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Research Document 2012/124

Maritimes Region

Document de recherche 2012/124

Région des Maritimes

Lake Utopia Rainbow Smelt (*Osmerus mordax*) Status, Trends, Habitat Considerations and Threats

Éperlan arc-en-ciel du lac Utopia (*Osmerus mordax*) : État, tendances, considérations liées à l'habitat et menaces

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ISSN 1499-3848 (Printed / Imprimé)
ISSN 1919-5044 (Online / En ligne)

Canada

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Correct citation for this publication:

Bradford, R.G., Bentzen, P., and Bradbury, I. 2013. Lake Utopia Rainbow Smelt (*Osmerus mordax*) Status, Trends, Habitat Considerations and Threats. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/124. iv + 42 p.

ABSTRACT

The native rainbow smelt (*Osmerus mordax*) inhabiting Lake Utopia, New Brunswick, consists of two co-existing (sympatric) morphologically, ecologically, and genetically differentiated populations: a small-bodied form and a large-bodied form. Each population was assessed in November 2008 by the Committee on the Status of Endangered Wildlife in Canada as meeting their criteria for a Designatable Unit (DU), and each DU was designated Threatened. This Recovery Potential Assessment was undertaken to provide information and advice, for both small-bodied smelt and large-bodied smelt, on current status, trends, their potential for recovery and to propose population abundance and distribution targets for recovery. Information on habitat requirements, as well as the impact of human activities on both the species and their habitat, including possible alternatives and management measures to mitigate these impacts, are also included. Spawning of the small-bodied (<170 mm fork length) form has been confirmed in only three small, vulnerable brooks at the northern end of Lake Utopia. The large-bodied (≥170 mm fork length) form spawns in the two larger tributaries at the northeastern end of Lake Utopia. Individual within-stream daily estimates of spawner abundance for small-bodied smelt have varied between 3,000 and 150,000 fish during the years that estimates have been acquired, with estimates on the order of 10^4 fish being the most frequent. Among-stream daily abundance estimates are typically in excess of 100,000 spawning small-bodied smelt. The abundance of the large-bodied Lake Utopia Rainbow Smelt (LURS) population cannot be assessed with the current data. Recovery targets for both body forms of LURS can be defined on the basis of abundance and distribution. An interim (five years) daily abundance target for small-bodied LURS of 100,000 spawning fish distributed among the three brooks during peak spawning period is recommended to demonstrate their continued high productivity. The recommended annual distribution target for small-bodied LURS is the synchronous occupation under natural conditions of the three spawning brooks, with no individual brook to be unoccupied for two consecutive years. An interim (until a population estimate is available) abundance target for the large-bodied LURS, derived from the estimated minimum population size needed to maintain genetic diversity, is recommended at 2,000 spawners. An interim (until more is learned about spawning in Trout Lake Stream and Spear Brook) distribution target for large-bodied LURS is the annual occupancy of Mill Lake Stream. Human activities have the potential to affect the smelt populations in the attributes of water quality, water quantity, direct mortality, and habitat impacts. Present mitigative measures, options to reduce affect, and research and monitoring proposals have been identified for all known threats under each attribute. Risks of potential effects under current management measures were ranked low, medium, or high for the individuals of both DUs of the LURS. The location of the effect (either lake or spawning streams) is also included. The recovery of both small-bodied and large-bodied rainbow smelt DUs in Lake Utopia is considered to be both biologically and technically feasible. Recovery requires maintaining self-sustaining populations for both DUs and mitigating the threats through existing regulations, education and stewardship efforts.

RÉSUMÉ

L'éperlan arc-en-ciel indigène (*Osmerus mordax*) habitant le lac Utopia, au Nouveau-Brunswick, consiste en deux populations (sympatriques) coexistantes qui sont morphologiquement, écologiquement et génétiquement différentes, soit le petit éperlan et le grand éperlan. En novembre 2008, le Comité sur la situation des espèces en péril au Canada a désigné les deux populations comme étant chacune une unité désignable, et chacune a été désignée « menacée ». Cette évaluation du potentiel de rétablissement a été réalisée pour fournir des renseignements et des conseils sur l'état et les tendances actuels du petit éperlan et du grand éperlan et sur leur potentiel de rétablissement, ainsi que pour proposer des cibles en matière de population et de répartition pour le rétablissement des populations. L'évaluation renferme également des renseignements sur les exigences de l'habitat et les répercussions des activités humaines sur les deux espèces et leur habitat, y compris des solutions de rechange possibles et des mesures de gestion afin d'atténuer ces répercussions. Seuls trois petits ruisseaux vulnérables situés à l'extrémité nord du lac Utopia sont des frayères avérées du petit éperlan (longueur à la fourche <170 mm). Le grand éperlan (longueur à la fourche ≥170 mm) fraye dans les deux plus grands affluents situés à l'extrémité nord-est du lac Utopia. Les estimations quotidiennes de l'abondance des petits éperlans reproducteurs au sein de chaque cours d'eau ont varié entre 3 000 et 150 000 poissons au fil des années durant lesquelles de telles estimations ont été effectuées, mais elles ont été le plus souvent de l'ordre de 10^4 poissons. Sur l'ensemble des cours d'eau considérés, les estimations quotidiennes de l'abondance se chiffrent en général à plus de 100 000 petits éperlans reproducteurs. Les données actuelles ne permettent pas d'évaluer l'abondance de la population de grands éperlans du lac Utopia. Des objectifs de rétablissement des populations de grands et de petits éperlans arc-en-ciel du lac Utopia peuvent être définis en fonction de l'abondance et de la répartition. Un objectif provisoire (sur cinq ans) d'abondance quotidienne qui serait de 100 000 reproducteurs répartis entre les trois ruisseaux durant le pic de la période de frai est recommandé pour ce qui est des petits éperlans arc-en-ciel du lac Utopia, afin que leur population puisse maintenir sa forte productivité. En ce qui concerne la répartition des petits éperlans arc-en-ciel du lac Utopia, on recommande comme objectif annuel l'occupation synchrone, dans les conditions naturelles, des trois cours d'eau servant de frayères, sans qu'aucun de ces cours d'eau ne reste inoccupé pendant deux années consécutives. Un objectif d'abondance provisoire (jusqu'à ce qu'on dispose d'une estimation de l'effectif de la population) qui serait de 2 000 reproducteurs est recommandé pour ce qui est des grands éperlans arc-en-ciel du lac Utopia, d'après l'estimation de l'effectif minimal nécessaire pour maintenir la diversité génétique. En ce qui concerne la répartition des grands éperlans arc-en-ciel du lac Utopia, l'occupation annuelle de la décharge du lac Mill représente un objectif provisoire (jusqu'à ce qu'on en sache plus sur le frai dans la décharge du lac Trout et dans le ruisseau Spear). Les activités anthropiques sont susceptibles de se répercuter sur les populations d'éperlans en raison des effets qu'elles ont sur la qualité de l'eau, sur la quantité d'eau, sur la mortalité directe et sur l'habitat. Pour chacun de ces paramètres, on a recensé les mesures d'atténuation actuelles, les solutions possibles pour réduire les effets et les possibilités qui s'offrent en matière de recherche et de surveillance. Les risques d'effets éventuels de ces activités sur les éperlans des deux unités désignables dans le cadre des mesures de gestion actuelles ont été classés par ordre d'importance (faible, moyen ou élevé). L'endroit (lac ou cours d'eau de fraye) où chacun de ces effets se ferait sentir est également indiqué. Le rétablissement des deux unités désignables d'éperlans arc-en-ciel du lac Utopia (grands et petits éperlans) est considéré comme réalisable sur les plans technique et biologique. Il nécessite dans les deux cas le maintien de populations autonomes et l'atténuation des menaces à l'aide de la réglementation existante, de l'éducation et d'initiatives de gérance.

INTRODUCTION

The native[1] rainbow smelt (*Osmerus mordax*) inhabiting Lake Utopia, New Brunswick (NB) (Figure 1), consists of two morphologically, ecologically, and genetically differentiated populations existing in sympatry[2] (Taylor and Bentzen 1993b; Bradbury et al. 2011). The populations consist of a small-bodied form and a large-bodied form. Each population was assessed in 2008 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as meeting their criteria for a Designatable Unit (DU), each DU was designated Threatened by COSEWIC in 2008 (COSEWIC 2008). The Fisheries and Oceans Canada (DFO), as the responsible jurisdiction for aquatic species under the *Species at Risk Act* (SARA), is required to undertake a number of actions that may require scientific information on the current status of each DU, threats to their survival and recovery, and the feasibility of their recovery, as well as information pertaining to their habitat requirements. However, the format and breadth of the science advice needs to take into consideration that the security of one member of a sympatric species pair cannot be assumed to be independent of the security of the other member (Schluter 1996; Taylor 1999).

The small-bodied LURS DU, also referred to as 'Lake Utopia Dwarf Smelt', was previously designated as Threatened by COSEWIC in 1998 (Taylor 1998) and 2000 (COSEWIC 2000). They have been protected under the SARA as Threatened since 2003. A draft Recovery Strategy has been prepared in compliance with Section 37 of SARA. However, the science advice developed to support the preparation of the Strategy preceded the adoption by the DFO of a National Framework for Recovery Potential Assessments (RPAs; DFO 2007). Finalization of the Recovery Strategy was, therefore, delayed, in part, to allow for the consideration of new, additional science advice that could result from completion of the RPA process for both the small- and large-bodied DUs.

COSEWIC (2008), therefore, represents a confirmation of the status of the small-bodied population and the first assessment of the large-bodied population.

DOCUMENT PURPOSE AND SCOPE

This document is intended to meet several objectives:

- To both update and re-state to the extent possible within the DFO Recovery Potential Assessment Framework (DFO 2007) information concerning the life-history, biological traits, status, trajectory, habitat requirements, threats (and alternatives and mitigation) of the small-bodied ('dwarf') LURS for use in completion of the Recovery Strategy,
- Fulfill the science information requirements for a RPA of large-bodied LURS,
- Provide habitat use information for both the small- and large-bodied LURS DUs, and
- Assess whether the concept of residence as defined under SARA applies to either DU.

LOCATION

Lake Utopia (45° 10' N; 66° 47' W) is part of the Magaguadavic River watershed in south-western NB (Figure 1). The Lake Utopia watershed lies entirely within Charlotte County. It is part of the NB Department of Natural Resources and Energy's Kingsclear Region (Region 3)

[1] Existing within a historical ecological range, usually within a balanced system of co-evolved organisms (CCFAM 2004).
[2] Species inhabiting the same or overlapping geographical areas.

and lies in the Fish and Wildlife Branch's Wildlife Management Zone 20 and Southwest Recreational Fishing Area. Southwest NB lies within the DFO Maritimes Administrative Region.

CHARACTERISTICS OF THE LAKE UTOPIA WATERSHED

The Lake Utopia catchment area is approximately 9,300 hectares (ha) and approximately 17.5% of this area consists of waterbodies, of which Lake Utopia is the dominant one. In addition to direct runoff from land, Lake Utopia receives input from Trout Lake (via Trout Lake Stream), Mill Lake (via Mill Lake Stream), and other (approximately 15) small tributary streams. The watershed has varied terrain ranging from wetlands to moderate relief and sharp relief.

Lake Utopia is at approximately 19 m above sea level, oligotrophic to mesotrophic, with average and maximum depths of about 11 and 26-28 m, respectively. It is approximately 7.2 km long, varies from 0.75 to 2.5 km in width and covers an area of approximately 1,370-1,390 ha (13.8 km^2). The morpho-edaphic index is 0.94 and pH typically ranges from 7.0 at the surface to 6.4 at 25 m. The mid-summer (July) thermocline was at 10-15 m on August 27, 1969, and temperatures ranging from 19°C (at surface) to 7.8°C (at 25 m) were recorded July 3, 1969 (Lanteigne and McAllister 1983). More recent physio-chemical data were collected August 12, 1996. The temperature and dissolved oxygen at the surface were 22.3°C and 11.1 mg/L, respectively, and those at 26 m, 7.9°C and 6.4 mg/l, respectively. The thermocline was between 10-16 m (Collet et al. 1999). The lake is typically frozen from early December until the first or second week in April (Curry et al. 2004).

Lake Utopia drains via The Canal, a low gradient waterway, into the Magaguadavic River, which continues past the Town of St. George and through an approximately 10 km in length estuary into Passamaquoddy Bay of the Bay of Fundy. There are falls in excess of 6 m at St. George (Figure 1).

A hydroelectric dam operated by St. George Pulp and Paper is located on the Magaguadavic River at St. George, NB. The presence of this structure, and the relatively low gradients of the river's mainstem and The Canal connecting Lake Utopia to the main river can affect Lake Utopia water levels. A combination of dam operation and river flow can be such that Magaguadavic River water will enter Lake Utopia and potentially affect access to the smelt spawning streams in the Lake. The reversal of flow from the river into Lake Utopia can act as a source of anthropogenic point and non-point discharge for the lake.

Land ownership within the Lake Utopia catchment is approximately 57% Crown, 25% private and 18% freehold (Currie and McMullin, unpublished report[3]). Most of the shoreline around Lake Utopia is either privately owned (72%) or freehold (25%) (Currie and McMullin, unpublished report).

LAKE UTOPIA RAINBOW SMELT AND BIODIVERSITY

Rainbow smelt are found in fresh and salt water along the North American coast (Scott and Crossman 1973). In New Brunswick, anadromous populations occur in most accessible coastal streams. Lacustrine populations have been detected within approximately 50 named inland water bodies, nine of which lie within the Magaguadavic River drainage (Table 1). The genetic

[3] Currie, S.L., and T.L. McMullen. 2002. A report on the activities and findings of the Lake Utopia rainbow smelt field studies. Unpublished report.

and phenetic traits of the populations occurring in the Magaguadavic River system outside of Lake Utopia have not been established.

