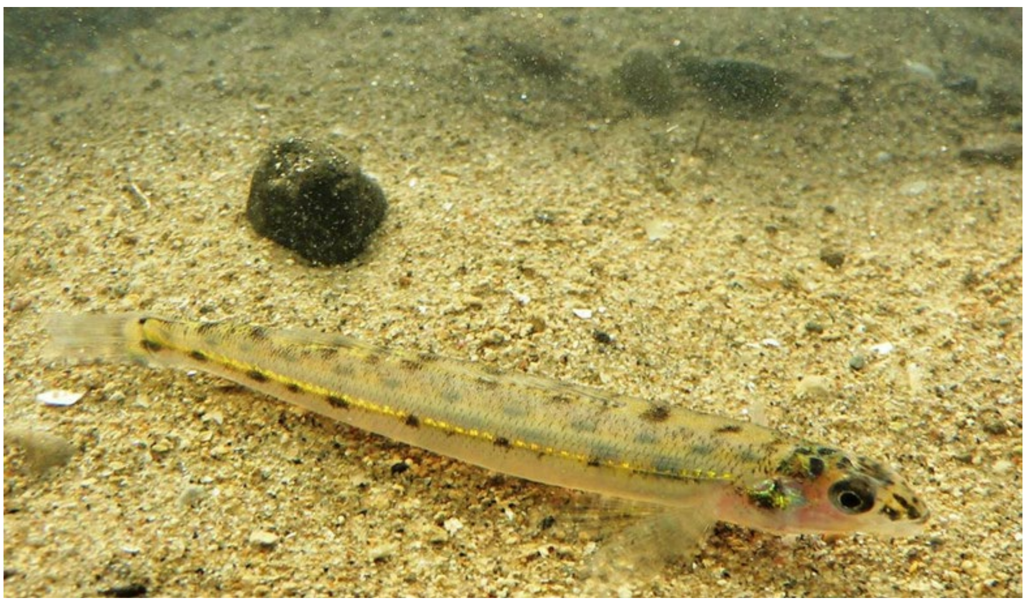
COSEWIC
Assessment and Status Report

on the

Eastern Sand Darter
Ammocrypta pellucida

Southwestern Ontario population
Quebec population
West Lake population

in Canada



Southwestern Ontario population - THREATENED
Quebec population - SPECIAL CONCERN
West Lake population - THREATENED
2022

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

COSEWIC. 2022. COSEWIC assessment and status report on the Eastern Sand Darter *Ammocrypta pellucida*, Southwestern Ontario population, Quebec population and West Lake population in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xxi + 74 pp. (https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html).

Previous report(s):

COSEWIC. 2009. COSEWIC assessment and status report on the Eastern Sand Darter *Ammocrypta pellucida*, Ontario populations and Quebec populations, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 49 pp. (https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html).

COSEWIC. 2000. COSEWIC assessment and update status report on the Eastern Sand Darter *Ammocrypta pellucida* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. v + 20 pp. (https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html).

Holm, E. and N.E. Mandrak. 1994. COSEWIC status report on the Eastern Sand Darter *Ammocrypta pellucida* in Canada. Committee on the Status of Endangered Wildlife in Canada. 17 pp.

Production note:
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Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur le Dard de sable (*Ammocrypta pellucida*), population du sud-ouest de l’Ontario, population du Québec et population du lac West au Canada.

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Eastern Sand Darter — Photograph by Alan Dextrase.

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COSEWIC
Assessment Summary

Assessment Summary – May 2022

Common name
Eastern Sand Darter - Southwestern Ontario population

Scientific name
Ammocrypta pellucida

Status
Threatened

Reason for designation
This small fish prefers the sand bottom areas of lakes and streams into which it burrows. This specific habitat preference makes it extremely susceptible to habitat changes caused by agricultural impacts. It is also negatively impacted by invasive species, such as Round Goby, which have invaded its preferred habitat. As a result, there is a continuing decline in habitat quality and quantity. As a result, fish numbers are declining, and three historical populations have been lost.

Occurrence
Ontario

Status history
The species was considered a single unit and designated Threatened in April 1994 and November 2000. When the species was split into separate units in November 2009, the "Ontario populations" unit was designated Threatened. Population name changed to Ontario population in May 2022, and was further split into two populations (West Lake population and Southwestern Ontario population). The Southwestern Ontario population was designated Threatened.

Assessment Summary – May 2022

Common name
Eastern Sand Darter - Quebec population

Scientific name
Ammocrypta pellucida

Status
Special Concern

Reason for designation
This small fish prefers sand bottom areas of lakes and streams in which it burrows. This specific habitat preference make it extremely susceptible to habitat changes related to human impacts. It is also negatively impacted by invasive species, such as Round Goby, which have invaded its preferred habitat. As a result, there is a continuing decline in habitat quality and quantity and, hence, abundance. The species no longer meets the current definition of severely fragmented and, therefore, the status has changed since the last assessment. The species may become Threatened if threats to the species are neither reversed nor managed effectively.

Occurrence
Québec

Status history
The species was considered a single unit and designated Threatened in April 1994 and November 2000. When the species was split into separate units in November 2009, the "Quebec populations" unit was designated Threatened. Population name changed to Quebec population in May 2022. Status re-examined and designated Special Concern in May 2022.

Assessment Summary – May 2022

Common name
Eastern Sand Darter - West Lake population

Scientific name
Ammocrypta pellucida

Status
Threatened

Reason for designation
This small fish was first discovered in West Lake in 2013. It prefers the sandy bottom areas of West Lake into which it burrows. This specific habitat preference makes it extremely susceptible to habitat changes. It is also negatively impacted by invasive species, such as Round Goby, which has invaded its preferred habitat. Actions to reduce the threats of habitat changes and the invasive goby are needed to prevent the risk of becoming endangered.

Occurrence
Ontario

Status history
The species was considered a single unit and designated Threatened in April 1994 and November 2000. When the species was split into separate units in November 2009, the "Ontario populations" unit was designated Threatened. Population name changed to Ontario population in May 2022, and was further split into two populations (West Lake population and Southwestern Ontario population). The West Lake population was designated Threatened.

COSEWIC
Executive Summary

Eastern Sand Darter
Ammocrypta pellucida

Southwestern Ontario population
Quebec population
West Lake population

Wildlife Species Description and Significance

Eastern Sand Darter is one of six species of the genus *Ammocrypta* and is the only member of its genus that occurs in Canada. It reaches a maximum total length of 84 mm. Eastern Sand Darter can easily be distinguished from other Canadian darters by its translucent colouration and slender, elongate body. The genetic differentiation of the southwestern Ontario, Quebec, and West Lake populations and occurrence in unique habitats isolated for ~10,000 years justify the recognition of three designatable units. Eastern Sand Darter is one of the few Canadian freshwater fishes that primarily exploits sandy habitats and related resources.

Distribution

Eastern Sand Darter occurs in the Ohio River basin in the United States (Ohio, Indiana, Illinois, Kentucky, West Virginia, Pennsylvania), a portion of the lower Great Lakes watershed (Lake Huron, Lake St. Clair, Lake Erie, and Lake Ontario watersheds in Michigan, Ohio, New York, Pennsylvania, and Ontario) and, farther east, in the St. Lawrence River and Lake Champlain watersheds (Quebec, Vermont, New York). In southwestern Ontario, populations have been found in Lake Erie and Lake St. Clair as well as in eight streams. In southeastern Ontario, a population was recently discovered in West Lake, Lake Ontario. In Quebec, populations are known from the St. Lawrence River and 23 of its tributaries. Populations have been extirpated from several southwestern Ontario watersheds.

Habitat

The preferred habitat of Eastern Sand Darter is sand-bottomed areas in rivers and sandy shoals in lakes. Spawning has not been observed in nature but, in the laboratory, Eastern Sand Darter spawned on a mixed sand and gravel substrate. The availability and quality of Eastern Sand Darter habitat are affected by agricultural activities and urbanization throughout its range.

Biology

Eastern Sand Darter is relatively short-lived, reaching a maximum age of 4 years. Fish of both sexes mature in the spring following their first growing season at age 1, but some females may not spawn until their second year. Generation time is estimated to be 2 years. Eastern Sand Darter spawn in spring and summer at water temperatures between 14.4°C and 25.5°C. Spawning is intermittent, and females may lay eggs several times during the protracted spawning season. The slightly adhesive eggs are likely laid in well-oxygenated sand and gravel substrates. Hatching occurs in 4 to 5 days at 20.5°C to 23°C, and larvae become benthic soon after emerging. Fossorial (burying) behaviour is well developed in the species. Eastern Sand Darter is a benthic insectivore that feeds primarily on the larvae of midges (Chironomidae). Individuals are capable of moving through the fragmented habitat of a stream, but the species' movements remain limited. Eastern Sand Darter appears to have limited adaptability, particularly owing to its strict habitat requirements and its low dispersal capability.

Population Sizes and Trends

In Canada, the largest populations of this species seem to be found in the Thames River, Grand River, and Aux Saumons River. In southwestern Ontario, Eastern Sand Darter populations have presumably been extirpated from three drainage systems: Ausable River, Catfish Creek, and Big Otter Creek. Since the last status assessment, 10 new populations have been discovered: one new population has been discovered in southwestern Ontario; one in West Lake, Ontario; and, eight in Quebec. Due to insufficient data, it is impossible to assess the trends of most Canadian populations. It is unlikely that the status of Eastern Sand Darter has improved over the last 10 years, given that none of the populations assessed appeared to be increasing throughout the Canadian range in 2010, and southwestern Ontario populations in Lake St. Clair and Long Point Bay appear to be declining, as is probably also the case for the Quebec populations in the Yamaska and Saint-François rivers.

Threats and Limiting Factors

There are several significant threats to Eastern Sand Darter populations in Canada. Pollution from agricultural effluents and domestic and urban wastewater appears to be the leading cause of habitat loss. Additional threats include invasion by the introduced Round Goby, pollution from industrial effluents, dams and water management/use, climate change, and the introduction of the bacterium *Bacillus thuringiensis israelensis* (BTI) in Quebec.

Protection, Status and Ranks

Eastern Sand Darter has been listed as Threatened under Schedule 1 of the federal *Species at Risk Act* since 2003. It is listed as Endangered in Ontario under the *Endangered Species Act, 2007*, and as Threatened under Quebec's *Act Respecting Threatened or Vulnerable Species*. These listings prohibit harvest or capture without specific authorization. Critical habitat identified and protected under the *Species at Risk Act* covers an area of 187 km^2 in Ontario and 23 km^2 in Quebec. The species is ranked as apparently secure globally (G4) by NatureServe and as least concern by the International Union for Conservation of Nature. In the United States, it is ranked as at risk by NatureServe in eight of the nine states where it occurs.

TECHNICAL SUMMARY – DU1 SOUTHWESTERN ONTARIO POPULATION

Ammocrypta pellucida

Eastern Sand Darter
Southwestern Ontario population

Dard de sable
Population du sud-ouest de l'Ontario

Range of occurrence in Canada (province/territory/ocean): Ontario

Demographic Information

Generation time	2 y
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes (overall trends inferred decline in habitat area, extent, and quality and from population trends: 2 declining, 2 stable, 3 extirpated, 6 unknown, 0 increasing)
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations, whichever is longer up to a maximum of 100 years].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations, whichever is longer up to a maximum of 100 years].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations, whichever is longer up to a maximum of 100 years].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, whichever is longer up to a maximum of 100 years] over a time period including both the past and the future.	Unknown
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. Some, yes b. Yes c. No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	Current populations: 10,603 km² All populations: 21,250 km²
Index of area of occupancy (IAO)	Current populations: 288 km² All populations: 576 km²

Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. Yes
Number of "locations"*	Based on pollution threat: 7 (including 1 discovered since publication of the previous report, excluding 3 presumed extirpated)
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Yes, observed.
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Yes, observed.
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Yes, observed.
Is there an [observed, inferred, or projected] decline in number of "locations"*?	Yes, observed.
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, observed in quality
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of "locations"*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
Ausable River	Presumably 0 (extirpated)
Lake St. Clair	Unknown
Thames River	Unknown
Sydenham River	Unknown
Detroit River	Unknown
Western Basin, Lake Erie	Unknown
Rondeau Bay	Unknown
Long Point Bay	Unknown
Catfish Creek	Presumably 0 (extirpated)
Big Otter Creek	Presumably 0 (extirpated)
Big Creek	Unknown

* See Definitions and Abbreviations on COSEWIC website and IUCN for more information on this term.

Grand River	Unknown
Total (12)	Unknown

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations whichever is longer up to a maximum of 100 years, or 10% within 100 years]?	Unknown

Threats (actual or imminent, to populations or habitats, from highest impact to least)

Was a threats calculator completed for this species? Yes, High-Medium.

9. Pollution (medium)
8. Invasive species (medium-low)
11. Climate change (medium-low)
7. Natural system modifications (low)

What additional limiting factors are relevant?
Quality of available habitats
Availability of food resources
Population recovery capacity
Fragmentation of populations

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada	United States: Pennsylvania (S1), Michigan (S1S2), Ohio (S3). Species listed as at risk in 5 states.
Is immigration known or possible?	Unlikely
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Are conditions deteriorating in Canada?[+]	Yes, habitat degradation appears to be ongoing
Are conditions for the source (i.e. outside) population deteriorating?[+]	Yes, habitat degradation appears to be ongoing
Is the Canadian population considered to be a sink?	No
Is rescue from outside populations likely?	No

Data Sensitive Species

Is this a data sensitive species?	No

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect).

Status History

COSEWIC Status History: The species was considered a single unit and designated Threatened in April 1994 and November 2000. When the species was split into separate units in November 2009, the “Ontario populations” unit was designated Threatened. Population name changed to Ontario population in May 2022, and was further split into two populations (West Lake population and Southwestern Ontario population). The Southwestern Ontario population was designated Threatened.

Status and Reasons for Designation

Recommended Status: Threatened	**Alpha-numeric codes:** B1ab(ii,iii,v)+2ab(ii,iii,v)
Reasons for designation: This small fish prefers the sand bottom areas of lakes and streams into which it burrows. This specific habitat preference makes it extremely susceptible to habitat changes caused by agricultural impacts. It is also negatively impacted by invasive species, such as Round Goby, which have invaded its preferred habitat. As a result, there is a continuing decline in habitat quality and quantity. As a result, fish numbers are declining, and three historical populations have been lost.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. Population size is inferred and suspected to decline over three generations as a result of declines in quality of habitat, but degree of decline unknown.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Threatened, B1ab(ii,iii,v)+2ab(ii,iii,v), with a small EOO (10,602 km^2) and IAO (288 km^2), 7 locations, and continuing decline in habitat quality, and, as a result, number of mature individuals.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. No population estimate available, although continuing decline is inferred.
Criterion D (Very Small or Restricted Population): Not applicable. IAO > 20 km^2 and number of locations > 5. No population estimate available
Criterion E (Quantitative Analysis): Analysis not completed.

TECHNICAL SUMMARY – DU2 QUEBEC POPULATION

Ammocrypta pellucida

Eastern Sand Darter
Quebec population

Dard de sable
Population du Québec

Range of occurrence in Canada (province/territory/ocean): Quebec

Demographic Information

Generation time	2 y
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes (trends inferred from inferred decline in habitat area, extent, and quality the populations: 3 declining, 4 stable, 20 unknown)
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations, whichever is longer up to a maximum of 100 years].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations, whichever is longer up to a maximum of 100 years].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations, whichever is longer up to a maximum of 100 years].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, whichever is longer up to a maximum of 100 years] over a time period including both the past and the future.	Unknown
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. Some, yes b. Yes c. No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	Current populations: 13,811 km² All populations: 17,694 km²
Index of area of occupancy (IAO)	Current populations: 560 km² All populations: 632 km²

Is the population “severely fragmented” i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. Yes
Number of “locations”*	Based on pollution threat: 27 (8 discovered since publication of the previous report)
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Yes, observed
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Yes, observed
Is there an [observed, inferred, or projected] decline in number of subpopulations?	No
Is there an [observed, inferred, or projected] decline in number of “locations”*?	No
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, observed in quality
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of “locations”*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
Montréal–Sorel section of the St. Lawrence River	Unknown
Lake Saint-Pierre archipelago	Unknown
Lake Saint-Pierre	Unknown
Trois-Rivières–Batiscan section of the St. Lawrence River	Unknown
Lake Des Deux Montagnes	Unknown
Des Milles Îles River	Unknown
Mascouche River	Unknown
L’Assomption River	Unknown
Ouareau River	Unknown
Maskinongé River	Unknown
Du Loup River	Unknown
Yamachiche River	Unknown

* See Definitions and Abbreviations on COSEWIC website and IUCN for more information on this term.

Little Yamachiche River	Unknown
Saint-Maurice River	Unknown
Champlain River	Unknown
Aux Saumons River	Unknown
Trout River	Unknown
Châteauguay River	Unknown
Richelieu River	Unknown
Yamaska River	Unknown
Saint-François River	Unknown
Nicolet River	Unknown
Bécancour River	Unknown
Gentilly River	Unknown
Aux Orignaux River	Unknown
Little du Chêne River	Unknown
Du Chêne River	Unknown
Total (27)	Unknown

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations whichever is longer up to a maximum of 100 years, or 10% within 100 years]?	Unknown

Threats (actual or imminent, to populations or habitats, from highest impact to least)

Was a threats calculator completed for this species? Yes, Very High-High

9. Pollution (high-medium)
8. Invasive species (high-medium)
11. Climate change (high-low)
7. Natural system modifications (medium)

What additional limiting factors are relevant?
Quality of available habitats
Availability of food resources
Population recovery capacity
Fragmentation of populations

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada	United States: Vermont (S1), New York (S2S3).
Is immigration known or possible?	Unlikely, but may be possible from Lake Champlain or from the Salmon River in New York
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes

Are conditions deteriorating in Canada?[+]	Yes, habitat degradation appears to be ongoing
Are conditions for the source (i.e. outside) population deteriorating?[+]	Yes, habitat degradation appears to be ongoing
Is the Canadian population considered to be a sink?	No
Is rescue from outside populations likely?	No

Data Sensitive Species

Is this a data sensitive species?	No

Status History

COSEWIC Status History: The species was considered a single unit and designated Threatened in April 1994 and November 2000. When the species was split into separate units in November 2009, the "Quebec populations" unit was designated Threatened. Population name changed to Quebec population in May 2022. Status re-examined and designated Special Concern in May 2022.

Status and Reasons for Designation

Status: Special Concern	**Alpha-numeric** codes: Not applicable
Reasons for designation: This small fish prefers sand bottom areas of lakes and streams in which it burrows. This specific habitat preference makes it extremely susceptible to habitat changes related to human impacts. It is also negatively impacted by invasive species, such as Round Goby, which have invaded its preferred habitat. As a result, there is a continuing decline in habitat quality and quantity and, hence, abundance. The species no longer meets the current definition of severely fragmented and, therefore, the status has changed since the last assessment. The species may become Threatened if threats to the species are neither reversed nor managed effectively.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. Population size is inferred and suspected to decline over three generations as a result of declines in quality of habitat, but degree of decline unknown.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. Small EOO (13,811 km^2) and IAO (560 km^2) and continuing decline in habitat quality and, as a result, number of mature individuals. However, not known to be severely fragmented, many more than 10 locations (27), and does not undergo extreme fluctuations.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. No population estimate available.
Criterion D (Very Small or Restricted Population): Not applicable. IAO > 20 km^2 and number of locations > 5. No population estimate available.
Criterion E (Quantitative Analysis): Analysis not completed.

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect).

TECHNICAL SUMMARY – DU3 WEST LAKE POPULATION

Ammocrypta pellucida

Eastern Sand Darter
West Lake population

Dard de sable
Population du lac West

Range of occurrence in Canada (province/territory/ocean): Ontario

Demographic Information

Generation time	2 y
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Possible, based on declines in other populations related to invasive Round Goby
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations, whichever is longer up to a maximum of 100 years].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations, whichever is longer up to a maximum of 100 years].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations, whichever is longer up to a maximum of 100 years].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, whichever is longer up to a maximum of 100 years] over a time period including both the past and the future.	Unknown
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	n/a
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	2010-2018: 5 km² (minimum convex polygon), 16 km² (EOO=IAO) 2000-2009: unknown Pre-2000: unknown
Index of area of occupancy (IAO)	2010-2018: 16 km² 2000-2009: unknown Pre-2000: unknown

Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. n/a
Number of "locations"*	Based on invasive species threat: 1
Is there an [observed, inferred, or projected] decline in extent of occurrence?	n/a
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	n/a
Is there an [observed, inferred, or projected] decline in number of populations?	n/a
Is there an [observed, inferred, or projected] decline in number of "locations"*?	n/a
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, in quality
Are there extreme fluctuations in number of populations?	n/a
Are there extreme fluctuations in number of "locations"*?	n/a
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Populations (give plausible ranges)	**N Mature Individuals**
West Lake	Unknown
Total (1 population)	Unknown

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations whichever is longer up to a maximum of 100 years, or 10% within 100 years]?	Unknown

* See Definitions and Abbreviations on COSEWIC website and IUCN for more information on this term.

Threats (actual or imminent, to populations or habitats, from highest impact to least)

Was a threats calculator completed for this species? Yes, Medium-Low 8. Invasive species (medium-low) What additional limiting factors are relevant? Quality of available habitats Availability of food resources Population recovery capacity

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada	United States: New York (S2S3).
Is immigration known or possible?	Unlikely
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Are conditions deteriorating in Canada?+	Yes, due to invasive Round Goby
Are conditions for the source (i.e. outside) population deteriorating?+	Yes, habitat degradation appears to be ongoing
Is the Canadian population considered to be a sink?	No
Is rescue from outside populations likely?	No

Data Sensitive Species

Is this a data sensitive species?	No

Status History

COSEWIC Status History: The species was considered a single unit and designated Threatened in April 1994 and November 2000. When the species was split into separate units in November 2009, the "Ontario populations" unit was designated Threatened. Population name changed to Ontario population in May 2022, and was further split into two populations (West Lake population and Southwestern Ontario population). The West Lake population was designated Threatened.

