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Canadian Science Advisory Secretariat
Maritimes Region **Science Response 2018/019**

UPDATED ESTIMATE OF LAKE UTOPIA RAINBOW SMELT (*OSMERUS MORDAX*), LARGE-BODIED POPULATION, SPAWNER ABUNDANCE AND ALLOWABLE HARM

CONTEXT

Lake Utopia is part of the Magaguadavic River watershed in southwestern New Brunswick. Lake Utopia Rainbow Smelt (LURS) (*Osmerus mordax*) represent one of the only three confirmed occurrences in Canada where genetically divergent smelt populations co-exist. Two populations of smelt co-exist in Lake Utopia; a Small-bodied Population (LURS-SbP) and a Large-bodied Population (LURS-LbP). Lake Utopia Rainbow Smelt (Large-bodied) Population was designated Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in November 2008. The rationale for the designation was "*population is part of a genetically divergent sympatric pair of Osmerus that is endemic to a single lake in Canada with an extremely small index of area of occupancy (6 sq. km). It spawns in only three (3) small streams in the watershed and could quickly become extinct through degradation of spawning streams from increasing development around the lake shore and impacts of the dip-net fishery. This population is threatened by introduction of exotic species and by increasing eutrophication*" (COSEWIC 2008). A Recovery Potential Assessment (RPA) for both LURS populations was undertaken in 2010 (DFO 2011).

The LURS-LbP is currently under consideration for listing as Threatened under the *Species at Risk Act* (SARA). Interim abundance and distribution objectives for LURS-LbP were proposed in the LURS RPA (DFO 2011) and adopted in the LURS-SbP Recovery Strategy (DFO 2016a). A Science Response Process (DFO 2016b) was undertaken in 2016 to estimate LURS-LbP abundance based on sampling conducted in 2014, update the interim population abundance target and provide advice on the likelihood that the population objective could be achieved under current levels of mortality. The results were inconclusive due to uncertainty about the genetic assignment of the smelt sampled and limitations associated with reliance on data from a single spawning season (DFO 2016b). Genetic analysis of the smelt sampled in 2014 has since produced relevant information that was not available at the time of the 2016 Science Response. Also, additional biological information and abundance estimates are available from a mark-recapture project conducted during the Mill Lake Stream LURS spawning run in 2017.

A Science Response Process was held on October 17, 2017, on Lake Utopia Rainbow Smelt, Large-bodied Population (LURS-LbP) Population Abundance and Allowable Harm (update to the 2016 Science Response), in Dartmouth, Nova Scotia. The intent of this meeting was to provide updated information on LURS-LbP abundance estimate, abundance target, and allowable harm, where available. The objectives were to:

- Provide a population abundance estimate for the LURS-LbP based on sampling conducted in 2014 and 2017 and on genetic analyses undertaken on the samples collected in 2014.
- Provide an updated recovery abundance target for the LURS-LbP to replace the interim recovery abundance target proposed in the Recovery Potential Assessment (DFO 2011).

- Provide the likelihood that the updated abundance objective for the LURS-LbP can be achieved under current levels of mortality.
- Provide the maximum level of allowable harm that the LURS-LbP can sustain without jeopardizing its survival or recovery.

This Science Response Report results from the Science Response Process of October 17, 2017, on the Lake Utopia Rainbow Smelt Large-bodied Population Abundance and Allowable Harm Estimate (update to 2016 Science Response).

Background

Historical data suggest that LURS-LbP spawns in Mill Lake Stream, Trout Lake Stream, and Spear Brook, whereas LURS-SbP spawns in Smelt Brook, Unnamed Brook, and Second Brook (Figure 1). Spawning for both populations occurs in the spring. The LURS-LbP spawns between late-March and mid-April and LURS-SbP spawns from mid-April until late May.

