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Methods used in evaluating the effectiveness of creating/enhancing stream habitats in Newfoundland and Labrador

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ABSTRACT

In 2003 a mining project in western Labrador included activities that, as a condition of regulatory approval, required the creation of similar riverine habitat that was impacted. In 2005 a mining project in central Newfoundland included activities that similarly required restoration of severely degraded riverine habitat. Monitoring for both habitat compensation projects included metrics used to demonstrate the effectiveness of the compensation including those for structural integrity, habitat suitability and fish utilization and changes to fish populations.

An evaluation of the metrics used revealed that most were useful, especially when used in conjunction with others. The metrics have been successful in identifying changes over time and have enabled the assessment of the status of the compensation and to determine whether additional changes were required in order for the compensation to function more effectively. The metric of population age structure was either not provided in one project or had uncertainties raised in the second project. Changes in population age structure should be monitored and the method to aging be verified (e.g. age-length key). When assessing compensation, metrics should be collected over a sufficient time period, be used in conjunction with other metrics, and should be detailed enough to provide a clear picture of trends. Baseline data is also critical as are the establishment of control sites to verify changes and subsequent effectiveness of the fish habitat compensation activities.

Méthodes utilisées pour l'évaluation de l'efficacité de la création/l'amélioration d'habitats fluviatiles à Terre-Neuve-et-Labrador

RÉSUMÉ

En 2003, un projet d’exploitation minière dans l'ouest du Labrador incluait des activités qui, en tant que condition de l'approbation réglementaire, nécessitaient la création d'un habitat riverain similaire à celui qui a eu une incidence. En 2005, un projet d’exploitation minière dans le centre du Labrador incluait des activités qui, de la même manière, nécessitaient la restauration d'un habitat riverain gravement endommagé. La surveillance des deux projets de compensation de l'habitat comprenait des paramètres utilisés pour démontrer l'efficacité de la compensation, notamment ceux de la solidité structurale, de la qualité de l'habitat, de l'utilisation par les poissons ainsi que des modifications aux populations de poissons.

Une évaluation des paramètres utilisés a été menée qui a révélé que la plupart d'entre eux sont utiles, notamment lorsqu'ils sont utilisés en conjonction avec d'autres paramètres. Les paramètres ont permis de détecter les changements au fil du temps et d'évaluer l'état de la compensation, en plus de permettre de déterminer si des changements supplémentaires étaient requis pour une plus grande efficacité de celle-ci. Le paramètre de la structure de l’âge de la population n'a pas été fourni dans l'un des projets et des incertitudes à son égard ont été soulevées dans l'autre projet. Les changements dans la structure de l'âge de la population doivent être surveillés et la méthode de détermination de l'âge doit être vérifiée (p. ex. la clé âge-longueur). Au moment d'évaluer l'efficacité de la compensation, il faudrait disposer de paramètres recueillis sur une période suffisamment longue, les utiliser en conjonction avec d'autres paramètres, et s'assurer qu'ils sont suffisamment détaillés pour donner un clair aperçu des tendances. Les données de base sont également essentielles, tout comme l'est la mise en place de sites témoins afin de vérifier les changements et l'efficacité future des activités de compensation de l'habitat du poisson.

BACKGROUND

Fisheries and Oceans Canada (DFO) typically requires proponents of authorized works that harm or destroy fish habitat to create or improve habitat elsewhere as a compensatory or offsetting measure. Compensation plans include requirements for monitoring to be conducted in order to determine the effectiveness of the compensation in offsetting the impacted habitat. In Newfoundland and Labrador (NL) compensating for the loss of riverine and/or lacustrine habitats can be challenging especially if it occurs in remote locations. Compensation for lost riverine habitat has generally been undertaken through the restoration, enhancement or the creation of riverine habitats. However compensating for loss of lacustrine habitats has proven more of a challenge and has necessitated the investigation and subsequent use of riverine-type compensation to offset lacustrine habitat losses.

In 2003 an iron ore mining project in western Labrador included activities that resulted in the destruction of 4,480 m^2 of spawning and rearing salmonid riverine habitat within the Luce Lake watershed in particular the loss of habitat within Hakim Brook (between Hakim and Luce lakes (Figure 1). The drainage area of Luce Lake watershed is approximately 24 km^2 and supports populations of Brook Trout (*Salvelinus fontinalis*), Lake Trout (*Salvelinus namyacush)*, Round Whitefish (*Prosopiun cylindraceum*), Longnose Dace (*Rhinichthys cataractae)*, Lake Chub (*Couvsius plumeus*) and Burbot (*Lota lota)* with Brook Trout being the most abundant and widely distributed throughout the watershed. Given the location in western Labrador there are limited opportunities for restoration/enhancement activities. In 2005, the loss of the riverine habitat in Hakim Brook was authorized by requiring creation of 5,000 m^2 of riverine habitat in downstream areas of the Luce Lake watershed in the form of a 710 m long and average 8 m width meandering stream which included run, riffle and pool habitats (Figure 2). Monitoring was undertaken to determine structural integrity of the new channel, habitat suitability, fish utilization, and revegetation. The seven-year monitoring program required a series of metrics to be collected in order to evaluate the structural integrity of the new channel and the function and utilization of the habitats created within the channel to support fish production. Monitoring was undertaken in 2006, 2007, 2009 and 2010.

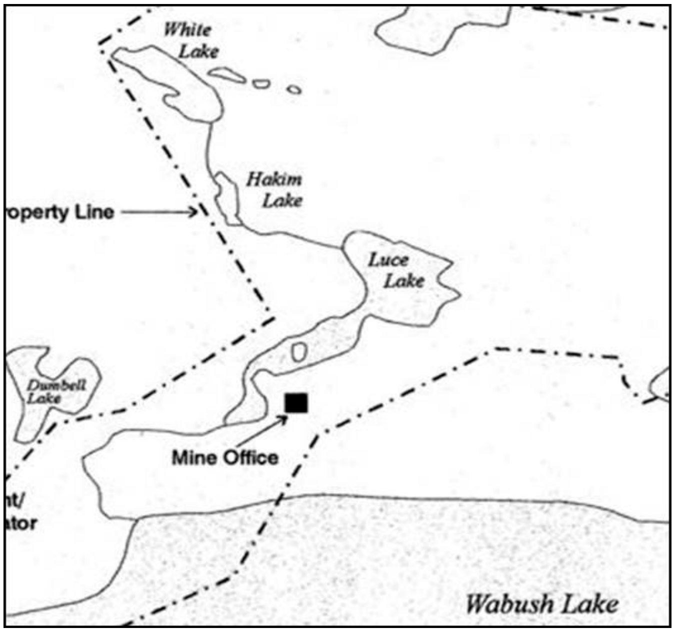

Figure 1. Map depicting Luce Lake watershed.

Figure 2. Tinto Brook restoration area.

In 2005 a copper-zinc mining project in central Newfoundland included activities that resulted in the destruction of two waterbodies (Trout Pond and “Sedimentation Pond”, a tributary to Gill’s Pond Brook) within the Harpoon Brook watershed causing a combined loss of 107,800 m^2 of productive fish habitat (Figure 3). These waterbodies contained Brook Trout, Ounaniche (*Salmo salar),* and three spine sticklebacks (*Gasterosteus aculeatus).* The production level within the impacted ponds was determined to be 115 g/100 m^2. This level of production is similar to other waterbodies in the area. Based upon this it was estimated that approximately 110,600 m^2 of riverine habitat would have to be restored in order to offset the level of production from the waterbodies.

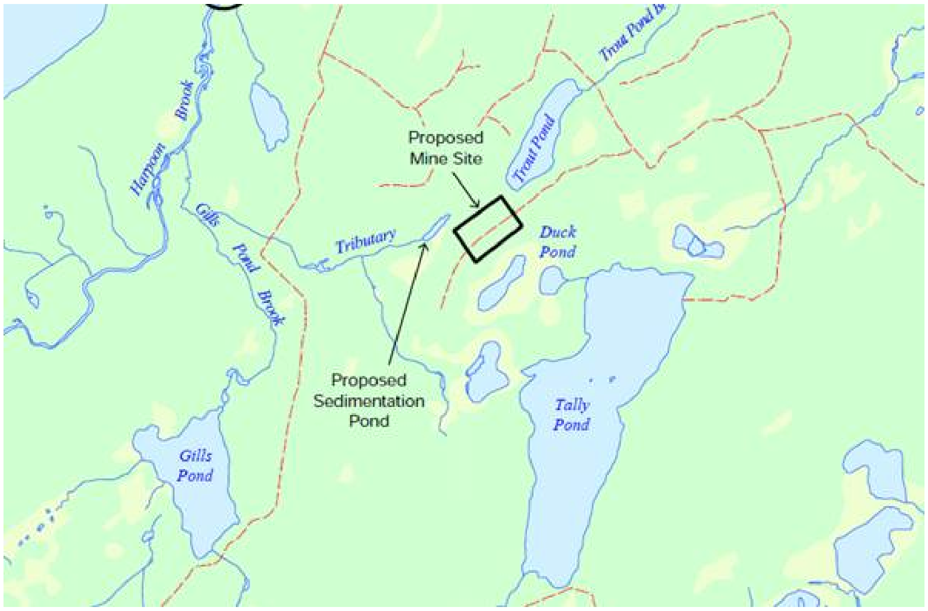

Figure 3. Location of fish habitat impacted by Duck Pond Mine project.

