanden 2010, Kornis et al. 2013, Burkett and Jude 2015). The rapid spread of Round Goby within the Great Lakes and tributaries is likely due to a number of factors including ballast water exchange (Ricciardi and MacIsaac 2000), natural dispersal (Bronnenhuber et al. 2011), advection of larvae (Hensler and Jude 2007), angler use of Round Goby as baitfish (Janssen and Jude 2001, Carman et al. 2006), and their tolerance of a wide range of habitats and prey (reviewed in Burkett and Jude 2015).

Round Goby distribution overlaps with that of River Darter in Lake St. Clair, the Thames River, and sections of the Sydenham River (COSEWIC 2016). The two species share a number of prey items (Balesic 1971, French and Jude 2001, Burkett and Jude 2015, COSEWIC 2016) and occur in similar habitats, thus there is potential for direct competition for resources (COSEWIC 2016). In parts of the St. Clair River, Michigan, competition between Round Goby and native benthic fish species occupying the nearshore zone (< 1 m depth) was likely a contributing factor to the decline of some native fish populations which occurred within five years of Round Goby introduction (French and Jude 2001). Round Goby may also feed on fish eggs and larvae (Thomas and Haas 2004, Poos et al. 2010), potentially including those of River Darter (COSEWIC 2016). However, Burkett and Jude (2015) found that eggs may not be an important component of the diet of Round Goby. Moreover, Burkett and Jude (2015) found only a few instances of significant diet overlap between Round Goby and native fishes in the St. Clair River, Michigan, and none of the native fish species with diet overlap exhibited a decline in relative abundance or catch-per-unit-effort over the length of the study (1994–2011). Similarly, Reid and Mandrak (2008) suggested that stressors other than Round Goby (e.g., shoreline modification, eutrophication) could be the cause of the decreased abundance of darter species in the St. Clair River. The combined effects of multiple stressors make the prediction of invasive Round Goby impacts on a specific species (e.g., River Darter) difficult (Burkett and Jude 2015).

Based on the above information and expert opinion of participants at the Recovery Potential Assessment meeting, the Level of Impact of Round Goby is ranked as Medium (Table 6 and Table 12).

Zebra Mussel

Zebra Mussels are present in DU 3 and have impacted the Lake St. Clair system. The abundances of amphipods, snails, and worms in the benthos increased, while abundances of native mussels decreased relative to pre-invasion conditions (Griffiths 1993. Nalepa et al. 1996, Baustian et al. 2014). Habitat impacts likely related to the invasion of Zebra Mussels in Lake St. Clair include increased water transparency, increased levels of bioavailable phosphorous in the sediment, and the range expansion of macrophytes (Nalepa and Gauvin 1988, Nalepa et al. 1996, Higgins et al. 2008, David et al. 2009, Auer et al. 2010, Baustian et al. 2014). However, Baustian et al. (2014) examined concentrations of total phosphorous and chlorophyll *a* and Secchi disk depth in Lake St. Clair before and after Zebra Mussel invasion and did not find clear evidence of a shift post-invasion. In other regions, as a result of the increased water transparency caused by Zebra Mussels, visual predator (e.g., Northern Pike, *Esox lucius*) abundance increased while that of species preferring turbid water (e.g., Walleye, *Sander vitreus*) decreased (MacIsaac 1996, Nalepa et al. 1996, Baustian et al. 2014). Zebra Mussels are a preferred food of Round Goby (Jude et al. 1995) and may therefore facilitate Round Goby invasion. On the other hand, since River Darter consume molluscs (Balesic 1971, Haag and Warren 2006), Zebra Mussels may benefit this species by providing an additional abundant food source (COSEWIC 2016). Overall, the potential impacts of Zebra Mussels on River Darter in DU 3 are not known (COSEWIC 2016, Table 6 and Table 12).

