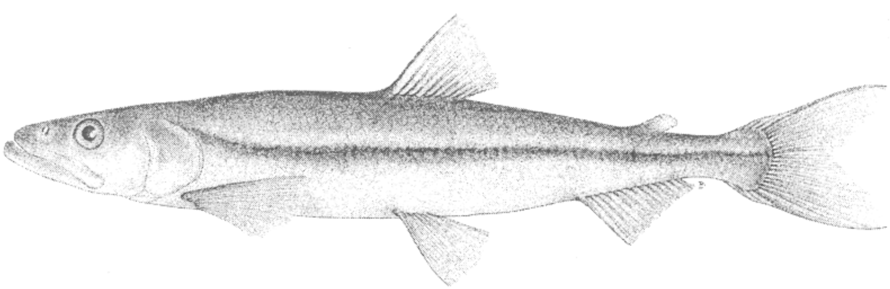
COSEWIC
Assessment and Update Status Report

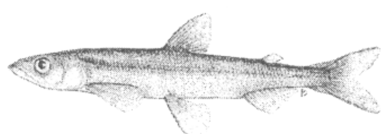
on the

Rainbow Smelt
Osmerus mordax

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

in Canada





THREATENED
2008

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. 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).

Previous reports:

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.

Production note:
COSEWIC acknowledges T.L. Johnston for writing the provisional status report on the Rainbow Smelt, Lake Utopia large-bodied and small-bodied populations *Osmerus mordax*, prepared under contract with Environment Canada. The contractor's involvement with the writing of the status report ended with the acceptance of the provisional report. Any modifications to the status report during the subsequent preparation of the 6-month interim and 2-month interim status reports were overseen by Dr. Eric B. Taylor, COSEWIC Freshwater Fishes Specialist Subcommittee co-chair and Dr. Claude Renaud, COSEWIC Freshwater Fishes Specialist Subcommittee past co-chair.

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COSEWIC
Assessment Summary

Assessment Summary – November 2008

Common name
Rainbow Smelt - Lake Utopia large-bodied population

Scientific name
Osmerus mordax

Status
Threatened

Reason for designation
This population is part of a genetically divergent sympatric pair of *Osmerus* that is endemic to a single lake in Canada with an extremely small index of area of occupancy (6 sq. km). It spawns in only three (3) small streams in the watershed and could quickly become extinct through degradation of spawning streams from increasing development around the lake shore and impacts of the dip-net fishery. This population is threatened by introduction of exotic species and by increasing eutrophication.

Occurrence
NB

Status history
Designated Threatened in November 2008. Assessment based on a new status report.

Assessment Summary – November 2008

Common name
Rainbow Smelt - Lake Utopia small-bodied population

Scientific name
Osmerus mordax

Status
Threatened

Reason for designation
This population is part of a genetically divergent sympatric pair of *Osmerus* that is endemic to a single lake in Canada with an extremely small index of area of occupancy (6 sq. km). It spawns in only three (3) small and ephemeral streams in the watershed and could quickly become extinct through degradation of spawning streams from increasing development around the lake shore. There may be impacts through illegal dip-net fishery. This population is threatened by introduction of exotic species and by increasing eutrophication.

Occurrence
NB

Status history
Designated Threatened in April 1998. Status re-examined and confirmed in May 2000 and November 2008. Last assessment based on an update status report.

COSEWIC
Executive Summary

Rainbow Smelt
Osmerus mordax

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

Species information

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 population and a Large-bodied population. Similar putative sympatric pairs are reported from a few other lakes in eastern North America, but molecular genetic data indicate that each pair has evolved independently 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 Héney, 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 locations 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 being 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. 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 range from up to several tens of thousands of the Large Smelt to potentially over a million for the Small Smelt.

Limiting factors and threats

The finite availability of spawning habitat and the productivity of the lake are important limiting factors. Lake Utopia's sympatric smelt, particularly the small-sized juveniles and mature Small Smelt, are potentially limited by predation by other indigenous fish species. Dipnet fisheries and the loss of spawning habitat through fluctuation in water levels, obstructions, recreational development, or degradation of the habitat, are important potential threats to the species pair. Lake water quality degradation from increasing development may also pose a threat. Species introduced to enhance the salmonid sport fishery or other exotic species introduced into the lake are also important potential threats. 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. Although these issues appear not to be a significant concern in Lake Utopia to date, there are no data to quantitatively assess these risk factors.