Habitat compensation included the restoration of stream sections within the same watershed (i.e., Harpoon Brook) that had been severely degraded by deposits of log debris from logging activities. The restoration activities were designed to enhance habitats for use by Brook Trout and anadromous Atlantic Salmon. Between 2005 and 2009 removal of the woody debris, in particular sunken logs, exposed suitable spawning/rearing substrates but areas were augmented with additional gravel material when necessary. In total five hundred and seventy-three (573) cords of pulp wood (Figure 4) were removed along a 5 km stretch of the river, in particular at Harpoon Brook Steady and East Pond Brook , resulting in the restoration of 111,470 m^2 of fish habitat for a compensation ratio of 1:1 (Figure 5). Monitoring was required to evaluate the structural integrity, habitat suitability and fish utilization. Over a nine year period between 2006 and 2014, a monitoring program was undertaken (2006, 2007, 2008, 2009, 2010, 2011, 2013 and 2014).

Figure 4. Example of pulp word removal, Harpoon Brook, 2007.

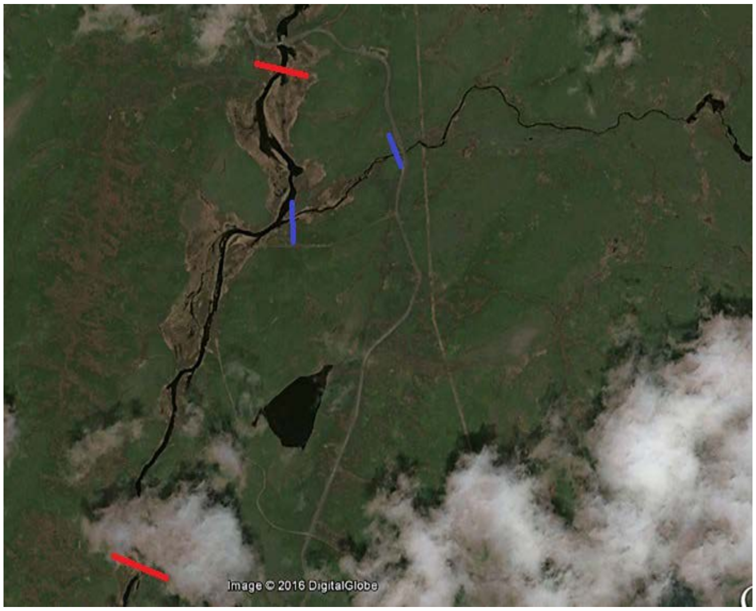

Figure 5. Location of Harpoon Brook steady (red) and East Pond Brook (blue) restoration areas.

METHODS

Whether creating or restoring riverine habitats there were four goals set in order to evaluate and determine whether compensation was effective: hydrology, habitat suitability, revegetation and fish utilization. The following provides a summary of the methodologies utilized in the collection of the metrics and the evaluation of the effectiveness of those metrics. Information presented on the fish habitat compensation programs is based upon data provided in proponent's monitoring reports which were required as conditions of the Authorization. For Tinto Brook information was from EcoMetrix Incorporated (EcoMetrix; 2006, 2007, 2008, 2009, 2010) and Jacques Whitford Environmental Limited (JWEL; 1997) and for Harpoon Brook/East Pond Brook from Environment Resource Management Association (ERMA; 2005, 2006, 2007, 2008, 2009), JWEL (2008a, 2008b, 2008c) and Stantec (2009a, 2009b, 2010, 2011a, 2011b, 2013a, 2013b, 2014).

HYDROLOGY

Hydrological evaluations for Tinto Brook consisted of measuring flows at locations along the length of the created riverine habitat. Flow measurements (m/s) were taken at high (May), medium (June-July) and low (August) flow conditions using a velocity meter. Measurements were to be taken during the same time period each year and were not to be taken at atypical conditions, e.g., right after storm events. Record of water level (m) and water velocity (m/s) were recorded across each of five established transects at 0.5 m intervals (Figure 6). Discharges were then calculated at each transect.

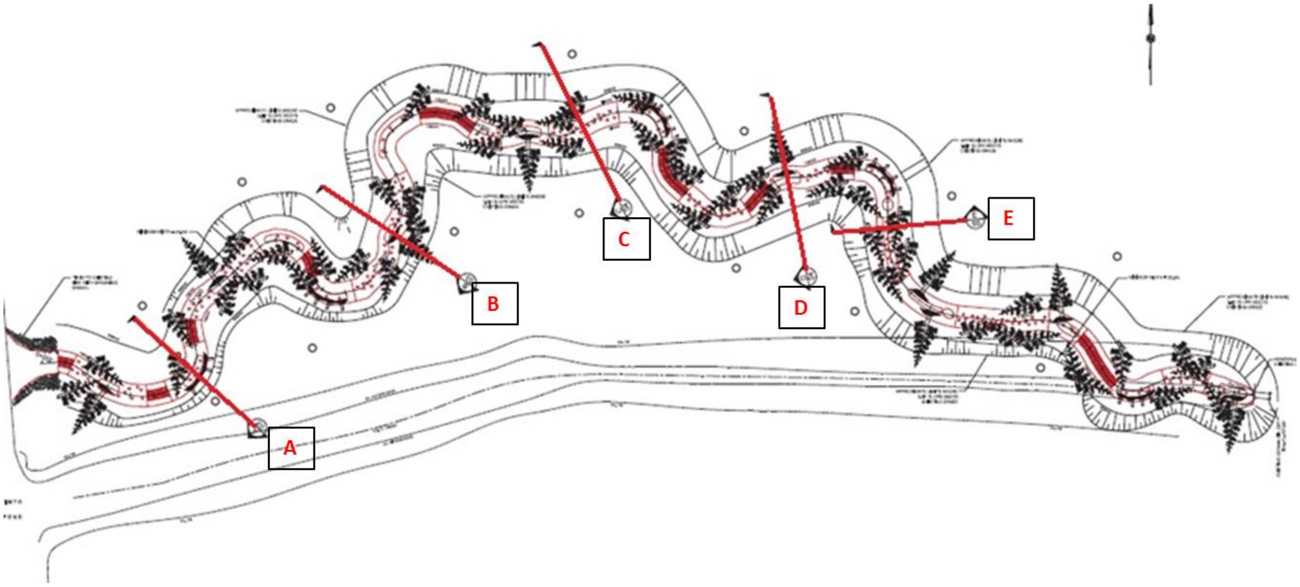

Figure 6. Schematic of Tinto brook showing five transects.

In Harpoon Brook/East Pond Brook, following the first year of monitoring a real-time monitoring station was established on East Pond Brook and records of water level (m) and water velocity (m/s) were recorded daily and discharges were calculated. These measurements were taken at 50 m intervals throughout the length of the restored habitats and at each flow measurements were taken at ¼, ½ and ¾ the distance across the stream width.

HABITAT STABILITY

Bank Stability

Monitoring for Tinto Brook included the requirement to evaluate the structural integrity of the new channel including stream banks and stream shape. Five cross sections were established to evaluate hydrological conditions and to map and record changes in bank stability, in particular to document changes in erosion (Figure 6) which was done through visual observations only. If erosion was noted then additional information was collected, e.g., length and width of erosion, location of eroded material within the stream and habitat type being affected. Stream shape was evaluated by recording changes to channel width, wetted width, maximum water depth and bank height.

Baseline mapping was undertaken for East Pond Brook and Harpoon Brook to record pre-restoration conditions. The river was divided into sections; Sections 3-5 in East Pond Brook and Section A2-G in Harpoon Brook (Figure 7). The area of each section determined using an IKONOS satellite image as a base map and then creating polygons over each stream section in ERSI ArcView GIS software and the area of each polygon was mathematically computed in ArcView and confirmed for accuracy in AutoCAD.

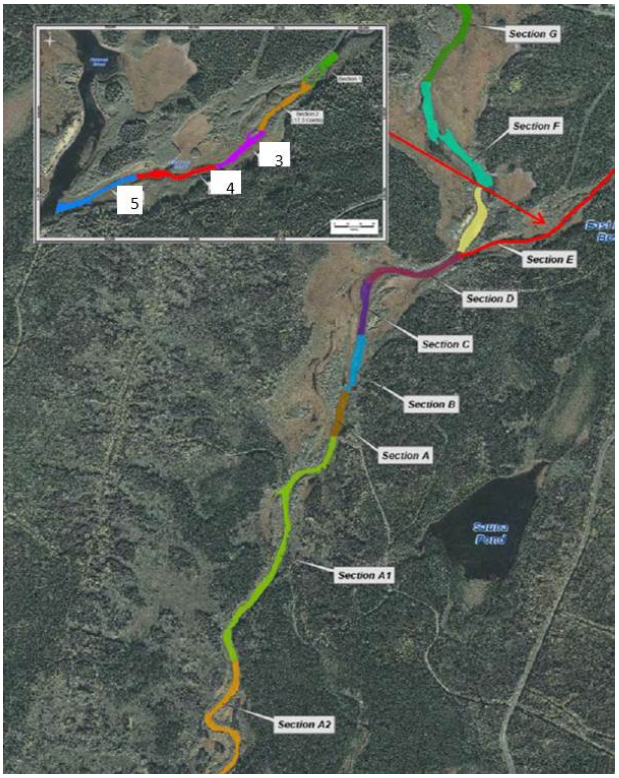

Figure 7. Map depicting stream sections within Harpoon Brook/East Pond Brook.

Monitoring for Harpoon Brook/East Pond Brook included visual observations and photographing riparian habitats. In particular the banks were visually inspected to check for erosion and any impacts due to restoration works on the riparian habitat that may require remedial works.