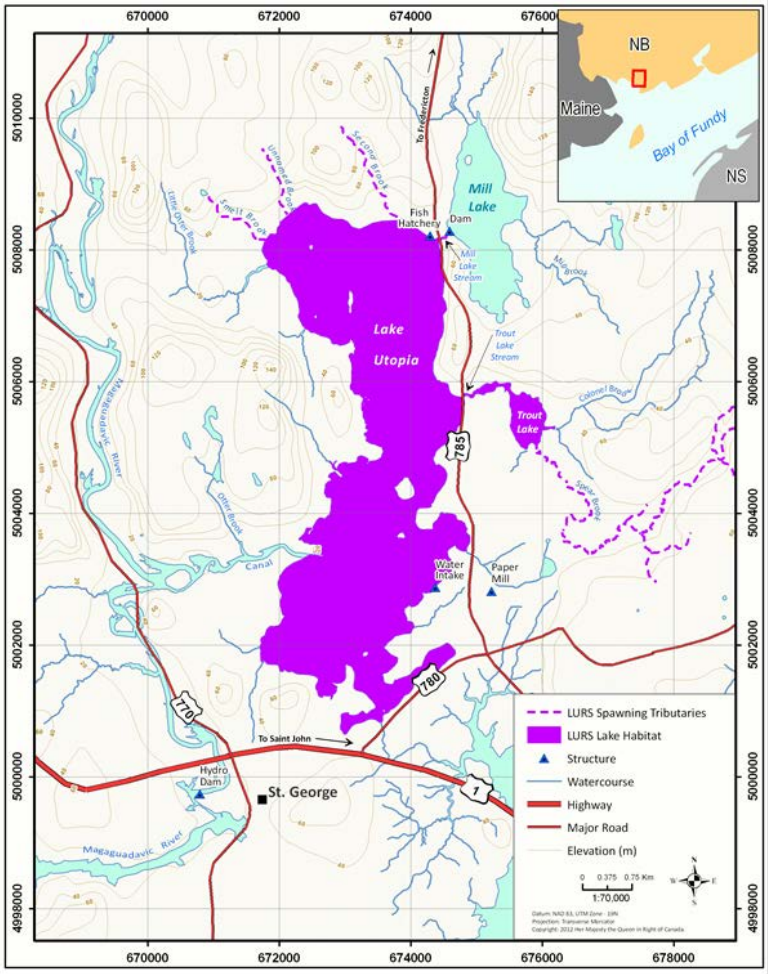

Figure 1. Lake Utopia, New Brunswick. Spawning tributaries for the LURS are indicated by the dashed line, industrial structures by blue triangles and roads are in red. The spawning tributaries of the Large–Bodied Population: Mill Lake Stream and Trout Lake Stream are located in the northeast portion of the lake.

The two body forms are distinguishable morphologically on the basis of their relative eye and jaw size to body size, number of gill rakers and size at maturity. The COSEWIC (2008) defines the large-bodied form as 15-25 cm in total length (136-227 mm fork length (FL)), while the small-bodied form ranges from 8-15 cm total length (73-136 mm FL). Based on a more recent evaluation of phenotypic and genotypic diversity in the 2 populations (Bradbury et al. 2011), Fisheries and Oceans Canada (DFO) adopted a minimum fork length of 170 mm (185 mm total length) to distinguish LURS-LbP from LURS-SbP (Bradford et al. 2013). Small numbers of one form can be genetically similar to the other form and hybrids of the two populations occurred in detectable numbers, indicating that gene flow occurs between the two populations (Bradbury et al. 2011).

Potential sources of mortality for LURS-LbP are reviewed in the LURS RPA and Recovery Strategy (DFO 2011, DFO 2016a). Sources were categorized by whether they caused mortality directly or indirectly through changes in the habitat, water quantity and water quality of Lake Utopia and its streams. Human activities posing a low level of threat to LURS are entrainment at the water intakes of a paper mill and a salmon hatchery (currently closed), predation by stocked landlocked salmon, and scientific research (Bradford et al. 2013; DFO 2016a). Two of three fisheries that posed a threat of direct mortality to LURS are currently closed (recreational smelt dip net fishery and recreational angling fishery). The third is an Aboriginal Food, Social and Ceremonial (FSC) fishery operating under a single communal license allowing dip-netting and angling for all smelt in New Brunswick, including both LURS populations. The fishing season runs from April 15th to May 31st, and license conditions include a spawning season dip-netting closure within Smelt, Unnamed and Second brooks.

Monitoring of Mill Lake Stream was conducted every year from 2009 to 2017 (with the exception of 2011) but few attempts to estimate abundance of LURS-LbP were successful (DFO 2016b, Themelis 2018). A single night of sampling in April 2009 generated an estimate of 5,000 adults (Bradford et al. 2013). Few smelt were observed during visual checks in 2010 and 2012; their absence was possibly due to beaver dams across the mouth of the main culvert in both years (DFO 2016b). In 2013, observers estimated nightly abundances declining from 5,500 smelt on April 4th to 2,000 on April 7th and none on a follow-up visit on April 10th. The smelt were congregated and spawning mainly in the area upstream of the main and secondary culverts and below the falls.

In 2014, a mark-recapture study conducted below the main culvert at the outflow of Mill Lake Stream, estimated nightly abundances ranging from 1,724-23,658 adults over 5 nights in April with a general increase in nightly abundances (DFO 2016b). Abundance estimates were confounded by the occurrence of small smelt (overall sampled length range 96-188 mm FL) in the spawning run. There was concern that the spawning run included an unknown proportion of LURS-SbP because a high proportion (89%) of the smelt measured were less than 170 mm FL.

In 2015 and 2016, weekly surveys of Mill Lake Stream were conducted during daytime only. No smelt were observed in 2015, and only a single, dead individual was found in 2016 (DFO, unpubl. data). Daytime checks began on April 1st in 2015 and March 10 in 2016, and included the beach area below the stream mouth and the stream banks up to the waterfall. Ice-out was late in 2015 (April 28th) and early in 2016 (March 10th). The first observations of eggs each year were mats of eggs near the secondary culvert and base of the waterfalls on April 29th in 2015, and a scattering of eggs in the rapid area below the falls on April 13th in 2016. No beaver activity or other stream blockages were observed but, in early April 2015, a combination of low stream flow and large boulders below the downstream end of the main culvert created a small cascade that may have been too high for smelt to jump, preventing upstream migration at the time of year when LURS-LbP spawn (DFO unpubl. data).