Status and Reasons for Designation

Status: Threatened	**Alpha-numeric codes:** Meets criteria for Endangered, B1ab(iii,v)+2ab(iii,v), but designated Threatened, B1ab(iii,v)+2ab(iii,v), as the magnitude of threats does not suggest that the species is at imminent risk of extinction.

+ See Table 3 (Guidelines for modifying status assessment based on rescue effect).

Reasons for designation:
This small fish was first discovered in West Lake in 2013. It prefers the sandy bottom areas of West Lake into which it burrows. This specific habitat preference makes it extremely susceptible to habitat changes. It is also negatively impacted by invasive species, such as Round Goby, which has invaded its preferred habitat. Actions to reduce the threats of habitat changes and the invasive goby are needed to prevent the risk of becoming endangered.

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. Population size is inferred and suspected to decline over three generations as a result of declines in quality of habitat, but degree of decline unknown.
Criterion B (Small Distribution Range and Decline or Fluctuation): EOO and IAO of <16 km^2 meet thresholds for Endangered. Occurs at 1 location, with a continuing decline in quality of habitat and, as a result, number of mature individuals.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. No population estimate available.
Criterion D (Very Small or Restricted Population): Not applicable, as the main known threat already exists.
Criterion E (Quantitative Analysis): Analysis not completed.

PREFACE

In the most recent assessment by COSEWIC in 2009, the Ontario and Quebec populations were separated into two designatable units and both assessed as Threatened. Since then, various measures have been taken to ensure the recovery of these populations. Consequently, our knowledge of the species has expanded considerably since the previous assessment. Hence, this update presents new information concerning the structure of the populations of the species, which has been studied across an extensive portion of its range. The new studies have also provided more detailed information about the specificity and variability of its diet during the year, examined the use of the food resources of the benthic fish community that shares its habitat, and assessed the impact of the presence of the Round Goby on its feeding strategy. The increased sampling effort has made it possible to confirm the species' persistence at several historical sites, the status of which was unknown in the previous report, and has led to the discovery of several new populations in Quebec and Ontario, including the disjunct West Lake population in southeastern Ontario. However, data are still insufficient to provide quantitative estimates of population abundance, and the trajectory of most of the populations remains difficult to assess.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2022)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment and Climate Change Canada
Canadian Wildlife Service
Environnement et Changement climatique Canada
Service canadien de la faune
Canada

The Canadian Wildlife Service, Environment and Climate Change Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

on the

Eastern Sand Darter
Ammocrypta pellucida

Southwestern Ontario population
Quebec population
West Lake population

in Canada

2022

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Class: Actinopterygii
Order: Perciformes
Family: Percidae
Genus: *Ammocrypta*
Species*: *Ammocrypta pellucida* (Putnam 1863)
Common Name:
English*: Eastern Sand Darter
French*: dard de sable
* Page *et al.* 2013

Ammocrypta is one of four recognized genera of darters (Family Percidae: Tribe Etheostomatini) (Page *et al.* 2013). There has been considerable debate regarding the generic placement of the sand darters, which have long been recognized in the genus *Ammocrypta*. Simons (1991, 1992) proposed that *Ammocrypta* be downgraded to the subgenus level and that six species within the subgenus, including *A. pellucida*, be placed in the genus *Etheostoma*. His study indicated that the genus *Ammocrypta* is not monophyletic and, when reduced to a monophyletic group (by removing the Crystal Darter, now recognized in its own genus as *Crystallaria asprella*), *Ammocrypta* exhibits a similar amount of character variation as the *Etheostoma* subgenera *Boleosoma* and *Ioa* (Simons 1991, 1992). Shaw *et al.* (1999) and Wood and Raley (2000) supported the placement of *Ammocrypta* as a subgenus of *Etheostoma*. However, Near *et al.* (2000) suggested that *Ammocrypta* should stand as a genus and this position was supported by Page *et al.* (2013) in the latest American Fisheries Society publication on common and scientific names of North American fishes. No subspecies of Eastern Sand Darter are currently recognized (Page *et al.* 2013).

Morphological Description

Species in the genus *Ammocrypta* are generally distinguished from other darters by their translucent, slender, elongate bodies, which are usually incompletely scaled. Eastern Sand Darter (Figure 1) differs from the other five species of the genus in the following characteristics (COSEWIC 2009). It is pale white, yellowish, or silvery coloured with a series of 10-14 lateral dark spots usually located entirely below the lateral line scale row. These spots are slightly smaller than the pupil and are frequently rounded anteriorly and oblong posteriorly. The median fins are not pigmented. Eastern Sand Darter is one of the most elongate species of *Ammocrypta*, with the ratio of body length/body depth usually 8 to 9 times. There are usually 10-12 transverse scale rows on each side, 4-7 of these below the lateral line, and 9-11 (usually 10) preopercular-mandibular canal pores (this canal is part of the lateral line system on the head). The pelvic rays of adult males are darkly pigmented and have small tubercles. Average adult size ranges from 46 to 71 mm total length (TL), and the maximum recorded size is 84 mm TL (DFO 2011). Simon *et al.* (1992) described larval characteristics of five sand darter species, including Eastern Sand Darter.

Williams (1975) examined morphological variation across the range of this species and found that, although the species is highly variable, there were no clinal or geographic trends.

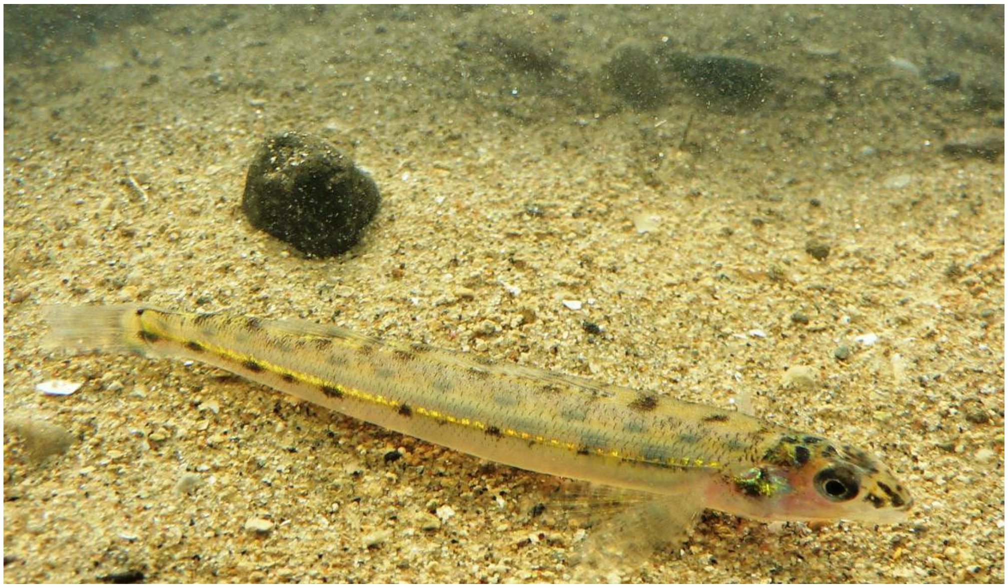


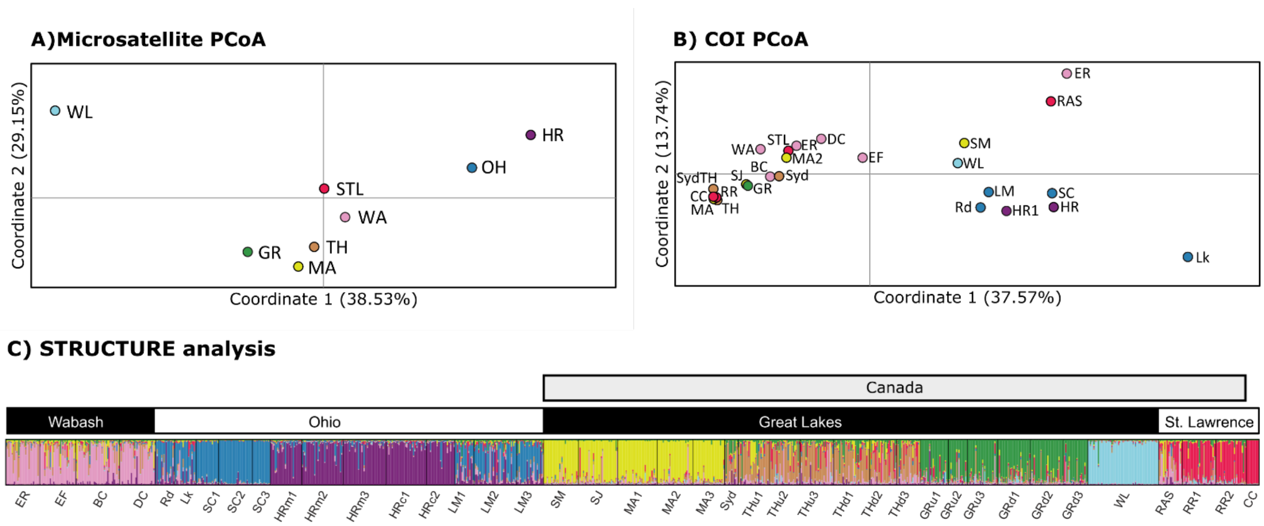
Figure 1. Eastern Sand Darter, *Ammocrypta pellucida*, from the Grand River (Ontario, July 2007). Photo taken by Alan Dextrase, Ontario Ministry of Natural Resources, Peterborough, Ontario.

Eastern Sand Darter is the only species of *Ammocrypta* that occurs in Canada. It can easily be distinguished from other Canadian darters by its translucent appearance, its slender, elongate body, and the large separation between its spiny and soft dorsal fins. Young-of-the-year Eastern Sand Darter are similarly distinctive and are unlikely to be confused with other Canadian darters.

Population Spatial Structure and Variability

Geographic genetic variation of Eastern Sand Darter was examined by Ginson *et al.* (2015) and by Walter *et al.* (2021) in a large portion of its northern range. Genotype analyses using 9 to 10 microsatellite loci were carried out on 1051 specimens captured at 39 sites in 16 streams in the Great Lakes, Ohio River, Wabash River, and St. Lawrence River drainages (Ginson *et al.* 2015), in addition to 63 specimens from the West Lake population (Walter *et al.* 2021). The results obtained by Ginson *et al.* (2015) revealed significant genetic differentiation of the populations between drainages (F_{ST} values of 0.047 to 0.289, $P < 0.001$), which illustrates that the effects of the events of the last glacial period continue to influence the genetic structure among Canadian Eastern Sand Darter populations. The overall genetic differentiation of the St. Lawrence River population ($F_{ST} = 0.11 \pm 0.022$) appeared to be greater than for those of the other drainages (F_{ST} values of 0.049 ± 0.011, 0.054 ± 0.011, and 0.044 ± 0.014 for the Great Lakes, Ohio River, and Wabash River drainages, respectively). Adding the West Lake population to the study, Walter *et al.* (2021) identified eight distinct population genetic clusters of Eastern Sand Darter in Canada and the northern United States (Figures 2, 3). Moreover, the West Lake population showed higher genetic differentiation than all other populations (F_{ST} values among populations ranged from 0.020 to 0.144 overall, while F_{ST} values ranged from 0.105 to 0.144 for the West Lake population).

At a regional scale, little genetic connectivity was observed between the populations within the same drainage (i.e., between different rivers of the same drainage) (F_{ST} values of 0.009 to 0.175, $P < 0.001$ in 88% of cases) (Ginson *et al.* 2015). This limited gene flow could be explained by the large distances between rivers, limited dispersal capabilities of the species, and large areas of unsuitable habitat, which contribute to isolating the populations (Ginson *et al.* 2015). This is further supported by no evidence of mixed ancestry in individuals between populations (Figure 2) (Walter *et al.* 2021).



Acronyms for A and B: WA = Wabash River; MA = Maumee River; OH = Ohio River; HR = Ohio – Hocking River; TH = Sydenham – Thames River; GR = Grand River; WL = West Lake; STL = St. Lawrence River.

Acroynyms for C: ER = Eel River; EF = East Fork White River; BC = Big Creek; DC = Deer Creek; Rd = Red River; Lk = Licking River; SC1, 2, 3 = Salt Creek; HRm1, 2 = Federal Creek; HRm3, HRc1, 2 = Hocking River; LM1, 2, 3 = Little Muskingum River; SM = St Mary's River; SJ = St Joseph River; MA1, 2, 3 = Maumee River; Syd = Sydenham River; Thu1, 2, 3, THd1, 2, 3 = Thames River; Gru1, 2, 3, GRd1, 2, 3 = Grand River; WL = West Lake; RAS = Little Salmon River; RR1, 2 = Richelieu River; CC = Champlain Canal.

Figure 2. PCoA of pairwise genetic differentiation (F_{ST}) relationships among *Ammocrypta pellucida* Canadian and American populations based on A) microsatellite and B) COI data. C) Population structure from microsatellite-based data shown in the STRUCTURE (K = 8). (Walter *et al.* 2021).

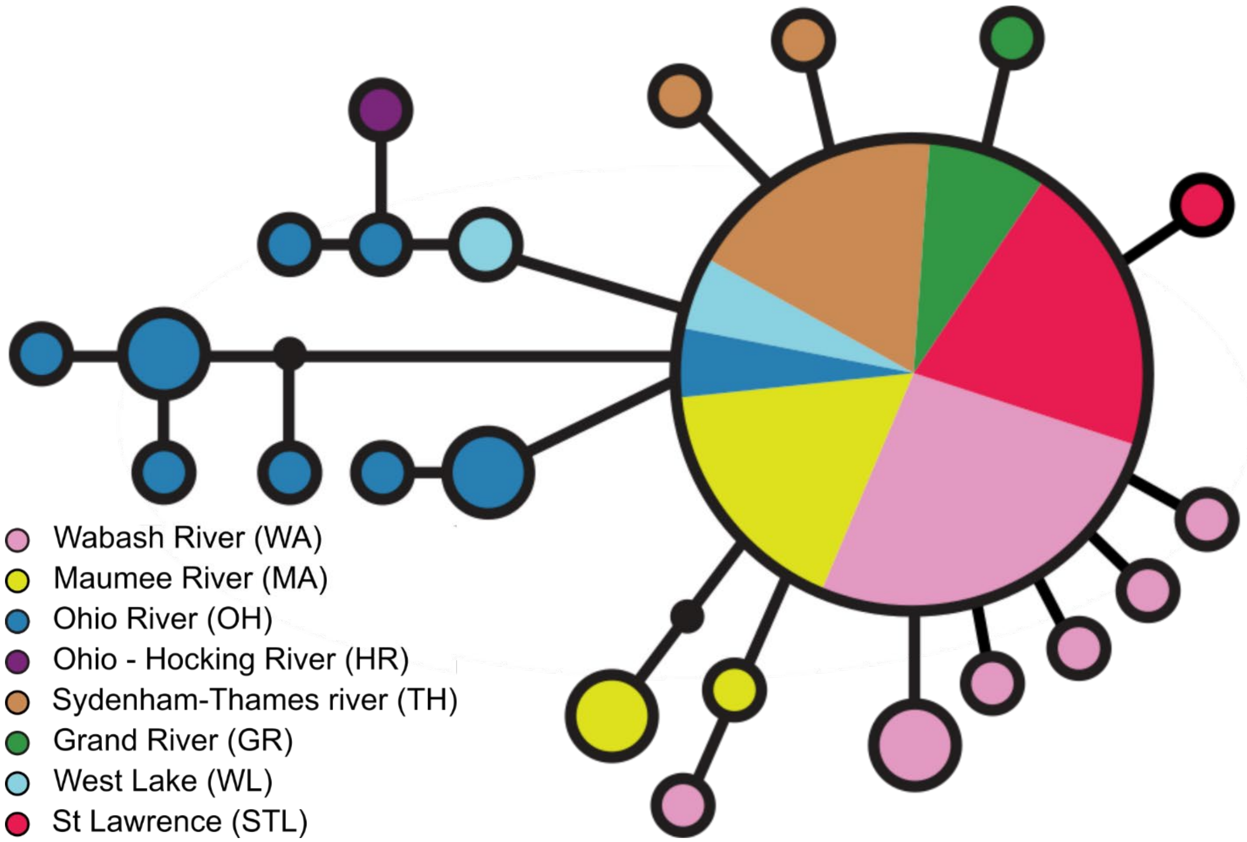


Figure 3. COI statistical parsimony haplotype network of *Ammocrypta pellucida* in Canada and United States (Walter *et al.* 2021).

However, there appears to be extensive genetic connectivity among habitat patches within rivers (F_{ST} values of 0 to 0.024, non-significant in 90% of cases), despite sandbars constantly being reshaped and the habitats highly fragmented (Ginson *et al.* 2015). This finding highlights the importance of dispersal in this species, although it is generally considered sedentary.

Designatable Units

All Canadian populations are found within the Great Lakes–Upper St. Lawrence Freshwater Biogeographic Zone.

<u>Discreteness</u>

Analyses of the genetic structure of Canadian populations indicate that the Quebec (St. Lawrence watershed) and West Lake (Lake Ontario watershed) populations present a distinct genotype from the other Canadian populations (southwestern Ontario), indicating discreteness between these three areas (Ginson *et al.* 2015; Walter *et al.* 2021).

Evolutionary Significance

The populations are located in unique physical (waterbody type and size) and ecological (e.g., fish community, climate) habitats, likely resulting in local adaptation and representing evolutionary significance. Quebec populations are mostly found in the St. Lawrence River and its tributaries (co-occurs with ~30 fish species; mean air annual temperature 7.1°C (Montréal, QC)), while the West Lake population is found in a small lacustrine habitat within the very rare Baymouth Barrier Dune ecosystem (co-occurs with ~20 fish species; mean annual air temperature 8.4°C (Kingston, ON)). The extant populations in southwestern Ontario are found in large to very large rivers and very large lakes (i.e., Lake St. Clair) (co-occurs with ~80 fish species; mean annual air temperature 10°C (London, ON)). Additionally, the populations in each of the three regions are separated from the next closest region by over 200 km, which precludes genetic exchange between the populations, which have likely been separated for ~10,000 years (~5,000 generations).

Therefore, the genetic differentiation of the southwestern Ontario, Quebec, and West Lake populations and their occurrence in unique habitats isolated for ~10,000 years represent distinctiveness and significance, respectively, and justify the recognition of three designatable units that have been on an independent evolutionary trajectory for an evolutionarily significant period. Information in this report and technical summaries is presented to allow assessment of the southwestern Ontario (DU1), Quebec (DU2) and West Lake (DU3) as separate designatable units.

Special Significance

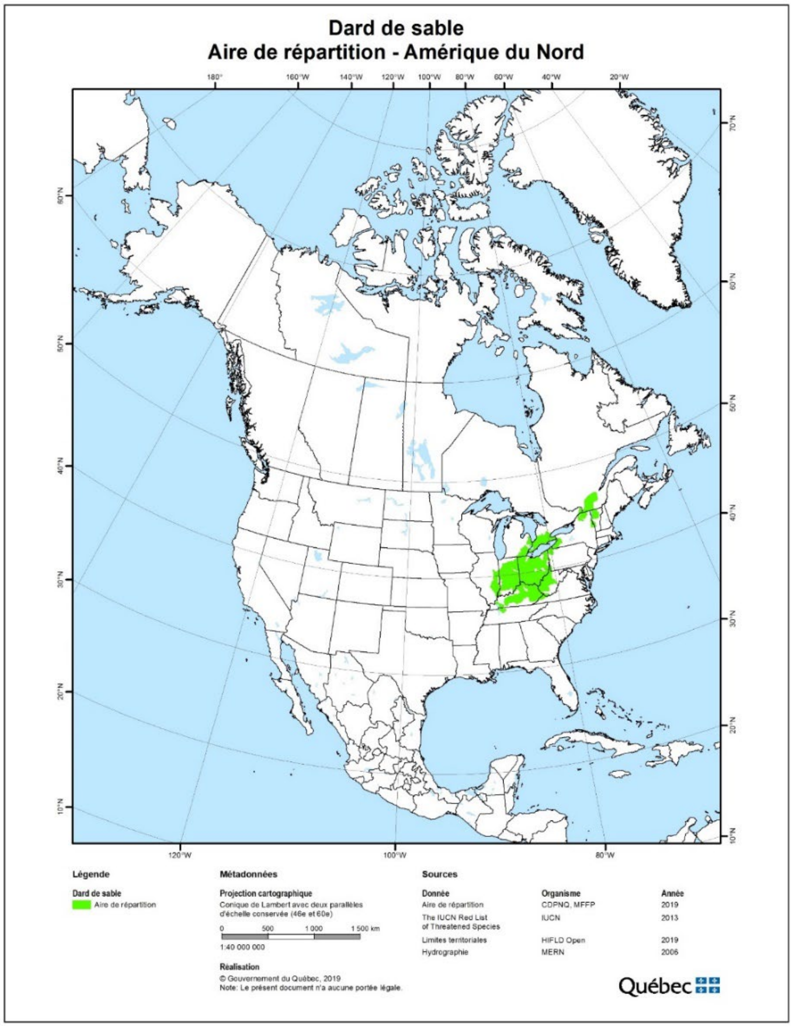
Eastern Sand Darter is the only member of the genus Ammocrypta that occurs in Canada and is one of the few Canadian freshwater fishes that specifically exploits sandbars and related resources, which contributes to the biodiversity of these habitats. Its fossorial behaviour is unusual for an adult freshwater fish in Canada. Although Eastern Sand Darter is of limited direct value in terms of human use, it may be an important prey item for other species where it is abundant. It may also serve as a host for the glochidia of the Endangered Round Hickorynut (*Obovaria subrotunda*) (COSEWIC 2003). Eastern Sand Darter is often considered an indicator of aquatic ecosystem health. However, it may not be a good bioindicator because it is a rare species, not easily detectable, and its physiological tolerances to various pollutants are unknown.

DISTRIBUTION

Global Range

Eastern Sand Darter has been found in the Ohio River basin in Ohio, Indiana, Illinois, Kentucky, West Virginia, and Pennsylvania (Figure 4). It has been recorded from the Lake Huron, Lake St. Clair, Lake Erie, and Lake Ontario watersheds in Michigan, Ohio, New York, Pennsylvania, and Ontario, and occurs farther east in the St. Lawrence River and

Lake Champlain watersheds in Quebec, Vermont, and New York (Figure 4). Reductions in distribution have been reported in Kentucky (Kuehne and Barbour 1983), Illinois (Smith 1971), Ohio (Trautman 1981), Michigan (Smith *et al.* 1981; Derosier 2004), and Pennsylvania (Cooper 1983).