Substrate stability

Substrate material placed within Tinto Brook stream sections were initially mapped for location and depth of material placed. Five cross sections were established and visual surveys were undertaken to determine shifts in substrates from the as-constructed stream constructed in 2006 (Figure 6). The instream features that were placed as part of the stream design (e.g., root wads, overlying trees, tree logs, etc.) were also mapped for location with visual observations made on changes in location and stability of structures. As well in 2012 water samples were taken to measure TSS/turbidity due to apparent sediment load in the river; no samples were taken in previous years as water was visibly clear.

In East Pond Brook and Harpoon Brook spawning gravels were placed in 36 locations along the restored channel in 2007 and 2009, respectively to augment the exposed substrates for use as spawning habitats (Figure 8). Due to the shallow water depths in the sections (mean ranges of 0.38-0.88 m in Harpoon Brook and 0.42-0.70 m in East Pond Brook) visual observations were able to be made and noted to determine if substrates had shifted the previous year.

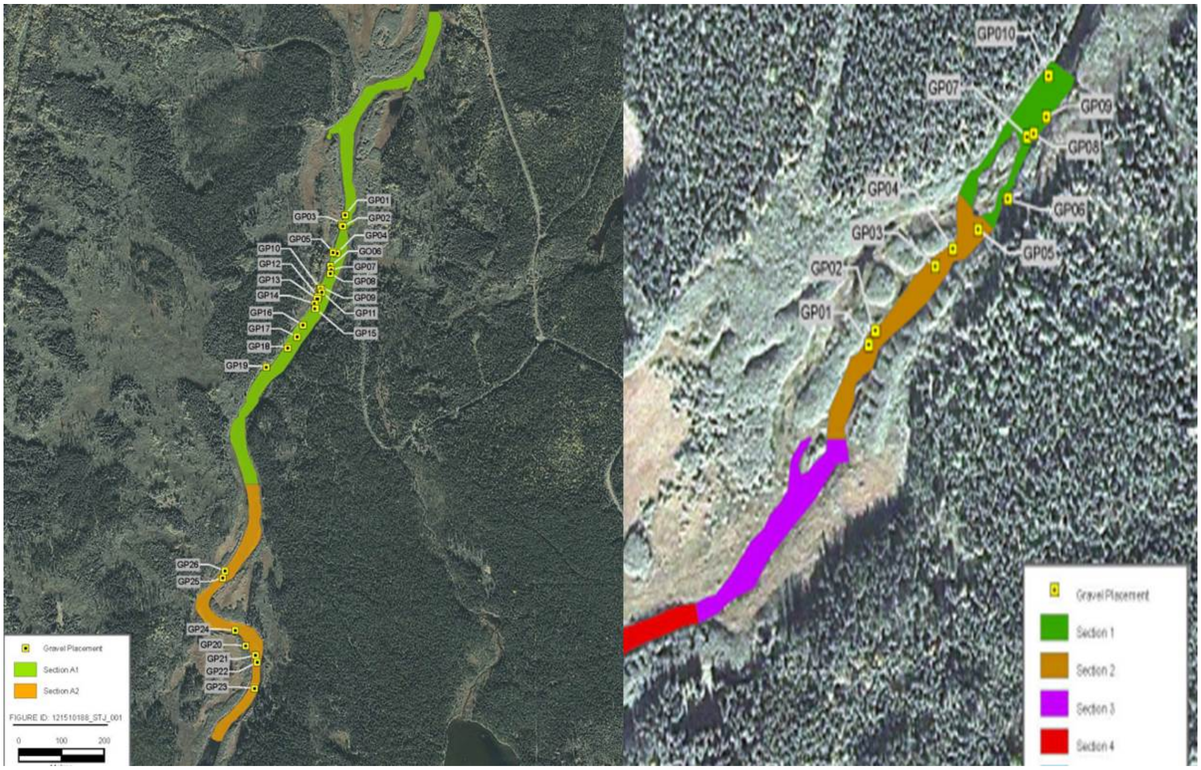

Figure 8. Gravel placement locations within Harpoon Brook and East Pond Brook.

VEGETATION FEATURES

Within the creation of riverine habitats in Tinto Brook there was a requirement to include vegetation features, either riparian or instream structures (root wads and overlying trees) as part of the design. Visual monitoring of the mapped features was undertaken to determine any changes in placement and survivability of vegetation from the original placement.

FISH UTILIZATION

Index electrofishing (qualitative) was conducted to determine presence of fish and to supplement quantitative electrofishing. The method used was based on Sooley et al. (1998) and factored in:

- Record of time fished;

- Fishing effort confined to a localized area so that the results provide a comparative indication of fish density; and
- Capture rates for non-quantitative stations were generally compared to the first 100 seconds of fishing at quantitative stations.

Index electrofishing was undertaken in Tinto Brook by directing electrofishing effort towards targeting preferred Brook Trout habitat in order to determine the presence of trout. At least two locations in Tinto Brook were used as index electrofishing stations. The first was taken from 15 m upstream of transect A to the outlet of Tinto Pond (approximately 150 m) and the second was a 100-200 m stretch downstream of the culvert (Figure 6).

In East Pond Brook and Harpoon Brook, index electrofishing was conducted between 2006 and 2013. However the surveys conducted between 2006 and 2008 were not based on standardized sites as they were not able to be established due to high water levels. Trap net surveys were undertaken within 9 sections utilizing fyke nets in areas where water velocity and/or water depth precluded electrofishing.

Visual surveys were conducted along the entire length of Tinto Brook. The brook was walked on both sides and observations recorded on the presence of fish (by species, if possible).

FISH POPULATION ESTIMATES

The method used to conduct quantitative electrofishing for both projects was generally in accordance with Sooley et al. (1998) which factored in:

- Electrofishing a contained area of a stream or river (generally cover up to 200 m^2) with successive sweeps (generally four sweeps);
- Electrofishing stations enclosed using barrier nets due to low conductivity waters prevalent in insular Newfoundland and Labrador;
- Removal method recommended for estimation of population size to provide for maximum comparability of results width of the river, with the standard upstream and downstream barrier nets;
- Use of computer software programs (e.g. MICROFISH or CAPTURE) to provide estimates of total number of fish and biomass within the electrofished river reach; and
- Separate estimates should be calculated by species, and age or length class.

An enclosed electrofishing station was established by block nets within the new channel in Tinto Brook to estimate fish abundance and assess species richness. Cross-channel transects were electrofished from downstream to upstream and three electrofishing passes were conducted (pass removal). The size of the area sampled was 180 m^2; 20 m in length with mean width of 9 m. Fish densities (number of fish/100 m^2) were calculated using the Zippin removal (depletion) method (Zippin 1956). Effort was recorded in seconds by pass for each station to calculate catch per unit effort (CPUE) as number of fish per minute. Because the density of fish continued to decline after each pass as fish were released downstream of the block net, only the first pass was used to calculate a measure of relative abundance (CPUE). Information collected in evaluating relative abundance was measured as catch/trap net night

In Harpoon Brook/East Pond Brook five stations were quantitatively sampled (three in East Pond Brook and two in Harpoon Brook); fast currents and/or deep water prevented surveying other locations. Areas surveyed were approximately 200 m^2 and Microfish 3.0 software (based on removals) was used to obtain populations estimates/biomass.

Morphometrics

Fish from Tinto Brook were not aged however in Harpoon/East Pond Brook age for trout and salmon was estimated using length histograms derived from field results (Gulland and Rosenburg 1992).

Fish caught during the quantitative electrofishing surveys in Tinto Brook and Harpoon/East Pond Brook were used to record fork length (mm) and weight (g). From these data fish condition (K) was derived by calculating the ratio of body weight to length, as follows:

condition factor (k) = 100*(body weight/fork length$_3$).

RESULTS AND DISCUSSION

TINTO BROOK

Between 2005 and 2006 the riverine compensation was completed with the creation of the Tinto Brook channel. Given the life cycle of Brook Trout in western Labrador was estimated to be five years, a five-year monitoring cycle was required with monitoring to be undertaken in 2006, 2007, 2009 and 2010.

From a purely aerial extent the 5,680 m^2 of new riverine habitat created within the meandering stream offsets the loss of the impacted 4,800 m^2 of Hakim Brook's riverine habitat. Pre-development survey of Hakim Brook conducted in 1997 identified the habitat type to be impacted was spawning and rearing habitats suitable for Brook Trout. The fish surveys caught 44 Brook Trout ranging in sizes from 43 mm to 256 mm (estimated ages 0+ to 3+ years). Standing stock estimates were calculated as 88 fish/100 m^2 (range 80-98 fish) and 1203.0 g/100 m^2.

Hydrology

Five stations were established along the length of the created channel (Figure 6). Data collected between 2006 and 2010 on wetted width, maximum water depth and velocity and discharges calculated is listed in Table 1. Water levels and thus depth were higher in all sections in 2010 due to higher level of annual precipitation.

Table 1. Stream Characteristics for each section within created Tinto Brook stream, 2006-10.

Section	Year	Wetted Width (m)	Maximum Water Depth (m)	Maximum Velocity (m/s)	Discharge (m^3/s)
A	2006	7.7	0.37	-	-
A	2007	8	0.43	0.53	-
A	2009	9.5	0.63	-	-
A	2010	10.5	0.70	0.36	0.72
B	2006	7.7	0.53	-	-
B	2007	8.2	0.58	0.4	-
B	2009	8.6	0.63	0.32	-
B	2010	8.9	0.76	0.38	0.76
C	2006	7	0.22	-	-
C	2007	7.3	0.25	0.99	-
C	2009	8.3	0.34	1.04	-
C	2010	7.8	0.42	0.72	-
D	2006	8.4	0.35	-	-
D	2007	8.8	0.37	0.57	-
D	2009	8.7	0.41	0.47	-
D	2010	9.2	0.45	-	-
E	2006	8.7	0.76	-	-
E	2007	8.9	0.85	0.44	-
E	2009	9.4	0.75	0.39	-
E	2010	9.6	0.80	0.58	0.87

Stream flows were measured at the five stations in May-June (spring), August (summer) and September-October (fall) between 2006 and 2011 (fall only). Data collected indicated that flows were variable among seasons and years (Figure 9). These metrics are useful in detecting changes in the created habitats.