Genetic analysis was conducted on tissue samples from smelt collected in Mill Lake Stream in 2014: 25 smelt sampled on April 5, 2014, during the early spawning run (April 3–10), and 15 smelt collected from a second spawning run on April 22nd. Tissue samples were also available from 86 smelt collected on May 5, 2015, from spawning runs in Second, Smelt and Unnamed brooks (LURS-SbP spawning tributaries). The resulting genotypes were compared to 603 typed samples from collections during 1990, 2002 and 2003 (sampling described in Bradbury et al. 2011).

Rationale for Choosing Mill Lake Stream and its Characteristics

Sampling for the establishment of an abundance target for LURS-LbP is concentrated in Mill Lake Stream, rather than Trout Lake Stream or Spear Brook, because Mill Lake Stream is a principle spawning tributary for LURS-LbP with multiple years of spawning run abundance estimates, while spawning activity has seldom been observed in the latter two streams. Estimates of spawner abundance in Mill Lake Stream are available for 2009 and 2014, as well as genetic analyses of the 2014 spawning run. The relative dependence of annual LURS-LbP productivity on Trout Lake Stream and Spear Brook is not well understood (Bradford et al. 2013). Trout Lake Stream is wider and deeper than Mill Lake Stream and smelt have only been observed in 1991, 2002, 2003 and 2012, and eggs have been only observed in 2002 and 2013 (Bradford et al 2013; Themelis 2018). Bradford et al. (2013) have suggested that Trout Lake Stream may be a migration corridor for smelt destined for Spear Brook and that the presence of smelt in either water body cannot be used to infer spawning activity therein.

Mill Lake Stream flows into Lake Utopia through two corrugated metal culverts under New Brunswick Route 785. The southern culvert is larger and situated at a lower elevation than the northern culvert and considered the main culvert for smelt access. Accessible spawning habitat in the stream is limited to a 50 m section between the culverts and a small (0.5 m) waterfall that acts as a natural barrier to upstream migration of LURS (DFO 2011). The stream averages 4 m in width and less than 1 m depth, with water velocities reaching 1 m per second or more (Curry et al. 2004; MacDonald 2017; Caissie and Savoie 2017).

Sampling Methods (2017 Mill Lake Stream Spawning Run)

The timing of the spawning run was determined through visual checks of Mill Lake Stream from March 16-30 and April 4-13. The stream was checked every one to three nights, at 30 minute intervals between 11:30 pm – 2:00 am, from the main culvert to the waterfall, and in the outflow below the culvert. Once smelt appeared abundant, a mark-recapture study was undertaken on April 13-14.

On each night of the abundance study at about 11:00 pm, smelt were dip-netted along the stream banks between the culvert and waterfall, marked by fin clipping and held in containers on shore. After all smelt were marked, they were released and allowed one hour to mix with other smelt present in the stream. Then, a second sample was collected, the number of marked and unmarked smelt counted, and all smelt released. Unmarked smelt captured during the second sampling (recapture) event on April 13th were marked before release. Smelt were marked by clipping the adipose fin on April 13th and by clipping the upper portion of the caudal fin on April 14th. The length frequency and sex ratio of the spawning run was characterized by measuring fork length to the nearest millimeter (mm) and sexing a portion of the smelt dip-netted each night. Fin clips were preserved for potential future genetic analysis.

A length stratified sample (5 smelt per cm) was collected on April 13th for ageing. Whole otoliths were immersed in water and viewed by two readers separately. Final ages were determined by

the two readers reviewing photographs of the otoliths together, without reference to smelt length.

Analysis and Response

Genetic Analyses of the 2014 (Mill Lake Stream) and 2015 Spawning Runs (LURS-SbP Streams)

Genotyping of tissue samples from the 2014 LURS spawning runs in Mill Lake Stream and 2015 spawning runs in Second, Brook and Smelt brooks, and comparison with samples collected from smelt spawning in these streams from 1990-2003 (Bradbury et al. 2011) indicates that:

- 76% of the LURS sampled during the early spawning run on April 5, 2014, genotyped as LURS-LbP (Table 1). One small individual (138 mm FL) genotyped as LURS-SbP and 5 LURS (140-164 mm FL) genotyped as hybrids.
- 80% of the LURS sampled during the second spawning run on April 22, 2014, genotyped as LURS-SbP (Table 1).
- 95% of the LURS sampled in the LURS-SbP spawning streams in 2015 genotyped as LURS-SbP (Table 1).

Table 1. Genetic morph assignments of Lake Utopia Rainbow Smelt samples collected in 2014-15.

		Genetic Assignment (Number / Percent)			
Sample Group	**Date**	Large-bodied	Hybrid	Small-bodied	Total
Mill Lake Stream	April 5, 2014	19 (76)	5(20)	1(4)	25
Mill Lake Stream	April 22, 2014	1(7)	2(13)	12 (80)	15
Second Brook, Smelt Brook, Unnamed Brook	May 5, 2015	2(2)	2(2)	82(95)	86

Comparing the length distributions of the 2014 and 2015 samples (Figure 2) to the genetic assignments (Table 1) suggests that the recommended minimum FL criterion of 170 mm may be too large for distinguishing LURS-LbP from LURS-SbP. Based on this single year of sampling, a minimum FL of 143 mm (Figure 2) is a more applicable criterion to characterize the 2014 spawning run, as smelt smaller than 143 mm FL were mainly LURS-SbP, and smelt larger than 143 mm FL were mainly LURS-LbP.

