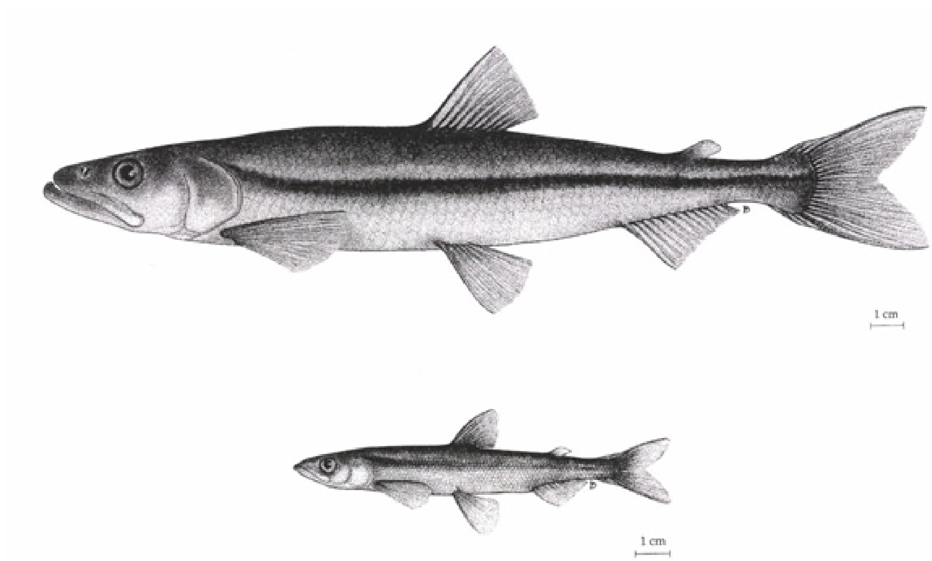
COSEWIC
Assessment and Status Report

on the

Rainbow Smelt
Osmerus mordax

Lake Utopia large-bodied population
Lake Utopia small-bodied population

in Canada



ENDANGERED
2018

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. 2018. COSEWIC assessment and status report on the Rainbow Smelt *Osmerus mordax*, Lake Utopia large-bodied population and the Lake Utopia small-bodied population, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xiv + 40 pp. (http://www.registrelep-sararegistry.gc.ca/default.asp?lang=en&n=24F7211B-1).

Previous report(s):

COSEWIC. 2008. COSEWIC assessment and update status report on the Rainbow Smelt, Lake Utopia large-bodied population and small-bodied population *Osmerus mordax* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 28 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

COSEWIC 2000. COSEWIC assessment and status report on the Lake Utopia Dwarf Smelt *Osmerus* sp. in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 13 pp. (www.sararegistry.gc.ca/status/status_e.cfm)

Taylor, E.B. 1998. COSEWIC status report on the Lake Utopia Dwarf Smelt *Osmerus* sp. in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1- 13 pp

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Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur L'éperlan arc-en-ciel (*Osmerus mordax*), population d'individus de grande taille du lac Utopia et population d'individus de petite taille du lac Utopia au Canada.

Cover illustration/photo:
Illustration of Lake Utopia Large (upper) and Small (lower) Rainbow Smelt. Artist: Diana McPhail.

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COSEWIC
Assessment Summary

Assessment Summary – November 2018

Common name
Rainbow Smelt - Lake Utopia large-bodied population

Scientific name
Osmerus mordax

Status
Endangered

Reason for designation
This population of smelt is the larger of a divergent species-pair endemic to a lake in southwestern New Brunswick. Its persistence is dependent on the ecological conditions that gave rise to the divergence of the species-pair from a single ancestor. Changing predator and prey environment through recent and potential invasive species, and hybridization with the smaller member of this species-pair threaten the long-term viability of the species-pair.

Occurrence
New Brunswick

Status history
Designated Threatened in November 2008. Status re-examined and designated Endangered in November 2018.

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Occurrence
New Brunswick

Status history
Designated Threatened in April 1998. Status re-examined and confirmed in May 2000 and November 2008. Status re-examined and designated Endangered in November 2018.

COSEWIC
Executive Summary

Rainbow Smelt
Osmerus mordax

Lake Utopia large-bodied population
Lake Utopia small-bodied population

Wildlife Species Description and Significance

The Lake Utopia smelt constitute a genetically divergent pair of Rainbow Smelt *Osmerus mordax* endemic to a lake in southwestern New Brunswick. In general, smelt are small (typically less than 30 cm in total length), slender pelagic fish that vary in colour from pale green to dark blue on the back, and whose sides display a rainbow of blue, purple and pink iridescence. Smelt are north temperate fish capable of living in both freshwater and saltwater. Smelt that permanently reside in freshwater environments occur in a variety of morphologically, ecologically, and genetically differentiated populations, some of which occupy the same geographical location and are reproductively isolated from each other. The sympatric pair of smelt in Lake Utopia, New Brunswick consists of two such distinct populations that behave as separate species: a Small-bodied (Small smelt) population and a Large-bodied (Large smelt) population. Similar putative sympatric pairs are reported from a few other lakes in eastern North America. Molecular genetic data indicate that each sympatric pair has evolved independently from all other sympatric pairs by parallel evolution.

Distribution

The Lake Utopia sympatric pair of Rainbow Smelt is found in a single lake in southwestern New Brunswick where Small and Large smelt have been observed to spawn in only six tributary streams. There are also putative sympatric pairs in lakes in other regions of northeastern North America, including Lac St-Jean and Lac Heney, Québec, and Lochaber Lake, Nova Scotia, but the levels of differentiation between populations within these other lakes are not well understood or are much lower than exhibited by the Lake Utopia pair.

Habitat

Lake Utopia is a relatively small, cold-water and oligotrophic lake. Small and Large smelt tend to occupy cool, deeper waters of the lake, except during the spring spawning season. Spawners make evening migrations to spawning sites in inlet tributaries of Lake Utopia. Spawning substrates vary and tend to include any secure substrate suitable for egg attachment: silt, gravel, rock, aquatic vegetation and wood debris.

Biology

The Lake Utopia sympatric smelt exhibit a life cycle similar to other freshwater and anadromous Rainbow Smelt populations, but with a key distinction: the development of trophic and reproductive isolation that promotes genetic divergence between the Small and Large smelt. The Small and Large smelt differ in spawning locations and peak spawning times within the lake and streams. Small smelt are adapted to feed on plankton and inhabit shallower waters, while Large smelt are piscivorous and live in deeper waters. There is no significant difference in the average age of maturity (about 3 years) or lifespan (about 6 years) between the Small and Large smelt.

Population Sizes and Trends

Estimates of the total spawning population in Lake Utopia have remained fairly consistent over the last 20 years, with estimates ranging from 5,000-20,000 Large smelt to about one million Small smelt.

Threats and Limiting Factors

The finite availability of spawning habitat and the productivity of the lake are important limiting factors. Small and Large smelt are both considered to be coldwater-adapted fishes such that changes to lake water temperature regimes driven by climate warming are potential threats. Recent genetic evidence has led some authorities to suggest that hybridization is becoming more prominent, which may be a response to other challenges and may itself pose a risk of population decline. Hybridization is both a potential threat and a response to other stressors on the populations. Lake Utopia's sympatric smelt, particularly the small-sized juvenile Large smelt and mature Small smelt, are potentially limited by predation by other indigenous fish species. Stocking to enhance the salmonid sport fishery and the presence of exotic species (Smallmouth Bass, Chain Pickerel) are also important potential threats. Lake water quality degradation from increasing development may also pose a threat. Fishing (Aboriginal Food, Social and Ceremonial, and dip-netting) poses potentially minor threats. Although these issues appear not to be a significant concern in Lake Utopia to date, based on 20 years of studies, there are no long-term data sets to quantitatively assess these risk factors.

Protection, Status and Ranks

The Lake Utopia Small smelt population was designated as threatened by COSEWIC in 1998, 2000 and 2008 and is protected under the federal *Species at Risk Act* (SARA) since 2003 under the name of Lake Utopia Small smelt population. In 2016, Fisheries and Oceans Canada (DFO) published a '*Recovery Strategy for Lake Utopia Rainbow Smelt (Osmerus mordax), Small-bodied Population (sympatric with the Large-bodied Population), in Canada'*. Given the significance and interdependence of both the Large and Small smelt populations as a sympatric species pair, this recovery strategy focuses on the Lake Utopia Rainbow Smelt species pair and each of its constituent populations. While only the Small smelt population is currently subject to the legislative applications of SARA, both the Large and Small smelt populations continue to be afforded all of the fisheries protection provisions under the *Fisheries Act*. In 2008 COSEWIC assessed both Small and Large smelt populations and designated each as Threatened. Listing under SARA for the Large smelt population is currently in process. Both the Small and Large Bodied Rainbow Smelt are listed as Threatened under the New Brunswick *Species at Risk Act*. The recreational dip-net fishery for smelt populations was closed in 2011, while the recreational angling fishery for smelt was closed in 2013.

TECHNICAL SUMMARY

Osmerus mordax

Rainbow Smelt
Lake Utopia large-bodied population

Éperlan arc-en-ciel
Population d'individus de grande taille du lac Utopia

Range of occurrence in Canada: New Brunswick (Lake Utopia, southwestern New Brunswick)

Demographic Information

Generation time (average age of parents in the population).	3 yrs
Is there an observed, inferred, or projected continuing decline in number of mature individuals?	Hybridization will likely reduce the effective size of the population
Estimated percent of continuing decline in total number of mature individuals within 10 years.	Unknown
Observed, estimated, inferred, or suspected percent change in total number of mature individuals over the last 10 years.	Unknown
Projected or suspected percent change in total number of mature individuals over the next 10 years.	Unknown
Observed, estimated, inferred, or suspected percent change in total number of mature individuals over any 10 years period, over a time period including both the past and the future.	Hybridization will likely reduce the effective size of the population
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. no b. uncertain c. no
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO) Area of Lake = 14 km^2	29 km^2
Index of area of occupancy (IAO) (Always report 2x2 grid value).	20 km^2 based on spawning streams but actual spawning habitat is likely much smaller
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. no
Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	1
Is there an observed, inferred, or projected decline in extent of occurrence?	No

* See Definitions and Abbreviations on COSEWIC website and IUCN (Feb 2014) for more information on this term

Is there an observed, inferred, or projected decline in index of area of occupancy?	No
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
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 population

Population	N Mature Individuals
Total	Estimates range from approximately 5,000-20,000 adults

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Unknown

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for this species?
Yes

- i. Habitat alteration and degradation
- ii. Enhancement of native predatory fishes and introduction of exotic species
- iii. Water quality degradation
- iv. Fishing
- v. Hybridization

The overall Threats Assessment was Medium.

What additional limiting factors are relevant?

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	NA, endemic to Lake Utopia
Is immigration known or possible?	No

Would immigrants be adapted to survive in Canada?	No
Is there sufficient habitat for immigrants in Canada?	NA, endemic to Lake Utopia
Are conditions deteriorating in Canada?+	No
Are conditions for the source population deteriorating?+	NA
Is the Canadian population considered to be a sink?+	NA
Is rescue from outside populations likely?	No

Data Sensitive Species

Is this a data sensitive species? No

Status History

COSEWIC: Designated Threatened in November 2008. Status re-examined and designated Endangered in November 2018.

Status and Reasons for Designation

Status: Endangered	**Alpha-numeric codes:** B1ab(iii)+2ab(iii)
Reasons for designation: This population of smelt is the larger of a divergent species-pair endemic to a lake in southwestern New Brunswick. Its persistence is dependent on the ecological conditions that gave rise to the divergence of the species-pair from a single ancestor. Changing predator and prey environment through recent and potential invasive species, and hybridization with the smaller member of this species-pair threaten the long-term viability of the species-pair.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered, B1ab(iii)+2ab(iii), with small EOO (29 km^2), small IAO (20 km^2), single location, and inferred and projected decline in the quality of habitat.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable.
Criterion D (Very Small or Restricted Population): Meets Threatened D2, since the population has a very restricted IAO (<20 km^2) and 1 location such that it is prone to the effects of human activities or stochastic events (invasive species) within a very short time period in an uncertain future, rendering the species capable of becoming Endangered or Extinct in a very short time period.
Criterion E (Quantitative Analysis): Not done.

