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Information in support of a Recovery Potential Assessment of Channel Darter (*Percina copelandi*) in Canada, Lake Erie (DU1) and Lake Ontario (DU2) Populations

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Canada

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 2002, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated Channel Darter (*Percina copelandi*) as Threatened. The species was re-assessed by COSEWIC in November 2016 into three designatable units (DU): Lake Erie, DU1 (Endangered), Lake Ontario, DU2 (Endangered), and the St. Lawrence River, DU3 (Special Concern). Rationale for the revised DU structure was based on evidence of local extirpations contributing to greater geographic separation (> 300 km) between Lake Erie and Lake Ontario populations; and, evidence of genetic distinctiveness between populations within Lake Erie, Lake Ontario, and the St. Lawrence River. A Recovery Potential Assessment was previously conducted by DFO in 2010 for Channel Darter; however, in light of the revised DU structure, this document evaluates the current state of the species within Lake Erie (DU1) and Lake Ontario (DU2), noting its distribution, abundance, population trends, habitat requirements, threats, and new research findings following the 2010 RPA. Results of a population status assessment ranked four of five Lake Erie populations (DU1) as poor while two out of three Lake Ontario (DU2) populations were ranked as good. A threat assessment indicated that the greatest threats to Lake Erie (DU1) populations are the invasive Round Goby (*Neogobius melanostomus*), shoreline modifications, and altered flow regimes. Similarly, the greatest threats to Lake Ontario (DU2) populations were Round Goby and altered flow regimes. This RPA provides background information and scientific advice needed to fulfill various requirements of SARA and will be used to inform federal recovery documents for this species.

INTRODUCTION

Channel Darter (*Percina copelandi)* is a small benthic fish belonging to the Percidae family that occurs in central North America within the Great Lakes and the Mississippi River basins. In Canada, the species has a disjunct distribution and is found only in areas of southern Ontario and Quebec. Channel Darter occupies both lacustrine and riverine habitats in Canada, preferring substrates of gravel or cobble (Reid and Mandrak 2008, Reid et al. 2016). The species is known to be susceptible to a range of habitat modifications, including dams and water level fluctuations, shoreline modification, nutrient loading, and sedimentation (COSEWIC 2002, Reid and Mandrak 2008, COSEWIC 2016). Establishment of the invasive Round Goby (*Neogobius melanostomus*), a small benthic fish, has also been implicated in the decline of Channel Darter (Reid and Mandrak 2008).

In May 2002, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated Channel Darter as Threatened based on small population sizes where the species is found and habitat perturbations involving fluctuations in water temperature and siltation (COSEWIC 2002). The species was subsequently listed as *Threatened* under Schedule 1 of the *Species at Risk Act* (SARA). However, the species' disjunct distribution (> 300 km of geographic separation between populations in Lake Erie, Lake Ontario, and the St. Lawrence River), along with genetic evidence indicating that dispersal among rivers is limited (Reid et al. 2013, COSEWIC 2016), prompted COSEWIC in November 2016 to re-assess Channel Darter into three designatable units (DU): Lake Erie (considers lacustrine populations in Lake Erie and lacustrine and riverine populations within the Huron-Erie corridor; DU1); Lake Ontario (considers riverine populations within the Bay of Quinte drainage; DU2); and, St. Lawrence populations (DU3). Both DU1 and DU2 were re-assessed by COSEWIC as Endangered. For DU1, the reason for designation provided by COSEWIC was that "This small-bodied species occupies nearshore lake and river habitats that are undergoing major shoreline modifications and the negative impact of the invasive Round Goby, having resulted in likely extirpation from large areas of Lake Erie and Lake St. Clair" (COSEWIC 2016). Similarly, the rationale for the designation of Endangered within DU2 was that "This small-bodied species is limited to three small watersheds. The primary threat is the invasive Round Goby, which is now found throughout the Trent River and has resulted in declines in the abundance of this population. For the time being, populations along the Moira and Salmon rivers are largely unaffected by Round Goby. However, introductions upstream of dams via bait bucket transfers are considered likely" (COSEWIC 2016).

A Recovery Potential Assessment (RPA) for Channel Darter was conducted by Fisheries and Oceans Canada (DFO) in 2010 (Bouvier and Mandrak 2010), which was based on the 2002 COSEWIC assessment and a single designatable unit of the species. The November 2016 re-assessment has prompted DFO to re-evaluate certain elements of the 2010 RPA with respect to the revised DU structure, specifically: **Biology, Abundance, Distribution and Life History Parameters** (Element 2 - Evaluate the recent trajectory for abundance, distribution, and number of populations); **Habitat and Residence Requirements** (Element 4 - Describe the habitat properties that Channel Darter needs for successful completion of all life history stages); **Threats and Limiting Factors to the Survival and Recovery of Channel Darter** (Element 8 - Assess and prioritize the threats to the survival and recovery of Channel Darter; Element 9 - Identify the activities most likely to threaten (i.e., damage or destroy) the habitat properties identified in elements 4 and provide information on the extent and consequences of these activities; Element 11 – Discuss the potential ecological impacts of the threats identified in element 8 to the target species and other co-occurring species); and, **Scenarios for Mitigation of Threats and Alternatives to Activities** (Element 16 – Develop an inventory of feasible mitigation measures and reasonable alternatives to the activities that are threats to the species and its habitat). In addition to evaluating these elements in consideration of the new DU structure, this document summarizes additional research on Channel Darter that has been undertaken since Bouvier and Mandrak (2010) with respect to the elements outlined above. Due to the lack of new information regarding life history parameters of Channel Darter, recovery potential modelling was not updated as part of this RPA. For the most recent estimates of allowable harm and recovery targets, see Venturelli et al. (2010). Similarly, Bouvier and Mandrak (2010) should be considered as the most recent source of information for elements not listed above.

Data collected post-2012 was not included in the 2016 re-assessment by COSEWIC as a result of publishing delays and may explain differences between the latest COSEWIC report and this document. As RPAs are conducted by DFO only for species assessed by COSEWIC as Threatened and Endangered, this document focuses solely on DUs 1 and 2.

BIOLOGY, DISTRIBUTION AND LIFE HISTORY PARAMETERS

Element 2: *Evaluate the recent species trajectory for abundance, distribution and number of populations.*

DISTRIBUTION

In North America, Channel Darter occurs as far north as the St Lawrence River, and lakes Huron, Erie, and Ontario (Scott and Crossman 1973). The species is also found as far east as the edge of the Appalachians, west to Michigan, and as far south as Alabama, Arkansas, Kansas, Oklahoma, and Louisiana (Bouvier and Mandrak 2010, COSEWIC 2016).

In Canada, Channel Darter has a disjunct distribution, occurring in the provinces of Ontario and Quebec. In Quebec, Channel Darter is found in tributaries of the St Lawrence River, including the Ottawa River. In Ontario, the species is found in Lake Erie, Lake St Clair, and the Huron-Erie Corridor (collectively placed in DU1; see detailed information below), as well as tributaries of Lake Ontario (DU2; see detailed information below and Figures 1 - 3). Despite recent search effort (LeBaron et al. in press), the species has not been detected in nearshore areas of Lake Huron.

Lake Erie Designatable Unit (DU1)

In DU1, Channel Darter is known from nearshore areas of Lake St. Clair and Lake Erie, as well as connecting channels of the Huron-Erie corridor (St. Clair River and the Detroit River; Figure 1, 2). An overview of current status and collection records is provided below.

Current Status - Lake Erie Designatable Unit (DU1)

There are six locations where Channel Darter is currently known to occur in the Lake Erie designatable unit (DU1): Detroit River, St. Clair River, Lake St. Clair, Lake Erie Western basin (restricted to the confluence of the Detroit River with Lake Erie and the Point Pelee area), Rondeau Bay, and Port Burwell. A population in the Lake Erie Eastern Basin near Port Dover was last detected in 1947 but is presumed extirpated (COSEWIC 2016). See Appendix for recent captures of Channel Darter in DU1.

Detroit River: Channel Darter was first collected from the Detroit River in 1940 (COSEWIC 2016), with the most recent captures in 2013 from untargeted surveys (32 individuals; DFO unpublished data; Appendix, Figure 1).

St. Clair River: The St. Clair River population has been poorly studied. Since Channel Darter was first collected from the St. Clair River in 1996, it has only been captured on two occasions (2013 and 2014). During this two year period, non-target surveys captured 12 individuals from 5 sites (DFO unpublished data).

