Protocols for monitoring spawning populations of Lake Utopia Rainbow Smelt (*Osmerus mordax*)

D. MacDonald and C. Burbidge

Fisheries and Oceans Canada
Maritimes Region
Bedford Institute of Oceanography
1 Challenger Drive
Dartmouth, Nova Scotia
B2Y 4A2

2017

Canadian Technical Report of
Fisheries and Aquatic Sciences 3195

Fisheries and Oceans Canada | Pêches et Océans Canada

Canada

Canadian Technical Report of Fisheries and Aquatic Sciences

Technical reports contain scientific and technical information that contributes to existing knowledge but which is not normally appropriate for primary literature. Technical reports are directed primarily toward a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of Fisheries and Oceans Canada, namely, fisheries and aquatic sciences.

Technical reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in the data base *Aquatic Sciences and Fisheries Abstracts*.

Technical reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page.

Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457-714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715-924 were issued as Department of Fisheries and Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Rapport technique canadien des sciences halieutiques et aquatiques

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. II n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques de Pêches et Océans Canada, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications à part entière. Le titre exact figure au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la base de données *Résumés des sciences aquatiques et halieutiques.*

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre.

Les numéros 1 à 456 de cette série ont été publiés à titre de Rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de Rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés à titre de Rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

Canadian Technical Report of
Fisheries and Aquatic Sciences 3195

2017

Protocols for monitoring spawning populations of Lake Utopia Rainbow Smelt (*Osmerus mordax*)

by

D. MacDonald and C. Burbidge

Fisheries and Oceans Canada
Maritimes Region
Bedford Institute of Oceanography
1 Challenger Drive
Dartmouth, Nova Scotia
B2Y 4A2
Email: Danielle.MacDonald@dfo-mpo.gc.ca

Cat. No. Fs97-6/3195E-PDF ISBN 978-0-660-07143-5 ISSN 1488-5379

Correct citation for this publication:

MacDonald, D. and Burbidge, C. 2017. Protocols for monitoring spawning populations of Lake Utopia Rainbow Smelt (*Osmerus mordax*). Can. Tech. Rep. Fish. Aquat. Sci. 3195. iv + 51 pg.

TABLE OF CONTENTS

ABSTRACT

MacDonald, D. and Burbidge, C. 2017. Protocols for monitoring spawning populations of Lake Utopia Rainbow Smelt (*Osmerus mordax*). Can. Tech. Rep. Fish. Aquat. Sci. 3195. iv + 51 pg.

Two populations of Rainbow Smelt (LURS) co-exist in Lake Utopia: a small-bodied form (SbP) listed as threatened under the Species at Risk Act (SARA), and a large-bodied form (LbP) under consideration for listing under SARA. The two populations differ in physical characteristics, life-history, and are reproductively isolated. This report outlines methods (and provides corresponding data collection forms) for monitoring the occupation and spawning by LURS in their Lake Utopia spawning streams and includes four activities: 1) Annual monitoring for the occupation (presence or absence) of LURS in specified spawning streams; 2) Annual monitoring for the presence of obstructions and barriers in specified LURS spawning streams; 3) Monitoring water depth in Mill Lake Stream; and 4) Nighttime monitoring in Mill Lake Stream in support of LURS-LbP abundance surveys. Following these protocols should promote a consistent approach to measuring progress towards survival and recovery of LURS as outlined in their Recovery Strategy and Action Plan.

RÉSUMÉ

Deux populations d'éperlans arc-en-ciel coexistent dans le lac Utopia : l'une composée d'éperlans de petite taille (petits éperlans) inscrits comme espèce menacée en vertu de la *Loi sur les espèces en péril* (LEP), et l'autre d'éperlans de grande taille (grands éperlans) à l'étude aux fins d'inscription en vertu de la LEP. Ces populations diffèrent de par leurs caractéristiques physiques, leur cycle biologique et elles ne s'accouplent pas entre elles. Le présent rapport décrit les méthodes (et fournit les formulaires de collecte des données correspondants) pour la surveillance de l'occupation du lac Utopia par les éperlans arc-en-ciel et de leur frai dans leurs cours d'eau de frai. Il rend compte de quatre activités : 1) la surveillance annuelle de la présence ou de l'absence des éperlans arc-en-ciel du lac Utopia dans les cours d'eau de frai déterminés; 2) la surveillance annuelle de la présence d'obstacles dans les cours d'eau de frai déterminés; 3) la surveillance de la profondeur de l'eau dans la décharge du lac Mill; 4) la surveillance de nuit de la décharge du lac Mill à l'appui des relevés d'abondance des éperlans arc-en-ciel de grande taille. Suivre ces protocoles devrait favoriser l'adoption d'une approche uniforme de mesure des progrès réalisés pour la survie et le rétablissement de l'éperlan arc-en-ciel du lac Utopia, comme il est indiqué dans le programme de rétablissement et le plan d'action pour l'espèce.

1. OVERVIEW

1.1 INTRODUCTION

The purpose of this technical report is to provide guidelines and procedures for monitoring in support of the Government of Canada's Recovery Strategy and Action Plan for Lake Utopia Rainbow Smelt (*Osmerus mordax*), Small-bodied Population (sympatric with the Large-bodied Population), in Canada (DFO 2016a, DFO 2016b). Two populations of Rainbow Smelt co-exist in Lake Utopia (collectively referred to as LURS), a small-bodied form known as the Small-bodied Population (SbP) and a large-bodied form known as the Large-bodied Population (LbP). These two populations differ in physical characteristics, life-history and are reproductively isolated (Taylor and Bentzen 1993; COSEWIC 2008, DFO 2011).

The SbP (formerly referred to as Lake Utopia Dwarf Smelt) was designated as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1998, 2000, and 2008. In 2003, this population was listed as Threatened under Schedule 1 of the federal *Species at Risk Act* (SARA). The LbP was designated as Threatened by COSEWIC in 2008 and is currently under consideration for listing under SARA. As such, SARA prohibitions do not apply to the LbP at this time.

As the lead federal agency responsible for recovery of aquatic species listed under SARA, Fisheries and Oceans Canada (DFO) recognizes the important role partner organizations can play in carrying out stewardship and recovery activities in support of achieving population objectives for species at risk. The monitoring protocols described in this report are intended to facilitate collaboration between DFO and its partners and to promote a consistent and efficient approach to monitoring progress towards survival and recovery of Lake Utopia Rainbow Smelt (LURS).

The Recovery Strategy for the SbP (DFO 2016a) emphasizes the interconnectedness of the two LURS populations by setting the following broad recovery goal:

> *Maintain the current population distribution and abundance of the small-bodied and large-bodied populations of Lake Utopia Rainbow Smelt and the genetic diversity of the Lake Utopia Rainbow Smelt sympatric species pair.*

To achieve this goal, the conservation of one population is essential to the survival of the other. Therefore, the Recovery Strategy focuses on both the SbP and the LbP and identifies the following population objectives:

- **Genetic Objective**:
    - Maintenance of the genetic diversity and genetic differentiation of LURS within the Lake Utopia system.

- **Abundance Objectives**:
    - Small-bodied Population: 100,000 spawning fish distributed among Second Brook, Unnamed Brook, and Smelt Brook during nights of peak spawning.
    - Large-bodied Population: 2,000 spawning fish in Mill Lake Stream during nights of peak spawning.

- **Distribution Objectives**:
    - Small-bodied Population: Occupation of Lake Utopia year round and annual, synchronous occupation of Second Brook, Unnamed Brook and Smelt Brook for spawning, with no individual stream to be unoccupied for two consecutive years.
    - Large-bodied Population: Occupation of Lake Utopia year round and annual occupation of Mill Lake Stream for spawning.

These population objectives guide the development and implementation of recovery activities for LURS, and provide the basis for monitoring and reporting on the implementation of the Recovery Strategy.

This report outlines monitoring methods (and provides corresponding data collection form templates) for four types of activities in support of LURS survival and recovery and implementation of the Recovery Strategy:

1. Annual monitoring for the occupation (presence or absence) of LURS in specified spawning streams
2. Annual monitoring for the presence of obstructions and barriers in specified LURS spawning streams
3. Monitoring water depth in Mill Lake Stream
4. Nighttime monitoring in Mill Lake Stream in support of LURS-LbP abundance surveys

2. LAKE UTOPIA RAINBOW SMELT BIOLOGY

2.1 DESCRIPTION

Physical features of LURS are shown in Figure 1 and include:

- slender, streamlined, laterally compressed body (flattened from side to side)
- elongated head with pointed snout
- pale green to dark blue back; silver and blue sides, purple and pink iridescence; slivery white belly
- small adipose fin located between dorsal fin and tail fin
- deeply forked tail fin

- prior to spawning, males develop tubercles (small, rounded bumps) on the head, body, and fins
- eggs are semi-transparent and measure 0.9 to 1.3 mm in diameter.