Map translation:

Dard de sable = Eastern Sand Darter

Aire de répartition – Amérique du Nord = North American Range

Légende = Legend

Aire de répartition = Range

Métadonnées = Metadata

Projection cartographique = Map projection

Conique de Lambert avec deux parallèles d'échelle conservée (46^{e} et 60^{e}) = Lambert conformal conical projection with standard parallels at 46°N and 60°N

Réalisation = Produced by

Note : Le présent document n'a aucune portée légale. = Note: This document has no legal authority.

Données = Data

Limites territoriales = Territorial boundaries

Hydrographie = Hydrography

Organisme = Organization

Année = Year

Figure 4. Global range of Eastern Sand Darter (*Ammocrypta pellucida*) (MFFP 2019).

Canadian Range

In Canada, the range of Eastern Sand Darter is disjunct and limited to southern Quebec and southern Ontario (Figures 5, 6, 7). In Ontario, the species is currently present in the Lake St. Clair, Lake Erie, and Lake Ontario watersheds of the Great Lakes watershed and was formerly present in the Lake Huron watershed (Figures 5, 6). In Quebec, it is currently distributed in the St. Lawrence River and some of its tributaries, from Aux Saumons River eastward to Du Chêne River. In addition to the St. Lawrence River, its distribution includes parts of five hydrographic regions: Outaouais and Montréal; St. Lawrence River; southwestern St. Lawrence; southeastern St. Lawrence; and northwestern St. Lawrence (Figure 7).

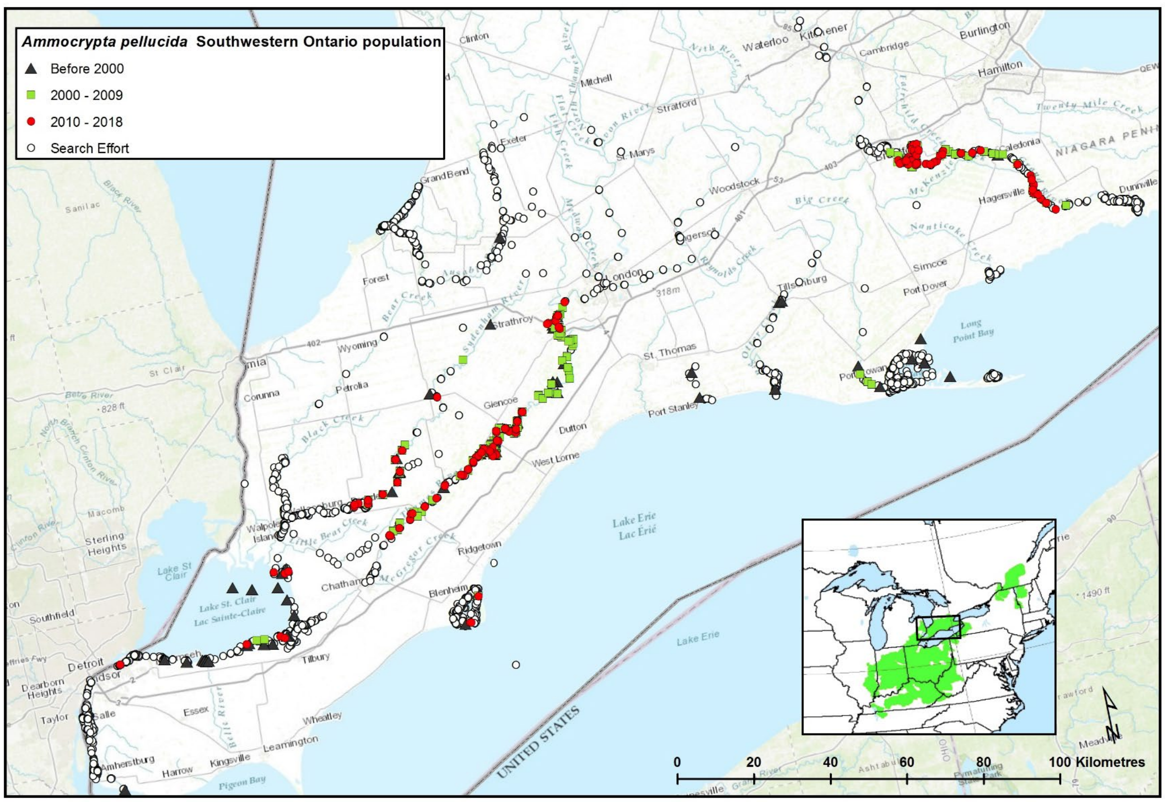


Figure 5. Range of Eastern Sand Darter (*Ammocrypta pellucida*) in the lakes Erie, Huron, and St. Clair watersheds, southwestern Ontario.

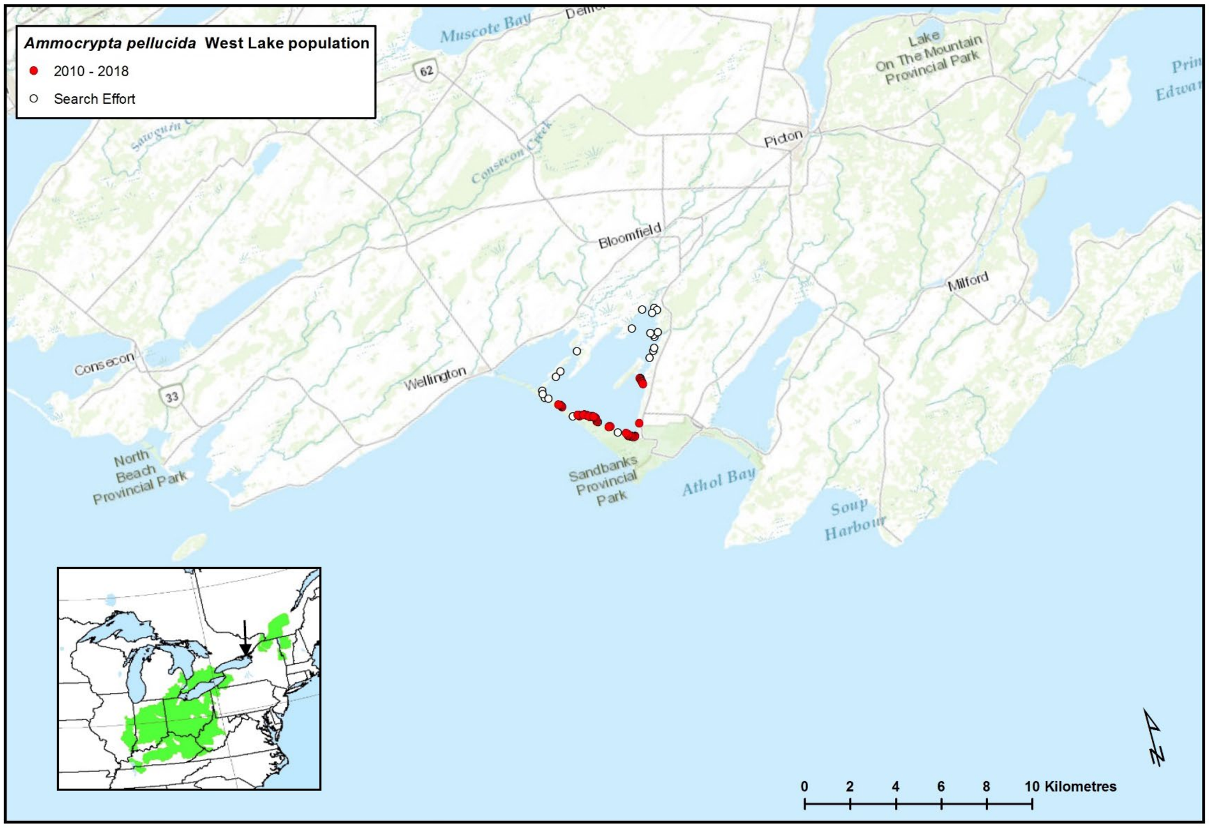


Figure 6. Range of Eastern Sand Darter (*Ammocrypta pellucida*) in the West Lake, Lake Ontario watershed, Ontario.

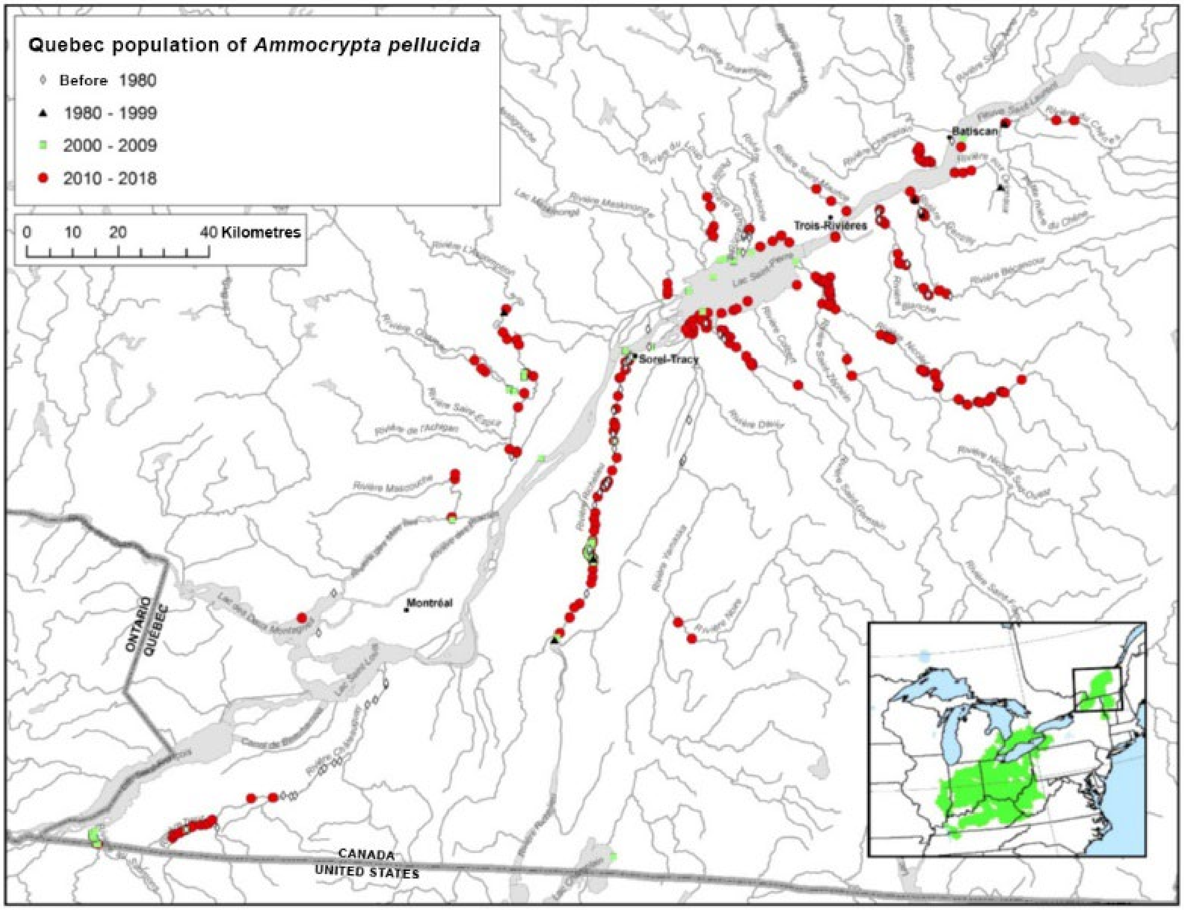


Figure 7. Range of Eastern Sand Darter (*Ammocrypta pellucida*) in Quebec.

The limited gene flow between rivers (Ginson *et al.* 2015) supports defining Canadian Eastern Sand Darter populations based on the watershed in which they are found (Boucher and Garceau 2010; Bouvier and Mandrak 2010). A total of 12 populations are recognized in southwestern Ontario (DU1). There are several populations in the Lake Erie watershed: Western Basin, Rondeau Bay, Long Point Bay, Grand River, and Catfish, Big Otter and Big creeks. The Lake St. Clair watershed contains four populations: Lake St. Clair, Thames River, Sydenham River, and Detroit River. Lastly, it was historically found in the Ausable River in the Lake Huron basin. Since the publication of the previous status report, a new population was identified in the Detroit River, south of Lake St. Clair. Three populations are considered extirpated: those in Ausable River, Catfish Creek, and Big Otter Creek (Barnucz *et al.* 2020), where the species was last detected in 1928, 1941 and 1955, respectively. In 2013, a new population was identified in West Lake, adjacent to Lake Ontario in eastern Ontario (Reid and Dextrase 2014) (DU3).

Twenty-seven populations are recognized in Quebec (DU2). First, the St. Lawrence River was divided in four given its large size: the Montréal–Sorel section, Lake Saint-Pierre archipelago, Lake Saint-Pierre, and the Trois-Rivières–Batiscan section. Second, one fluvial lake and 22 tributaries of the St. Lawrence River have populations: Lake Des Deux Montagnes, Aux Saumons River, Châteauguay River, Trout River, Des Milles Îles River, Mascouche River, L'Assomption River, Ouareau River, Richelieu River (including Missisquoi Bay on Lake Champlain), Yamaska River, Saint-François River, Maskinongé River, Du Loup River, Yamachiche River, Saint-Maurice River, Nicolet River, Bécancour River, Gentilly River, Champlain River, Aux Orignaux River, Du Chêne River, Little du Chêne River, and Little Yamachiche River. As of the publication date of the previous status report in 2009, the species was potentially extirpated from the Châteauguay River, Yamaska River, Saint-François River, Yamachiche River, Gentilly River, Bécancour River, Aux Orignaux River, Little du Chêne River and Lake Des Deux Montagnes (COSEWIC 2009). Recent surveys have confirmed that Eastern Sand Darter is still present in all these localities. Until recently, the Lake Des Deux Montagnes population was considered as likely extirpated, since the last record dates from 1946, and the species was not detected during surveys in 1990, 2013 (targeted seine net surveys carried out by the firm WSP) and 2015 (targeted trawl net surveys carried out by the Quebec Department of Forests, Wildlife and Parks (MFFP)). Seining carried out by the MFFP in 2018 at 80 stations, although not specifically targeting Eastern Sand Darter, resulted in the capture of five specimens in the Oka beach sector, Lake Des Deux Montagnes. Since the publication of the previous COSEWIC report, eight new populations have also been discovered: Trois-Rivières–Batiscan section (2009), Mascouche River (2016), Maskinongé River (2016), Du Loup River (2013), Saint-Maurice River (2016), and Champlain River (2013) on the north shore of the St. Lawrence River, as well as the Nicolet River (2013) and Du Chêne River (2016) on the south shore. Moreover, the Little Yamachiche River population, discovered in 1973, was not included in the previous COSEWIC report. Therefore, the distribution of Eastern Sand Darter in Quebec is more extensive than previously known. However, these results are likely more attributable to an increased sampling effort than to an actual increase in abundance or an expansion of the populations (Ricard *et al.* 2018).

Extent of Occurrence and Area of Occupancy

The extent of occurrence (EOO) and the index of area of occupancy (IAO) were estimated for the three designatable units based on historical (20 years or more), past (2000 to 2009), and current (2010 to 2018) data (Table 1; Appendix 1). EOO and IAO have expanded substantially in Quebec, likely owing to the increased search effort and the number of new populations that have been discovered over the past two decades. Trends are less clear for southwestern Ontario populations. EOO decreased between historical and 2000-2009 periods, then was stable in the last decade. Conversely, IAO increased between historical and 2000-2009 periods, and then slightly decreased, despite ongoing targeted sampling. This decline in IAO should be considered as a continuing decline as defined by COSEWIC as it was observed over the most recent 10-year time period. No trends in EOO and IAO could be observed for the West Lake population as it was only recently discovered (Reid and Dextrase 2014).

Table 1. Historical (pre-2000), past (2000-2009), and current (2010-2018) estimated extent of occurrence (EOO) and index of area of occupancy (IAO) for Eastern Sand Darter (*Ammocrypta pellucida*) DUs of southwestern Ontario, Quebec, and West Lake.

Variable estimated	Period	Ontario populations	Quebec populations	West Lake population
Extent of occurrence (km^2)	Historical	21,250	17,694	n/a
	Past	10,128	11,940	n/a
	Current	10,618 (minimum convex polygon) 10,603 (within Canada jurisdiction)	13,811	5 (minimum convex polygon) 16 (EOO=IAO)
Index of area of occupancy (km^2)	Historical	576	632	n/a
	Past	340	120	n/a
	Current	288	560	16

Search Effort

A number of surveys in Canada have specifically targeted Eastern Sand Darter or areas where several fish species at risk, including Eastern Sand Darter, are known to occur (Tables 2, 3). Many Eastern Sand Darter records are from general stream surveys or surveys conducted for other purposes. Throughout most of Eastern Sand Darter Canadian range, pre-1970 sampling effort was sparse and was conducted with seine nets and traps. Tables 2 and 3 present a synthesis of the survey data on Eastern Sand Darter for populations in Ontario and Quebec, respectively. It should be noted that the absence data provided are not exhaustive, because the targeted surveys that did not result in the capture of Eastern Sand Darter were very likely not all catalogued.

In the 1970s, the Ontario Ministry of Natural Resources (OMNR) conducted stream surveys that included systematic fish sampling using a variety of gear types (including backpack electrofishing) throughout most streams and their major tributaries within the Ontario range of Eastern Sand Darter (Table 2). The OMNR conducted a standard nearshore seining program along the south shore of Lake St. Clair (from 1979 to 1981, 1990 to 1996, 2005, and 2007 to 2017). Index-trawling transects have been conducted by OMNR in Long Point Bay since 1972. Over the past 20 years, specific surveys have been conducted using a variety of gear types by Fisheries and Oceans Canada (DFO), OMNR, Royal Ontario Museum, and conservation authorities, targeting historical locations and potential habitats for species at risk in the Ausable River, Bayfield River, Big Creek, Big Otter Creek, Catfish Creek, Detroit River, Grand River, St. Clair River, Sydenham River, and Thames River watersheds. Similar surveys have also been conducted on beaches along the north shore of Lake Erie, as well as in West Lake and Weller’s Bay in Lake Ontario (Reid and Dextrase 2014; Reid and Haxton 2020). Since 2004, intensive systematic sampling of all Ontario stream habitats that are, or were once, occupied by Eastern Sand Darter has been conducted by graduate students, DFO, and conservation authorities (e.g. Drake *et al.* 2008; Dextrase 2013; Dextrase *et al*. 2014; Barnucz *et al*. 2020; Barnucz and Drake 2021; Gaspardy and Drake 2021).

Table 2. Summary of surveys of Eastern Sand Darter in Ontario. ✓ = present; ∅ = absent in targeted surveys or surveys with a high probability of detecting Eastern Sand Darter (appropriate fishing gear [electrofisher, seine net, trawl net, standardized gillnets or eDNA] and fishing site); XXXX = year of survey; () = number of individuals captured (non-standardized data based on effort). Populations in italics are those discovered since the publication of the 2009 COSEWIC report. Data for the 1922-2009 period are taken from COSEWIC (2009). Data from 2010 to 2018 are from the recent Report on the Progress of Recovery Strategy Implementation for Eastern Sand Darter (Ontario Populations) (DFO 2018), and this synthesis was completed using data available from the Ontario Natural Heritage Information Centre (NHIC 2019) and information provided by the various authorities contacted. Most absence data are from DFO (unpubl. data) and may not be exhaustive.