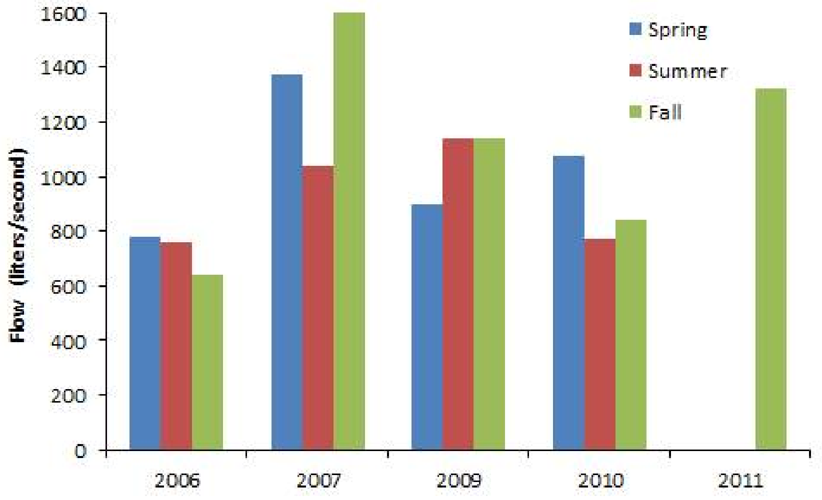

Figure 9. Seasonal stream flows (liters/second) for Tinto Brook, 2006-10.

Habitat stability

Bank stability

Visual observations have indicated that the banks within all five sections remained stable with no signs of erosion. Vegetation planted along the banks has improved bank stability and the aesthetics of the site with increased growth in the floodplain and associated slopes.

Substrate stability

Substrates placed in the constructed channel in 2006 (gravels, boulder) as well as the in-stream features (root wads and overlying trees) have generally remained in similar locations between 2006-11.

Between 2006 and 2010, total suspended solid levels (TSS) within the created stream were measured but were found to be below the method of detection limit of <10 mg/l during all surveys. Pockets of small amounts of sediment deposited in the brook, especially in areas of slower velocities, were noted during the visual surveys between 2010 and 2011 but did not impact the spawning gravels which remained clean. In 2012, TSS and turbidity levels of 5.2 mg/L and 2.3 NTU (nephelometric turbidity unit), respectively were measured which indicated minimal transport of suspended material moving through the stream.

Fish utilization

Visual surveys were conducted at the end of June and fall in 2006, 2007, 2009 and 2010. An additional survey was conducted in 2011. In 2006 no fish were observed within the channel however in 2007 Lake Chub were identified in the spring and fall. In the spring 2009 survey fish were observed within the brook including Brook Trout and minnows however in 2010 after three consecutive days of heavy rains, fish were not observed given the turbid water. In the fall survey in 2010, approximately 20 Brook Trout were noted in spawning condition. In 2011 schools of adult Brook Trout were observed in the stream and a number of large redds were present. Brook Trout fry were observed which indicated they were utilizing the created habitat for spawning and rearing. As well Tinto Brook supported high densities of Lake Chub, Longnose Dace and Burbot in comparison to other streams in the area.

Index electrofishing was undertaken between 2006 and 2010 for those areas upstream not encompassed by the closed quantitative electrofishing station. In 2006 and 2007 only Brook Trout were captured. However in 2009 two Brook Trout and one each of Longnose Sucker and White Sucker each were captured in the same reach. In 2010, similar species were again captured. The capture of suckers indicated that they were now moving upstream from Wabush Lake to utilize the created habitat.

Fish Populations

Relative abundance

The same quantitative electrofishing station was surveyed in 2006, 2007 and 2010. In 2009, the station was moved 20 m downstream due to high water levels. The area surveyed and number of fish caught during the quantitative electrofishing surveys between 2006 and 2010 are presented in Table 2. The relative abundance, measured as catch per unit effort, and the estimated population numbers utilizing the created habitat in Tinto Brook are presented in Table 3.

Table 2. Number of fish caught from the quantitative electrofishing survey in Tinto Brook, 2006-10.

Year	Area (m^2)	Total Number Fish Caught	Brook Trout	Longnose Dace	Lake Chub	Burbot	White Sucker	Longnose Sucker
2006	180	575	0	68	507	1	-	-
2007	323	191	0	145	27	19	-	-
2009	333	100	2	69	17	8	3	3
2010	575	282	2	199	58	21	3	1

Table 3. Catch per unit effort (CPUE) and estimated population size for fish utilizing Tinto Brook, 2006-10.

Year	CPUE (fish/min)	Estimated Population Abundance (fish/100 m^2)
2006	40.1	466
2007	6.9	449
2009	2.9	42
2010	7.0	58

The 2006 and 2007 surveys revealed a high density of fish. Although the abundance of fish was lower in 2009 and 2010, fish diversity and relative abundance remained high. The change in fish caught in 2009 from other years is believed to be due to the change in location of the station surveyed. Longnose Dace and Lake Chub continued to be the dominant species however there is a notable decrease in Lake Chub since 2007 which may be indicative of competition with other species. It is also important to note that suckers have occurred in the brook since 2009 which is due to ability to migrate upstream with the improvement made to the culvert located downstream of the created habitat.

Brook Trout have only shown a minimal presence however visual observations indicated that between 2009 and 2010 they were utilizing the created habitat for spawning as indicated by the presence of spawning adults and large redds observed during the fall surveys. However with the utilization by other fish species the estimated population abundance in Tinto Brook was, in 2006 and 2007, greater than the 88 fish/100 m^2 estimated from the impacted Hakim Brook. The decline in 2009 may be due to change in the survey location however the lower population abundance in 2010 may be due to sedimentation effects.

In 2012 additional surveys were undertaken within Tinto Pond, located upstream of the newly created Tinto Brook, to identify possible reasons for the minimal utilization of the created habitat by Brook Trout. Results of the different aspects of the investigation (sedimentation, water velocities in Brook Trout habitats throughout the year, egg and embryo survival, fry displacement and recruitment success) suggested that the primary reason for the minimal Brook Trout utilization of Tinto Brook was due to low levels of recruitment success as a result of heavy siltation of spawning beds which is likely suffocating Brook Trout eggs/alevin (Ecometrix 2012).

The metrics used to evaluate the effectiveness of the fish habitat compensation appear to be suitable in detecting changes and trends including the level of fish utilization.

Morphometrics

Fish captured were measured for length (mm), weight (g) and condition factor (K). Longnose Dace mean length was similar between 2006 and 2007 (SE=2.3), while Lake Chub have decreased in size since 2007 (SE=8.2) (Figure 10). Mean length of Burbot increased in size (SE=16.6) as did Brook Trout (SE=27.5). However sizes for these fish are based on extremely small numbers so trends are difficult to determine with any certainty.

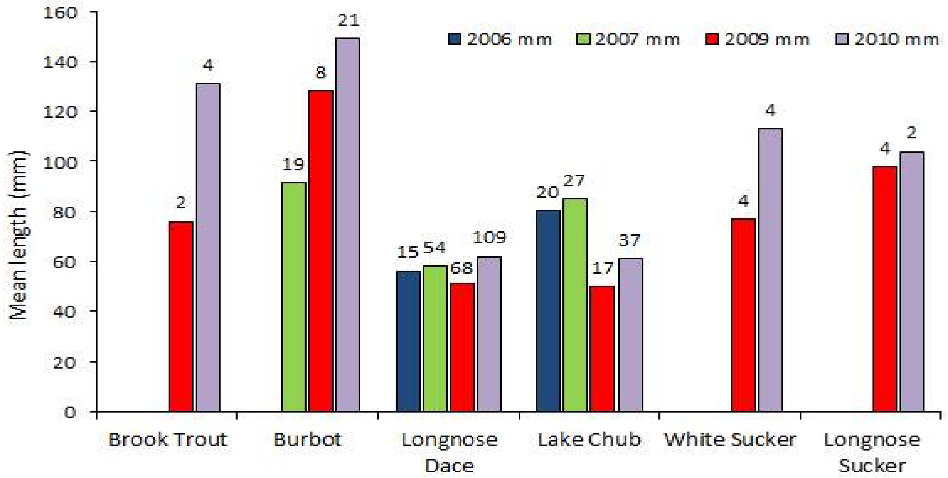

Figure 10. Mean length of fish from Tinto Brook, 2006-2010 (numbers sampled included).

Mean values for weight and condition factor for fish caught in Tinto Brook in the quantitative electrofishing surveys from 2006 to 2010 are presented in Table 4. Given the small sample sizes trends are difficult to determine with any certainty.

Table 4. Mean weight (g) and condition factor (K) of fish from Tinto Brook, 2006-10.