Special significance of the species

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 sympatric Rainbow Smelt pair, therefore, represents a significant irreplaceable unit of biodiversity based on novelty and the probable processes involved in their evolution. Each member of the sympatric pair in Lake Utopia also satisfy 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 taxonomically as distinct (Taylor 2006). Hence, this report considers two DUs: Rainbow Smelt, Lake Utopia large-bodied population and the Rainbow Smelt, Lake Utopia small-bodied population.

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Existing protection or other status designations

The "Lake Utopia Dwarf Rainbow Smelt" (herein referred to as Rainbow Smelt, Lake Utopia small-bodied population or Small Smelt) was designated as threatened by COSEWIC in 2000 and is protected under the federal *Species at Risk Act* (SARA), but the Small Smelt is still taken in dipnet fisheries and critical habitat has not yet been delineated. No protection exists for the Large-bodied Smelt (Large Smelt) beyond existing federal and provincial environmental and water quality regulations. 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 potential for 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. The Lake Utopia small-bodied and large-bodied populations are both assessed in the same report.

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
(2008)

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 Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune

Canada

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

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2008

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SPECIES INFORMATION

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-bodied population) and a larger (so-called “normal” or “giant”) form (Rainbow Smelt, Lake Utopia large-bodied 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”. 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, *Osmerus 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 following report summarizes information required to: 1) update the status of Lake Utopia Small Smelt, a federally listed species under the *Species at Risk Act*, and 2) assess the status of the Lake Utopia Rainbow Smelt sympatric species pair by incorporating information on the sympatric Large Smelt.

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 2008). 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 (*Osmerus 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*). Indeed, 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 as *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 (*Osmerus 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. Subsequent 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 sympatrically. This genetic evidence also cast doubt on the rationale for designating the small and large forms across northeastern North America as *Osmerus spectrum* (Cope 1870) and *Osmerus 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). Consequently, the various life-history forms of Rainbow Smelt are all named *Osmerus mordax* (Mitchill 1814) and the taxon *Osmerus spectrum* is considered an invalid, junior synonym of *Osmerus 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. 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.

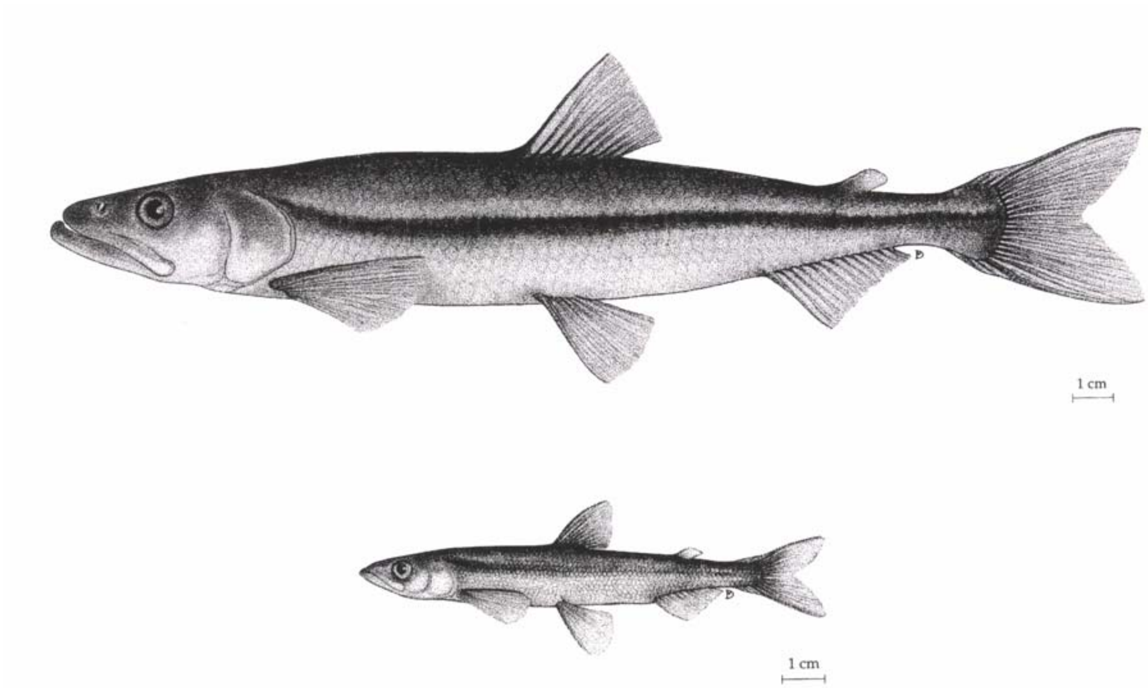


Figure 1. Illustration of Lake Utopia Large (upper) and Small (lower) Rainbow Smelt. Both specimens are mature males (Taylor 2001). Artist: Diana McPhail