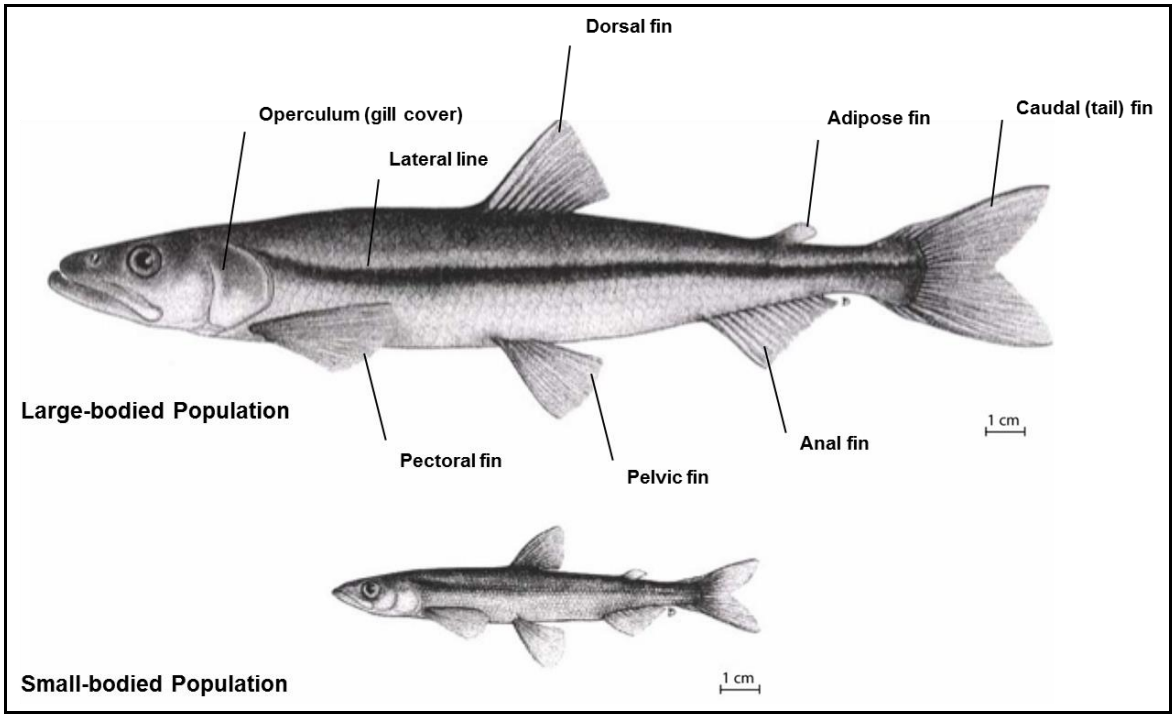

Figure 1. Diagram showing physical features of Lake Utopia Rainbow Smelt, Small-bodied population and Large-bodied population.

Distinguishing characteristics of smelt populations include physical characteristics such as total length, and biological characteristics like spawning location (Table 1) and time of spawning (Table 2 and 3).

Table 1. In-stream visual characteristics of Small-bodied and Large-bodied Lake Utopia Rainbow Smelt.

Characteristic	Small-bodied Population	Large-bodied Population
Maximum fork length	Generally less than 170 mm	Generally larger than 170 mm
Spawning streams	Second Brook, Unnamed Brook, Smelt Brook, Mill Lake Stream	Mill Lake Stream, Trout Lake Stream, Spear Brook

2.2 REPRODUCTION AND DISTRIBUTION

The two LURS populations are reproductively isolated both temporally and spatially (Table 2 and 3). The LbP spawns first in the spring season; their spawning period is approximately 5-10 days from late March to mid-April around ice break-up in Lake Utopia and when spawning stream water temperatures are less than 6°C (Table 2;

Curry et al. 2004; MacDonald 2017). They are known to spawn primarily in Mill Lake Stream and their eggs have also been observed in Trout Lake Stream and in Spear Brook (Curry 2004, MacDonald 2017) (Figure 2).

Table 2. Timing of in-stream life processes of Lake Utopia Rainbow Smelt, Large-bodied Population. The timing of these life processes varies from year to year and the shaded areas represent the range of possible periods for each life process based on historic records.

LIFE PROCESS	MONTH																			
	MARCH				APRIL				MAY				JUNE				JULY			
Spawning (5-10 days)																				
Egg Incubation (~ 3 weeks)																				
Larval Dispersal																				

The SbP spawns later in the spring, over a 2-4 week period from late April to early May when spawning stream water temperatures are between 6°C and 9°C (Table 3; Curry et al 2004; MacDonald 2017). The SbP is known to spawn in three small streams at the north end of Lake Utopia: Smelt Brook (also known as Mill Brook), Unnamed Brook and Second Brook (also known as Scout Brook) (Figure 2) and recent information suggests they may spawn in Mill Lake Stream as well (IKANAWTIKET Environmental Incorporated 2014a, 2014b, DFO 2016c).

Table 3. Timing of instream life processes of Lake Utopia Rainbow Smelt, Small-bodied Population. The timing of these life processes varies from year to year and the shaded areas represent the range of possible periods for each life process based on historic records.

LIFE PROCESS	MONTH																			
	MARCH				APRIL				MAY				JUNE				JULY			
Spawning (2-4 weeks)																				
Egg Incubation (~ 4 weeks																				
Larval Dispersal																				

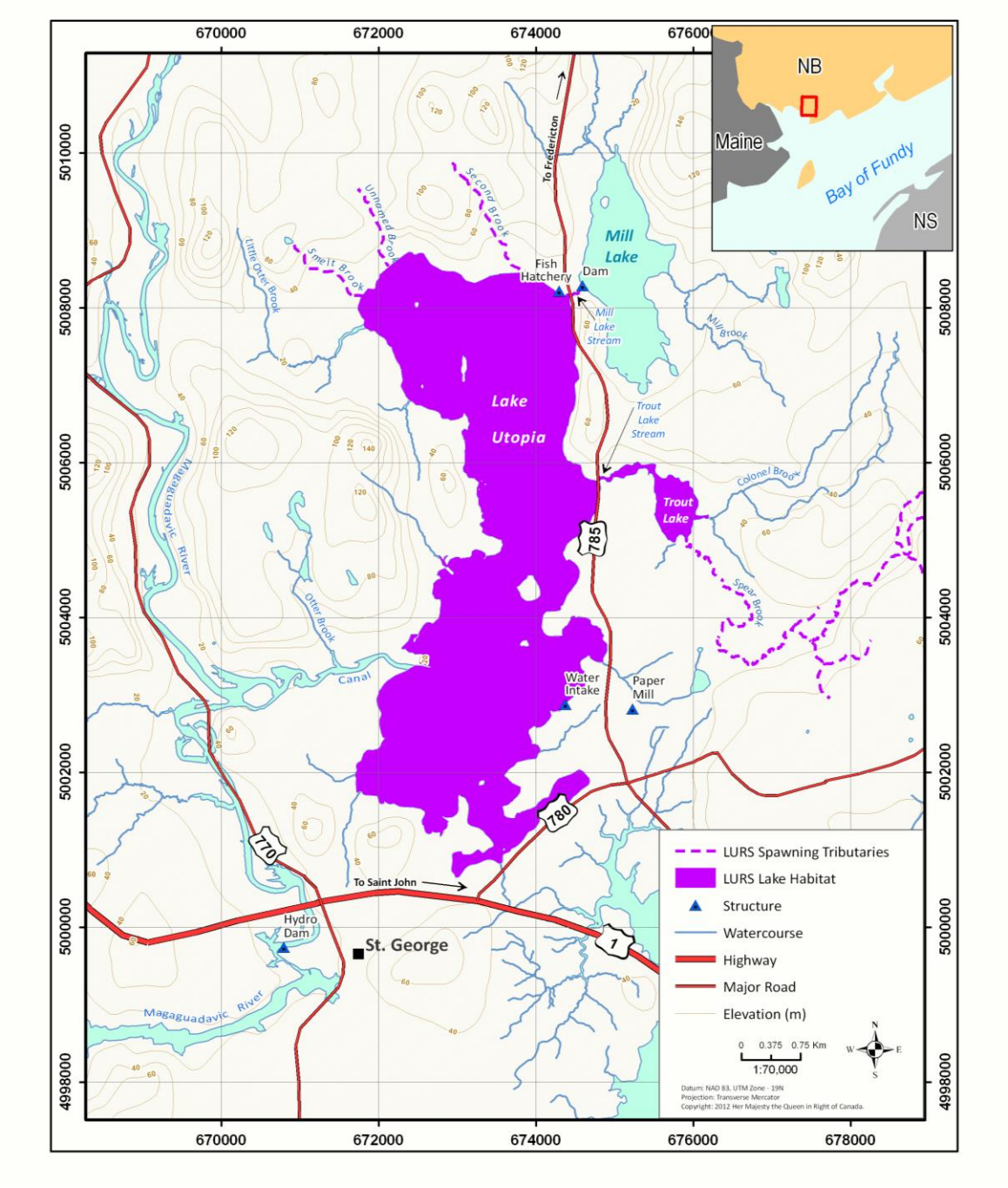

Figure 2. Lake Utopia, New Brunswick and its tributaries. (Datum: NAD83, UTM Zone 19N; Projection: Transverse Mercator; © 2011 Her Majesty the Queen in Right of Canada).

LURS are nighttime spawners and both the SbP and the LbP ascend the streams at night to spawn with the majority of spawning occurring at night between 9:30 PM and 4:30 AM, and peak spawning activity occurring between 12:00 AM and 1:30 AM (Curry et al. 2004). Females typically return to the lake during the day, while some males may remain in the spawning streams during the day (Figure 3). SbP spawners are more likely to be present in streams during the daytime than LbP spawners.