Lake St. Clair: Channel Darter was collected in Lake St. Clair as early as 1980. Targeted sampling during the 2000s (2004-2005 and 2007-2010) failed to detect the species but one individual was captured in 2012 (DFO unpublished data).The 2012 collection is the only record of Channel Darter from this locality since 1996.

Western Lake Erie: Historically, Channel Darter occurred at Holiday Beach, Pelee Island, and the Point Pelee area. Populations from Holiday beach and Pelee Island may be extirpated as the species has not been detected there since 1997 and 1984, respectively (COSEWIC 2016). The last detection from Point Pelee was in 2010, when 50 individuals were captured (COSEWIC 2016).

Rondeau Bay: Channel Darter was initially detected at Rondeau Bay in 1951-53 (Bouvier and Mandrak 2010), but a lack of repeat detections in recent years suggested that extirpation had occurred. However, in 2018, 27 individuals were captured by the Ontario Ministry of Natural Resources and Forestry (OMNRF) (LeBaron et al. in press).

Port Burwell: Channel Darter was first collected near Port Burwell in 1950 and 1951. No individuals were observed thereafter until a single Channel Darter was captured in 2017 near the mouth of Big Otter Creek (DFO unpublished data). The recent Rondeau Bay (2018) and Port Burwell (2017) collections represent the only recorded occurrences of Channel Darter in the central basin of Lake Erie since 1953.

Port Dover: Channel Darter was last observed near Port Dover in 1947 and is presumed extirpated.

Lake Ontario Designatable Unit (DU2)

In DU2, Channel Darter has been collected from the Trent River (from Glen Ross to the town of Trenton), the Moira River system (including tributaries Skootamatta and Black rivers), and Salmon River (from Kingsford to Shannonville) (Figure 3). The only possible extirpation that has occurred within DU2 is in an unnamed creek near Moira Lake (COSEWIC 2016). See Appendix for recent captures of Channel Darter for DU2.

Current Status - Lake Ontario Designatable Unit (DU2; Bay of Quinte Drainage).

Trent River: Channel Darter was initially detected in the Trent River in 1976. OMNRF has regularly targeted and captured this species in research surveys since 2001. From 2012-18, 1,592 individuals were captured in targeted surveys by OMNRF (S. Reid, DFO, unpublished data).

Salmon River: Channel Darter was initially detected in the Salmon River in 2003, as reported in Reid et al. (2005). The last known detection of Channel Darter in the Salmon River occurred in 2014, when 30 individuals were captured (S. Reid, DFO, unpublished data).

Moira System: Channel Darter was initially detected in the Moira River system (Moira, Skootomatta, and Black rivers) as early as 1948, when two individuals were collected from an unnamed creek near Moira Lake. The capture of Channel Darter has occurred as recently as 2014 (DFO unpublished data). Sampling of the Moira River in 2013 captured 25 individuals (Reid and Haxton 2017).

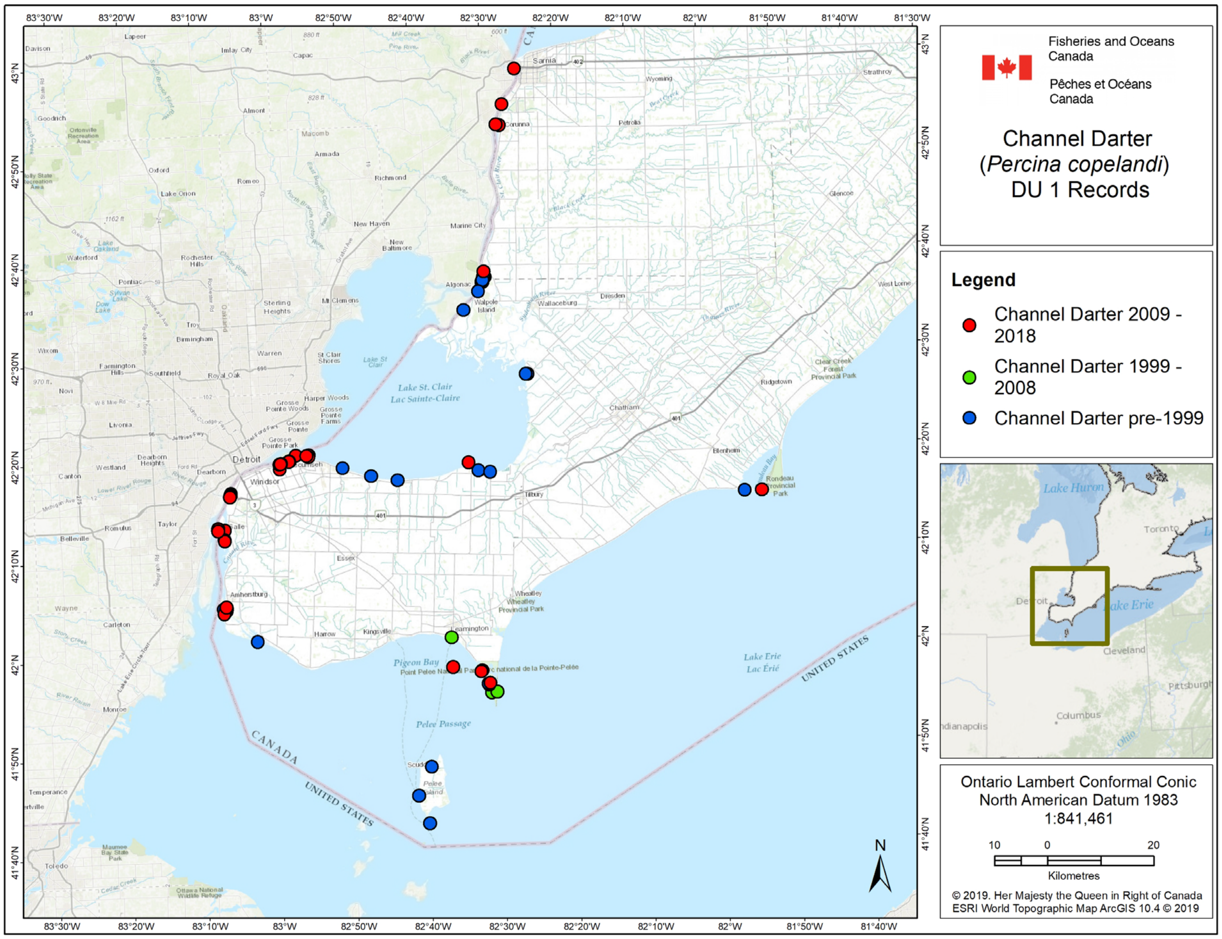

Figure 1. Distribution of Channel Darter in western Lake Erie and the Huron-Erie Corridor (Lake Erie Designatable Unit – DU1).