Habitat Alteration

Dredging

During spawning, River Darter deposit their eggs into the substrate (Simon 1998), thus dredging represents a potential threat to this species (Freedman 2010). The impacts of sedimentation caused by dredging may also threaten River Darter. In DU 3, maintenance dredging occurs in Lake St. Clair and several of its tributaries including the Thames River (Barnucz et al. 2015, COSEWIC 2016). Maintenance dredging removes excess sediments and increases lake depth for safe navigation of the waterway by recreational boaters and other users. The substrate removed (dredgeate) is disposed of within the waterbody at dredgeate disposal sites (Barnucz et al. 2015). In the Allegheny River, Pennsylvania, Freedman (2010) found dredged sites to have decreased abundance and diversity of small fishes compared to non-dredged sites, likely due to reduced food availability or forage efficiency and sedimentation impacts. However, Barnucz et al. (2015) found no significant difference in the catch-per-unit-effort of fish species at risk, including small benthic species such as Northern Madtom (*Noturus stigmosus*), Channel Darter (*Percina copelandi*), and Eastern Sand Darter (*Ammocrypta pellucida*), between both sites that had been dredged and dredgeate disposal sites and reference sites on the southern shore of Lake St. Clair. Abundance of these species was deemed to be low. However, a detection analysis was not conducted and sites were not visited immediately after dredging activities had occurred. Barnucz et al. (2015) concluded that "*If sufficient mitigation steps are followed through the maintenance dredging activities the direct and indirect impacts to fish species at risk* [on the southern shore of Lake St. Clair] *could be considered minimal*" (pg. 8).

Based on the above information and expert opinion of participants at the Recovery Potential Assessment meeting, the Level of Impact of dredging is ranked as Medium (Table 6 and Table 12).

Shoreline Hardening

Shoreline hardening generally refers to the construction of stabilizing structures (e.g., vertical seawalls, cribbing [retaining walls backfilled with stone], riprap [large rocks or pieces of broken concrete]) to protect the shoreline from erosion and flooding and to improve recreational access (Wensink and Tiegs 2016). The loss of, or damage to, gravel and cobble substrates in rivers and exposed shorelines of lakes caused by shoreline hardening has been identified as a threat to other darter species (Grandmaison et al. 2004, Bouvier and Mandrak 2010, DFO 2011) and is a potential threat to River Darter (COSEWIC 2016).

Shoreline hardening has been completed along large sections of the south shore of Lake St. Clair (COSEWIC 2016). Wensink and Tiegs (2016) found that riprap hardening on the shores of Lake St. Clair caused changes in shoreline morphology and invertebrate communities and impaired resource exchanges between the terrestrial and aquatic environments. Shoreline hardening may hasten the spread of invasive species (e.g., dreissenid mussels) by allowing for colonization (Goforth and Carman 2005, Meadows et al. 2005, Strayer et al. 2012, Wensink and Tiegs 2016) and providing nesting cavities for Round Goby (Jude and DeBoe 1996, Wensink and Tiegs 2016). However, invasive invertebrates were found to be equally common on hardened and natural shorelines of Lake St. Clair (Wensink and Tiegs 2016). Additional research is needed to determine the impacts on nearshore fish species (Wensink and Tiegs 2016), and the Level of Impact of shoreline hardening on River Darter in DU 3 are unknown (COSEWIC 2016, Table 6 and Table 12).

Nutrient Loading

Prior to human settlement and the development of agriculture, nitrogen and phosphorous limited productivity in aquatic ecosystems. The amount of nitrogen and phosphorous available for plant uptake today is much higher as nitrogen has doubled since the 1940s and anthropogenic sources of phosphorous are much higher than natural sources (Environment Canada 2001).

