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RECOVERY POTENTIAL ASSESSMENT – RIVER DARTER, *Percina shumardi* (GREAT LAKES-UPPER ST. LAWRENCE POPULATIONS)

River Darter, Percina shumardi*. Courtesy of Doug Watkinson, DFO.*

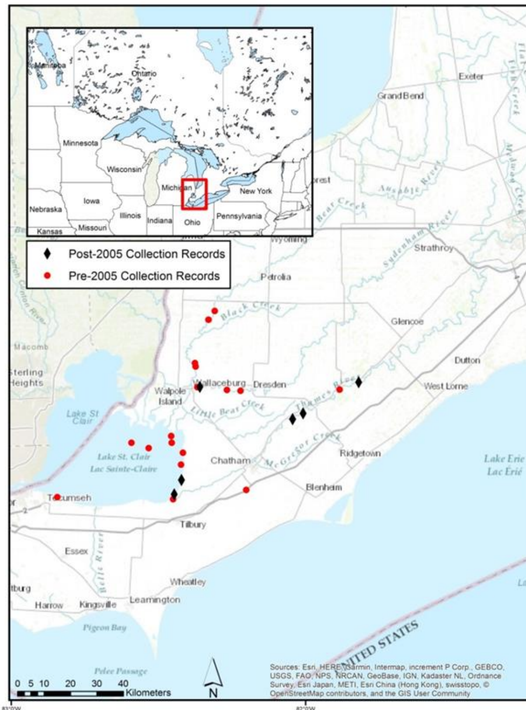

Figure 1. The distribution of River Darter in DU 3 (Great Lakes-Upper St. Lawrence populations).

Context:

*River Darter (*Percina shumardi*) is a small, elongate fish 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. In May 2016, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated River Darter, Great Lakes-Upper St. Lawrence populations, Designatable Unit (DU) 3, as Endangered. Within this DU River Darter have a very restricted distribution, occur at few locations, and are exposed to high risk threats from shoreline hardening, exotic/invasive species, dredging, and nutrients and effluents from urban waste, spills, and agriculture.*

DU 3 River Darter is being considered for legal listing under the Species at Risk Act *(SARA). In advance of making a listing decision, Fisheries and Oceans Canada (DFO) Science has been asked to undertake a Recovery Potential Assessment (RPA). This RPA summarizes the current understanding of the distribution, abundance, and population trends of River Darter in DU 3, along with recovery targets and times. The current state of knowledge about habitat requirements, threats to both habitat and River Darter, and measures to mitigate these impacts for DU 3 are also included. This information may be used to inform both scientific and socio-economic elements of the listing decision, develop a* *recovery strategy and action plan, and to support decision-making with regards to the issuance of permits, agreements, and related conditions as per sections 73, 74, 75, 77, and 78 of the SARA.*

This Science Advisory Report is from the January 31, 2019 regional science peer review meeting of the Recovery Potential Assessment – River Darter, Percina shumardi*, Great Lakes-Upper St. Lawrence Populations (Designatable Unit 3). Additional publications from this meeting are posted on the [DFO Science Advisory Schedule](#).*