Applying a FL criterion of 143 mm to the overall spawning run sampled (Figure 2, bottom panel) as an indicator of population identity, 83% of the smelt sampled during the 2014 spawner abundance study (DFO 2016a) were LURS-LbP. Hybrids are not excluded by this length criterion, as 3 of the 5 LURS hybrids were larger than 143 mm FL (overall length range of LURS hybrids 140-164 mm FL, Table 1).

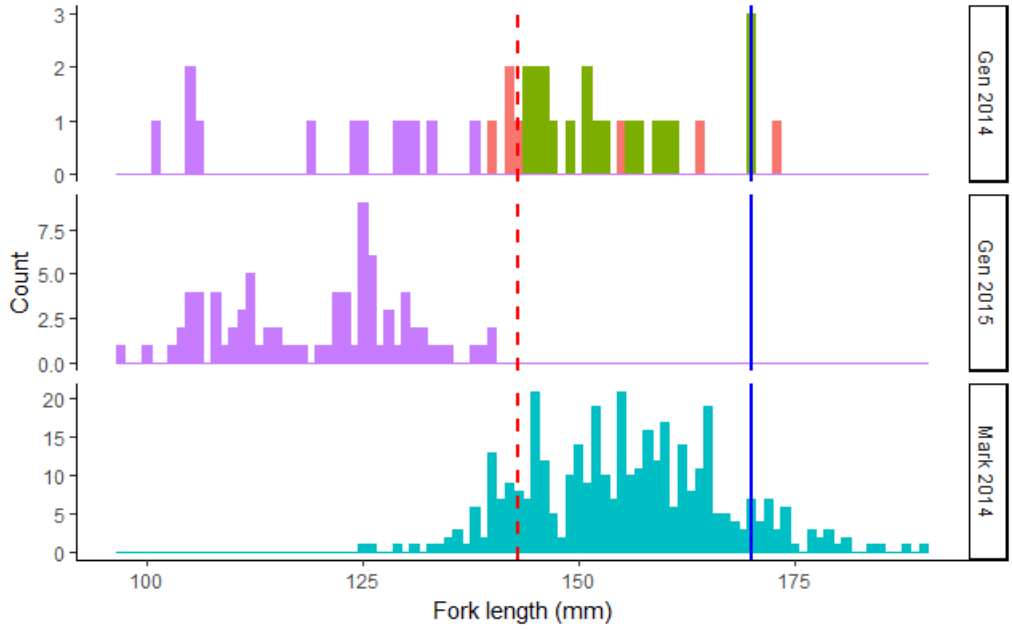

Figure 2. Length frequency distributions of Lake Utopia Rainbow Smelt (LURS) sampled in 2014 (upper panel, n=40) and 2015 (mid panel, n=86) for genetic analyses and for an abundance study in 2014 (bottom panel, n=348). Purple – Small-Bodied Population; orange – hybrid; green – Large-Bodied Population; blue – not genotyped. Vertical lines indicate minimum fork length of Large-Bodied Population: blue line – current 170 mm criterion (DFO 2011); red line – 143 mm criterion based on genetic analyses of LURS sampled in 2014 and 2015.

Updated 2014 Population Abundance Estimates

Nightly abundance estimates of LURS in the 2014 study ranged from 1,724 on April 3rd to 23,658 individuals on April 10th (DFO 2016b). Adjusting these numbers by a ratio of 0.83, as the proportion of LURS-LbP comprising this early April spawning run in Mill Lake Stream, the nightly abundance estimates of LURS-LbP ranged from 1,414 to 19,400 individuals (Table 2). Applying the 170 mm minimum FL recommended by the RPA (DFO 2011), nightly abundance estimate of LURS-LbP ranged from 197 to 2,697 individuals (Table 2).

Table 2. Nightly abundance estimates of spawning Lake Utopia Rainbow Smelt (LURS) in Mill Lake Stream in 2014 (from DFO 2016b) and estimated abundance of Large-Bodied Population based on the percentage of LURS with minimum fork length (FL) of 170 mm (11%) and 143 mm (83%).

		Large-bodied Population Abundance	
Date	**LURS abundance**	**Minimum 170 mm** FL	**Minimum 143 mm** FL
April 3rd	1,724	197	1,414
April 4th	3082	351	2,527
April 5th	14,542	1,658	11,924
April 6th	12,058	1,375	9,888
April 10th	23,658	2,697	19,400

Observations at the Start of the 2017 Mill Lake Stream Spawning Run

Sticks placed by beavers at the upper end of the main culvert were reported on March 16th and removed a few days later. Smelt were first observed in Mill Lake Stream at the outflow below the culverts on April 4th and above the culverts on April 8th (Table 3). The spawning run size increased to > 1,800 smelt about a week after smelt were first observed, with the highest numbers occurring around 1:30 – 2:00 am. Smelt first passed through the main culvert and congregated below the falls on April 8th. Numbers of smelt below the falls were estimated at 3,500 by observers on April 13th, the first night of the abundance study.