The presence of smelts, in abundance, in Lake Utopia appears to have been local knowledge for many years. Sweetser (1875) commented upon the abundance of both brook trout and smelts in the tributaries of Lake Utopia. Recognition of two forms (small and large) of smelt in the lake, the segregation of the two forms for spawning, and the differing morphological character of the large form from typical anadromous smelt was documented in 1922 (MacLeod 1922). Distinct phenetic differences between the small and large smelt occurring in the lake was demonstrated by Lanteigne and McAllister (1983, although recognition that the two sympatric forms were genetically discrete did not occur until later (Taylor and Bentzen 1993b). There is recent (Bradbury et al. 2011) evidence for a size-based phenotypic subdivision of the small-bodied form that may explain the prevalence of three length frequency modes within samples pooled across both DUs. These modes appear to correspond to the dwarf, intermediate and giant morphotypes described in Curry et al. (2004). The postulated small-bodied morphotypes exhibit differing growth trajectories from about the onset of first feeding as larvae (Shaw 2006). There is evidence that they differ in size at age as spawning adults (Curry et al. 2004).

LURS have been variously assigned to either the Atlantic (Baby et al. 1991; Taylor and Bentzen 1993a) or the Acadian[4] (Barrett et al. 2009) glacial refugial lineage. They represent one of the three occurrences in Canada of sympatric rainbow smelt species, which have been confirmed on the basis of both their genetic and their phenetic traits; the other two pairs occur in Lochaber Lake, Nova Scotia (Taylor and Bentzen 1993a) and Lac St-Jean, Québec (Saint-Laurent et al. 2003).

The two DUs co-exist with at least 25 other species of freshwater fishes within Lake Utopia. The general healthy state of the smelt community in Lake Utopia is reflected in the recreational angling fisheries that have occurred over many decades in the lake for landlocked Atlantic salmon (*Salmo salar*), smallmouth bass (*Micropterus dolomieu*) and brook trout (*Salvelinus fontinalis*), all of which rely upon a forage base that includes rainbow smelt.

LAKE UTOPIA RAINBOW SMELT LIFE-HISTORIES

SPAWNING SITES

Available data indicates that all spawning activity occurs in tributary streams located within the northern basin of Lake Utopia (Figure 1). Surveys during 2009 and 2010 in the areas adjacent to known spawning tributaries revealed no evidence of shoreline spawning activity by either DU (DFO, unpublished data), a reproductive strategy known to occur within other lacustrine smelt populations (Scott and Crossman 1973).

A 2003 survey documented smelt spawning activity in only five of the 14 principle tributary streams of Lake Utopia (COSEWIC 2008). The largest tributaries, Mill Lake Stream and Trout Lake-Spear Brook (Figure 1) are used by large-bodied smelts. Smelt Brook, Unnamed Brook, and Scout Brook (Figure 1) are used by small-bodied smelt.

Sporadic and, likely minor, spawning outside of these five brooks can occur. For example, smelt eggs, probably a result of small-bodied smelt spawning, were observed on April 15, 2010, at the entrance to a previously un-surveyed stream lying between Scout and Unnamed brooks (DFO,

[4] The Northeastern Bank refugia defined by Schmidt (1985).

unpublished data) (Figure 1). There, the lake shoreline is exposed, relatively steep, and comprised of boulders that impede access by smelt to the stream. Desiccated eggs on the boulders and stones at the mouth of the brook, stranded by receding lake water levels, indicated that the eggs observed within the lower 1-2 m of the stream were deposited, while the habitat was accessible to smelts at a higher lake level (DFO, unpublished data).

SPAWNING TIME AND DURATION

Spawning for both DUs occurs during spring and begins around the time of ice break-up (usually late March to early April). Both small- and large-bodied smelt ascend the tributary streams at night, when spawning occurs. Some fish may remain in the spawning streams throughout the day. Observations show that although the time of spawning for the two DUs can overlap, the large-bodied form tends to spawn earlier (Figure 2).

Large-bodied smelt are reported to spawn from late March-mid April (Curry et al. 2004), which is consistent with a representation of their spawning season derived from a compilation of all documented reports. The reports, grouped into five-day increments, of presence of large-bodied smelts in both Mill Lake Stream and Trout Lake-Spears Brook are shown in Table 2 and Figure 2. The raw data is available in Appendix I. Although observations are few between 20 March and 3 April, the data indicate that large-bodied smelt are less likely to be present in these brooks after 18 April (Table 2; Figure 2), which is only partially consistent with the estimated 16-20 April spawning period stated by Shaw (2006). Large-bodied smelts have been most frequently observed in the brooks between 9-14 April, suggesting that spawning activity for this form is of relatively short duration and on average most intense around these dates (Table 2; Figure 2). This is consistent with Shaw’s (2006) conclusion that the duration of the 2004 spawning season for the large-bodied smelts was five days (16-20 April).

The spawning season for small-bodied smelt is reported as from mid-April until mid-late May (Curry et al. 2004), which is supported by the compilation of small-smelt presence data into five-day increments, beginning on 1 April, and grouped for the three spawning tributaries (Table 2; Figure 2). There are no indications from available observation data that the timing of small-bodied smelt occurrences varies among the three tributary streams (Appendix I). Smelt are most likely to be observed in one or more of the tributaries between 21 April and 25 May (Table 2; Figure 2), suggesting that spawning activity is a more protracted activity for the smaller-bodied form than for the larger-bodied form. These observations are consistent with Shaw’s (2006) finding where spawning periods during 2004 of five days and 15 days for large-bodied and small-bodied smelts, respectively, were estimated.

SPAWNING AND INCUBATION TIMES IN RELATION TO WATER TEMPERATURE

Water temperatures in the tributary streams used by large-bodied smelts during spawning activity are reported as less than 6°C by Curry et al. (2004) and 5°C by Shaw (2006). The water temperatures in the tributary streams used by small-bodied smelts while large-bodied smelts are spawning are reported to be 3°C (Shaw 2006). Water temperatures are reported to vary between 4°C and 9°C when the small-bodied smelts are in the streams (Curry et al. 2004).

Mean incubation times of 22 days and 28 days have been estimated for large- and small-bodied smelts, respectively, yielding estimates of degree day requirements of 214 (mean temperature 9.3°C) for large-bodied smelt and 192 (mean temperature 6.9°C) for small-bodied smelt (Shaw 2006). Larvae of both forms drift downstream to the lake during periods of darkness (Curry et al. 2004).

BIOLOGICAL TRAITS

DISTINGUISHING TRAITS OF SMALL- AND LARGE-BODIED LAKE UTOPIA SMELT

Recent phylogenetic and phenotypic analyses confirm the existence of only two genetically discrete forms of rainbow smelts in Lake Utopia (Bradbury et al. 2011): a small-bodied form and a large-bodied form. Genetic analysis indicates that these forms may hybridize and the hybrids are not strictly associated with either stream or brook habitats, suggesting a combination of phenotypic and genetic criteria will need to be applied for the conservation of these forms.

Adult body size is recommended as the most useful and practical criteria for the general description and operational definition of the two body forms. Small-bodied smelt would be those less than 170 mm fork length (FL), whereas the large-bodied smelt would be those ≥170 mm FL. A length of 170 mm FL is equivalent to 187 mm total length. However, the genetic assignment of multiple small-bodied individuals to the large-bodied form suggests that absolute phenotypic criteria for separation of the two DUs may not be possible (Bradbury et al. 2011).

Small-bodied LURS possess a larger eye and smaller upper jaw relative to their body size, and a higher (33-38 versus 31-34) gill raker count than large-bodied LURS (Bradbury et al. 2011). A bi-modal size distribution is evident for the small-bodied form in all years that sampling has occurred since the first description of small-bodied LURS in 1980[5] (Figure 3). Bi-modality in body length is, therefore, a phenomenon that cannot be attributed to any anthropogenic changes within the lake-tributary ecosystem that may have occurred over the past three decades.

SMALL-BODIED SMELT

Average age of mature small-bodied smelts has been estimated as 2.8 years (Curry et al. 2004). Preliminary aging (based upon interpretations of otolith annuli) of samples collected from the 2010 spawning season indicates that most individuals were 3-4 years old (n =70, mean=3.3±0.7, range=2-5 years; DFO, unpublished data). The presence of two length modes, not differing in age structure (Curry et al. 2004), complicates the description of size-at-age. Available data indicates that, generally speaking, a sample of adult fish drawn from a length range of 80 mm-120 mm FL could be expected to exhibit the same age structure as those from 125 mm-155 mm FL.

Fecundity of small-bodied smelts is size dependent and reported in Shaw et al. (2004) as:

$$\text{Eggs} = 0.0003\ \text{FL}^{3.465} \quad n=27,\ r^2=0.83$$

indicating egg number per female varies between 2,100 to 12,000 between 95 mm to 155 mm FL, respectively, with an average of 400 eggs per gram of female smelt (range 240-600 eggs/g; Shaw et al. 2004).

The proportion of the spawning aggregation comprised of females on individual days varies from 0.10 to 0.64 (Table 3). Females usually represented less than 50% of the sample population for any year (Table 3).

[5] The so-called ‘pygmy’ smelt of Lanteigne and McAllister (1983).

LARGE-BODIED SMELT

Fewer data concerning the biological traits of the large-bodied form are available. Curry et al. (2004) reported an average age of 3.1±0.7 years for the spawning population, samples included in the study of Jardine and Curry (2006) were estimated to be between 2 and 6 years of age. MacLeod (1922) reported ages of between 4 and 7 years.

There are no estimates of the fecundity of large-bodied LURS.

The proportion of the annual spawning runs of large-bodied smelts has been estimated on only a few occasions, all estimates are less than 35% females in all years (Table 3).

TRENDS AND CURRENT STATUS

Small-bodied smelt have received greater attention than large-bodied smelt, a reflection of the elevated attention to the conservation concerns associated with the smaller form in the years leading up to and since the listing in 2003 of the Lake Utopia dwarf (small-bodied) smelt on Schedule 1 of SARA. Information on spawner abundance is accordingly skewed toward the small-bodied form. There have been numerous daily capture-mark-recapture (M-R for short) based estimates of small-bodied smelt spawner abundance acquired between 1999 (see Curry et al. 2004) and 2009 (DFO, unpublished data).

Summation of the daily population estimates for the years when multiple estimates of spawner abundance have been obtained for small-bodied smelt suggest total spawner abundances in the range of 250 thousand (Curry et al. 2004; COSEWIC 2008) to perhaps more than 1 million (Curry et al. 2004). Summation of estimates for the season is, however, confounded by the lack of independence of individual daily estimates; the example shown for Unnamed Brook in 2003 (Table 4) indicates that individual marked smelts may remain available to recapture for eight days, perhaps longer.

Only daily quantitative estimates are considered here in order to portray the variability in spawner abundance that may be considered typical within- and among-years. Estimates acquired in multiple tributary streams on a single night/adjacent nights can, however, be summed to estimate a minimum spawner population size in the years these are available for either DU.

All estimates considered here have been generated using the Gazey and Staley (1986) Bayesian algorithm that yields maximum likelihood estimates of spawner abundance.

Inference from the quantitative estimates concerning trends over time (years) in abundance are not possible at this time.

SMALL-BODIED SMELT

Individual within-stream daily estimates vary from between 3,000 and 150,000 fish (Table 5). Estimates on the order of 10^4 fish are the most frequent and among stream estimates are generally similar for common dates, indicating small-bodied smelt do not exhibit a preference for one tributary over the others (Table 5). Summation of discrete daily estimates among streams for common dates indicates that the number of small-bodied smelt participating in spawning activity can number in the hundreds of thousands (Table 5). Dates when spawner abundance estimates within individual tributaries are in the tens of thousands generally correspond with the

21 April-25 May time period when the expectation of observing the presence of small-bodied smelts in the tributaries is greatest (Figure 2).

There were fewer recorded occurrences of small-bodied smelt in Scout Brook during 2009 and 2010 than during: 1) the previous years of observations in that stream, and 2) in the other two tributaries during the same dates in 2010 (Appendix I). Spawning later in May, as occurred during 2003, and after the 2009 and 2010 search efforts had ceased, does not appear to explain the change. Later spawning in 2003 relative to all other years of observation was synchronous among all three tributaries. Spawning during both 2009 and 2010 occurred in both Smelt Brook and Unnamed Brook during the time of the search efforts.

Few (approximately 500) smelt were observed in Scout Brook on 10 May 2007, on the day that rough estimations indicated over 100,000 and 10,000 smelt were present at/near the mouths of Smelt Brook and Unnamed Brook, respectively (Connell and Seymour, unpublished report[6]). This report indicated that access to Scout Brook at the time was less than ideal, perhaps due to a lower than usual water levels in the lake, and possibly limited attraction flow at the streams point of entry into Lake Utopia.

Directed efforts to census small-bodied smelts in Scout Brook during 2009 were unsuccessful. Few (<100) smelt were observed in the brook on 7 May, and on 11 May there were no smelt to catch (DFO, unpublished data). Egg mats observed in the stream on that date were patchy and $\leq$2 cm thick (DFO, unpublished data). Direct evidence for the use of Scout Brook during 2010 by small-bodied smelt is limited to a single, small (1-2 m^2), egg mat (plus one dead smelt nearby), which was detected during a 15 April visual survey of the 100-150 m stretch of the brook that lies upstream of the small still water above the beach (DFO, unpublished data). Attraction flow and stream depth through the section of barrier beach at the stream mouth were considered to be adequate for smelts by the DFO Habitat biologist who was present at the time.

LARGE-BODIED SMELT

Daily spawner abundance has been estimated quantitatively for large-bodied smelt on a single occasion, the evening of 17 April, 2009. Median spawner abundance was estimated to be 5,000 fish (Table 5). Attempts during 2010 to sample large-bodied smelts on Mill Lake Stream, beginning 22 March, were not successful (Appendix I). Small ($<0.1m^2$) patches of eggs were observed on 15 April (DFO, unpublished data) stranded above the stream immediately below the natural barrier that has defined the upper limit of spawning activity in previous years (DFO, unpublished data; R.G. Bradford, personal observation). Very small numbers of smelt (≤3 fish) were observed during subsequent evenings, near the culvert that is installed in the outlet of Mill Lake Stream several tens of meters below the spawning area. Beavers (*Castor canadensis*) occupying a lodge upstream of the culvert had begun constructing a dam across the entrance to the culvert by 20 March. It was removed by the NB Department of Transport before 29 March (DFO, internal correspondence).