Mean Weight (g)	Brook Trout	Burbot	Longnose Dace	Lake Chub	White Sucker	Longnose Sucker
2006	NA	NA	2.3	5.8	NA	NA
2007	NA	11.2	2.4	7.2	NA	NA
2009	5.1	14.7	2.0	2.3	6.3	11.7
2010	33.1	21.6	1.8	4.2	16.6	13.9

Mean Condition (K)	Brook Trout	Burbot	Longnose Dace	Lake Chub	White Sucker	Longnose Sucker
2006	NA	NA	1.1	1.1	NA	NA
2007	NA	0.7	1.1	1.1	NA	NA
2009	1.2	0.6	1.1	1.1	1.3	1.2
2010	1.2	0.6	1.3	1.2	1.1	1.2

HARPOON BROOK/EAST POND BROOK

Between 2005-06 and 2006-09 riverine compensation was completed in East Pond Brook and Harpoon Brook, respectively with the restoration of fish habitat that was impacted until the mid-1990s by logging activities. During logging activities pulp logs sank and smothered the natural habitats with wood, bark and wood chips thereby making the spawning and rearing habitats unsuitable for use by Brook Trout and anadromous Atlantic Salmon. An eight-year monitoring program was undertaken between 2007 and 2014.

Hydrology

Mean velocities were recorded for each restored section during the surveys (late July-August) (Figure 11). Velocities did not vary significantly between years (SE≤0.02) except for Sections 1, 2 and 5 (SE=0.08) in East Pond Brook. Measurement of velocity was a useful metric in evaluating the potential suitability of the habitat by both Brook Trout and Anadromous Salmon for spawning/rearing (Grant and Lee 2004).

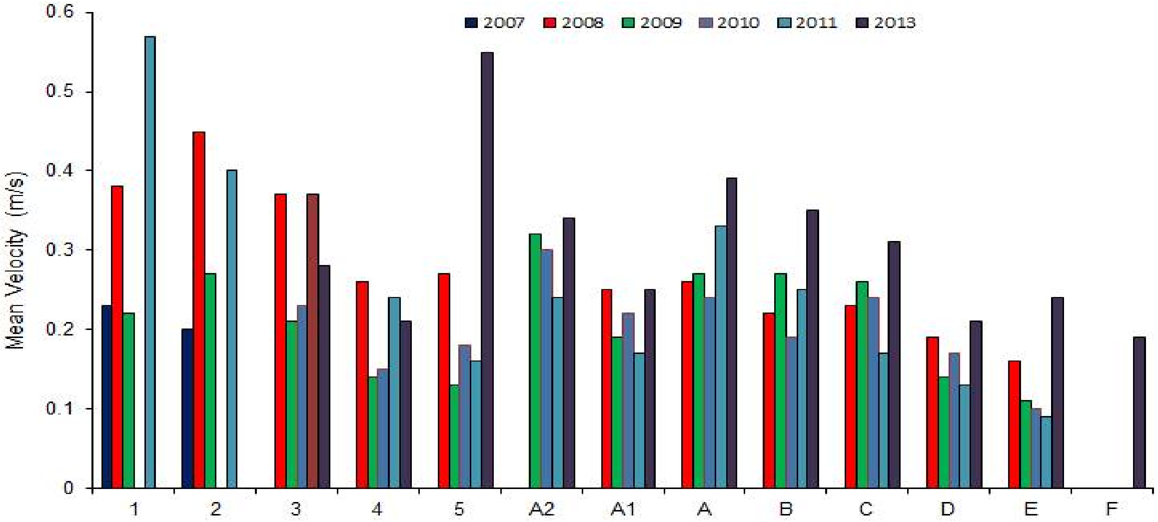

Figure 11. Mean velocities at each section in East Pond Brook (1-5) and Harpoon Brook (A2-E), 2007-13.

Habitat stability

Bank Stability

Habitat was restored primarily through the removal of pulp wood and debris from previous logging activities. Within East Pond Brook 6,030 m^2 of habitat was restored including the removal of 56 cords of wood. Within Harpoon Brook, 105,400 m^2 of habitat was restored including the removal of 517 cords of pulpwood. Visual surveys indicated no evidence of stream bank erosion. Vegetation within the riparian zone appeared to be minimally impacted by restoration activities; however any impacted areas were shown to re-vegetate naturally over the monitoring period.

Substrate Stability

Due to the lack of suitable spawning substrate material in some areas, spawning gravels were placed at 26 locations within Harpoon Brook in 2009; 19 in section A1 and 7 in section A2. Visual observations in 2013 indicated that three showed no loss of integrity, eight had minor shifts or fanning downstream (≤1 m), two shifted >1 m and thirteen were either dispersed with naturally occurring gravels downstream or could not be located. In East Pond Brook 10 locations had spawning gravels placed in 2007 to augment natural substrates; five each in sections 1 and 2. Visual observations in 2013 indicated that the ten gravel placements showed evidence of downstream movement and interspersion with natural gravel substrates thereby overall augmenting natural substrates.

Given the low water depths in the surveyed sections in Harpoon Brook (mean 0.59-0.69 m) and East Pond Brook (mean 0.26-0.27 m) visual observations were useful in monitoring changes in substrate stability in the restored areas.

Fish Utilization

Relative Abundance

Index electrofishing was undertaken to provide an indication of utilization of the restored habitats. To facilitate comparability of results, variation in fishing effort (time fished) was standardized to the number of fish (trout or salmon) caught per minute of effort. Results from the index electrofishing surveys conducted prior to 2009 were not included as standardized sites were not able to be established due to high water levels. As well sections E and F could not be surveyed as the depth of water precluded the ability to undertake an electrofishing survey. Index electrofishing was also not undertaken in Sections 1 and 2.

Relative abundance as measured by CPUE were calculated as number of salmon and trout caught per minute in East Pond Brook and Harpoon Brook (Figure 12). This metric indicated that Atlantic Salmon and Brook Trout are utilizing the restored habitats in both brooks. Relative abundance for both species generally increased between 2009 and 2011 but declined in 2013. Within both brooks differences of utilization of Atlantic Salmon and Brook Trout were noted between sections and years (Table 5 and 6, respectively).

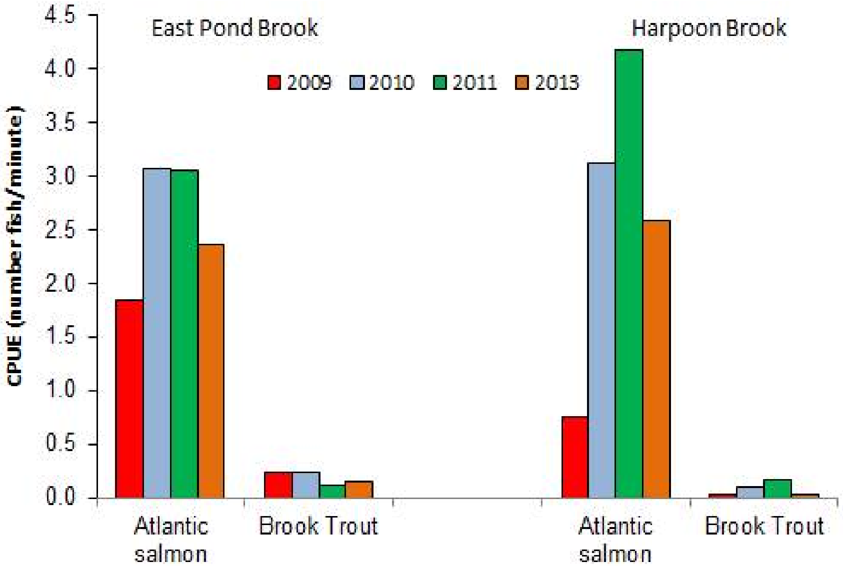

Figure 12. CPUE for Atlantic Salmon and Brook trout caught in index electrofishing surveys in East Pond Brook and Harpoon Brook, 2009-2013.

Table 5. Catch per unit effort (fish/minute) of Atlantic Salmon in East Pond Brook (3-5) and Harpoon Brook (A2-D), 2009-10.

Year	3	5	A2	A1	A	B	C	D
2009	2.13	1.56	0	1.07	1.73	0.8	0.28	0.67
2010	4.31	1.81	4.96	3.24	6.19	1.37	1.8	1.15
2011	3.00	3.1	4.38	2.76	7.23	5.36	4.05	1.27
2013	3.62	1.1	5.99	3.38	1.96	1.03	0.86	2.25

Table 6. Catch per unit effort (fish/minute) of Brook Trout in East Pond Brook (3-5) and Harpoon Brook (A2-D), 2009-2010.

Year	3	5	A2	A1	A	B	C	D
2009	0.33	0.15	0	0.17	0	0.0	0.0	0
2010	0.34	0.11	0.23	0	0.11	0	0.13	0.1
2011	0.10	0.14	0.52	0.05	0	0.09	0.36	0
2013	0.29	0.0	0.2	0.0	0.0	0.0	0.0	0

Traps nets were set especially in areas where electrofishing was not possible due to fast and/or deep waters. In East Pond Brook nets were only set in Sections 4 and 5 and in Harpoon Brook they were set in sections A2-F. CPUE was calculated for each surveyed section (Figure 13). In East Pond Brook and Harpoon Brook, CPUE indicated the presence of both Atlantic Salmon and Brook Trout in the restored habitats. There did not appear to be an obvious reason for the variability in CPUE as timing of sampling, water velocities and water depth were similar.