Watershed and localities	Period				
	Before 1960	1960-1979	1980-1999	2000-2009	2010-2018
LAKE HURON WATERSHED					
AUSABLE RIVER					
Ausable River	✓ 1928 (1) ∅ 1936	∅ 1974	∅ 1982	∅ 2002 ∅ 2003-2005 ∅ 2007 ∅ 2009	∅ 2012-2018
Old Ausable Channel				∅ 2002 ∅ 2004 ∅ 2005 ∅ 2007 ∅ 2009	∅ 2010 ∅ 2012
Little Ausable River				∅ 2004	
OTHER SITES					
North shore of Lake Huron				∅ 2009	
LAKE ST. CLAIR WATERSHED					
LAKE ST. CLAIR					
South shore		✓ 1979 (1)	✓ 1980 (104) ✓ 1981 (45) ✓ 1993 (1) ✓ 1995 (3) ✓ 1996 (1)	✓ 2000 (≥1) ✓ 2001 (≥1)	✓ 2010 (≥1) ✓ 2012 (1) ✓ 2013 (1)
Mitchell's Bay			✓ 1983 (97) ✓ 1984 (66) ✓ 1985 (26) ∅ 1990-1996	∅ 2005 ∅ 2007-2009	∅ 2010-2015 ✓ 2012 (1) ✓ 2016 (2) ✓ 2017 (2)
East shore		∅ 1979	✓ 1980 (≥1) ∅ 1981 ∅ 1990-1996	∅ 2005 ∅ 2007-2009	∅ 2010-2017
THAMES RIVER					
Thames River	✓ 1923 (46) ∅ 1941	✓ 1974 (2) ✓ 1976 (5) ✓ 1978 (2)	✓ 1981 (≥2) ✓ 1989 (1) ✓ 1991 (38) ✓ 1997 (≥1) ✓ 1998 (2)	∅ 2002 ✓ 2003 (≥9) ✓ 2004 (≥75) ✓ 2005 (≥215) ✓ 2006 (≥571) ✓ 2007 (≥193) ✓ 2008 (≥87) ✓ 2009 (≥25)	✓ 2010 (≥36) ✓ 2011 (≥41) ✓ 2012 (63) ✓ 2013 (90) ✓ 2014 (35) ✓ 2015 (111) ✓ 2016 (5) ∅ 2017-2018
Middle Thames River				∅ 2002	∅ 2011
North Thames River					∅ 2011

Watershed and localities	Period				
	Before 1960	1960-1979	1980-1999	2000-2009	2010-2018
Phelan Creek				∅ 2007	
SYDENHAM RIVER					
Sydenham River	✓ 1927 (1) ✓ 1929 (3)	✓ 1972 (15) ✓ 1975 (2)	✓ 1989 (30) ✓ 1991 (≥9) ✓ 1997 (≥5)	✓ 2002 (≥7) ✓ 2003 (≥5) ✓ 2004 (≥4) ✓ 2009 (2)	✓ 2010 (136) ✓ 2012 (4) ✓ 2013 (1) ✓ 2015 (6) ✓ 2016 (56) ∅ 2017-2018
North Sydenham River				∅ 2003	∅ 2010 ∅ 2012 ∅ 2015
Bear Creek					∅ 2015
Fansher Creek				∅ 2003	
DETROIT RIVER					
Detroit River				∅ 2002-2004 ∅ 2007 ∅ 2009	∅ 2010-2011 ✓ 2013 (1) ∅ 2014-2018
LAKE ERIE WATERSHED					
WESTERN BASIN					
Pelee Island	✓ 1953 (≥1)			∅ 2005-2006	
North shore of the basin		✓ 1975 (2)		∅ 2005-2006	
RONDEAU BAY					
Rondeau Bay		✓ 1975 (3)		∅ 2002 ∅ 2004 ✓ 2005 (1)	∅ 2012-2017 ✓ 2018 (4)
LONG POINT BAY					
Long Point Bay			✓ 1980 (≥1) ✓ 1983 (≥1) ✓ 1984 (≥1) ✓ 1985 (≥1) ✓ 1986 (≥1) ✓ 1987 (≥1) ✓ 1996 (1)	∅ 2004 ∅ 2009	∅ 2012-2018
Anderson's and Bluffs Ponds, Long Point Provincial Park					∅ 2016
CATFISH CREEK					
Catfish Creek	✓ 1922 (1) ✓ 1941 (5)	∅ 1973 ∅ 1975	∅ 1980 ∅ 1983 ∅ 1989 ∅ 1990 ∅ 1997	∅ 2002 ∅ 2008	∅ 2016
BIG OTTER CREEK					
Big Otter Creek	✓ 1923 (1) ✓ 1955 (8)	∅ 1973-… (9 surveys)		∅ 2000-2003 ∅ 2002	∅ 2013-2018
BIG CREEK					
Big Creek	✓ 1923 (9) ✓ 1955 (1)	∅ 1973-… (6 surveys)		∅ 2005 ∅ 2007 ✓ 2008 (3)	∅ 2013-2018

Watershed and localities	Period				
	Before 1960	1960-1979	1980-1999	2000-2009	2010-2018
GRAND RIVER					
Grand River	∅ 1966	∅ 1976	✓ 1987 (1) ✓ 1991 (43) ✓ 1997 (≥1) ✓ 1998 (≥1) ✓ 1999 (27)	✓ 2000 (6) ∅ 2002-2003 ✓ 2004 (≥6) ∅ 2005 ✓ 2006 (59) ✓ 2007 (357) ∅ 2008 ✓ 2009 (≥24)	✓ 2010 (459) ✓ 2011 (≥40) ✓ 2013 (502) ✓ 2014 (161) ✓ 2015 (≥1) ✓ 2016 (95) ∅ 2017 ✓ 2018 (60)
Upstream of Wilkes Dam, Brantford					∅ 2014
OTHER SITES					
Georgie Creek					∅ 2013
Willow Creek					∅ 2013
Willow Creek Drain					∅ 2013
Indian Creek					∅ 2010 ∅ 2013
Nanticoke Creek					∅ 2013-2018
McLean's Drain					∅ 2013
LAKE ONTARIO WATERSHED					
WEST LAKE					
West Lake					✓ 2013 (866) ✓ 2014 (373) ✓ 2015 (45) ✓ 2018 (≥1)
OTHER SITES					
North shore of Lake Ontario					∅ 2009
Weller's Bay					∅ 2014 ∅ 2018
North Beach					∅ 2014

In Quebec, data on this species have been collected through some recurrent survey programs not specifically targeting Eastern Sand Darter (Table 3). Since 1997, between 40 and 64 seine stations have been sampled almost annually in the Richelieu River (except for 2000, 2002, 2005, 2014, and 2015), to monitor Copper Redhorse (*Moxostoma hubbsi*) recruitment (N. Vachon pers. comm. 2019; Vachon 2007). This program also offers the opportunity to monitor other rare fish species in the Richelieu River. In 1995, a large-scale, standardized monitoring program, called the *Réseau de suivi ichtyologique du fleuve Saint-Laurent* (RSI) [St. Lawrence River Fish Monitoring Network], was initiated in the Quebec freshwater portion of the St. Lawrence River. These surveys cover the river between Lake Saint-François and Quebec City. However, sampling of the downstream section was discontinued in 2006. Fishing is carried out using gillnets and seine nets in one or two sectors (out of seven sectors) every year. Since 2003, Missisquoi Bay in Lake Champlain and, more recently, the Upper Richelieu have also been surveyed.

Table 3. Summary of surveys of Eastern Sand Darter in the locations surveyed in Quebec. ✓ = present; ∅ = absent in targeted surveys or surveys with a high probability of detecting Eastern Sand Darter (appropriate fishing gear [electrofisher, seine net, trawl net, standardized gillnets, or eDNA] and fishing site); XXXX = year of survey; () = number of individuals captured (non-standardized data based on effort). Populations in italics are those that have been discovered since the publication of the 2009 COSEWIC report. Data for the 1940-2010 period are taken from DFO (2013), data for 2011 to 2018 are from a recent unpublished compilation produced by DFO, and this synthesis was completed using data available at the Centre de données sur le patrimoine naturel du Québec [Quebec Natural Heritage Data Centre] (CDPNQ 2019) and information provided by the MFFP.

Hydrographic region and location	Period				
	1940-1959	1960-1979	1980-1999	2000-2009	2010-2018
ST. LAWRENCE RIVER					
MONTRÉAL–SOREL SECTION					
Montréal–Sorel		∅ 1973		✓ 2001 (1) ✓ 2006 (2)	
LAKE SAINT-PIERRE ARCHIPELAGO					
Lake Saint-Pierre archipelago	✓ 1944 (1)	✓ 1974 (20)	∅ 1995	✓ 2003 (3)	∅ 2010 ✓ 2013 (3) ✓ 2015 (5)
LAKE SAINT-PIERRE					
Lake Saint-Pierre		∅ 1974	∅ 1995	✓ 2002 (7) ✓ 2005 (2) ✓ 2006 (17) ✓ 2007 (1)	✓ 2013 (10) ✓ 2016 (8) ✓1 2018 (38)
Colbert River					∅ 2012
Ruisseau Traverse de la Commune					∅ 2012
Chenal du Nord in Saint-Barthélemy					∅ 2012
Chenal du Nord near Maskinongé					∅ 2012
Canal portes de la Mauricie					∅ 2012
TROIS-RIVIÈRES–BATISCAN SECTION					
Trois-Rivières–Batiscan		✓ 1975 (1)	∅ 1996	∅ 2001 ∅ 2008 ✓ 2009 (1)	✓ 2017 (2) ✓ 2018 (8)
OTHER SITES					
Lake Saint-François			∅ 1996	∅ 2004 ∅ 2009	
Lake Saint-Louis			∅ 1997	∅ 2005	
Grondines–Saint-Nicolas			∅ 1997	∅ 2006	
OUTAOUAIS AND MONTRÉAL HYDROLOGIC REGION					
LAKE DES DEUX MONTAGNES					
Lake Des Deux Montagnes	✓ 1941 (?) ✓ 1946 (2)	∅ 1964-1977	∅ 1990		∅ 2013 ∅ 2015 ✓ 2018 (5)
DES MILLES ÎLES RIVER					
Des Milles Îles River				✓ 2008 (2)	∅ 2013
Aux Chiens River					∅ 2017
Du Chicot River					∅ 2017
Du Chêne River (Laurentians)					∅ 2017

Hydrographic region and location	Period				
	1940-1959	1960-1979	1980-1999	2000-2009	2010-2018
MASCOUCHE RIVER					
Mascouche River					✓ 2016 (6)
OTHER SITES					
Du Nord River					∅ 2017
Rouge River					∅ 2017
NORTHWEST ST. LAWRENCE HYDROLOGIC REGION					
L'ASSOMPTION RIVER					
L'Assomption River		✓ 1969 (14)	✓ 1983 (?) ∅ 1990	✓ 2002 (8) ✓ 2009 (10)	✓ 2010 (33) ✓ 2011 (24) ✓ 2013 (3) ✓ 2014 (3)
Noire River (Lanaudière)					∅ 2016
Noir Lake					∅ 2016
OUAREAU RIVER					
Ouareau River			∅ 1990	✓ 2002 (1) ✓ 2009 (2)	✓ 2011 (1) ✓ 2013 (6)
Lake Pontbriand					∅ 2012
MASKINONGÉ RIVER					
Maskinongé River					✓ 2016 (32)
DU LOUP RIVER					
Du Loup River					∅ 2012 ✓ 2013 (3) ✓ 2014 (89) ✓ 2017 (4) ✓ 2018 (21)
Little du Loup River					∅ 2012
YAMACHICHE RIVER					
Yamachiche River	✓ 1944 (11)	✓ 1972 (5)			∅ 2012 ✓ 2013 (4) ∅ 2014
LITTLE YAMACHICHE RIVER					
Little Yamachiche River		✓ 1973 (5)			∅ 2012-2013
SAINT-MAURICE RIVER					
Saint-Maurice River					✓ 2016 (4) ✓ 2017 (2)
CHAMPLAIN RIVER					
Champlain River					✓ 2013 (2) ✓ 2015 (19)
OTHER SITES					
Aux Glaises River					∅ 2012
Batiscan River					∅ 2013 ∅ 2016
Saint-Charles River					∅ 2012
Noire River (Capitale-Nationale)					∅ 2013
Sainte-Anne River					∅ 2013 ∅ 2016
Jacques-Cartier River					∅ 2013

Hydrographic region and location	Period				
	1940-1959	1960-1979	1980-1999	2000-2009	2010-2018
SOUTHWEST ST. LAWRENCE HYDROLOGIC REGION					
AUX SAUMONS RIVER					
Aux Saumons River (Montérégie)				✓ 2008 (359)	✓ 2010 (22) ✓ 2017 (1)
TROUT RIVER					
Trout River		✓ 1976 (3)	∅ 1993	✓ 2006 (1)	✓ 2010 (1) ✓ 2012 (1) ✓ 2015 (34)
CHÂTEAUGUAY RIVER					
Châteauguay River	✓ 1942 (3) ✓ 1944 (11)	✓ 1975 (32) ✓ 1976 (8)	∅ 1993	∅ 2006	✓ 2016 (4)
RICHELIEU RIVER					
Richelieu River		✓ 1970 (108) ✓ 1974 (2)	✓ 1993 (1) ∅ 1995 ✓ 1999 (96)	✓ 2001 (30) ✓ 2004 (13) ✓ 2006 (5) ✓ 2007 (32) ✓ 2008 (14) ✓ 2009 (30) ✓ 2010 (136)	✓ 2011 (36) ✓ 2015 (138)
Missisquoi Bay (Lake Champlain)				✓ 2003 (1)	∅ 2017
Aux Bluets River					∅ 2013
YAMASKA RIVER					
Yamaska River		✓ 1967 (42)	∅ 1995	∅ 2003	∅ 2010 ✓ 2015 (7)
Noire River					✓ 2012 (1) ∅ 2013 ✓ 2015 (2)
SAINT-FRANÇOIS RIVER					
Saint-François River	✓ 1944 (57)	∅ 1965-1974	∅ 1991	∅ 2002-2003 ∅ 2008-2009	✓ 2012 (16) ✓ 2013 (9) ✓ 2014 (102) ✓ 2015 (13) ✓ 2016 (12) ✓ 2018 (14)
Lake Massawippi			∅ 1987		∅ 2017
Niger River					∅ 2013
Au Saumon River (Richmond, Estrie)					∅ 2013
Au Saumon River (Weedon, Estrie)					∅ 2013
NICOLET RIVER					
Nicolet River					∅ 2012 ✓ 2013 (3) ✓ 2014 (91) ✓ 2017 (948) ✓ 2017 (129)
Southwest Nicolet River					✓ 2013 (2) ✓ 2014 (141)
SOUTHEAST ST. LAWRENCE HYDROLOGIC REGION					
BÉCANCOUR RIVER					
Bécancour River		✓ 1964 (121) ✓ 1975 (1)			✓ 2013 (22) ✓ 2015 (30) ✓ 2016 (77)

Hydrographic region and location	Period				
	1940-1959	1960-1979	1980-1999	2000-2009	2010-2018
GENTILLY RIVER					
Gentilly River	✓ 1941 (1)		✓ 1982 (10)		✓ 2013 (2) ✓ 2014 (3)
AUX ORIGNAUX RIVER					
Aux Orignaux River			✓ 1982 (1)		✓ 2013 (1) ✓ 2014 (2) ✓ 2015 (1)
LITTLE DU CHÊNE RIVER					
Little du Chêne River			✓ 1982 (4)		✓ 2016 (1)
Aux Ormes River					∅ 2013
DU CHÊNE RIVER					
Du Chêne River (Chaudière-Appalaches)					∅ 2013 ✓ 2016 (8)
Henri River					∅ 2013

In addition to these non-targeted surveys, surveys targeting Eastern Sand Darter are also carried out from time to time by the MFFP and DFO. In 2015, bottom trawling specifically designed to catch small benthic fish species was carried out by the MFFP in the Richelieu, Saint-François and Yamaska rivers, the Lake Saint-Pierre archipelago sector, and Lake Des Deux Montagnes. These surveys specifically targeting Eastern Sand Darter and Channel Darter successfully caught specimens of Eastern Sand Darter in deep water at some sites. Targeted surveys for Eastern Sand Darter were also carried out in several rivers from 2012 to 2017 by various consultants under contracts awarded by DFO. The increase in the number of reports of Eastern Sand Darter from the 2000s onward, particularly over the past decade, reflects the increased sampling effort in response to the designation of the species as threatened (Ricard *et al.* 2018).

In addition to the surveys described above, Eastern Sand Darter records have been contributed by non-profit organizations, consultants, Indigenous organizations, and students during targeted or non-targeted sampling. Such surveys are usually carried out with an electrofisher or by seining from shore. An analysis of the data collected in Quebec between 2010 and 2016 for four fish species at risk ((Eastern Sand Darter, Channel Darter (*Percina copelandi*), Bridle Shiner (*Notropis bifrenatus*) and Grass Pickerel (*Esox americanus vermiculatus*)) reveals that 30% of the data come from the MFFP, 23% from surveys conducted in the context of university research work, 19% from non-profit organizations, and 19% from DFO (Ricard *et al.* 2018). These results illustrate the important contribution of non-governmental organizations to the acquisition of data on Eastern Sand Darter and other at-risk fish species.

HABITAT

Habitat Requirements

Sand bottoms of streams and sandy shoals in lakes are the preferred habitat of Eastern Sand Darter (Scott and Crossman 1973). The species frequents the sandy portions of medium- to large-sized streams with moderate current that maintains a silt-free substrate without washing away sand (Trautman 1981). Eastern Sand Darter is typically found in the depositional areas downstream of bends in these streams and rivers (Daniels 1993; Facey 1998).

Although Eastern Sand Darter has been caught on mud, silt, gravel and cobble stream bottoms (Vladykov 1942; Holm and Mandrak 1996), its preference for sand habitats has been demonstrated both in the field (Dextrase *et al.* 2014) and in the laboratory (Daniels 1993; O'Brien and Facey 2008). According to Daniels (1993), few temperate stream fishes are as strongly associated with a particular habitat variable as is Eastern Sand Darter. In Ontario, occupancy models developed using data collected at 131 sites and 151 sites distributed within randomly selected sections in the Thames and Grand rivers, respectively, indicate that the proportion of sand and fine gravel (2.0 – 8.0 mm) is the most important variable for Eastern Sand Darter (Dextrase *et al.* 2014). In the Sydenham River, Poos *et al.* (2008) determined that the presence of the species was positively associated with coarse, clean substrates and negatively associated with silt, although no association was observed with the proportion of sand. In Ontario, the analysis of habitat data collected by Fisheries and Oceans Canada (DFO) from 2003 to 2018 in eight streams, rivers and lakes reveals that sand or gravel were the dominant substrate types at 79% of the sites where Eastern Sand Darter was captured (n = 437) (DFO unpubl. data). A similar analysis carried out in Quebec for 24 rivers and lakes sampled between 1941 and 2016 indicates that sand or gravel are the dominant substrate types at 83% of the sites where Eastern Sand Darter was observed (n = 153) (Ricard *et al.* 2018). The recent work carried out by Thompson *et al.* (2017) in the laboratory and in the natural environment indicate that Eastern Sand Darter of the Elk River, West Virginia, prefers streambeds composed of fine to coarse sand (0.125 – 1.0 mm) over those composed of very coarse sand (1.0 – 2.0 mm) and fine gravel (2.0 – 4.0 mm). This corroborates the results previously obtained by O'Brien and Facey (2008) in Vermont.

Eastern Sand Darter has been observed in clear, tea-coloured, and highly turbid waters (light attenuation depth assessed by means of a Secchi disk ≥ 7 cm), but a negative association with high turbidity was demonstrated by Poos *et al.* (2008) in the Sydenham River, Ontario. In Quebec, analysis of the habitat data collected from 1941 to 2016 indicates that the capture sites are characterized by low turbidity (values of 1 to 22 NTU, average = 5 NTU, n = 86) (Ricard *et al.* 2018). However, the turbidity values measured in Ontario between 2003 and 2018 are considerably higher (2 to 167 NTU, average = 49 NTU, n = 118), and water transparency at the capture sites is low (average light attenuation depth assessed at 13 cm using a Secchi disk; n = 215) (DFO unpubl. data). Dextrase *et al.* (2014) found a positive relationship between water clarity and occupancy in additive models with substrate in the Thames and Grand rivers. The average current velocity in the centre of the water column at the capture sites was assessed at 11.6 cm/s in the Mettawee River, New York (SD = 5.2, n = 213) (Daniels 1993), and at 10 cm/s in the Elk River, West Virginia (SD= 2, n = 47) (Thompson *et al.* 2018). In the Thames River, Ontario, the presence of Eastern Sand Darter is negatively correlated with current velocity when measured near the stream bottom (Finch 2009). In a study on the Sydenham River, Poos *et al.* (2008) found a positive association between presence of Eastern Sand Darter and flow. In the Grand and Thames rivers, flow does not seem to be an important factor in determining occupancy, but moderate flow or wave action may assist in maintaining the silt-free sand and gravel substrates preferred by the species (Dextrase 2013). Sites dominated by aquatic macrophytes are unlikely to be occupied (Facey 1998; Dextrase *et al.* 2014), and the frequency of captures decreases with the increase in vegetation cover in Quebec (n = 83) (Ricard *et al.* 2018).

Although most Eastern Sand Darter captures are made at depths of less than 1.5 m, this may be the result of a sampling bias related to the fishing gear most commonly used to catch this species (seining from shore and electrofisher). For example, individuals have been captured by trawl net at depths of 2 to 3 m in the Grand and Thames rivers (Dextrase 2013), and at depths of 2 to 5 m in the Richelieu, Saint-François, and St. Lawrence rivers (S. Garceau unpubl. data). One specimen was also caught at a depth of 14.6 m in Lake Erie, Ontario (Scott and Crossman 1973). Gáspárdy and Drake (2021) reported that trawling provides an advantage over seining during cooler periods because it allows effective fishing in deep water.

Few data exist on habitat use by young stages. Spawning of Eastern Sand Darter has not been observed in the wild but, in the laboratory, eggs were buried in a mixed sand and gravel substrate (Johnston 1989). In the Tippecanoe River, Indiana, post yolk-sac larvae were collected near shore in slow water downstream of riffles (Simon and Wallus 2006). Dextrase (2013) found adults and juveniles together at some sites, but juveniles were also found at sites with no adult detections — the co-occurrence models showed that they are likely to occur independently of each other. Simon and Wallus (2006) reported that early juveniles are more tolerant than adults of silt substrates adjacent to areas of coarse sand and gravel. Dextrase (2013) also found that occupancy of silty sites in the Thames River was more likely for juveniles than adults. However, use of these habitats may be related to current and predator avoidance as opposed to silt tolerance. Drake *et al.* (2008) demonstrated that first-year growth in the Thames River was lower for fish found in silt-dominated habitats than for those in sand-dominated habitats.

There is little information available on seasonal changes in habitat use. Eastern Sand Darter were captured in wadeable habitats of a 1.2-km stretch of the Little Muskingum River, Ohio, throughout the year, although captures were lower in winter (Faber 2006). The species was found in similar habitats from May to September in the Grand and Thames rivers (Dextrase 2013), although capture rates decreased sharply in October in the Grand River (Gáspárdy and Drake 2021). In the Richelieu River, more than 235 Eastern Sand Darter were collected with 82 seine hauls during a particularly high spring flood period in May and June 2007 while, in the same sector, none were caught in 40 seine hauls in September (N. Vachon unpubl. data). In the fall, in the same river, Eastern Sand Darter is usually observed on sites with sand substrates exposed to weak currents, with vegetation cover absent in 46% of cases and ranging from 10% to 50% in 51% of cases (N. Vachon pers. comm. 2019).

The habitat of Eastern Sand Darter is sometimes occupied by other species designated as at risk by COSEWIC. These include: fishes, Channel Darter (*Percina copelandi*), Silver Shiner (*Notropis photogenis*), Spotted Sucker (*Minytrema melanops*), River Redhorse (*Moxostoma carinatum*), Black Redhorse (*Moxostoma duquesnei*), Copper Redhorse, and Northern Madtom (*Noturus stigmosus*); freshwater mussels, Northern Riffleshell (*Epioblasma torulosa rangiana*), Snuffbox (*Epioblasma triquetra*), Rayed Bean (*Villosa fabalis*), Mudpuppy Mussel (*Simpsonaias ambigua*), Mapleleaf (*Quadrula quadrula*), Round Hickorynut, and Round Pigtoe (*Pleurobema sintoxia*); and turtles, Spiny Softshell (*Apalone spinifera*), Map Turtle (*Graptemys geographica*), and Wood Turtle (*Glyptemys insculpta*).