Table 3. Observations of Lake Utopia Rainbow Smelt in Mill Lake Stream in April 2017; location with highest numbers of smelt, nightly maximum numbers of smelt and time of the peak numbers.

Date	Location	Max Numbers Smelt	Time of Max (hr)
April 4th	Lake shore to culvert	45	01:30
April 7th	Lake shore to culvert	120	01:30
April 8th	Above culvert	165	01:30
April 9th	Checked above and below culvert	0	-
April 10th	Above culvert	200	02:00
April 11th	Above culvert, below falls	1800	02:00
April 12th	Below falls	3000	02:00
April 13th	Below falls	3500	02:00

2017 Length and Age Frequency Distributions

Smelt sampled during marking events on April 13-14, 2017, ranged from 103-277 mm FL (n = 348, Figure 3). Applying a minimum 143 mm FL criterion for inclusion, 85% of the LURS sampled in 2017 were LURS-LbP. Using a minimum 170 mm FL criterion (DFO 2011), 50% of the LURS were LURS-LbP.

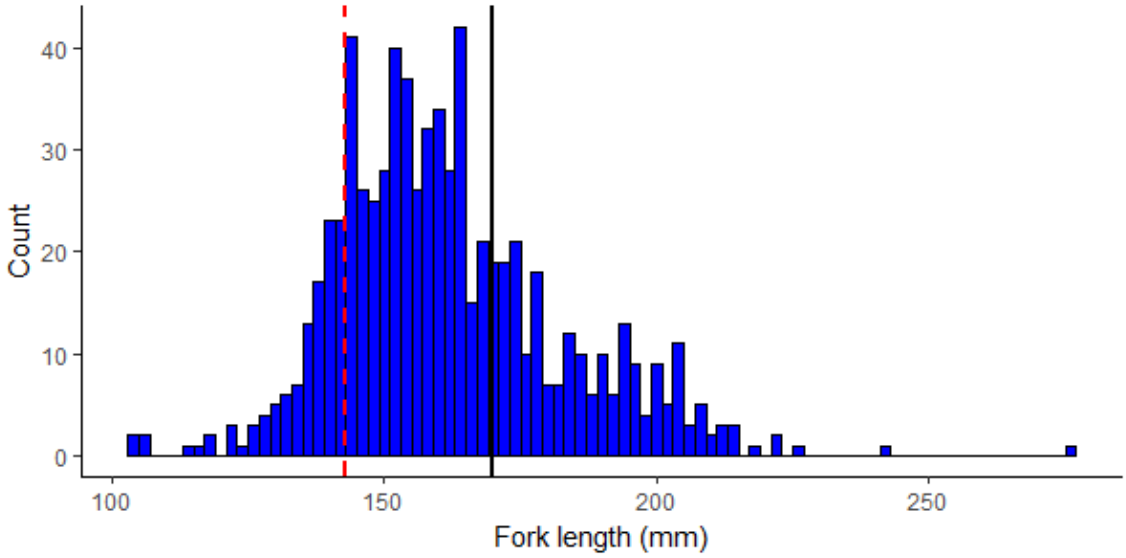

Figure 3. Length frequency distribution of Lake Utopia Rainbow Smelt (LURS) sampled in Mill Lake Stream in April 2017 (n=348). Vertical lines indicate minimum fork length for assignment to Large-Bodied Population: black line – current 170 mm criteria (DFO 2011); red line – 143 mm based on genetic analyses of LURS sampled in 2014 and 2015.

Estimated ages from otoliths taken from a length stratified sample of 80 smelt collected in Mill Lake Stream on April 13-14, 2017 ranged from 2-6 years (average = 3.3 years) (Figure 4).

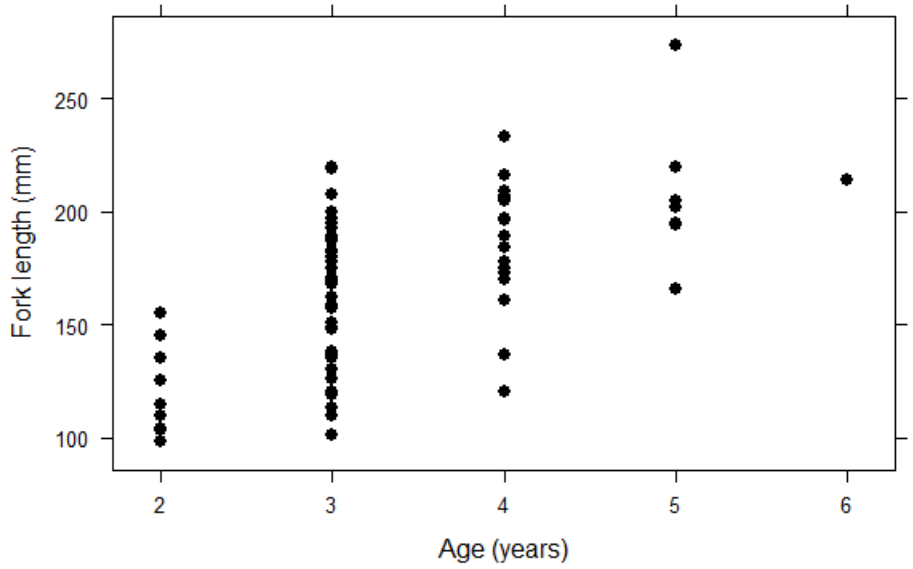

Figure 4. Relationship between fork length (mm) and age (years) of smelt sampled in Mill Lake Stream on April 13-14, 2017 (n=80).