Agriculture is the primary land use in DU 3 (Staton et al. 2003, Lake St. Clair Canadian Watershed Coordination Council 2008, Baustian et al. 2014). In the Sydenham River basin, intensive agriculture covers 81% of the land area. If grazing, pasture and idle lands are included, this rises to 85%. Most of this land (60% of the basin) is tile drained and surface drains are also prevalent (Staton et al. 2003). In the Canadian portion of the St. Clair watershed, 75% of land was in agricultural use as of 2001 (Lake St. Clair Canadian Watershed Coordination Council 2008). Agriculture is also the predominant land use in the lower Thames watershed, covering 80% of the total area (Nürnberg and LaZerte 2015, Thames-Sydenham and Region Source Protection Committee 2015). An average of 59% of the agricultural area in the Thames watershed is tile drained (Nürnberg and LaZerte 2015). Agricultural runoff into the eastern and western rivers draining into Lake St. Clair (e.g., Clinton, Sydenham, and Thames rivers) is the main source of nutrients entering the lake.

Total phosphorous levels at three provincial water quality monitoring stations in the lower Thames River (Figure 4) ranged from 0.018–277 mg/L between 2010 and 2016, the latest years for which data is available (OMECC 2018). Of 198 samples, only nine fell below the provincial water quality objective (PWQO) for the protection of aquatic life for TP of < 0.03 mg/L (OMOEE 1994). Thirty-nine samples from these stations exceeded 40 mg/L TP in 2015 and 2016. However, nutrient loading follows the seasonal flow pattern with highest loads occurring during winter and spring high flows. When flows are accounted for, there has been a statistically significant decrease in TP concentration (flow-weighted) in the Thames River, South Thames River, and possibly the North Thames River from 1986–2012 (Nürnberg and LaZerte 2015). At the Sydenham River stations TP ranged from 0.04–142 mg/L over the same time period (OMECC 2018). Of 247 samples, 31 fell below the PWQO. In Bear Creek, TP ranged from 0.02–260 mg/L between 2010 and 2016 (OMECC 2018). Of 122 samples, only 1 fell below the PWQO. Sixteen samples from these two stations were ≥ 78 mg/L in 2016. A flow-weighted analysis of TP concentrations is not available for the Sydenham River or Bear Creek.

Nutrient loading from sources such as agricultural runoff, intensive livestock operations, sewage treatment plants, and other municipal sources can speed eutrophication thereby causing algal blooms which lead to decreased concentrations of dissolved oxygen as the blooms die (Khan and Ansari 2005). Internal loading from sediments may also occur, particularly in impoundments and slow moving river sections (e.g., lower Thames River). Internally loaded phosphorus is released in a form that is nearly 90% biologically available while phosphorus loaded from external sources (other than point sources) is typically less than 50% biologically available (Nürnberg and LaZerte 2015). Low concentrations of dissolved oxygen impact fish survival and reproduction by increasing disease susceptibility, slowing growth, decreasing swimming ability, and changing survival behaviours (e.g., predator avoidance, feeding, and reproduction) (Barton and Taylor 1996). Dissolved oxygen levels at the water quality monitoring stations shown in Figure 4 have fallen below the PWQO (4 mg/L for warm water biota; OMOEE 1994) on several occasions between 2010 and 2016 – 15 samples in the Thames River, one sample in the Sydenham River, and one sample in Bear Creek (OMECC 2018). This threat is chronic and widespread. The Level of Impact of nutrient loading on River Darter in DU 3 is ranked as Low at current levels of nutrient loading (Table 6 and Table 12), but if nutrient loading intensified the level of impact is likely to increase.