Current status of large-bodied LURS, in the context of adult population size, cannot be assessed with the data currently available. Inference concerning change in status with time is not possible.

[6] Connell, C., and P. Seymour. 2007. Lake Utopia dwarf smelt monitoring-May 10, 2007. New Brunswick Department of Natural Resources. Unpublished report.

SMALL- AND LARGE-BODIED SMELT SYMPATRY

Detectable levels of hydridization between large- and small-bodied LURS (Bradbury et al. 2011) may be an indication of instability within this sympatric species pair. Statements on the general status of LURS will need to consider as factors environmental stability within Lake Utopia and the tributary streams used by smelt, and as well the selective mechanisms within the ecosystem that maintain smelt diversity. Neither factor is well understood at the present time. Indications of recent change in spawning tributary stream use by small-bodied smelt, and evidence of potential for disruption of both access to, and availability of, spawning habitat for large-bodied smelt lend uncertainty to the stability of the production potential for both members of the species pair.

HABITAT REQUIREMENTS AND RESIDENCE

CHARACTERISTICS OF SPAWNING HABITAT

Spawning substrates are similar for both DUs. They consist of substrate suitable for egg attachment, such as sand, gravel, rock, aquatic vegetation and wood debris (DFO, unpublished data). Smelt generally ascend and occupy the entire stream between the mouth and either an obstruction or abrupt increase in stream gradient. Areas immediately downstream of the obstructions can contain high densities of eggs. Water temperatures associated with spawning activity for both populations are reported above.

CHARACTERISTICS OF SPAWNING TRIBUTARIES: LARGE-BODIED SMELT

The spawning tributaries used by the large-bodied smelt DU have been defined as being lake-headed (COSEWIC 2008), that is, they use the outlet streams from Mill Lake and Trout Lake that drain into Lake Utopia (Figure 1). However, Trout Lake receives water from Spear Brook, which is not lake-headed, and where both adult large-bodied smelt (Curry et al. 2004) and smelt eggs (New Brunswick-Dept. of Natural Resources (NB-DNR 2008) have been observed. A more accurate general description of the spawning tributaries may need to include reference to the areas of these catchments, and their relative greater size when compared both to small-bodied smelt spawning tributaries, and all other tributary streams to Lake Utopia.

Mill Lake Stream averages 4 m wide and less than 1 m deep (Curry et al. 2004). Water velocities in Mill Lake Stream may reach 1 m/sec (Curry et al. 2004). A small (approximately 0.5 m, dependent upon lake levels; R.G. Bradford, personal observation) waterfall that cannot be ascended by the smelts, except perhaps during times of extreme high lake water levels, limits available spawning habitat for large-bodied to the stretch immediately below the waterfall. Stream length within the spawning area has apparently not been measured with precision, visual estimations suggest a length of between 10 m-<30 m (DFO, unpublished data).

Trout Lake Stream averages about 10 m wide with slow-moving water and deeper pools (Curry et al. 2004). The only known report of the presence of eggs within the stream is within the culvert under the road that crosses the stream at its mouth (J. Shaw, UNB/DFO Ottawa, personal communication). The eggs were inadvertently collected with a dip net while sampling smelts. Large-bodied smelt (Curry et al. 2004) and egg deposits (16 April and 22 April of 2002; DFO, unpublished data) have also been observed in Spear Brook, a tributary of Trout Lake. Thus, Trout Lake and its outlet stream function as a migration corridor for smelts destined for Spear Brook, meaning adult smelt presence in either water body cannot be used to infer spawning activity therein.

CHARACTERISTICS OF SPAWNING TRIBUTARIES: SMALL-BODIED SMELT

Small-bodied smelt spawn in the smaller (1-2 m wide), slower-flowing (<10 cm/s) streams. None of the streams are lake-headed, which perhaps accounts for the lower temperatures of their waters relative to either Mill Lake Stream or Trout Lake Stream during the spring months. The three streams combined have been estimated to provide less than 500 m of accessible linear habitat for spawning by small-bodied smelt (Curry et al. 2004). General correspondence, among years and, among observers on the locations of egg deposits in these streams, as well as the lowermost permanent obstruction to ascent by smelts of the streams (DFO, unpublished data), indicates that it may be possible to calculate precise estimates of available spawning area for the individual tributary streams.

USE OF THE LAKE

Smelt larvae can be found throughout the surface waters of Lake Utopia, at night (Shaw 2006) at lengths ranging between 20 to 25 mm at the end of June to between 20 to 30 mm at the end of July (Shaw 2006). None of the larvae examined by Shaw (2006) were considered to be the progeny of large-bodied smelts. The distribution of older smelt larvae within Lake Utopia is not well known. Metamorphosis is thought to occur by October. The extent to which habitat usage varies with ontogenetic development is not known.

Lacustrine smelt, generally speaking, are schooling, pelagic fishes that occupy mid to deep cool waters of lakes (Scott and Crossman 1973). This would appear to be the case for Lake Utopia smelts irrespective of their DU-membership. Curry et al. (2004) assessed the stable carbon and nitrogen signatures of adult smelts representing both DUs. The stable carbon isotopic signatures, an indicator of habitat use, were the same, whereas the stable nitrogen isotopic signatures (and indicator of trophic status) indicated small-bodied smelt occupied a lower trophic niche than did large-bodied smelt. Jardine and Curry (2006) presented evidence that this difference in trophic status was more strongly associated with differences in body size between the DUs than age.

The diet of smaller smelt (e.g., all small-bodied smelts and the young of the larger form) in Lake Utopia consists primarily of zooplankton, which could include organisms such as *Daphnia, Diaptomus, Cyclops, Bosmina, Leptodora* and *Epischura* (Bajkov 1936 in Lanteigne and McAllister 1983). The diet of the larger members of the large-bodied form can consume fish, including smaller smelt (Curry et al. 2004), and as well consume invertebrates such as *Mysis*, copepods and *Ephemeroptera* (Delisle 1969a in Lanteigne and McAllister 1983).

The bioenergetics of gonad maturation for Lake Utopia smelts is not known. How inter-annual variability in both the climate and productivity of the lake may influence age at maturity, spawner potential, and partial recruitment is, therefore, uncertain.

Fish species present in Lake Utopia known to prey upon smelts include landlocked Atlantic salmon, brook trout, burbot, perch (Scott and Crossman 1973), smallmouth bass and smelt (Curry et al. 2004).

APPLICATION OF DEFINITION OF RESIDENCE CRITERIA

The *Species at Risk Act* defines residence as, "*a dwelling place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating.*"

Residency for the LURS DUs will require additional consideration once guidelines and criteria to identify residences for aquatic species are established. The egg masses resulting from spawning activity might be considered at that time, as they fulfill the crucial function of breeding and are geographically predictable in their distribution.

RECOVERY TARGETS

The *Species at Risk Act* (SARA article 41(1)(d)) requires that, in a recovery strategy, a statement be made regarding the population and distribution objectives that will assist the recovery and survival of the species.

The Threatened designations of the small-bodied and large-bodied LURS DUs are not a result of either demonstrated declines in abundance to below a critical threshold or contractions in range. Rather, they are a result of their natural small areas of occurrence (29 km^2) and occupancy (6 km^2), and the concern that management measures are not in effect to mitigate perceived threats related to habitat degradation, directed fishing, aquatic invasive species, and lake eutrophication (COSEWIC 2008).

There is no solution to the first concern, the rainbow smelt sympatric species pair is endemic to Lake Utopia; it is literally a product of the lake. The second suite of concerns, and additional concerns, can be addressed during development of the population and distribution targets when survival and a reduction in the probability of species extinction are the goals.

The recovery goal for small-bodied LURS has already been defined within the context of ensuring survival. The goal of the draft recovery strategy is:

> *"to maintain Lake Utopia small-bodied (dwarf) smelt at a self-sustaining level"*

A similar goal can be anticipated for large-bodied smelts.

POPULATION ABUNDANCE TARGETS

Small-Bodied Smelt

Mark-recapture experiments have consistently demonstrated that, at the peak of the spawning season, daily small-bodied smelt spawner abundances are in the tens of thousands within tributaries and often a hundred thousand or more among all three tributaries. In the absence of good seasonal abundance estimates, it is suggested that continued, simultaneous, high productivity within all of the spawning tributaries, all resulting in cumulative daily estimates of about a hundred thousand fish be used as an interim abundance target. Compliance with the interim target can be demonstrated with a series of multiple daily abundance estimates for each of the three known spawning tributaries on a periodic basis (e.g., every second or third year whichever may correspond with the true generation time for the population).

An accurate estimate of total spawner abundance should be developed to replace the interim target. Information on the rates of immigration to and emigration from the spawning tributaries will be required.

<u>Large-Bodied Smelt</u>

There is insufficient quantitative data with which to establish quantitative abundance targets relative to productive capacity.

The minimum population size needed to maintain genetic diversity can be used as a coarse abundance target, as has been done with the Atlantic whitefish (*Coregonus huntsmani)*(DFO 2009). This value can be estimated from the effective population size required to maintain genetic diversity and the ratio of the effective population size (Ne) to the census population size (Ncensus). An initial attempt to measure Ne largely failed owing to a lack of power in estimation associated in part from a lack of good information on the age structure of the sample populations (Bradbury et al. 2011).

An effective population size of 500 mature individuals is thought to be sufficient to maintain genetic diversity in many vertebrate species and could be assumed as a proxy for both populations of LURS. A review of Ne/Ncensus ratios for salmonids showed this ratio to be typically in the vicinity of 0.26 to 0.88, and these values could be assumed to be a rough approximation of the range of this ratio for large-bodied LURS. Taken together, these ratios would place the minimum census population size required to maintain genetic diversity in the vicinity of 550–2,000 mature individuals, which is below the range that might be anticipated for large-bodied smelt in light of the single estimate of 5,000 spawners in 2009. In light of the relative high risk to the stability of the population arising from catastrophic events and/or environmental variability (i.e., small area of occupancy/occurrence), an estimated potential annual harvest from a directed fishery of about 1,250 adults, and evidence for hybridization with the smaller form of smelt, the upper value of 2,000 mature individuals is suggested as the interim population abundance target.

As was the case with small-bodied smelt, an accurate estimate of total spawner abundance should be developed to replace the interim target.

DISTRIBUTION TARGETS

<u>Small-Bodied Smelt</u>

Annual, synchronous occupation of the three spawning tributaries; Smelt Brook, Unnamed Brook, and Scout Brook is suggested as the distribution target for small-bodied smelt. The sparse historical documentation of annual spawning activity, however, introduces uncertainty concerning the relative role that natural (e.g., climate, natural variability in total spawner abundance) versus human factors may play in stream use. A compliance rule can be implemented to accommodate this uncertainty: occupancy of all three streams four out of every six years with no single stream to be unoccupied for two consecutive years, for example. Provisions can be made within the compliance rule for among-stream variability in attraction flows and water supply to aid migration when the underlying factors are natural and unrelated to human activity. Occupancy would need to linked to an abundance thresh hold that clearly reflects a risk to the productive capacity of the stream below the thresh hold.

<u>Large-Bodied Smelt</u>

The relative dependence of annual large-bodied smelt productivity on use of the Trout Lake-Spear Brook stream system for spawning is not well understood. A distribution target that can act as an indicator of production relative to production potential is, therefore, not possible at present. There is consensus that Mill Lake Stream is a principle spawning tributary for the large bodied-smelt; annual occupancy of Mill Lake Stream is suggested as the interim distribution target. In light of the higher intrinsic risk to large-bodied smelts than small-bodied smelt, tolerance for absence of spawning in any year is not advisable. As was the case with small-bodied smelt, the definition of occupancy will need to be linked to an abundance thresh hold that clearly reflects a risk to the productive capacity of the stream below the thresh hold. Quantitative census data will be required to establish a definition for occupancy.

THREATS, ALTERNATIVES, AND MITIGATION MEASURES

HISTORICAL FACTORS

Rainbow smelts have co-existed with people within the Lake Utopia basin for millennia. The earliest archaeological evidence of human occupation in the basin is from about 7,000 Before Present (BP) (Suttie 2005), which corresponds to the Middle Archaic period (7,500-6,000 BP) (Suttie 2005). The archaeological record includes evidence for human activity at the mouths and/or along the banks of all but one (Spear Brook) of the known spawning tributaries (see Suttie 2005). Direct interaction with the smelts was possible.

Early industrial activity, mostly associated with the lumber industry, on both the tributary streams and on the lake, began with the arrival of Loyalists from the United States of America during the late 18th Century. Local knowledge indicates that Mill Lake Stream was used as a sluiceway to facilitate the transport of logs to mills located in St. George (R. Mackay, Mahone Bay, NS, personal communication), for example. By 1867, the stream was used as a source of water power for a sawmill (Saint John Globe, 6 August 1867), the remains of which are still in evidence (R.G. Bradford, personal observation). The latter activity would have likely deposited sawdust into the stream. Legal prosecution of the discharge of sawdust into fish habitat was unsuccessful in Canada until 1902 (Gillis 2006).

The lengthy co-occurrence of the smelt populations with people is all the more remarkable when the attributes of the physical setting are considered. That is, a smelt assemblage, with limited production potential, undergoing rapid evolution within a small lake with every generation potentially susceptible to direct manipulation by people at a sensitive life-history stage. Here, perhaps more so than for anywhere else in Canada, species assigned high conservation values in the present day, are the reflection in part of their history with people.