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

TECHNICAL SUMMARY

Osmerus mordax

Rainbow Smelt Lake Utopia small-bodied population	Éperlan arc-en-ciel Population d'individus de petite taille du lac Utopia

Range of occurrence in Canada: New Brunswick (Lake Utopia, southwestern New Brunswick)

Demographic Information

Generation time (average age of parents in the population).	3 yrs
Is there an observed, inferred, or projected continuing decline in number of mature individuals?	Population appears to be stable
Estimated percent of continuing decline in total number of mature individuals within 10 years.	NA
Observed, estimated, inferred, or suspected percent change in total number of mature individuals over the last 10 years.	NA
Projected or suspected percent change in total number of mature individuals over the next 10 years.	NA
Observed, estimated, inferred, or suspected percent change in total number of mature individuals over any 10 years period, over a time period including both the past and the future.	Population appears to be stable
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. NA b. NA c. NA
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO) Area of Lake = 14 km	29 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	20 km² based on spawning streams but actual spawning habitat is likely much smaller
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. no
Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	1

* See Definitions and Abbreviations on COSEWIC website and IUCN (Feb 2014) for more information on this term

Is there an observed, inferred, or projected decline in extent of occurrence?	No
Is there an observed, inferred, or projected decline in index of area of occupancy?	No
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
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 population

Population	N Mature Individuals
Total	Estimated up to 1,000,000 spawners

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Unknown

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for this species?
Yes

i. Habitat alteration and degradation
ii. Enhancement of native predatory fishes and introduction of exotic species
iii. Water quality degradation
iv. Fishing
v. Hybridization

The overall Threats Assessment was Medium-Low.

What additional limiting factors are relevant?

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	NA, endemic to Lake Utopia
Is immigration known or possible?	No

Would immigrants be adapted to survive in Canada?	No
Is there sufficient habitat for immigrants in Canada?	NA, endemic to Lake Utopia
Are conditions deteriorating in Canada?+	No
Are conditions for the source population deteriorating?+	NA
Is the Canadian population considered to be a sink?+	NA
Is rescue from outside populations likely?	No

Data Sensitive Species

Is this a data sensitive species? No

Status History

COSEWIC: Designated Threatened in April 1998. Status re-examined and confirmed in May 2000 and November 2008. Status re-examined and designated Endangered in November 2018

Status and Reasons for Designation:

Status: Endangered	**Alpha-numeric codes:** B1ab(iii)+2ab(iii)
Reasons for designation: This population of smelt is the smaller of a divergent species-pair endemic to a lake in southwestern New Brunswick. Its persistence is dependent on the ecological conditions that gave rise to the divergence of the species-pair from a single ancestor. Changing predator and prey environment through recent and potential invasive species, and hybridization with the larger member of this species-pair threaten the long-term viability of the species-pair.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered, B1ab(iii)+2ab(iii), with small EOO (29 km²), small IAO (20 km²), single location, and inferred and projected decline in the quality of habitat.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable.
Criterion D (Very Small or Restricted Population): Meets Threatened, D2, since the population has a very restricted IAO (<20 km²) and 1 location such that it is prone to the effects of human activities or stochastic events (invasive species) within a very short time period in an uncertain future, rendering the species capable of becoming Endangered or Extinct in a very short time period.
Criterion E (Quantitative Analysis): Not done.

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

PREFACE

The status of the Lake Utopia Rainbow Smelt Large- and Small-bodied populations (hereafter Large smelt and Small smelt) was last assessed by COSEWIC in 2008 when both populations were recommended as Threatened. The Small smelt population is protected under the federal *Species at Risk Act* (SARA) such as prohibitions and recovery planning under the name of Lake Utopia Small smelt population. Since the last update, frequent efforts have been made to determine the spawning abundances of the Lake Utopia Large smelt population (e.g., DFO 2011, 2016a, 2018, Bradford *et al.* 2012, McNeely and LaBillois 2014, Themelis 2018) and Small smelt population (e.g., DFO 2011, Bradford *et al.* 2012, Themelis 2018). In addition, several other studies of the populations have included habitat evaluations (e.g., DFO 2011, Bradford *et al*. 2012,) and genetic analyses (Bradbury *et al.* 2011). In 2016, Fisheries and Oceans Canada (DFO) published a '*Recovery Strategy for Lake Utopia Rainbow Smelt (Osmerus mordax), Small-bodied Population (sympatric with the Large-bodied Population), in Canada*' (DFO 2016b). Given the significance and interdependence of both the Large- and Small smelt populations as a sympatric species pair, this recovery strategy focuses on the species pair and each of its constituent populations. Accordingly, the goal set out in the Recovery Strategy is to "maintain the current population distribution and abundance of the Small smelt and Large smelt populations of Lake Utopia Rainbow Smelt and the genetic diversity of the Lake Utopia Rainbow Smelt sympatric species pair. While only the Small smelt population is currently subject to the legislative applications of SARA, both populations continue to be afforded protection provisions under the *Fisheries Act*. This goal can be achieved by maintaining the genetic diversity and differentiation of the Lake Utopia sympatric pair and maintaining at least 100,000 spawning Small smelt population, and 2,000 spawning Large smelt in Mill Lake Stream (interim abundance targets, DFO 2016b).

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
(2018)

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.

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

In freshwater lacustrine habitats, Rainbow Smelt *Osmerus mordax* may exhibit a complex of morphologically, ecologically, and genetically differentiated populations in sympatry that are reproductively isolated from each other by factors other than spatial separation. The Rainbow Smelt populations residing in Lake Utopia, New Brunswick are an example of this phenomenon, occurring as two distinct populations that behave as separate species: a smaller (so-called “dwarf”) form (Rainbow Smelt, Lake Utopia Small smelt population) and a larger (so-called “normal” or “giant”) form (Rainbow Smelt, Lake Utopia Large smelt population). In smelts, and other temperate freshwater fishes where this phenomenon has been observed, the monikers “normal” and “dwarf” are often applied to the size variants (see Taylor 1999, 2001). All freshwater smelt are, however, ultimately derived from anadromous populations which show variable sizes at maturity and thus it is difficult to denote one of the freshwater forms or the other as “normal”.

The occurrence of genetically distinct sympatric populations of freshwater Rainbow Smelt is relatively rare, and the genetic divergence of the Lake Utopia pair has occurred independently from sympatric pairs in other lakes and provides an example of possible sympatric speciation and parallel evolution. They also highlight the importance of deterministic processes in speciation, such as natural selection. The Lake Utopia Rainbow Smelt sympatric pair, therefore, represents a significant and irreplaceable unit of biodiversity based on their novelty and the probable processes involved in their evolution. Each member of the sympatric pair in Lake Utopia also satisfies criterion 1 in the Key to Designatable Units accepted for use by COSEWIC, i.e., the phenotypes of the Lake Utopia sympatric Rainbow Smelt behave as separate species, yet the two populations are not currently recognized as taxonomically distinct (Taylor 2006). Consequently, in this report the different-sized ecotypes of smelt in Lake Utopia will simply be referred to as “Small smelt” and “Large smelt” to reflect their sizes relative to each other. When referring to the Small and Large smelt collectively, the term “sympatric pair” will be used. When inferences on the biology of Small and Large smelt from Lake Utopia are made based on information for *O. mordax* as a whole, the common name Rainbow Smelt will be employed.

The Small smelt of Lake Utopia was previously considered to be a distinct species (*Osmerus spectrum*) owing to its morphological distinctness from other smelt (but see Taylor and Bentzen 1993a). This “Lake Utopia Dwarf Smelt, *O. spectrum*” was assessed by COSEWIC in 2000, and was designated as “threatened”. Since the 2000 assessment, however, further study of divergent smelt of Lake Utopia has led to recognition that both the Small smelt and Large smelt within the lake comprise a complex population structure that should be evaluated in a common report. The sympatric pair were assessed again in 2008 and both the Small smelt and Large smelt were designated as threatened. The following report summarizes information required to update the status of each of the Lake Utopia sympatric pair which were both assessed by COSEWIC as ‘Threatened’ in 2008.

There are other putative sympatric pairs in lakes in other regions of northeastern North America, including Lac St-Jean and Lac Heney, Québec, and Lochaber Lake, Nova Scotia. The levels of differentiation between populations within these other lakes are not well understood or are much lower than exhibited by the Lake Utopia pair.

Name and Classification

Class: Actinopterygii

Order: Osmeriformes

Family: Osmeridae

Scientific Name: *Osmerus mordax* (Mitchill, 1814)

Common Names:

English	Rainbow Smelt, Dwarf Smelt, Pygmy Smelt, American Smelt, Freshwater Smelt, frost fish, ice fish, leefish
French	éperlan arc-en-ciel, éperlan du nord, éperlan d’Amérique

The taxonomic relationships among members of the genus *Osmerus* have been the subject of continued debate, a not unusual situation in the family Osmeridae (Ilves and Taylor 2009). While acknowledging some uncertainty, both Scott and Crossman (1973) and Nelson *et al*. (2004) treated populations of smelt with disjunct distributions in the Atlantic and Pacific basins as distinct subspecies (*O. mordax mordax and O. m. dentex,* respectively). Subsequent genetic investigations (Taylor and Dodson 1994) strongly suggest, however, that the Pacific and Atlantic populations are distinct at levels of sequence divergence commonly associated with full species rank in other taxa (e.g., Pacific salmon, *Oncorhynchus*). Recent compilations of Pacific basin and European freshwater fishes (Kottelat and Freyhof 2007, McPhail 2007) recognize distinct species of Pacific/Arctic Smelt and northwestern Atlantic Smelt (*O. dentex* and *O. mordax,* respectively). There is a third species of *Osmerus* native to the eastern Atlantic basin known as *O. eperlanus*. Consequently, this report considers the Lake Utopia Small and Large smelt within the context of the recognition of only the northwestern Atlantic basin Rainbow Smelt, *O. mordax*.

Taxonomic studies conducted in the 1920s (MacLeod 1922) identified morphological differences between freshwater and anadromous Rainbow Smelt and raised the question of the relationship between the two. In lacustrine Rainbow Smelt populations, early literature described the occurrence of coexisting “large” and “small” forms that were subsequently treated as two distinct species (Lanteigne and McAllister 1983). In the absence of genetic data, Lanteigne and McAllister (1983) considered the small form of *Osmerus* in northeastern North America to be a distinct species; the pygmy smelt (*O. spectrum*), first described by E.D. Cope in 1870 from specimens captured in Maine (Taylor

2001). Lanteigne and McAllister (1983) argued that the two species had allopatric origins and co-occurred as a result of post-glacial secondary contact. Genetic research by Taylor and Bentzen (1993a) showed, however, that the Small and Large forms of Rainbow Smelt are monophyletic within individual lakes and suggested that they may have originated in sympatry. This genetic evidence also cast doubt on the rationale for designating the small and large forms across northeastern North America as *O. spectrum* (Cope 1870) and *O. mordax* (Mitchill 1814), respectively (Taylor 2001). Subsequently, taxonomic recognition of the small form collectively has been characterized as inadvisable because of their apparent multiple independent origins (Nelson *et al*. 2004). The various life-history forms of Rainbow Smelt are thus all named *O. mordax* (Mitchill 1814) and the taxon *O. spectrum* is now considered an invalid, junior synonym of *O. mordax* and is no longer recommended or used (Nelson *et al*. 2004, ITIS 2006).

Morphological Description

The Rainbow Smelt is a slender, streamlined, slightly laterally compressed fish (Figure 1). Colouration varies from pale green to dark blue on the back, and the sides are predominantly silver with a rainbow of blue, purple and pink iridescence that is the basis of the species' common name (i.e., rainbow), while the belly is a silvery white (Scott and Crossman 1973). The body is elongated, with the greatest body depth anterior to the single dorsal fin. The head is elongate, with a long, pointed snout. The mouth is large, with a protruding lower jaw and teeth on both mandibles. The maxillary jaw extends to the middle of the eye or beyond. The caudal (tail) fin is deeply forked, and a small adipose fin is located between the dorsal fin and tail fin. Scales are cycloid, numbering 62 to 72 in lateral series. Breeding males develop nuptial tubercles on the head, body, and fins.