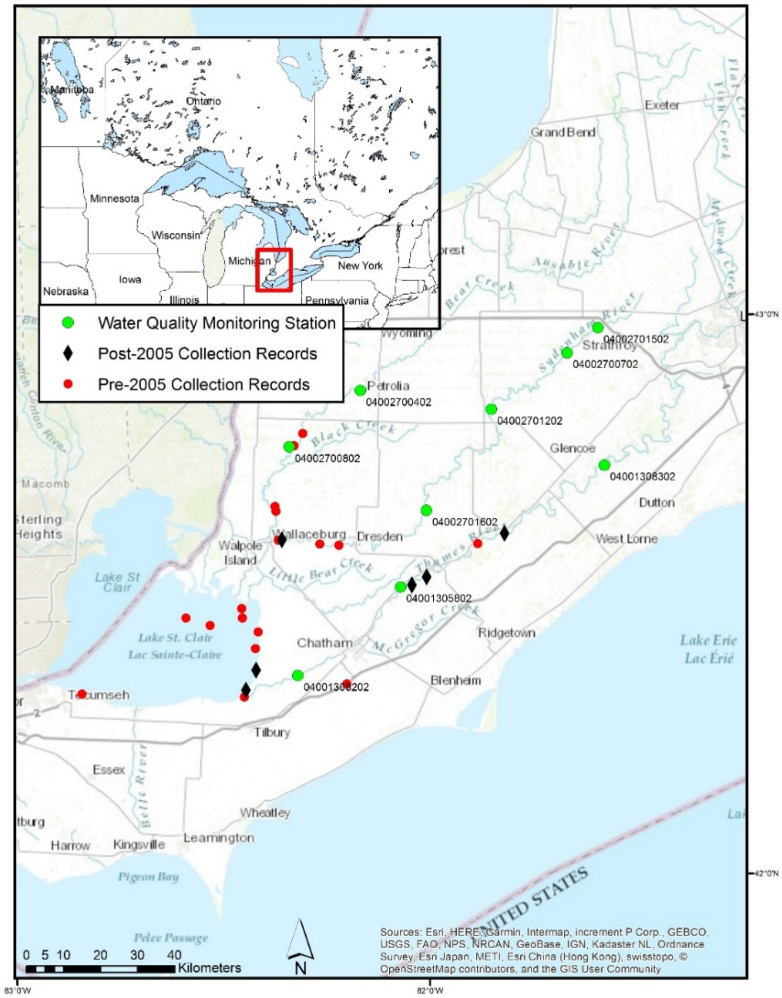

Figure 4. Location and station numbers of water quality monitoring stations for which data was examined in Bear Creek and the Thames and Sydenham rivers. Coordinates were obtained from the [Provincial (Stream) Water Quality Monitoring Network record in the Ontario Data Catalogue](#).

Contaminants and Toxic Substances

Agriculture, forestry, industrial, household, and urban effluents are present in some of the watersheds in DU 3. These effluents may decrease water quality and have negative and cumulative impacts (Essex-Erie Recovery Team [EERT] 2008 cited in COSEWIC 2016). Impacts may be lethal or sublethal. Sublethal effects may include reduced egg production, decreased survival, changes in behaviour, reduced growth, impaired osmoregulation, and subtle endocrine, immune, and cellular changes. Fish species may also be indirectly harmed by reduced prey availability. Lethal effects are most often caused by spills while sublethal effects are typically the result of land use activities (Shively et al. 2007). Contaminant uptake occurs via the gills, ingestion, and/or across the skin with the latter being particularly relevant for benthic fish species such as River Darter that burrow or live near toxic sediments (Scholz and McIntyre 2016). Sediment contaminant concentrations in the St. Clair River have decreased substantially since the 1970s likely due to remedial actions including elimination of sources, upgrades to industrial and municipal facilities, and dredging (Gewurtz et al. 2007, 2010, Baustian et al. 2014).