Figure 3. School of Lake Utopia Rainbow Smelt in Smelt Brook, May 5, 2015. Photo credit: Fisheries and Oceans Canada, Maritimes Region.

Rainbow Smelt lay adhesive eggs near the stream bottom (Rothschild 1961, Scott and Crossman 1973), creating egg mats that are often several eggs thick (Figure 4). Dead or dying eggs can be distinguished by colour changes from translucent to white (Figure 5). Depending on temperature, viable eggs incubate for approximately 3 weeks for the LbP and 4 weeks for the SbP (Tables 2 and 3; Curry et al. 2004, Shaw 2006) before hatching as larvae hatch and drifting downstream into the lake.

Figure 4. Smelt and eggs of Lake Utopia Rainbow Smelt over a sand substrate in Smelt Brook, May 5, 2015 (upper panel) and close-up of an egg mat on substrate in Smelt Brook, May 5, 2015 (lower panel). Photo credit: Fisheries and Oceans Canada, Maritimes Region.

Figure 5. Desiccated eggs (white dots) of Lake Utopia Rainbow Smelt adhered to a rock in Unnamed Brook, May 5, 2015. Photo credit: Fisheries and Oceans Canada, Maritimes Region.

2.3 SPAWNING HABITAT

LURS are year-round residents of Lake Utopia and use specific streams that drain into the lake as spawning habitat. Spawning substrates are similar for both LURS populations, consisting of one or more of the following: sand, gravel, rock, aquatic vegetation and wood debris. Eggs typically appear in small clusters early in the spawning period and may form mats as the spawning period progresses. LURS generally ascend and occupy the stream between the mouth (above the beaches at the lakeshore) and either an obstruction or abrupt increase in stream gradient (DFO 2011). A change in vertical height of just a few centimeters can prevent upstream movement of LURS (DFO 2017). The upper limit of spawning habitat in each of the LURS spawning streams was previously defined based on permanent or semi-permanent natural barriers (could eventually break down but is made up of a lot of structure) and were described in the Recovery Strategy (DFO 2016a).

2.3.1 Second Brook, Unnamed Brook, and Smelt Brook

Moving from east to west, Second Brook, Unnamed Brook, and Smelt Brook are small streams that flow out of upland, forested areas and through natural sandy beaches along the north shore of Lake Utopia (Figure 2). All three streams are shallow, average

1 m in width, and provide limited accessible spawning habitat due to the presence of natural barriers (Curry et al. 2004; DFO 2011). Water velocities in these streams are estimated to be less than 0.1 m per second, and spawning substrates include sand, gravel, rock, aquatic vegetation, and wood debris (Curry et al. 2004; DFO 2011; MacDonald 2017). Temporary barriers downstream of the upper limit of spawning habitat may limit the area of accessible spawning habitat for the SbP for a short or longer period of time depending on its structure. Collected organic material such as branches and leaves commonly create temporary barriers on Second and Smelt brooks.

2.3.2 Mill Lake Stream

Mill Lake Stream is one of the two largest tributaries of Lake Utopia (the other is Trout Lake Stream) and is located at the northeastern end of Lake Utopia (NATECH 2009). It flows southwest from Mill Lake for approximately 200 m discharging into Lake Utopia along its northeastern shore (Figure 2). The stream averages 4 m in width and less than 1 m depth with water velocities reaching 1 m per second (Curry et al. 2004). A rock dam (equipped with a sluice gate) at the outflow of Mill Lake prohibits upstream migration of fish into the lake from the stream (Figure 6a). A small waterfall, approximately 0.5 m high, acts as a hard barrier to the upstream migration of LURS and limits the accessible spawning habitat to the 30 m section downstream of the waterfall to the mouth of the stream, except during high flow conditions (Table 5, Figure 7; DFO 2011). Mill Lake Stream flows through two corrugated metal culverts (Figures 6b and 6c) under New Brunswick Route 785. The southern culvert serves as the primary stream channel because it is larger and situated at a lower elevation than the northern culvert, and is therefore considered the ‘primary culvert’ (Figure 6b). Both culverts are prone to seasonal blockages created by beaver dams which can inhibit LURS spawning. In Mill Lake Stream, eggs are commonly laid along the stream edges and may also be seen on larger rocks in riffles.

Figure 6a. Rock dam at the outflow of Mill Lake into Mill Lake Stream (45.206494°N 66.776860°W). Photo credit: Fisheries and Oceans Canada, Maritimes Region.

Figure 6b. Primary culvert at the outflow of Mill Lake Stream into Lake Utopia. Photo credit: Fisheries and Oceans Canada, Maritimes Region.

Figure 6c. Secondary culvert at the outflow of Mill Lake Stream into Lake Utopia. Photo credit: Fisheries and Oceans Canada, Maritimes Region.

Figure 7. Small waterfall representing the upper limit of spawning habitat for LURS in Mill Lake Stream (45˚12'21"N, 66˚46'38"W). Photo credit: Fisheries and Oceans Canada, Maritimes Region.

3. PLANNING A MONITORING PROGRAM

3.1 ROLES AND RESPONSIBILITIES

The roles and responsibilities of various groups and organizations in the implementation of this monitoring plan are outlined below.

Species at Risk Management Division, DFO Maritimes Region

- Serves as a central point of contact for the coordination of LURS recovery, stewardship and monitoring activities carried out by DFO and its partners.
- Leads and coordinates, through cooperation and consultation with others, the development of LURS recovery documents (recovery strategies, action plans, and five year progress reports) required under SARA.
- Coordinates and facilitates where needed the implementation of recovery measures in support of the survival and recovery of LURS as outlined in recovery documents.

Science Branch, DFO Maritimes Region

- Provides scientific advice related to the survival and recovery and the development of recovery documents and monitoring protocols based on best available scientific information.
- Conducts and/or supervises research and monitoring activities in support of LURS survival and recovery.
- Assesses, obtains required permits, and removes barriers in smelt spawning streams that were identified by the stewardship and monitoring partners.

Stewardship and Monitoring Partners

- Leads or participates in stewardship and monitoring activities that support the implementation of the LURS Recovery Strategy and Action Plan.
- Secures funding sources to carry out stewardship and monitoring activities that support implementation of the LURS Recovery Strategy and Action Plan (e.g., Habitat Stewardship Program for Species at Risk, Aboriginal Fund for Species at Risk, etc.).
- Participates in established LURS recovery implementation coordination groups as appropriate.
- Obtains all required permits and approvals before undertaking activities outside the scope of the monitoring activities described in this report (see Section 3.2 below).
- Fulfills reporting requirements as described in section 4 of this report as well as in any applicable funding agreements.

3.2 PERMITS AND APPROVALS

SARA includes prohibitions that protect endangered, threatened, and extirpated species (Section 32), their residences (Section 33), and their critical habitat (Section 58). Provided specific criteria can be met, SARA allows activities that would otherwise be prohibited to proceed through the issuance of permits or agreements under Section 73 and 74. Partners interested in undertaking LURS monitoring work must contact Fisheries and Oceans Canada, Species at Risk Management Division (Dartmouth, Nova Scotia, SpeciesatRisk.xmar@dfo-mpo.gc.ca) several months prior to undertaking monitoring activities to confirm whether or not a Species at Risk Act Permit is needed. For more information on SARA permits: http://www.dfo-mpo.gc.ca/species-especes/sara-lep/permits-permis/index-eng.html

Note: Partners are not to remove any stream barriers themselves. Any necessary permits/approvals and activities associated with the removal of barriers will be coordinated by DFO.

3.3 ACCESS TO MONITORING SITES

This section provides an overview of access considerations and constraints related to the various LURS monitoring sites.

3.3.1 Second Brook, Unnamed Brook, and Smelt Brook

The three SbP spawning streams are located on privately owned lands and can be accessed via land through these properties, but prior permission from the landowners is required to cross these lands in order to access these streams. Access over land is via a private road (Sandleigh Lane) off Route 785 at the northeastern end of the lake and then by hiking along the shoreline and beaches. These streams are also accessible via water by boat, which provides the easiest means of access regardless of lake levels, but landowner permission to access these streams is still required. Two public boat launch areas are available on Lake Utopia: one on the west side of the lake at the Lake Utopia Beach and Boat Launch in the community of Canal near the inflow of the Canal waterway into Lake Utopia, the other at MacLean Beach Lane at the mouth of Trout Lake Stream on the east side of the lake (Figure 2). Boats can be beached near the mouth of each stream and upstream areas accessed by hiking along the streams' edges.

3.3.2 Mill Lake Stream

Mill Lake Stream can be accessed at its intersection with New Brunswick Route 785 which roughly follows the eastern shoreline of the lake (Figure 2). Mill Lake Stream is also surrounded by privately owned land and permissions may be required to access the streams. Currently, there is a well-defined footpath along the left bank (facing upstream) of Mill Lake Stream which can be accessed from the eastern side of the road.

The area of the stream below the culverts can be accessed along the stream banks and lake shore.