Rainbow Smelt is one of the several north temperate freshwater fish species that exhibit a complex of morphologically distinct body types occurring in sympatry (Taylor and Bentzen 1993b). The Lake Utopia Small and Large smelt differ in various morphological attributes (Taylor and Bentzen 1993a). For example, small smelt tend to have about 3 more gill rakers on the first arch than large smelt when fish from the same year are compared (Lanteigne and McAllister 1983; Taylor and Bentzen 1993a,b, Curry *et al*. 2004, Bradbury *et al*. 2011). Taylor and Bentzen (1993a) also observed that Large smelt had longer jaws (16.46[1]±0.16mm) than Small smelt (14.00±0.23mm), while Large smelt had shallower heads (16.17±0.16mm) than Small smelt (16.69±0.23mm). Bradbury *et al.* (2011) concluded that size at maturity and gill raker counts consistently distinguished the two morphs. Large smelt average from 15 to 25 cm in total body length, while the Small smelt measures between 8 and 15 cm (Lanteigne and McAllister 1983, Taylor and Bentzen 1993b, Curry *et al*. 2004). A study of genetic data suggested that Large smelt have a fork length of greater than or equal to 17 cm while Small smelt have fork lengths of less than 17 cm (Bradbury *et al*. 2011). A fork length of 17 cm is approximately equivalent to a total length of 18.4 cm (Bradford *et al.* 2012). Yet genetic data collected more recently, in 2014, suggest that the cut-off for Large smelt is about 14.3 cm fork length (DFO 2018).

[1] Jaw length and head depths adjusted to a fish total length of 160 mm.

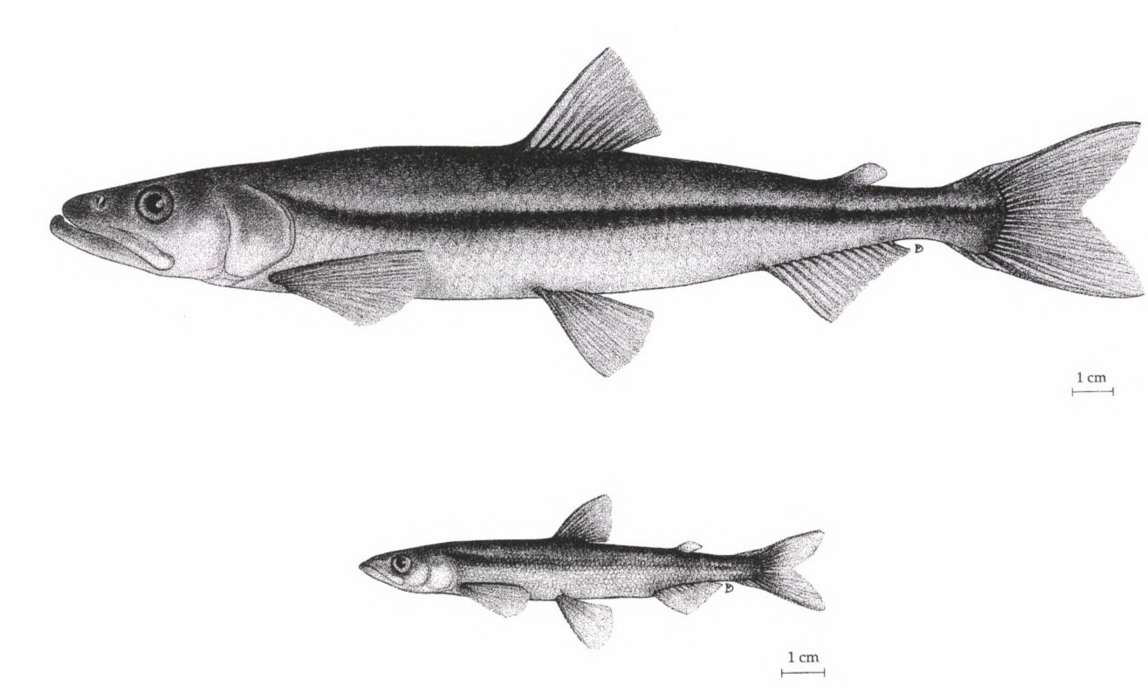

Figure 1. Illustration of Lake Utopia Large (upper) and Small (lower) Rainbow Smelt. Both specimens are mature males (Taylor 2001). Artist: Diana McPhail

Curry *et al*. (2004) suggested the possibility of a third “giant-sized” smelt in Lake Utopia, measuring up to 29 cm with as few as 23 gill rakers. According to Taylor and Bentzen (1993a) and COSEWIC (2008), however, the body size and other morphological aspects of the “giant” Rainbow Smelt are no more extreme than is characteristically seen in the Large smelt found in other lakes, specifically Lochaber Lake and Grand Lake in Nova Scotia. In addition, the size-frequency histograms of the two largest (and earliest spawning) groups of smelt show a very high degree of overlap, as do the gill raker counts; both of which remain highly distinct from those of the Small smelt (Curry *et al*. 2004). This suggests that the “giant” Rainbow Smelt (*sensu* Curry *et al*. 2004) sampled in Lake Utopia likely represent larger-than-average specimens of the Large smelt. Recent extensive genetic analyses conducted also show no evidence of a third giant morphotype (Bradbury *et al.* 2011, DFO 2018, Themelis 2018).

There is evidence of hybridization between the sympatric pair. Bradbury *et al*. (2011) used principal coordinates analysis to interpret 10 microsatellite loci for smelt from five sites in Lake Utopia in 2002. There was a general relationship between the first principal coordinate and fish size, but a number of fish that had the Large genetic form (i.e., large PC1 scores) were short (Small smelt morph). On the basis of two decades of stable genetic differentiation between Large smelt and Small smelt morphs, Bradbury *et al.* concluded that ‘selection’ pressures were removing hybrids. Themelis (2018) concluded on the basis of comparison of hybridization rates from 2014 and 2015 to more historical rates that hybridization was increasing. Themelis (2018) was in particular considering

Rainbow Smelt from Mill Lake Stream in 2014 that were 20% hybrids.

Semi-transparent clusters or blankets of Rainbow Smelt eggs are found in spawning areas in early spring (MacDonald 2017), with each egg weighing approximately 0.35 mg (Shaw and Curry 2005). Emerging larvae appear semi-transparent and measure approximately 5 mm long (Shaw and Curry 2005). Sampling conducted in Lake Utopia in 2004 found no significant difference between egg and emerging larval sizes of Small and Large smelt (Shaw and Curry 2005). Diverging rates of growth between forms, however, become evident almost immediately after emergence (Shaw and Curry 2005). Rainbow Smelt grow rapidly, doubling their size within two weeks of emergence (Shaw and Curry 2005).

Population Spatial Structure and Variability

Analyses of mitochondrial DNA (mtDNA) restriction site variation of Rainbow Smelt throughout their native range revealed the presence of two evolutionarily (phylogenetically) distinct lineages that diverged from each other sometime during the Pleistocene (i.e., over approximately the last 2 million years): the “Acadian” group found predominantly in the St. Lawrence River watershed, and the “Atlantic” group whose waters drain directly to the Atlantic Ocean (Taylor and Bentzen 1993a, Bernatchez 1997). Depending on the geographic location, freshwater and anadromous Rainbow Smelt were dominated by mtDNA genotypes that clustered within one or the other evolutionary lineage, indicating that there is no phylogenetic distinction among Rainbow Smelt trophic ecotypes (Taylor and Bentzen 1993a, Bernatchez 1997). The sympatric populations in Lake Utopia both belong within the Atlantic mtDNA assemblage (Baby *et al*. 1991, Taylor and Bentzen 1993a, Bernatchez 1997).

The lack of phylogenetic distinction among life history types of Rainbow Smelt refuted previous hypotheses of a common evolutionary ancestry for all small or dwarf-like Rainbow Smelt populations and cast doubt on the validity of its designation as *O. spectrum* (Taylor and Bentzen 1993a). Furthermore, small-sized Rainbow Smelt from various lakes were found to be more similar to geographically proximate large-sized freshwater or anadromous populations than to each other (Taylor and Bentzen 1993a). In Lake Utopia, the sharing of the *Sty* I mitochondrial DNA haplotype by the Small and Large Rainbow Smelt, a genotype unique to that lake, argues strongly for an intra-lacustrine (sympatric) origin of Lake Utopia’s sympatric populations (Taylor and Bentzen 1993b). An allopatric origin followed by gene flow following secondary contact (e.g., Taylor and McPhail 2000), however, cannot be completely discounted as an alternative explanation for monophyly of Lake Utopia Small and Large smelt. Regardless of the geography of their evolution, the Rainbow Smelt forms in Lake Utopia are genetically distinct from each other and from smelt from other lakes and have arisen independently from smelt in other lakes (Taylor and Bentzen 1993a, Taylor 2001).

The genetic divergence between Small and Large smelt in Lake Utopia is at a level comparable to divergence between populations from different lakes (Taylor and Bentzen 1993a); net mtDNA sequence divergence between forms within Lake Utopia was reported as 0.16%, while net divergence among 16 allopatric smelt populations was 0.19%. Small and large forms in Lake Utopia were also divergent at minisatellite loci, with fragment frequency differences averaging 14% higher between forms than within forms (Taylor and Bentzen 1993b). Significant mitochondrial and minisatellite DNA divergence between the forms in Lake Utopia indicates that each is a distinct gene pool. This, coupled with the pronounced morphological and ecological differences between populations, and differences in spawning time and distribution among streams (see below), suggests that there is a high degree of reproductive isolation between them and, consequently, that they are behaving as distinct biological species (Taylor and Bentzen 1993b).

Microsatellite analyses of Lake Utopia Rainbow Smelt forms, conducted in spawning runs between 1998 and 2015 (Curry *et al*. 2004, Bradbury *et al.* 2011, DFO 2018, Themelis 2018) indicate hybridization. The rate of hybridization is thought to be potentially increasing (Themelis 2018) although the evidence is not strong because of the lack of historical data. Evidence from genetic analysis also suggested that distinctions among spawning populations within forms is present (Curry *et al*. 2004), but also that these intra-form differences are much less than between Small and Large smelt (COSEWIC 2008). Bradbury *et al.* (2011) did not find evidence of these intra-morph differences and suggest that further study is needed to better understand the genetics of intra-morph distinctions.

Designatable Units

Divergent morphology between Small and Large smelt in Lake Utopia has evolved independently from the few pairs reported from other lakes (see “Distribution” below), and the replicate sympatric pairs provide an example of parallel evolution within each lake (Taylor and Bentzen 1993a). The existence of a sympatric pair in Lake Utopia is, therefore, the result of a unique evolutionary process, and supports the view that the sympatric Small and Large smelt in Lake Utopia represent a significant, irreplaceable unit of biodiversity. Also, the behaviour of Small and Large smelt in Lake Utopia as distinct biological species satisfies criterion 1 in the key for designatable units of Taylor (2006) that has been accepted for use by COSEWIC. Consequently, the Lake Utopia smelt constitute two DUs independent from *O. mordax* as a whole: Rainbow Smelt, Lake Utopia Large smelt population and Rainbow Smelt, Lake Utopia Small smelt population.

The existence of several discrete populations of sympatric Rainbow Smelt pairs is similar to that of sympatric stickleback species pairs (*Gasterosteus* sp.) in southwestern British Columbia, where the sympatric pairs from each lake were designated by COSEWIC as distinct designatable units and assessed independently (COSEWIC 2002, CWS 2017). In addition, it is appropriate and important that the status of both members of the pair be assessed in the same report for several reasons. First, the significance of the Lake Utopia smelt pair rests on their distinctions and persistence in sympatry; neither form considered in isolation from the other is particularly distinctive within *O. mordax*. Second, interactions between them may contribute to their evolution and persistence. Third, the Small and Large smelt share common threats to their habitats, especially breeding habitats, and disturbance to such habitats could lead to increased hybridization between Small and Large smelt as has been documented for sympatric pairs of *Gasterosteus* (Taylor *et al*. 2006).