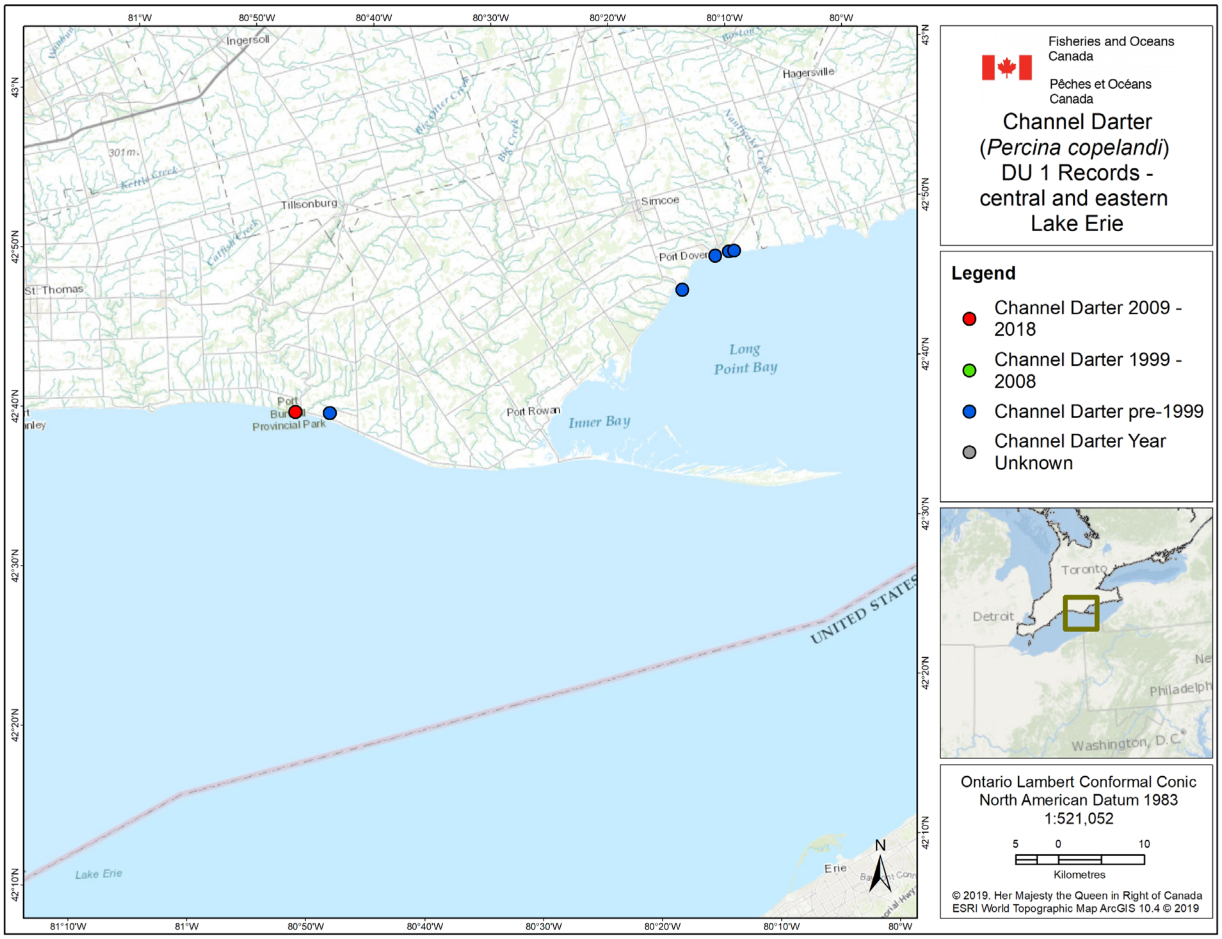

Figure 2. Distribution of Channel Darter in central and eastern Lake Erie (Lake Erie Designatable Unit – DU1).

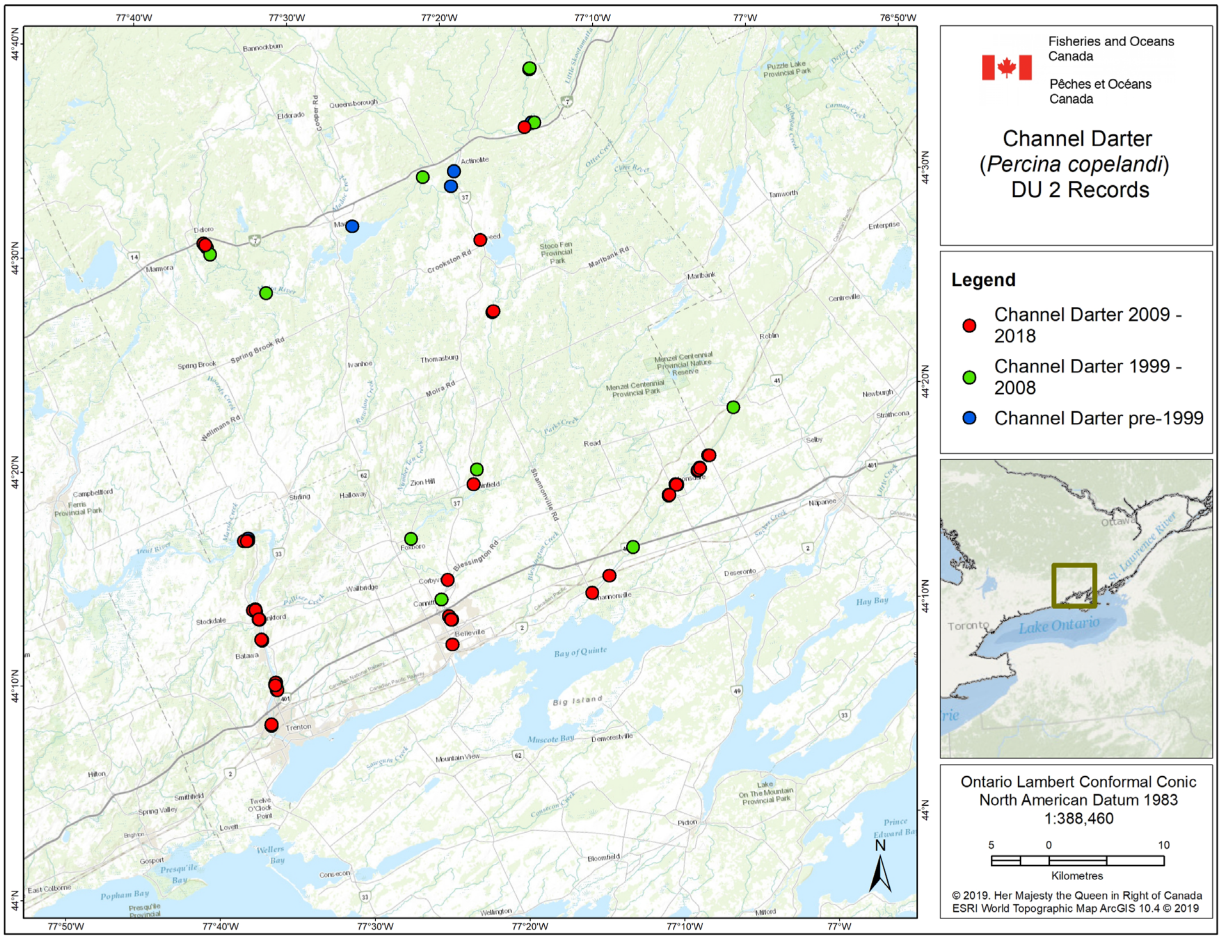

Figure 3. Distribution of Channel Darter in the Lake Ontario Designatable Unit (DU2).

POPULATION ASSESSMENT

To assess the population status of Channel Darter (DU1 & 2), each population was ranked in terms of its abundance (Relative Abundance Index) and trajectory (Population Trajectory; Table 1).

The Relative Abundance Index was assigned as Extirpated, Low, Medium, High or Unknown based on sampling that has occurred since the 2010 RPA (i.e., 2010 onwards). Sampling parameters considered included sampling effort and gear used, area sampled, and whether the study was targeting Channel Darter. The number of individual Channel Darter caught during each sampling period was then considered when assigning the Relative Abundance Index. The Relative Abundance Index is a relative parameter in that the values assigned to each population are relative to the most abundant population. In the case of Channel Darter, all populations were assigned an Abundance Index relative to the Trent River population. Catch-data from populations sampled using different gear types were assumed to be comparable when assigning the Relative Abundance Index.

The Population Trajectory was assessed as Decreasing, Stable, Increasing, or Unknown for each population based on the best available knowledge about the current trajectory of the population. The number of individuals caught over time for each population was considered. Trends over time were classified as Increasing (an increase in abundance over time), Decreasing (a decrease in abundance over time) and Stable (no change in abundance over time). If insufficient information was available to inform the Population Trajectory, the population was listed as Unknown.

The Relative Abundance Index and Population Trajectory values were then combined in the Population Status matrix (Table 2) to determine the Population Status for each population. Each Population Status is subsequently ranked as Poor, Fair, Good, Unknown, or Not applicable (Table 3). Certainty assigned to each Population Status is reflective of the lowest level of certainty associated with either initial parameter (Relative Abundance Index, or Population Trajectory).

Table 1. Relative Abundance Index and Population Trajectory of Channel Darter (DUs 1 & 2) populations in Ontario. Certainty has been defined as: 1=quantitative analysis; 2=CPUE or standardized sampling; 3=expert opinion.

Population	Relative Abundance Index	Certainty	Population Trajectory	Certainty
Lake Erie (DU1)				
• **Lake Erie Western basin: Pelee Island, Point Pelee, Holiday Beach**	Unknown	3	Unknown	3
• **Lake Erie Central/Eastern basin: Port Dover, Port Burwell, Rondeau Bay**	Low	3	Unknown	3
• **Detroit River**	Medium	3	Unknown	3
• **St. Clair River**	Medium	3	Unknown	3
• **Lake St. Clair**	Low	3	Unknown	3
Lake Ontario (DU2)				
• **Trent River**	High	2	Decreasing	2
• **Salmon River**	High	2	Stable	2
• **Moira system: Moira, Skootamatta and Black Rivers**	High	2	Stable	2

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

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

Table 3. Population Status for Channel Darter (DU1 & 2) populations in Ontario, resulting from both the Relative Abundance Index and Population Trajectory. Certainty assigned to each Population Status is reflective of the lowest level of certainty associated with either initial parameter (Relative Abundance Index, or Population Trajectory).