SUMMARY

- The current distribution of the Great Lakes-Upper St. Lawrence population of River Darter is limited to the Lake St. Clair watershed (Figure 1). Since 2005, River Darter have been collected from the Sydenham River, Thames River, and Lake St. Clair. Distribution in DU 3 appears to be decreasing.
- River Darter are typically collected in medium to large rivers or nearshore areas of lakes. They generally occur in deeper, moderate-velocity water over a variety of substrates, and are known to tolerate turbid waters. Little is known about spawning and feeding habitat but clean gravel and cobble substrates may be important features. Specific habitat information for River Darter in DU 3 is limited.
- The trajectory for abundance cannot be evaluated for DU 3 other than that River Darter continue to be rare.
- Recovery targets based on the minimum viable population (MVP) in the range of 27,000 to 31,000 are recommended. These estimates assume density-dependence with a maximum population growth rate of 2.49, a catastrophe frequency of 15% per generation, and a 1% extinction probability. MVP estimates were highly sensitive to simulation criteria, ranging from 3,700 to > 220,000.
- A population with an initial density of 10% of MVP would require between 33–35 years to reach recovery targets assuming the same simulation criteria and MVP analysis.
- An MVP sized population would require between 10.6 and 12.1 ha (1 ha = 10,000 m^2) of habitat based on an Ordinary Least Squares (OLS) regression analysis of DU 1 and 2 River Darter densities assuming a 5% catchability (0.25 fish/m^2 density).
- In DU 3, the greatest threats to the survival and persistence of River Darter are exotic/invasive species (Round Goby), dredging, and sediment loading. Secondary threats include nutrient loading and contaminants and toxic substances. The potential impacts of Zebra Mussels and shoreline hardening are unknown.
- River Darter population dynamics are particularly sensitive to perturbations affecting young-of-year (YOY) survival rates and fertility. Harm to these aspects of life history should be avoided. Decreases in YOY-survival or fertility greater than 31–34% may result in population decline. Populations with an initial population growth rate of 1.32 may experience declines if anthropogenic harm (i.e., mortality) exceeds 24.5% for all age-classes or if YOY survival or reproductive success is reduced by 31–34%. Relationships between anthropogenic activities and changes in vital rates have not yet been established and require further research.
- There remain numerous sources of uncertainty related to DU 3 River Darter biology, ecology, life history, habitat requirements, population abundance, population structure, vital rates, and distribution. A thorough understanding of the threats affecting the decline of River Darter in DU 3 is also lacking.

INTRODUCTION

Rationale for Assessment

In May 2016, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated River Darter, *Percina shumardi* (Great Lakes-Upper St. Lawrence populations, Designatable Unit [DU] 3) Endangered. Designatable Units 1 (Saskatchewan-Nelson River populations) and 2 (southern Hudson Bay-James Bay populations) were designated Not at Risk. The species was previously assessed as a single unit in April 1989 and was designated Not at Risk.

When COSEWIC designates a species as Threatened or Endangered, the Minister of Fisheries and Oceans (DFO) is required by the *Species at Risk Act* (SARA) to undertake a number of actions. Many of these actions require scientific information such as the current status of the populations, the threats to its survival and recovery, and the feasibility of it recovery. This scientific advice is developed through a Recovery Potential Assessment (RPA). This allows for the consideration of peer-reviewed scientific analyses in subsequent SARA processes including recovery planning and the issuance of SARA permits.

The regional science peer review meeting for the River Darter RPA was held on January 31, 2019. Three research documents, that provide technical details and the full list of cited material, were reviewed during the meeting and will be made available on the Canadian Science Advisory Secretariat website. This science advisory report summarizes the main conclusions and advice from the science peer review.

Species Biology and Ecology

River Darter is a small, elongate fish with a short, rounded snout, a moderately sized terminal mouth, and large eyes that are positioned high on the head and close together. This species reaches a maximum total length of 94 mm in Canada. Scales are ctenoid and are usually found on the cheeks and the operculum with the breast typically scaleless. There are 42–62 lateral line scales. 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. Breeding males are typically darker in colour and they may exhibit nuptial tubercles on the caudal, anal, and pelvic fins as well as the vent and head along the infraorbital and preopercular mandibular canals. Spawning males also develop an enlarged anal fin which reaches nearly to the caudal fin. 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*).

River Darter live to a maximum age of 3 or 4 in the United States of America (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.

In Canada, River Darter spawn from May to early July with their reproductive cycle being determined by photoperiod and temperature. They spawn mainly in rivers but ripe individuals have been collected in lakes. In the Assiniboine River, Manitoba ripe individuals were collected between June 22 and 24 at a water temperature of 24°C. Generally, males arrive at the spawning site before females. During spawning 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, eggs were observed to be adhesive and to hatch 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*).