2017 Population Abundance Estimate

A total of 2,276 smelt were caught during the mark-recapture events on April 13th and 14th (Table 4). On the first night, 8% of the smelt caught during the recapture phase had been marked previously. On the second night, April 14th, 8% of the smelt caught during the marking phase had clips indicating they had been marked the previous night. The recapture phase on April 14th was less successful, with upper caudal fin clipped smelt comprising 6% of the catch. The appearance of smelt with clipped adipose fins in the marking and recapture phases on April 14th indicates that some proportion of smelt were present in the stream on both nights (Table 4).

Table 4. Mark-recapture data for Lake Utopia Rainbow Smelt abundance study including recaptures of marked smelt for a given period, unmarked smelt captured minus mortalities during a given period, total smelt caught (recaptures and unmarked) in a given period and marked smelt available for recapture from the previous night. Clip types are ADF: Adipose fin and UCC = Upper Caudal fin. The recapture phase each night was after midnight, therefore on the following date.

Start Date	Phase	Recaptures	Unmarked	Total Caught	Marks available
April 13th	Marking (ADF)	NA	519	519	0
	Recapture	47	566	613	519
April 14th	Marking (UCC)	79	765	844	1085
	Recapture	47 ADF 28 UCC 1 ADF+UCC	426	502	1850
Total		**202**	**2276**	**2478**	**1850**

Nightly abundance estimates were calculated using an adjusted Petersen method (Table 5) and including only the smelt clipped on that night. Abundance estimates increased from 6,652 LURS on April 13th to 12,843 LURS on April 14th (Table 5). Using a minimum fork length criterion of 143 mm for inclusion as LURS-LbP, and the resulting length frequency distribution calculated above in 2017 (i.e. 85% of the smelt captured during the mark-recapture events were equal to or larger than 143 mm FL), the length-adjusted abundance estimates of LURS-LbP in 2017 are 5,654 individuals on April 13th and 10,917 smelt on April 14 (Table 5). Using the 170 mm minimum FL criterion recommended by the RPA (DFO 2011), 50% of smelt were LURS-LbP and the length-adjusted abundance estimates are 3,326 (April 13th) and 6,422 LURS-LbP (April 14th, Table 5).

Table 5. Nightly abundance estimates of spawning Lake Utopia Rainbow Smelt (LURS) in Mill Lake Stream in 2017. Abundance of Large bodied Population estimated by applying a minimum FL of 170 mm (50% of smelt sampled) or 143 mm (85%) of smelt sampled.

	Number of LURS			LURS Abundance		Large Bodied Population Abundance	
Date	Marked	Caught	Recaptured	Numbers Estimated	95% Confidence Interval	Minimum 170 mm FL	Minimum 143 mm FL
April 13th	519	613	47	6,652	5,200-9,200	3,326	5,654
April 14th	765	502	29	12,843	9,600-19,200	6,422	10,917

Updated Proposed Recovery Abundance and Distribution Objectives

The overall objective of the LURS Recovery Strategy (DFO 2016a) is to maintain the current population distribution and abundance of LURS-LbP and LURS-SbP and the genetic diversity of the sympatric species pair. The recovery objectives and performance indicators specific to LURS-LbP are based on abundance (2,000 spawning fish in Mill Lake Stream during nights of peak spawning), distribution (occupation of Lake Utopia year round and annual occupation of Mill Lake Stream for spawning) and genetics (maintenance of the genetic diversity and genetic differentiation of LURS within the Lake Utopia system) (DFO 2016a).

The interim recovery abundance target proposed for the LURS-LbP was based on the concept of the minimum population size (Ne) necessary to maintain genetic diversity (DFO 2011). Initial attempts to estimate effective population sizes had failed (Bradbury et al. 2011), so a value of 500 mature individuals was chosen as an Ne considered sufficient to maintain vertebrate species (Bradford et al. 2013). Using 0.26-0.88 as the range of possible ratios in effective population size/ minimum census population size (Ne/Nc) for salmonid populations, Bradford et al. (2013) derived minimum census population sizes at 550-2,000 spawners. An abundance target of 2,000 mature individuals was recommended because of the population's vulnerability to catastrophic events, environmental variability (a very small index of area of occupancy in a single location), an estimated potential annual harvest from a directed fishery of about 1,250 adults, and evidence for hybridization with the small-bodied population of smelt co-existing in Lake Utopia (Bradford et al. 2013).

A more recent review of the application of Ne and Ne/Nc ratios in conservation biology (Frankham et al. 2014) recommends a minimum Ne of 1,000 as a more appropriate value for retaining evolutionary potential for fitness in perpetuity. Their meta-analyses shows ratio averages for Ne/Nc = 0.1-0.2, and a minimum population size of 5,000-10,000 individuals. The consensus of this Science Response Process was that an increase in the minimum recovery target from 2,000 to 5,000 adults is supported by current understanding of smelt life-history and

the new analysis by Frankham et al. (2014), and is also considered to be feasible for this population.