Chloride is a surface and groundwater pollutant that is highly soluble and mobile. In the East Sydenham River, chloride concentrations have generally been low (rarely over 50 mg/L) but are slowly increasing (Staton et al. 2003). This may be due to the increased use of road salts for de-icing (e.g., Bowlby et al. 1987, Staton et al. 2003). In the North Sydenham River, however, chloride concentrations have been over 1,000 mg/L on several occasions and have reached 14,200 mg/L between 1967 and 1990 (Staton et al. 2003). The Canadian water quality guidelines for the protection of aquatic life for chloride are 120 mg/L for long-term exposure and 640 mg/L for short-term exposure (CCME 2011). Prior to 1990, the formation water produced by local oil wells was disposed of in surface waters of the North Sydenham watershed. This practice was stopped in 1990 and the formation water is now injected back into the ground. Consequently, chloride concentrations in the North Sydenham River have declined to 10–50 mg/L (Staton et al. 2003). At the water quality monitoring stations examined in the Thames River (Figure 4) chloride concentrations have ranged from 27.2–132 mg/L (160 samples) between 2010 and 2016. Two measurements, both from November 2016, fell above the Canadian water quality guideline for the protection of aquatic life. At the stations examined on the Sydenham River chloride concentrations ranged from 14.4–61 mg/L (224 samples) and at Bear Creek from 17.9–101 mg/L (110 samples) between 2010 and 2016 (OMECC 2018).

The frequency of this threat can be single, recurrent, or continuous (Table 10) and impacts may be cumulative. The Level of Impact is related to the intensity and length of exposure (COSEWIC 2016). The Level of Impact of contaminants and toxic substances on River Darter in DU 3 is ranked as Low at current levels (Table 6 and Table 12).

Sediment Loading

Sediment loading occurs throughout DU 3. Impacts include increased turbidity, increased fine substrates (i.e., siltation), and sediment loading may be involved in transporting pollutants and nutrients (e.g., phosphorous) into the water body. Increased turbidity reduces a species' vision and may impede respiration (COSEWIC 2016). Siltation may decrease abundance of River Darter prey species (Holm and Mandrak 1996) and may cause egg mortality through smothering (Finch 2009).

Both the Sydenham and Thames watersheds have high levels of turbidity (> 60 NTU in 2012 and 2016 DFO samples) (Mandrak 2018). Suspended solids in the North Branch Sydenham River generally range from 50–90 mg/L and up to 900 mg/L. The East Sydenham River is less turbid with suspended solids typically ranging from 28–77 mg/L, increasing downstream. The main source of sediments is believed to be agriculture via overland runoff and tile drainage (Staton et al. 2003). Sediments delivered through tile drains are typically fine grained (Grass et al. 1979) and are a large contributor to the high levels of turbidity in the watershed (Staton et al. 2003). Staton et al. (2003) noted that siltation appeared to be occurring along the entire length of the North Branch. The Bear Creek channel was impacted by tractor crossings and livestock access, but these were not common along the North Branch in general. In the Thames River flow-weighted concentrations of total suspended solids increase towards the mouth of the river and are generally highest in March, high in the surrounding months, and lower in the summer (Nürnberg and LaZerte 2015).

River Darter is found in turbid waters throughout its range, thus is likely tolerant of turbidity (Pfleiger 1975, Trautman 1981, COSEWIC 2016). However, Roseman et al. (2009) note that six species, including River Darter, have declined appreciably in the Lake Huron basin due to loss of clear-water stream habitat. The Level of Impact of sediment loading on River Darter in DU 3 is ranked as Medium (Table 6 and Table 12).

Dams

Dams are not included in the threat assessment because no major dams occur within the known range of River Darter in DU 3. Potential future sites for water power developments are shown in Figure 3. Impacts to River Darter should be considered before any of these potential sites are developed.

Interactive and Cumulative Impacts

Effects can cumulate over time and space (CEARC and U.S. NRC 1986) and the impacts of multiple stressors acting at the same time may also interact in various ways. They may be additive (effect is equal to the sum of the impacts when each acts alone), synergistic (effect is greater than the sum of the impacts when each acts alone), or antagonistic (effect is less than additive). Several studies examining the impacts of two stressors acting at once found that antagonistic effects are generally more common (e.g., Darling and Côté 2008. Piggott et al. 2015, Jackson et al. 2016, Radinger et al. 2016). However, net effects may still be detrimental (Jackson et al. 2016). Synergistic effects may be more predominant if there are three or more stressors acting on the same system (e.g., Przeslawski et al. 2005, Mora et al. 2007. Darling and Côté 2008).The impact of cumulative effects may be even greater for species living in less than ideal habitat, nearer to their environmental tolerance limits (Radinger et al. 2016).