Habitat Trends

Eastern Sand Darter habitat quality and availability are affected by agricultural activities and urbanization throughout the species' range. The quality of aquatic habitat is closely related to water quality, and the assessment of water quality can serve as an indicator for assessing habitat trends for this species.

In Ontario rivers, siltation associated with intensive agriculture has adverse effects on the clean sand habitats preferred by Eastern Sand Darter (Holm and Mandrak 1996). Excessive nutrient enrichment and turbidity are problematic in most of these watersheds (Staton *et al.* 2003; Portt *et al.* 2004; TRRT 2004; Edwards *et al.* 2007). In addition, impoundments have been constructed in most of the watersheds occupied by the species, which are characterized by widespread agricultural drainage. The hydrology of the Ausable River has been particularly affected by stream straightening (Nelson *et al.* 2003). In the Grand River, the construction of dams in the range of Eastern Sand Darter has resulted in habitat loss over several kilometres upstream and is probably modifying the natural sedimentation processes associated with the formation and maintenance of the sandbars used by the species (Portt *et al.* 2004; Dextrase 2013). In addition to the effects related to agricultural activities, major urban centres are expanding upstream of the range occupied by Eastern Sand Darter in the Grand and Thames rivers. Measures to improve water quality have been successfully instituted in the Grand River (Plummer *et al.* 2005), but the pressures on the watershed are still very much present owing to the growth of the human population (Edwards *et al.* 2007). Analysis of water quality in the lower course of the Grand River for the 2013-2015 period indicates that nutrient concentrations generally exceed the quality criteria for the maintenance of aquatic life, often significantly (GRCA 2017). In addition, the phosphorus load of the Grand River is the highest of the Lake Erie tributaries. For the Thames River, some reduction in the risk of nitrogen contamination of surface water from agricultural activities occurred during the 1981-2011 period (AAFC 2016a), but an increased risk of phosphorus contamination from agricultural activities occurred during the same period (indicators based on the residual quantities of these nutrients in the soil) (AAFC 2016b).

Nearshore habitats in lakes Erie and St. Clair have changed considerably over the last half century. Eutrophication of Lake Erie resulted in a generalized reduction in oxygen concentrations and changes to the benthic community over the period from 1955 to 1980 (Koonce *et al.* 1996). Water quality has since improved and a downward trend in phosphorus concentrations was observed for the period 1972-2013, but concentrations remain high (ECCC 2017). Lake Erie shoreline habitat has been extensively modified by erosion control structures that have altered nearshore sediment transport. Habitat in Lake St. Clair changed dramatically after the invasion of Zebra Mussel (*Dreissena polymorpha*) in the late 1980s, when water clarity and the abundance of aquatic macrophytes increased significantly (Griffiths 1993). This may have been detrimental to Eastern Sand Darter habitat in the lake. Water-quality analysis in the Lake St. Clair watershed from 2001 to 2015 showed that the water quality of the various sub-watersheds in the Canadian portion of the watershed is relatively stable and is assessed as poor to fair (index based on phosphorus concentrations, fecal coliform levels, and benthic communities) (SCRCA 2018).

In Quebec, Eastern Sand Darter occupies watersheds subject to intensive urban and agricultural development. Similar to Ontario rivers, these watersheds are altered by siltation, turbidity, and excessive nutrient inputs (Edwards *et al.* 2007; ERCPPQ 2020). Large Eastern Sand Darter populations are found in some of the most polluted rivers in Quebec: Richelieu, Châteauguay, L'Assomption, Saint-François, and Yamaska. These rivers all exhibited substantial phosphorus, nitrogen, and suspended matter loads during the 2009-2012 period (Patoine 2017). Water-quality monitoring for the 2002-2011 period revealed downward trends for total phosphorus in the L'Assomption River, Saint-François River, and Yamaska River (MELCC 2019). Nitrite and nitrate concentrations appear to be decreasing in the Saint-François River, but could be increasing in the L'Assomption River. Concentrations of suspended matter in the five rivers have remained stable. Recent analyses were also conducted to assess the water quality in 11 tributaries of Lake Saint-Pierre (including the Richelieu, Yamaska, and Saint-François rivers) (Simoneau *et al.* 2017). The results indicate a significant improvement in the bacteriological water quality and significant downward trends for phosphorus concentrations for the period 1979-2014. Despite the improvements observed, the water quality of several of these tributaries is still unsatisfactory, as evidenced by the frequency of exceedance of the water-quality guideline for phosphorus, which varies from 24% to 100%, depending on the tributary. There are, therefore, still significant pressures on the habitat of Eastern Sand Darter throughout its range.

BIOLOGY

Eastern Sand Darter is a globally rare species and there have been few studies specifically examining its biology. Most life-history studies have been conducted in the Ohio River basin in the United States, but there have been a few recent studies in rivers in southwestern Ontario, particularly the Thames River.

Life Cycle and Reproduction

Eastern Sand Darter is relatively short-lived, reaching a maximum age of 4 years in the Thames River, Ontario (Drake *et al.* 2008), although most adults are 1 or 2 years old (Finch *et al.* 2009). Studies of populations from two Ohio streams found a maximum age of 2 to 3 years (Spreitzer 1979; Faber 2006). The annual survival rate of Eastern Sand Darter in the Thames River was estimated at 0.38 ± 0.03 by Finch *et al.* (2013). Reported sex ratios (female:male) are 2.54:1 for the Thames River (Finch *et al.* 2013), 1.16:1 for the Little Muskingum River, Ohio (Faber 2006), and 1:1 for Salt Creek, Ohio (Spreitzer 1979).

Eastern Sand Darter grow quickly and attain most of their total length during their first year of life with growth rates strongly related to annual discharge (Drake *et al.* 2008). The work of Finch *et al.* (2013) indicated that individuals in the Thames River grew faster than those in the Little Muskingum River. Fish of both sexes mature in the spring following their first growing season at age 1 (Spreitzer 1979; Finch *et al.* 2013), but some females may not reproduce until their second year (Faber 2006). Given that fish mature at age 1, and that few live beyond age 3, generation time is estimated at 2 years.

Fecundity is low but comparable to many darter species. In the Thames River, clutch size of the 10 females collected ranged from 35 to 123 eggs (mean = 71.5 ± 22.7 SD) (Finch *et al.* 2013). Clutch size ranged from 16 to 97 eggs (mean = 61.2 ± 8.2) for the population in the Little Muskingum River (Finch *et al.* 2013). In Salt Creek, the total number of eggs counted in ova-bearing females ranged from 22 to 829 (mean = 343) and the number of mature ova in fecund females (eggs that are actually laid, hence clutch size) ranged from 30 to 170 (mean = 71) (Spreitzer 1979). Larger females had larger clutch sizes in the two Ohio populations, while the gonadosomatic index (gonad weight/total body weight) and fecundity of the females were not related to the size of the individuals in the case of the Thames River.

Eastern Sand Darter is an intermittent spawner, and females may lay eggs several times during the spawning season (Johnston 1989; Simon and Wallus 2006). For American Eastern Sand Darter populations, spawning periods from April to August at water temperatures of 14.4°C to 25.5°C have been reported (Williams 1975; Spreitzer 1979; Johnston 1989; Facey 1998; Faber 2006; Simon and Wallus 2006). Eastern Sand Darter has been observed to spawn in the laboratory at water temperatures of between 20.5°C and 23°C (Johnston 1989). Analysis of daily growth increments on otoliths of 535 young-of-the-year Eastern Sand Darter from the Thames River suggests that spawning occurs between late April and mid-June (Finch *et al.* 2013). Spawning could therefore take place earlier than previously believed. Examination of the gonads of 17 specimens from several watersheds in Ontario previously suggested that spawning occurred between late June and late July (Holm and Mandrak 1996). However, it is difficult to determine whether the early onset of the spawning period in 2006 in Ontario is typical of Canadian populations, or rather specific to the Thames River population. It is possible that this early spawning was the result of the particular hydrologic conditions observed in 2006, which led to greater spring warming of the river water. Water temperature is an important factor in triggering spawning. According to Spreitzer (1979), the spawning season could also be synchronized with low silt levels in the habitat.

Actual observations of the spawning act have only been made in the laboratory (Johnston 1989). During spawning, the male mounts the female and the pair vibrate and bury their tails and caudal peduncles in the substrate where eggs are deposited and then buried in the substrate. “Sneaker males” (males that quickly sneak in and fertilize eggs of a female spawning with another male) often joined mating pairs (Johnston 1989). Spawning activity was observed during day and night. A well-oxygenated substrate, such as unsilted sand, is likely required for high egg survivorship.

The average diameter of mature ova of breeding females is 0.94 ± 0.01 mm for the Thames River and 1.08 ± 0.01 mm for the Little Muskingum River (Finch *et al.* 2013). Fertilized eggs, observed in the laboratory, are slightly adhesive and average 1.4 mm in diameter (Johnston 1989). Hatching occurs in 4 to 5 days at 20.5°C to 23°C (Simon *et al.* 1992). Newly hatched larvae are 5.5 to 5.7 mm long (total length) and remain in the substrate for a short period until exogenous feeding commences (Simon *et al.* 1992; Simon and Wallus 2006). Post yolk-sac larvae from the Tippecanoe River, Ohio, were found in pelagic drift samples during dusk and night periods, but became benthic at total lengths greater than 7.4 mm (Simon and Wallus 2006). Larvae transform into juveniles at a total length of 18 mm (Simon and Wallus 2006). In the Thames River, juvenile fish large enough to be captured in a 3-mm mesh seine net were first detected on July 5 (Dextrase 2013), but the smallest juvenile (total length = 18 mm) was seen at the end of July, which supports the hypothesis of a protracted spawning period. The juvenile stage is relatively short-lived, as most fish mature in the spring following hatching.

Fossorial (burying) behaviour is well-developed in the sand darter genus *Ammocrypta*. Daniels (1989) provided evidence that burying is an adaptation to maintain position on relatively homogenous sand beds, particularly during periods of extremely high or low flow. His experiments suggested that Eastern Sand Darter does not bury to avoid predators or to ambush prey. Similar experimental work by Simon (1991) supported the hypothesis that burying is a resting response used during occupation of homogeneous sand habitats. Low oxygen levels in silted substrate may discourage complete burial or reduce the length of burial time. This may have a negative survival effect by increasing the amount of energy expended to maintain position in its habitat. Despite the two experimental studies, Eastern Sand Darter in the wild have been observed to quickly dart under the sand upon being approached by juvenile Smallmouth Bass (*Micropterus dolomieu*), suggesting that fossorial behaviour may be used in some instances to escape predation (Dextrase 2013).

Feeding/nutrition

The diet of Eastern Sand Darter is composed of benthic invertebrates. Due to its small mouth size and restricted habitat, several authors suggest that Eastern Sand Darter feeds essentially on midge larvae (Chironomidae) and black-fly larvae (Simuliidae), and probably some crustaceans (Turner 1921; Scott and Crossman 1973; Smith 1979; Cooper 1983). In Salt Creek, Ohio, midge larvae composed an average of 94.4% of the diet of Eastern Sand Darter. Aquatic worms (Oligochaeta) and water fleas (Cladocera) composed significant, but smaller, proportions in June and November, respectively (Spreitzer 1979). In the Little

Muskingum River, Ohio, midge larvae composed 93% of the diet over all seasons, but several other aquatic invertebrate taxa were consumed, including biting midges (Ceratopogonidae), fingernail clams (Sphaeriidae), and seed shrimp (Ostracoda) (Faber 2006).

The study of the diet of Eastern Sand Darter in the Thames River, however, reveals that the place of midge larvae in the species' diet could be less important than previously assumed (Burbank *et al.* 2019). First, analysis of the stomach contents of 38 individuals indicates that midge larvae composed 50% of the summer diet, while ostracods composed 21%. Second, the analysis of stable isotopes carried out based on samples from 65 individuals suggests more generalist feeding behaviour on an annual basis, while mayflies (Ephemeroptera), oligochaetes, chironomids, ostracods, and water fleas accounted for, respectively, 33%, 29% 19%, 17%, and 1% of the diet.

Eastern Sand Darter capture their prey using quick lunges of 0.5 to 1.0 cm and then retreating to their pre-strike position (Spreitzer 1979; Dextrase 2013). Incidentally ingested sand is then expelled through the mouth.

Predation

There are several potential predators of Eastern Sand Darter, but actual predation has rarely been recorded. Potential fish predators include Channel Catfish (*Ictalurus punctatus*), Stonecat (*Noturus flavus*), Smallmouth Bass, and Rock Bass (*Ambloplites rupestris*), which commonly co-occur with Eastern Sand Darter. Eastern Sand Darter have been found in the stomach contents of Channel Catfish from the Thames River (M. Finch pers. comm., 2009). Piscivorous birds, such as Belted Kingfisher (*Ceryle alcyon*) and Great Blue Heron (*Ardea herodias*), are also potential predators. The fossorial behaviour and cryptic colouration of Eastern Sand Darter likely provide some protection from predation, and predation has not been linked to declines or been identified as a threat in Eastern Sand Darter populations.

Physiology and Adaptability

Eastern Sand Darter appears to have limited adaptability. The species has strict habitat requirements (i.e., clean sand substrates) and has declined throughout much of its range where habitat alteration has occurred (Grandmaison *et al.* 2004). Eastern Sand Darter likely has limited dispersal capability, and Canadian populations are genetically isolated between rivers (Ginson *et al.* 2015). Consequently, when isolated populations are extirpated, natural recolonization of the habitats is unlikely. Conversely, the natural movements of individuals within the same river (Ginson *et al.* 2015) could make it possible to compensate for the local and temporary loss of certain habitats. In addition, Daniels (1993) reported that Eastern Sand Darter seem to have colonized the Mettawee River, New York, after improvement of habitat conditions following reforestation of riparian buffers.

A study on the tolerance of Eastern Sand Darter to increased temperatures and low oxygen concentrations is being conducted in Grand and Thames rivers. Preliminary results indicate that Eastern Sand Darter can tolerate temperatures of up to 36.4 ± 0.23°C in July, when the species is acclimated at 25°C. Individuals can tolerate oxygen concentrations of 1.15 mg/L at 25°C and of 0.64 mg/L at 17°C (Firth *et al.* 2021).

Dispersal and Migration

Eastern Sand Darter is a small fish that does not have a swim bladder and is well adapted to a benthic and relatively sedentary lifestyle, as are most darter species (Page 1983). Little is known about the movements of this species. Johnston (1989) reported that male Eastern Sand Darter congregated during the spawning season at a site in the Tippecanoe River, in Indiana, in July 1987, while the 1:1 sex ratio observed by Spreitzer (1979) year-round in Salt Creek, Ohio, suggested that there is no migration during the spawning season. However, Eastern Sand Darter may migrate to feed when the abundance of chironomids is low in a habitat (Spreitzer 1979). Based on genetic data, Ginson *et al.* (2015) concluded that individuals are capable of moving through the naturally fragmented habitats of a stream. The movements of adults are undoubtedly influenced by their dependency on sandbars, which are constantly shifting. Larval Eastern Sand Darter appear to drift downstream for a short period of time before they become benthic, a phenomenon confirmed by Simon and Wallus (2006). The distances associated with this downstream drift are unknown.

Interspecific Interactions

Lamothe *et al.* (2019) assessed the patterns of co-occurrence of Eastern Sand Darter with other species of the community in the Thames and Grand rivers, Ontario, considering the detectability of the species present. The results show a positive association between Eastern Sand Darter and Northern Hog Sucker (*Hypentelium nigricans*) and Silver Shiner (*Notropis photogenis*) in the Grand River. Conversely, a negative association was observed with Rosyface Shiner (*Notropis rubellus*). These findings illustrate the similarity between the preferred habitat of the former three species, which seek out substrates dominated by sand and fine gravel, substrates that appear to be avoided by Rosyface Shiner. However, Lamothe *et al.* (2019) found no significant associations between Eastern Sand Darter and other fish species in the Thames River after accounting for imperfect detection. In the Thames River, naïve Eastern Sand Darter abundance (without accounting for detectability) was positively associated with the abundance of several species. The strongest correlations (in order of strength of correlation) were with Bluntnose Minnow (*Pimephales notatus*), Mimic Shiner (*Notropis volucellus*), and Logperch (*Percina caprodes*) (COSEWIC 2009). Johnny Darter (*Etheostoma nigrum*) was the most abundant species among the darter species found in the sites used by Eastern Sand Darter. Eastern Sand Darter has also been associated with Johnny Darter in Ohio (Spreitzer 1979) and New York (Daniels 1993).

Apart from these associations, few studies have documented the nature of the interspecific interactions of Eastern Sand Darter. Burbank *et al.* (2019) recently highlighted the overlap of the trophic niche of Eastern Sand Darter with those of Johnny Darter and Blackside Darter (*Percina maculata*) in the Thames River, which suggests possible competition between these species when food resources become scarce. A significant overlap of the diet of Eastern Sand Darter with the diets of Johnny Darter, Brindled Madtom (*Noturus miurus*), and Round Goby (*Neogobius melanostomus*) was also identified in the Sydenham River, Ontario (Firth *et al.* 2021). The observations of Ray and Corkum (2001) suggested that, when their densities are high, adult gobies force juvenile gobies to retreat to sandy habitats, generally less desired by this species, which could then place them in direct competition with Eastern Sand Darter (Poos *et al.* 2010).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Quantitative data that would make it possible to assess the abundance and trends of Eastern Sand Darter populations are very limited. Many of the surveys conducted are limited to the information related to the presence or absence of the species, particularly in Quebec, where a survey protocol published in 2011 recommended that sampling be halted as soon a specimen is captured to minimize the impact of repeated sampling on populations (Couillard *et al.* 2011). It is difficult to conduct an analysis of demographic trends, as there are too few localities where samples were collected on several occasions using similar sampling gear and methods.

The available information on the abundance and trajectory of the populations was included in two reports published by DFO (Boucher and Garceau 2010; Bouvier and Mandrak 2010). These reports only include the data available before 2010 and, therefore, do not include sites surveyed since then. The West Lake population, unknown at the time, was not assessed. In these reports, qualitative indices were developed to assess the relative status of the populations. A relative abundance index was attributed to each of the known populations, based on available data. The trajectory over time was then estimated, considering the number of individuals captured over time for each population. When insufficient information was available to assess the relative abundance index or the trajectory, a ranking of “unknown” was assigned. A level of certainty was also associated with each of the indices assessed for a population. The values of the two indices were then combined in a matrix to determine the status of each population. Note that the population status index is also relative as it is based on the relative abundance index. The degree of certainty associated with the estimate of the status of a population is the lowest assigned to any of the initial parameters.

Abundance

The abundance of Eastern Sand Darter populations in southwestern Ontario and Quebec, assessed in 2010 with the relative abundance index described above, is presented in Table 4. The results indicate that the populations with the highest abundance in 2010 (among those that were assessed) were those of the Thames and Grand rivers in southwestern Ontario and the Aux Saumons River in Quebec. Capture data provided in Tables 2 and 3 suggest that, currently, the abundance of the species could be high in West Lake, Ontario, and in the Richelieu and Nicolet rivers, Quebec. However, the relative abundance index of these populations has not yet been estimated. The populations where abundance appears to be the lowest in 2010 in southwestern Ontario were in Lake St. Clair, Sydenham River, and Ausable River (species extirpated), Catfish Creek (extirpated), Big Otter Creek (extirpated), Big Creek, and Long Point Bay. In Quebec, abundance was lowest in the Montréal–Sorel section of the St. Lawrence River, Lake Saint-Pierre archipelago, Lake Saint-Pierre, Lake Des Deux Montagnes, and Châteauguay, Yamaska, and Saint-François rivers. However, data collected between 2010 and 2018 and presented in Tables 2 and 3 indicate that the abundance of the population of the Saint-François River could currently be higher than during the assessment conducted in 2010. Finally, it should be noted that the available information was insufficient to assess the relative abundance of the populations in the southeastern St. Lawrence region in Quebec.

Table 4. Relative abundance index, trajectory, and status of Eastern Sand Darter in the southwestern Ontario and Quebec populations in 2010 (adapted from Boucher and Garceau 2010, and Bouvier and Mandrak 2010). The populations in italics are those discovered since the publication of the previous COSEWIC report. A level of certainty was assigned based on the type of information available: 1 = quantitative analysis, 2 = catch per unit of effort (CPUE) or standardized sampling, 3 = expert opinion. The level of certainty assigned to the population status corresponds to the lowest level of certainty associated with the other parameters.