An updated LURS-LbP distribution target of occupation of Mill Lake Stream by adult smelt at least once in every three years is proposed. Three years is the average age of spawning smelt sampled in Mill Lake Stream (Curry et al. 2004; Bradford et al. 2013, this study) and an indicator of generation time. Annual sampling since the 2011 RPA (DFO 2011) suggests that the current target of annual occupation of Mill Lake Stream by spawning LURS-LbP may not reflect population status. In 2014, LURS congregated below the Mill Lake Stream outflow but there were no indications that they spawned in the stream between the culverts and waterfall. The absence of smelt or eggs in Mill Lake Stream in 2015 and 2016 generated concerns about recruitment failure. These two years of apparent poor spawning were followed by a large spawning run in 2017 spanning several years in age, suggesting that LURS-LbP spawning is not limited to Mill Lake Stream. However, it is a principle spawning stream and the only location observers have been able to reliably count and estimate numbers of spawning smelt. A time interval longer than three years between spawning runs would be indicative of population decline.

Likelihood that Updated Recovery Abundance Objective can be Achieved

Abundance estimates for the 2014 and 2017 runs indicate that LURS-LbP production can meet the updated recovery abundance target. In both years, nightly abundance estimates of LURS-LbP surpassed both the interim recovery target (2,000 spawners) and the proposed recovery target (5,000 adults). Using a minimum FL of 143 mm, peak population abundance estimates of LURS-LbP were approximately 19,000 in 2014 and 11,000 in 2017 (Table 2 and Table 5). Using a minimum FL of 170 mm (DFO 2011), the total number of adults observed was approximately 6,200 in 2014 and 9,700 in 2017.

Allowable Harm

The maximum human-induced mortality that LURS-LbP can sustain without jeopardizing its survival or recovery cannot be determined without information on trends in abundance and levels of mortality. Given the vulnerability of the population to catastrophic events and environmental variability, the previous Science Response on population size and allowable harm (DFO 2016b) recommended that allowable harm should be determined in terms of nightly abundance rather than overall population size.

The maximum level of allowable harm that the LURS-LbP can sustain without jeopardizing survival or recovery cannot be quantified given the unpredictability of the spawning run size occupying Mill Lake Stream from one year to the next. However, the occurrence of large spawning runs in Mill Lake Stream (2009, 2014, 2017), and the presence of several year classes in the 2017 spawning run, indicate that the LURS-LbP continues to produce new individuals and that current levels of mortality are not threatening the species survival or recovery.

Direct mortality caused by fishing activities is a high-level concern for LURS-LbP (DFO 2016a). The one remaining fishery for smelt, operating under a communal FSC fishery, is managed cooperatively with the New Brunswick Aboriginal People's Council (NBAPC). In 12 years of observations, LURS-LbP has been recorded only once later than April 17th (April17, 2009, Bradford et al. 2013; Themelis, 2018). The 2017 spawning run was later than anticipated but was well underway on April 14th. In most years, LURS-LbP spawning appears to end prior to the opening of the FSC fishing season. Provided the fishing season and fishery remain separated in

time, there is low potential for the FSC fishery to jeopardize the survival or recovery of LURS-LbP.

In those years in which spawning runs exceed the updated recovery target of 5,000 LURS-LbP adults, there is some scope for harm. If abundance estimates show a declining trend in abundance, as indicated by spawning runs below the recovery target, then allowable harm would need to be reevaluated.

Sources of Uncertainty

The timing of the 2017 spawning run and the presence of large-sized LURS (i.e., > 170 mm FL) in Mill Lake Stream were consistent with known life history characters of LURS-LbP (Curry et al. 2004; Bradford et al. 2013).

Any abundance estimate of LURS-LbP in Mill Lake Stream in 2017 is uncertain because of the size range of LURS occupying the stream (103 -277 mm FL). The minimum length criterion used to assign membership to LURS-LbP or LURS-SbP varies from 136 mm (COSEWIC 2008) to 170 mm (Bradbury et al. 2011, DFO 2011) to 143 mm (this study). LURS-LbP comprised 50% of the spawning run, if a minimum FL of 170 mm is used to differentiate the two populations (DFO 2011) and 85% of the 2017 spawning run, using a minimum FL of 143 mm.

The total number of adults occupying Mill Lake Stream in 2017 cannot be estimated with the current data. An unknown proportion of smelt migrate into and out of the stream over more than one night, as indicated by the occurrence of smelt with clipped adipose fins on the second night of sampling in 2017, and capture of fish marked on previous nights during sampling in the 2014 abundance study (DFO 2016b).

The overall abundance of LURS-LbP is uncertain because of the unknown contribution to LURS-LbP by other spawning streams (Trout Lake Stream and Spear Brook). Lactions where LURS-LbP spawn during years in which they are not observed in Mill Lake Stream is not known.