Population	Population Status	Certainty
DESIGNATABLE UNIT 1		
Lake Erie Western basin: Pelee Island, Point Pelee, Holiday Beach	Unknown	3
Lake Erie Central/Eastern basin: Port Dover, Port Burwell, Rondeau Bay	Poor	3
Detroit River	Poor	3
St. Clair River	Poor	3
Lake St. Clair	Poor	3
DESIGNATABLE UNIT 2		
Trent River	Fair	2
Salmon River	Good	2
Moira system: Moira, Skootamatta and Black Rivers	Good	2

HABITAT AND RESIDENCE REQUIREMENTS

Element 4: *Describe the habitat properties that Channel Darter needs for successful completion of all life-history stages. Describe the function(s), feature(s), and attribute(s) of the habitat, and quantify by how much the biological function(s) that specific habitat feature(s) provides varies with the state or amount of habitat, including carrying capacity limits, if any.*

Adult Channel Darter inhabit small to large sized rivers or connecting channels with moderate current and nearshore areas of lakes with gravel or coarse-sand beaches (Bouvier and Mandrak 2010). Lake Ontario (DU2) populations are riverine and confined to tributaries of eastern Lake Ontario, while Lake Erie (DU1) populations are primarily lacustrine, relying on nearshore beach habitat of large lakes, but also riverine, relying on the flowing waters of connecting channels. Within both DU's, Channel Darter can be found in a variety of habitats including coarse sand beaches, riffles, shoals, and pools (Reid et al. 2005, Bouvier and Mandrak 2010). Coarse substrates, such as cobble and gravel, are common in areas occupied by Channel Darter, especially in rivers (Reid et al. 2005, Reid et al. 2016). Fine particles such as silt and organic material are rarely used by adults. Much of the information about Channel Darter habitat is based on adults collected during the summer months. Very little is known about juvenile habitat use or the habitat features used by Channel Darter during winter (COSEWIC 2016).

Channel Darter is believed to migrate short distances to access spawning shoals and riffle habitat (Winn 1953). Spawning occurs in June in Ontario in areas with coarse substrate dominated by cobble and gravel; however, the species has also been observed spawning near larger rocks (Lane et al. 1996a, Bouvier and Mandrak 2010, Reid et al. 2016). Water temperature during spawning ranged from 14 – 26 °C in Ontario and Quebec (Comtois et al. 2004, Reid 2004). In the Trent River, Channel Darter was associated with water depths from 0.1 – 0.4 m and water temperatures ranged from 19 – 27 °C (Reid et al. 2016) during the spawning period.

FUNCTIONS, FEATURES AND ATTRIBUTES

Essential functions, features, and attributes associated with Channel Darter habitat have been described to guide the identification of critical habitat for this species (Table 4). The habitat required for each life stage has been assigned a function that corresponds to a biological requirement of Channel Darter (e.g., spawning, nursery). In addition to the habitat function, a feature has been assigned to each life stage, considered as the structural component of the habitat necessary to complete the function and 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 from the literature for each life stage have been combined with habitat attributes from current records to show the range of habitat attributes within which Channel Darter may be found (see Table 4 and references therein).

Table 4. Summary of the essential functions, features, and attributes for each life stage of Channel Darter. Habitat attributes from published literature and those measured during Channel Darter surveys have been combined to derive the habitat attributes required for the delineation of critical habitat (see text for a detailed description of categories).

			Habitat Attributes		
Life Stage	**Function**	**Features**	**Scientific Literature**	**Current Records**	**For Identification of Critical Habitat**
Spawn to Hatch	Spawning Cover Nursery	Riffle and shoal habitats	• Spawning has been observed at temperatures ranging from 14°C to 26°C (Comtois et al. 2004, Reid 2004) • Spawns on gravelly shoals in Michigan lakes (Winn 1953), but also near large rocks (Lane et al. 1996a)	• Spawning occurs from May to mid-July in the Trent River (DFO 2016) • Mid-column water velocities of 0.46 m/s (range 0 – 1.0), mean water depths of 0.49 m (range 0.23 – 0.77), and coarse substrate (21% gravel, 64% cobble) were found in areas containing gravid females in the Trent River (Reid 2004, Reid et al. 2016)	For DU1 lacustrine populations • coarse sand – fine gravel beaches For DU2 • Riffles and shoals with moderate flow • Cobble and gravel substrates • Known from depths <1m • Flow velocity 0 – 1 m/s
YOY/ Juvenile (age 1 until sexual maturity)	Feeding Cover Nursery Winter refugia	Riffles, shoals, pools	• Strong association with gravel and sand and moderate association with silt substrates (Lane et al. 1996b) • Depths ranging from 0 – 5+ m (Lane et al. 1996b). • Juveniles (fish < 35 mm TL) likely used coarse sand-fine gravel beaches at Point Pelee (inferred from Reid and Mandrak 2008)	• None available	• Unknown

			Habitat Attributes		
Life Stage	**Function**	**Features**	**Scientific Literature**	**Current Records**	**For Identification of Critical Habitat**
Adult	Feeding Cover	Riffles, shoals, coarse-sand beaches, pools	• For Lake Ontario tributaries, avg. depth = 0.35 m, avg. width = 21.3m, avg. flow velocity = 0.34 m/s, avg. conductivity = 239.2, median particle size = 123 mm (Reid et al. 2005)	For DU1 (riverine populations) • Mean substrate (percent composition of site) as follows: 32% sand, 32% clay, 20% silt, 7% gravel, 5% boulder, 4% organic (n=20; DFO unpublished data) • $\bar{x}$ DO = 9.99 mg/L $\bar{x}$ water temp = 18.1 °C $\bar{x}$ Turbidity = 5.43 ntu $\bar{x}$ Stream depth = 4.1 m (1.7 – 5.3 m) $\bar{x}$ stream velocity = 0.22 m/s ○ n = 30; DFO unpublished data) For DU2 • Avg. water velocity of 0.32 m/s in Trent River (Reid 2019) • Avg. depth of 0.42 m in Trent River (Reid 2019) • Riffles flowing into deep pool or run habitats (Reid et al. 2005)	For DU1 lacustrine populations • coarse sand – fine gravel beaches For DU1 riverine populations • Known from water depths of less than 6 m • Water velocity ranging between 0.03 – 0.57 m/s (DFO unpublished data) For DU2 • Riffles and shoals with depth less than 1 m and flow less than 1 m/s • Coarse sand, gravel and cobble
Adult	Winter refugia	Coarse-sand beaches, pools	• None available	• None available	Unknown

THREATS AND LIMITING FACTORS TO SURVIVAL AND RECOVERY

Element 8: *Assess and prioritize the threats to the survival and recovery of the Channel Darter.*

THREAT CATEGORIES

Threat assessment was based on threat categories identified in Bouvier and Mandrak (2010) and COSEWIC (2016). When new threat information following Bouvier and Mandrak (2010) was available, it was incorporated into the current threat assessment; otherwise, threat ratings from the 2010 RPA were retained. Analysis of recent literature indicated that new information was only available for altered flow, exotic species, and incidental catch as it relates to impacts on Channel Darter or its habitat.

A variety of threats negatively impact Channel Darter across its range. The greatest threats to the survival and persistence of Channel Darter (DUs 1 & 2) are related to habitat alteration and invasive species. Important threats to habitat include degradation due to sediment loading, contaminants, nutrient loading, shoreline modifications, altered flow regimes, and barriers to movement. Aquatic invasive species, specifically the Round Goby, is a significant threat to Channel Darter via competition for food resources. Incidental harvest can lead to direct mortality of Channel Darter, but is not suspected to be a significant source of mortality. These threats may be amplified by the effects of climate change, which is expected to increase water and air temperatures, decrease water levels, shorten the duration of ice cover, increase the frequency of extreme weather events, change the dynamics of pathogens and diseases, and shift predator-prey dynamics, all of which may negatively impact native fishes (Lemmen and Warren 2004). Channel Darter, a species that spawns in shallow riffle or run habitat, may be particularly vulnerable to changing water levels. Comparison of threats between DUs reveal important distinctions. Altered flow regimes and barriers to movement are more important in DU2 as many man-made barriers/dams exist for the Trent and Moira river populations. Also, Round Goby is not yet present for each population in DU2, while all DU1 populations have been susceptible to negative impacts from Round Goby over the last twenty years.