Population	Relative abundance index	Certainty	Trajectory	Certainty	Population status	Certainty
SOUTHWESTERN ONTARIO DESIGNATABLE UNIT						
LAKE HURON WATERSHED						
Ausable River	Extirpated	2	N/A	2	Extirpated	2
LAKE ST. CLAIR WATERSHED						
Lake St. Clair	Low	2	Decreasing	3	Poor	3
Thames River	High	1	Stable	1	Good	1
Sydenham River	Low	2	Unknown	3	Poor	3
Detroit River	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*
LAKE ERIE WATERSHED						
Western Basin	Unknown	3	Unknown	3	Unknown	3
Rondeau Bay	Unknown	3	Unknown	3	Unknown	3
Long Point Bay	Low	2	Decreasing	2	Poor	2
Catfish Creek	Extirpated	3	N/A	3	Extirpated	3
Big Otter Creek	Extirpated	3	N/A	3	Extirpated	3

Population	Relative abundance index	Certainty	Trajectory	Certainty	Population status	Certainty
Big Creek	Low	3	Unknown	3	Poor	3
Grand River	High	2	Stable	2	Good	2
QUEBEC DESIGNATABLE UNIT						
ST. LAWRENCE RIVER						
Montréal–Sorel section	Low	2	Unknown	3	Poor	3
Lake Saint-Pierre archipelago	Low	2	Unknown	3	Poor	3
Lake Saint-Pierre	Low	2	Unknown	3	Poor	3
Trois-Rivières–Batiscan section	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*
OUTAOUAIS AND MONTRÉAL HYDROGRAPHIC REGION						
Lake Des Deux Montagnes	Low	3	Unknown	3	Poor	3
Des Milles Îles River	Unknown	2	Unknown	3	Unknown	3
Mascouche River	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*
NORTHWEST ST. LAWRENCE HYDROGRAPHIC REGION						
L’Assomption River	Medium	2	Stable	3	Fair	3
Ouareau River	Medium	2	Stable	3	Fair	3
Maskinongé River	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*
Du Loup River	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*
Yamachiche River	Unknown	3	Unknown	3	Unknown	3
Little Yamachiche River	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*
Saint-Maurice River	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*
Champlain River	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*
SOUTHWEST ST. LAWRENCE HYDROGRAPHIC REGION						
Aux Saumons River	High	2	Stable	3	Good	3
Trout River	Unknown	2	Unknown	3	Unknown	2
Châteauguay River	Low	2	Decreasing	3	Poor	3
Richelieu River	Medium	2	Stable	3	Fair	3
Yamaska River	Low	3	Decreasing	3	Poor	3
Saint-François River	Low	2	Decreasing	3	Poor	3
Nicolet River	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*
SOUTHEAST ST. LAWRENCE HYDROGRAPHIC REGION						
Bécancour River	Unknown	3	Unknown	3	Unknown	3
Gentilly River	Unknown	3	Unknown	3	Unknown	3
Aux Orignaux River	Unknown	3	Unknown	3	Unknown	3
Little du Chêne River	Unknown	3	Unknown	3	Unknown	3
Du Chêne River	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*
WEST LAKE DESIGNATABLE UNIT						
LAKE ONTARIO WATERSHED						
West Lake	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*	*Not assessed*

Fluctuations and Trends

The trends concerning the abundance of the Canadian populations of Eastern Sand Darter for each of the populations assessed in 2010 are presented in Table 4. It should be noted that the data were insufficient to assess the trajectory of four of 12 southwestern Ontario and 11 of 27 Quebec populations. In addition, trends were not assessed for many recently discovered populations (one in southwestern Ontario, West Lake, and eight in Quebec). Moreover, the Little Yamachiche River population trend was not assessed as this population was not included in the previous COSEWIC report. Therefore, our knowledge of the trends of Eastern Sand Darter populations remains incomplete. It is unlikely that the status of Eastern Sand Darter has significantly improved over the past 10 years given that, in 2010, none of the populations assessed appeared to be increasing throughout the Canadian range and the populations of Lake St. Clair, Long Point Bay (DU1) and Yamaska, Châteauguay, and Saint-François rivers (DU2) appeared to be declining. These declines are observed in populations whose abundance is already low, which raises concerns about their long-term survival. This finding is supported by the population status index, which combines the relative abundance index and the population trajectory (Table 4). Only three of the populations assessed appear to be in good condition in 2010: the populations of the Thames and Grand rivers in Ontario, and of the Aux Saumons River in Quebec. Fourteen of the 29 populations assessed were considered extirpated or in poor condition.

Nonetheless, the discovery of 10 new populations since the previous status report, one in southwestern Ontario, eight in Quebec and one in West Lake, Ontario, is encouraging. For example, in Quebec, during the period of 2013-2018, the species was detected at 107 stations distributed in the Nicolet River watershed, over a distance of more than 70 km from the mouth. However, these discoveries undoubtedly reflect increased sampling effort over the past decade rather than an actual range extension (Ricard *et al.* 2018).

Rescue Effect

Eastern Sand Darter is listed as at risk in all five American states adjacent to Canadian populations (Endangered - Pennsylvania; Threatened - Michigan, Vermont, New York; Vulnerable - Ohio). It is possible that populations in Michigan (Michigan State University n.d.) could disperse into Canadian waters of Lake Huron and Lake St. Clair if suitable habitat were available. Eastern Sand Darter was collected from the Pennsylvania and New York waters of Lake Erie in the 1990s (Grandmaison *et al.* 2004) and may still be present in the Ohio waters of the lake. There are no records from the Michigan waters of Lake Erie (Bailey *et al.* 2004). Fish from the American waters of eastern Lake Erie would need to traverse a considerable distance of unsuitable deep, cold habitat to colonize areas in the Canadian waters of Lake Erie, so rescue from these populations seems unlikely. Eastern Sand Darter occurs in five tributaries to Lake Champlain in Vermont and New York. Although it has not been captured from the lake itself in the United States (Daniels 1993; Facey 1998; Grandmaison *et al.* 2004), it was detected in Missisquoi Bay, Lake Champlain, Quebec, and it is possible that these populations could serve as a source of rescue for downstream populations in the Richelieu River system in Quebec. The population in Aux

Saumons River could potentially be rescued from upstream populations in New York. Rescue would be contingent on suitable habitat being present in Canadian waters. Overall, rescue appears unlikely given the rarity of bordering American populations, the strict habitat requirements of this species, and its limited dispersal abilities. Furthermore, the absence of connectivity between the Canadian populations of Eastern Sand Darter (Ginson *et al.* 2015) makes the idea of potential connectivity between Canadian designatable units and with the American populations all the more improbable.

THREATS AND LIMITING FACTORS

Threats

A threats calculator was used to identify the nature and magnitude of threats to Eastern Sand Darter. This calculator is based on the IUCN-CMP (World Conservation Union-Conservation Measures Partnership) unified threats classification system (IUCN and CMP 2006; Salafsky *et al.* 2008). Results indicate that the overall threat impact is high-medium for the Southwestern Ontario population (DU1), very high to high for the Quebec population (DU2), and medium to low for the West Lake population (DU3) (Appendices 2, 3, and 4).

<u>9. Pollution (DU1 – medium; DU2 – high-medium; DU3 – negligible)</u>

9.1. Domestic and urban wastewater

Domestic and urban wastewater is often discharged into rivers and may contain contaminants such as detergents, heavy metals, hydrocarbons, hormones or pharmaceutical compounds (DFO 2014a). Although most municipalities today are equipped with wastewater treatment systems, these systems often do not have the capability to eliminate micropollutants such as pesticides and chemical substances of medical origin (ERCPPQ 2019). In addition, sewer overflows are often discharged directly into rivers (DFO 2014a). In addition to these pollutants, alteration of the banks by urban development also generates sediment inputs into rivers (DFO 2014a). In Quebec, the impacts of contaminants of domestic and urban origin on Eastern Sand Darter populations were serious cause for concern in the Montréal–Sorel section of the St. Lawrence River and in the Richelieu, Yamaska, L'Assomption, Châteauguay, Saint-François, and Gentilly rivers in 2007 (Edwards *et al.* 2007) and may be still significant according to recent water-quality reports (Patoine 2017; Simoneau 2017). However, it should be noted that it is difficult to discriminate between pollution from urban and agricultural sources and to assess those threats separately. The presence of large urban centres in the Lake St. Clair watershed (along the U.S. border) and the Thames and Grand rivers, in southwestern Ontario, suggests that this threat could be significant for Eastern Sand Darter populations.

9.2. Industrial effluents

Industrial activities in urban areas may release effluents containing various contaminants that could have direct or indirect effects on Eastern Sand Darter populations. However, severity and scope of this threat are difficult to assess due to our incomplete understanding of problematic industries and of the nature of the compounds present. As there are urban areas located upstream of most populations in southwestern Ontario, industrial effluents could represent a significant threat, particularly around Lake St. Clair. In Quebec, this threat is likely more prevalent in the Montréal area, and maritime terminal extension projects in development in Contrecoeur, near Sorel, and Quebec City could increase the scope of this threat in the near future.

9.3. Agricultural effluents

In southwestern Ontario, as in Quebec, most rivers and lakes occupied by Eastern Sand Darter are in watersheds affected by intensive agriculture. These activities, combined with the absence of permanent vegetation cover, expose the soil to surface runoff, which carries various pollutants into the rivers.

Sediment inputs resulting from agricultural activities, which are responsible for the major losses of Eastern Sand Darter habitats in the last century (Holm and Mandrak 1996), still pose a significant threat to the survival of these populations. These inputs are particularly significant when there is loss of riparian vegetation (DFO 2014) or when tillage, application of pesticides, herbicides or fertilizers, as well as harvesting and grazing activities, occur too close to the streams (Vachon 2003). The resulting siltation of the substrate reduces available oxygen, which can affect egg survival, reduce the availability of spawning sites (Finch 2009), reduce the growth rate of juveniles (Drake *et al.* 2008), and limit the fossorial behaviour of the fish. Modification of the substrate also disrupts communities of benthic invertebrates, consequently affecting the species that feed on them (Berkman and Rabeni 1987; Holm and Mandrak 1996).

In addition, nutrient inputs associated with agricultural activities have been identified as the primary threat to aquatic species at risk in the Ausable, Sydenham, and Thames watersheds in southwestern Ontario (Nelson *et al.* 2003; Staton *et al.* 2003; Taylor *et al.* 2004), and this is also considered a very serious threat in the Big and Big Otter creeks (Edwards *et al.* 2007). In Quebec, agricultural pollution (all types of contaminants combined) has been ranked as a high severity threat for 11 Eastern Sand Darter populations: Montréal–Sorel section of the St. Lawrence River, Lake Saint-Pierre archipelago, Lake Saint-Pierre, and the Yamaska, Richelieu, Châteauguay, Trout, L'Assomption, Saint-François, Bécancour, and Gentilly rivers (Edwards *et al.* 2007). More recent data suggest that those areas are still very affected by agricultural effluents (Patoine 2017; Simoneau 2017). Intensive corn and soybean production, often associated with the hog industry, is a concern in many of the Quebec watersheds. Poos *et al.* (2008) found a negative association between the occurrence of Eastern Sand Darter and nitrate levels in the Sydenham River, Ontario. Excessive nutrient inputs promote the growth of macrophytes and algae, which can directly impact habitat and reduce dissolved oxygen levels.

The impacts of pesticide use on Eastern Sand Darter populations are also of concern. Depending on their nature and concentration, chemical substances, such as pesticides, can have lethal effects on fishes or cause disturbances of their endocrine and immune systems, behaviour or development (De Lafontaine *et al.* 2002; Jobling and Tyler 2003; Aravindakshan *et al.* 2004). The impact of the accumulated contaminants in the substrate could be significant for Eastern Sand Darter due to its fossorial behaviour and benthic feeding (Grandmaison *et al.* 2004). As an example, the systemic use of neonicotinoid pesticides in Quebec may represent a significant threat for Eastern Sand Darter as they have been shown to reduce abundance of aquatic insects (Morrissey *et al.* 2015). Although still used in Ontario, the prophylactic planting of neonicotinoid-coated corn and soybeans has been reduced by a 2017 regulation that requires an assessment of need before use (Ministry of the Environment, Conservation and Parks 2019).

8. Invasive species (DU1 – medium-low; DU2 – high-medium; DU3 – medium-low)

The introduced Round Goby is a potential threat to most Eastern Sand Darter populations in Ontario and Quebec. It was first found in North America in the St. Clair River in 1990 (Jude *et al.* 1992) and has since spread to each of the Great Lakes, where it is now the most abundant species in some areas and is present in all river systems occupied by Eastern Sand Darter in Ontario (Bouvier and Mandrak 2010) as well as in West Lake (Reid and Dextrase 2014). In Quebec, Round Goby was first discovered in the St. Lawrence River in 1998 but is now widespread from Lake Saint-François in the west to the limits of brackish waters downstream of Quebec City (Boucher and Garceau 2010). Presumably, all tributaries to the St. Lawrence River with Eastern Sand Darter populations, downstream of dams, are vulnerable to invasion by Round Goby. To date, the species has been detected in the downstream section of three rivers occupied by Eastern Sand Darter: Aux Saumons River, Richelieu River, and Saint-François River (O. Morissette unpubl. data). Predation and competition from Round Goby have been implicated in declines of Mottled Sculpin (*Cottus bairdii*) and, possibly, Logperch populations in the St. Clair River (French and Jude 2001), Logperch in Lake Ontario (Balshine *et al.* 2005), several darter species in lakes Erie and St. Clair (Thomas and Haas 2004; Baker 2005; Reid and Mandrak 2008), and Tessellated Darter (*Etheostoma olmstedi*) in the St. Lawrence River (Morissette 2018). There have been few studies on the impact of Round Goby on Eastern Sand Darter due to the low frequency of capture of this rare species, but our knowledge of the possible competition between these species suggests an adverse effect. In the Grand River, Ontario, the abundance of Eastern Sand Darter is negatively correlated with the abundance of Round Goby (Raab *et al.* 2018). The presence of Round Goby is considered a medium to low impact threat to all Eastern Sand Darter populations of Ontario and a high to medium impact threat for populations inhabiting the St. Lawrence River and its tributaries, in reaches located downstream of dams, in Quebec.

7. Natural system modifications (DU1 – low; DU2 – medium; DU3 – na)

7.2. Dams and water management/use

River management efforts, carried out for various purposes, inevitably have an impact on hydrology and are likely to disturb the habitat of Eastern Sand Darter. In Canada, there are dams and impoundments in several of the river systems occupied by the species. These dams significantly alter the habitats by flooding upstream riffles, promoting siltation, and reducing flows downstream (Grandmaison *et al.* 2004; Edwards *et al.* 2007). Scouring and resultant armouring usually occurs downstream of dams, making the substrate coarser (A.J. Dextrase pers. comm. 2020). Upstream from the dams, the impounded areas have minimal flow, are much wider, contain large amounts of fine sediment, and sometimes have well-developed macrophyte cover, which influences the structure of benthic fish communities and could adversely affect Eastern Sand Darter (COSEWIC 2009). However, paradoxically, in the Grand River, Raab *et al.* (2018) observed that the presence of impoundments was associated with an increase in the abundance of Eastern Sand Darter, probably because this species selects sandy substrate typical of lower water velocities. Conversely, Dextrase *et al.* (2014) found that reach occupancy in the Grand River was positively related to the distance upstream of dams, suggesting that impounded sections were not suitable for Eastern Sand Darter – modelled occupancy began to increase about 25 km upstream of dams. In addition, impoundments were also identified as elements that facilitate the invasion of upstream sections of rivers by invasive aquatic species, such as the Round Goby (Raab *et al.* 2018), which could ultimately have an adverse effect on Eastern Sand Darter populations.

In addition to dams, stream channelization and widening, and the construction of drains carried out in many areas for flood control and to improve drainage for agricultural production, also have impacts on stream hydrology. These modifications increase peak flows, decrease low flows, and can lead to increased erosion and interfere with the natural sediment deposition processes that create the sandbars used by Eastern Sand Darter (Paine and Watt 1994; Helfman 2007). In lakes Erie and St. Clair, sediment transport has been altered by shoreline protection structures, and tile drains prevalent throughout southwestern Ontario, but the impacts on Eastern Sand Darter populations are difficult to assess. In the St. Lawrence River, recent climate trends and human channel alterations (e.g., dredging for shipping, water-control structures) have concentrated the flow in the main channel and reduced flows in shallow habitats inhabited by Eastern Sand Darter. A modelling exercise suggested that Eastern Sand Darter populations in the St. Lawrence River are sensitive to alterations in water levels and flows (Giguère *et al.* 2005). According to Bouvier and Mandrak (2010), the hydrological disturbances associated with the alteration of flow regimes and shoreline/riverbank modifications are considered a significant threat to seven Eastern Sand Darter populations in southwestern Ontario (Rondeau Bay, the Ausable, Thames, Sydenham and Grand rivers, and Catfish and Big creeks). In Quebec, almost all rivers occupied by Eastern Sand Darter have dams (M.-A. Couillard pers. comm. 2020).

In addition, the presence of dams, flow-management structures, poorly designed bridges and culverts, and work carried out in rivers (e.g., maintenance, straightening, filling) can create obstacles to the free movement of fishes (DFO 2014a). These obstacles contribute to fragmenting habitats and populations by limiting gene flow and reducing the likelihood of recolonization when small isolated populations are extirpated by other factors (Grandmaison *et al.* 2004). In Canada, barriers to free movement have been identified as an issue for the Eastern Sand Darter population of the Saint-François River, Quebec (Boucher and Garceau 2010; Bouvier and Mandrak 2010), but could be an issue for virtually every population because of significant presence of dams (M.-A. Couillard pers. comm. 2020).

7.3. Other ecosystem modifications

The introduction of the bacterium *Bacillus thuringiensis israelensis* (BTI) in lotic environments to control black-fly populations could also have an effect on the availability of food resources for Eastern Sand Darter in Quebec. This selective insecticide also has an impact on chironomid larvae (Liber *et al.* 1998; Boisvert and Lacoursière 2004), which are important prey of Eastern Sand Darter. Although there is a current lack of data on BTI use in Quebec, it may be widely used for the control of black flies in certain rivers in Quebec, and its impacts are cause for concern for the MFFP (M.-A. Couillard pers. comm. 2020).

<u>11. Climate change and severe weather (DU1 – medium-low; DU2 – high-low; DU3 – unknown)</u>

Although the effects of climate change on Eastern Sand Darter are largely unknown and difficult to predict, it can be assumed that changes in temperature and precipitation will have an impact on stream hydrology and on the habitat of Eastern Sand Darter (ERCPPQ 2019). In Quebec, anticipated effects include an increase in the annual precipitation, an increase in the frequency of heavy and extreme precipitation events, an extension of the number of consecutive days without precipitation during the summer season, significant increases in the duration of heat waves, lower spring floods and higher summer and fall floods (Ouranos 2015). These changes will have an impact on flow regimes and sedimentation patterns (Boyer *et al.* 2010), and fluctuations in water levels are likely to compromise the quality of shallow habitats, particularly in the St. Lawrence River (Mortsch *et al.* 2000; Fan *et al.* 2002; Croley 2003), where sandbars could become exposed (DFO 2014). The increase in water temperature could also reduce dissolved oxygen concentrations and create periods of hypoxia, a phenomenon to which Eastern Sand Darter could be vulnerable (Samson in prep.). In addition, the increase in the frequency of heavy precipitation events could lead to an increase in the number of discharges of overflow water, resulting in an additional contaminant load (DFO 2014). A climate-change vulnerability assessment conducted for Eastern Sand Darter in the Ontario Great Lakes Basin suggested that the species is highly vulnerable to climate change (Brinker *et al.* 2018). Anthropogenic barriers to dispersal, low dispersal ability, and narrow historical thermal niche are the main variables that promote Eastern Sand Darter sensitivity to climate change. Conversely, Firth *et al.* (2021) found Eastern Sand Darter to be not as sensitive to thermal effects as other species.

Other threats

Although their impacts could be minor or negligible, the following factors could also represent threats for some Eastern Sand Darter populations: residential, commercial and agricultural development inside habitats (mostly affecting Quebec population); dredging and wave action related to shipping lanes; by-catch in bait fishery (mostly affecting Southwestern Ontario population, see Drake and Mandrak 2014); and human disturbance from recreational activities and Eastern Sand Darter research.

Limiting Factors

Quality of the available habitats

Eastern Sand Darter has specific needs in terms of habitat. Its marked preference for clean sand and fine gravel substrates reduces its degree of resilience to environmental changes such as the disturbance of its habitat by siltation (Finch *et al.* 2013). Therefore, the quality of available habitats is a factor likely to limit the survival and recovery of the species.

Availability of food resources

The sandy habitats used by Eastern Sand Darter offer a low availability of prey, and the species' diet is more limited than the diet of other species that use adjacent habitats (Burbank *et al.* 2019). Eastern Sand Darter feeds almost exclusively on benthic invertebrates, which limits the availability of food resources. In addition, although the species is probably more generalist than it appears, chironomids nonetheless represent a major part of its diet during the summer season (Burbank *et al.* 2019). The availability of food resources could be a limiting factor for Eastern Sand Darter and a disturbance of communities of benthic invertebrates could affect the survival of a population, especially if a reduction in the abundance of chironomids occurred. In addition, intraspecific and interspecific competition could make the species vulnerable during periods when food resources are more limited. Benthic and benthopelagic species are the most likely to exert competitive pressure on Eastern Sand Darter for food resources (Burbank *et al.* 2019).

Population recovery capacity

The limited size of Eastern Sand Darter clutches and the species' short lifespan are biological characteristics that can limit the recovery of populations. First, the small clutch size generates only a limited number of juveniles. Second, the species' limited longevity results in individuals reproducing only a few times during their lifetime, which contributes to further reducing the fecundity of the species (Finch *et al.* 2013). The adaptive capacity of Eastern Sand Darter is limited, as the adaptive value of a fish population is partly determined by the fecundity and longevity of the species (Smith 1995). Therefore, Eastern Sand Darter populations are particularly vulnerable to disturbances that have an impact on the survival of fish of age 0+ and on the fecundity of spawners of age 1+ (Finch *et al.* 2011).

Fragmentation of populations

The genetic isolation of Eastern Sand Darter populations from one watershed to another reveals the lack of connectivity between habitats and populations (Ginson *et al.* 2015). Therefore, it appears unlikely that the species can recolonize an isolated population due to the distances that separate the populations, the small size of the species, its benthic lifestyle, and the presence of obstacles to movement. Consequently, a reduction in the abundance of an isolated population and the lack of immigration from neighbouring populations could result in a substantial reduction of genetic diversity (Grandmaison *et al.* 2004). This low genetic diversity could, in turn, result in a decrease in fecundity and reproductive fitness (Grandmaison *et al.* 2004).

Number of Locations

Seven locations are identified in southwestern Ontario (DU1), 27 in Quebec (DU2), and one in West Lake (DU3). Extirpated populations (Ausable River, Catfish Creek and Big Otter Creek in southwestern Ontario) were excluded from the count. Locations have been defined using the incidence of pollution and invasive species, as those are considered the main threats to Eastern Sand Darter in Canada. Non-point source pollution related to agricultural activities and urban areas or point-source pollution related to industrial activities are most likely to affect all areas downstream of the pollution sources. In Quebec, the invasion of Round Goby is considered as an equally important threat to Eastern Sand Darter populations. Populations co-occurring with Round Goby in the St. Lawrence and its tributaries downstream of impassable dams could be considered a single location. However, using this argument to define a larger location could mask the effect of more localized threats such as pollution. Therefore, all Canadian locations were primarily defined based on watershed (Boucher and Garceau 2010; Bouvier and Mandrak 2010). However, given its large size, it seems unlikely that pollution equally affects the entire St. Lawrence River itself. For these reasons, the St. Lawrence River was divided into four locations (Montréal–Sorel section, Lake Saint-Pierre archipelago, Lake Saint-Pierre, and Trois-Rivières–Batiscan section) (Boucher and Garceau 2010). On the other hand, in southwestern Ontario, Western Basin, Rondeau Bay, and Long Point Bay were considered as a single location (Lake Erie) based on the Round Goby threat as pollution is not a direct threat due to dilution. West Lake was defined as a location based on Round Goby threat as pollution is considered a negligible threat.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Eastern Sand Darter is listed as Threatened under Schedule 1 of the federal *Species at Risk Act* and as Endangered under Ontario’s *Endangered Species Act, 2007*. These listings prohibit killing or capturing this species without authorization, but the federal listing does not automatically ensure the protection of its habitat. In Quebec, Eastern Sand Darter was listed as Threatened under the *Act Respecting Threatened or Vulnerable Species* in

October 2009. In the United States, the darter is not listed under the *Endangered Species Act*, the species is not a candidate for listing, and its listing under this act has not been proposed.