4. MONITORING ACTIVITIES

This section outlines field methods for four types of monitoring activities in support of LURS survival and recovery and implementation of the Recovery Strategy and Action Plan:

1. Annual monitoring for the occupation (presence or absence) of LURS in specified spawning streams.
2. Annual monitoring for the presence of obstructions and barriers in specified LURS spawning streams.
3. Monitoring water depth in Mill Lake Stream.
4. Nighttime monitoring in Mill Lake Stream in support of LURS-LbP abundance surveys

This document provides field data form templates in Appendix I for each monitoring activity. These forms are meant to capture all the data that is required for each activity at the time of this report.

Important information to note before getting started:

Lake Utopia itself as well as sections of Second Brook, Unnamed Brook, and Smelt Brook have been identified as critical habitat for the SbP in the Recovery Strategy (DFO 2016a). Everyone engaged in monitoring activities in the lake and these streams must be familiar with the location and description of SbP critical habitat and avoid undertaking any activities that may result in the destruction of any part of LURS-SbP critical habitat.

Aquatic invasive species (AIS) are non-native plant or animal species that are introduced to new freshwater habitats either accidentally or intentionally. AIS are a threat to the survival and recovery of LURS and anyone undertaking monitoring activities in LURS habitat must take precautions to avoid the accidental introduction of AIS. Chain pickerel are considered a local invasive species and are identified as a threat to LURS in Lake Utopia. Additionally, *Didymo sp*. ('rock snot'), is also a concern in many New Brunswick waterways. *Didymo* is an algal species that is visually recognized as thick wolly mats growing over rocky substrate. Care should be taken to not introduce this to Lake Utopia and its tributaries. The following precautions are good to follow to prevent the introduction or spread of AIS:

- **Recognize** and learn to identify AIS to help prevent their spread and establishment. Never remove aquatic plants or animals from their original area and then release them into another waterway.

- **Remove** aquatic plants and animals from boat hulls, motors, and gear and dispose of them away from water in proper garbage and compost containers. Then **CLEAN** and **DRY** your boat and all of your gear.
- **Report** all sightings of AIS to Fisheries and Oceans Canada at: 1-888-435-4040 or XMARinvasive@mar.dfo-mpo.gc.ca

4.1 ANNUAL MONITORING FOR THE PRESENCE OR ABSENCE OF LURS IN SPAWNING STREAMS

4.1.1 Objective

The objective of this activity is to monitor the annual occupation (i.e., presence or absence) of LURS in specified spawning streams and to confirm whether spawning has occurred (i.e., via observation of viable eggs as egg presence confirms that spawning has occurred). Information gathered from this monitoring program will help measure progress towards the LURS distribution objectives identified in the Recovery Strategy (DFO 2016a).

4.1.2 Methods

The timing, frequency and locations for monitoring for the presence or absence of LURS in spawning streams are summarized in Tables 4 and 5. Detailed monitoring efforts will be focused on two locations that will serve as index streams for each population: Mill Lake Stream for the LbP and Second Brook for the SbP. A simplified monitoring protocol should be used for Unnamed and Smelt brooks as well as Mill Lake Stream during the SbP spawning period (monitoring protocol in Section 4.1.2.2). Everyone participating in this monitoring activity should be familiar with the visual characteristics of LURS described in Section 2.1 of this report and capable of distinguishing LURS from other freshwater fish species known to occur in Lake Utopia. A list of fish species known to occupy Lake Utopia can be found in Appendix III. Physical descriptions and distinguishing characteristics of these species can be found in reference books such as *Freshwater Fishes of Canada (* Scott and Crossman 1973).

Table 4. Timing and frequency for annual monitoring of the presence or absence of LURS in spawning streams.

Stream	Population	Annual Monitoring Period and Frequency
Mill Lake Stream	LbP	Twice weekly beginning March 16 until eggs or spawners are observed, and then daily (weekdays) until spawning complete or April 15 (whichever comes first)
Mill Lake Stream	SbP	Twice weekly beginning April 16 until spawning complete or May 15 (whichever comes first)
Second Book (Scout Brook)	SbP	Twice weekly beginning April 16 until spawning complete or May 31 (whichever comes first)
Unnamed Brook	SbP	After fish observed in Second Brook or after May 8; twice with 1 week interval between observations until spawning complete or May 31 (whichever comes first)
Smelt Brook (Mill Brook)	SbP	After fish observed in Second Brook or after May 8; twice with 1 week interval between observations until spawning complete or May 31 (whichever comes first)

Table 5. Start and end locations for monitoring for the presence or absence of LURS in spawning streams.

Stream	Start	End
Mill Lake Stream	Shoreline of Lake Utopia at downstream end of Mill Lake Stream ~ 45.1837°N, 66.7749°W	Rock dam at Mill Lake outlet to Mill Lake Stream ~ 45.2064°N, 66.7759°W
Second Book	Downstream end at Lake Utopia ~ 45.2081°N, 66.7852°W	~30 m above bridge ~ 45.2108°N, 66.7894°W
Unnamed Brook	Downstream end at Lake Utopia ~ 45.2092°N, 66.8081°W	Cascades among the boulders ~45.2099°N, 66.8083°W
Smelt Brook	Downstream end at Lake Utopia ~ 45.2059°N, 66.8125°W	Increased gradient and in-stream debris ~45.2064°N, 66.8146°W

4.1.2.1 Detailed Monitoring in Index Streams (Mill Lake Stream and Second Brook)

Given the importance and sensitivity of the LURS habitat and individuals, extreme care should be taken to not disturb the fish, their eggs, or their habitat. Observations should be made from the shore and schools of fish should be approached slowly so as to minimize any interactions that may disrupt their natural behaviours.

Detailed monitoring involves streamside visual observations of each stream and recording estimated numbers of LURS (LbP and SbP) and their eggs (as numbers of egg mats). Other data to be recorded includes the georeferenced location of observed smelt and egg mats, habitat types occupied, substrate of the stream where eggs are found, weather conditions, stream visibility, upper and lower limits (georeferenced) of eggs and smelt, etc. This information should be recorded on Form B in Appendix I.

Detailed monitoring of Mill Lake Stream for LbP should occur twice weekly beginning March 16 until eggs or spawners are observed, and then daily (weekdays) until spawning is complete or April 15 (whichever comes first). Monitoring for SbP spawning in Mill Lake Stream should occur twice weekly beginning April 16 until spawning is complete or May 15 (whichever comes first) (Table 4). Visual observations should be made from the stream shoreline at its downstream end where it flows into Lake Utopia (i.e., below the culverts to the beaches along the lake edge) to its upstream end at the dam just below Mill Lake (Table 5). Monitoring of Second Brook also involves streamside visual observation of the stream for the SbP and their eggs. This includes all areas of the Second Brook from its downstream end where it flows into Lake Utopia to at least 30 m above the upper limits defined in Table 5. Second Brook should be monitored twice weekly beginning April 16 until spawning is complete or May 31 (whichever comes first) (Table 4).

Mill Lake Stream and Second Brook should be subdivided into stream zones and units (as described below) prior to data collection and observations. It is expected that these same subdivisions should be used annually and thus the requirement to establish these zones and units would occur only in the first year of monitoring. The subdivisions will allow the stream to be broken into smaller georeferenced units for which observational data about approximate numbers of fish and eggs should be recorded. This should allow for annual estimates of stream habitat use and a qualitative comparison of estimated fish and egg densities each year.

Setting up the Stream Zones and Units*:*

Mill Lake Stream should be divided into three distinct zones (Figure 8):

> Zone A: the area from the shoreline of Lake Utopia at the downstream end of Mill Lake Stream to the downstream ends of the culverts;

Zone B: the area between the upstream ends of the culverts and the riffle area below the falls; and

Zone C: the area between the riffles and the dam at Mill Lake.

Second Brook should also be subdivided into three zones (Figure 9):

Zone A: the area between the opening of the stream at the lake to the start of the wetland area;

Zone B: the wetland area to the point that it narrows back into a discernible stream channel; and

Zone C: the end of the wetland area to 20 metres beyond the bridge.

Zone C in both streams, should be further subdivided into 10 metre units to allow for more detailed data collection as described above. Mill Lake Stream should be marked off in 10 metre units beginning at the riffles below the falls to the base of the dam at Mill Lake (Zone C). Second Brook should be marked off in 10 metre units beginning at the end of the wetland to the area just upstream of the bridge (Zone C) The start and end of each 10 metre segment should be georeferenced with a hand-held GPS device and marked with labelled (by unit number) flagging tape placed on trees or stakes along the stream edge. Visual markers should be placed so that they will not be swept away or submerged in flood waters. The georeferenced coordinates should always represent the absolute 10 metre unit start and end points of each segment, and should remain constant from year to year.

Figure 8. Mill Lake Stream Zones. Note that these areas are approximate and Zones A and B will differ depending on water levels. Photo credit: Google, DigitalGlobe.

Figure 9. Second Brook Zones. Note that these areas are approximate and Zones A and B will differ depending on water levels. Photo credit: Google, DigitalGlobe.

Temperature should be recorded at two locations per stream for each observation period. These can be marked and georeferenced at the start of the season and should be in the following locations:

- Mill Lake Stream: downstream end of the main culvert and the base of the waterfall
- Second Brook: Deeper portion of channel just before it passes across the beach and under the bridge.

Filling out Form A in Appendix I:

- Record the start and end coordinates of each stream unit (including those for Zones A and B) and the type of marker used in the field to delineate each zone/unit.