Turbidity and sediment loading

Turbidity and sediment loading occurs throughout both DUs, but affects lacustrine and riverine populations differently. For example, development of breakwaters, docks, and jetties in lacustrine environments has led to shoreline hardening in many areas, causing habitat change through increased deposition of fine sediments. In riverine populations, turbidity and sediment loading can occur through several forms of landcover change, including agricultural activity and urbanization. Increased sediment can smother eggs laid in gravel and cobble habitats, reduce benthic prey availability, and may reduce dissolved oxygen in the benthic zone (Berkman and Rabeni 1987, COSEWIC 2009). An increase in sedimentation has occurred at numerous locations where Channel Darter has occurred historically (Phelps and Francis 2002). No causal studies on the effect of turbidity exist for Canadian populations; however, two studies conducted in the United States identified a correlation between Channel Darter declines and increasing turbidity (Trautman 1981, Berkman and Rabeni 1987).

Contaminant and toxic substances

Channel Darter is presumed to be intolerant to pollution, but little research has been conducted on the effects of contaminants. Within DU1, the species inhabits two Great Lakes Areas of Concern (AOC; Detroit River and St. Clair River) where elevated toxicants are known to affect aquatic species (ECCC 2017). For example, the DNA damage ratio in cells from other benthic fishes in the Detroit River [Brown Bullhead (*Ameiurus nebulosus*) and Common Carp (*Cyprinus carpio*)] was more than twice that of fishes from healthier regions of the Great Lakes, possibly due to high levels of PAHs and PCBs found in sediments (Green et al. 2010). Toxicants are also a concern for DU2 populations, as all locations can be found within the Bay of Quinte AOC where high PCB and dioxin loads have been observed in fishes near the outlet of the Trent and Moira rivers (Simmons et al. 2014).

Nutrient loading

Degradation of Channel Darter habitat may result from nutrient loading (nitrates and phosphorus) due to urbanization and agricultural practices. Nutrient loading can result from fertilizer releases into a waterbody, loadings from sewage treatment plants, and runoff from manure piles. Increased nutrient levels can subsequently lead to the development of algal blooms and, consequently, decreased levels of dissolved oxygen. Eutrophication has been identified as an important issue in certain areas occupied by populations in DU1 such as the south shore of Lake St. Clair, Detroit River, Rondeau Bay and Point Pelee (EERT 2008). Similarly, Lake Erie has seen an increase in large harmful algal blooms as a result of nutrient loading and this has led to increased phytoplankton biomass and hypoxia since the mid-1990s (Scavia et al. 2014, Watson et al. 2016). The effects of nutrient-driven hypoxia can be ecologically significant as was observed on Lake Erie's north shore in 2012, when nutrient loading and subsequent hypoxia resulted in a large die-off of fishes (Rao et al. 2014). This threat is less of a concern for DU2; however, urban areas and agricultural activities, which can result in loading, occur near areas occupied by Channel Darter.

Shoreline modifications

Shoreline modification of Channel Darter habitat has been identified as more important for lacustrine as opposed to riverine populations (COSEWIC 2016), and thus is of greater concern for populations within DU1. Shoreline modifications can include the creation of docks, jetties, marinas, breakwaters, and groynes, all of which lead to shoreline hardening (Reid and Mandrak 2008). The alteration of shorelines can also affect the transport of sediments, which has led to decreased habitat in some areas. For example, the creation of two jetties at Port Burwell and Port Dover resulted in a high degree of sediment deposition, which made the surrounding habitat unsuitable for Channel Darter (Reid and Mandrak 2008). In addition to shoreline hardening on Lake Erie's north shore, substantial modification of the Detroit and St. Clair rivers has occurred via filling and dredging to facilitate navigation (Moulton and Thieme 2009).

Altered flow regimes

Suitable flow velocity is needed for spawning to occur in riverine populations of Channel Darter; spawning behaviour may cease when flow is reduced beyond a critical threshold (Winn 1953). Within DU2, flow is altered by dams on the Trent and Moira rivers within the range occupied by Channel Darter (Reid et al. 2005). In the Trent River, flow from multiple dams is altered for the purposes of navigation, public safety, and flood control (Reid et al. 2016). Dam-induced flow alteration has caused the critical habitat of Channel Darter to experience reduced flow (or the loss of water entirely) during past dewatering events, one of which also stranded several Channel Darter individuals (COSEWIC 2016, Reid et al. 2016). Reid et al. (2016) investigated flow alteration throughout the Trent River and found that river discharge influences the availability of riffle and shoal habitats where Channel Darter is found. Results from the study indicated that optimal flow differed between sites based on river morphology (Reid et al. 2016). As a result, optimal flow targets differ for different areas of the Trent River to ensure that spawning habitats have adequate flow, particularly during the June spawning period (Reid et al. 2016).

For DU1, altered flow regimes are of less of a concern compared to DU2. Flow regimes of the Detroit and St. Clair rivers have been altered significantly since the late 1800s by way of large-scale dredging and disposal of spoils (Moutlon and Thieme 2009, Bennion and Manny 2011). Maintenance dredging for the purposes of navigation still occurs on an annual basis. Although the direct impacts of maintenance dredging on fish species at risk are generally low (Barnucz et al. 2015), indirect effects caused by altered flow regimes could negatively impact Channel Darter.

Barriers to movement

Dams can impact fishes by altering water flow and prey availability, and can reduce overall species diversity (Haas et al. 2010, Freedman 2010, Freedman et al. 2014). The primary impact of dams for most species is the disruption of migratory behavior, which can restrict access to optimal areas of reproduction, foraging, rearing, or cover. Barriers to movement are found throughout DU2, with the Trent River in particular having multiple dams within the range occupied by Channel Darter. These barriers have led to fragmented populations of Channel Darter throughout the Trent River (Reid et al. 2016). The Moira System also has several dams, which may have contributed to reduced Channel Darter distribution in this system (Reid et al. 2005). Barriers that prevent Channel Darter from accessing suitable spawning habitat can negatively impact spawning success in this species (Phelps and Francis 2002). Any barriers to movement, whether natural or artificial, have the potential to impact Channel Darter as individuals are thought to migrate seasonally to different habitats (Branson 1967, Cooper 1983). There are no known barriers to movement for DU1.

Invasive species and diseases

Round Goby, a small benthic fish species native to the Ponto-Caspian region of Europe, is pervasive throughout much of the Canadian range of Channel Darter and has been implicated in the decline of other small-bodied benthic fishes in the Great Lakes basin (French and Jude 2001, Janssen and Jude 2001). Round Goby may negatively impact native benthic fishes through competition for food resources, predation, aggressive behavior and spawning interference (Corkum et al. 2004, Reid and Mandrak 2008). Diet overlap is also a possibility, as several important invertebrate prey items for Channel Darter were also consumed by Round Goby in the Trent River (Reid 2019). Furthermore, Dipterans and Ephemeropterans are known important prey items for both Channel Darter and Round Goby (Reid and Mandrak 2008). Based on habitat and diet overlap, Reid (2019) surmised that Round Goby are potentially competing with Channel Darter for ecological resources in the Trent River. Further research is required to better understand the impacts, both direct and indirect, that Round Goby may have on Channel Darter in Ontario. Round Goby is prevalent throughout DU1 whereas in DU2, Round Goby is found only within the Trent River. Round Goby are of greatest concern for DU1 populations.

Incidental harvest

The use of Channel Darter as baitfish is illegal in Ontario (OMNRF 2018). However, as with most fisheries, the potential for bycatch exists during the harvest of baitfish by anglers and commercial harvesters. The likelihood of bycatch is dependent on the distribution and intensity of baitfish harvest in relation to the distribution and abundance of Channel Darter.

Bycatch of Channel Darter during the angler harvest of bait is currently unknown, but bycatch from commercial harvest has been estimated (Drake and Mandrak 2014a). Commercial harvest occurs in tributary streams of the Great Lakes, and nearshore areas of Lake Erie. Drake and Mandrak (2014a) estimated bycatch-effort relationships based on species-specific catchability and the co-occurrence of target and non-target fishes for nearshore areas of Lake Erie. Based on a general harvest model, the median bycatch likelihood for Channel Darter was $p = 0.0042$, indicating that 240 harvest events would be necessary for a single event to capture Channel Darter as bycatch during the harvest of target baitfish species in Lake Erie (Drake and Mandrak 2014a). Given the species rarity, the chance of angler encounter is likely to be similarly low, but has not been quantified (Drake and Mandrak 2014b). During an extensive survey of baitfish retailers in southern Ontario, Channel Darter was not detected and darters in general represented a low proportion of total catch (Drake and Mandrak 2014b). Overall, these results indicate that the probability for incidental harvest and transfer throughout the pathway for Channel Darter is low for both DUs.