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 several morphological attributes (Taylor and Bentzen 1993a). The most obvious difference between the morphotypes is their size at maturity. Existing data suggest that Large Smelt average from 15 to 25 centimetres in total body length, while the Small Smelt measures between 8 and 15 centimetres (Lanteigne and McAllister 1983, Taylor and Bentzen 1993b, Curry *et al*. 2004). The Small Smelt also has relatively larger eyes, a smaller upper jaw and a higher gill raker count than the Large Smelt (Taylor and Bentzen 1993a). Gill rakers of the Small Smelt number 33 to 37, while the Large Smelt has 31 to 33 (Lanteigne and McAllister 1983, Taylor and Bentzen 1993a, Curry *et al*. 2004).

Curry *et al*. (2004) have suggested the possibility of a third "giant-sized" smelt in Lake Utopia, measuring up to 29 centimetres with as few as 23 gill rakers. According to Taylor and Bentzen (1993a) and Bentzen (pers. comm. 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 (Fig. 5, 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 (Bentzen pers. comm. 2008).

Semi-transparent clusters or blankets of Rainbow Smelt eggs are found in spawning areas in early spring (Currie pers. comm. 2006) 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).

Genetic description

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 *Osmerus 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 intralacustrine (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 sympatric 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 by Curry *et al*. (2004), suggested that some gene flow between forms occurs, but that genetic divergence remained high. This suggests that Small and Large smelt maintain some degree of assortative mating, or else that any hybrids produced between forms suffer from reduced survivability at some early stage in life. 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 (Bentzen, pers. comm. 2008).

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 *Osmerus mordax* as a whole: Rainbow Smelt, Lake Utopia large-bodied population and Rainbow Smelt, Lake Utopia small-bodied 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 2007). 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 unique 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).

DISTRIBUTION

Global range

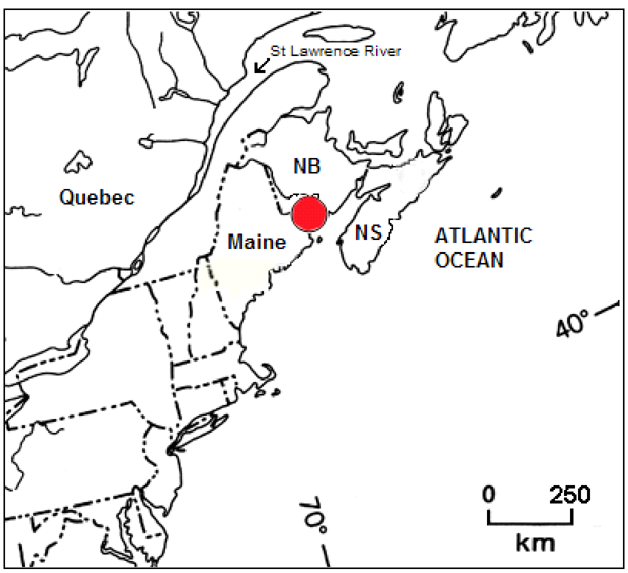
The taxon *Osmerus mordax* is native to watersheds of the northwestern Atlantic Ocean and is widely distributed along the northeastern North American coast, from Long Island New York to Lake Melville on the Labrador coast (Scott and Scott 1988). Throughout their range, Rainbow Smelt may be anadromous, 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 east into Lake Winnipeg and the western coast of Hudson Bay, via the Nelson River (Stewart and Watkinson 2004).

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 *Osmerus 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 (45° 10'N, 66° 47' W), which is located in southwestern New Brunswick, approximately 70 km west of Saint John (Figure 2). Its length is approximately 7.2 km, surface area is 14 km^2, mean depth is 11 m and maximum depth is 26 m (Lanteigne and McAllister 1983; Taylor 2001). The lake is part of the Magaguadavic River drainage system that flows into the Bay of Fundy, and is connected to the Magaguadavic River via an outflow on the southern half of the lake. The extent of occurrence determined by the convex polygon method is approximately 29 km^2. The index of the area of occupancy (IAO) both of the Small and Large smelt determined by overlaying a 1 x 1 km grid across their spawning streams is 6 km^2. The IAO of each smelt using a 2 x 2 km grid is 20 km^2.