A federal recovery strategy was published in 2012 for the Ontario populations (DFO 2012) and in 2014 for the Quebec populations of Eastern Sand Darter (DFO 2014a). These strategies propose a series of measures aimed at attaining short- and long-term objectives. The recovery strategy for Ontario populations sets out various strategies relating to: (1) research and monitoring; (2) management and habitat protection; and (3) stewardship, outreach and education. In Quebec, the measures proposed involve: (1) surveys and monitoring; (2) knowledge acquisition; (3) protection, restoration, and stewardship; (4) communication and outreach; and (5) partnership and coordination.

A provincial recovery plan was prepared for Eastern Sand Darter in Quebec in 2020 (ERCPPQ 2020). The status and the recovery of Eastern Sand Darter have been monitored in the province since the species was added to the list of species managed by the *Équipe de rétablissement des cyprinidés et petits percidés du Québec* (ERCPPQ) [Quebec Cyprinidae and Small Percidae Recovery Team] in 2005. In Ontario, ecosystem recovery strategies, aimed at Eastern Sand Darter and other species, have been prepared for Ausable, Grand, Sydenham, and western Lake Erie watersheds. Several recovery actions associated with these plans and strategies have been implemented, including stewardship initiatives with a view to improving the health of streams and watersheds, identification of the important habitats, and research to address knowledge gaps.

Non-Legal Status and Ranks

Eastern Sand Darter is listed as a species of least concern by the International Union for Conservation of Nature (NatureServe 2013) and as vulnerable according to the list of imperilled freshwater and diadromous fishes of North America of the American Fisheries Society Endangered Species Committee (Jelks *et al.* 2008). NatureServe ranks it as apparently secure globally (G4) and in the United States (N4) and as imperilled in Canada (N2) (Table 5) (NatureServe 2019). Among the conservation status ranks assigned to the species in the provinces and states where it occurs (Table 5), only the Kentucky and Indiana populations are considered apparently secure (S4), while the Illinois, Pennsylvania, and Vermont populations are considered critically imperilled (S1) and appear to be of greatest concern. The Ontario and Quebec populations are considered imperilled (S2).

Table 5. Conservation status ranks assigned to Eastern Sand Darter (*Ammocrypta pellucida*) at the global, national and subnational levels (NatureServe 2019).

Scale	Jurisdiction	Rank[1]
Global		G4
National	Canada	N2
	United States	N4
Subnational	Ontario, Quebec	S2
	Illinois, Pennsylvania, Vermont	S1
	Michigan	S1S2
	New York	S2S3
	Ohio, West Virginia	S3
	Kentucky, Indiana	S4

[1] G4/N4/S4 – Apparently secure: the species is uncommon, but not rare, and there is some cause for long-term concern due to declines or other factors at the scale considered; S3 – Vulnerable: vulnerable due to relatively restricted range, relatively low populations or occurrences, recent and widespread declines or other factors making it vulnerable to extirpation at the scale considered; N2/S2 – Imperilled: imperilled due to restricted range, few populations or occurrences, steep declines or other factors making it very vulnerable to extirpation at the scale considered; S1 – Critically imperilled: critically imperilled because of very restricted range, very few populations or occurrences, very steep declines or other factors making it especially vulnerable to extirpation at the scale considered. For more information on the ranks, consult: http://www.natureserve.org.

Habitat Protection and Ownership

The habitat of Eastern Sand Darter is subject to the general habitat protection provisions of the federal *Fisheries Act*. In addition, the federal *Species at Risk Act* protects the critical habitats of Eastern Sand Darter when these habitats are legally identified. In Ontario, critical habitats have been identified under the *Species at Risk Act* in the Sydenham, Thames, and Grand rivers, in Big Creek and in Long Point Bay of Lake Erie, an area covering 187 km^2. In Quebec, the federal critical habitats are distributed in certain segments of the L'Assomption River, Ouareau River, Richelieu River, and Aux Saumons River, which total approximately 23 km^2. In Ontario, the species is listed as a threatened species under the *Endangered Species Act, 2007*, and its habitat is also protected by a habitat protection regulation passed in 2015 under this act. In Quebec, although Eastern Sand Darter is designated as a threatened species under the *Act Respecting Threatened or Vulnerable Species*, its habitat does not receive any additional protection on the basis of the Act as these habitats have not been legally identified.

In Ontario, riparian lands adjacent to the habitat of Eastern Sand Darter receive policy-level protection through the fish habitat provisions of the Provincial Policy Statement (PPS) under the provincial *Planning Act*. The PPS prohibits development and site alteration on adjacent lands to fish habitat unless the ecological function of the adjacent lands has been evaluated and it has been demonstrated that there will be no negative impacts on the fish habitat and its ecological functions. The PPS only allows development and site alteration in fish habitat if it is permitted by relevant federal and provincial policies and legislation related to fish and fish habitat. The provincial *Lakes and Rivers Improvement Act* may also indirectly protect Eastern Sand Darter habitat when applications for the construction or maintenance of dams and dredging activities are reviewed. Certain provisions of the provincial *Nutrient Management Act, Environmental Protection Act, Water Resources Act,* and *Source Water Protection Act* may also provide indirect protection for Eastern Sand Darter habitat.

In Quebec, Eastern Sand Darter receives protection on public lands under the *Act Respecting the Conservation and Development of Wildlife*, which prohibits any activity likely to alter any biological, physical or chemical component of fish habitat. The application of this Act may soon be extended to private land. The Quebec *Environment Quality Act* provides general protection to habitat, in addition to considering the presence of species at risk in the analysis of the environmental impacts of projects submitted for authorization. Indirect protection is also provided through the *Protection Policy for Lakeshores, Riverbanks, Littoral Zones and Floodplains* and the resulting regulatory framework, which promotes the sustainability of aquatic habitats by preventing shoreline degradation and erosion and promoting the restoration of degraded riparian environments. Lastly, the *Act Respecting the Conservation of Wetlands and Bodies of Water*, which came into effect in Quebec in 2017, contributes to preserving the quality of aquatic habitats, including those used by Eastern Sand Darter, through the conservation, restoration, and creation of wetlands that promote the maintenance and improvement of water quality. This act also requires all regional county municipalities (RCMs) and metropolitan regions in Quebec to adopt a conservation plan for wetlands and waterbodies on their territory, and the habitat of species at risk, such as Eastern Sand Darter, will be identified as conservation priorities in these plans.

The beds of the rivers inhabited by Eastern Sand Darter are largely Crown-owned, but most of the adjacent riparian lands are privately owned. Throughout the species' entire range, a substantial proportion of these lands are used for agricultural purposes and some are heavily urbanized, such as in the watersheds of the Grand and Thames rivers in Ontario, and those of the Mascouche, L'Assomption, and Richelieu rivers in Quebec. Only a very small percentage of Eastern Sand Darter habitat is within protected areas (COSEWIC 2009). The Ontario range of Eastern Sand Darter includes Rondeau, Komoka, and Sandbanks provincial parks. In Quebec, Eastern Sand Darter is present in some waterfowl conservation areas, in the Pointe-du-Lac Wildlife Preserve, and in the Pierre-Étienne-Fortin Wildlife Preserve, a protected area created in 2002 in the Chambly Rapids of the Richelieu River to protect a spawning ground used by several species at risk, including Copper Redhorse, River Redhorse, Channel Darter, and Eastern Sand Darter. Some of the private lands adjacent to segments of rivers occupied by Eastern Sand Darter are also subject to voluntary conservation initiatives. This is particularly the case of Jeannotte Island and Île aux Cerfs, in the Richelieu River watershed, which were acquired by the Nature Conservancy of Canada in 2006 and 2009. Ownership of Île aux Cerfs has since been transferred to the Quebec Department of Forests, Wildlife and Parks (MFFP).

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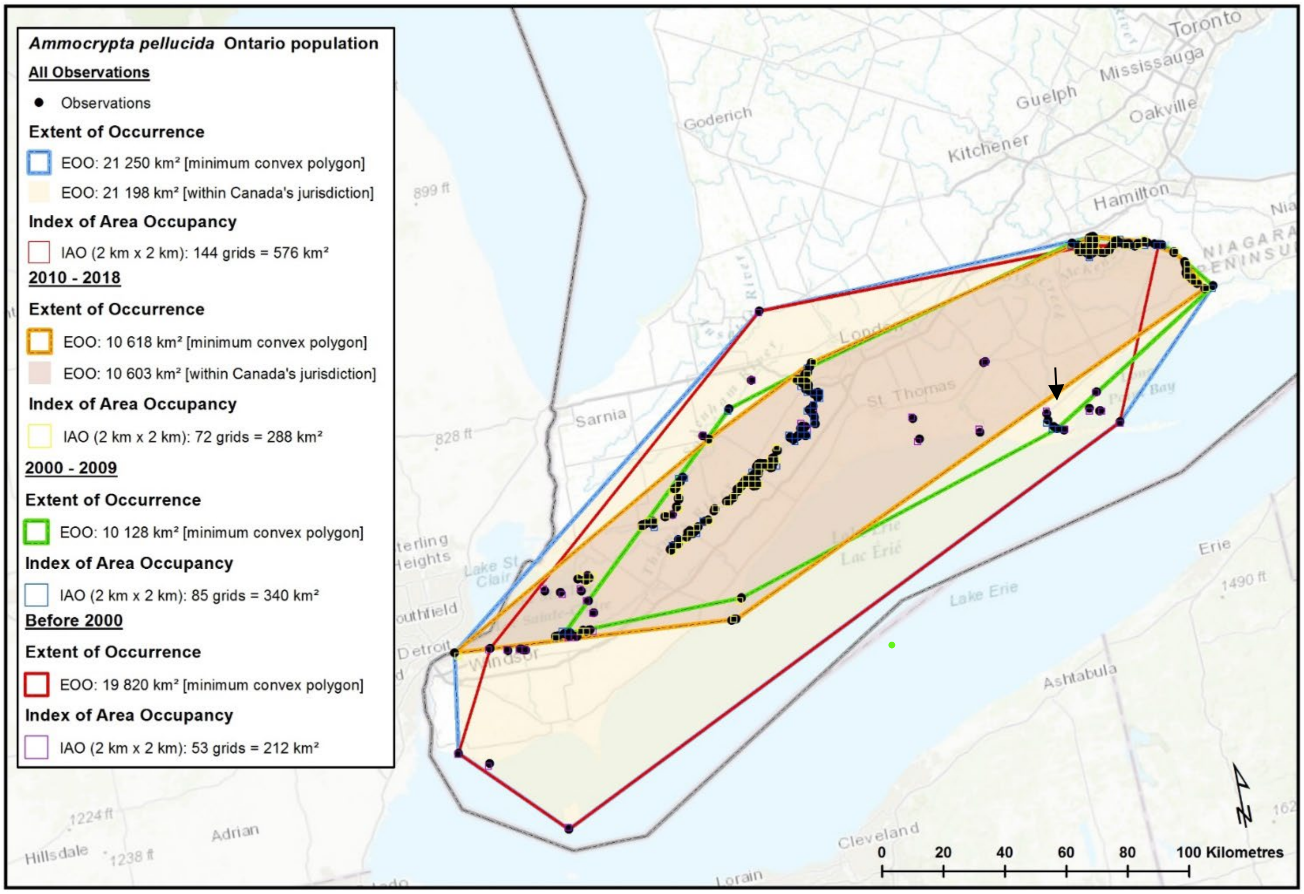
Marylène Ricard is a biologist specializing in aquatic wildlife at the Bureau d'écologie appliquée, an ecological consulting firm. She is a member of the Équipe de rétablissement des cyprinidés et petits percidés du Québec (ERCPPQ) [Québec Cyprinidae and Small Percidae Recovery Team] and coordinator of the Équipe de rétablissement de l'éperlan arc-en-ciel, population du sud de l'estuaire du Saint-Laurent [Recovery Team for the Rainbow Smelt, Southern St. Lawrence Estuary Population]. She wrote the provincial status report and recovery plan for Eastern Sand Darter in Québec as well as the provincial recovery plans for the Channel Darter and the Rainbow Smelt, southern St. Lawrence Estuary population.

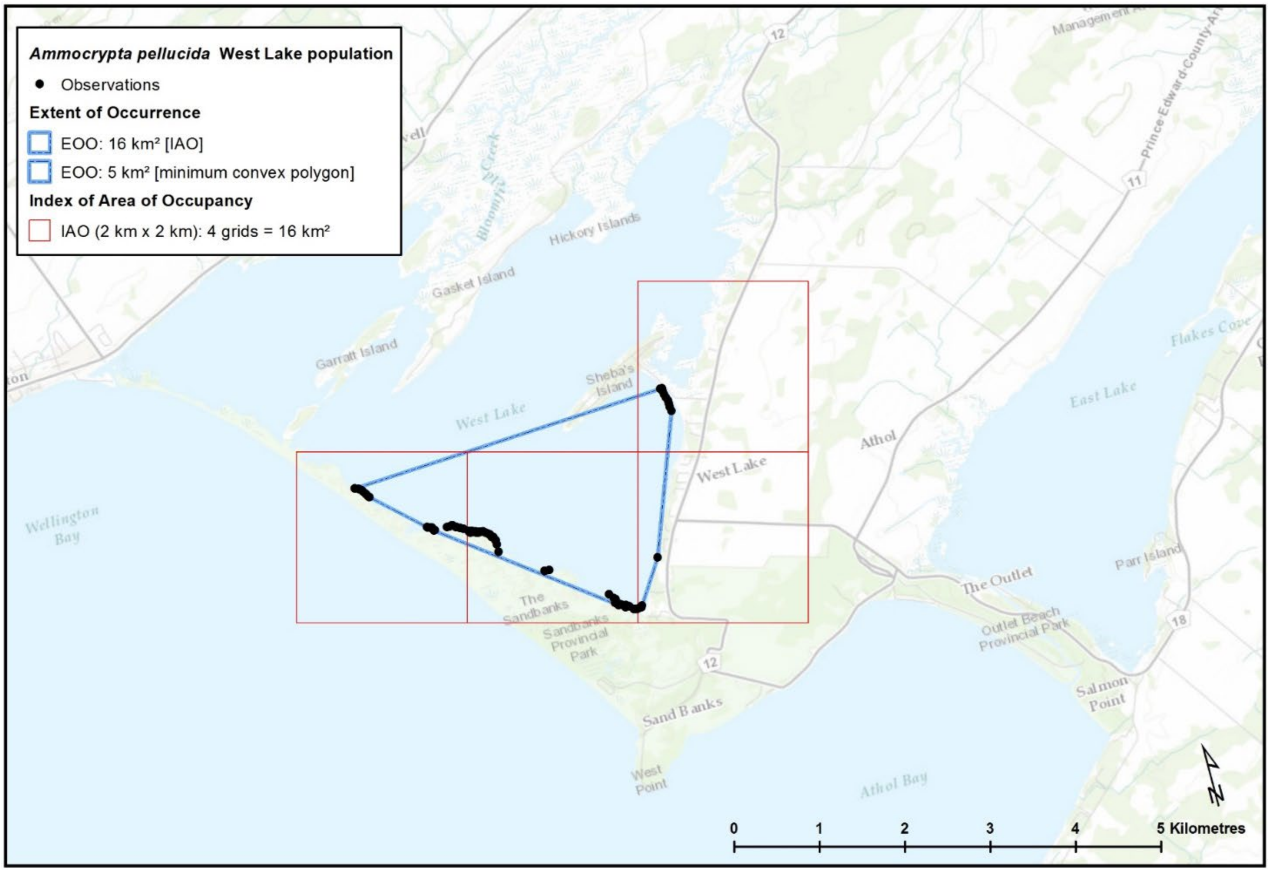
COLLECTIONS EXAMINED

Accession number UMMZ 85543, collected in the Ausable River in 1928, was examined and confirmed by Douglas Nelson, from the University of Michigan Museum of Zoology.

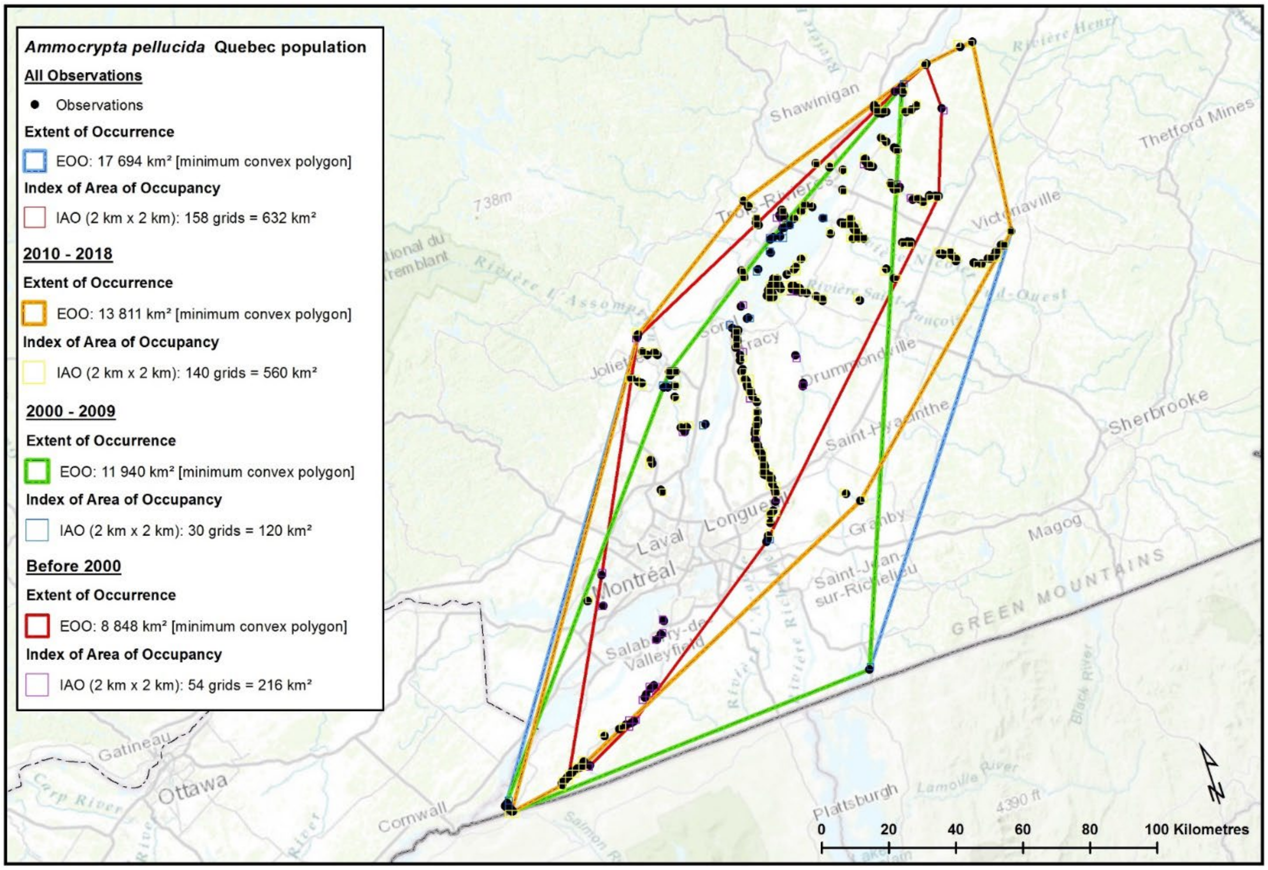
Appendix 1. Historical (pre-2000), past (2000-2009), and current (2010-2018) estimated extent of occurrence (EOO) and index of area of occupancy (IAO) for Eastern Sand Darter (*Ammocrypta pellucida*) DUs of (a) southwestern Ontario, (b) West Lake, and (c) Québec.



a) Southwestern Ontario


Ammocrypta pellucida West Lake population
Observations
Extent of Occurrence
EOO: 16 km² [IAO]
EOO: 5 km² [minimum convex polygon]
Index of Area of Occupancy
IAO (2 km x 2 km): 4 grids = 16 km²
Hickory Islands
Gasket Island
Garratt Island
Sheba's Island
West Lake
West Lake
Athol
East Lake
Flakes Cove
Wellington Bay
The Sandbanks
Sandbanks Provincial Park
The Outlet
Outlet Beach Provincial Park
Parr Island
Salmon Point
Sand Banks
West Point
Athol Bay
0
1
2
3
4
5 Kilometres

b) West Lake


Ammocrypta pellucida Quebec population
All Observations
Observations
Extent of Occurrence
EOO: 17 694 km² [minimum convex polygon]
Index of Area of Occupancy
IAO (2 km x 2 km): 158 grids = 632 km²
2010 - 2018
Extent of Occurrence
EOO: 13 811 km² [minimum convex polygon]
Index of Area of Occupancy
IAO (2 km x 2 km): 140 grids = 560 km²
2000 - 2009
Extent of Occurrence
EOO: 11 940 km² [minimum convex polygon]
Index of Area of Occupancy
IAO (2 km x 2 km): 30 grids = 120 km²
Before 2000
Extent of Occurrence
EOO: 8 848 km² [minimum convex polygon]
Index of Area of Occupancy
IAO (2 km x 2 km): 54 grids = 216 km²
0 20 40 60 80 100 Kilometres
Shawinigan
Thetford Mines
Victoriaville
Drummondville
Saint-Hyacinthe
Sherbrooke
Granby
Magog
Laval
Longueuil
Montréal
Saint-Jean-sur-Richelieu
GREEN MOUNTAINS
Gatineau
Ottawa
Cornwall
Plattsburgh
c) Québec

Appendix 2. Threat Calculator results for Eastern Sand Darter (*Ammocrypta pellucida*) – Southwestern Ontario (DU1).