Feeding occurs mainly during the day and the River Darter diet includes a wide variety of prey items. In an Illinois study, stomach contents consisted of dipterans, trichopterans, ephemeropterans, crustaceans, and fish eggs. A study in Manitoba found the same items in addition to corixids and fishes. Gastropods have been found to be an important prey item for River Darter in Alabama, Tennessee, and Manitoba. A study in Ontario and Manitoba (DUs 1 and 2) found common prey items to include 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 diet components. Dominant prey varied between study sites and seasons, likely due to differences in prey availability.

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

In Canada, upstream spawning migrations occur in May to July. In a laboratory study, the swimming position of larval River Darter was observed to be 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.

Growth patterns, stage-specific annual mortality, and fecundity-at-stage of River Darter were determined using data and estimates from the literature (van der Lee and Koops 2019). Table 1 summarises the range of values for life history parameters used to model River Darter populations. The parameter values used in the modelling (Table 1) are based on the best information available.

Table 1. Values, symbols, descriptions, and sources for parameters used to model River Darter populations. Sources are provided in van der Lee and Koops (2019).

	Description	Value
Age	Longevity	4
	Age-at-maturity	1
	Generation time	1.8
Growth	Length at hatch	6.15
	Break point; age when growth pattern changes	0.25
	Length at break point (mm)	37.1
	Asymptotic length (mm)	61.9
	von Bertalanffy growth coefficient	0.31
Spawning	Fecundity allometric exponents	197.9
	Fecundity allometric intercept	1
	$\log_e$ standard deviation of fecundity	0.05
	Proportion female	0.5
	Spawning periodicity	1
	Proportion reproductive at age-0	0
	Proportion reproductive age-1 to age-4	1
Weight	Length-weight allometric exponents	2.3×10^{-6}
	Length-weight allometric intercept	3.30
Adult Mortality	Instantaneous mortality	0.752
	Coefficient of variation of YOY mortality	0.1
	Coefficient of variation of adult mortality	0.2

ASSESSMENT

Historic and Current Abundance and Trends

The trajectory for abundance cannot be evaluated for River Darter in DU 3 other than that River Darter continues to be rare. Only a few specimens have been captured since the previous COSEWIC report was written (1989) with low catch per unit effort. This is the case despite extensive search effort, particularly since 2005. Over 1,000 sites within the range of River Darter in DU 3 have been sampled using a variety of gear.

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 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 1). The extent of occurrence has declined from a pre-2005 estimate of 2,224 km^2 to 907 km^2 in the most recent decade. The discrete index area of occupancy (IAO) has declined from a pre-2005 estimate 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 (16 km^2) than the continuous estimate, indicating a trend of decreasing distribution in DU 3.

Habitat Requirements

Typically collected in medium to large rivers or nearshore areas of lakes, River Darter generally occur in deeper, moderate-velocity water over a variety of substrates. This species tolerates turbid waters. 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.

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.

Functions, Features and Attributes

Table 2 describes the functions, features, and attributes associated with River Darter habitat. The habitat required for each life stage of River Darter has been assigned a function that corresponds to a biological requirement and features considered 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. Habitat attributes associated with current records may differ from optimal habitat as River Darter may be occupying sub-optimal habitat where optimal habitat is not available.

There are no data to quantify how the biological functions that specific habitat features provide vary with the state or amount of habitat including carrying capacity limits.

The spatial extents of spawning, rearing, and overwintering habitat have not been quantified for River Darter in DU 3.

Residence

The concept of residence as defined by the SARA does not apply to River Darter.

Table 2. 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. See Sawatzky (2019) for the full list of citations.

Life Stage	Function	Feature(s)	Attributes
Egg / Embryo – spawning through emergence	Spawning (May to early July) Incubation and early rearing	• Sand or gravel substrate • Clean gravel and cobble substrate	• Ripe individuals collected between June 22 and 24 in the Assiniboine River (Manitoba) at a water temperature of 24ºC • Eggs hatched nine days post-fertilization at water temperatures between 19 and 21ºC in the laboratory
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 • Clean gravel and cobble substrates may be important	• In DU 3 in the Thames and Sydenham rivers collected from four locations at: ○ 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 and 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
Juvenile Adult	Overwintering	Unknown	Unknown

Naturally Occurring Limiting Factors

River Darter in DU 3 has a very restricted distribution and only a small number of individuals have been collected. 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, although it is suspected to be substantially less than 8 km per year.