THREAT ASSESSMENT

To assess the Threat Level of Channel Darter DUs 1 & 2, each threat was ranked in terms of the threat Likelihood of Occurrence (LO), threat Level of Impact (LI) and Causal Certainty (CC) on a population-by-population basis, following the approach outlined in DFO (2014). The Likelihood of Occurrence was assigned as Known, Likely, Unlikely, Remote or Unknown, and the Level of Impact was assigned as Extreme, High, Medium, Low, or Unknown (Table 5). The level of certainty associated with each threat was assessed and classified as: 1=very high, 2=high, 3=medium, 4= low, 5=very low. The Population-Level Threat Occurrence (PTO), Threat Frequency (PTF) and Threat Extent (PTE) were also evaluated and assigned a status based on the definitions outlined in Table 5 (Table 6a; Table 6b; Table 7; DFO 2014). The Likelihood of Occurrence and Level of Impact for each population were subsequently combined in the Threat Risk Matrix (Table 8) resulting in the Population-Level Threat Risk (PTR, Table 9; Table 10). The DU-level Threat Assessment in Table 11 is a roll-up of population-level threats identified in Table 9 and 10.

Table 5. Definition and terms used to describe likelihood of occurrence (LO), level of impact (LI), causal certainty (CC), population level threat occurrence (PTO), threat frequency (PTF) and threat extent (PTE) Information taken from DFO (2014).

Term	Definition
Likelihood of Occurrence (LO)	
Known or very likely to occur (K)	This threat has been recorded to occur 91-100%
Likely to occur (L)	There is a 51-90% chance that this threat is or will be occurring
Unlikely (UL)	There is 11-50% chance that this threat is or will be occurring
Remote (R)	There is 1-10% or less chance that this threat is or will be occurring
Unknown (U)	There are no data or prior knowledge of this threat occurring or known to occur in the future
Level of Impact (LI)	
Extreme (E)	Severe population decline (e.g., 71-100%) with the potential for extirpation
High (H)	Substantial loss of population (31-70%) or threat would jeopardize the survival or recovery of the population
Medium (M)	Moderate loss of population (11-30%) or threat is likely to jeopardize the survival or recovery of the population
Low (L)	Little change in population (1-10%) or threat is unlikely to jeopardize the survival or recovery of the population

Term	Definition
Unknown (U)	No prior knowledge, literature or data to guide the assessment of threat severity on population
Causal Certainty (CC)	
Very high (1)	Very strong evidence that threat is occurring and the magnitude of the impact to the population can be quantified
High (2)	Substantial evidence of a causal link between threat and population decline or jeopardy to survival or recovery
Medium (3)	There is some evidence linking the threat to population decline or jeopardy to survival or recovery
Low (4)	There is a theoretical link with limited evidence that threat is leading to a population decline or jeopardy to survival or recovery
Very low (5)	There is a plausible link with no evidence that the threat is leading to a population decline or jeopardy to survival or recovery
Population-Level Threat Occurrence (PTO)	
Historical (H)	A threat that is known to have occurred in the past and negatively impacted the population
Current (C)	A threat that is ongoing, and is currently negatively impacting the population
Anticipatory (A)	A threat that is anticipated to occur in the future, and will negatively impact the population
Population-Level Threat Frequency (PTF)	
Single (S)	The threat occurs once
Recurrent (R)	The threat occurs periodically, or repeatedly
Continuous (C)	The threat occurs without interruption
Population- Level Threat Extent (PTE)	
Extensive (E)	71-100% of the population is affected by the threat
Broad (B)	31-70% of the population is affected by the threat
Narrow (NA)	11-30% of the population is affected by the threat
Restricted (R)	1-10% of the population is affected by the threat

Table 6a. Threat Likelihood of Occurrence (LO), Level of Impact (LI), Causal Certainty (CC), Population-Level Threat Occurrence (PTO), Population-Level Threat Frequency (PTF) and Population-Level Threat Extent (PTE) for Channel Darter DU1 populations in the Detroit River, Rondeau Bay, and Lake Erie Western Basin (Point Pelee). The threat ratings were based on COSEWIC (2016). Grey cells indicate that the threat is not applicable to the population due to the nature of the aquatic system where the population is located.

	Detroit River							Lake Erie Western Basin (Point Pelee)							Lake Erie Central Basin (Rondeau Bay)						
	LO	**LI**	**CC**	**PTO**	**PTF**	**PTE**	**Ref**	**LO**	**LI**	**CC**	**PTO**	**PTF**	**PTE**	**Ref**	**LO**	**LI**	**CC**	**PTO**	**PTF**	**PTE**	**Ref**
Turbidity and sediment loading	L	M	4	H,C	R,C	E	-	L	M	4	H,C	R,C	E	3	L	M	4	H,C	R,C	E	-
Contaminant and toxic substances	K	M	4	H,C	R,C	E	-	U	U	4	H,C	R,C	E	4	U	U	4	H,C	R,C	E	-
Nutrient loading	L	M	4	H,C	R,C	E	-	L	M	4	H,C	R,C	E		L	M	4	H,C	R,C	E	-
Shoreline modifications	K	M	4	H	R	B	-	K	H	3	H	R	B	4	K	H	3	H	R	B	-
Altered flow regimes	K	H	4	H,C	R,C	B	-														
Barriers to movement																					
Exotic species and diseases	K	H	3	C	C	E	-	K	H	3	C	C	E	-	K	H	3	C	C	E	-
Incidental harvest	K	L	4	H,C	R	R	-	K	L	4	H,C	R	R	-	K	L	4	H,C	R	R	-

Table 6b. Threat Likelihood of Occurrence (LO), Level of Impact (LI), Causal Certainty (CC), Population-Level Threat Occurrence (PTO), Population- Level Threat Frequency (PTF) and Population-Level Threat Extent (PTE) for Channel Darter DU1 populations in the St. Clair River, Lake St. Clair, and the Lake Erie Central Basin (near Port Burwell). The threat ratings were based on COSEWIC (2016). Grey cells indicate that the threat is not applicable to the population due to the nature of the aquatic system where the population is located.

	Lake Erie Central Basin (Port Burwell)							St. Clair River							Lake St. Clair						
	LO	**LI**	**CC**	**PTO**	**PTF**	**PTE**	**Ref**	**LO**	**LI**	**CC**	**PTO**	**PTF**	**PTE**	**Ref**	**LO**	**LI**	**CC**	**PTO**	**PTF**	**PTE**	**Ref**
Turbidity and sediment loading	L	M	4	H,C	R,C	E	-	K	L	4	H,C	R,C	E	-	K	M	4	H,C	R,C	E	-
Contaminant and toxic substances	U	U	4	H,C	R,C	E	-	K	U	4	H,C	R,C	E	-	K	L	4	H,C	R,C	E	-
Nutrient loading	L	M	4	H,C	R,C	E	-	K	L	4	H,C	R,C	E	-	K	L	4	H,C	R,C	E	-
Shoreline modifications	K	H	3	H	R	B	-	K	M	4	H	R	B	-	K	H	4	H	R	B	-
Altered flow regimes								K	L	4	H,C	R,C	B	-	UL	H	4	H,C	R,C	B	-
Barriers to movement																					
Exotic species and diseases	K	H	3	C	C	E	-	K	H	3	C	C	E	-	K	H	3	C	C	E	-
Incidental harvest	K	L	4	H,C	R	R	-	K	L	4	H,C	R	R	-	K	L	4	H,C	R	R	-

Table 7. Threat Likelihood of Occurrence (LO), Level of Impact (LI), Causal Certainty (CC), Population-Level Threat Occurrence (PTO), Population-Level Threat Frequency (PTF) and Population-Level Threat Extent (PTE) for Channel Darter DU2 populations in Ontario. The threat ratings were based on COSEWIC (2016).