Species or Ecosystem Scientific Name	*Ammocrypta pellucida*		
Element ID	Southwestern Ontario Population	**Elcode**	DU1
Date:	2020-06-09		
Assessor(s):	Kristiina Ovaska, Nicholas Mandrak, Marylène Ricard, Alan Dextrase, Julien April, Scott Reid, Vicki McKay, Jason Barnucz, Hans-Frederic Ellefsen, Rowshyra Castaneda, Sophie Foster, Christina Davy, Karine Robert and Sydney Allen		
References:	COSEWIC draft status report, March 2020		
Overall Threat Impact Calculation Help:	**Level 1 Threat Impact Counts**		
Threat Impact		**high range**	**low range**
A	Very High	0	0
B	High	0	0
C	Medium	3	1
D	Low	1	3
Calculated Overall Threat Impact:		High	High
Assigned Overall Threat Impact:	**BC = High - Medium**		
Impact Adjustment Reasons:	Much uncertainty in highest threats, and no change in EOO or IAO and at least some subpopulations are stable.		
Overall Threat Comments	Generation time: 2 years		

Threat		**Impact (calculated)**	**Scope (next 10 Yrs**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development					
1.1	Housing & urban areas					NA
1.2	Commercial & industrial areas					NA
1.3	Tourism & recreation areas					NA
2	Agriculture & aquaculture					
2.1	Annual & perennial non-timber crops					NA
2.2	Wood & pulp plantations					NA
2.3	Livestock farming & ranching					NA
2.4	Marine & freshwater aquaculture					NA
3	Energy production & mining					

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
3.1	Oil & gas drilling						NA
3.2	Mining & quarrying						NA
3.3	Renewable energy						NA
4	Transportation & service corridors		Unknown	Small (1-10%)	Unknown	High (Continuing)	
4.1	Roads & railroads						See 9.1 Household Sewage and Urban Waste Water
4.2	Utility & service lines						
4.3	Shipping lanes		Unknown	Small (1-10%)	Unknown	High (Continuing)	Dredging in small sections of the range (Lake St. Clair).
4.4	Flight paths						NA
5	Biological resource use		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals						NA
5.2	Gathering terrestrial plants						NA
5.3	Logging & wood harvesting						NA
5.4	Fishing & harvesting aquatic resources		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Bait fishery mostly outside ESD range. Incidental captures, but unlikely (proportion of ESD should be extremely low) (Drake and Mandrak 2014)
6	Human intrusions & disturbance		Unknown	Small (1-10%)	Unknown	High (Continuing)	
6.1	Recreational activities		Unknown	Small (1-10%)	Unknown	High (Continuing)	Recreational vehicles seen in rivers.
6.2	War, civil unrest & military exercises						NA
6.3	Work & other activities		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Care is taken to minimize mortality during targeted sampling, which occurs in a negligible proportion of the population.
7	Natural system modifications	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	
7.1	Fire & fire suppression						NA

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
7.2	Dams & water management/ use	D	Low	Restricted (11-30%)	Slight (1-10%)	High (Continuing)	Dams present in habitat without fish ladders causes isolation and reduce potential colonization of rivers. New dams could alter habitats by flooding upstream riffles, promoting siltation and reducing flows downstream (Grandmaison *et al.* 2004; Edwards *et al.* 2007). However, paradoxically, in the Grand River, Raab *et al.* (2018) observed that the presence of impoundments was associated with an increase in the abundance of Eastern Sand Darter, probably because this species selects sandy substrate typical of lower water velocities. On the other hand, impoundments were also identified as elements that facilitate the invasion of upstream sections of rivers by invasive aquatic species, such as Round Goby (Raab *et al.* 2018). There are very few dams in Ontario, except on Grand River. Poorly designed bridges and culverts, widening and maintenance (cleaning), construction of drains and riverbank modifications are not a significant issue in this DU.
7.3	Other ecosystem modifications						BTI is only used in standing water, so probably no effect on ESD.
8	Invasive & other problematic species & genes	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	
8.1	Invasive non-native/alien species/diseases	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Round Goby present in all watersheds occupied by ESD in Ontario. Predation on eggs and competition from Round Goby has been implicated in declines of several darters in Ontario and Quebec, and the abundance of ESD is negatively correlated with abundance of Round Goby in the Grand River. There's uncertainty about the severity.
8.2	Problematic native species/diseases						NA
8.3	Introduced genetic material						NA
8.4	Problematic species/diseases of unknown origin						NA
8.5	Viral/prion-induced diseases						NA
8.6	Diseases of unknown cause						NA

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9	Pollution	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	For this category, it would be difficult to relate actual population decline to pollution. Also, those threats are already going on, and it seems unrealistic that we could lose large proportion of populations (e.g. >70%) in the next ten years. Urban areas and agricultural intensification are increasing in watersheds - 70% may be unlikely but, as discussed >30% may not be out of question
9.1	Domestic & urban waste water	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Detergents, heavy metals, hydrocarbons, hormones, and pharmaceutical compounds. Many municipal wastewater treatment systems do not eliminate micropollutants and sewer overflows are discharged into rivers. Alteration of banks by urban development generates sediment inputs. Serious source of concern in Lake St. Clair watershed and Thames and Grand rivers. Urban areas upstream to most populations, but effects should be more indirect than direct. Even less populated areas could be problematic because of deficient septic installations (e.g., Rondeau). Effect is difficult to discriminate from 9.3.
9.2	Industrial & military effluents		Unknown	Restricted - Small (1-30%)	Unknown	High (Continuing)	Industrial effluents in urban areas. Industrial activities in urban areas, upstream of most populations, but effects should be more indirect than direct. Threat could be particularly important around Lake St. Clair. Some pipelines, leaking possible but no data available. Severity difficult to evaluate because compounds present unknown.
9.3	Agricultural & forestry effluents	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	Pesticides, herbicides, fertilizers, and sediments. Most rivers occupied in watersheds affected by intensive agriculture. Serious source of concern in Ausable, Sydenham, and Thames watersheds and in Big and Big Otter creeks.
9.4	Garbage & solid waste						NA
9.5	Air-borne pollutants						Pollutants (i.e., fuel dumping from emergency landings) from airplanes around Windsor.
9.6	Excess energy						NA
10	Geological events						
10.1	Volcanoes						NA
10.2	Earthquakes/tsunamis						NA

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
10.3	Avalanches/landslides						NA
11	Climate change & severe weather	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	High (Continuing)	This category has much speculation on both how the climate will change (models are for longer term than 10 years) and on population impacts (severity).
11.1	Habitat shifting & alteration						
11.2	Droughts	D	Low	Small (1-10%)	Moderate - Slight (1-30%)	High (Continuing)	Higher temperatures and evapotranspiration predicted to cause lower water levels in Great Lakes. Sandbars could become exposed. The only population vulnerable is probably the Sydenham River. Low water levels could occur later in the year, which could limit impact on reproduction (OBC 2015).
11.3	Temperature extremes	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	Moderate (Possibly in the short term, < 10 yrs/3 gen)	Water temperatures should increase and could create periods of hypoxia, especially in shallow rivers. Preliminary results indicate that Eastern Sand Darter can tolerate temperatures of up to 36.4 ± 0.23°C in July, when the species is acclimated at 25°C. Individuals can tolerate oxygen concentrations of 1.15 mg/L at 25°C and of 0.64 mg/L at 17°C (B. Firth unpubl. data).
11.4	Storms & flooding			Large (31-70%)	Unknown	High (Continuing)	Increase in frequency of heavy precipitations events could lead to increase in the number of discharges of overflow water and additional contaminant load. On the other hand, floods can also flush sediments and clean substrates. Flooding events occur in the Thames River, but seem lower than the ones seen before.
11.5	Other impacts						
Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).							

Appendix 3. Threat Calculator results for Eastern Sand Darter (*Ammocrypta pellucida*) – Québec (DU2).

Species or Ecosystem Scientific Name	*Ammocrypta pellucida*			
Element ID	Quebec Population	**Elcode**	DU2	
Date:	2020-06-09			
Assessor(s):	Kristiina Ovaska, Nicholas Mandrak, Marylène Ricard, Margaret Docker, James Grant, Alan Dextrase, Mark Poesch, Mark Ridgway, Julien April, Marc-Antoine Couillard, Marie-Pierre Veilleux, Scott Reid, Vicki McKay, Jason Barnucz, Virginie Christopherson, Hans Frederic Ellefsen, Rowshyra Casteneda, Sophie Foster, Shannan-May McNally, Jocelyne Alie Maisonneuve, Christina Davy, Isabelle Gauthier, Ashley Kling, Karine Robert, France Pouliot and Sydney Allen.			
References:	COSEWIC draft status report, March 2020			
Overall Threat Impact Calculation Help:			**Level 1 Threat Impact Counts**	
	Threat Impact		**high range**	**low range**
	A	Very High	0	0
	B	High	3	0
	C	Medium	1	3
	D	Low	3	4
Calculated Overall Threat Impact:			Very High	High
Assigned Overall Threat Impact:	**AB = Very High - High**			
Impact Adjustment Reasons:				
Overall Threat Comments	Generation time: 2 years			

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development	D	Low	Small (1-10%)	Serious (31-70%)	High (Continuing)	
1.1	Housing & urban areas		Negligible	Negligible (<1%)	Serious (31-70%)	High (Continuing)	Some new housing development near the shoreline. It includes mainly riprap needed to increase property size.
1.2	Commercial & industrial areas						NA
1.3	Tourism & recreation areas	D	Low	Small (1-10%)	Serious (31-70%)	High (Continuing)	Docks and launching ramp. <Lower end of small>
2	Agriculture & aquaculture		Negligible	Negligible (<1%)	Serious (31-70%)	High (Continuing)	
2.1	Annual & perennial non-timber crops		Negligible	Negligible (<1%)	Serious (31-70%)	High (Continuing)	Limited new agricultural development near the shoreline, (e.g., around Lake St-Pierre), but agricultural activities near shoreline are continuing right now.
2.2	Wood & pulp plantations						NA

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.3	Livestock farming & ranching		Negligible	Negligible (<1%)	Slight (1-10%)	High (Continuing)	Grazing and poaching of riparian vegetation and increase erosion, re-suspension of sediments and siltation (FAPAQ 2002, Vachon 2003).
2.4	Marine & freshwater aquaculture						NA
3	Energy production & mining						
3.1	Oil & gas drilling						NA
3.2	Mining & quarrying						NA
3.3	Renewable energy						NA
4	Transportation & service corridors	D	Low	Small (1-10%)	Moderate (11-30%)	High (Continuing)	
4.1	Roads & railroads	D	Low	Small (1-10%)	Moderate (11-30%)	High (Continuing)	Riprap built to protect roads along rivers, e.g., Richelieu River. Also, undersized bridges have impacts on stream flow and contribute to modify habitats.
4.2	Utility & service lines						NA
4.3	Shipping lanes	D	Low	Small (1-10%)	Moderate - Slight (1-30%)	High (Continuing)	In the St. Lawrence, ship wave action. Dredging for shipping lanes included.
4.4	Flight paths						NA
5	Biological resource use		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals						NA
5.2	Gathering terrestrial plants						NA
5.3	Logging & wood harvesting						Erosion and sedimentation under 9.3.
5.4	Fishing & harvesting aquatic resources		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Incidental captures. Bait fishery is prohibited during summer.
6	Human intrusions & disturbance	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	
6.1	Recreational activities	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	Includes human disturbance in beach shallow waters and wave action from recreational boats.
6.2	War, civil unrest & military exercises						NA
6.3	Work & other activities		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	ESD research is active and can lead to some mortality, but impact is minimal because once a site is confirmed, catch is minimized at that site.
7	Natural system modifications	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	
7.1	Fire & fire suppression						NA

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
7.2	Dams & water management/ use	C	Medium	Large (31-70%)	Moderate (11-30%)	High (Continuing)	This threat includes: (1) Dams present in habitat without fish ladders causes isolation and reduces potential colonization of rivers. New dams could alter habitats by flooding upstream riffles, promoting siltation and reducing flows downstream (Grandmaison *et al.* 2004; Edwards *et al.* 2007). However, paradoxically, in the Grand River, Raab *et al.* (2018) observed that the presence of impoundments was associated with an increase in the abundance of Eastern Sand Darter, probably because this species selects sandy substrate typical of lower water velocities. On the other hand, impoundments were also identified as elements that facilitate the invasion of upstream sections of rivers by invasive aquatic species, such as the Round Goby (Raab *et al.* 2018). (2) Poorly designed bridges and culverts can also create obstacles to free movement of fishes. (3) Even if most stream channelization was done in the past, stream channelization, widening and maintenance (cleaning), construction of drains and riverbank modifications still happen and have impacts on stream hydrology.
7.3	Other ecosystem modifications	BD	High - Low	Large - Small (1-70%)	Serious - Slight (1-70%)	High (Continuing)	The introduction of BTI in lotic environments to control black-fly populations has an impact on chironomid larvae, an important prey of ESD. BTI is widely used in certain rivers in Quebec. Its impact on ESD is a source of concern.
8	Invasive & other problematic species & genes	BC	High - Medium	Large (31-70%)	Serious - Moderate (11-70%)	High (Continuing)	
8.1	Invasive non-native/alien species/diseases	BC	High - Medium	Large (31-70%)	Serious - Moderate (11-70%)	High (Continuing)	Round Goby widespread form Lake Saint-François in the west to Quebec City. Detected in Rivière aux Saumons, Richelieu River, and Saint-François River. Most tributaries to St. Lawrence River are vulnerable to invasion. Predation on eggs and competition from Round Goby has been implicated in declines of several darters in Ontario and Quebec, and the abundance of ESD is negatively correlated with abundance of Round Goby in the Grand River. According to Morissette *et al.* (2018), CPUE of Tessellated Darter decreased by 66% after the invasion of Round Goby in the St. Lawrence system.
8.2	Problematic native species/diseases						NA
8.3	Introduced genetic material						NA
8.4	Problematic species/diseases of unknown origin						NA

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
8.5	Viral/prion-induced diseases						NA
8.6	Diseases of unknown cause						NA
9	Pollution	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	For this category, it would be difficult to relate actual population decline to pollution. Also, those threats are already going on, and it seems unrealistic that we could lose large proportion of populations (e.g. >70%) in the next ten years (see DU1).
9.1	Domestic & urban waste water	BD	High - Low	Large (31-70%)	Serious - Slight (1-70%)	High (Continuing)	Detergents, heavy metals, hydrocarbons, hormones, and pharmaceutical compounds. Many municipal wastewater treatment systems do not eliminate micropollutants and sewer overflows are discharged into rivers. Alteration of banks by urban development generates sediment inputs. Serious source of concern in at least 7 localities: Montreal–Sorel section of the St. Lawrence River and in the Richelieu, Yamaska, L'Assomption, Châteauguay, Saint-François, and Gentilly rivers.
9.2	Industrial & military effluents	CD	Medium - Low	Restricted - Small (1-30%)	Serious - Slight (1-70%)	High (Continuing)	Some industrial effluents in urban areas. Maritime terminal expansion projects in St. Lawrence River. Problematic industries have not been identified. Scope and severity hard to evaluate.
9.3	Agricultural & forestry effluents	BC	High - Medium	Pervasive (71-100%)	Serious - Moderate (11-70%)	High (Continuing)	Pesticides, herbicides, fertilizers, and sediments. Most rivers occupied in watersheds affected by intensive agriculture. Serious source of concern in at least 11 localities: Montreal–Sorel section of the St. Lawrence River, Lake Saint-Pierre archipelago, Lake Saint-Pierre and the Yamaska, Richelieu, Châteauguay, Trout, L'Assomption, Saint-François, Bécancour, and Gentilly rivers
9.4	Garbage & solid waste						NA
9.5	Air-borne pollutants						NA
9.6	Excess energy						NA
10	Geological events						
10.1	Volcanoes						NA
10.2	Earthquakes/tsunamis						NA
10.3	Avalanches/landslides						NA
11	Climate change & severe weather	BD	High - Low	Large (31-70%)	Serious - Slight (1-70%)	High (Continuing)	
11.1	Habitat shifting & alteration		Unknown	Large - Restricted (11-70%)	Unknown	High (Continuing)	Water flow and sedimentation patterns are expected to change in the St. Lawrence and its tributary (Boyer *et al.* 2010), possibly leading to habitat alteration.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.2	Droughts	CD	Medium - Low	Large - Restricted (11-70%)	Moderate - Slight (1-30%)	High (Continuing)	Higher temperatures and evapotranspiration can cause lower water levels in the St. Lawrence, especially during summer (Mortsch *et al.* 2000; Fan et Fay 2002; Croley 2003). Sandbars could become exposed.
11.3	Temperature extremes	BD	High - Low	Large (31-70%)	Serious - Slight (1-70%)	High (Continuing)	Water temperatures should increase and could create periods of hypoxia, especially in shallow rivers. Preliminary results indicate that Eastern Sand Darter can tolerate temperatures of up to 36.4 ± 0.23°C in July, when the species is acclimated at 25°C. Individuals can tolerate oxygen concentrations of 1.15 mg/L at 25°C and of 0.64 mg/L at 17°C (B. Firth unpubl. data).
11.4	Storms & flooding	CD	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	High (Continuing)	Increase in frequency of heavy precipitations events could lead to increase in the number of discharges of overflow water and additional contaminant load.
11.5	Other impacts						

Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).

Appendix 4. Threat Calculator results for Eastern Sand Darter (*Ammocrypta pellucida*) – West Lake (DU3).

Species or Ecosystem Scientific Name	*Ammocrypta pellucida*			
Element ID	West Lake Population	**Elcode**	DU3	
Date:	2020-06-16			
Assessor(s):	Kristiina Ovaska, Nicholas Mandrak, Marylène Ricard, Margaret Docker, Alan Dextrase, Scott Reid and Sydney Allen			
References:	COSEWIC draft status report, March 2020			
Overall Threat Impact Calculation Help:		**Level 1 Threat Impact Counts**		
Threat Impact		**high range**	**low range**	
A	Very High	0	0	
B	High	0	0	
C	Medium	1	0	
D	Low	0	1	
Calculated Overall Threat Impact:		Medium	Low	
Assigned Overall Threat Impact:		**CD = Medium - Low**		
Impact Adjustment Reasons:				
Overall Threat Comments		Generation time: 2 years		

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development						
1.1	Housing & urban areas						NA
1.2	Commercial & industrial areas						NA
1.3	Tourism & recreation areas						NA
2	Agriculture & aquaculture						
2.1	Annual & perennial non-timber crops						NA
2.2	Wood & pulp plantations						NA
2.3	Livestock farming & ranching						NA
2.4	Marine & freshwater aquaculture						NA
3	Energy production & mining						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
3.1	Oil & gas drilling						NA
3.2	Mining & quarrying						NA
3.3	Renewable energy						NA
4	Transportation & service corridors						
4.1	Roads & railroads						See 9.1 Household Sewage and Urban Waste Water
4.2	Utility & service lines						NA
4.3	Shipping lanes						
4.4	Flight paths						NA
5	Biological resource use		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals						NA
5.2	Gathering terrestrial plants						NA
5.3	Logging & wood harvesting						NA
5.4	Fishing & harvesting aquatic resources		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Potential incidental captures from bait fishery. However, most of the population is restricted to Sandbanks Provincial Park, where no bait fishery is allowed.
6	Human intrusions & disturbance		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
6.1	Recreational activities		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Beaches and shallow waters highly used in the summer time. Human disturbance occurring but impact on ESD is unknown.
6.2	War, civil unrest & military exercises						NA
6.3	Work & other activities		Negligible	Small (1-10%)	Negligible (<1%)	High - Moderate	Care is taken to minimize mortality during targeted sampling, which occurs in a negligible proportion of the population.
7	Natural system modifications						
7.1	Fire & fire suppression						NA
7.2	Dams & water management/use						NA

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
7.3	Other ecosystem modifications						NA
8	Invasive & other problematic species & genes	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	
8.1	Invasive non-native/alien species/diseases	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Round Goby abundant in the lake system and present at ESD sites. Impacts of coexistence is highly uncertain, as there are no species-specific studies for ESD. Predation on eggs and competition from Round Goby has been implicated in declines of several darters in Ontario and Quebec, and the abundance of ESD is negatively correlated with abundance of Round Goby in the Grand River.
8.2	Problematic native species/diseases						NA
8.3	Introduced genetic material						NA
8.4	Problematic species/diseases of unknown origin						NA
8.5	Viral/prion-induced diseases						NA
8.6	Diseases of unknown cause						NA
9	Pollution		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	
9.1	Domestic & urban waste water		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Detergents and domestic fertilizers. No large urban centres in the DU. Alteration of banks by residential development can also generate sediment inputs. One blue-green algae bloom reported (Intelligencer Staff 2015). Extreme precipitation and flood events may temporarily increase discharges.
9.2	Industrial & military effluents						NA

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.3	Agricultural & forestry effluents		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Pesticides, herbicides, fertilizers, and sediments. Watershed affected by agriculture, but severity is less than in DU1. Extreme precipitations and floods can temporarily increase discharges.
9.4	Garbage & solid waste						NA
9.5	Air-borne pollutants						NA
9.6	Excess energy						NA
10	Geological events						
10.1	Volcanoes						NA
10.2	Earthquakes/tsunamis						NA
10.3	Avalanches/landslides						NA
11	Climate change & severe weather		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	There is a lot of uncertainty for West Lake because most studies are broad scale.
11.1	Habitat shifting & alteration						Habitats could shift, but sand substrates are widespread in West Lake.
11.2	Droughts		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Higher temperatures and evapotranspiration predicted to cause lower water levels in Great Lakes and West Lake water level believed to be regulated by Lake Ontario water level. Increase water temperatures combined with level drop could create periods of hypoxia.
11.3	Temperature extremes						Increased water temperatures combined with level drop could create periods of hypoxia.
11.4	Storms & flooding						See 9. Pollution. Climate change is not suspected to increase pollution significantly.
11.5	Other impacts						

Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).