CURRENT HUMAN ACTIVITIES AS POTENTIAL THREATS

Information on the scope of current human activities within the Lake Utopia catchment area on rainbow smelt was gathered during development of the draft Recovery Strategy for the Lake Utopia dwarf (small-bodied) smelt, beginning in 2002-2003. Identified activities included forestry, agriculture/silviculture, both year-round and seasonal human settlement, heavy industry (e.g., a pulp mill), aquaculture, recreational use (e.g., boating, all-terrain vehicle (ATV) use), hunting, recreational angling, fisheries enhancement via stocking, linear developments (roads, railways and transmission lines) and water storage for the generation of hydroelectricity. Science activities associated with research and assessment require direct handling and limited lethal sampling of members of both populations of rainbow smelt.

Far-field human activities can potentially influence fish habitat in Lake Utopia because of the lakes susceptibility to influx of water from the Magaguadavic River. Flow reversal from the river to the lake, via The Canal, occurs from both natural (e.g., large freshets) and human (e.g., water storage) processes. The suite of human activities identified to occur within the Lake Utopia basin, as well as mining occur in the portions of the Magaguadavic River lying upstream of The Canal. Lake Utopia is also susceptible to colonization by non-indigeneous fish species that may be introduced either directly into the lake or through the lake's open connection with the Magaguadavic River.

These activities could potentially threaten LURS productivity through alteration of one or more of the following four attributes: water quality, water quantity, direct mortality and impacts on habitat. The distribution of the human activities among the four attributes and whether or not a regulatory framework presently exists to manage these activities is summarized below.

Attribute	Activity	Regulated
Water Quality	Hatchery Effluent	Yes
	Inputs from Magaguadavic River: flow reversal	Yes
	Residential and Recreational Effluent	Yes
	Agriculture/silviculture	Yes
	Cumulative Effluent (All Sources)	Yes
Water Quantity	Water Level Fluctuations	Yes
	Water Withdrawal for Industrial Use	Yes
Direct Mortality	Entrainment at Industry Intakes	Yes
	Fisheries (Directed and Non-Directed)	Yes
	Predation: stocked fish	Yes
	Predation: aquaculture escapees	Yes
	Predation:non-indigenous fish species	No
	ATV and Foot Traffic	Yes
	Scientific Research	Yes
	Hatchery Effluent	Yes
Impacts on Habitat	Forestry on Crown and Private Lands	Yes
	Stream Blockages (Man-Made Structures)	Yes
	ATV and Foot Traffic (Spawning Tributaries)	Yes
	Residential/Urban Development	Yes

ASSESSMENT OF THREATS

Water Quality

Effluent generated by human activities can potentially result in eutrophication[7] of water bodies. Lake Utopia itself receives nutrient enriched effluent water directly from a fish hatchery and residences along its shoreline. The Lake Utopia watershed watershed receives effluent or run-off water from additional residential developments. Each of these sources, in addition to inputs from the Magaguadavic River via The Canal (Figure 1), increases the nutrient load into the lake. Water quality monitoring from 1989 to 2002 indicated stable to declining levels of phosphorus and nitrogen, but showed a significant increase of Chlorophyll A, which was associated with an increase in frequency of algal blooms in the lake (Hanson 2003). The location of the point sources of pollution, and limitations to the flushing mechanisms of the lake, may facilitate the build-up of nutrients (Hanson 2003), thereby creating the conditions for increased productivity, making the lake less suitable for LURS.

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[7] Eutrophication (also known as nutrient enrichment) is a result of large amounts of nutrients, frequently phosphorous, being released into a nutrient deficient water body which leads to excessive amounts of aquatic plant growth. Eutrophication can be accelerated by the release of nutrients from human activities such as from fertilizers used in agriculture and at our homes. This rapid transition is not beneficial for the fish and other organisms which live in lakes who have to cope with depleted oxygen levels because of the decomposition of plants, as well as changing biodiversity and species abundance (Environment Canada: https://www.ec.gc.ca/air/default.asp?lang=En&n=64CD2186-1).

Herbicides and pesticides applied on to planted crops (agricultural) or woodlands (silviculture) are also identified as a threat because of potential effects on fish health. Neither activity occurs directly adjacent to the lake or spawning streams although both activities occur within the Lake Utopia drainage and within the Magaguadavic River basin.

Appendix II provides for each human induced threat to water quality a summary of effect on water quality to be mitigated, present mitigation, the options to reduce effect, monitoring and research activities to help assess effects and the effect on both populations of rainbow smelt under current management strategies. The location (lake or spawning tributary) of the effect is also identified.

The rank effect to water quality varies from low to medium for the individual human activities (Appendix II). Present mitigation consisting of compliance with existing standards and regulations as set out in the *Clean Water Act* and *Pesticide Control Act*, and recent (since July 2008) actions to reduce the nutrient load of hatchery effluent, and incorporation of a low phosphorous feed at the Lake Utopia hatchery is considered to be generally effective. Water quality within the lake continues to be monitored.

Cumulative Effluent (All Sources)

At present, the cumulative effects of all sources of effluent is considered to be only a medium level of concern because monitoring has demonstrated that implementation of new operational limits for nutrient loading placed upon the hatcheries inside and outside Lake Utopia under the NB *Aquaculture Act* and *Clean Water Act* has reduced phosphorus levels in Lake Utopia water (D. Fox, NB Department of the Environment, Fredericton, NB, personal communication). These limits continue to be under review and may be subject to change if the results from ongoing water quality monitoring suggest that it is needed.

Water Quantity

Changes to water quantity can impact on several elements of function of both the spawning tributaries and the lake. When lake water levels are too low, access to or exit from spawning sites can be impeded. High lake levels could potentially flood and thereby alter the character of spawning sites in the lower portions of the streams. High water velocities associated with intense run-off, may reduce the stability of the egg mats deposited on stream substrate. If fluctuations in water levels are too severe, eggs may become vulnerable to excessive submergence or to desiccation as water levels change. These effects would be considered to be severe, without effective mitigation, given the implications to the populations' ability to propagate.

Stream Water Level Fluctuations

There is no information available on whether current land-use practices such as removal/ thinning of forest canopy and/or conversion of forest habitat to open space (residential open area) has influenced the hydrological cycles of the high stream order, small, tributaries used by small-bodied smelt.

Nonetheless, it needs to be noted that use for spawning of Scout Brook by small-bodied smelt has appeared to have declined recently. Scout Brook is the only one of the three brooks that has been subject to forest harvest operations within the several years, and where an extensive residential development has occurred within the catchment. Both activities have resulted in loss of forest canopy.

The water supplies to Mill Lake Stream and Trout Lake-Spear Brook are at low risk to alteration from human activity.

Lake Water Level Fluctuations

A man-made dam on the top of a natural falls located in the Town of St. George creates a headpond that includes Lake Utopia to both enable, and manage the water supply for, hydroelectric power generation (Jacques Whitford Environmental Limited (JWEL) 2001). The normal full level of the headpond varies between 16.76 m (55 ft) and 17.7 m (58 ft) (JWEL 2001). The hydroelectric generating plant has recently been re-developed; it became operational in 2004. The rate of drawdown when the plant is operating at full capacity has been estimated as 0.02 m/hr, assuming zero inflow into the headpond. The operating procedure of the plant attempts to maintain a high head in the headpond, with drawdown restrictions of between 16.76 m and 17.67 m (JWEL 2001). There do not appear to be any regulations in effect concerning the management of water levels in the headpond (R. MacDougall, DFO, St. George, NB, personal communication). The Fisheries Management Planning (FMP) for the facility has not been completed, and there are presently no provisions within the FMP process for consideration of large-bodied smelt. A survey of small-bodied smelt spawning tributaries in 2004, conducted to fulfill a requirement within the FMP process, indicated that access to and from the stream by adults was not impeded. The study also indicated that drift of larvae from the tributaries was not impeded by the operation of the re-developed facility.

Since the re-developed plant became operational, concern has been expressed by private (residential/recreational) property owners on Lake Utopia regarding what they considered to be higher lake water levels than was the historic norm. The data required to test this perception is not presently available. Therefore, it is not possible to assess whether water levels in the lake at the time of staging for spawning, migration to and from the streams, and spawning by both small- and large-bodied smelt has changed since 2004. It is also not possible at the present time to address the seemingly contradictory reports of a ‘high’ stream gradient impeding passage of small-bodied smelts across the beaches and into some of the streams in 2007 and 2010 (see Trends and Current Status above).

Water levels on Mill Lake Stream, which is used for spawning by large-bodied smelt, were high in March 2010. The only eggs observed in the stream were in the low energy interstitial spaces between the rocks forming the falls, and a few upstream of the falls (R.G. Bradford, personal observation).

The level of threat to large-bodied smelt from high water levels appears to be high at Mill Lake Stream. The effects of water level fluctuations on spawning habitat accessibility and availability on Trout Lake-Spear Brook are not known.

Water Withdrawal (Pulp Mill)

The Lake Utopia Paper Mill withdraws water directly from the lake for its industrial operation and the effects of this are not all clear; however, the facility has been in operation for decades without triggering concerns over lake or stream levels. Accordingly, the level of concern for this threat is considered to be low for both the lake and streams.

Direct Mortality

Entrainment (Paper Mill and Hatchery)

All intakes are screened, so entrainment of juvenile and older smelt is probably low. Larvae may be at risk, but intakes are deep relative to vertical distribution of larvae. Risk is considered to be low.

Directed Fisheries

A recreational smelt dip net fishery has occurred in the tributary streams of Lake Utopia for many years between 1 April and 31 May. Much of the dip netting occurs on spawning tributaries used by large-bodied smelt, Mill Lake Stream and Trout Lake Brook, owing, in part, to their ease of access. Catch/effort data has never been gathered. There is, nonetheless, general consensus that fishing effort is low. The fishery is authorized under the *Maritime Provinces Fishery Regulations*, under the federal *Fisheries Act,* and is subject to daily bag limits, closed times and gear restrictions, as stipulated in Part XIII of the regulations. A daily bag and possession limit of 30 smelts is presently in effect.

Small-Bodied Smelt

Information provided by the NB Department of Natural Resources during the development of the Lake Utopia dwarf smelt Recovery Strategy estimated the potential maximum annual take from the smelt fishery at 2,500 fish in the years that the daily bag and possession limit was 60 fish. Under the present daily bag and possession limit of 30 fish, the estimated potential annual maximum take is 1,250 fish. Fishing mortality on small-bodied smelt is expected to be low; current spawner abundance has been conservatively assessed as a hundred thousand fish. The level of threat to small-bodied smelt from direct removal of spawning fish by the fishery is low.

Large-Bodied Smelt

Much of the take from the directed smelt dip net fishery in the lake targets large-bodied smelt. The current status of large-bodied smelt is not certain but expected to be low relative to abundance of small-bodied smelt. The estimated five-day duration of the dip net fishery (NB Department of Natural Resources, see above) is virtually of the same duration as the estimated time that smelts are likely to be observed in the brooks (9-14 April; Table 2; Figure 2). There is high potential for much of the annual spawning runs to be susceptible to fishing. Large-bodied smelt are at high potential risk from recreational dip net fishing owing to uncertainty in status and higher potential for exploitation.

Bycatch in Recreational Angling Fisheries

There is not a significant by-catch of either small-bodied or large-bodied smelts in any recreational fishery occurring within the lake. The level of threat to small-bodied smelt and large-bodied from bycatch in non-directed fishing is low.

Predation (Stocked Fish)

The NB Department of Natural Resource has maintained a low stocking density practice while enhancing the recreational angling fishery for land-locked Atlantic salmon in Lake Utopia. Stocking densities have been limited since 2000 to 0.3-0.4 yearling per hectare every two years

(P. Cronin, NB Department of Natural Resource, personal communication, 2002), when stocked. Fewer salmon have been stocked than allowed for in this policy (Table 6). Distributions of brook trout are low. The level of threat to small-bodied smelt and large-bodied from enhanced fisheries is low.

Predation (Aquaculture Escapees)

There are no indications that the level of escapement of salmonids from the aquaculture facilities located in the lake result in elevated numbers of potential predators on rainbow smelts in Lake Utopia. Compliance with the National Code on Introductions and Transfers of Aquatic Organisms[8] and relevant provincial regulations is expected to result in a low level of threat to both the small- and large-bodied populations.

Aquatic Invasive Species

An aquatic invader is a non-native species, whose introduction will likely cause (or has already caused) damage to the host ecosystem, existing species therein, the economy, or human well-being. Aquatic invasive species (AIS) thrive in the absence of their native predators and have the potential to drastically alter habitat, rendering it inhospitable for native species[9]. At least five AIS have been recorded from within the Magaguadavic River drainage, with two (smallmouth bass, *Micropterus dolomieu*; chain pickerel, *Esox niger*) a result of unauthorized, intentional introductions[10], one (Pacific salmonid, species unknown) a likely result of an accidental introduction, and an another (largemouth bass, *M. salmoides*) by an unknown means. Rainbow trout (*Oncorhynchus mykiss*), the fifth AIS, were sampled while ascending the fishway located at St. George from 1983-2000, but there are no indications that the species has become naturalized within the Magaguadavic River (Carr and Whoriskey 2009).

Only one of the five AIS reported from the Magaguadavic River has become naturalized[11] to Lake Utopia - the smallmouth bass. Chain pickerel appear to have become naturalized to the headwater lakes of the Magaguadavic River, where they were first detected in 2003 (Carr and Whoriskey 2009). Records of ‘humpback’ (Pacific) salmon are limited to a report from a conservation officer of a single fish in Mill Lake Stream during August, 1938 (Sutherland 1938). The origin of the fish is not known but it may have ascended the fishway constructed in 1929 to bypass First Falls in St. George (Bruce 1936). A single adult largemouth bass was retrieved from the St. George fishway on July 11, 2006 (J. Carr, Atlantic Salmon Federation, Chamcook, NB, personal communication). There have been no additional reports since. Largemouth bass have been stocked into, and become naturalized to, some rivers in the State of Maine (Scott and Crossman 1973).

Only chain pickerel and smallmouth bass are considered further because both species have naturalized to the Magaguadavic River, and either presently interact, or could be expected to interact at a future time, with the LURS. Guidance for the prevention/control of other potential AIS within the Magaguadavic River drainage is provided by the Canadian Action Plan to Address the Threat of Aquatic Invasive Species (Canadian Council of Fisheries and Wildlife Ministers (CCFAM 2004).