Special Significance

In evolutionary biology, allopatric speciation is considered the most common way that new species arise. Also known as "geographic speciation", genetic divergence occurs following geographic partitioning of a lineage (Taylor 2001). The evolution of reproductive isolation is thought to be an incidental by-product of adaptive changes in response to different environmental conditions in separate geographic areas. By contrast, the reproductively isolated sympatric pair of smelt in Lake Utopia is thought to have developed relatively rapidly (<12,000 years) and in the absence of any obvious geographic separation. This possible example of sympatric speciation (Taylor and Bentzen 1993a,b) has contributed to increasing empirical support for a phenomenon that was once considered impossible by many (see discussions in Bush 1994, Taylor 2001; Coyne and Orr 2004). Also, because the genetic divergence of Small and Large smelt in Lake Utopia has occurred independently from sympatric populations in other lakes, the Lake Utopia sympatric pair provides an example of parallel evolution and the likely importance of deterministic processes, such as natural selection, in speciation, another contentious issue in evolutionary biology (Schluter 1996, Taylor 2001). Given that Lake Utopia holds an endemic genetically distinct sympatric complex *O. mordax* of importance to speciation research, there would be an irreplaceable loss of biodiversity if this sympatric pair of Small and Large smelt became extinct.

The sympatric Small and Large smelt in Lake Utopia are morphologically and ecologically distinct from each other and are, to a large extent, reproductively isolated from each other and consequently behave as separate species (Taylor and Bentzen 1993b, Mallet 2008). The Small and Large smelt are, however, not presently recognized taxonomically and the biological diversity of the complex cannot be described by current taxonomic procedures for species designation – a situation that is not unique to *Osmerus* (Taylor 1999). This poses a problem to systematists, and challenges the rules and procedures governing the current practices of biological nomenclature (Taylor 2001). In addition, it is the co-existence of genetically divergent forms within the same lake (i.e., their behaviour as distinct species) that marks the significance of the Small and Large smelt in Lake Utopia and distinguishes each of them from comparable forms occurring allopatrically in many lakes in eastern Canada.

DISTRIBUTION

Global Range

The taxon *Osmerus mordax* is native to watersheds of the northwestern Atlantic Ocean and is widely distributed along the northeastern North American coast, from New

Jersey to Lake Melville on the Labrador coast (Scott and Crossman 1973, Scott and Scott 1988). Throughout their range, Rainbow Smelt may be anadromous, living most of their adult lives in salt water and returning to freshwater to spawn, or they may reside permanently in lakes. Rainbow Smelt are thought not to be native to the Great Lakes (Scott and Crossman 1973) but have subsequently spread throughout these lakes via introductions and the opening of various canals in eastern Canada and the US. Introductions to inland lakes of Ontario have resulted in their dispersal further west into Lake Winnipeg and the western coast of Hudson Bay, via the Nelson River (Stewart and Watkinson 2004). Rainbow Smelt have been captured at the mouth of the Moose River and are expected to thrive and establish anadromous populations in Hudson Bay (Coad 2018).

Studies designed to systematically assess the distribution and number of reproductively isolated, sympatric pairs have not been completed; rather, sampling has been mostly opportunistic as part of more general studies of the Rainbow Smelt. Notwithstanding this limitation, the occurrence of genetically distinct sympatric populations of Rainbow Smelt appears to be relatively rare when viewed in the context of overall geographic range of *O. mordax. S*tudies by Baby *et al*. (1991), Taylor and Bentzen (1993a) and Bernatchez (1997) have examined a total of 47 populations of Rainbow Smelt in northeastern North America and evidence of sympatric pairs consisting of a combination of genetic, ecological, and morphological data has been reported in only three instances: Lake Utopia, Lochaber Lake (Nova Scotia, Taylor and Bentzen 1993a), and Lac St. Jean, Québec (Saint Laurent *et al*. 2003). While there are suggestions of sympatric pairs in a few other lakes in Canada and the US (Héney and Kénogami lakes, Québec; Onawa and Green lakes and Wilton Pond, Maine: Lanteigne and McAllister 1983, Baby *et al*. 1991, Taylor and Bentzen 1993a), the evidence in support of other sympatric pairs is not compelling owing to small sample sizes or lack of one of either ecological, morphological, or genetic data.

The Lake Utopia sympatric pair is endemic to a single locality in Canada (see below).

Canadian Range

The Lake Utopia sympatric pair is endemic to Lake Utopia (45º 10'N, 66º 47' W), which is located in Charlotte County in southwestern New Brunswick, approximately 70 km west of Saint John, and just northeast of Saint-George (Figure 2). The lake drains via the canal on the southwestern shore into the Magaguadavic River approximately 10 km from its mouth into the Bay of Fundy. Its length is approximately 7.2 km, 0.75 to 2.5 km wide, with a surface area of 14 km^2, a mean depth of 11 m, a maximum depth of 26 to 30 m, and a total water volume of approximately 1.3×10^8 m^3 (Lanteigne and McAllister 1983, Taylor 2001, Hanson-Lee 2003, Curry *et al.* 2004, Brylinsky 2009, Bradford *et al.* 2012, Hebb 2013). The lake is part of the Magaguadavic River drainage system that flows into the Bay of Fundy.

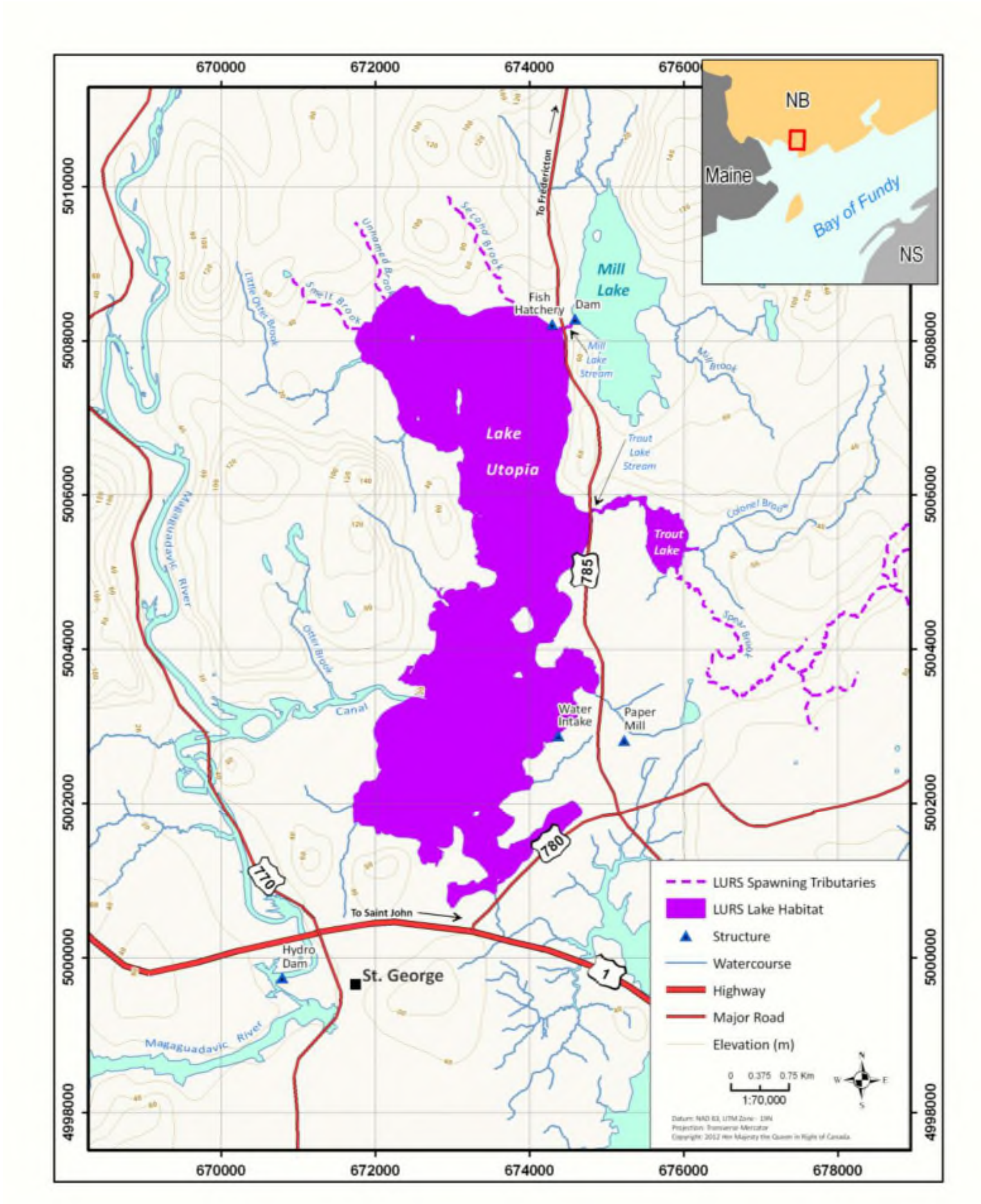

Figure 2. The location of Lake Utopia, New Brunswick, with the confirmed spawning tributaries used by the Small (Second Brook, Smelt Brook, Unnamed Brook, Mill Lake Stream) and Large (Mill Lake Stream, Trout Lake Stream, Spear Brook) smelt populations (DFO 2016b).

Extent of Occurrence (EOO) and Index Area of Occupancy (IAO)

The EOO for Lake Utopia rainbow smelt is approximately 29 km^2, calculated via the convex polygon method. The IAO for both Large smelt and Small smelt is estimated as 6 km^2, based on a 1 × 1 grid, or 20 km^2, based on a 2 × 2 grid, for each population The IAO was determined by overlaying these two grids over the smelts known spawning streams. Because spawning is likely restricted to small reaches within the streams the actual IAO for each population is likely much smaller than 20 km^2.

HABITAT

Habitat Requirements

Lake Utopia is a relatively small lake, with mesotrophic to oligotrophic conditions (Lanteigne and McAllister 1983, Taylor 2001, Hanson-Lee 2003, Brylinsky 2009, Hebb 2013). It is a coldwater lake, with ice cover from mid-December until mid-April, and thermal stratification during the summer months (Lanteigne and McAllister 1983, Taylor 2001). The morphoedaphic index, a measure of total dissolved solids relative to mean depth that is used to determine fish production, is 0.94 (values can range from near 0 to over 100 for the most productive lakes). Values of pH range from about 7.0 at the surface to about 6.0 at 25 or 26 m (Taylor 2001, Hebb 2013). In July 2012, dissolved oxygen concentrations ranged from about 8.9 mg/L at the surface to about 6.8 mg/L at 26 m (Hebb 2013), concentrations that are above the guidelines set for dissolved oxygen by the Canadian Council of Ministers of the Environment for the survival of cold water biota (6.5 mg/L; CCME 1999). The summer water temperature in Lake Utopia, although not monitored frequently, has shown a slight increase over the last 40 years (1969 to 2012; Lanteigne and McAllister 1983, Taylor 2001, Hanson-Lee 2003, Hebb 2013). In 1969, summer water temperatures ranged from about 21°C at the surface to about 8.0ºC at 25 m (Taylor 2001). In 1996, water temperatures ranged from 22ºC on the surface to 8.0ºC at 25 m (COSEWIC 2008). In 2012, water temperatures ranged from about 23ºC on the surface to 9.0ºC at 26 m (Hebb 2013). The mid-summer thermocline has been fairly consistent throughout these sampling dates at about 10 to 15 m deep (Taylor 2001, COSEWIC 2008, Hebb 2013).

Scott and Crossman (1973) characterized Rainbow Smelt as pelagic fish that tend to occupy cool, deeper waters. In Lake Utopia, there have been no observations of either Small or Large smelt aggregating at any particular depth or location and there is evidence that both forms mix in the lake (Curry *et al*. 2004).

Inlet streams of Lake Utopia are used by Small and Large smelt for spawning grounds (Taylor and Bentzen 1993a, Taylor 2001). Sampling has been conducted in all seventeen tributaries in Lake Utopia where potentially suitable spawning habitat exists, and visual inspections for spawning adults or eggs were conducted. Spawning has been observed in six small streams at the northern end of the lake: Mill Lake Stream, Trout Lake Stream, Second Brook (also referred to as Scout Brook), Unnamed Brook, Spear Brook, and Smelt Brook (Taylor and Bentzen 1993a, Curry *et al*. 2004, Bradford et al. 2012, DFO 2018, Themelis 2018), although minor and sporadic spawning does occur in other streams and may occur along the shoreline in some years (DFO 2011, Themelis pers. comm. 2017). Eggs were observed, for example, in the first 5 m of New (Unmapped) Brook along the northern shoreline between Second Brook and Unnamed Brook in 2013 (Themelis 2018). This brook, however, is only accessible in times of unusually high water (Themelis pers. comm. 2017).