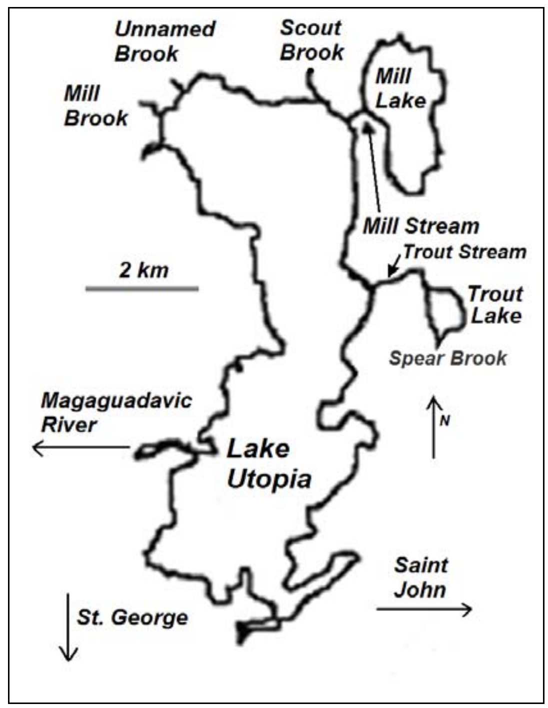


Figure 2. Left, the large dot indicates the location of Lake Utopia, New Brunswick. Right, a map of Lake Utopia and spawning tributaries used by Small (Mill Brook, Scout Brook, Unnamed Brook) and Large (Mill Stream, Trout Stream, Spear Brook) smelt.

HABITAT

Habitat requirements

Lake Utopia is a relatively small lake, with mesotrophic to oligotrophic conditions (Lanteigne and McAllister 1983; Taylor 2001; Hanson 2003). 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 7.0 at the surface to 6.4 at 25 metres. In 1969, the July thermocline was 10 – 15 metres deep, and temperatures ranged from 19 ^{o}C on the surface to 7.8 ^{o}C at 25 metres (Taylor 2001). In 1996, the August thermocline was 10 – 16 metres deep, with temperatures ranging from 22 ^{o}C on the surface to 7.9 ^{o}C at 25 metres (Department of Fisheries and Oceans, DFO, unpublished data).

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, but spawning has been observed in only six small streams at the northern end of the lake: Mill Stream, Trout Stream, Scout (Second) Brook, Unnamed Brook, Spear Brook, and Mill (Smelt) Brook (Taylor and Bentzen 1993a; Curry *et al*. 2004; DFO unpubl. data)). Large Smelt spawn in Mill Stream and Trout Stream, both of which are outlet streams for smaller lakes that flow into Lake Utopia (Curry *et al*. 2004). Mill Stream averages 4 m wide and less than 1 m deep. Trout Stream averages 10 m wide with slow-moving water and deeper pools (Curry *et al*. 2004). Large Smelt were also observed spawning in Spear Brook, a tributary of Trout Lake (Curry *et al*. 2004). An abandoned dam at the head of Mill Stream prohibits smelt from entering Mill Lake. 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 (1-2 m wide), slower-flowing (<10 cm/s) streams that are not lake-headed; Scout Brook, Mill Brook, and Unnamed Brook (Taylor 2001). In total, these smaller streams provide less than 500 metres 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). Although shore-shoal spawning is not uncommon in Rainbow Smelt (Scott and Crossman 1973), this has not been observed in Lake Utopia.

Spawning substrates vary to include any secure substrate suitable for egg attachment, such as silt, gravel, rock, aquatic vegetation and wood debris (DFO unpubl. data, EC 2004). 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.

Habitat trends

Changes in the condition of Lake Utopia have not been monitored over time, and overall habitat trends are unknown.

Habitat protection/ownership

The land surrounding much of Lake Utopia and its tributaries is privately owned, and there are numerous permanent and seasonal residences along the waterfront. A game refuge at the northeast end of the lake encompasses Mill Lake and its outlet stream, Mill Stream (Taylor 2001). Over the years, various fish-rearing facilities have existed on or near Lake Utopia. Currently Cook Aquaculture (http://www.cookeaqua.com) raises Atlantic salmon (*Salmo salar*) for the ocean net-pen industry in a facility at the northeastern end of the lake.