Threats

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 have cumulative and synergistic effects. Dams and interactive and cumulative impacts are not assessed as threats but are noted as important considerations. Sawatzky (2019) provides a detailed description of the principle threats to River Darter in DU 3.

Exotic/Invasive Species – Round Goby

Round Goby (*Neogobius melanostomus*) distribution overlaps with that of River Darter in Lake St. Clair, the Thames River, and sections of the Sydenham River. The two species share a number of prey items and occur in similar habitats, thus there is potential for direct competition for resources. 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. Round Goby may also feed on fish eggs and larvae, potentially including those of River Darter. However, Burkett and Jude (2015) found that eggs may not be an important component of the diet of Round Goby and found only a few instances of significant diet overlap between Round Goby and native fishes in the St. Clair River, Michigan.

Exotic/Invasive Species – 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. 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. 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. Zebra Mussels are a preferred food of Round Goby and may therefore facilitate Round Goby invasion. On the other hand, since River Darter consume molluscs, Zebra Mussels may benefit this species by providing an additional abundant food source. Overall, the potential impacts of Zebra Mussels on River Darter in DU 3 are not known.

Habitat Alteration – Dredging

During spawning, River Darter deposit their eggs into the substrate, thus dredging represents a potential threat to this species. The impacts of sedimentation caused by dredging may also threated River Darter. In DU 3, maintenance dredging occurs in Lake St. Clair and several of its tributaries including the Thames River. 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. In the Allegheny River, Pennsylvania, dredged sites were found 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, a different study 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. The authors 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*" (Barnucz et al. 2015, pg. 8).

Habitat Alteration – 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. 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 and is a potential threat to River Darter.

Shoreline hardening has been completed along large sections of the south shore of Lake St. Clair. Hardening on the shores of Lake St. Clair has 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 and providing nesting cavities for Round Goby. However, invasive invertebrates were found to be equally common on hardened and natural shorelines of Lake St. Clair. Additional research is needed to determine the impacts on nearshore fish species and the impacts on River Darter in DU 3 are unknown.

Habitat Alteration – Nutrient Loading

Agriculture is the primary land use in DU 3. 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. 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. 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, reproduction). This threat is chronic and widespread.

Habitat Alteration – 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. 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. 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. 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.

Habitat Alteration – 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. Siltation may decrease abundance of River Darter prey species and may cause egg mortality through smothering. River Darter is found in turbid waters throughout its range, thus is likely tolerant of turbidity. 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 (see Mandrak 2018).

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 Sawatzky (2019). Impacts to River Darter should be considered before any of the potential sites are developed.

Interactive and Cumulative Impacts

Effects can cumulate over time and space 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). The impact of cumulative effects may be even greater for species living in less than ideal habitat, nearer to their environmental tolerance limits. Interactive and cumulative impacts are not included in the threat assessment but the potential for their occurrence 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

Table 3 summarizes the threat level, threat occurrence, threat frequency, and threat extent for each of the identified threats potentially impacting River Darter in DU 3.

Table 3. 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 survival can be minimized 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. 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 (Coker et al. 2010). This guidance should be referred to when considering mitigation and alternative strategies for habitat-related threats. Table 4 summarizes applicable pathways of effects associated with each activity reported to DFO that occurred from November 2013 through November 2018 within a 1-km radius of River Darter occurrence records in DU 3.

To minimize interactions with exotic/invasive species, the following mitigations may be appropriate:

- Physically remove non-native species from areas known to be inhabited by River Darter.
- Monitor the range of River Darter in DU 3 for exotic/invasive species that may negatively impact River Darter directly or affect River Darter 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.

There are no alternatives to unauthorized introductions. Authorized introductions should follow the National Code on Introductions and Transfers of Aquatic Organisms.