The two smelt morphs are, for the most part, reproductively isolated, with Large smelt known to spawn in Mill Lake Stream and Trout Lake Stream, both of which are outlet streams for smaller lakes that flow into Lake Utopia (Curry *et al*. 2004, Bradford *et al*. 2012). Trout Lake Stream averages 10 m wide with slow-moving water and deeper pools (Curry *et al*. 2004). Large smelt egg deposits have been observed in Trout Lake Stream within a culvert at the mouth of the stream (Bradford *et al.* 2012). Large smelt have been observed spawning, and later egg deposits observed, in Spear Brook, a tributary of Trout Lake (Curry *et al*. 2004, DFO 2011, Bradford *et al.* 2012). Spear Brook is about 4 m wide with a low gradient and has an extensively braided outlet due to beaver (*Castor canadensis*) damming activities (DFO 2011). Trout Lake Stream and Trout Lake may thus provide a connection corridor for smelts migrating to Spear Brook. Large smelt egg deposits have been observed in Mill Lake Stream, at around the same time that Small smelt were running in Second, Smelt and Unnamed Brooks (McDonald 2017). Mill Lake Stream averages 4 m wide and less than 1 m deep. There are two culverts that pass under Highway 785, upstream of these culverts, the stream opens up into a large beaver pond (MacDonald 2017). Passage to Mill Lake is prevented by the presence of an abandoned dam at the head of Mill Lake Stream and a small, approximately 0.5 m high, waterfall that is impassable, except perhaps in times of extreme high water (Taylor 2001, Bradford *et al.* 2012). In a regular year, these features leave an approximately 10 to 30 m spawning reach for the smelt (DFO 2011, Bradford *et al.* 2012). During spawning these streams have high to moderate flow (up to 1 m/s; Taylor 2001) and water temperatures of less than 6^{o}C (Curry *et al*. 2004).

Small smelt spawn in the smaller (1 to 2 m wide), slower-flowing (< 10 cm/s) streams that do not originate from a lake; Second Brook, Smelt Brook, and Unnamed Brook (Taylor 2001). In total, these smaller streams provide less than 500 m of accessible linear habitat (Curry *et al*. 2004). Water temperatures range from 4^{o}C to 9^{o}C in the smaller streams at spawning time (Curry *et al*. 2004, MacDonald 2017). McNeely and LaBillois (2014) observed smaller smelt, believed to be from the Small smelt population, in Mill Lake Stream during the 2014 spawning period, and DFO staff observed new eggs in the stream long after the termination of the Large smelt spawning run. Genetic analyses from a subset of these fish revealed that about 80% of these individuals were indeed pure Small smelt while the others were hybrids between the two morphs (MacDonald 2017, DFO 2018, Themelis 2018). Eggs were observed again in 2015 during the Small smelt spawning run in Mill Lake Stream (MacDonald 2017).

Out of the eleven remaining tributaries in Lake Utopia, one unnamed stream (referred to as Big Hike Brook) that flows into the west-centre of the lake possesses similar thermal regimes and habitat features to the known Small smelt spawning streams and thus may provide potential spawning habitat for Small smelt (MacDonald 2017). No smelt have been observed spawning in this tributary, yet it has not been monitored frequently. Shore-shoal spawning is not uncommon in Rainbow Smelt (Scott and Crossman 1973), yet this would be difficult to observe in Lake Utopia (DFO 2011).

Spawning substrates vary to include any secure substrate suitable for egg attachment, such as silt, gravel, rock, aquatic vegetation and wood debris (Bradford *et al.* 2012, DFO 2016b). Rainbow Smelt generally ascend the streams until they encounter an obstruction or increase in stream gradient. Areas immediately downstream of the obstructions contain some of the greatest densities of Rainbow Smelt eggs in the stream. Confirmed Small smelt spawning streams, namely Second, Smelt and Unnamed Brooks, consist predominantly of sand, with fines and gravel also present (≥ 10%; MacDonald 2017).

Critical habitat for the Large smelt population has been identified in the Recovery Strategy (DFO 2016) as: *The water column, substrate and LbP features of Lake Utopia in the Magaguadavic River watershed in Charlotte County, New Brunswick (total surface area 14 km^2), and part of the following tributaries of Lake Utopia: Smelt Brook, Unnamed Brook, and Second Brook (total combined length of 586 m).*

Habitat Trends

Some physical and chemical monitoring data are available (1969 to 2012, Lanteigne and McAllister 1983, Taylor 2001, Hanson-Lee 2003, COSEWIC 2008, Hebb 2013), but no peer-reviewed analysis of temporal variations has been completed. Hanson-Lee (2003) examined temporal variability in some water quality parameters (e.g., phosphorus) and documented largely stable concentrations through to 2002. There have been no subsequent analyses of time trends.

BIOLOGY

Lake Utopia's sympatric pair exhibit a life cycle similar to other freshwater and anadromous Rainbow Smelt populations, with a key distinction being the development of ecological differences and reproductive isolation that promote and maintain the genetic distinctions between Small and Large smelt in Lake Utopia.

The diet of Small smelt is primarily zooplankton, consisting of species such as *Daphnia, Diaptomus, Cyclops, Bosmina, Leptodora* and *Epischura* (Bajkov 1936, Lanteigne and McAllister 1983). Adult Large smelt are at a higher trophic level, being macrophagous and piscivorous. They feed on invertebrates, such as copepods, and smaller fish (Lanteigne and McAllister 1983, Curry *et al.* 2004). Little is known of the effects that foraging activities of the Lake Utopia sympatric pair have on other resident fish species. Inland Rainbow Smelt populations throughout eastern North America, however, are known to prey heavily on young-of-the-year fish and have led to major declines of several species (Franzin *et al*. 1994).

Life Cycle and Reproduction

In Lake Utopia, smelt spawning occurs each spring, beginning as early as mid-March while the lakes are still ice-covered, and continues until mid- to late May (Delisle 1969, Curry *et al*. 2004). There is some temporal separation in the peak spawning activities of the different smelt, with the Large smelt consistently spawning first in late March to mid-April and Small smelt spawning from mid- to late April to mid- to late May (Delisle 1969, Taylor and Bentzen 1993b, Curry *et al*. 2004, MacDonald 2017, DFO 2018). A later spawning event in Mill Lake Stream (April/May) has been observed, believed to be Small smelt (McNeely and LaBillois 2014, MacDonald 2017).

There exists, to a substantial degree, reproductive isolation between the two smelt morphs: the Large smelt spawners (12-29 cm fork length) ascend Mill Lake Stream, Trout Lake Stream and Spear Brook in late March/early April, possibly related to the full moon (e.g., Hebb 2012); and the Small smelt spawners (< 12 cm fork length) ascend Unnamed, Second and Smelt brooks in late April to May (Curry *et al.* 2004, Bradford *et al.* 2012). There are no reports of Large smelt spawning in Trout Lake Stream and Spear Brook since 2012, albeit the substrate of culverts where eggs have been observed in the past has not been the focus of studies. Furthermore, Spear Brook was only checked twice, in 2013 and 2015, due to access constraints (Themelis 2018). Furthermore, no Large smelt were observed spawning in Mill Lake Stream in 2015 and only one individual was observed in 2016, yet egg mats were observed in mid- to late April 2016, suggesting that more individuals had been present at some time during the Large smelt spawning run than were observed (MacDonald 2017, Themelis 2018). This perceived lack of spawning may have been a result of beaver activity and other debris blocking the stream entrance (in 2015) and higher velocity flows than smelt can swim against (in 2016; MacDonald 2017).

In recent years, a later spawning event in Mill Lake Stream has been observed, believed to be Small smelt (McNeely and LaBillois 2014, MacDonald 2017). This belief was confirmed through genetic assessment of individuals caught in 2014 (DFO 2018, Themelis 2018). Small smelt have thus been confirmed to spawn in at least five tributaries (Unnamed, Second, Smelt, and New brooks, and Mill Lake Stream), yet only three have consistent observations (Unnamed, Second, and Smelt brooks).

Detailed spawning information for both Lake Utopia Small and Large smelt is available for 2004 and indicates the spawning, incubation and emergence time frames for spawning populations recorded. For Large smelt, the spawning period takes place over 5 to 10 days (DFO 2011, McNeely and LaBillois 2014), whereas for Small smelt, the spawning takes place over 2 to 4 weeks (DFO 2011). Spawning runs are typically dominated by male smelt, with females comprising approximately 20 to 37% of the total spawners (Bradford *et al.* 2012). Fecundity ranges from ~2,000 to 12,000 eggs for Small smelt from females ranging from 9.5 to 15.5 cm in fork length (Shaw *et al.* 2004; Bradford *et al*. 2012). There are no estimates of fecundity for Large smelt (Bradford *et al*. 2012). Mean egg incubation time lasts 22 days and 28 days for Large and Small smelt, respectively (Shaw 2006). After hatching, juvenile smelt drift downstream during periods of darkness to disperse within Lake Utopia (Curry *et al.* 2004, Shaw and Curry 2005).

Spawning occurs at night between the hours of 21:30 and 05:30, with peak activity occurring from about 00:00 to 01:30 (Curry *et al*. 2004, McNeely and LaBillois 2014). There is no evidence of spawning activity in the day, and most smelt return to the lake upon daybreak (Curry *et al*. 2004).

For fish sampled on the spawning grounds, the average age of maturity was determined to be 2.8 years, with no significant age difference between Small and Large smelt in any of the tributaries (Curry *et al*. 2004). Possible differences in age at first spawning are not known. Generation time both for Small and Large smelt is approximately 3 years, and their life span is approximately 6 years.

Physiology and Adaptability

The Rainbow Smelt demonstrates great variability throughout its range and is capable of living both in marine and freshwaters (Nellbring 1989). Small Rainbow Smelt from Lake Utopia were transplanted into Meech Lake, Québec in 1924 and a self-sustaining population appears to be established. Mature individuals have been collected in Meech Lake as recently as 1991 (Taylor 2001), but it is unknown whether these smelt are offspring of the original transplants that have adapted to the conditions in Meech Lake, or if they arrived at the lake by other means (COSEWIC 2008). Meech Lake spawners also appear to migrate into streams, similar to their Lake Utopia counterparts (Bridges and Delisle 1974).

Dispersal and Migration

The only apparent migration performed by Lake Utopia smelt is the nightly movements to spawning sites in inlet tributaries, up to a few hundred metres, that occur each spring. Upon hatching, larval smelt drift downstream and disperse into the lake (Curry *et al.* 2004, Shaw and Curry 2005).

The Magaguadavic River system drains Magaguadavic and Digdeguash lakes found upriver from Lake Utopia. These lakes support Rainbow Smelt populations, but no sympatric forms have been observed and it does not appear that the sympatric pair from Lake Utopia migrate beyond their resident lake. The Magaguadavic River continues from Lake Utopia to St. George. At St. George, a waterfall impassable to upstream fish movements exists and a fishway has been constructed here for migrating Atlantic Salmon (*Salmo salar*).

Interspecific Interactions

Species that are known to prey upon lacustrine Rainbow Smelt and are present in Lake Utopia include landlocked Atlantic Salmon, Brook Trout (*Salvelinus fontinalis*), older smelt (Curry *et al*. 2004), Burbot (*Lota lota*) and Yellow Perch (*Perca flavescens*; Scott and Crossman 1973). Invasive predatory species have also recently been found in the Magaguadavic River system, including Smallmouth Bass (*Micropterus dolomieu*) and

Chain Pickerel (*Esox niger,* Carr and Whoriskey 2009, Bradford *et al.* 2012). Analyses of isotope signatures in Lake Utopia Salmon, Trout and Smallmouth Bass identified these species as potential predators of Small smelt and juvenile Large smelt (Curry *et al*. 2004). Small smelt were found in the stomachs of Brook Trout in 1996 (Taylor 2001), and in Large smelt in 1999 (Curry *et al*. 2004). Chain Pickerel are also thought to be potential predators of Small smelt and juvenile Large smelt (DFO 2016b). Chain Pickerel has been spreading from Magaguadavic Lake down the river mainstream since 2003, and appears to have become established in Lake Utopia (Carr and Whoriskey 2009).