As the Small Smelt is listed as Threatened under *SARA* it is supposed to receive protection from exploitation and to have critical habitats identified. To date, neither of these protective measures has been implemented. Some protection from habitat degradation is also provided through various federal and provincial regulations, such the federal *Fisheries Act*, DFO's Policy for the Management of Fish Habitat, and provincial environmental protection acts that include the *Clean Water Act* and the *Clean Environment Act*.

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.

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, and body sizes declining over the duration of the spawning period (Delisle 1969, Taylor and Bentzen 1993b, Curry *et al*. 2004).

Curry *et al*. (2004) identified three groups of spawning smelt based on differences in timing of spawn: the earliest and largest spawners (12-29 cm fork length) ascend Mill Stream, Trout Stream and Spear Brook; smaller spawners (10-15 cm fork length) spawning in Unnamed, Mill and Scout brooks; and the smallest-sized fish (< 12 cm fork length) are the last to spawn, also in Unnamed, Mill and Scout brooks. Detailed spawning information for Lake Utopia Small and Large smelt is available for 2004 and indicates the spawning, incubation and emergence time frames for spawning populations recorded. For each spawning group, the spawning period takes place over 7 to 14 days (Shaw and Curry 2005). Fecundity ranges from 2,000 to 16,000 eggs from females ranging from 9.5 to 15.5 cm in fork length (Currie and Shaw unpublished). Egg incubation lasts for 20 to 26 days, and after hatching juvenile smelt drift downstream to disperse within Lake Utopia (Shaw and Curry 2005).

Spawning occurs at night between the hours of 21:30 and 04:30 hours, with peak activity occurring from 00:00 to 01:30 (Curry *et al*. 2004). 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 life span is 6 years.

Herbivory/predation

Species that are known to prey upon lacustrine Rainbow Smelt and are present in Lake Utopia include landlocked Atlantic salmon, brook trout (*Salvelinus fontinalis*), smallmouth bass (*Micropterus dolomieui*) (Curry *et al*. 2004), burbot (*Lota lota*) and yellow perch (*Perca flavescens*, Scott and Crossman 1973). Exotic predatory species have also recently been found in the Magaguadavic River system; NB Department of Natural Resources have found chain pickerel (*Esox niger*) in their surveys of Magaguadavic Lake since 2003, and anglers reported largemouth bass (*Micropterus salmoides*) in waters around Lake Utopia in 2006 (Carr pers. comm. 2007; see also NB Natural Resources 2008). 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).

The Atlantic salmon population in Lake Utopia has received supplemental stocking at least 12 times since 1984 to support a recreational fishery, and the lake is presently stocked at a rate of 3,400 salmon every other year (Collet *et al*. 1999, Curry *et al*. 2004). 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's 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 (Curry *et al*. 2004).

The diet of small-bodied Rainbow Smelt is primarily zooplankton, consisting of species such as *Daphnia, Diaptomus, Cyclops, Bosmina, Leptodora* and *Epischura* (Bajkov 1936, Lanteigne and McAllister 1983). Larger adult Rainbow 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). 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).

Dispersal/migration

The only apparent migration performed by Lake Utopia smelt is the nightly movements to spawning locations in inlet tributaries, up to a few hundred metres, that occur each spring. Upon hatching, larval smelt drift downstream and disperse into the lake.

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.

Interspecific interactions

Please refer to Herbivory/predation.

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 (Fournier pers. comm. 2006). Meech Lake spawners also appear to migrate into streams, similar to their Lake Utopia counterparts (Bridges and Delisle 1974).

POPULATION SIZES AND TRENDS

Search effort

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 in 1983, and Taylor and Bentzen in 1990 and 1991, and more focused collections were made by Curry *et al*. from 1998 to 2003. Spawning populations have been sampled in Lake Utopia each spring since 2002 for a detailed genetic study that is ongoing (Bentzen pers. comm. 2008).

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 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-metre section of the stream, and the count was extrapolated across the entire length of accessible habitat. Later still, 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 2007 during April and May (the typical spawning period), but spawning has been reported in only the six streams discussed above.

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 Mill, Unnamed and Scout brooks in 2003 were conservatively estimated to range from 5,361 to 169,000. The Large Smelt had single evening estimates of 50,000, suggesting a total population of 250,000 to 500,000 spawners (DFO unpubl. data). Similar abundances were observed in 2000 (Curry *et al*. 2004).