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, 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.

Abundance Targets (MVP)

Abundance targets were estimated using population viability analysis and estimates of minimum viable population (MVP). Simulations incorporated density-dependence, environmental stochasticity, and random catastrophes. Targets varied depending on the desired persistence probability, catastrophe rate, and maximum population growth rate (Table 5).

Conservative estimates of MVP utilize a 1% quasi-extinction probability and a catastrophe rate of 0.15/generation. Maximum growth rate for River Darter populations at low density is unknown. The value of 2.49 was taken from an allometry (Randall and Minns 2000) based on the lower prediction interval and is therefore potentially conservative; 1.32 may be overly cautious. As a result, MVP estimates in the range of 27,000 to 31,000 are recommended.

Recovery targets based on MVP can be easily misinterpreted as a reference point for exploitation or allowable harm. A recovery target is neither of these things because it pertains exclusively to a minimum abundance level for which the probability of long-term persistence within a recovery framework is high. Therefore, 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. These MVP targets refer to adult numbers only. If juveniles are being included in abundance or density estimates then the MVP must include these age-classes as well.

Additionally, MVP estimates for River Darter were made using a post-breeding matrix model. This means that abundance estimates were made directly after spawning has occurred and before age-specific mortality has acted. Therefore, abundance estimates from MVP analysis represent maximum annual abundances for a given population. When compared to field observations of abundance, sampling date relative to spawning date should be considered and the expected mortality rate over this time period accounted for.

Current populations abundances and trajectories are unknown for DU 3 River Darter. Simulations have been conducted for River Darter populations with an initial abundance of 10% of MVP and projected time to recovery where recovery is MVP (MVP was also set as carrying capacity). Assuming a maximum growth rate of 2.49 and a catastrophe rate of 15% per generation, River Darter had a 95% chance of reaching these recovery targets after 33–35 years.

Table 4. 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 Nov 2013–Nov 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
Water management (stormwater management, water withdrawal)		✓	✓	✓						
Structures in water **(**boat launches, docks, effluent outfalls, water intakes, dams)	✓	✓	✓	✓						1
Invasive species introductions (accidental and intentional)					✓					

Habitat Targets (MAVP)

GIS software (ESRI ArcMap 10.6.1) was used to quantify the available habitat (as wetted area) in the Thames River, bounded by locations where River Darter have been sampled. This totalled a 28.7 km length of river and an area of 109 ha of potential habitat. Assuming this is all usable habitat, MVP abundances (31,000 adults) can be achieved with densities of 0.028 fish/m^2. It is unlikely that the entirety of this stretch of river is suitable habitat for River Darter. However, densities greater than 0.028 fish/m^2 are likely achievable. Assuming catchability of River Darter was 5%, standardized mean densities of River Darter in northern Not At Risk populations were estimated to be 0.25 or 0.57 fish/m^2. Using these densities, MVP abundances required between 10.6 and 12.1 ha or between 4.7 and 5.4 ha of suitable habitat. Therefore, there is likely sufficient habitat in the Thames River to meet the needs of a sustainable River Darter population. The quantity of habitat in other inhabited areas of DU 3 (i.e., Sydenham River) has not been calculated.

Table 5. Estimates of the adult minimum viable population (MVP) for River Darter populations and a 5% and 1% probability of extinction. Simulations were conducted for three waterbodies, using two levels of maximum population growth rate (λ) and two rates of catastrophes.