	Moira River							Salmon River							Trent River						
	LO	**LI**	**CC**	**PTO**	**PTF**	**PTE**	**Ref**	**LO**	**LI**	**CC**	**PTO**	**PTF**	**PTE**	**Ref**	**LO**	**LI**	**CC**	**PTO**	**PTF**	**PTE**	**Ref**
Turbidity and sediment loading	UL	M	4	H,C	R,C	E	1,2	UL	M	4	H,C	R,C	E	-	UL	M	4	H,C	R,C	E	-
Contaminant and toxic substances	UL	M	4	H,C	R,C	E	-	UL	L	4	H,C	R,C	E	-	UL	L	4	H,C	R,C	E	-
Nutrient loading	UL	L	4	H,C	R,C	E	8	UL	L	4	H,C	R,C	E	-	UL	L	4	H,C	R,C	E	-
Shoreline modifications	UL	L	4	H	R	NA	-	UL	L	4	H	R	NA	-	L	L	4	H	R	NA	-
Altered flow regimes	K	L	4	H,C	R,C	B	-	K	L	4	H,C	R,C	R	-	K	H	4	H,C	R,C	B	-
Barriers to movement	K	M	3	H,C	C	NA	-	K	L	3	H,C	C	R	-	K	M	3	H,C	C	B	-
Exotic species and diseases	L	H	3	A	C	E	-	L	H	3	A	C	E	-	K	H	3	C	C	E	-
Incidental harvest	K	L	4	H,C	R	R	-	K	L	4	H,C	R	R	-	K	L	4	H,C	R	R	-

Table 8. The Threat Level Matrix combines the Likelihood of Occurrence and Level of Impact rankings to establish the Threat Level for Channel Darter DUs 1 & 2 populations in Ontario. The resulting Threat Level has been categorized low, medium, high or unknown.

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

Table 9. Threat Level Assessment for Channel Darter DU1 populations in Ontario, resulting from an analysis of both the Threat Likelihood and Threat Impact. The number in brackets refers to the level of certainty associated with the threat impact (1 = Very High; 2 = High; 3 = Medium; 4 = Low; 5 = Very Low).

	DU1					
Threat	**Detroit River**	**Lake Erie Western Basin (Point Pelee)**	**Lake Erie Central Basin (Rondeau Bay)**	**Lake Erie Central Basin (Port Burwell)**	**St. Clair River**	**Lake St. Clair**
Turbidity and sediment loading	Medium (4)	Medium (4)	Medium (4)	Medium (4)	Low (4)	Medium (4)
Contaminant and toxic substances	Medium (4)	Unknown (4)	Unknown (4)	Unknown (4)	Unknown (4)	Low (4)
Nutrient loading	Medium (4)	Medium (4)	Medium (4)	Medium (4)	Low (4)	Low (4)
Shoreline modifications	Medium (4)	High (3)	High (3)	High (3)	Medium (4)	High (4)
Altered flow regimes	High (4)				Low (4)	Medium (4)
Barriers to movement						
Exotic species and diseases	High (3)	High (3)	High (3)	High (3)	High (3)	High (3)
Incidental harvest	Low (4)	Low (4)	Low (4)	Low (4)	Low (4)	Low (4)

Table 10. Threat Level Assessment for Channel Darter DU2 populations in Ontario, resulting from an analysis of both the Threat Likelihood and Threat Impact. The number in brackets refers to the level of certainty associated with the threat impact (1 = Very High; 2 = High; 3 = Medium; 4 = Low; 5 = Very Low).

	DU2		
Threat	**Moira System**	**Salmon River**	**Trent River**
Turbidity and sediment loading	Medium (4)	Medium (4)	Medium (4)
Contaminant and toxic substances	Medium (4)	Low (4)	Low (4)
Nutrient loading	Low (4)	Low (4)	Low (4)
Shoreline modifications	Low (4)	Low (4)	Low (4)
Altered flow regimes	Low (4)	Low (4)	High (4)
Barriers to movement	Medium (3)	Low (3)	Medium (3)
Exotic species and diseases	High (3)	High (3)	High (3)
Incidental harvest	Low (4)	Low (4)	Low (4)

Table 11. DU-level Threat Assessment for Channel Darter DU1 & 2 in Canada, resulting from a roll-up of population-level Threat Assessment. DU-level Threat Risk, Threat Occurrence (H = Historical; C = Current; A = Anticipatory), Threat Frequency (S = Single; R = Recurrent; C = Continuous), and Threat Extent (E = Extensive; B = Broad; R = Restricted). The DU-level Threat Extent is calculated as the mode of population-level Threat Extent.

Threat	**DU-level Threat Risk**		**DU-level Threat Occurrence**		**DU-level Threat Frequency**		**DU-level Threat Extent**	
	DU1	**DU2**	**DU1**	**DU2**	**DU1**	**DU2**	**DU1**	**DU2**
Turbidity and sediment loading	M	M	H,C	H,C	R,C	R,C	E	E
Contaminant and toxic substances	M	M	H,C	H,C	R,C	R,C	E	E
Nutrient loading	M	L	H,C	H,C	R,C	R,C	E	E
Shoreline modifications	H	L	H	H	R	R	B	NA
Altered flow regimes	H	H	H,C	H,C	R,C	R,C	B	B
Barriers to movement		M		H,C		C		NA*
Exotic species and diseases	H	H	C	C	C	C	E	E
Incidental harvest	L	L	H,C	H,C	R	R	R	R

**Mode could not be calculated.*

Element 9: *Identify the activities most likely to threaten (i.e., damage or destroy) the habitat properties identified in elements 4-5 and provide information on the extent and consequences of these activities.*

Based on the threat assessment, the greatest threat to habitat for DUs 1 & 2 is altered flow regimes. There are multiple dams that alter flow in the Trent and Moira river systems for the purposes of navigation, public safety, and flood control. Altered flows can lead to failure to initiate spawning or, in extreme cases, dewatering of spawning habitat. Alterations of channel morphology by way of dredging and water-level compensating works has altered historical flow regimes in the Detroit River and has led to the loss of fish spawning habitat (Bennion and Manny 2011). For DU1, shoreline modifications also pose a threat to Channel Darter. Shoreline modification includes activities such as the creation of docks, jetties, marinas, breakwaters, and groynes that are common on the north shore of Lake Erie, all of which lead to shoreline hardening. These activities have been shown to alter nearshore sediment transport, which has negatively impacted Channel Darter habitat through the deposition of fine substrates. These threats may be amplified by the effects of climatic change, including increased water temperatures, decreased water levels, and increased frequency of extreme weather events.

Element 11: *Discuss the potential ecological impacts of the threats identified in element 8 to Channel Darter and other co-occurring species. List the possible benefits and disadvantages to the target species and other co-occurring species that may occur if the threats are abated. Identify existing monitoring efforts for the target species and other co-occurring species associated with each of the threats, and identify any knowledge gaps.*

Altered flow regimes and modified shorelines can decrease the availability and quality of habitat to Channel Darter and other benthic fish species. In addition, fragmentation through the construction of barriers (e.g., dams and weirs) can alter habitat function, including by restricting movements of individual fish and limiting gene flow between populations. In Ontario, Channel Darter co-occurs with other SARA-listed aquatic species such as Eastern Sand Darter (DU1; *Ammocrypta pellucida*), River Redhorse (DU2; *Moxostoma carinatum*), Eastern Pondmussel (DUs 1 & 2; *Ligumia nasuta*), Round Pigtoe (DU1; *Pleurobema sintoxia*), Mapleleaf (DU1; *Quadrula quadrula*), Round Hickorynut (DU1; *Obovaria subrotunda*), Rainbow (DUs 1&2; *Villosa iris*), and Wavy-rayed Lampmussel (DU1; *Lampsilis fasciola*). Therefore, the restoration of Channel Darter habitat would likely benefit several fish and mussel species at risk. Improvements to Channel Darter habitat such as the removal of barriers would likely benefit fishes and mussels found in the those watersheds by increasing habitat connectivity, but may also facilitate range expansion of the invasive Round Goby.

Channel Darter is poorly monitored throughout much of its range, particularly for the DU1 population. There are ongoing efforts to monitor Channel Darter in the Trent River (DU2), but targeted monitoring does not occur to the same degree for DU1. Many captures of Channel Darter in DU1 have been incidental, resulting from targeted sampling for other species or general fish community monitoring.

SCENARIOS FOR MITIGATION OF THREATS AND ALTERNATIVES TO ACTIVITIES

Element 16: *Develop an inventory of feasible mitigation measures and reasonable alternatives to the activities that are threats to the species and its habitat (as identified in element 8 and 10).*

Threats to species survival and recovery can be reduced by implementing mitigation measures to reduce or eliminate potential harmful effects that could result from works or undertakings associated with projects or activities in Channel Darter habitat. Within this section, an updated review of works, undertakings, and activities is provided; however, mitigations and alternatives to activities that threaten Channel Darter or its habitat have not changed since the previous RPA and therefore are not provided in this document [see Bouvier and Mandrak (2010) for best available mitigations and alternatives].