Conducting in steam observations for LURS spawners and eggs:

Surveys for eggs and spawners should be conducted simultaneously by two observers with one observer on each bank (left and right) of the stream. Observations should be made in all zones where possible (e.g. Zone B of Second Brook may not always be observable due to high water). Observers should start at the downstream point and move upstream at the same pace and look into the stream as far as possible towards the stream centre. Observers should stay out of the water and off emergent rocks to avoid disturbing substrate and harming eggs. A

measurement of the observer's focal distance (the distance from the observer to the point in the stream where reliable observations for eggs and spawners can be made) should be taken with a range finder or estimated visually and recorded in centimetres on the data sheet. Since the wetted width of the stream may vary from day to day, the focal distance from each bank must be recorded each observation day. Observers should look closely at the bottom substrate and stream edges to locate eggs and throughout the stream to locate spawners. Eggs may look very similar to grains of sand so focused observation is required. Polarized sunglasses, an underwater camera, or a glass-bottom bucket may help an observer to locate eggs from the shoreline. Sections 2.2 and 2.3 provide detailed information about LURS spawning behaviour and habitat and can help observers locate eggs and spawners.

Data Collection and Filling out Form B in Appendix I

Form B should capture the detailed information for each zone and unit for each stream. Instructions for completing the form can be found immediately following the form in Appendix I.

Within each stream zone or unit, the following information should be recorded on Form B:

- Number of discrete egg mats observed
- Substrate type(s) to which eggs are adhered (e.g. sand, vegetation, rock)
- Egg condition (submerged, exposed to air, dead, alive)
- Proportion of substrate covered by eggs in each stream segment
- Approximate number of smelt (e.g., 0, 1-10, 11-50, 51-100, 101-499, >500)
- Habitat type(s) occupied by smelt (run, riffle, pool)
- Smelt behaviour (schooling, holding, upstream migration)
- Georeferenced locations of eggs and smelt observed.

Representative photographs should be taken to show dead and live eggs, the relative size of egg mats, the density of eggs and spawners, and stream habitat conditions where eggs and spawners were located (see Appendix II for photo examples). A photo log can be recorded on Form G.

Temperature loggers should already be present in each of the index streams; however, surface temperature (0.1°C) and water depth (1 cm) should be taken each monitoring day at the two index sites within each stream.

4.1.2.2 Simplified Monitoring (Unnamed Brook and Smelt Brook)

Monitoring of Unnamed Brook and Smelt Brook should include the portion of the streams from their downstream end where they flow into Lake Utopia (start location) to the upper limits (end location) indicated in Table 5. Unnamed Brook and Smelt Brook do

not need to be subdivided into zones or units and only presence or absence of eggs and spawners should be recorded for the entire stream length (i.e., no estimated counts needed). Unnamed Brook and Smelt Brook should be monitored twice with at least a one week interval between observations after eggs and/or spawners have been observed in Second Brook or May 8, whichever comes first, until spawning is complete or May 31, again whichever comes first.

Temperature should be recorded at two locations per stream for each observation period. These can be marked and georeferenced at the start of the season and will be in the following locations:

- Smelt Brook: downstream end at the deep channel just before it crosses the beach and the upstream georeferenced limit point in Table 5 (~45.2064°N, 66.8146°W).
- Unnamed Brook: downstream end at the deep channel just before it crosses the beach and the upstream georeferenced limit point in Table 5 (~45.2099°N, 66.8083°W).

Surveys for eggs and spawners in Unnamed Brook and Smelt Brook should generally follow the same methods described above for Mill Lake Stream and Second Brook; however, only the information outlined in the following section is required for Unnamed Brook and Smelt Brook.

Data Collection and Filling out Form C in Appendix I

For each simplified monitoring stream (Unnamed Brook and Smelt Brook), record the following information on Form C in Appendix I:

- Presence or absence of eggs.
- Presence or absence of LURS spawners.
- Georeferenced upper and lower limits of eggs and smelt observed in the stream.
- Surface temperature (0.1°C) and depth (1 cm) should be taken each monitoring day at the two pre-determined index sites outlined above within each stream.

Representative photographs should be taken to show dead and live eggs, the relative size of egg mats, the density of eggs and spawners, and stream habitat conditions where eggs and spawners were located (see Appendix II for examples). A photo log can be recorded on Form G.

Data Management and Reporting

All data recoded from the field should be verified as soon as possible for accuracy and completeness. Completed data sheets should be scanned to PDF (portable document format) and named in the format of StreamName_Date.pdf.

Templates and instructions for entering field data into spreadsheets will be provided by the appropriate DFO responsible authority. The data should be entered as soon as possible following field collection and verified for accuracy.

All digital photographs should be saved using a name or number that corresponds to the photo number on the data sheet. Photos should be saved in a folder named according to the stream segment in which they were taken (For example :Mill_Lake_Stream_Segment01) and organized in subfolders named by the date the photographs were taken.

Provision of data and reporting requirements should be met as per any contractual or funding agreements.

4.2 ANNUAL MONITORING FOR FISH PASSAGE BARRIERS AND OBSTRUCTIONS IN SPAWNING STREAMS

4.2.1 Objective

LURS spawning habitat is very limited and any temporary barriers or obstructions that prevent or inhibit access to their habitat may reduce spawning year success. The objective of this monitoring activity is to identify barriers and obstructions in LURS spawning streams that may prevent or inhibit the ability of LURS to migrate upstream for spawning. This activity should be completed prior to the LURS spawning season (i.e., mid- March for Mill Lake Stream and early April to no later than mid- April for Second, Unnamed and Smelt Brooks) and reports provided immediately to DFO for evaluation. DFO will investigate reports of temporary barriers or obstructions in LURS spawning streams and assess whether mitigation measures should be taken and follow-up as necessary.

4.2.2 Background

Natural barriers and obstructions in streams can limit the ability of fish to access upstream habitat. Barriers can be permanent, like impassable waterfalls, for example, the photograph of the small waterfall (Figure 6) on page 10, or temporary like beaver dams, fallen organic matter, or low water levels (Figure 7). Barriers can also be full or partial. Full barriers completely block upstream and/or downstream fish passage (e.g., dams without a fish ladder), while partial barriers may prevent passage for some fish species or life stages, or they may only block a section of the stream and still allow passage in other areas (e.g., small cascade).

Temporary barriers and obstructions caused by rock and wood debris and beaver dams have been a recurring issue at the primary culvert at the mouth of Mill Lake Stream (DFO 2011, D. Killorn, ECW, New Brunswick, pers. comm. IKANAWTIKET Environmental Incorporated 2014a). Temporary barriers on Second, Unnamed and Smelt brooks typically consist of collected organic material such as branches and

leaves. These barriers are often small and create flow that is too strong for LURS to swim through, or the debris creates a small cascade that is too high for LURS to ascend. Even a cascade a few centimetres in height can act as a barrier to LURS migration. The location of temporary barriers change as new ones form and old ones deteriorate or get washed out and as a result the upstream limit of LURS-SbP spawning habitat may vary from year to year. Temporary barriers may also form in the sandy beach areas at the mouth of Second, Unnamed, or Smelt brooks where they flow into Lake Utopia. Such barriers may be the result of low water levels in the streams and/or Lake Utopia. Permanent barriers could include rock dams or large fallen trees that can't be moved (Fig. 10.

Figure 10. A log embedded diagonally in Second Brook in 2011 acting as a temporary barrier to LURS-SbP dispersal, which if not present in future years, LURS-SbP may disperse beyond. Photo credit: Fisheries and Oceans Canada, Maritimes Region.

4.2.3 Observing Streams for Potential Barriers

Observing streams for barriers to fish passage should include all portions of the following LURS spawning streams from their downstream end at Lake Utopia to the upper limit of spawning habitat identified in Table 5: Mill Lake Stream, Second Brook, Unnamed Brook, and Smelt Brook. Each stream should be checked for temporary

barriers at least once prior to the start of the LURS spawning season (mid- March for Mill Lake Stream and early April to no later than mid- April for Second, Unnamed and Smelt Brooks). Continued monitoring for barriers and obstructions should then be conducted following the same schedule as the monitoring for the presence or absence of LURS eggs or spawners described in Section 4.1.2 of this document. **All identified barriers should be reported to the DFO contract authority on the same day that they are first observed**. **No removals or alterations of barriers should be undertaken as part of this monitoring activity.** This is important to ensure that any barrier mitigation is addressed as needed prior to the commencement of LURS spawning season.

Monitoring should begin at the mouth of each stream at Lake Utopia where observers should assess if water depth through the sandy beach areas is sufficient to allow for fish passage. While there is no specified depth recorded for smelt passage, a general rule of thumb is that water should be of sufficient depth to cover a smelt when swimming, or about 5-10 cm. Continuing upstream, observers should look into the stream for any barriers to fish passage, similar to those described in Section 4.2.2 above. If a potential barrier is observed, flagging tape should be placed on a nearby tree or stake.

Data Collection and Filling out Form D in Appendix I

Record the following information on Form D in Appendix I. Instructions for completing the form can be found immediately following the form in Appendix I:

- Stream name
- Barrier ID#
- Date
- Georeferenced location of each barrier observed.
- Whether it's a permanent or temporary barrier.
- Whether it's a full or partial barrier.
- Barrier composition (rocks, sticks, leaves, organic debris, fast water flow, fallen trees, roots, shallow water, etc.).
- Brief written description of each barrier with an explanation of how it may be affecting LURS passage.
- Whether eggs or spawners are present upstream and downstream of the barrier (once spawning season has begun).
- Smelt behaviour at the barrier.