[8] http://www.dfo-mpo.gc.ca/aquaculture/ref/NCITAO_e.pdf.
[9] http:www.dfo-mpo.gc.ca/science/enviro/ais-eae/index-eng.htm.
[10] The deliberate release, or holding, of live aquatic organisms in open-water or within a facility with flow-through circulation or effluent access to the open-water environment outside its present range (CCFAM 2004).
[11] Reproduce consistently and sustain populations over more than one life cycle without direct human intervention (or in spite of human intervention) (CCFAM 2004).

Chain Pickerel

Chain pickerel are established and common in many of the inland water bodies of NB. The history of their introduction into the Province, together with information on the present-day fish assemblages where chain pickerel have naturalized, may provide insight into the potential consequences for the rainbow smelt DUs of Lake Utopia. Following their introduction in 1852 to the West Branch of the St. Croix River in the State of Maine, chain pickerel eventually spread to all accessible waterways in the river, including the boundary waters of NB (Kain 1893a). Chain pickerel collected in 1868 from the boundary waters were transported to and released, reportedly four fish in total, into the Eel River lakes that are located within the upper Saint John River drainage (Kain 1893a). While the source of the donor stock for the unauthorized introduction into the Magaguadavic River is not known, it seems unlikely that these fish would be anything but a naturalized sub-population of the fish originally stocked into the St. Croix that underwent range expansion by either natural or artificial means.

Lake fish assemblage survey data, acquired in recent decades, and assembled and maintained by the NB Department of Natural Resources shows that rainbow smelt are present in several named water bodies that also contain chain pickerel. The water bodies include Spednic and North lakes of the St. Croix River, and First and Second Eel lakes of the Upper Saint John River drainage, where chain pickerel have been present for at least 130 years. This time scale represents, conservatively, at least 30 generations of rainbow smelts assuming an age of first maturity of four years. The likelihood that chain pickerel pose a threat to the survival of lacustrine populations of rainbow smelts, therefore, appears to be low.

However, whether chain pickerel could potentially negatively impact the trophic status of smelts, or differentially impact the status of individual members of sympatric species pairs is not known. Only the small-bodied (‘dwarf’) form of rainbow smelt has been documented from North Lake, on the St. Croix River (Taylor and Bentzen 1993a), for example. It is not known if a large-bodied form existed in the lake prior to the invasion by chain pickerel. The morphotype(s) of the resident smelt populations of First Eel Lake and Second Eel Lake are not known, nor is there any biological data for the lacustrine rainbow smelts occurring in Big Magaguadavic Lake and Little Magaguadavic Lake prior to the recent introduction of chain pickerel that would facilitate an assessment of their effects on smelt status.

Effect on Small-Bodied Designatable Unit

The available information, therefore, indicates that the small-bodied LURS DU is likely to survive the presence of a naturalized population of chain pickerel in the lake. The pelagic, zooplanktivorous character of their life-history (Curry et al. 2004) is likely to limit the scope for harm that may arise from predation by chain pickerel on this DU to the spawning season for smelts as they assemble at the mouths of the brooks prior to spawning, and upon their departure.

Effect on Large-Bodied Designatable Unit

There is no available data with which to demonstrate that large-bodied rainbow smelt morphotypes can co-exist with chain pickerel[12]. The entrances to both Mill Lake Stream and

[12] Chain pickerel were illegally introduced in 1997 into Shubenacadie-Grand Lake, Nova Scotia, where the large-bodied smelt morphotype is expressed among the rainbow smelt population. The current status of the smelts is not known.

Trout Lake-Spear Brook, the spawning tributaries used by large-bodied rainbow smelt in Lake Utopia, possess stretches of the low water current, shallow, weedy habitats favoured by chain pickerel for both foraging and spawning in early April (Scott and Crossman 1973). There is, therefore, potential for direct predation on large-bodied rainbow smelts, the least abundant, possibly by at least an order of magnitude, of the two DUs. The likelihood of encounters of large-bodied smelt with chain pickerel in the lake cannot be determined at the present but could be potentially greater than for the small-bodied DU. Macro-invertebrates and small fishes are included in the diet of the large-bodied form (Curry et al. 2004), for example. The potential threat of chain pickerel to the survival and recovery of the large-bodied rainbow smelt DU is, therefore, high.

Mitigation

Neither control nor eradication of chain pickerel, either before or following their appearance in Lake Utopia, will be feasible. Maintenance of both the productive capacity of the lake, and of the physical conditions within the spawning tributaries that can favour high spawner success (access to and from the lake, removal of debris that may prevent ascent of the streams) for both DUs, may present the best opportunity to mitigate presence of chain pickerel. Consideration should be given to increasing the amount of habitat available to the large-bodied rainbow smelt DU for spawning and, where possible, facilitating rapid ascent and descent of the tributaries on both Mill Lake Stream and Trout-Spears Brook.

Smallmouth Bass

As was the case with the chain pickerel, the introduction of the smallmouth bass to the inland waters of NB occurred via unauthorized releases of fish acquired in the State of Maine where they had been introduced in 1869 (Kain 1893b). The source of fish that were initially stocked into NB inland waters, in 1881 or 1882, is not known (Kain 1893b). Those now present in the Magaguadavic River drainage, including Lake Utopia, are the result of the unauthorized transfer of 142 mature fish from Spednic Lake, located within the boundary water of the St. Croix River, to Magaguadavic Lake in May, 1925 (Catt 1943). Smallmouth bass were reported to be present in Lake Utopia in 1942 (Smith 1942), there are indications that they were abundant by 1944. An effort to prevent smallmouth bass from entering Trout-Spears Brook and predating on trout fry resulted in the capture of 66[13] bass between May 11 and June 3 of that year (Tingley 1944).

Effect on Small- and Large-Bodied Smelt Designatable Units

Smallmouth bass and both the small-bodied and large-bodied rainbow smelt DUs have remained self-sustaining since the naturalization of smallmouth bass in Lake Utopia for about 65 years, or for at least 16 generations of smelts (assuming an age at first maturity of 4 years). Whether the presence of smallmouth bass has resulted in any change in absolute abundance or the phenetic or genetic traits of either DU cannot be determined, as biological information prior to the introduction of smallmouth bass is limited to coarse measures of body morphology for the large-bodied form (MacLeod 1922), although the existence of the small-bodied form was known by that time (MacLeod 1922). The threat to the survival or recovery of the present day populations is low.

[13] Sixty-one of the intercepted smallmouth bass were subsequently transported to and released live, with authorization, into Lake Micmac, Nova Scotia (Tingley 1944).

Mitigation

Maintain the productive capacity of the lake and promote the physical conditions within the spawning tributaries that favour high spawner success (access to and from the lake, removal of debris that may prevent ascent of the streams) for both DUs. These can be achieved via a blend of compliance with existing regulations and stewardship.

ATV and Foot Traffic

Traffic on ATV and on foot occurs along most of the known spawning tributaries for LURS. Traffic through spawning sites during the spring can result in direct mortality both to adults and eggs, potentially in significant numbers. It is possible that recreationally dip netting for smelt can result in direct mortality of eggs while fishing for spawning adults. Foot traffic during the spring from other sources like hiking and research could also potentially result in direct mortality. The small-bodied population spawning streams are considered more vulnerable to traffic than the large-bodied population spawning streams because they are smaller and it is, therefore, more likely that ATV users and pedestrians would attempt to cross them or to walk in them. However, ATV and foot traffic appear to be general low occurrence activities. The level of threat is, therefore, considered to be low.

Hatchery Effluent (inside Lake Utopia)

Fish hatcheries are regulated federally by the *Canadian Environmental Assessment Act* and the *Fish Health Regulations* of the *Fisheries Act,* as well as provincially by the *Aquaculture Act*. Regulatory compliance require measures to be employed to monitor and control disease within the facility and to minimize the risk of releasing contaminated effluent into the surrounding natural environment. These measures are in place, in part, because of the risk for fish disease to spread rapidly and widely in a population once individuals have been exposed, and an epidemic could result in levels of mortality sufficient to jeopardize the viability of a population. This existing level of mitigation is thought to be effective in preventing the spread of parasites or disease to resident LURS.

Impacts on Habitat

Forestry on Crown and Private Lands

The Magaguadavic River watershed, including Lake Utopia and its tributaries, is currently subject to widespread and recurrent forestry activities, as well as land clearing for other purposes like residential/urban developments. Forestry activities include the harvest of trees and potential supporting activities that may have short or long term effects on the environment (e.g., road construction, pre-commercial thinning). Given the essential role of the spawning habitat, the current and potential impacts (e.g., stream temperature, soil compaction, surface run off, accessibility of streams to smelts) of these activities on the specific water courses used by LURS requires further consideration.

No data specific to any of the five known spawning tributaries is available. A rise in mean water temperatures of 0.3^{o}C to 0.7^{o}C (4-8%) has been demonstrated for small high order streams elsewhere in NB following clear-cutting (Bourque and Pomeroy 2001). The study streams where mean water temperatures rose the highest were those with the greatest proportion of the upper catchment harvested (16.8%) and the highest calculated potential solar loading (e.g., facing south). Thinning applied to the forest buffers (with a basal area removal of approximately 28%) did not, however, cause significant change in the observed stream temperature. In essence, the harvesting of trees within the upper catchment without providing adequate shade protection to the low-ordered streams (<0.5 m wide), sub-surface water, and seepage points upslope of buffered streams diminished the practical value (in the context of temperature) of the forest buffer further downstream (Barton et al. 1985).

It may be relevant (as reported under Water Quantity) that spawning activity by small-bodied smelt in Scout Brook has appeared to have declined recently. Scout Brook is the only one of the three brooks where extensive tree cutting (and land clearing for a residential development) has occurred within the past several years. Scout Brook catchment, as is the case with all three of the brooks face towards the south and could, therefore, be expected to have relatively high solar insolation values.

Mill Lake Stream and Trout Lake-Spear Brook are considered to be at low risk to alteration from forestry.

While forestry and development is currently and continuously taking place in the watershed, these activities are not of the same immediate concern to LURS as the impact from localized activities taking place near spawning habitat. The watershed-level effects should be evaluated in more detail, with particular attention to their scope and existing mitigation.

Stream Blockages Associated with Man-Made Structures

Spawning stream blockages from the build-up of debris at man-made structures, such as culverts, can also pose a threat to habitat by serving as a barrier to access to spawning habitat. This could limit the spawning habitat accessible during a given year to the habitat below the blockage or potentially impede larval exit from above the blockage to the lake. These impacts are considered to be potentially severe in light of the inherent low number of streams used by LURS.

There are no culverts installed on any of the spawning tributaries used by the small-bodied population. However, temporary naturally occurring blockages from woody debris are common.

The culvert across the mouth of Mill Lake Stream, one of the two spawning streams for the large-bodied population, was used by beavers to anchor a dam that was present as early as 20 March 2010. The presence of the beaver dam creates the potential for impeding the upstream migration of spawning large-bodied smelts. There are no recent records of Trout Lake Brook ever having been blocked by either natural or man-made structures.

However, the culvert between Lake Utopia and one of the large-bodied populations spawning streams (Mill Lake Stream) requires ongoing monitoring. The level of concern for this threat is considered low for the small-bodied population and high for the large-bodied population. Annual monitoring of the culvert on Mill Lake Stream prior to and during the spawning season for the large-bodied population could help to ensure that debris from beaver activity does not interfere with fish passage.

ATV and Foot Traffic

Traffic on foot or by ATVs has the potential to jeopardize spawning habitat through physical disturbance of the substrate. ATV use is common in the Lake Utopia area. The small-bodied population streams are considered more vulnerable to traffic because they are smaller than the large-bodied population streams, and it is more likely that ATV users and pedestrians would attempt to cross them. Historically, only low levels of such activity have been observed in the area during the spawning season.

Residential/Urban Development

The issues and concerns are essentially the same as has been described under 'Forestry on Crown and Public Lands' above.

OTHER CONSIDERATIONS

Climate Change

Trends toward earlier ice-melt and later lake-ice formation, since 1961 and 1971, respectively, have been demonstrated for Lake Utopia (Duguay et al. 2006). The consequences of a shorter period of ice cover on the productive potential of the lake for both DUs are not known. The extent, or whether the trends in ice-cover indicate a potential for change in the hydrological and temperature cycles of the tributaries used for spawning, is not known.

MEASURES TO INCREASE PRODUCTIVITY OR SURVIVORSHIP

There are opportunities to increase productivity for both small-bodied and large-bodied smelt.

SMALL-BODIED SMELT

The brooks used for spawning by small-bodied smelt are susceptible to inter-annual variability in the amount of accessible spawning habitat through the deposition of organic debris (logs, accumulation of detritus around stones, tree branches, etc.) downstream of the natural limit to fish passage. Stream surveys, prior to the arrival of the smelts, could be effective at maintaining high production potential. The discovery of spawning activity at the mouth of a small brook not previously known to be attractive for spawning by small-bodied smelt suggests there is potential to increase the absolute quantity of spawning habitat with relatively minor alterations to the lower stretch of the brook. The desirability of doing so will, however, need to be evaluated in the context of fitness consequences for the sympatric species pair, and land-owner acceptance.

LARGE-BODIED SMELT

Mill Lake Stream, upstream of the small falls that acts as the natural barrier to fish passage in most years, possesses more suitable habitat for spawning than there is presently available to large-bodied smelt in this stream. Only minor alterations to the stream would be required to reduce the gradient at the falls. Evidence abounds upstream of the falls of the extensive alteration of the stream bed to facilitate human use, likely saw-milling. It is feasible that the present barrier to upstream passage is a consequence of the early stream alterations.