River	λ	Catastrophe Rate	MVP	
			***P[ext]* = 5%**	***P[ext]* = 1%**
Assiniboine	1.32	0.10	10,095	47,992
		0.15	36,421	209,213
	2.49	0.10	4,085	15,234
		0.15	7,545	27,097
English	1.32	0.10	9,020	38,707
		0.15	36,859	218,524
	2.49	0.10	3,788	12,850
		0.15	7,781	29,085
Rainy	1.32	0.10	8,860	37,919
		0.15	37,313	223,698
	2.49	0.10	3,769	12,955
		0.15	8,152	30,910

Allowable Harm

The maximum anthropogenic harm that can be applied to a River Darter population without causing population decline was estimated (Table 6). These values represent the maximum proportional changes to vital rates, in the absence of any other harm, that prevent mean population growth rate (λ) being < 1. Estimates were taken from elasticity analysis (see van der Lee and Koops 2019), assume density-independence, and are specific to assumed rates of population growth (1.32 and 2.49). Elasticity analysis revealed that River Darter populations are most sensitive to perturbations to young-of-year (YOY) survival rates and fertility. Harm to these aspects of life history should be avoided. Decreases in YOY-survival or fertility greater than 31 to 34% may result in population decline. Perturbations greater than 24.5% affecting all age-classes may also cause population decline. Relationships between anthropogenic activities and changes in vital rates have not yet been established and require future research.

Table 6. Maximum harm estimates for River Darter populations. The greatest proportional change in vital rates that maintains mean λ > 1. σ_y is young-of-year survival rate, ƒ is fertility, σ_a is adult survival rate, and σ is survival rate of all life stages.

River	Population Growth Rate (λ)	Vital Rate		
		σ_y / ƒ	σ_a	σ
Assiniboine	1.32	-0.341	-0.867	-0.245
	2.49	-0.654	< -1	-0.598
English	1.32	-0.315	< -1	-0.245
	2.49	-0.639	< -1	-0.598
Rainy	1.32	-0.324	< -1	-0.245
	2.49	-0.644	< -1	-0.598

Simulation analysis was also used to investigate the impact of harm (Figures 2 and 3). Again, these simulations were conducted assuming density-independence and were specific to an initial (unharmed) mean λ = 1.32. These results demonstrate the risks associated with various levels of harm to River Darter populations. Risk was quantified as the probability of population decline (λ < 1) under harm to different life-stages over three time-frames: 1 year, 10 years, and 100 years. Initially, due to environmental stochasticity, there was an approximately 21% chance of observing population decline annually, although, the risk was 0% over 10 and 100 years. As harm was increased the risk of population decline also increased. At our estimate of maximum harm (24% for all ages) there was approximately a 51%, 44%, and 32% probability of population decline over 1, 10, and 100 years, respectively. The time-frame of interest and level of acceptable risk will have to be determined.

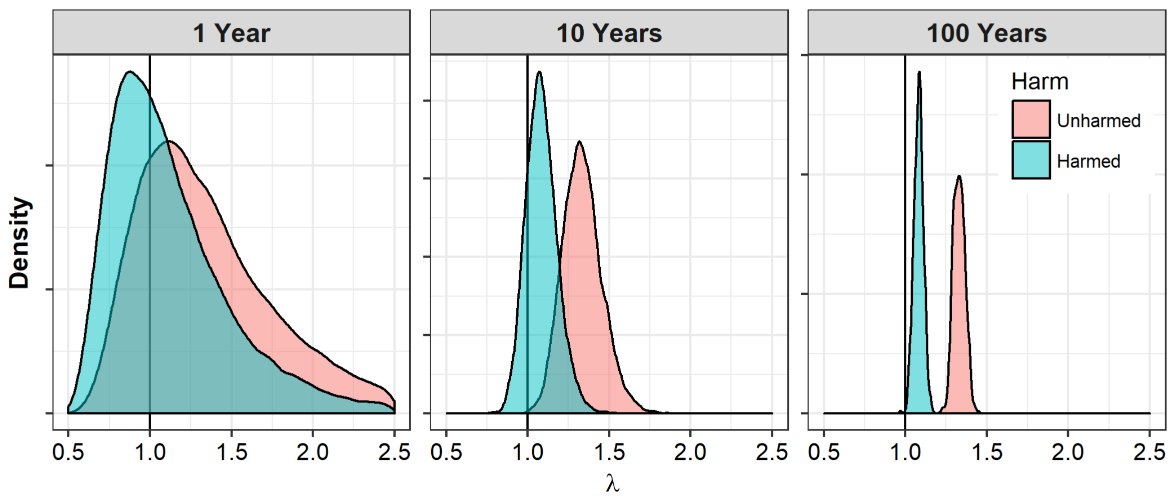

Figure 2. Examples of distributions of population growth rates (λ) from stochastic simulations of River Darter populations over 1, 10, and 100 years when unharmed (average λ = 1.32) and experiencing maximum harm (Table 6; λ ≈ 1). The vertical line at λ = 1.0 indicates population stability. The results to the left of this line represent the probability of decline.