The Atlantic Salmon population in Lake Utopia has received supplemental stocking at least 16 times since 1984 to support a recreational fishery, and the lake is presently stocked at a rate of 3,400 yearling salmon every other year (Collet *et al*. 1999, Curry *et al*. 2004, NB DERD 2017). The consumption of Rainbow Smelt by landlocked Atlantic Salmon populations is well documented (Nellbring 1989, Curry *et al*. 2004). No specific information, however, is available on the importance of the various life stages of Small and Large smelt as a forage species for landlocked salmon in Lake Utopia. Based on Curry *et al.*'s (2004) analysis of stable isotope signatures in forage species, it does not appear that Small and Large smelt are the only species preyed upon by Atlantic Salmon in Lake Utopia.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Until recently, search efforts to locate Small and Large smelt in Lake Utopia have largely been for the purpose of sampling for fundamental studies of growth, life history, taxonomy, and genetics, rather than to calculate abundance *per se*. Small and Large smelt were opportunistically sampled by Lanteigne and McAllister (1983) in 1983, and Taylor and Bentzen (1993) in 1990 and 1991, and more focused collections were made by Curry *et al*. (2004) from 1998 to 2003. Spawning population abundance was estimated by Bradford *et al.* (2012) based on data collected in 1999, 2001, 2003, and 2009. Large smelt spawning population abundance was also estimated by DFO (2016, 2018) in 2014 and 2017.

In recent years, efforts have been made to calculate population abundance in Lake Utopia, and sampling of spawning Small and Large smelt for that purpose was conducted from 1998 to 2003 (Curry *et al*. 2004, Shaw and Curry 2005). In 1999, estimates of abundance were determined for spawning populations by capturing, tagging, and releasing Small and Large smelt from approximately 21:30 until 04:30 when most smelt entered tributary streams (Curry *et al*. 2004). Schnabel estimates of abundances were calculated, based on the number of smelt entering the stream during sampling (1.5 hrs). Stream-specific estimates of five sampling periods were summed to provide the total abundance for each stream. When too few smelt were encountered for a mark-recapture estimate, estimates were based on actual counts. When too many smelt were encountered to enumerate with the mark-recapture method, all fish were counted within an isolated 1 m section of the stream, and the count was extrapolated across the entire length of accessible habitat.

Directed search of apparently suitable spawning tributaries was conducted by DFO personnel in conjunction with recovery efforts for the Small smelt. A total of 17 streams were searched during April and May (the typical spawning period) 2007 and in April 2013. Annual spawning has been reported in only the six streams discussed above. Small smelt have also been opportunistically observed in at least one of the three known spawning brooks from 2012 to 2017 (Themelis 2018).

Later still, Bradford *et al*. (2012) estimated spawner abundance for Small smelt in Second Brook in 1999, 2001, and 2003, Smelt Brook in 1999, 2001, 2002, 2003, and 2009, and Unnamed Brook in 1999, 2003, and 2009, and for Large smelt in Mill Lake Stream in 2009, using quantitative Bayesian estimates.

Most recently, DFO conducted a mark-recapture study of spawning Large smelt in Mill Lake Stream in 2014 and 2017 (DFO 2016a, 2018, Themelis 2018) and spawning Small smelt in Unnamed Brook in 2014 (Themelis 2018). Abundance was estimated from these mark-recaptures using an adjusted Schnabel method. Large smelt numbers were then adjusted based on the proportion of individuals captured from 2014 with a fork length of over 14.3 mm (83%) to eliminate Small smelt and potential hybrids from the estimate (DFO 2018).

Abundance

Taylor and Bentzen (1993b) reported that Large smelt were abundant and Small smelt were fewer in number in Lake Utopia. Based on the most recent estimates, however, it was demonstrated that the actual abundance of Small smelt was much higher than previously suggested.

Single evening estimates of Small smelt from 1999 suggest a total population of perhaps 1 million or more spawners. Single evening counts of spawners in Second, Smelt and Unnamed brooks in 2003 were conservatively estimated to range from 5,361 to 169,000. The Small smelt had single evening estimates of between 3,000 and 150,000, suggesting a total population of between 250,000 and 1,000,000 spawners (Curry *et al.* 2004, COSEWIC 2008, DFO 2011, Bradford *et al.* 2012, Themelis 2018). Small smelt have been opportunistically observed in at least one of the three known spawning brooks in 2012, 2013, 2015, 2016 and 2017 (Themelis 2018). This summation of nightly spawner abundance is confounded as individuals can enter a stream on multiple nights, as many as eight nights, thus generating overestimates of actual total abundance (Bradford *et al.* 2012).

Surveys in spawning streams by Curry *et al*. (2004) indicated that in both Smelt Brook and Unnamed Brook all suitable substrates were densely packed with eggs, in some instances creating 5 cm deep mats covering the entire width of the stream for distances of 5 m. Smaller mats were observed in Second Brook in 2001 and 2002 (Curry *et al*. 2004). Significant numbers of adult Small smelt also remained in the streams during the day, enough that they could easily be captured by hand in 1999 and 2000. In 2001, drifting smelt larvae were observed at rates of 1 to 44 larvae per cm^3 per hour from Smelt, Unnamed and Second brooks (Curry *et al*. 2004).

Bradford *et al*. (2012) considered the multiple years of available spawning run data for Small smelt and determined that the within-stream median nightly spawning abundance across the three brooks where they are known to spawn (Smelt Brook, Unnamed Brook, Second Brook) and across all years of record ranged between 3,000 and 150,000. Spawner numbers were most frequently 1,000 per night (Bradford *et al*. 2012).

Bradford *et al.* (2012) estimated the spawning abundance of Large smelt in Mill Lake Stream in 2009 to be about 5,000 individuals. This is a conservative estimate as it was based on one night only. The Large smelt spawning period typically lasts between 5 to 10 days (DFO 2011, McNeely and LaBillois 2014).

In 2014, DFO (DFO 2016a) conducted a mark-recapture study and generated Schnabel estimates of spawning population abundance of Large smelt in Mill Lake Stream of about 23,000, with nightly estimates of between 1,700 and 23,700, generally increasing with time. These estimates were based on total numbers of fish observed, yet it is now apparent that Small smelt and hybrids are present in the Large smelt spawning run (e.g., DFO 2018, Themelis 2018). DFO (2018) re-estimated the Large smelt spawning population during the 2014 run based on those fish with a fork length of 14.3 cm and over (83%) and estimated there to be almost 20,000 spawning individuals. During the same time, McNeely and LaBillois (2014) observed a total of about 16,000 Large smelt in this stream over an 8-day period. As with the estimates of total abundance by Curry *et al.* (2004), caution should be taken, however, when interpreting this number as individuals can be present in the stream on multiple days and hence be counted multiple times.

The number of Large smelt participating in the 2017 spawning run on April 14 and 15 was also calculated by DFO (2018). Assuming 83% of fish observed were, in fact, Large smelt, approximately 10,500 spawners were estimated. Again, this number may represent a conservative estimate as observations were made on only two nights of the spawning window.

Fluctuations and Trends

Collections made in Lake Utopia in the early 1990s were intended for genetic studies, as acknowledged by Taylor (2001), and underestimated abundance of Small smelt; sampling effort focused only on four of seventeen possible tributaries that could contain spawners, sample sizes were small, and sampling took place over a very short duration of the entire spawning period. Based on sampling conducted from 1998 to present, the population abundances of the Lake Utopia Small and Large smelt appear fairly consistent over time. The high abundance of Small smelt spawners and their apparent restriction to only a few of the available tributaries may indicate that the lake itself is at maximum carrying capacity for Small smelt (Curry *et al*. 2004).

Rescue Effect

Given that Lake Utopia holds a genetically distinct sympatric pair of Rainbow Smelt, there would be an irreplaceable loss of diversity if these populations were lost; i.e., there is no possibility of a natural rescue effect. The upstream Harvey Lake is home to a population of Rainbow Smelt that is closely related to the Lake Utopia pair, suggesting recent gene flow between the populations (Bentzen pers. comm. 2017). This Harvey Lake population was found to be intermediate between the sympatric pair, but more closely related to the Small smelt (Bentzen pers. comm. 2017). Introducing these individuals into Lake Utopia, therefore, would not contribute to a rescue of the Large smelt population.

THREATS AND LIMITING FACTORS

Threats and limiting factors that have the potential to influence populations of Large smelt include various natural factors, hybridization and anthropogenic. Each is discussed below.

Natural Limiting Factors

Natural factors that limit the number and abundance of individual smelt populations in Lake Utopia are presumed to be: (1) low lake productivity, (2) predation pressures from native salmonids and other fishes, and (3) the use of only a small number of potential spawning areas, tributaries to the lake.

Lake Productivity

Lake Utopia is a relatively small, cold-water and oligotrophic lake (Hanson-Lee 2003). The lake water has low alkalinity (< 10 mg/L), low hardness (< 15 mg/L) and low concentrations of phosphorus (generally < 10 µg/L). These factors will naturally limit fisheries production, including production by Rainbow Smelt.

Predation Pressures

Several species of fish that predate on Rainbow Smelt are present in Lake Utopia including landlocked Atlantic Salmon, Brook Trout (*Salvelinus fontinalis*), older smelt (Curry *et al*. 2004), Burbot (*Lota lota*) and Yellow Perch (*Perca flavescens*; Scott and Crossman 1973). Invasive predatory species have also recently been found in the Magaguadavic River system, including Smallmouth Bass (*Micropterus dolomieu*) and Chain Pickerel (*Esox niger,* Carr and Whoriskey 2009, Bradford *et al.* 2012).

Limited Spawning Areas

Spawning areas for Rainbow Smelt are limited in number, particularly for Small smelt which is known to spawn in only four brooks (Mill Lake, Smelt, Unnamed, Second).

Hybridization

Recent genetic studies (Bradbury *et al.* 2011, Bentzen pers. comm. 2017, DFO 2018, Themelis 2018) provide evidence of hybridization between the two smelt morphs. Fish collected from the 2014 spawning run in Mill Lake Stream, for example, showed that approximately 19 out of 25 spawners caught in early April were of the large body genotype (76%), one was of the small body genotype (4%), and five were hybrids between the two morphs (20%), whereas 12 out of 15 of the spawners in late April were of the Small smelt genotype (80%), one was of the Large smelt genotype (7%), and two were hybrids (13%; DFO 2018, Themelis 2018). A 2015 genetic assessment of known Small smelt spawning streams found that 82 out of 86 spawners were Small smelt (95%), two were Large smelt (2%), and two were hybrids (2%), with three out of the four non-Small smelt captured from a single tributary, Second Brook (DFO 2018, Themelis 2018). When comparing these contemporary rates of hybridization to historical samples, Themelis (2018) concluded that hybridization is on the rise. An increase in hybridization rates is considered a potential risk factor for collapse to a single population (Taylor *et al.* 2006, Bradbury *et al.* 2011), and so is of concern for the Large smelt population which has lower total numbers. And because the pair of Large and Small smelt depend on each other for their continued existence, hybridization is a threat to both.

Factors that could potentially increase hybridization rates are also a concern. Hybridization rates have the potential to increase if overall abundances decline, or if habitats are reduced in size or quality. Hybridization is therefore both a risk to the population, as well as a potential response to other various threats such as habitat loss and degradation, or exotic/invasive species introductions, etc.

Anthropogenic Threats

There are four major categories of anthropogenic threats that potentially impact the Lake Utopia sympatric pair: (a) habitat alteration and degradation; (b) enhancement of native predatory fishes and/or introduction of exotic species; (c) water quality; and (d) resource use (i.e., angling and fishing).

Fisheries and Oceans Canada have previously undertaken assessments of the potential threats to smelt populations in Lake Utopia (DFO 2011, 2016b, Bradford *et al.* 2012). Some of what is described below, in particular the extent of these threats, has been summarized from these assessments.