Interactive and cumulative impacts are not included in the threat assessment but the potential for the occurrence of these impacts is an important consideration. More work is needed to determine the interactive and cumulative impacts of the threats acting on River Darter in DU 3.

THREAT ASSESSMENT

Threats were assessed following the procedures outlined in DFO (2014) – Guidance on Assessing Threats, Ecological Risk and Ecological Impacts for Species at Risk. Threats were assessed at the DU 3 level. The Likelihood of Occurrence (Table 5), Level of Impact (Table 6), Causal Certainty (Table 7), Threat Risk (product of Likelihood of Occurrence and Level of Impact; Table 8), Threat Occurrence (Table 9), Threat Frequency (Table 10), and Threat Extent (Table 11) were evaluated for each identified threat.

Table 5. Categories of Likelihood of Occurrence.

Likelihood of Occurrence	Definition
Known or very likely to occur	The threat has been recorded to occur 91–100% of the time
Likely to occur	There is 51–90% chance that this threat is or will be occurring
Unlikely	There is 11–50% chance that this threat is or will be occurring
Remote	There is 1–10% chance that this threat is or will be occurring
Unknown	There are no data or prior knowledge of this threat occurring now or in the future

Table 6. Categories of Level of Impact linked to a threat.

Level of Impact	Definition
Extreme	Severe population decline (i.e., 71–100%) with the potential for extirpation
High	Substantial loss of population (31–70%) or threat would jeopardize the survival or recovery of the population
Medium	Moderate loss of population (11–30%) or threat is likely to jeopardize the survival or recovery of the population
Low	Little change in population (1–10%) or threat is unlikely to jeopardize the survival or recovery of the population
Unknown	No prior knowledge, literature or data to guide the assessment of threat severity on population

Table 7. Categories of Causal Certainty linked to a threat.

Causal Certainty	Definition
Very high	Very strong evidence that the threat is occurring and the magnitude of impact to the population can be quantified
High	Substantial evidence of a causal link between the threat and population decline or jeopardy to survival or recovery
Medium	There is some evidence linking the threat to population decline or jeopardy to survival or recovery
Low	There is a theoretical link with limited evidence that the threat is leading to a population decline or jeopardy to survival or recovery
Unknown	There is a plausible link with no evidence that the threat is leading to a population decline or jeopardy to survival or recovery

Table 8. The Threat Risk Matrix combines the Likelihood of Occurrence and Threat Impact rankings to establish the Threat Risk. The resulting Threat Risk is categorized as Low, Medium, High, or Unknown.

		Threat Impact				
		Low	**Medium**	**High**	**Extreme**	**Unknown**
Likelihood of Occurrence	**Known**	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 9. Categories of Threat Occurrence.

HUC-level Threat Occurrence	Definition
Historical	A threat that is known to have occurred in the past and negatively impacted the population
Current	A threat that is ongoing, and is currently negatively impacting the population
Anticipatory	A threat that is anticipated to occur in the future, and will negatively impact the population

Table 10. Categories of Threat Frequency.

HUC-level Threat Frequency	Definition
Single	The threat occurs once
Recurrent	The threat occurs periodically or repeatedly
Continuous	The threat occurs without interruption

Table 11. Categories of Threat Extent.

HUC-level Threat Extent	Definition
Extensive	71–100% of the population is affected by the threat
Broad	31–70% of the population is affected by the threat
Narrow	11–30% of the population is affected by the threat
Restricted	1–10% of the population is affected by the threat

The Likelihood of Occurrence, Level of Impact and Causal Certainty for the threats which may be impacting River Darter in DU 3 are listed in Table 12.

Table 12. The likelihood of occurrence, level of impact, and causal certainty of threats potentially impacting River Darter in DU 3.