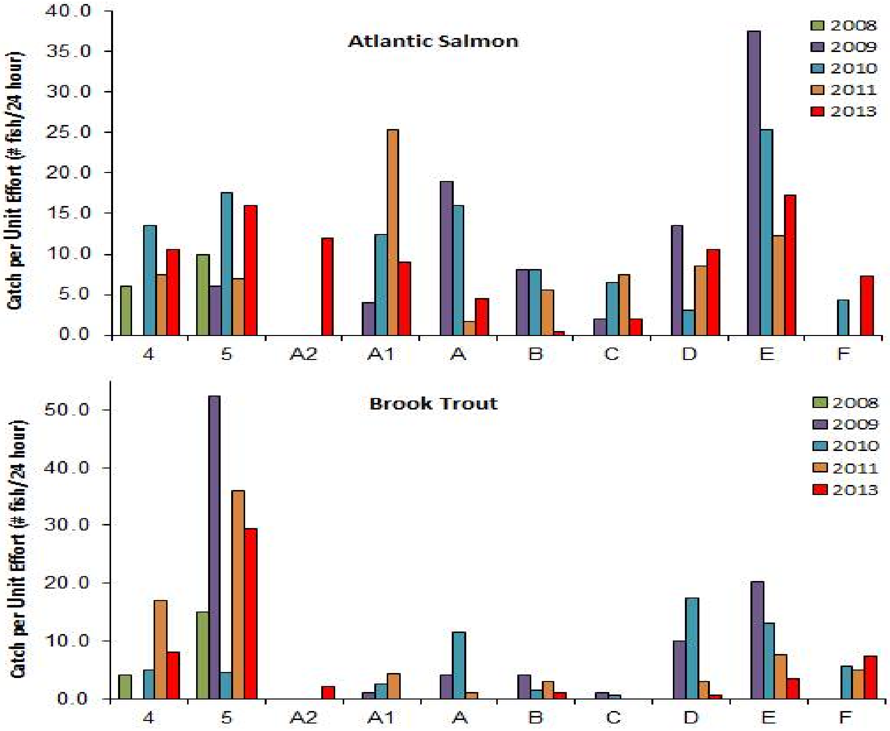

Figure 13. CPUE for Atlantic Salmon and Brook Trout caught in trap net surveys in East Pond Brook (4-5) and Harpoon Brook (A2-F), 2008-2013.

Fish Populations

The metric of biomass (g/100 m^2) was used to determine changes in Atlantic Salmon and Brook Trout utilization of the restored habitats. Biomass was determined through quantitative electrofishing surveys undertaken in nine stations at various times (5 in East Pond Brook and 4 in Harpoon Brook). Other sections were not quantitatively surveyed due to high velocities, depth of water and/or unsuitable river bottom topography.

Biomass estimates for Atlantic Salmon (Table 7) and Brook Trout (Table 8) varied between sections and between years. Between 2011 and 2013, some sections were surveyed in July and again in September with noted changes in biomass between months within the same year.

Table 7. Biomass (g/100 m^2) of Atlantic Salmon in East Pond Brook (1-5) and Harpoon Brook (A2-C), 2007-14.

Year/ Section	Reference Reach	1	2	3	4	5	A2	A1	B	C
2007	-	202.0	59.0	-	-	-	-	-	-	-
2008	-	50.0	42.0	-	-	-	-	-	-	-
2009	-	113.0	97.0	-	35.7	-	-	-	46.0	3.0
2010	-	-	-	-	49.8	-	-	-	99.5	29.7
2011	-	61.0	54.0	-	4.3	-	-	-	16.6	14.0
2011 (fall)	-	-	-	-	-	-	-	-	85.3	15.6
2013	-	8.8	32.0	20.7	11.9	21.6	12.1	42.7	47.1	2.9
2013 (fall)	148.7	244.0	163.0	-	61.6	-	-	-	168.7	16.0
2014	-	527.3	123.7	318.9	23.8	123.6	-	-	63.7	5.3
2014 (fall)	54.5	108.8	49.6	78.3	41.0	136.6	-	-	52.0	31.9

Table 8. Biomass (g/100 m^2) of Brook Trout in East Pond Brook (1-5) and Harpoon Brook (A2-C), 2007-14.

Year/ Section	Reference Reach	1	2	3	4	5	A2	A1	B	C
2007	-	31.0	1.4	-	-	-	-	-	-	-
2008	-	17.0	7.6	-	-	-	-	-	-	-
2009	-	3.9	9.4	-	20.8	-	-	-	0.9	0
2010	-	-	-	-	27.9	-	-	-	0.8	0
2011	-	30.0	29.0	-	35.2	-	-	-	0	0.5
2011 (fall)	-	-	-	-	-	-	-	-	3.5	1.6
2013	-	10.3	2.2	0	23.1	20.5	1.1	2.9	0	0
2103 (fall)	135.1	39.0	6.0	-	139.4	-	-	-	1.4	0
2014	-	4.8	12.0	8.1	57.4	3.5	-	-	4.8	0
2014 (fall)	6.1	2.2	4.5	0	0	56.6	-	-	0	0

In order to determine likely changes, only those years for which at least 7 years of sampling were undertaken at similar times were compared. Generally most sections showed an increase in Atlantic Salmon biomass since restoration was completed (Figure 14). In East Pond Brook, Brook Trout biomass in Sections 1 and 2 fluctuated between years but section 4 generally showed a continually increase between 2009 and 2014 (Figure 15). In Harpoon Brook, Brook Trout were not prevalent in section B and were only found in Section C in 2014.

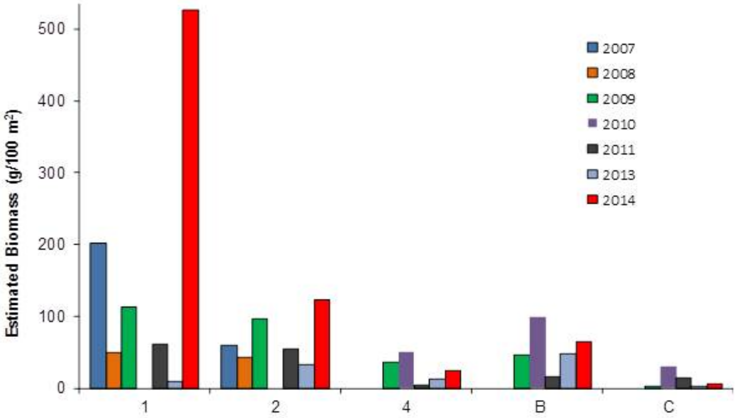

Figure 14. Biomass of Atlantic Salmon in East Pond Brook (1-4) and Harpoon Brook (B-C), 2007-14.

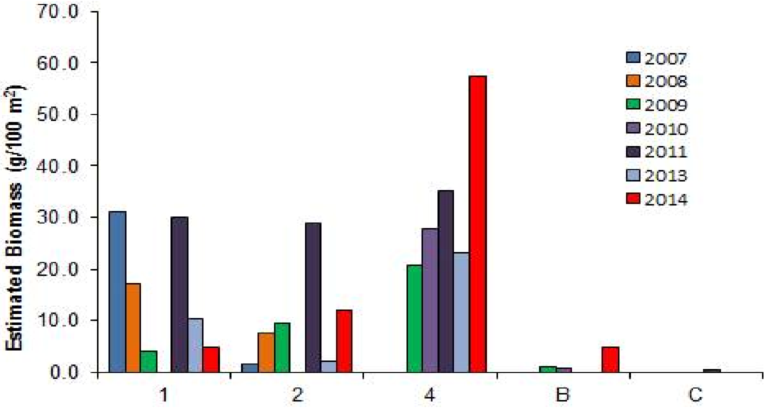

Figure 15. Biomass of Brook Trout in East Pond Brook (1-4) and Harpoon Brook (B-C), 2007-14.

Sampling of a reference reach located above Section 1 of East Pond Brook was only undertaken in the fall (September) of 2013 and 2014. Biomass estimates for Atlantic Salmon were 148.7 g/100 m^2 and 54.5 g/100 m^2, respectively. In comparison the fall surveys in 2013 and 2014 indicated biomass estimates greater than the reference reach in Sections 1, 2 and B in 2013 and in 2014 Section 1 was greater with Sections 2 and B similar to the reference reach (Table 7). Section C in 2013 and 2014 was below the biomass in the reference reach. Brook Trout biomass was 135 g/100 m^2 in 2013 and 6.1 g/100 m^2 in 2014 in the reference reach (Table 8). In comparison, Brook Trout biomass was only higher in Section 4 in 2013 and all sections were below the reference reach in 2014. Control sites are an important metric in order to verify before and after how effective are the restored habitats. However, given that there were only two years of data and only one brook had a control site it is difficult to make an overall assessment other than to say biomasses within the sections were within or higher than the reference biomass.

When looking at the mean total salmonid biomass in relation to the target biomass of 115 g/100 m^2, the target was surpassed in three-years (2007, 2013 and 2014) with the trendline indicative of likely continued increase (Figure 16). It also shows that the timing of sampling can affect the results. For example biomass was higher in the fall in 2013 compared to summer sampling with the reverse happening in 2014.

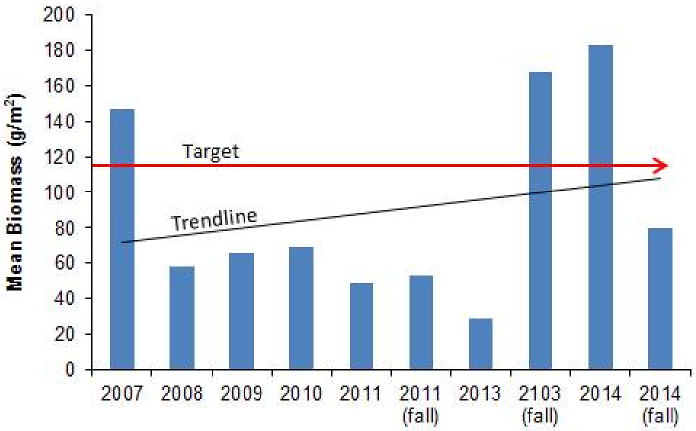

Figure 16. Mean total salmonid biomass from Harpoon Brook and East Pond Brook, 2007-14.