<u>Habitat alteration and degradation</u>

The loss of available spawning grounds in Lake Utopia is a serious potential threat especially for the streams used by the Small smelt population. These streams may be under particular threat given the increasing pressure for shoreline housing development in their vicinity as well as some logging activity in the watershed. Water level fluctuations from hydroelectric drawdown, natural variation, climate change, physical obstructions or degradation of the habitat may block access to spawning grounds or render them unsuitable. Stream blockages, by beaver dams for example, can drastically alter flows in tributary streams. This has been a recurring issue in Mill Lake Stream, seriously impeding Large smelt spawning activity (Bradford *et al.* 2012). Similarly, a beaver dam upstream of the spawning area in Spear Brook has resulted in extensive braiding of the outlet (DFO 2011), potentially affecting Large smelt spawning. Blockages of human-made structures, such as culverts, are also a threat to habitat as it can impede access to spawning grounds. This is particularly true for the culvert between Lake Utopia and Mill Lake Stream where blockages from debris or excessive spring water flows have hindered Large smelt passage (DFO 2016b).

Industrial uptake of water in and around the lake, by means of the St. George Pulp and Paper hydroelectricity facility and the Lake Utopia Paper Mill may lower water levels and impede access to spawning grounds (DFO 2016b). The Lake Utopia paper mill withdraws water from Lake Utopia for their operation, yet threats from this water withdrawal are considered low as the facility has been operational for decades without triggering concerns regarding lake or tributary stream water levels (Bradford *et al.* 2012). The re-developed St. George hydroelectricity facility, located at First Falls on the Magaguadavic River in the town of St. George, became operational in 2004 and also has the potential to affect the water levels in Lake Utopia and its associated tributaries (DFO 2011, 2016b, Bradford *et al.* 2012). Decreases in water levels have the potential to reduce the amount of habitat available to adult smelt, impede access to spawning tributaries, and increase the stranding and desiccation of eggs, whereas increases in water levels have the potential to flood spawning sites, making them less desirable to the smelt (DFO 2011, 2016b, Bradford *et al.* 2012). Local residents expressed concern over the perceived higher water levels because the facility became operational, yet this concern has not been substantiated (Bradford *et al.* 2012). Until 2016, the target minimum water level after the spring freshet was 17.4 m, yet after negotiations between DFO and the St. George Power Limited Partnership (SGPLP) in 2016 this level was reduced to 1.0 m to make spawning grounds more attractive to smelt (Themelis 2018).

DFO (DFO 2011, 2016b, Bradford *et al.* 2012) considered the threats of the operation of the hydroelectricity facility on the lake to be low. There is considered to be some potential that hydroelectric operations could influence access to spawning streams in some circumstances. Other factors that affect water quantity in Lake Utopia and its tributary streams are climate change, habitat alteration (e.g., deforestation), and stream blockages associated with human-made structures. Deforestation can lead to altered water levels in streams, as well as increased solar radiation, leading to an increase in water temperatures, making these streams less suitable for smelt spawning. Second Brook is the only spawning tributary that has experienced recent forest harvest operations within its catchment (Bradford *et al.* 2012). The levels of concern raised by these additional factors are thus low or unknown (DFO 2011, 2016b, Bradford *et al.* 2012).

Recreational development and activities on the foreshore, associated with cottage development, foot traffic and ATV use around the lake, may also impact spawning habitat by degrading the substrate where eggs are deposited. These potential threats are especially important because of the apparently high densities of spawners in tributary streams and the restriction of spawning to a few of the available tributaries, all of which suggests that suitable spawning habitats are limited (Taylor 2001, Curry *et al*. 2004). Small smelt spawning streams are considered more vulnerable as they are smaller and thus more susceptible to crossing by both ATVs and pedestrians (Bradford *et al.* 2012, DFO 2016b). Evidence of fresh ATV tracks in 2011 across a Small smelt spawning stream in a portion of prime spawning habitat when smelt were in the stream preparing to spawn demonstrates the threat to both spawners and eggs (DFO 2016b). Current impacts were thus rated as low for Large smelt streams (DFO 2011, 2016b, Bradford *et al.* 2012) and medium for Small smelt streams (DFO 2016b). Finally, Small and Large smelt both are considered to be coldwater-adapted fishes such that changes to lake water temperature regimes driven by climate warming are potential threats (e.g., Kling *et al*. 2003, Ficke *et al.* 2007, Helland *et al*. 2007).

Enhancement of native fishes and introduction of exotic species

Population enhancement programs of sport fishes, such as landlocked Atlantic Salmon, could upset the natural predator-prey balance between smelt and such piscivorous fishes and negatively impact smelt populations, particularly for smaller-sized juvenile smelt and adult Small smelt. In Lake Utopia the stocking of Atlantic Salmon is done on an alternate year basis and the total stocked biannually is 3,400 yearlings (Bradford *et al.* 2012, NB DERD 2017). The stocking level is, apparently, designed to minimize the effects on the trophic balance in the lake (COSEWIC 2008).

A major potential threat is the introduction of invasive species which are, in general, considered one of the most serious threats to freshwater biodiversity in Canada (Dextrase and Mandrak 2006). An invasive species is a non-native species that thrives in the absence of their native predators and whose introduction might hinder native species (Bradford *et al.* 2012). Smallmouth Bass (*Micropterus dolomieu*) and Chain Pickerel (*Esox niger*) are two aquatic invasive species reported in Lake Utopia (Bradford *et al.* 2012, DFO 2016b, Themelis 2018). Large smelt may have to compete with the Chain Pickerel population and juveniles may become a food source (DFO 2016b). The Atlantic Salmon fish hatchery on Lake Utopia, which has been closed since 2011, represented a potential source of introduced fish as does the current stocking of Atlantic Salmon that could impact smelt populations. The threats associated with these native fisheries enhancements and invasive species are considered generally to be low. Chain Pickerel is considered to pose a medium threat to Small smelt and a large threat to Large smelt (DFO 2011, 2016b, Bradford *et al.* 2012). Large smelt are considered more vulnerable to the effects of Chain Pickerel because they are less abundant and because they might have to compete for resources as they share preferred foraging and spawning area characteristics with Chain Pickerel (DFO 2016b).

Water quality

Lake Utopia receives direct nutrient enrichment from the 130 shoreline residences (Brylinsky 2009, Bradford *et al.* 2012). This nutrient buildup creates conditions for increased productivity which would be detrimental to the smelt populations (Bradford *et al.* 2012). Recent water quality surveys (Hanson-Lee 2003, Brylinsky 2009, Hebb 2013) listed several non-point sources of inputs to Lake Utopia: seasonal and recreational developments, and agriculture and silviculture, including both blueberry and cranberry farms. Individual effects of these influences have not been explicitly quantified yet are assumed to be low as most of these operations do not occur directly adjacent to the lake and tributary streams (Bradford *et al.* 2012). Although there is the Lake Utopia Paper Mill on the lake, it discharges into the Letang estuary rather than Lake Utopia. Water quality monitoring from 1989 to 2002 showed stable to declining levels of phosphorus and nitrogen concentrations, but a significant increase in chlorophyll *a* (Hanson-Lee 2003). The increase in chlorophyll *a* production was associated with an increase in the frequency of algal blooms reported in the lake in the past (Hansen-Lee 2003). Blooms of cyanobacteria (blue-green algae), which result in elevated levels of phytotoxins, were a recurring phenomenon in the lake from 2000 to 2013 (Hansen-Lee 2003, Brylinsky 2009, DFO 2011, Hebb 2013). DFO (DFO 2011, 2016b, Bradford *et al.* 2012) considered the impacts from the various pollution sources to range from low (pesticide contamination) to medium (hatchery effluent and residential and recreational inputs) and the cumulative impacts to be of a medium level of concern, principally in terms of increased eutrophication.

Resource use

There are two recreational fisheries that have previously posed a threat to the Lake Utopia Rainbow smelt populations: (i) the recreational smelt dip-net fishery, and (ii) the recreational smelt angling fishery. The dip-net fishery was first closed in 2011. DFO issued an *Order Varying the Close Time for Fishing for Smelt in New Brunswick* in April 2013, which implemented a year-round closure of both fisheries. Anecdotal information suggests that illegal fishing still occurs (DFO 2016a).

Other fisheries that could potentially pose a threat include the Aboriginal Food, Social and Ceremonial (FSC) smelt fishery that allows angling and dip-netting for all smelt in Southwestern New Brunswick, including Lake Utopia smelt (DFO 2016a,b). The Aboriginal FSC runs from April 15th to May 31st. Limits were set to 60 fish per person per day for Southwestern New Brunswick (DFO 2016a). The FSC licence holder has, since 2013, agreed to conditions that include spawning season dip-net closure in the three Small smelt streams (Second, Smelt and Unnamed Brooks), yet the Mill Lake and Trout Lake Streams dip-net and angling fisheries remain operational. Although the risks of this fishery to Small smelt is considered low, the risks to Large smelt are considered higher (DFO 2011, 2016b, Bradford *et al.* 2012) though still low relative to the overall population size. The timing restrictions mean that in most years the fish spawn and leave the streams before the licences are in place. A quantitative analysis of the real or potential effects of fishing itself or trampling in spawning streams while fishing and resulting habitat degradation is unavailable, and the actual numbers of fish retained by the fishery is not monitored. Consequently, overfishing is a potential threat, more so for Large smelt in the two streams with the greatest ease of access (Mill Lake Stream and Trout Lake Stream have direct road access). DFO (DFO 2011, 2016b, Bradford *et al.* 2012) also noted the potential effects of scientific collections through direct mortality and trampling of habitats during biological collection. In general, the threats from resource use are considered to be low, but effects have not been quantified (DFO 2011, 2016b, Bradford *et al.* 2012).

PROTECTION, STATUS AND RANKS

Legal Protection and Status

The Lake Utopia Small smelt population was designated as Threatened by COSEWIC in 2000 and 2008 and is protected under the federal *Species at Risk Act* (SARA) since 2003. Fishing for Small smelt is allowed with an Aboriginal FSC licence as Small smelt abundance is currently sufficient to sustain some directed fishing without jeopardizing the survival and recovery of the species. Fishing carried out under an Aboriginal FSC licence continues to be managed cooperatively between DFO and the Indigenous community licence holder. Both the Small and Large smelt populations are protected under the New Brunswick *Species at Risk Act* (GNB 2013). Both populations continue to be afforded all of the fisheries protections under the federal *Fisheries Act*. Listing under SARA is currently in process for Large smelt.

Since the 2000 assessment of the Small smelt, further examination of divergent Rainbow Smelt populations has led to recognition that both populations within Lake Utopia comprise a system in which the populations persist as genetically distinct, despite evidence of gene flow between them. Because these distinctive populations co-exist within the same lake, habitat and interactions in sympatry may be important to their persistence. Fisheries and Oceans Canada (DFO) published a ‘Recovery Strategy for Lake Utopia Rainbow Smelt (*Osmerus mordax*), Small-bodied Population (sympatric with the Large-109 bodied Population), in Canada’ (DFO 2016b).

Non-Legal Status and Ranks

Neither of the Lake Utopia sympatric smelt pair is listed by any other national or international organization.

Habitat Protection and Ownership

The land ownership around the perimeter of Lake Utopia consists of a mixture of private land holdings and crown land. The northeastern, eastern and southern shorelines consist of predominantly residential dwellings, with the western shoreline being dominated by recreational land and woodland (Hanson-Lee 2003). To the west, there is also a narrow band of a mixture of land uses (recreation, woodland, residential, and industrial) before the Magaguadavic River (Hanson-Lee 2003). A blueberry farm (agriculture) is located to the east, approximately 4 km away from the lake shoreline, bordering Spear Brook headwaters. The Lake Utopia Paper Mill is the only industry bordering Lake Utopia and is located approximately 600 m from the shoreline.

In 2009, there were 130 shoreline residences (Brylinsky 2009). Development and forestry practices are ongoing (DFO 2016b), which, potentially, could impact water quality and quantity. Harvesting within a 30 m buffer zone from the lake is regulated by the provincial government (NB DELG on private land and NB ERD on crown land). The lake is also afforded protection under the federal *Fisheries Act* (DFO 2016b).

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BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Ross Breckels is an aquatic ecologist with expertise in studying the effects of environmental changes on freshwater organisms. Dr. Breckels completed his PhD at the University of Western Ontario where he studied the effects of acute and chronic exposure to increased temperature and pollution on freshwater fishes. He has 10 years' experience with diverse aquatic projects relating to fish habitat and distribution, the effects of anthropogenic stressors on fish, various species assessments, and species at risk.