Note: The presence or absence of LURS eggs or spawners upstream of each barrier should help determine whether the barrier is full or partial.

Photo Records:

Representative photographs should be taken to show each barrier as well and the upstream and downstream areas of the stream immediately adjacent to the barrier. The number of each photograph should be recorded on the photo record portion of the barrier inventory Form D (Appendix I).

Data Management and Reporting

All data recoded from the field should be verified as soon as possible for accuracy and completeness. Completed data sheets should be scanned to .pdf format and named in the format of StreamName_Date.pdf.

Templates and instructions for entering field data into spreadsheets should be provided by the responsible authority (eg, DFO-SARMD or DFO-Science) as appropriate. The data should be entered as soon as possible following field collection and verified for accuracy.

All digital photographs should be saved using a name or number that corresponds to the photo number on the data sheet. Photos should be saved in a folder named according to the stream segment in which they were taken (for example:, Mill_Lake_Stream_Segment01) and organized in subfolders named by the date the photographs were taken.

Provision of data and reporting requirements should be met as per any contractual or funding agreements.

4.3 MONITORING WATER DEPTH IN MILL LAKE STREAM

4.3.1 Objective

DFO installed a pressure sensor in Mill Lake Stream in May 2016 to measure water flows through the primary (southern) culvert. The objective of this monitoring activity is to collect data on water depth inside the primary culvert to augment data collected by the pressure sensor. This information will be used to determine stream discharge rates and water velocities at the culvert to inform its passability by LURS.

4.3.2 Methods

Water depth inside the primary culvert at the mouth of Mill Lake Stream should be measured each time that Mill Lake Stream is checked for smelt/eggs or as requested as long as the conditions are safe (i.e. not fast or deep water). At the downstream end of the primary culvert and one foot inside the culvert , place a meter stick on the top of a corrugation at the bottom of the stream and record the water depth to the nearest centimetre. Be sure to have the meter stick oriented so that the 0 cm mark is at the bottom of the stream. Note that the area should be checked for eggs and spawners

prior to entry and that care should be taken not to disturb the LURS or their habitat during the spawning season.

Data Collection and Filling out Form E in Appendix I

Record the following information on Form E in Appendix I:

- Date and time.
- Names of personnel and affiliated organization.
- Water depth (centimetres).
- Weather conditions and air temperature.
- Any conditions that may have affected the depth measurement (e.g., weather, flood or fast flowing water, presence of a beaver dam or other stream blockage).

Data Management and Reporting

Completed data sheets should be scanned to pdf and data should be entered into Microsoft Excel in the same format as the spreadsheet. Scanned data sheets and completed MS Excel spreadsheets should be sent to the appropriate DFO contacts as laid out in the contract or funding agreements.

4.4 NIGHTTIME MONITORING FOR THE PRESENCE OR ABSENCE OF LURS IN MILL LAKE STREAM

Important information to note before getting started:

The precise year(s) that this activity should be undertaken will be determined in the contract/agreement established with DFO. You may contact DFO-SARMD (xmarsara@mar.dfo-mpo.gc.ca and 1-866-891-0771) to indicate your interest in this activity and to inquire about the years that this may be undertaken.

4.4.1 Objective

The objective of this monitoring activity is to identify the start of the spawning period for LURS-LbP in years that quantitative abundance surveys (e.g., mark recapture studies) are conducted in Mill Lake Stream.

4.4.2 Conducting nighttime steam observations for LURS spawners

The undertaking of this nighttime monitoring activity in Mill Lake Stream should include the portion of the stream from its downstream end where it flows into Lake Utopia to the upstream end of the culverts (Zone A: Figure 8). If conditions allow, monitoring may extend further upstream to the base of the small waterfall (Zone B: Figure 8). Note that the right bank of Mill Lake Stream below the culverts (facing downstream) is not easily walkable so all observations should be made from the road and from the left bank (facing downstream). Nighttime observations should begin on March 16 and should

occur every second night during peak spawning times each night (11:30 PM and 2:00 AM). Note that nighttime observations should continue throughout the spawning season and will co-occur on some nights with spawner abundance surveys conducted by DFO (Table 4).

Observations should be made every 30 minutes beginning at 11:30 PM and ending at 2:00 AM. Each observation period should be approximately 10-15 minutes. Starting from the mouth of each stream and moving in an upstream direction, sweep a light into the stream and estimate the total number of spawners. Try to count or to observe large clusters of smelt to give an approximate number of smelt. LURS can be disturbed by bright light, so a red light should be used when feasible. If a red light is not adequate to illuminate an area, a stronger light may be used and care taken to minimize exposure to LURS. Slow sweeping motions should be used when shining the light into the water. Some spawners may be found along the edge of the stream but most should be in the main channel.

Data Collection and Filling out Form F in Appendix I

Record the following information on Form F in Appendix I:

- Observation start time.
- Observation end time.
- Estimate of number of smelt below the culverts (e.g. 0, 1-10, 11-50, 51-100, 101-499, >500).
- Surface water temperature below main culvert (°C).
- Estimate of number of smelt upstream of culverts.
- Comments.

Photographs of smelt in the stream are not usually possible at night and therefore not required for this monitoring activity.

Data Management and Reporting

Since DFO Science will be using these data to determine when to begin detailed spawner abundance surveys, contracted organizations will be required to contact DFO Science authority on a daily basis, the morning immediately following nighttime observations. Data sheets and other written reports that may be required will be detailed in the contract or funding agreements.

All data recoded from the field should be verified as soon as possible for accuracy and completeness. Completed data sheets should be scanned to .pdf format and named in the format of StreamName_Date.pdf.

Templates and instructions for entering field data into spreadsheets should be provided by the responsible authority (e.g., DFO-SARMD or DFO-Science) as appropriate. The

data should be entered as soon as possible following field collection and verified for accuracy.

Provision of data and reporting requirements should be met as per any contractual or funding agreements.

REFERENCES

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

Curry, R.A., Currie, S.L., Bernatchez, L., and Saint-Laurent, R. 2004. The rainbow smelt,*Osmerus mordax*, complex of Lake Utopia: threatened or misunderstood? Environ. Biol.Fishes 69(1-4): 153-166.

DFO 2011. Recovery Potential Assessment for Lake Utopia Rainbow Smelt (*Osmerus mordax*) Designatable Units. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/004.

DFO. 2016a. Recovery Strategy for the Lake Utopia Rainbow Smelt (*Osmerus mordax*), Small-bodied Population (sympatric with the Large-bodied Population), in Canada. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada. Ottawa viii + 57 pp.

DFO. 2016b. Action Plan for the Lake Utopia Rainbow Smelt (*Osmerus mordax*), Small-bodied Population (sympatric with the Large-bodied Population), in Canada [DRAFT]. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada. Ottawa 29 pp.

DFO. 2016c. Estimating Lake Utopia Rainbow Smelt (*Osmerus mordax*) Spawner Abundance and Allowable Harm. DFO Can. Science Advisory Secretariat Science Response 2016/024. 11 pp.

IKANAWTIKET Environmental Incorporated. 2014a. Presence/Absence of Lake Utopia Rainbow Smelt (*Osmerus mordax*) Large-bodied Population and Small-bodied Population: March-May 2013 Spawning Run Field Study. Unpublished report submitted to Fisheries and Oceans Canada. 15 pp.

IKANAWTIKET Environmental Incorporated. 2014b. Presence/Absence of Lake Utopia Rainbow Smelt (*Osmerus mordax*) Large-bodied Population and Small-bodied Population: April-May 2014 Spawning Run Field Study. Unpublished report submitted to Fisheries and Oceans Canada. 26 pp.

NATECH 2009. Hydraulic performance of the canal at Lake Utopia. NATECH Environmental Services Report to the New Brunswick Department of the Environment. 25p.

Shaw, J. 2006. Variation in early life-history characteristics of sympatric rainbow smelt populations in Lake Utopia, New Brunswick. M.Sc. Thesis, University of New Brunswick, Fredericton, New Brunswick, Canada. vii + 61 pp.

Rothschild, B.J. 1961. Production and survival of eggs of the American Smelt, *Osmerus mordax* (Mitchill), in Maine, Trans. Am. Fish. Soc. 90:42-48.

Taylor, E.B., and Bentzen, P.B. 1993. Molecular genetic evidence for reproductive isolation between sympatric populations of smelt *Osmerus* in Lake Utopia, South-western New Brunswick, Canada. Molecular Ecology 2:345-357.

Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. J. Fish. Res. Bd. Can. Bull. 184.. 966 p.