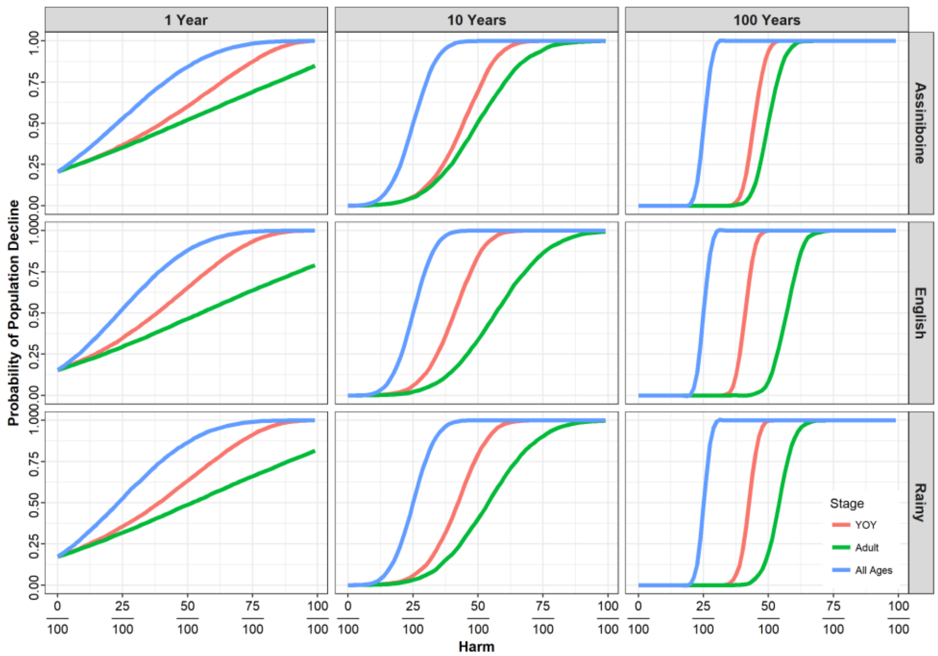

Figure 3. The probability of River Darter population decline (λ < 1) for various levels of harm (deaths per 100 fish) to different life stages (YOY, adult, or all ages) over 3 time periods (1 year, 10 years, and 100 years).

Similarly, the impact of transient harm was estimated (Figure 4). This measures the risk of population decline over 10 years after a one time death of fish event. Stage-specific effects were small but with all ages-impacted, the effects at high rates (> 75%) of harm were significant. These results are specific to an assumed density-independent λ of 1.32 and to harm occurring no more than once every 10 years. As the frequency of harm increases, the results will begin to approximate those of chronic harm (Figure 3).