RECOVERY POTENTIAL

The recovery of both small-bodied smelt and large-bodied smelt in Lake Utopia is considered to be both biologically and technically feasible. A strong, multi-jurisdictional regulatory framework exists to enforce recovery activities. These regulatory frameworks can be applied to maintain, and increase where required, the level of protection of these fish, and their supporting habitat in both Lake Utopia and the tributary streams they use for reproduction. The time frame for recovery, that is, the time before both populations of smelt can be declared to be both self-sustaining and meeting the ecological requirements that promote and maintain sympatry, will depend upon several factors. The first is continued compliance with regulations that can be demonstrated to be effective in protection of fish and fish habitat. The second is the speed that the responsible jurisdictions work to address existing threats through stronger application of the regulatory framework when required. The third is the speed that knowledge gaps are addressed, particularly where the potential for harm appears to be high but where essential information needs to be gathered before effective mitigation can be applied. A fourth factor is the willingness of the local public to engage in effective local stewardship and monitoring of both the fish and their habitat.

RESEARCH AND MONITORING

An assessment of large-bodied LURS status is required to both help prioritize, and to support implementation of, recovery activities. The assessment will need to define current abundance, the age- and sex- composition of the adult population, and the timing, duration and distribution of spawning activity within the known spawning tributaries.

Spawner abundance estimates for both small-bodied smelt and large-bodied smelt are needed to set population recovery targets.

The tasks of understanding the mechanisms contributing to hybridizing between the two DUs, and the fitness consequences for each DU of hybridization, will benefit from the creation of an archive for genetic and phenetic materials that would be gathered periodically.

The influence of water supply management within Lake Utopia for hydroelectric power generation on rainbow smelt production in the lake and tributaries needs to be understood.

Several of the issues identified in this assessment could be more efficiently and effectively addressed through research directed at other populations of the same species occurring elsewhere. These issues include the response of the LURS DUs to the eventual appearance and naturalization of chain pickerel to Lake Utopia, and identification of the specific characteristics of smelt spawning habitat that establish viability. Explicit provisions within the present funding formulas to enable species at risk science to incorporate the gathering of data on populations of the same species not presently at risk would help to enable meta-analytical solutions.

The science and monitoring requirements in support of management objectives defined to meet recovery targets that are specific, measurable, achievable, relevant and results-focused, and time-bound (SMART) need to be defined.

SOURCES OF UNCERTAINTY

The geographic scale of the individual spawning tributaries used by small-bodied smelt is small, in comparison with the scale of modern forest harvesting practices, and, seemingly, the scale of at least some residential developments. The proper weighting of risk is difficult in the absence of site-specific information, and in the absence of effects-focused data gathered from comparable physical settings.

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Table 1. Named waterbodies of New Brunswick where presence of lacustrine populations of rainbow smelt have been reported. Those also containing chain pickerel and smallmouth bass are indicated.

ID	Basin	Catchment	Water Body	Chain Pickerel	Rainbow Smelt	Smallmouth Bass
32812	East Fundy		Balls Lake		*1*	
32904	East Fundy		Loch Lomond		*1*	
32902	East Fundy		Robertson Lake		*1*	
32747	East Fundy		Taylor Lake		*1*	
64201	Lower Saint John		Belleisle Bay	1	*1*	
57419	Lower Saint John		French Lake	1	*1*	
57400	Lower Saint John		Grand Lake	1	*1*	1
57704	Lower Saint John		Indian Lake	1	*1*	
57401	Lower Saint John		Maquapit Lake	1	*1*	
52146	Lower Saint John		Oromocto Lake	1	*1*	1
52862	Lower Saint John		South Oromocto Lake		*1*	
50684	Lower Saint John		Trout Lake		*1*	1
61800	Lower Saint John		Washademoak Lake		*1*	
52328	Lower Saint John		Yoho Lake		*1*	1
7589	Miramichi		North Lake	1	*1*	1
28326	Peticodiac		New Horton Lake		*1*	1
19243	Restigouche		States Lake		*1*	
39440	St. Croix		Goldsmiths Lake		*1*	
38504	St. Croix		Grand Lake	1	*1*	1
38658	St. Croix		La Coote Lake		*1*	
38506	St. Croix		North Lake	1	*1*	1
38651	St. Croix		Palfrey Lake	1	*1*	1
38743	St. Croix		Sixth Lake	1	*1*	
38672	St. Croix		Skiff Lake		*1*	1
38793	St. Croix		Spednic Lake	1	*1*	1
70967	Upper Saint John		First Eel Lake	1	*1*	1
70101	Upper Saint John		Mactaquac Lake	1	*1*	1
79761	Upper Saint John		Nictau Lake		*1*	
70992	Upper Saint John		Second Eel Lake	1	*1*	1
21081	West Fundy		Chamcook Lake		*1*	1
22585	West Fundy		Clear Lake		*1*	
23689	West Fundy		Crystal Lake		*1*	
23212	West Fundy	Lepreau	Cundy Lake		*1*	
23832	West Fundy		Deer Lake		*1*	1
21483	West Fundy	Magaguadavic	Digdeguash Lake		*1*	1
24052	West Fundy		East Branch Reservoir		*1*	1
23294	West Fundy		East Long Lake		*1*	
21998	West Fundy	Magaguadavic	Harvey Lake		*1*	1
21038	West Fundy		Kerrs Lake		*1*	
22467	West Fundy	Magaguadavic	Lake Anthony		*1*	
22488	West Fundy	Magaguadavic	Lake Utopia		*1*	1
21087	West Fundy		Little Chamcook Lake		*1*	1
23926	West Fundy		Little John Lake		*1*	
21848	West Fundy	Magaguadavic	Little Magaguadavic Lake	1	*1*	1
23855	West Fundy		Loch Alva		*1*	
21751	West Fundy	Magaguadavic	Magaguadavic Lake	1	*1*	1
22500	West Fundy	Magaguadavic	Mill Lake		*1*	1
23919	West Fundy		Ogden Lake		*1*	
23928	West Fundy		Robin Hood Lake		*1*	
22464	West Fundy	Magaguadavic	Sparks Lake		*1*	
22516	West Fundy	Magaguadavic	Trout Lake		*1*	1

Table 2. Summary of daily observations of spawner presence in Lake Utopia spawning tributaries. Data are pooled across years, and grouped into five-day increments for both small- and large bodied smelt.

Tributary Use	Day	5-Day Increment	Obs	Smelt Present	P(Present)
Small	01-Apr	1	4	0	0.00
	06-Apr	2	1	0	0.00
	11-Apr	3	7	2	0.29
	16-Apr	4	10	4	0.40
	21-Apr	5	14	9	0.64
	26-Apr	6	8	8	1.00
	01-May	7	18	13	0.72
	06-May	8	25	19	0.76
	11-May	9	20	15	0.75
	16-May	10	5	4	0.80
	21-May	11	4	3	0.75
	26-May	12	3	1	0.33
Large	20-Mar	1	1	0	0.00
	25-Mar	2			
	30-Mar	3	5	1	0.20
	04-Apr	4	5	2	0.40
	09-Apr	5	13	11	0.85
	14-Apr	6	7	4	0.57
	19-Apr	7	5	0	0.00
	24-Apr	8	1	0	0.00
	29-Apr	9	3	0	0.00
	04-May	10	3	0	0.00
	09-May	11	1	0	0.00

Table 3. Proportion of spawning aggregations of small- and large-bodied Lake Utopia smelts that is comprised of females, by day of year, and year of sampling.

		Small (n)			Large (n)		
Year	**Date**	**Male**	**Female**	**P(Female)**	**Male**	**Female**	**P(Female)**
2002	12-Apr				95	28	0.23
	17-Apr	1	0	0.00			
	20-Apr	23	14	0.38			
	22-Apr	102	12	0.11			
	24-Apr	99	42	0.30			
	29-Apr	6	0	0.00			
	30-Apr	19	10	0.34			
	01-May	116	13	0.10			
	06-May	29	11	0.28			
	08-May	10	1	0.09			
	09-May	5	1	0.17			
	13-May	13	2	0.13			
	Overall			**0.20**			**0.23**
2003	13-Apr				45	18	0.29
	14-Apr				117	65	0.36
	01-May	56	27	0.33			
	04-May	30	47	0.61			
	06-May	60	60	0.50			
	08-May	278	89	0.24			
	12-May	88	155	0.64			
	15-May	151	98	0.39			
	20-May	136	123	0.47			
	22-May	280	35	0.11			
	Overall			**0.37**			**0.34**
2009	16-Apr				50	11	0.18
	26-Apr	1	0	0.00			
	27-Apr	46	16	0.26			
	05-May	95	75	0.44			
	Overall			**0.39**			**0.18**
2010	14-Apr	35	50	0.59			
	20-Apr	50	42	0.46			
	Overall	85	92	**0.52**			

Table 4. Daily mark-recapture estimates acquired during 2003 on Unnamed Brook (M =Total number marked, C = total number captured during recapture phase, R =number of recaptures).

Unnamed Brook: 2003

						Recaptures of Fish Marked on Previous Days			
DATE	**Notes**	**CLIP**	**M**	**C**	**R**	**M Phase**		**R Phase**	
01-May	<1000								
04-May		UCC	300	915	17				
06-May		LCC	360	904	20			12UCC	12
08-May		LPL	440	668	4	3LCC 1UCC	4	3UCC 7 LCC	10
12-May		RPL	303	710	14		0	2LCC 1UCC	3
15-May		UCC	380	1118	20	*lostdata		4LCC 2 LPL	6
20-May		LCC	505	1078	18	1LCC 1LPL	2		0
22-May		LPL	481	393	24	1UCC 2 RPL	3		0

UCC =Upper Caudal Clip; LCC = Lower Caudal Clip; LPL = Left Pelvic; RPL = Right Pelvic

Table 5. Quantitative Bayesian estimates of spawner abundance for large-bodied and small-bodied Lake Utopia Rainbow Smelt by year, day of year, and spawning tributary.

Morph	Spawning Tributary	Year	Date	Marked (n)	Catch (n)	Recaptures (n)	Estimated Population Size (n) 95%Low	Median	Mode	95%Up
Large	**Mill Lake Stream**	2009	17-Apr-09	326	121	9	2,625	5,000	4,375	10,500
Small	**Scout**	1999	21-Apr-99	1377	1718	114	17,500	20,750	20,750	25,000
		2001	11-May-01	1298	907	59	15,750	20,000	20,250	26,250
		2003	04-May-03				0			
			08-May-03	463	918	14	19,800	30,600	33,000	58,800
			12-May-03	1121	815	17	36,000	54,000	57,000	96,000
			15-May-03	1051	322	11	19,000	31,000	34,000	66,250
			20-May-03	808	1079	29	22,000	30,000	31,000	46,000
			22-May-03	707	91	12	3,500	5,375	5,875	10,875
			24-May-03				0			
	Smelt	1999	03-May-99	345	788	86	2,600	3,150	3,150	3,900
		2001	11-May-01	2988	1151	89	32,000	48,000	38,500	38,500
		2002	01-May-02	1916	780	217	6,160	6,880	6,880	7,760
		2003	04-May-03				0			
			08-May-03	285	542	24	4,600	6,400	6,700	10,300
			12-May-03	509	420	23	6,500	9,300	9,650	15,075
			15-May-03	969	1208	22	37,000	53,000	56,000	88,000
			20-May-03	835	2768	22	72,750	104,250	109,500	174,250
			22-May-03	1285	1198	36	31,750	43,000	43,750	61,750
			26-May-03				0			
		2009	07-May-09				19,000	27,500	26,500	41,000
	Unnamed	1999	21-Apr-99	569	643	15	16,000	26,000	24,500	46,000
			03-May-99	986	600	5	65,000	155,000	120,000	425,000
		2003	04-May-03	300	915	17	10,950	16,200	17,250	29,150
			06-May-03	360	904	20	11,300	16,200	16,900	11,300
			08-May-03	440	668	4	36,000	72,000	104,000	3,332,000
			12-May-03	303	710	14	9,800	15,400	16,600	30,200
			15-May-03	380	1118	20	14,600	21,400	22,200	35,800
			20-May-03	505	1078	18	20,450	30,350	32,000	52,900
			22-May-03	481	393	24	5,625	7,825	8,250	12,625
		2009	05-May-09	256	557	3	20,500	76,500	48,500	293,500

Table 6. Distributions of land-locked Atlantic salmon into Lake Utopia: years 1980-2010.