Morphometrics

For both Atlantic Salmon and Brook Trout larger numbers of small fish (0-100 mm) were sampled through electrofishing and were taken consistently between 2009 to 2013 indicating there was recruitment occurring in the restored habitats (Figure 17 and Figure 18). Fyke trap nets were successful in catching larger fish, especially for fish larger than 100 mm. While sampling can be conducted using one gear or the other, the metric of length frequencies has shown difference in gear selectivity which indicates that both should be used in order to obtain a clear picture of the population structure.

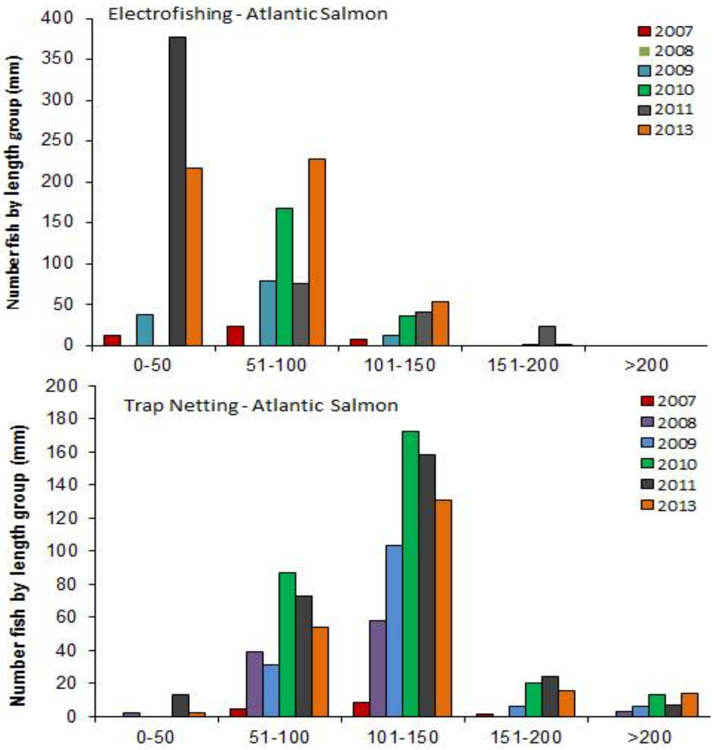

Figure 17. Length frequencies of Atlantic Salmon in Harpoon Brook and East Pond Brook, 2007-13.

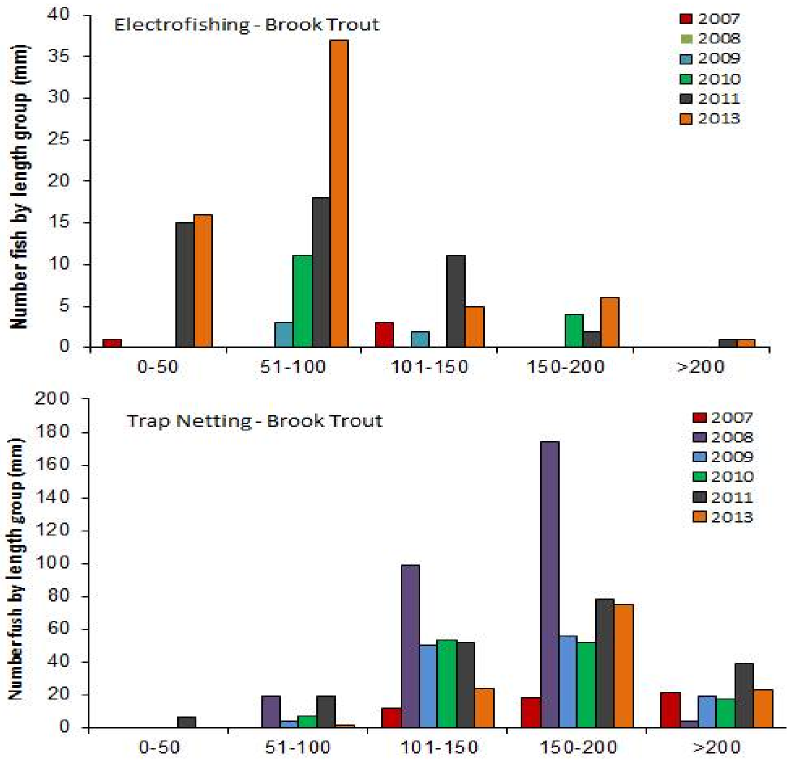

Figure 18. Length frequencies of Brook Trout in Harpoon Brook and East Pond Brook, 2007-13.

The estimated age structure for Atlantic Salmon in East Pond Brook indicated recruitment was ongoing and increased between 2007 and 2014 due to the presence of 0+ and 1+ fish in the electrofishing surveys (Figure 19). Within Harpoon Brook Atlantic Salmon recruitment began in 2009 likely due to the placement of spawning gravels that same year.

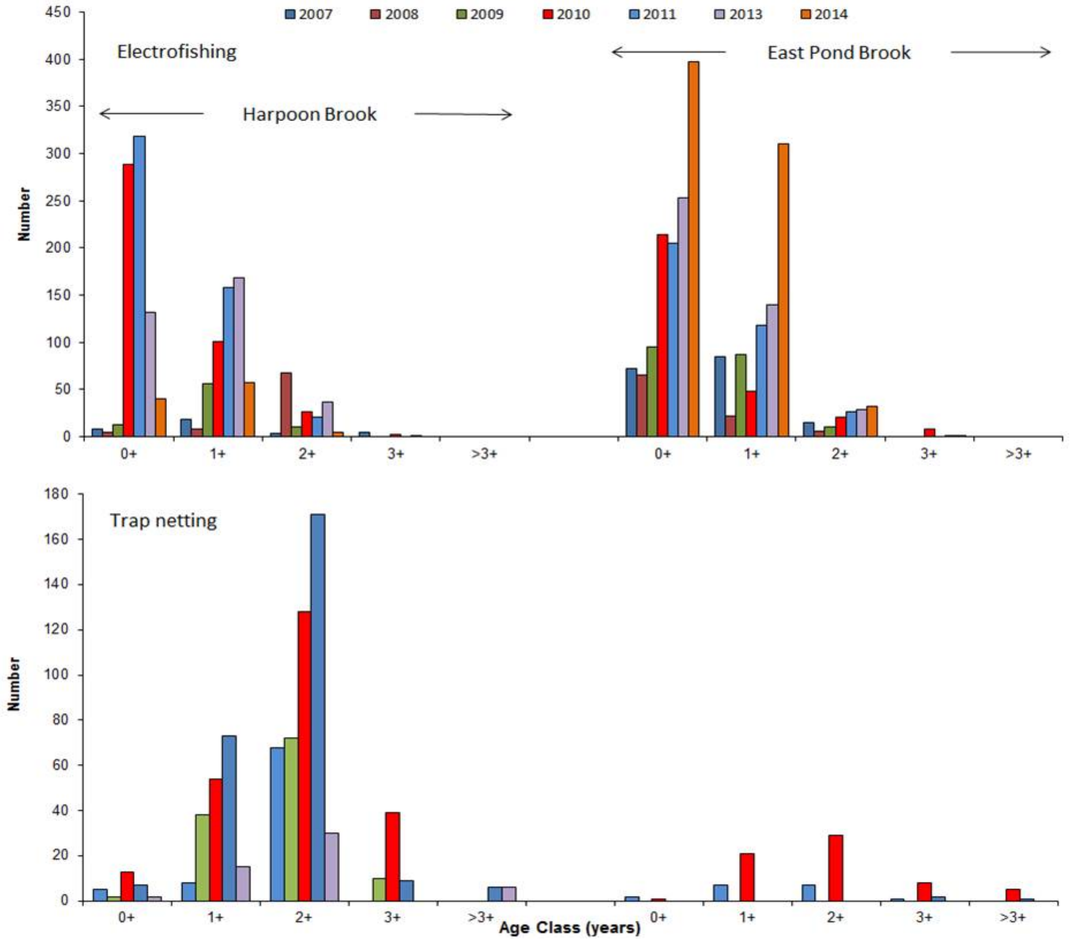

Figure 19. Age class distributions for Atlantic Salmon from electrofishing and trap netting surveys from Harpoon Brook and East Pond Brook, 2007-14.

Brook Trout age class distributions from the electrofishing surveys also indicated recruitment occurred in the restored habitats with East Pond Brook (Figure 20). However the small numbers of fish in Harpoon Brook do not allow trends to be identified.