Threat	Likelihood of Occurrence	Level of Impact	Causal Certainty
Exotic/Invasive Species			
Round Goby	Known	Medium	Low
Zebra Mussel	Known	Unknown	Unknown
Habitat Alteration			
Dredging	Likely	Medium	Medium
Shoreline Hardening	Known	Unknown	Low
Nutrient Loading	Known	Low	Medium
Contaminants and Toxic Substances	Known	Low	Medium
Sediment Loading	Known	Medium	Unknown

The Threat Risk was then determined for each threat using the Threat Risk Matrix shown in Table 8. Threat Risk is Unknown for Round Goby, Zebra Mussel, shoreline hardening and sediment loading; Low for dredging; and Medium for nutrient loading and contaminants and toxic substances (Table 13).

Table 13. Threat Risk, threat occurrence, threat frequency, and threat extent of threats potentially impacting River Darter in DU 3.

Threat	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Exotic/Invasive Species				
Round Goby	Medium	Current, Anticipatory	Continuous	Extensive
Zebra Mussel	Unknown	Current, Anticipatory	Continuous	Extensive
Habitat Alteration				
Dredging	Medium	Current, Anticipatory	Recurrent	Broad
Shoreline Hardening	Unknown	Current, Anticipatory	Continuous	Narrow to Broad
Nutrient Loading	Low	Current, Anticipatory	Recurrent	Extensive
Contaminants and Toxic Substances	Low	Current, Anticipatory	Recurrent	Extensive
Sediment Loading	Medium	Current, Anticipatory	Recurrent	Extensive

MITIGATIONS AND ALTERNATIVES

Threats to species survival and recovery can be lessened by implementing mitigation measures to reduce or eliminate potential harmful effects that could result from works or undertakings associated with projects or activities in River Darter habitat.

Within River Darter habitat, a variety of works, undertakings, and activities have occurred in the last five years with project types including: shoreline and streambank works (e.g., stabilization); channel modifications and drain maintenance and dredging activities. A review has been completed summarizing the types of work, activity, or projects that have been undertaken in habitat known to be occupied by River Darter (Table 14). 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 November 2013 through November 2018 within a 1-km radius of River Darter occurrence records in DU 3. Twenty-two (22) projects were identified in River Darter habitat, but these likely do not represent a complete list of projects or activities that have occurred in these areas (Table 14). Some projects occurring in proximity but not in the area of known River Darter habitat may also have impacts, but were not included. Some projects may not have been reported to DFO as they may have met self-assessment requirements and were not required to be reported. The review included those areas where historical records exist, although the COSEWIC status report indicated that River Darter is likely extirpated in the North Sydenham River.

The only project authorized under the *Fisheries Act* was for a bridge replacement project on the Thames River near Thamesville. Most projects were deemed low risk to fishes and fish habitat and were addressed through letters of advice with standard mitigation. Four projects were triaged out as mitigation was in place. Without appropriate mitigation, projects or activities occurring adjacent or close to these areas could have impacted River Darter (e.g., increased sedimentation and/or nutrient loading from upstream channel works).

The most frequent project types were shoreline stabilization and drain maintenance activities in close proximity to the main rivers. Based on the assumption that historical and anticipated development pressures are likely to be similar, it is expected that similar types of projects will likely occur in or near River Darter habitat in the future. The primary project proponents were adjacent landowners and municipalities.

There are no known projects currently proposed which would likely impact River Darter, but the Thames and Sydenham are currently identified as critical habitat for other fishes or mussels. The measures that may be used to protect critical habitat should therefore be protective for River Darter.

Some threats affecting River Darter populations are shoreline hardening, dredging, and nutrients and effluents from urban waste, spills, and agriculture. These will likely continue to occur but habitat-related threats to River Darter can been linked to the Pathways of Effects developed by DFO Fish Habitat Management (FHM) (Table 14). 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. Additional mitigation and alternative measures, specific to River Darter, related to invasive species, harvest mortality, and interactive and cumulative impacts are listed below.