Surveys in spawning streams by Curry *et al*. (2004) indicated that both in Mill Brook and Unnamed Brook all suitable substrates were densely packed with eggs, in some instances creating 5-cm deep mats of eggs covering the entire width of the stream for distances of 5 metres. Smaller mats have been observed in Scout Brook in 2001 and 2002 (Curry *et al*. 2004). Significant numbers of adults 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 Mill, Unnamed and Scout brooks (Curry *et al*. 2004).

New Brunswick's Department of Natural Resources carried out daylight observations of Small Smelt spawners on May 10, 2007 (Connell and Seymour 2007). Small Smelt were observed throughout Mill (Smelt) Brook, and roughly 100,000 were visible in Lake Utopia near the mouth of the brook. Approximately 10,000 spawners were present in Unnamed Brook, as well as in the lake at the mouth of the brook. Roughly 500 Small Smelt were seen in Scout Brook.

Fluctuations and trends

Collections made in Lake Utopia in the early 1990s intended for genetic studies and, as acknowledged by Taylor (2001), 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 samples conducted from 1998 to present, the population abundance of the Lake Utopia sympatric pair appears fairly consistent from year to year. 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, at least for the Small Smelt (Curry *et al*. 2004).

Rescue effect

Given that Lake Utopia holds a genetically distinct sympatric pair, 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 Lake Utopia Small Smelt was transplanted into Meech Lake (Québec), in 1937 (Dymond 1939). It is, however, uncertain if this is the only source of smelt in Meech Lake and no spawners have been observed in Meech Lake over the last 3 years (C. Lougheed, Department of Fisheries and Oceans, pers. comm.). Consequently, Meech Lake smelt are not suitable for transplantation into Lake Utopia as a potential form of artificial rescue.

ABORIGINAL TRADITIONAL KNOWLEDGE

A request for Aboriginal traditional knowledge (ATK) on the sympatric pair was submitted to the ATK Subcommittee of COSEWIC in May 2008, but, to date, no information has been received.

LIMITING FACTORS AND THREATS

The low productivity of the lake, predation pressure from native salmonids, and the use of only a small number of potential spawning areas tributary to the lake are presumably important natural factors that limit the number and abundance of individual smelt populations in Lake Utopia.

There are four 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, pollution, and dipnet fishing and collection. A discussion of threats to smelt of Lake Utopia was undertaken in 2003 by New Brunswick Department of Natural Resources (NBNR) regional staff (M. Toner, pers. comm.). Some of what is described below, in particular the assessments of the extent of these threats, has been summarized from that discussion. In general, the consensus opinion of the regional staff was that threats to Lake Utopia smelt could be mitigated within existing mechanisms and that a combination of compliance with existing regulations, modest monitoring programs, and a limited number of targeted stewardship projects could largely address concerns around the maintenance of Lake Utopia smelt. The discussion of these threats by regional staff, however, focused on the Small Smelt (the only DU recognized and listed at that time) and did not explicitly address the issue of maintenance of two or more genetically distinct populations within the lake. It is generally unknown to what extent the various situations below have changed since 2003.

Habitat alteration and degradation

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, physical obstructions or degradation of the habitat may block access to spawning grounds or render them unsuitable. Industrial uptake of water in and around the lake, by means of the St. George Pulp and Paper Mill and the fish hatchery, may lower water levels and impede access to spawning grounds. In terms of water quantity from these potential drawdown/extraction sources, NBNR considered these threats to have low to medium impact. Recreational development and traffic on the foreshore, associated with cottage development, foot traffic and ATV use around the lake may also degrade 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). Current impacts were, however, rated as low by NBNR. 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; Helland *et al*. 2007).

Enhancement of native fishes and introduction of exotic species

Population enhancement programs of sport fishes such as 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. This stocking level is, apparently, designed to minimize the effects on the trophic balance in the lake (R. Bradford, DFO, Moncton, personal communication). A major potential threat is the introduction of exotic species which are, in general, considered one of the most serious threats to freshwater biodiversity in Canada (Dextrase and Mandrak 2006). Although Lake Utopia has no reported exotics, two potential predator species, the largemouth bass and the grass pickerel have been reported immediately downstream in the Magaguadavic River (NBNR 2008). The Atlantic salmon fish hatchery on Lake Utopia represents a potential source of introduced fish as does the current stocking of Atlantic salmon that could impact smelt populations. NBNR considered these risks to be low.