A variety of works, undertakings, and activities have occurred in Channel Darter habitat in the last five years, with project types including shoreline and streambank works (e.g., stabilization), dredging, infilling, and placing structures in water. A review has been completed summarizing the types of work, activity, or projects that have been undertaken in habitat known to be occupied by Channel Darter (Table 12). 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 2014 through 2019. Forty five (45) projects were identified in Channel Darter habitat, but these likely do not represent a complete list of projects or activities that have occurred in these areas (Table 12). Some projects occurring near Channel Darter may also impact the species, but were only included in the review if they were in direct proximity to occurrence records. Some projects may not have been reported to DFO as they may have met self-assessment requirements and were thus not reported. The review included those areas where both current and historical Channel Darter occurrence records exist, defined as those occurring between 1999 and 2018.

The only project authorized under the *Fisheries Act* was for infilling to create an aggregate terminal in the Detroit River. This project was issued four authorizations as permitting conditions changed during the life of the project; therefore, the total number of projects is less than number of authorizations. Half the projects (22) were triaged out from further review as standard mitigation was proposed. Nineteen (19) projects were deemed low risk to fishes and fish habitat and letters of advice were provided, specifying the proposed mitigation. Without appropriate mitigation, projects or activities occurring near these areas could have impacted Channel Darter (e.g., increased sedimentation and/or nutrient loading from upstream or adjacent channel works).

The most frequent project types were dredging, shoreline stabilization, and shoreline infilling. 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 Channel Darter habitat in the future. The primary project proponents were adjacent landowners.

There are a number of projects currently proposed that would likely impact Channel Darter, notably hydro retrofits and infrastructure upgrades in the Trent Severn system.

Some threats affecting Channel Darter include shoreline hardening, dredging, and nutrients and effluents from urban waste and spills. Habitat-related threats to Channel Darter can been linked to the Pathways of Effects developed by DFO’s Fish and Fish Habitat Protection Program (FFHPP). DFO FFHPP 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. For mitigations and alternatives to non-habitat related threats, please see Bouvier and Mandrak (2010).

Table 12. Summary of works, projects and activities that have occurred during the period of April 2014 to April 2019 in areas known to be occupied by Channel 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 Channel 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; 18 – Structure removal; 19 – Placement of marine finfish aquaculture site).

Work/Project/Activity	**Threats** (associated with work/project/activity)								**Watercourses / Waterbodies** (number of works/projects/activities between April 2014 – April 2019)	
	Habitat removal and alteration	**Nutrient loading**	**Turbidity and sediment loading**	**Contaminants and toxic substances**	**Altered Flow Regime**	**Barriers to Movement**	**Exotic species and disease**	**Incidental harvest**	**DU1**	**DU2**
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	3, 4, 5, 6, 10, 11, 12, 14, 16, 17, 18	3, 4, 5, 6, 10, 11, 12, 14, 16, 17, 18	-	-	-	-
Water crossings (bridges, culverts, open cut crossings)	✓	-	✓	✓	✓	✓	-	-	1	1
Shoreline, streambank work (stabilization, infilling, retaining walls, riparian vegetation management)	✓	-	✓	✓	-		✓	-	18	3
Instream works (channel maintenance, restoration, modifications, realignments, dredging, aquatic vegetation removal)	✓	✓	✓	✓	✓	✓	✓	-	11	1

Work/Project/Activity	Threats (associated with work/project/activity)								Watercourses / Waterbodies (number of works/projects/activities between April 2014 – April 2019)	
	Habitat removal and alteration	Nutrient loading	Turbidity and sediment loading	Contaminants and toxic substances	Altered Flow Regime	Barriers to Movement	Exotic species and disease	Incidental harvest	DU1	DU2
Water management (stormwater management, water withdrawal)	-	✓	✓	✓	✓	✓	-	-	0	0
Structures in water (boat launches, docks, effluent outfalls, water intakes, dams)	✓	✓	✓	✓	✓	✓	✓	-	8	2
Baitfishing	-	-	-	-	-	-	-	✓	-	-
Invasive species introductions (accidental and intentional)	-	-	-	-	-	-	✓	-	-	-

SOURCES OF UNCERTAINTY

Sources of uncertainty for Channel Darter in DUs 1 and 2 relate to incomplete knowledge of life history, distribution, abundance, and threats; these uncertainties are highlighted in the federal recovery strategy and previous RPA (DFO 2013, Bouvier and Mandrak 2010). Life history parameters outlined in Bouvier and Mandrak (2010) and Venturelli et al. (2010), such as clutch size, fecundity, age at maturity, and maximum age, need to be evaluated to better understand whether variation exists within and between DUs 1 and 2; however, life history parameters are difficult to obtain without lethal sampling. Further knowledge of the life history of Channel Darter will improve the development of population models and associated recovery targets (Venturelli et al. 2010). A long-term, standardized monitoring program would allow the distribution and abundance of extant populations to be assessed, as well as the identification of spawning sites and overwintering areas. Repeat standardized sampling would help inform estimates of population trajectory and abundance and, pending the capture of early life stages, would inform habitat use for juveniles and young of the year. Identifying the causal mechanisms leading to the decline of Channel Darter, including the impacts of Round Goby, barriers to movement, shoreline alterations, contaminants, and climate change, would reduce uncertainty in threat assessment and allow for the cumulative effect of these threats to be evaluated. The feasibility of rehabilitating degraded habitats that once supported Channel Darter populations should also be investigated. Evaluating the extent of past and present suitable habitat would support this process. Factors that may be limiting abundance, such as prey availability, predation, fish community interactions, and disease, are additional sources of uncertainty that require future research.

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APPENDIX

Table A.1. Summary of recent (2010 – 2019) fish surveys within the known distribution of Channel Darter for DU1. Gear: BPEF = Backpack Electrofishing Unit, BEF = Boat electrofishing, MFN =Mini fyke net, GN = Gillnet, HN = Hoopnet, SN = Bag seine, TN = Trap net, TRM = Trammel net, DN = Larval dip net, FN = Fyke net, QLT = Quadrafoil larval light trap, TRL = Siamese Trawl. n = Number of Channel Darter captured in DU1.

Waterbody	n	Year	Gear	Channel Darter Targeted?	Reference
Detroit River	32	2013-18	BEF, MFN, GN, HN, SN, TN, TRM, TRL	No	DFO unpublished data
Detroit River	1	2012	Unknown	No	USFWS unpublished data
Detroit River	79	2010-11	BEF, TRL	Yes	DFO unpublished data
Lake St. Clair	0	2013	TRL	No	DFO unpublished data
Lake St. Clair	1	2012	TRL	No	DFO unpublished data
Lake St. Clair	0	2010-11	SN, TRL	No	M. Belore, OMNRF, pers. comm. in COSEWIC 2016 DFO unpublished data
St. Clair River	12	2013, 14, 18	BEF, TRL, TRM	No	DFO unpublished data
St. Clair River	0	2012	BEF, TRL	No	DFO unpublished data
St. Clair River	0	2010	TRL	Yes	DFO unpublished data
Big Otter Creek	1	2013-18	BEF, MFN, GN, HN, SN, TN, TRM	No	DFO unpublished data
Rondeau Bay	0	2013-18	BEF, DN, FN, MFN, GN, HN, SN, QLT, TN, TRM, TRL	No	DFO unpublished data
Rondeau Bay	27	2018	SN	No	LeBaron et al. (in press)
Point Pelee	0	2015	BEF	No	DFO unpublished data
Point Pelee	>50	2010	SN	No	S. Reid, DFO, pers. comm. in COSEWIC 2016
Port Dover	0	2017	SN	Yes	OMNRF unpublished data

Table A.2. Summary of recent (2010 – 2019) fish surveys within the known distribution of Channel Darter for DU2. Gear: BPEF = Backpack Electrofishing Unit, BEF = Boat electrofishing, MFN =Mini fyke net, GN = Gillnet, HN = Hoopnet, SN = Bag seine, TN = Trap net, TRM = Trammel net, DN = Larval dip net, FN = Fyke net, QLT = Quadrafoil larval light trap, TRL = Siamese Trawl. n = Number of Channel Darter captured in DU2.

Waterbody	n	Year	Gear	Channel Darter Targeted?	Reference
Moira River	25	2013	BPEF	Yes	Reid and Haxton 2017
Salmon River	30	2014	BPEF	Yes	Reid and Haxton 2017
Trent River	1,592	2012-18	BPEF	Yes	Reid et al. 2016, Reid and Haxton 2017, Reid 2019, S. Reid, DFO, unpublished data,
Trent River	421	2010-2011	BPEF	Yes	S. Reid, DFO, pers. comm.