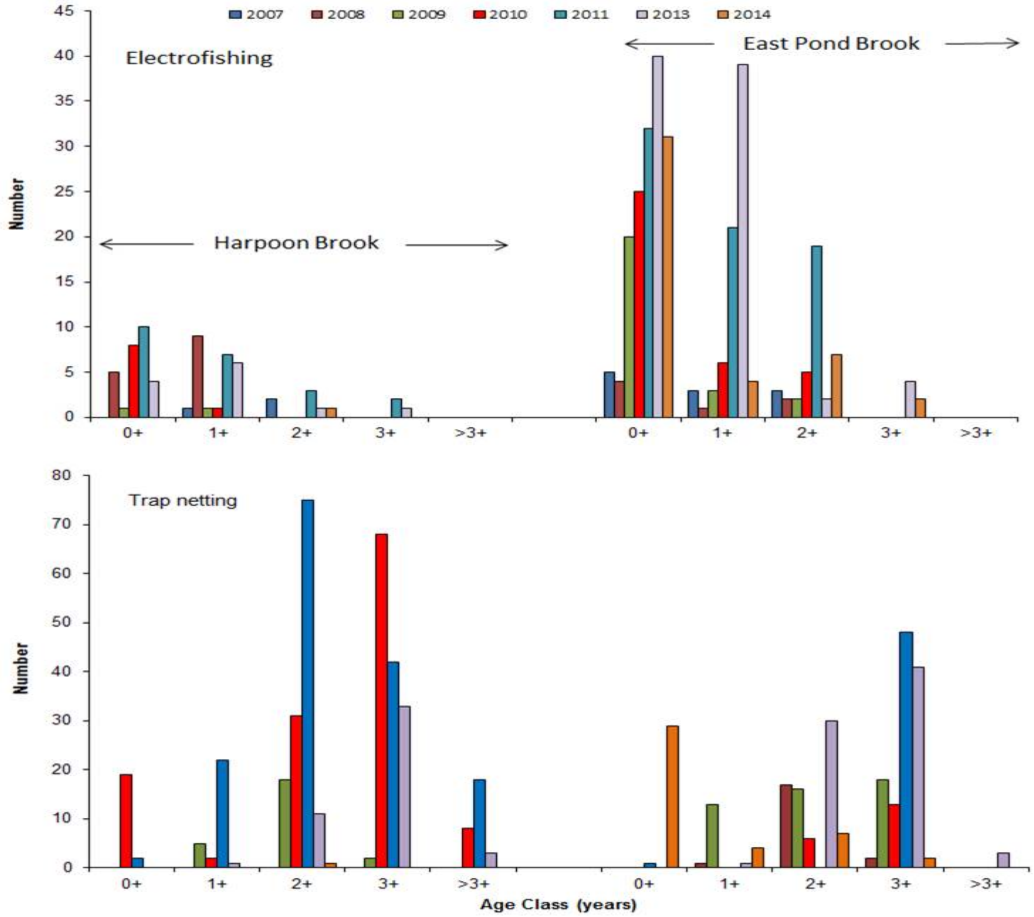

Figure 20. Age class distributions for Brook Trout from electrofishing and trap netting surveys from Harpoon Brook and East Pond Brook, 2007-14.

The use of 'age' as a metric is useful in indicating gear selectivity. As mentioned above for length, electrofishing tends to work well for younger, smaller fish where trap netting tend to collect older fish. By using the two types of gear, a more accurate picture of the age structure of the existing populations can be made. While sampling can be conducted using one gear or the other, the metric of age has shown difference in gear selectivity which indicated that both should be used in order to obtain a clearer picture of the population structure and utilization of the restored habitats.

Figure 21 indicates that weight-at-age has fluctuated between 2007 and 2014 however Atlantic Salmon in the younger age classes (1+ and 2+) have shown increases over the years and appear to be stabilizing. While Brook trout weight at age has fluctuated there is indication that that each age class has shown increases since the start of the restoration of the habitat. However, there may be an overlap between age classes (i.e. >2 and 3 years) which can impact the weight at age distribution.

The linear regressions of the natural logarithms of length and weight were plotted showing an excellent correlation between length and weight for both Atlantic Salmon and Brook Trout (Table 9). Overall the values indicate the fish populations are relatively healthy.

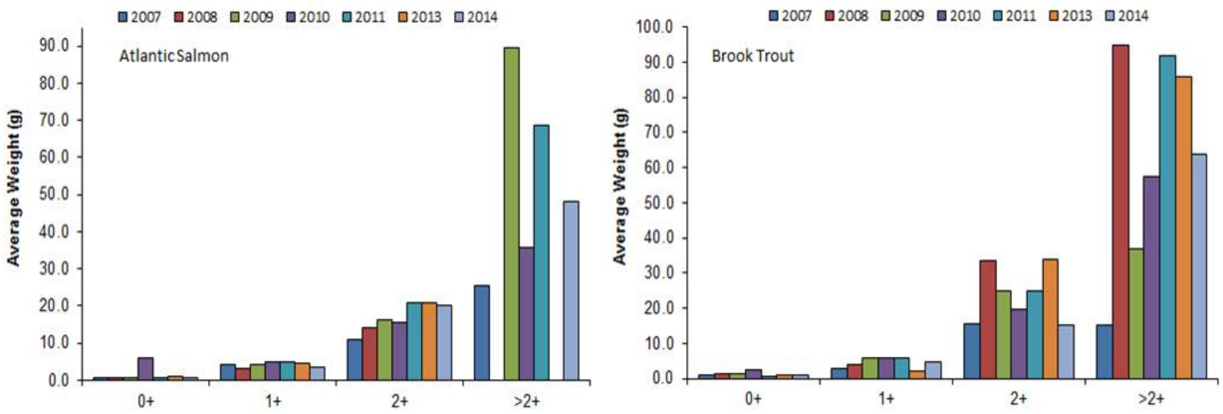

Figure 21. Weight-at-age for Atlantic Salmon and Brook Trout in Harpoon Brook and East Pond Brook, 2007-2014.

Table 9. Length-weight relationships for Atlantic Salmon and Brook Trout from Harpoon Brook and East Pond Brook, 2009-14.

Atlantic Salmon	N	R^2	Linear Regression	Brook Trout	N	R^2	Linear Regression
2009	307	0.944	y = 3.0625x -11.737	**2009**	33	0.993	y = 2.9693x - 11.219
2010	317	0.973	y = 5.5738x - 22.426	**2010**	NA	NA	NA
2011	888	0.984	y = 3.0236x - 11.558	**2011**	NA	NA	NA
2013	975	0.993	y = 2.9459x - 11.189	**2013**	217	0.996	y = 2.9824x - 11.327
2014	676	0.973	y = 3.0906x - 11.889	**2014**	43	0.985	y = 2.9383x - 11.291

While weight as a metric, provides a good measure of a healthy population it should be used in conjunction with other metrics, such as length, age and condition, to provide a clear picture of the overall health of the population.

Condition factor (K) is a useful metric in showing any change in the health of the fish populations over time. Condition factors for Atlantic Salmon and Brook Trout did not differ significantly between years (SE=0.10 and SE=0.07, respectively) (Table 10). This indicated that Brook Trout and Atlantic Salmon populations are generally in good health.

Table 10. Mean condition factor (K) for Atlantic Salmon and Brook Trout from East Pond Brook and Harpoon Brook, 2007-2014.

Atlantic Salmon	2007	2008	2009	2010	2011	2013	2014
Mean K	1.33	NA	1.09	1.09	1.07	1.11	1.00
Number	55	NA	226	245	888	976	677
Brook Trout	**2007**	**2008**	**2009**	**2010**	**2011**	**2013**	**2014**
Mean K	1.09	NA	1.21	1.11	NA	1.12	0.99
Number	54	NA	22	49	NA	219	43

CONCLUSIONS

Where it is required, monitoring of created or restored habitat should assess structural and habitat stability, the extent of fish utilization, changes in fish population size and population structures. Monitoring of habitats must also be undertaken for a long enough period of time in order to allow changes to be reflected and any modification to be identified to remediate the fish habitat if necessary. Monitoring for both the Tinto Brook and Harpoon/East Pond Brook sites was over a five-year and nine year period, respectively to ensure that at least one life cycle for Brook Trout and Atlantic Salmon (freshwater stage) was monitored. While Quigley et al. (2006) suggest at least two life cycles, the logistics and cost especially in remote locations, may be prohibitive.

The metrics used in the monitoring program for Tinto Brook have shown that the habitat is functioning and being used by a number of fish species. However the trout population in the created stream was quite low and given this was the targeted species remedial actions were subsequently undertaken. In the case of Harpoon/East Pond Brook, metrics have indicated that positive changes occurred within the restored habitats (i.e. increases in fish populations and biomass), but it is critical to continue monitoring to ensure that fish populations will stabilize and the biomass targets are met. However to demonstrate that the production lost has been offset by the restoration works, it is critical that biomass estimates are determined for the other sections.

The use of multiple metrics is also important when monitoring fish habitat. The use of one metric on its own may only capture one piece of the puzzle. For instance, the use of multiple gears in acquiring data for the assessment of population structure is very common practice. It is important to collect data on the various life stages of fish which may be occupying different habitats. As well CPUE can be a useful metric in providing a measure of relative abundance over time. However, it is important to sample using similar gear types and conduct sampling at similar time periods in order to reduce variability. Furthermore a control site should be established in order to verify changes noted in the created /restored habitats.

Another important consideration is to ensure there is baseline data to compare to the monitoring results. Given that the area of Harpoon Brook and East Pond Brook had been severely degraded due to decades of logging the predicted initial level of productivity was assumed to be minimal to nil. However a pre-restoration survey, in particular associated with fish utilization, would have ensured a further validation to any increase in utilization, i.e., before-after measurements. As well at a minimum the establishment of a control site upstream/downstream at the start of the monitoring would have provided useful metrics for comparison.

Finally, estimations of age by length should be verified by the use of a length-age key. It can be difficult to estimate the appropriate age of small fish and there is the potential for overlap between age classes. While age can be estimated from length, a sub-sample should be collected to construct a length-age key that would provide a more accurate means of designating small fish to the appropriate age class. Correct aging will also ensure that when comparing to other metrics such as length and weight, the relationship correlations are reasonable.

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