Month	Year	Number	Age	Fin Clip	Avg. Length (mm)	Avg. Weight (g)	Source
October	1984	3528	Fall Fingerling	None			DFO Saint John
June	1985	3596	Yearling	None			DFO Saint John
June	1986	2689	Yearling	None			DFO Saint John
May	1987	3400	Yearling	None			DNRE Minto
May	1988	3400	Yearling	Adipose			DFO Saint John
	1989	0					
June	1990	3400	Yearling	Right Ventral			DNRE Minto
	1991	0					
May	1992	3400	Yearling	Adipose			DNRE Minto
	1993	0					
May	1994	3400	Yearling	Right Ventral			DNRE Minto
June	1995	595	Yearling	Both Ventrals	217.5		Atlantic Salmon Federation Chamcook
June	1995	261	Yearling	Both Ventrals	270.9		Stolt Sea Farms Ltd. Digdeguash
May	1996	3400	Yearling	Adipose	240.5		DNRE Minto
	1997	0					
June	1998	3741	Yearling	Right Ventral	242.9		Connors Bros. Lake Utopia
	1999	0					
June	2000	3150	Yearling	Left Ventral	248		Connors Bros. Lake Utopia
	2001	0					
	2002	0					
	2003	0					
	2004	0					
	2005	0					
	2006	0					
	2007	0					
	2008	0					
May	2009	3550	Yearling	Right Ventral	165	42	Mactaquac Biodiversity Center
	2010	0					

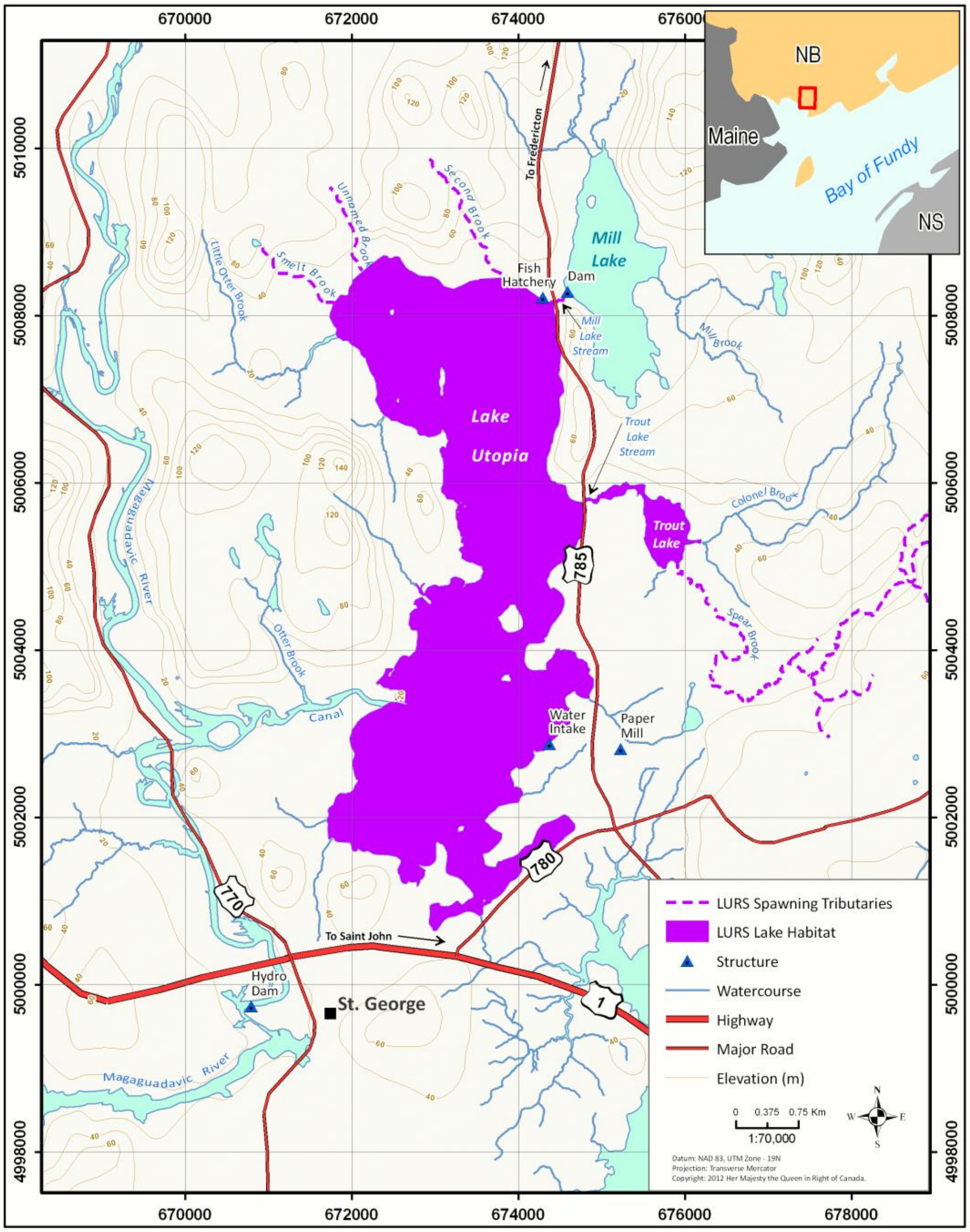

Figure 1. Lake Utopia, located in the Magaguadavic River watershed that flows into the Bay of Fundy in southwestern New Brunswick. Lake Utopia is connected to the lower Magaguadavic River via an outflow called The Canal. Spawning tributaries for the LURS are highlighted and industrial structures are also identified. (Datum: NAD83, UTM Zone 19N; Projection: Transverse Mercator; © 2011 Her Majesty the Queen in Right of Canada).

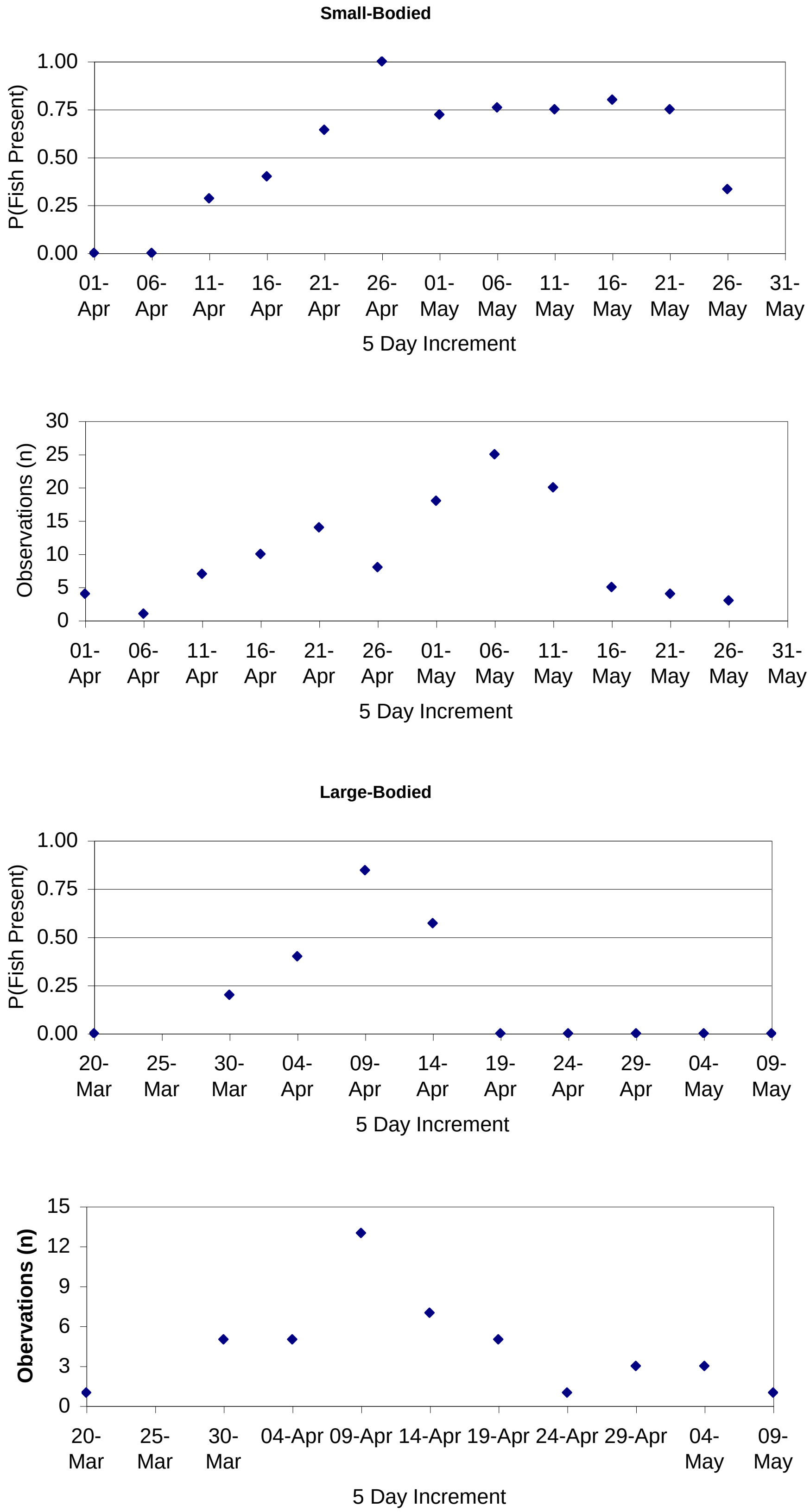

Figure 2. Proportion of observation of smelt presence in small-and large-bodied spawning tributaries and number of observations available for discrete five-day time increments pooled among years.

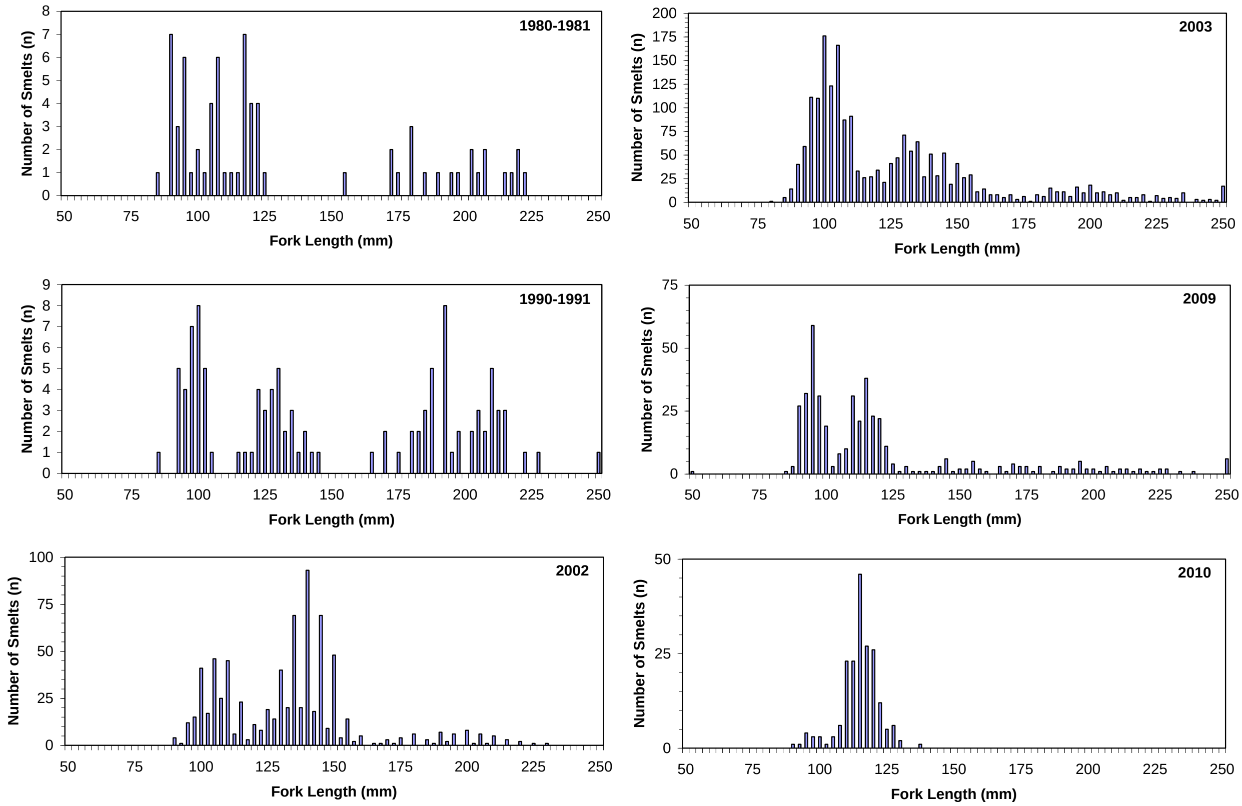

Figure 3. Length (fork, mm) frequency distributions of Lake Utopia Rainbow Smelt by year of sampling.

APPENDIX I

Table 1. Reported occurrences of Lake Utopia Rainbow Smelt for Smelt, Unnamed and Scout brooks, by Designatable Unit, spawning tributary, year, and day of year (0 =smelt not present; 1 = smelt present).

Smelt Brook	Year								
Day of Year	1981	1991	1998	1999	2002	2003	2007	2009	2010
01-Apr									
02-Apr				0					
03-Apr									
04-Apr									
05-Apr									
06-Apr									
07-Apr									
08-Apr									
09-Apr									
10-Apr									
11-Apr									
12-Apr									
13-Apr									
14-Apr									1
15-Apr				0					
16-Apr									
17-Apr					0				
18-Apr									
19-Apr									
20-Apr			1					0	1
21-Apr			1	0					0
22-Apr					1				
23-Apr									
24-Apr									
25-Apr								0	
26-Apr				1					
27-Apr									
28-Apr									
29-Apr									
30-Apr					1				
01-May					1				
02-May									
03-May				1					
04-May						0			
05-May			1					1	0
06-May					0	1			0
07-May		1						1	
08-May					1	1			
09-May									
10-May		1			1		1		
11-May		1						1	
12-May	1	1			0	1			
13-May				1	1				
14-May									
15-May						1			
16-May					1				
17-May									
18-May									
19-May									
20-May						1			
21-May					0				
22-May						1			
23-May									
24-May									
25-May									
26-May						0			
27-May									
28-May									
29-May									
30-May									
31-May									

Unnamed Brook	Year						
Day of Year	1999	1998	2002	2003	2007	2009	2010
01-Apr							
02-Apr	0						
03-Apr							
04-Apr							
05-Apr							
06-Apr							
07-Apr							
08-Apr							
09-Apr							
10-Apr							
11-Apr							
12-Apr							
13-Apr							
14-Apr							1
15-Apr	0						
16-Apr							
17-Apr			1				
18-Apr							
19-Apr							
20-Apr						0	1
21-Apr	1						1
22-Apr							
23-Apr							
24-Apr			1				
25-Apr						1	
26-Apr	1						
27-Apr						1	
28-Apr							
29-Apr							
30-Apr			1				
01-May				1			
02-May							
03-May	1						
04-May				1			
05-May		1				1	0
06-May			1	1			0
07-May						1	
08-May				1			
09-May			1				
10-May					1		
11-May						1	
12-May				1			
13-May	1		1				
14-May							
15-May				1			
16-May							
17-May							
18-May							
19-May							
20-May				1			
21-May							
22-May				1			
23-May							
24-May							
25-May							
26-May				1			
27-May							
28-May							
29-May							
30-May							
31-May							

Scout Brook	Year						
Day of Year	1998	1999	2002	2003	2007	2009	2010
01-Apr							
02-Apr		0					
03-Apr			0				
04-Apr							
05-Apr							
06-Apr							
07-Apr							
08-Apr			0				
09-Apr							
10-Apr							
11-Apr			0				
12-Apr							
13-Apr							
14-Apr							
15-Apr		0					0
16-Apr							
17-Apr			0				
18-Apr							
19-Apr							
20-Apr						0	0
21-Apr		1					0
22-Apr			1				
23-Apr							
24-Apr			1				
25-Apr						0	
26-Apr		1					
27-Apr							
28-Apr							
29-Apr			1				
30-Apr			1				
01-May			1				
02-May							
03-May		1					
04-May				0			
05-May	1					1	0
06-May			1	1			0
07-May			0			1	
08-May				1			
09-May							
10-May			0		1		
11-May						0	
12-May			0	1			
13-May		0	0				
14-May							
15-May				1			
16-May			0				
17-May							
18-May							
19-May							
20-May				1			
21-May							
22-May				1			
23-May							
24-May							
25-May							
26-May				0			
27-May							
28-May							
29-May							
30-May							
31-May							

Table 2. Reported occurrences of Lake Utopia Rainbow Smelt for Mill Lake and Trout Lake streams by Designatable Unit, spawning tributary, year, and day of year (0 =smelt not present; 1 = smelt present).