Genetic analyses of samples from the 2017 spawning run and comparisons with fish length would aid in determining an operational fork length to distinguish the two LURS populations. A minimum FL of 143 mm FL for 2014 LURS-LbP is a substantial decrease from a minimum FL of 170 mm. The genetic analyses were based on a small sample size (40 LURS) from a single year. Genetic samples used to establish the 170 mm FL criterion were collected in 1990-2003 (Bradbury et al. 2011; DFO 2011), so decreases in fish length may indicate recent changes in LURS-LbP life history characteristics such as maturation at an earlier age or smaller length.

Difficulty in locating the position of the first annulus, and a tendency for otoliths to exhibit subannual checks (Walsh et al. 2008), means that the true age range is not certain. However, the positive relationship between the size of the otolith, number of translucent and opaque bands in the outer margin of the otoliths, and smelt length lends confidence to the conclusion that the Mill Lake Stream spawning run is comprised of smelt with ages spanning three or more years. Although other studies on Rainbow Smelt have reported that ages derived from scales and sectioned fin rays to be more precise and less biased than whole otoliths (Walsh et al. 2008; O'Malley et al. 2017), otoliths from two landlocked smelt populations in Maine showed sharp transitions between winter and summer growth, facilitating a high degree of precision (O'Malley et al. 2008).

Recommendations

Checking Mill Lake Stream prior to the onset of the LURS spawning run in March of each year is recommended to ensure that there are no blockages to impede smelt passage to the spawning

area between the waterfall and culvert. Sticks or boulders were present in 2010, 2012, 2015 and 2017 (Themelis, 2018).

Genetic analyses of tissue samples from the 2017 spawning run, and collection and genetic analyses of samples from future spawning runs, is required to refine a practical minimum FL for differentiating the two LURS populations.

Further biological sampling is required to determine the degree of hybridization between the two populations, the use of Mill Lake Stream by the LURS-SbP, and identify the mechanisms encouraging hybridization.

A recovery target of 5,000 adults observed within a timespan of three years is an effective population size to maintain genetic diversity in LURS-LbP. In other years, annual nighttime checks in April would provide indications of whether smelt were occupying Mill Lake Stream annually.

Given uncertainties around the use of Trout Lake Stream and Spear Brook by LURS, new methods for sampling eggs or larvae should be deployed in Trout Lake Stream to determine whether it is used by spawning LURS-LbP, and whether it is used in years when spawning is not observed in Mill Lake Stream.

Ageing, in combination with genetic analyses, will aid in understanding the life history strategies of LURS-LbP. Although otoliths are useful for growth analyses, scales can be collected for ageing without sacrificing fish.

Conclusions

A comparison of genetic analyses and body length of smelt from the early April 2014 spawning run in Mill Lake Stream indicated that more were of LURS-LbP origin than was apparent by applying a minimum FL of 170 mm (DFO 2011) to differentiate LURS-LbP from LURS-SbP.

Genetic analyses indicates that a minimum fork length of 143 mm is a more applicable criterion differentiating LURS populations, as smelt smaller than 143 mm FL were mainly LURS-SbP, and smelt larger than 143 mm FL were mainly LURS-LbP. Updated nightly abundance estimates of the 2014 LURS-LbP spawning run in Mill Lake Stream range from 1,414 to 19,400. These estimates range from 197-2,697 using the minimum 170 mm criterion.

The second run observed in Mill Lake Stream was comprised of LURS-SbP. Genetic analyses of 15 tissue samples from LURS collected on April 22, 2014, Lake Stream indicated that 80% of these were LURS-SbP.

A total of 2,276 smelt were caught during mark-recapture events in 2017. Nightly abundance estimates ranged from 6,652 on April 13th to 12,843 on April 14th. Using a minimum FL of 143 mm, abundance estimates of LURS-LbP increased from 5,654 (April 13) to 10,917 (April 14th). Using a minimum 170 mm FL, abundance estimates increased from 3,326 (April 13th) to 6,422 (April 14th).

A recovery abundance target of 5,000 adults in Mill Lake Stream observed on nights of peak spawning would be consistent with the broad goal of maintaining current population of LURS-LbP.

Abundance estimates for the 2014 and 2017 runs indicate that LURS-LbP production can meet the updated recovery abundance target. In both years, mean abundance estimates surpassed both the interim recovery target (2,000 spanners on nights of peak spawning) and the updated proposed recovery target (5,000 adults).

The maximum level of allowable harm that the LURS-LbP can sustain without jeopardizing survival or recovery cannot be quantified given the unpredictability of the spawning run size occupying Mill Lake Stream from one year to the next. However, the occurrence of large spawning runs in Mill Lake Stream (2009, 2014, 2017), and the presence of several year classes in the 2017 spawning run, indicate that the LURS-LbP continues to produce new individuals and that current levels of mortality are not threatening the species survival or recovery.

Provided the fishing season and fishery remain separated in time, there is low potential for the existing FSC fishery to jeopardize the survival or recovery of LURS-LbP. In those years in which spawning runs exceed the updated recovery target of 5,000 LURS-LbP adults, there is some scope for harm. If abundance estimates show a declining trend in abundance, as indicated by spawning runs below the recovery target, then allowable harm would need to be reevaluated.

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