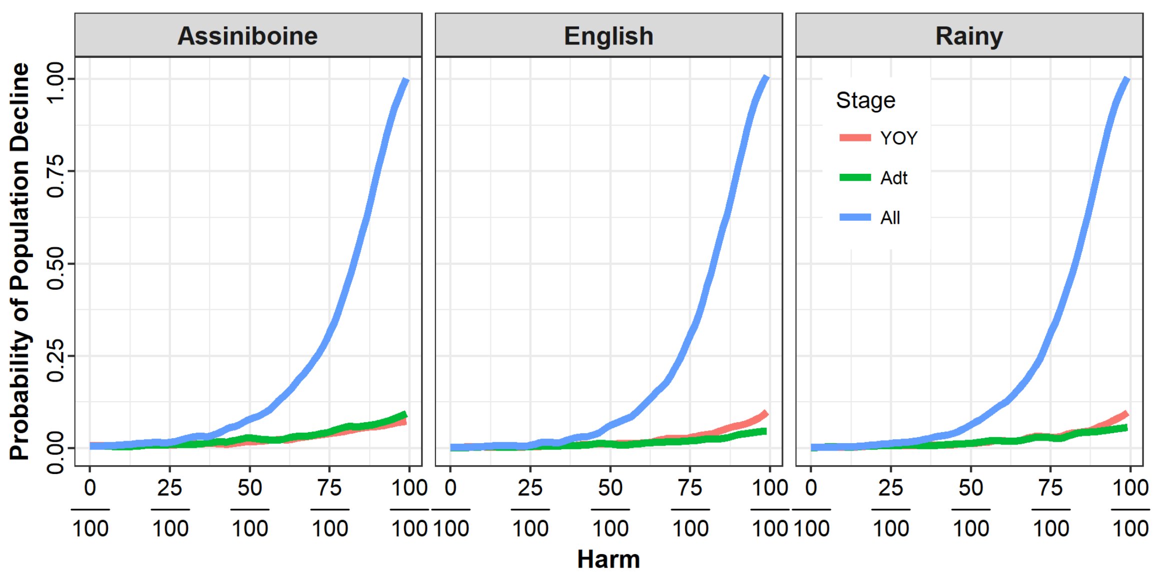

Figure 4. The effects of transient harm (a 1-time death) as the probability of observing population decline over a 10 year time period for three waterbodies and 3 stages impacted by harm.

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.

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.

Limited data were available to parameterize the River Darter population model. Data were available from DUs 1 and 2, which were deemed Not at Risk in the most recent COSEWIC assessment. It is unknown what differences may exist between DU 1 and 2 versus DU 3 River Darter. There is limited empirical data related to important vital rates such as survival and fecundity. A single estimate of adult mortality was available and its estimation may have violated the assumptions of catch-curve analysis. As well, no data are available on the survival of younger age classes. Interannual variability in vital rates and sex-specific survival rates are also largely unknown.

Data on population sizes and trajectories are lacking. To accurately determine population size, current trajectory, and trends over time there is a need for continuation of quantitative sampling of River Darter in areas where it is known to occur. The catchability of this species should also be investigated. This information would aid in the refinement of estimates of population growth rates, allowable harm, and recovery targets.

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.

Finally, the frequency and impacts of catastrophic events for River Darter are unknown. The choice of catastrophe frequency has a large impact on MVP estimates. Research that identifies the magnitude and frequency of catastrophic events at the population level would greatly reduce uncertainty in estimates of MVP size and in recommendations for the conservation of River Darter.

LIST OF MEETING PARTICIPANTS

Name	Affiliation
David Andrews (Chair)	DFO, Science
Jofina Victor (Rapporteur)	DFO, Science
Adam van der Lee	DFO, Science
Marten Koops	DFO, Science
Sara Eddy	DFO, Fisheries Protection Program
Josh Stacey	DFO, Species at Risk Program
Dave Balint	DFO, Species at Risk Program
Scott Reid	Ministry of Natural Resources and Forestry
Jason Barnucz	DFO, Science
Chantelle Sawatzky	DFO, Science
Vicki McKay	Lower Thames Valley Conservation Authority

Name	Affiliation
Doug Watkinson	DFO, Science
Tom Pratt	DFO, Science
Jessica Epp-Martindale	DFO, Species at Risk Program

SOURCES OF INFORMATION

This Science Advisory Report is from the January 31, 2019 Recovery Potential Assessment – River Darter, *Percina shumardi*, Great Lakes-Upper St. Lawrence Populations (Designatable Unit 3). 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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Center for Science Advice (CSA)
Central and Arctic Region
Fisheries and Oceans Canada
501 University Crescent
Winnipeg, Manitoba
R3T 2N6

Telephone: (204) 983-5232
E-Mail: xcna-csa-cas@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

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