Pollution

A recent water quality survey (Hanson 2003) listed three major non-point sources of inputs to Lake Utopia: seasonal and recreation developments, forestry operations, and a blueberry farm. Individual effects of these influences were not quantified. One potential point source of pollutants is the Lake Utopia Fish Hatchery (north end of lake) which produces up to 1,000,000 Atlantic salmon smolts. Its effluent is partially treated in settling ponds and then discharged into the lake, which could contribute to increased phosphorus loading in the lake. This may be of particular concern because the outflow of the lake is at the south end and it occasionally reverses its flow back into Lake Utopia, which can influence the flushing rate of the lake (Hanson 2003). Although there is the St. George Pulp and Paper Mill on the lake, it discharges into the Letang estuary rather than Lake Utopia. Water quality monitoring from 1989-2002 showed stable to declining levels of phosphrous and nitrogen concentrations, but a significant increase in chlorophyll A (Hanson 2003). The increase in chlorophyll A production was associated with an increase in the frequency of algal blooms reported in the lake (Hansen 2003). NBNR considered the impacts from the various pollution sources to range from low (recreational impacts) to high (hatchery and residential effluent impacts) and the cumulative impacts to be high, principally in terms of increased eutrophication.

Recreational fishing

Dipnet fishing is permitted on spawning smelt in Lake Utopia with a daily possession limit of 60 fish and focuses predominantly on the Large Smelt, but Small Smelt, despite their status as a Schedule 1 species under SARA, are also taken. Although local fisheries biologists believe that the impact of this fishery is minimal (DFO unpubl. data; NBNR unpubl. data), 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 potentially an important threat, especially for Large Smelt in the two streams with the greatest ease of access (Mill Stream and Trout Stream). NBNR also noted the potential effects of scientific collections through direct mortality and trampling of habitats during biological collection. In general, NBNR considered the threats from resource use to be low, but any effects are unquantified.

SPECIAL SIGNIFICANCE OF THE SPECIES

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.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

The Rainbow Smelt, Lake Utopia small-bodied population was designated as threatened by COSEWIC in 2000 and is protected under the federal *Species at Risk Act* (SARA) under the name of Lake Utopia Dwarf Smelt. In 2002, the Department of Fisheries and Oceans (DFO) and the New Brunswick Department of Natural Resources and Energy formed a Lake Utopia Dwarf Smelt Conservation and Recovery Team to plan for the survival and recovery of the fish. This recovery document, however, has not yet been released publicly and critical habitats have not been identified or protected.

No protection exists for the Large Smelt in Lake Utopia, beyond existing federal and provincial environmental and water quality regulations.

TECHNICAL SUMMARY (1) - Lake Utopia Large-Bodied Population

Osmerus mordax

Rainbow smelt — Éperlan arc-en-ciel

Lake Utopia large-bodied population — Population de l'éperlan arc-en-ciel de grande taille du lac Utopia

Range of Occurrence in Canada: Lake Utopia, southwestern New Brunswick

Demographic Information

Generation time (average age of parents in the population)	3 yrs
Observed percent reduction in total number of mature individuals over the last 10 years.	Unknown
Projected percent reduction in total number of mature individuals over the next 10 years.	Unknown
Observed percent reduction in total number of mature individuals over any 10-year period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible? NA	Unknown
Are the causes of the decline understood? NA	Unknown
Have the causes of the decline ceased? NA	Unknown
Observed trend in number of populations	Stable
Are there extreme fluctuations in number of mature individuals?	Unknown
Are there extreme fluctuations in number of populations?	No

Number of mature individuals in each population

Population	**N Mature Individuals**
Grand Total	Estimated at up to 250,000 or more

Extent and Area Information

Estimated extent of occurrence (km²) Area of lake = 14 km sq.	29 km²
Observed trend in extent of occurrence	Stable
Are there extreme fluctuations in extent of occurrence?	No
Index of area of occupancy (km²) (2x2 km grid is 20 km^2)	6 km² (based on 1x1 km grid of 3 spawning streams)
Observed trend in area of occupancy	Stable
Are there extreme fluctuations in area of occupancy?	No
Is the extent of occurrence or area of occupancy severely fragmented?	No
Number of current locations	3 spawning streams within 1 lake watershed
Trend in number of locations	Stable
Are there extreme fluctuations in number of locations?	No
Observed trend in area of habitat	Stable

Quantitative Analysis

Not done	Ex.: % probability of extinction in 50 years

Threats (actual or imminent, to populations or habitats)

Degradation of spawning streams from logging, increasing housing development, pollution and eutrophication, hydroelectric drawdown and potentially by an unmonitored dip-net fishery. Introduction of exotic species that have been recorded in areas immediately downstream from Lake Utopia.