Mill Lake Stream								Trout Lake Stream			
	Year								Year		
Day of Year	1922	1980	1999	2002	2003	2009	2010	Day of Year	1991	2002	2003
20-Mar								20-Mar			
21-Mar								21-Mar			
22-Mar							0	22-Mar			
23-Mar								23-Mar			
24-Mar								24-Mar			
25-Mar								25-Mar			
26-Mar								26-Mar			
27-Mar								27-Mar			
28-Mar								28-Mar			
29-Mar								29-Mar			
30-Mar								30-Mar			
31-Mar								31-Mar			
01-Apr						0		01-Apr			
02-Apr			1		0			02-Apr			
03-Apr				0	0			03-Apr			
04-Apr				0				04-Apr			
05-Apr						0[1]		05-Apr			
06-Apr						0[1]		06-Apr			
07-Apr		1			0			07-Apr			
08-Apr				0				08-Apr	1		
09-Apr				0				09-Apr	1		
10-Apr					0			10-Apr	1		
11-Apr	1			1				11-Apr	1		
12-Apr				1				12-Apr	1	1	
13-Apr					1	0[1]		13-Apr	1		1
14-Apr					1			14-Apr			1
15-Apr			0				0	15-Apr			
16-Apr				0		1		16-Apr			
17-Apr						1		17-Apr			
18-Apr								18-Apr			
19-Apr							0	19-Apr			
20-Apr								20-Apr			
21-Apr			0				0	21-Apr			
22-Apr				0			0	22-Apr			
23-Apr								23-Apr			
24-Apr								24-Apr			
25-Apr								25-Apr			
26-Apr			0					26-Apr			
27-Apr								27-Apr			
28-Apr								28-Apr			
29-Apr				0				29-Apr			
30-Apr								30-Apr			
01-May				0				01-May			
02-May								02-May			
03-May			0					03-May			
04-May								04-May			
05-May							0	05-May			
06-May				0			0	06-May			
07-May								07-May			
08-May								08-May			
09-May								09-May			
10-May								10-May			
11-May								11-May			
12-May								12-May			
13-May			0					13-May			
14-May								14-May			
15-May								15-May			

	M1922	L&A19	Cetal2	Cetal1	DFO/U	DFO/U	NBDNR		DFO	DFO	T&B1993b
	1922	1980	1998	1999	2002	2003	2007		2009	2010	1991

APPENDIX II

Table 1. Summary of human induced threats to specific habitat attributes, the effect to be mitigated, present mitigation, options to reduce effect, monitoring and research activities to help assess effects and the effect on both populations of rainbow smelt under current management strategies. The location (lake or spawning tributary) of the effect is also identified.

Attributes	Human Induced Threats	Effect to be Mitigated	Present Mitigation	Options to Reduce Effect	Monitoring and/or Research Activities to Help Assess Effects	Effect Under Current Management Strategies			
						Small-bodied		Large-bodied	
						Individuals	Location of Effect	Individuals	Location of Effect
Water Quality	Hatchery Effluent (Inside Lake Utopia)	Increased nutrient load causing trophic status change (eutrophication); other contamination. Accumulation of nutrients in the sediment.	Compliance with existing standards and regulations as set out in the Clear Water Act and Pesticide Control Act. Reduced nutrient load of hatchery effluent and recent (July 2008) incorporation of a low phosphorous feed (Lake Utopia facility).	"Treat, reduce, or eliminate effluent. Regulate for Reduced Nutrient Load. Dredging and chemically neutralizing. "	Research and monitoring to help assess impacts on trophic structure of the lake.	Medium	Lake	Medium	Lake
Water Quantity	Hatchery Effluent (outside Lake Utopia)	Increased nutrient load causing trophic status change (eutrophication); other contamination.	Compliance with existing standards and regulations as set out in the Clear Water Act and Pesticide Control Act	"Treat, reduce, or eliminate effluent. Manage Flows to and from Lake Utopia to promote flushing. Regulate for Reduced Nutrient Load "	Hydrological study required to support development of a management strategy.	Low	Lake	Low	Lake
Water Quantity	Inputs from Magaguadavic River (non-point sources)	Increased nutrient load causing trophic status change (eutrophication); other contamination.	Compliance with existing regulations	Manage Flows to and from Lake Utopia to promote flushing. Stewardship programs and public awareness	Hydrological study required to support development of a management strategy. Investigate impacts of agri-chemical use.	Low	Lake	Low	Lake

Attributes	Human Induced Threats	Effect to be Mitigated	Present Mitigation	Options to Reduce Effect	Monitoring and/or Research Activities to Help Assess Effects	Effect Under Current Management Strategies			
						Small-bodied		Large-bodied	
						Individuals	Location of Effect	Individuals	Location of Effect
Water Quantity	Residential and Recreational Inputs (non-point sources)	Increased nutrient load causing trophic status change (eutrophication); other contamination.	"Compliance with existing regulations as set out in the Clean Water Act, Pesticide Control Act and Clean Environment Act "	Divert domestic waste water away from the lake. Continue to conduct shoreline audits to assess change in inputs with time. Stewardship programs and public awareness.		Medium	Lake	Medium	Lake
Water Quantity	Agriculture/silviculture (Herbicides and pesticides)	Unknown health effects	Legislation (Pesticide Control Act) to control spraying around watercourses is currently in place.	Organic control of undesirable vegetation and/or insects.	Monitor for presence of herbicides/ pesticides in spawning streams.	Low	Lake/Stream	Low	Lake/Strea m
Water Quantity	Cumulative Effluent (all Sources)	Increased nutrient load causing trophic status change (eutrophication); other contamination.	All the above	All the above plus adopting a watershed management approach	Develop a nutrient load model for the lake.	Medium	Lake	Medium	Lake
Water Quantity	Water Level Fluctuations due to hydro-electric dam operation	Impede access to spawning sites; submergence of spawning sites; stranding and drying out of eggs	Operational definitions of water levels are identified in Fisheries Management Plan for the hydroelectric generating facility in St. George	Assess spawning habitat requirements and current availability and use under present water level management plan. Manage lake levels to match biological requirements of smelt.	Establish lake level targets relative to stream elevations during spawning.	High	Stream	High	Stream
Water Quantity	Water Level Fluctuations due to hydro-electric dam operation	Potential of flushing of larvae from the lake.	None	Water management considerations in a fisheries management plan if required.	Research to develop requirements to assess potential for larval flushing.	Low	Lake	Low	Lake
Water Quantity	Water Withdrawal for Paper Mill	Impede access to spawning sites.	None	Alternative water supply. Reduce water withdrawal.	Determine impact of water withdrawal on	Low	Lake	Low	Lake

Attributes	Human Induced Threats	Effect to be Mitigated	Present Mitigation	Options to Reduce Effect	Monitoring and/or Research Activities to Help Assess Effects	Effect Under Current Management Strategies			
						Small-bodied		Large-bodied	
						Individuals	Location of Effect	Individuals	Location of Effect
					access to spawning sites.				
Direct Mortality	Entrainment at Intakes for Paper Mill and Hatchery	Direct mortality	Compliance with DFO's "Freshwater Intake End-of-Pipe Fish Screen Guideline".	Alternative water supply.	Monitor water supplies for entrained smelt.	Low	Lake	Low	Lake
Direct Mortality	Directed Fisheries	Direct mortality on Adults. Destruction of egg mats while dipnetting.	Compliance with existing regulations as set out under the Fisheries Act and the Fish and Wildlife Act. Smelt dip net fishery has season and gear restrictions and a daily bag limit.	Close directed fishery.	Assess status of Lake Utopia rainbow smelt and fishery.	Low	Stream	Medium	Stream
Direct Mortality	Bycatch in Recreational Angling Fishery	Handling mortality	Compliance with existing regulations as set out under the Fisheries Act and the Fish and Wildlife Act.	Varied season closures or gear restrictions.	Assess status of Lake Utopia rainbow smelt and fishery.	Low	Lake	Low	Lake
Direct Mortality	Predation (stocked fish)	Increase in rate of predation on Lake Utopia smelt.	Stocking at a rate designed to minimize impact on the smelt population.	Stop stocking.	Assess status of Lake Utopia rainbow smelt and fishery.	Low	Lake	Low	Lake
Direct Mortality	Predation (aquaculture escapees)	Increase in rate of predation on Lake Utopia smelt.	I&T regulations and provincial regulations	Implement escapement reduction techniques at all hatcheries located within the Magaguadavic River drainage.	Monitor effectiveness of escapement reduction techniques at hatcheries.	Low	Lake	Low	Lake
Direct Mortality	Aquatic Invasive Species (Chain Pickerel Esox niger; naturalized in the Magaguadavic system)	"Competition, predation, displacement, community shift"	Regulations as set out under the Fisheries (General) Regulations	Eradicate non-indigenous species	Acquire information on Chain Pickerel-Smelt interactions in other systems	Medium	Lake	High	Lake/Stream

Attributes	Human Induced Threats	Effect to be Mitigated	Present Mitigation	Options to Reduce Effect	Monitoring and/or Research Activities to Help Assess Effects	Effect Under Current Management Strategies			
						Small-bodied		Large-bodied	
						Individuals	Location of Effect	Individuals	Location of Effect
Direct Mortality	Aquatic Invasive Species (Largemouth Bass and others; non-naturalized)	"Competition, predation, displacement, community shift"	Regulations as set out under the Fisheries (General) Regulations	Control access at fishway.	Acquire information on Smelt-Largemouth Bass and other(s) interactions in other systems	Low	Lake	Low	Lake
Direct Mortality	Aquatic Invasive Species (Smallmouth Bass; naturalized)	"Competition, predation, displacement, community shift"	Regulations as set out under the Fisheries (General) Regulations	Reduce and control numbers	Acquire information on Smelt-Smallmouth Bass within Lake Utopia	Low	Lake	Low	Lake
Direct Mortality	ATV and foot traffic in/around spawning areas	Destruction of eggs. Introduction of deleterious substances.	"Compliance with existing legislation as set out in the Off-Road Vehicle Act, Clean Water Act, Fisheries Act, and SARA"	"Enforcement of current legislation. Signage, education and targeted public awareness initiatives.Increase presence of enforcement personnel"		Low	Stream	Low	Stream
Direct Mortality	Scientific Research	Lethal sampling and/or incidental harm results in mortality.	"Sampling authorized under Section 52 F(G)R, \section 73(SARA). "	"Do not authorize lethal sampling. Archived collections available at the Atlantic Resource Center, Huntsman Marine Science Center. 'Low' number of removals. Review all proposed research programs, incorporate conditions on Section 73 (SARA) permits. "		Low	Stream	Low	Stream
Direct Mortality	Hatchery Effluent (Inside Lake Utopia)	Increased parasite load; disease transfer	Fisheries Act - Fish Health Protection Regulations	Treat effluent; recirculation facility	Monitor fish health	Low	Lake	Low	Lake
Impacts on Habitat	Forestry on Crown and Private land	"Increased siltation, flow alterations, reduced water quality, reduce	Compliance with existing legislation as set out under the Crown Land and	Stop or reduce activity. Alternative harvest options. Develop and distribute best	Assess effectiveness of existing regulations as applied to	High	Stream	Low	Stream

Attributes	Human Induced Threats	Effect to be Mitigated	Present Mitigation	Options to Reduce Effect	Monitoring and/or Research Activities to Help Assess Effects	Effect Under Current Management Strategies: Small-bodied Individuals	Small-bodied Location of Effect	Large-bodied Individuals	Large-bodied Location of Effect
		food supply. Altered water temperatures in spawning tributaries. Change in timing of water discharge patterns (seasonal)."	Forest Act and Fisheries Act and best management practices	management practices. Education of land owners.	small streams.				
Impacts on Habitat	Stream Blockages associated with man-made structures	Alteration of spawning habitat.	Ad Hoc: Debris cleared from structures when noted	Replace culverts with a bridge. Remove beaver colonies. Monitoring through increased stewardship to identify stream blockages.		Low	Stream	High	Stream
Impacts on Habitat	ATV and foot traffic in/around spawning areas	Alteration of spawning habitat.	"Compliance with existing legislation as set out in the Off-Road Vehicle Act, Clean Water Act, Fisheries Act, and SARA"	"Enforcement of current legislation. Signage, education and targeted public awareness initiatives. Increase presence of enforcement personnel"	Monitoring through stewardship and reporting of activities	Low	Stream	Low	Stream
Impacts on Habitat	Residential/urban development within the watersheds	"Increased siltation, flow alterations, reduced water quality, reduce food supply. Altered water temperatures in spawning tributaries. Change in timing of water discharge patterns (seasonal)."	"Compliance with existing legislation as set out under the Fisheries Act, Canadian Environmental Assessment Act, and Clean Environment Act"	Watershed management. Education of land owners.	Assess spawning and rearing habitat requirements and current effectiveness of existing regulatory frameworks to protect fish habitat.	High	Stream	Low	Stream