APPENDIX I. DATA FORM TEMPLATES

FORM A STREAM UNITS GEOREFERENCE POINTS

Stream Name_____ Date_____

Unit #	Latitude (decimal degrees)	Longitude (decimal degrees)	Marker in field (indicate type of marker)
ZONE A			
ZONE B			
ZONE C: 10 m INCREMENTS			
1			
2			
3			
4			

FORM B: DETAILED PRESENCE/ABSENCE OBSERVATION FORM (SECOND BRK BRK &MLS)

Form No. _____of _____		Date (dd/mm/yyyy)_____/_____/_____	
Stream Name			
Bank	LB or RB		
Observer completing form			
Second Observer			
Start time		End time	
Weather Conditions			
Visibility in stream			
Air Temperature (°C)			
ZONE /UNIT SUMMARY			
Zone/Unit #	Avg wetted width of unit (m)	Avg. focal distance of unit (cm)	
EGG INFO:	Eggs Seen in Unit? YES NO	Proportion of unit with eggs (%)	
SMELT INFO:	Smelt Seen in Unit? YES NO	App.# of smelt in Zone/Unit:	

EGG INFO		**Location #**	**Location #**	**Location #**	**Location #**	**Location #**
Egg mat location	latitude					
	longitude					
Approx. number of mats per Location						
Substrate(s) eggs adhered to						
Dead/Alive proportion in location		Dead____%	Dead____%	Dead____%	Dead____%	Dead____%
		Alive____%	Alive____%	Alive____%	Alive____%	Alive____%
Submerged/Exposed proportion in location		Sub.____%	Sub.____%	Sub.____%	Sub.____%	Sub.____%
		Exp._____%	Exp.____%	Exp.____%	Exp.____%	Exp._____%
Photograph (yes/no)						

FORM B Detailed Presence/Absence Field Observation Form

SMELT INFO		Location #	Location #	Location #	Location #	Location #
Smelt location	latitude					
	longitude					
Approx. number of smelt per location						
Number of groups of smelt per location						
Habitat Type occupied						
Smelt Behaviour						
Photograph (yes/no)						

Comments/Field Notes

Temperature (0.1°C)

Downstream Index Site _____ Time Recorded_____

Upstream Index Site _____ Time Recorded_____

Attach completed Photo Record Form G

INSTRUCTIONS FOR COMPLETING FORM B

Form no: Number the forms sequentially beginning with 01 on the first page and 02 on the second page.

Date: Enter the date that the observations are made dd/mm/yyyy.

Stream name: Enter the full stream name (e.g. Second Brook).

Bank: Indicate from which bank the observations are being made. Banks are determined by looking upstream for the purpose of this activity since you will be walking upstream.. LB= Left bank; RB= Right Bank. Separate forms are to be completed for each bank by separate observers (Mill Lake Stream only).

Observer completing form: Full name of the observer that is completing the form (for the indicated bank side observations).

Second observer: Full name of second observer (for SbP streams only).

Start time of observation survey: Record the time that the observations begin at the most downstream point (2400hrs).

End time of observation survey: Record the time that the observations end at the most upstream point (2400hrs).

Weather conditions: Record the weather conditions experienced during the survey. Use common categories like showers, rain, partial cloud, full sun, fog.

Visibility in stream: Indicate visibility levels during the survey. Glare, light levels, high turbidity, and surface disturbance by wind and rain may impact the clarity. Use categories: excellent (clear view into all parts of the stream), good (can see into >80% of the stream area), fair (can see into 50-80%) of stream area, poor (can see into 20-50% of stream area), none (0-20%). Indicate reason for poor visibility if known.

Air temperature: measured at the start of the survey. Precision 0.1°C.

Zone/Unit #: Record the zone or unit # assigned from stream delineation (10 m sections) prior to seasonal surveys. Unit numbers should be sequential and start at 01. Note that subsequent fields all relate to each unique zone or unit #.

Avg wetted width of zone/unit (m): For each zone or unit, estimate the average wetted width of the stream for each day of observations. For larger streams, a range finder would be useful.

Avg. focal distance of zone/unit (cm): For each zone or unit, indicate the average distance that the observer can see into the stream and still see the bottom adequately enough to observe eggs and fish. This may be less than a metre in some units of Mill Lake Stream. Where observers can see into each other's half of the stream (Mill Lake only), be cautious to not double record data and to determine who will record information if the smelt or eggs fall on the midline of the stream.

Eggs Seen in Unit: Circle YES or NO on the form. Record YES even if only one egg was observed within the unit.

Proportion of unit with eggs (%): Indicate the proportion of the substrate covered by eggs for the entire unit. This should be an estimate and the observer must consider the entire 10 m unit X focal distance to centre as the area (for Mill Lake Stream), and the entire 10 m unit X average unit width (for Second Brook) to determine what proportion is covered in eggs.

Smelt Seen in Unit: Circle YES or NO on the form. Record YES even if only one smelt was observed within the unit.

Approximate number of smelt in Zone/Unit

EGG INFO TABLE:

Location: The area that is visible to you while standing stationary and contains visible eggs or smelt. Typically a unit should be an area equal to the distance the distance the observer can see and reasonably estimate numbers of egg mats and/or smelt while looking slightly upstream or downstream of one position. Locations are numbered sequentially starting at 01 within each zone or unit. If not enough room on form for all the locations in a zone/unit, start a second form for the same unit. Be sure to number your forms.

Record the Remaining Information for each location in the appropriate column for each location.

Egg mat location: For each location that contains eggs or egg mat(s), record the latitude and longitude in decimal degrees (0.00001) in the column for that location.

Approx. number of mats per location: Indicate the number of egg mats observed for that GPS location.This should be an integer or whole number.

Substrate eggs adhered to: Record all the substrate types to which the eggs are attached for the GPS location. There will likely be more than one so be sure to include them all. Note: If eggs are found on aquatic vegetation that is attached to a boulder, include both numeric codes 1 and 7. You may use the numerical codes or the substrate types in the cell separated by commas. Use the following categories:

Numeric Code	Substrate type	Description
1	Aquatic vegetation	Any live plant material This includes algae, grasses, leaves
2	Organic debris	Any dead or decomposing organic material. This includes fallen leaves, sticks, logs
3	Fine silt, sand, clay	Particle size <0.1 cm
4	Sand and gravel	Particle size 0.1-1.5 cm
5	Pebble	Particle size 1.6-6.5 cm
6	Cobble	Particle size 6.6-25.5 cm
7	Boulder	Particle size >25.5 cm

Dead/Alive proportion in location: Based on the descriptions provided below, estimate the proportion (%) of eggs that are dead and those that are alive for each location.

Alive	Eggs are clear or translucent. Embryo may be visible
Dead	Eggs are opaque or white

Submerged/Exposed proportion in location: Based on the descriptions provided below, estimate the proportion (%) of eggs that are submerged in water or exposed for each location.

Submerged	Eggs are still covered by water
Exposed	Eggs are out of water

Photograph: Record YES or NO to indicate if photos were taken at this location.

SMELT INFO TABLE

Location: The area that is visible to you while standing stationary and contains visible eggs or smelt. Typically a unit will be an area equal to the distance the distance the observer can see and reasonably estimate numbers of egg mats and/or smelt while looking slightly upstream or downstream of one position. Locations are numbered sequentially starting at 01 within each zone or unit. If not enough room on form for all the locations in a zone/unit, start a second form for the same unit. Be sure to number your forms.

Record the Remaining Information for each location in the appropriate column for each location.

Smelt location: For each location that contains smelt, record the latitude and longitude in decimal degrees (0.00001) in the column for that location.

For each GPS location completed, complete the following data in the same column:

Approx. number of smelt per location: Provide an approximate number of smelts for that location using the following scale: 1-10, 11--50, 51-100, 100-499, >500.

Number of groups of smelt per location: Indicate the number of smelt clusters (schools) observed for that GPS location. This should be an integer or whole number.

Habitat type occupied: For each GPS location, indicate the type of habitat where the smelt were observed. Habitat categories are:

Habitat Type	**Description**
Run	deep with fast water and little or no turbulence
Riffle	shallow with fast, turbulent water ***running*** over rocks
Pool	deeper areas with slow water. Have steep slopes along the edges so that it is like a bowl inset in the stream

Smelt Behaviour: Record what you observe the smelt doing. You may record more than one behaviour for each observation location as many fish may be doing different things.Behaviour categories are:

Behaviour Type	**Description**
Schooling	Many smelt together and occupying space beside, below and above one another. Looks like a ball of fish. Often seen in pools.
Holding Station	Smelt oriented upstream and swimming just enough to maintain a stationary location in the stream
Upstream Migration	Smelt actively swimming upstream to other sections of the stream. This includes moving through/over partial barriers and openings.

Photograph: Record YES or NO to indicate if photos were taken at this location.

Comments/Field Note Box: Record any metadata relevant to the zone or unit, any observations not included in fields on the sheet, anything new and noteworthy (e.g. new barriers), issues or problems encountered that day. An example of comments/field notes for the reach may be:

> *Many more smelt today than previous day.Egg mats appear to be thickening and expanding. A lot of smelt lined up in the stream.Water levels are slightly lower than previous day and more eggs are exposed. Some smelt appear to be victims of predation as they are chopped in half and lying at the*

bottom of the stream. Suspect new barrier in Zone 12 due to low water (see barrier form for details). Camera is not working well. Double check photos and file numbers in office.

Temperature record box:

Record temperature in °C (0.1) for each index location indicated for each observation day.

Time recorded: Record the time the temperature was taken (2400 hrs).

Attach a Completed Photo Record Form (Form G):

A separate photo record form should be completed for each stream and for each day of observations.