ADDITIONAL MITIGATION AND ALTERNATIVE MEASURES

Exotic/Invasive Species

As discussed in the Anthropogenic Threats section, introduction and establishment of exotic/invasive species could have negative effects on River Darter.

Mitigation

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

Alternatives

Authorized Introductions

- Use only native species.
- Follow the National Code on Introductions and Transfers of Aquatic Organisms for all aquatic organism introductions (DFO 2003).

Interactive and Cumulative Impacts

Where multiple stressors are impacting a system it is important (and an ongoing challenge) to determine the types of stressor interactions (e.g., additive, synergistic, antagonistic) and to disentangle the pathways by which the stressors are interacting. In situations with antagonistic stressors, attempts to reduce or eliminate one stressor may not result in the expected benefit unless it is the dominant stressor that is driving the interaction. In situations with synergistic stressors on the other hand, reducing or eliminating one stressor may result in larger benefits than expected. Additive effects imply stressors that are acting independently, thus mitigation of individual stressors should yield predictable results (Piggott et al. 2015).

Table 14. Summary of works, projects, and activities that have occurred during the period of November 2013 to November 2018 in areas known to be or historically occupied by River Darter. 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 River Darter 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; and 18 – Structure removal).

Work/Project/Activity	**Threats** (associated with work/project/activity)						**Watercourse / Waterbody** (number of works/projects/activities between November 2013- November 2018)			
	Habitat removal and alteration	**Nutrient loading**	**Turbidity and sediment loading**	**Contaminants and toxic substances**	**Exotic species and disease**	**Incidental harvest**	**Lake St. Clair**	**Thames River**	**Sydenham River**	**North Sydenham (Bear Creek)**
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)	✓	-	✓	✓	-	-	-	2	-	1
Shoreline, streambank work (stabilization, infilling, retaining walls, riparian vegetation management)	✓	-	✓	✓	-	-	5	-	-	1
Instream works **(**channel maintenance, restoration, modifications, realignments, dredging, aquatic vegetation removal)	✓	✓	✓	✓	-	-	3	4	3	2

Work/Project/Activity	Threats (associated with work/project/activity)						Watercourse / Waterbody (number of works/projects/activities between November 2013- November 2018)			
	Habitat removal and alteration	**Nutrient loading**	**Turbidity and sediment loading**	**Contaminants and toxic substances**	**Exotic species and disease**	**Harvest Mortality**	**Lake St. Clair**	**Thames River**	**Sydenham River**	**North Sydenham (Bear Creek)**
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 management (stormwater management, water withdrawal)	-	✓	✓	✓	-	-	-	-	-	-
Structures in water (boat launches, docks, effluent outfalls, water intakes, dams)	✓	✓	✓	✓	-	-	-	-	-	1
Invasive species introductions (accidental and intentional)	-	-	-	-	✓	-	-	-	-	-

EXISTING PROTECTION

River Darter is listed as Endangered under the Ontario *Endangered Species Act*.

SOURCES OF UNCERTAINTY

Information on the biology, habitat use, and distribution of River Darter in DU 3, particularly in Lake St. Clair, is lacking. The current extent of spawning, rearing, and overwintering habitats have not been quantified. These habitats should be investigated and mapped.

Data on population sizes and trends are lacking. To accurately determine population size, current trajectory, and trends over time there is a need for the continuation of quantitative sampling of River Darter in areas where it is known to occur. The catchability of this species should also be investigated.

There is a need for more causative studies to evaluate the impacts of threats on River Darter with greater certainty as well as an estimation of the cumulative effects of interacting threats.

There is also a need to improve our understanding of the physiology and adaptability of River Darter. Studies examining the physiological limitations of this species and its capacity to adapt and evolve as environmental regimes are altered are required to provide a mechanistic understanding of the impacts of stressors.

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