Catherine Proulx is an aquatic ecologist with a background in aquatic environments and spatial ecology. Catherine completed her MSc thesis at the University of Ottawa, where she studied darter assemblages (Percidae) in several tributaries of the Ottawa River, Québec, Canada. Her research focused on determining the growth, habitat use, and distribution of several species, including the Endangered Channel Darter (*Percina copelandi*).

Bruce Kilgour is an aquatic ecologist, with a background in monitoring, study design and ecological inventory. He obtained his PhD from the University of Waterloo in 1997. He has worked in both freshwater and marine environments and has developed and implemented aquatic monitoring programs for dozens of pulp mills and mines that discharge wastewater to rivers, lakes and coastal areas across Canada. He has led various baseline studies documenting the habitat uses of various fish species, including the Threatened Lake Sturgeon (*Acipenser fulvescens*).

Appendix 1a. IUCN Threats calculation on the Rainbow Smelt - Lake Utopia Large-bodied population (*Osmerus mordax*)

Species or Ecosystem Scientific Name	*Osmerus mordax* Lake Utopia Large-bodied population
Date:	18/01/2018
Assessor(s):	Ross Breckels and Bruce Kilgour (report writers), Dwayne Lepitzki (moderator), John Post and Nick Mandrak (co-chairs), Julien April (SSC member), Mary Sabine (NB), Jen Shaw and Daphne Themelis (DFO), Jordan Rossenfelt (BC), Angèle Cyr (COSEWIC Secretariat).
References:	Lanteigne and McAllister 1983, COSEWIC 2008, Brylinski 2009, Bradford *et al.* 2012, Hebb 2013, DFO 2016; draft COSEWIC 2017 report

		Level 1 Threat Impact Counts	
Overall Threat Impact Calculation Help:			
	Threat Impact	**high range**	**low range**
A	Very High	0	0
B	High	0	0
C	Medium	1	1
D	Low	2	2
Calculated Overall Threat Impact:		Medium	Medium
Assigned Overall Threat Impact:		**C = Medium**	
Impact Adjustment Reasons:		N/A	
Overall Threat Comments		There are five major categories of threats that potentially impact the Lake Utopia sympatric pair: habitat alteration and degradation; enhancement of native predatory fishes and/or introduction of exotic species; water quality; recreational fishing; and hybridization. The threats to the Large-bodied population are considered high due to the recent perceived use of just one tributary stream for spawning (Mill Lake Stream). Additionally, spawning was not observed in this stream at all in some years. Generation time is 3 years therefore timeframe for severity and timing is 10 years. Small in shallower waters eat plankton, Large in deeper waters and eat fish & inverts. More small smelt. No long-term abundance trends but appears stable. 3 spawning streams (Mill Lake Stream, Trout Lake Stream, Spear Brook) but observed spawning in only one (Mill Lake Stream) since 2012. Large spawn before small but have shorter spawning period (5-10 d). Not SARA listed yet.	

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development						
1.1	Housing & urban areas						Not applicable

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1.2	Commercial & industrial areas						Not applicable
1.3	Tourism & recreation areas						Not applicable
2	Agriculture & aquaculture						
2.1	Annual & perennial non-timber crops						Not applicable
2.2	Wood & pulp plantations						Not applicable
2.3	Livestock farming & ranching						Not applicable
2.4	Marine & freshwater aquaculture						Not applicable
3	Energy production & mining						
3.1	Oil & gas drilling						Not applicable
3.2	Mining & quarrying						Not applicable
3.3	Renewable energy						Not applicable
4	Transportation & service corridors	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	
4.1	Roads & railroads	D	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	Culvert replacement expected within the next decade. With effective culvert management the severity is probably towards the lower end. Addition of new bridge could mitigate this.
4.2	Utility & service lines						Not applicable
4.3	Shipping lanes						Not applicable
4.4	Flight paths						Not applicable
5	Biological resource use		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals						Not applicable
5.2	Gathering terrestrial plants						Not applicable
5.3	Logging & wood harvesting						Not applicable
5.4	Fishing & harvesting aquatic resources		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Aboriginal Food, Social, and Ceremonial dip-net fishery is still permitted to take up to 60 fish/person/day of Large Smelt from spawning streams but the timing restrictions mean that in most years the fish spawn and leave the streams before the licences are in place.
6	Human intrusions & disturbance						
6.1	Recreational activities						Not applicable

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
6.2	War, civil unrest & military exercises						Not applicable
6.3	Work & other activities						Not applicable
7	Natural system modifications						
7.1	Fire & fire suppression						Not applicable
7.2	Dams & water management/use						The hydroelectric facility controls water levels in Lake Utopia but not considered to have any impact on Large-bodied Rainbow Smelt in the spawning tributaries.
7.3	Other ecosystem modifications						Not applicable
8	Invasive & other problematic species & genes	C	Medium	Pervasive (71-100%)	Moderate (11-30%)	High (Continuing)	
8.1	Invasive non-native/alien species/diseases	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Chain Pickerel (confirmed) and Largemouth Bass (not unconfirmed) have been reported in Lake Utopia - both would prey on juvenile Smelt. There is uncertainty in the severity of the impact.
8.2	Problematic native species/diseases	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Stocking of Atlantic Salmon occurs bi-annually and they prey on Rainbow Smelt. Also considered hybridization with Small-Bodied Rainbow Smelt. Paul Bentzen argued that there is evidence of reduced size distinctions and this is happening rapidly. The large-bodied profile is changing but sample size is small so uncertainty. So hybridization is considered the primary threat.
8.3	Introduced genetic material						Introducing new genetic material would serve to increase hybridization between the sympatric pair which would be detrimental.
8.4	Problematic species/diseases of unknown origin						Unknown
8.5	Viral/prion-induced diseases						Not applicable
8.6	Diseases of unknown cause						Not applicable
9	Pollution	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	
9.1	Domestic & urban waste water	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	Domestic and urban waste water and turbidity from continuing development along the shoreline is decreasing water quality.

Threat		Impact (calculated)	Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.2	Industrial & military effluents					Not applicable
9.3	Agricultural & forestry effluents	Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Agricultural effluents (e.g., fertilizer, pesticides) have the potential to decrease water quality. Blueberry farms 4 kms away and could be a source.
9.4	Garbage & solid waste					Not applicable
9.5	Air-borne pollutants					Not applicable
9.6	Excess energy					Not applicable
10	Geological events					
10.1	Volcanoes					Not applicable
10.2	Earthquakes/tsunamis					Not applicable
10.3	Avalanches/landslides					Not applicable
11	Climate change & severe weather	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	
11.1	Habitat shifting & alteration					Unknown
11.2	Droughts					Droughts could impede access to spawning streams
11.3	Temperature extremes					Monitoring data are scarce, but the limited water quality data indicate a temperature rise in Lake Utopia over the past 30 years
11.4	Storms & flooding					If water level is too high, spawning grounds become flooded making them less appealing to Smelt; if water velocity is too high it could make spawning grounds inaccessible
11.5	Other impacts					Unknown
Classification of Threats adopted from IUCN-CMP, Salafsky *et al*. (2008).						

Appendix 1b. IUCN Threats calculation on the Rainbow Smelt - Lake Utopia Small-bodied population (*Osmerus mordax*)

Species or Ecosystem Scientific Name	*Osmerus mordax* Lake Utopia Small-bodied population
Date:	18/01/2018
Assessor(s):	Ross Breckels and Bruce Kilgour (report writers), Dwayne Lepitzki (moderator), John Post and Nick Mandrak (co-chairs), Julien April (SSC member), Mary Sabine (NB), Jen Shaw and Daphne Themelis (DFO), Jordan Rossenfelt (BC), Angèle Cyr (COSEWIC Secretariat).
References:	Lanteigne and McAllister 1983, COSEWIC 2008, Brylinski 2009, Bradford *et al.* 2012, Hebb 2013, DFO 2016; draft COSEWIC 2017 report

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	2	3
Calculated Overall Threat Impact:		Medium	Low

Assigned Overall Threat Impact:	**CD = Medium - Low**
Impact Adjustment Reasons:	N/A
Overall Threat Comments	There are five major categories of threats that potentially impact the Lake Utopia sympatric pair: habitat alteration and degradation; enhancement of native predatory fishes and/or introduction of exotic species; water quality; recreational fishing; and hybridization. The threats to the Small-bodied population are considered medium. Generation time is 3 years therefore timeframe for severity and timing is 10 years. Small in shallower waters eat plankton, Large in deeper waters and eat fish & inverts. More small smelt. No long-term abundance trends but appears stable. 3 (and possibly 4) spawning streams (Scout, Smelt, Unnamed brooks and possibly Mill Lake Stream).Large spawn before small and have a longer spawning period (3-4 wks).

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development						
1.1	Housing & urban areas						Not applicable
1.2	Commercial & industrial areas						Not applicable

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1.3	Tourism & recreation areas						Not applicable
2	Agriculture & aquaculture						
2.1	Annual & perennial non-timber crops						Not applicable
2.2	Wood & pulp plantations						Not applicable
2.3	Livestock farming & ranching						Not applicable
2.4	Marine & freshwater aquaculture						Not applicable
3	Energy production & mining						
3.1	Oil & gas drilling						Not applicable
3.2	Mining & quarrying						Not applicable
3.3	Renewable energy						Not applicable
4	Transportation & service corridors	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	
4.1	Roads & railroads	D	Low	Small (1-10%)	Slight (1-10%)	High (Continuing)	Culvert replacement expected and upstream development in one spawning brook is underway.
4.2	Utility & service lines						Not applicable
4.3	Shipping lanes						Not applicable
4.4	Flight paths						Not applicable
5	Biological resource use		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals						Not applicable
5.2	Gathering terrestrial plants						Not applicable
5.3	Logging & wood harvesting						Not applicable
5.4	Fishing & harvesting aquatic resources		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Body size is too small for fishing.
6	Human intrusions & disturbance		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
6.1	Recreational activities		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Mostly upstream of spawning areas.
6.2	War, civil unrest & military exercises						Not applicable
6.3	Work & other activities						Not applicable
7	Natural system modifications						
7.1	Fire & fire suppression						Not applicable

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
7.2	Dams & water management/use						Lake level could have higher impact on small-bodied spawning. Water levels are controlled to maintain spawning access to streams so not considered a current threat.
7.3	Other ecosystem modifications						Not applicable
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)	Chain Pickerel (confirmed) and Largemouth Bass (not confirmed) have been reported in Lake Utopia which both would prey on juvenile Smelt. There is uncertainty in the severity of the impact.
8.2	Problematic native species/diseases	CD	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	High (Continuing)	Stocking of Atlantic Salmon occurs bi-annually. Both these species prey on Rainbow Smelt. Also considered hybridization with Large-Bodied. Paul Bentzen argued that there is evidence of reduced size distinctions and this is happening rapidly. Hybridization may be less of an issue for small-bodied.
8.3	Introduced genetic material						Introducing new genetic material would serve to increase hybridization between the sympatric pair which would be detrimental.
8.4	Problematic species/diseases of unknown origin						Unknown
8.5	Viral/prion-induced diseases						Not applicable
8.6	Diseases of unknown cause						Not applicable
9	Pollution	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	
9.1	Domestic & urban waste water	D	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	Domestic and urban waste water and turbidity from continuing development along the shoreline is decreasing water quality.
9.2	Industrial & military effluents						Not applicable
9.3	Agricultural & forestry effluents		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Agricultural effluents (e.g., fertilizer, pesticides) have the potential to decrease water quality and there could be some logging in headwaters of streams in the longer term.
9.4	Garbage & solid waste						Not applicable

	Threat	Impact (calculated)	Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.5	Air-borne pollutants					Not applicable
9.6	Excess energy					Not applicable
10	Geological events					
10.1	Volcanoes					Not applicable
10.2	Earthquakes/tsunamis					Not applicable
10.3	Avalanches/landslides					Not applicable
11	Climate change & severe weather	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	
11.1	Habitat shifting & alteration					Unknown
11.2	Droughts					Droughts could impede access to spawning streams
11.3	Temperature extremes					Monitoring data are scarce, but the limited water quality data indicate a temperature rise in Lake Utopia over the past 30 years
11.4	Storms & flooding					If water level is too high, spawning grounds become flooded making them less appealing to Smelt; if water velocity is too high it could make spawning grounds inaccessible
11.5	Other impacts					Unknown

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