FORM C SIMPLIFIED PRESENCE/ABSENCE FIELD OBSERVATIONS (UNNAMED AND SMELT BROOKS)

<table>
<tr><td colspan="2">Stream Name</td><td>Date (dd/mm/yyyy)</td><td>Form No. ___of ____</td></tr>
<tr><td colspan="4">Organization Name:</td></tr>
<tr><td>Observer completing form</td><td>Second Observer</td><td>Start time of survey</td><td>End Time of Survey</td></tr>
<tr><td colspan="2">Weather Conditions</td><td colspan="2">Visibility in stream</td></tr>
<tr><td>Air Temp (0.1 °C)</td><td>Water Temp (0.1 °C) index site #1</td><td>Water Temp (0.1 °C) index site #2</td><td></td></tr>
<tr><td>GPS Start Point latitude</td><td>GPS Start Point longitude</td><td>GPS End Point latitude</td><td>GPS End Point longitude</td></tr>
<tr><td colspan="4">EGG INFORMATION</td></tr>
<tr><td rowspan="2">Eggs Observed (Circle one) YES NO</td><td>Egg Lower Limit Latitude</td><td>Egg Lower Limit Longitude</td><td rowspan="2">Egg Notes</td></tr>
<tr><td>Egg Upper Limit Latitude</td><td>Egg Upper Limit Longitude</td></tr>
<tr><td colspan="4">SMELT INFORMATION</td></tr>
<tr><td rowspan="2">Smelt Observed (Circle one) YES NO</td><td>Smelt Lower Limit Latitude</td><td>Smelt Lower Limit Longitude</td><td rowspan="2">Smelt Notes</td></tr>
<tr><td>Smelt Upper Limit Latitude</td><td>Smelt Upper Limit Longitude</td></tr>
</table>

FORM D BARRIER INVENTORY FORM

Organization:_____ Staff: _____

Stream Name	Barrier ID #	Date (dd/mm/yyyy)	Latitude	Longitude	Permanent or Temporary	Full or Partial	Barrier Composition

FORM D BARRIER INVENTORY FORM SIDE B

			Above Barrier		Below Barrier		
Stream Name	Barrier ID #	Barrier Description	Smelt?	Eggs?	Smelt?	Eggs?	Smelt behaviour at barrier

FORM D BARRIER INVENTORY FORM: PHOTO RECORDS

Stream Name	Barrier ID #	Photo #s	Photo orientation (US, DS, RB, LB)	Description of what is seen in the photos

Comments/Field Notes

INSTRUCTIONS FOR COMPLETING FORM D

Form No: Number the forms sequentially beginning with 01 on the first page and 02 on the second page and so on.

Stream name: Enter the full stream name (e.g. Second Brook).

Barrier ID #: Sequentially number the barriers for each stream starting at 01.

Date: Enter the date that the observations are made dd/mm/yyyy.

Latitude: Enter the latitude for the barrier location (decimal degrees 0.00001).

Longitude: Enter the longitude for the barrier location (decimal degrees 0.00001).

Temporary or Permanent Barrier: Indicate permanent if the barrier is more stable and less likely to change from year to year. Examples of permanent barriers include waterfalls, beaver dams, cascades with steep gradient, and made-made dams. Temporary barriers would include an area of the stream choked off by fallen leaves and sticks, areas where flow is fast due to increased discharge from rain or flood events, fallen tree limbs, rocks, and roots exposed by low water levels. Please note that a temporary obstruction may become permanent due to changes in the stream resulting from the watercourse alteration caused by the barrier. Please only note the current stratus of the barrier and not its potential status in the future.

Full or Partial Barrier: Indicate if the barrier fully obstructs passage (full barrier) or partially limits passage (partial barrier). If smelt are unable to proceed past the barrier on the date of observation, it is marked as a full barrier. This would include culverts during periods of high water flow. Partial barriers should allow some LURS movement around or through the barrier. Examples would include small cascades that some LURS can ascend and openings in organic debris barriers that some LURS can swim through. Barriers can be full on a given day due to water flows and change to partial or non-existent on other days when the water flow and levels change in the stream. Mark the status of the barrier for the day that you observe it.

Barrier composition: Record the material that makes up the barrier. Use broad categories and only record items that you can see without disturbing the barrier. Examples of materials would include rocks, sticks, leaves, organic debris, fast water flow, fallen trees, roots.

Barrier description: Describe how the barrier is preventing some or all fish passage. Indicate if it spans the full width of the stream, if water flow is the issue, if there is an opening in the barrier that some fish can swim through. Provide any detailed descriptions that would accompany a photograph.

The next section can only be completed when smelt spawning season has begun

Smelt above barrier: Indicate YES or NO if smelt are observed in areas above the barrier (in the next 10-15 metres).

Eggs above barrier: Indicate YES or NO if eggs are observed in areas above the barrier (in the next 10-15 metres).

Smelt below barrier: Indicate YES or NO if smelt are observed in areas immediately below the barrier (in the 5 metres below).

Eggs below barrier: Indicate YES or NO if eggs are observed in areas immediately below the barrier (in the 5 metres below).

Smelt behaviour at barrier: Record any behaviours that you observe smelt displaying in the areas immediately adjacent to the barrier, both upstream and downstream. For example, you observe that smelt are attempting to ascend a small cascade and some of the larger ones are making it up while the remainder are swimming on station in a large school below the barrier.

PHOTO RECORDS:

Photograph the barrier itself to capture the entire barrier and then sections of the barrier to capture what the barrier is composed of and if any openings are visible. You should also capture the area of the stream immediately adjacent to the barrier both upstream and downstream.

Photograph #: Record the photograph number indicated on the camera for all photographs taken in the barrier location.

Location: describes the area that is being photographed. For example:, US barrier indicates that the photo is taken upstream of the barrier in the area immediately adjacent to the barrier. DS indicates downstream of the barrier.

Description: a brief description of what the photo captures. For example: school of smelt on RB, dead eggs on boulder.

Comments/field note box: Record any metadata relevant to the stream and barriers, any observations not included in fields on the sheet, anything new and noteworthy, issues or problems encountered that day. An example of comments/field notes for the reach may be:

Many more barriers today than previous day. Stream discharge rates greatly lower than last observation day so many areas are dry and many roots and debris fields are sticking up above the water level. A lot of smelt in the bottom part of the stream below Barrier #3- suspect they are unable to migrate further upstream and egg mats are thick in the area between barrier 2 and 3. .Camera is not working well. Double check photos and file numbers in office.

FORM E WATER DEPTH MILL LAKE STREAM

Date (dd/mm/yyyy)	Time (2400hrs)	Personnel	Depth in culvert (1.0 cm)	Air temp (0.1°C)	Weather Conditions	Field Notes/Comments

FORM F NIGHTTIME OBSERVATIONS MILL LAKE STREAM

Form No. _____of _____	Date (dd/mm/yyyy)
Stream Name	Air Temp (°C)
Organization Name	Observer completing form
Weather Conditions	Visibility in stream

OBSERVATIONS						
Observation Period	Start time	End Time	~# smelt below culvert	Surface water temp below main culvert	~# smelt upstream of culverts	Comments
11:30						
12:00						
12:30						
1:00						
1:30						
2:00						

FORM G PHOTO RECORD FORM

Date	Stream Name	Photo #	Photo Description

APPENDIX II. SAMPLE HABITAT AND IN SITU PHOTOS

Figure 1. Smelt egg mat in stream just above small ripple.

Figure 2. Smelt eggs attached to aquatic vegetation. White eggs are dead.

Figure 3. Eggs and egg mat on stream bed.

Figure 4. Smelt oriented upstream in run type habitat.

Figure 5. Riffle type habitat in a smelt stream.

Figure 6. Small cascade (full barrier) on a smelt stream.

Figure 7. Smelt in pool type habitat.

Figure 8. Smelt congregated in pool near partial barrier.

APPENDIX III. FISH SPECIES OCCURRING IN LAKE UTOPIA

Common Name	Scientific Name	Common Name	Scientific Name
Alewife (Gaspereau)	*Alosa pseudoharengus*	Lake Whitefish	*Coregonus clupeaformis*
American Eel	*Anguilla rostrata*	Longnose Sucker	*Catostomus catostomus*
Atlantic Salmon (Landlocked)	*Salmo salar*	Nine Spine Stickleback	*Pungitius pungitius*
Banded Killifish	*Fundulus diaphanus*	Pearl Dace	*Margariscus margarita*
Blueback Herring	*Alosa aestivalis*	Pumpkinseed Fish	*Lepomis gibbosus*
Brook Trout	*Salvelinus fontinalis*	Rainbow Smelt	*Osmerus mordax*
Brown Bullhead	*Ameiurus nebulosus*	Sea Lamprey	*Petromyzon marinus*
Burbot	*Lota lota*	Slimy Sculpin	*Cottus cognatus*
Chain Pickerel	*Esox niger*	Smallmouth Bass	*Micropterus dolomieu*
Common Shiner	*Luxilus cornutus*	Threespine Stickleback	*Gasterosteus aculeatus*
Creek Chub	*Semotilus atromaculatus*	White Perch	*Morone americana*
Fallfish	*Semotilus corporalis*	White Sucker	*Catostomus commersonii*
Golden Shiner	*Notemigonus crysoleucas*	Yellow Perch	*Perca flavescens*
Lake Chub	*Couesius plumbeus*		

Data provided by C. Connell, New Brunswick Department of Natural Resources 2016.