Rescue Effect (immigration from an outside source)

Status of outside population(s)? USA: 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	Yes
Is rescue from outside populations likely? NA, endemic	No

Current Status

COSEWIC: Threatened (2008)

Status and Reasons for Designation

Status: Threatened	**Alpha-numeric code:** D2
Reasons for designation: This population is part of a genetically divergent sympatric pair of *Osmerus* that is endemic to a single lake in Canada with an extremely small index of area of occupancy (6 sq. km). It spawns in only three (3) small streams in the watershed and could quickly become extinct through degradation of spawning streams from increasing development around the lake shore and impacts of the dip-net fishery. This population is threatened by introduction of exotic species and by increasing eutrophication.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. No evidence of declines.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. Extremely small index of area of occupancy (6 km^2), but no evidence of decline.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Well above thresholds and no evidence of declines.
Criterion D (Very Small Population or Restricted Distribution): Found within a single lake (one location) with an index of area of occupancy of < 20 km^2; spawners are found in only three (3) tributaries within this lake.
Criterion E (Quantitative Analysis): Not available.

TECHNICAL SUMMARY (2) - Lake Utopia Small-Bodied Population

Osmerus mordax

Rainbow smelt — Éperlan arc-en-ciel

Lake Utopia small-bodied population — Population de l'éperlan arc-en-ciel de petite taille du lac Utopia

Range of Occurrence in Canada: Lake Utopia, southwestern New Brunswick

Demographic Information

Generation time (average age of parents in the population)	3 yrs
Observed percent reduction in total number of mature individuals over the last 10 years.	Unknown
Projected percent reduction in total number of mature individuals over the next 10 years.	Unknown
Observed percent reduction in total number of mature individuals over any 10-year period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible? NA	Unknown
Are the causes of the decline understood? NA	Unknown
Have the causes of the decline ceased? NA	Unknown
Observed trend in number of populations	Stable
Are there extreme fluctuations in number of mature individuals?	Unknown
Are there extreme fluctuations in number of populations?	No

Number of mature individuals in each population

Population	**N Mature Individuals**
Grand Total	Estimated up to 1,000,000 or more

Extent and Area Information

Estimated extent of occurrence (km²) Area of lake = 14 km sq.	29 km²
Observed trend in extent of occurrence	Stable
Are there extreme fluctuations in extent of occurrence?	No
Estimated area of occupancy (km²) based on 1x1 grid of three spawning streams 2x2 grid IAO = 20 sq km	6 km²
Observed trend in area of occupancy	Stable
Are there extreme fluctuations in area of occupancy?	No
Is the extent of occurrence or area of occupancy severely fragmented?	No
Number of current locations	3 spawning streams within 1 lake watershed
Trend in number of locations	Stable
Are there extreme fluctuations in number of locations?	No
Observed trend in area of habitat	Stable

Quantitative Analysis

Not done	Ex.: % probability of extinction in 50 years

Threats (actual or imminent, to populations or habitats)

Degradation of spawning streams from logging, increasing housing development, pollution and eutrophication, hydroelectric drawdown and potentially by an unmonitored dip-net fishery. Introduction of exotic species that have been recorded in areas immediately downstream from Lake Utopia.

Rescue Effect (immigration from an outside source)

Status of outside population(s)? USA: 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	Yes
Is rescue from outside populations likely? NA, endemic	No

Current Status

COSEWIC: Threatened (2008)

Status and Reasons for Designation

Status: Threatened	**Alpha-numeric code:** D2
Reasons for designation: This population is part of a genetically divergent sympatric pair of *Osmerus* that is endemic to a single lake in Canada with an extremely small index of area of occupancy (6 sq. km). It spawns in only three (3) small and ephemeral streams in the watershed and could quickly become extinct through degradation of spawning streams from increasing development around the lake shore. There may be impacts through illegal dip-net fishery. This population is threatened by introduction of exotic species and by increasing eutrophication.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. No evidence of declines.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. Extremely small index of area of occupancy (6 sq. km), but no evidence of decline.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. Well above thresholds and no evidence of declines.
Criterion D (Very Small Population or Restricted Distribution): Found within a single lake (one location) with an index of area of occupancy of < 20 km^2; spawners are found in only three (3) tributaries within this lake.
Criterion E (Quantitative Analysis): Not available.

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