

Atlantic Whitefish (*Coregonus huntsmani*) Stocking in Anderson Lake, Nova Scotia

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ABSTRACT

Bradford, R.G., Themelis, D., LeBlanc, P., Campbell, D.M., O'Neil, S.F., and Whitelaw, J. 2015. Atlantic Whitefish (*Coregonus huntsmani*) Stocking in Anderson Lake, Nova Scotia. Can. Tech. Rep. Fish. Aquat. Sci. 3142: vi + 45p.

Development of captive rearing and captive breeding protocols at the DFO Mersey Biodiversity Facility, Milton, Nova Scotia for the endangered Atlantic Whitefish (*Coregonus huntsmani*) resulted in a supply of F1 progeny that were surplus to research needs. Experimental stocking to assess the suitability of hatchery raised fish as an aid to recovery, to develop stocking criteria and to develop habitat suitability criteria for use in identification of recipient water bodies was determined to represent a best use of the surplus fish. In result, 7,000 larvae, 4,500 juveniles and 396 adult aged F1 Atlantic Whitefish were released into Anderson Lake (64 ha), Halifax County, Nova Scotia. The lake was assessed as potentially suitable following application of the 2003 Canada National Code on Introductions and Transfers of Aquatic Organisms to available data. Monitoring, principally with trap nets, of the general status of the stocked fish and for progeny resulting from spawning was conducted during 2005-2010 and 2012. Both male and female stocked juvenile F1 Atlantic Whitefish exhibited body growth and attained sexual maturation during late November-early December, consistent with the inferred spawning period for wild Atlantic Whitefish. However, no Atlantic Whitefish that would be the result of spawning in the lake were observed. Losses of stocked juveniles from predation and perhaps starvation appeared to be high. None of the larvae released into the lake were observed during 2009, 2010, and 2012 when they would have been of a body size that was susceptible to capture in the trap nets. Water quality and the composition of the forage base of Anderson Lake appear to be suitable for juvenile Atlantic Whitefish but remains uncertain for eggs and larvae. The high abundance of piscivorous Brook Trout relative to the lakes that presently support wild Atlantic Whitefish as well as differences in the species composition of the fish assemblages indicates that trophic structure should be a consideration when selecting lakes to receive Atlantic Whitefish for the purpose of range extension. Aligning stocking densities and the selection of life-stages for stocking with those used to establish refuge populations of other coregonid fish species may increase the likelihood that viable spawning activity can result from stocking Atlantic Whitefish.

RÉSUMÉ

Bradford, R.G., Themelis, D., LeBlanc, P., Campbell, D.M., O'Neil, S.F. et Whitelaw, J. 2015. Empoisonnement en corégone de l'Atlantique (*Coregonus huntsmani*) du lac Anderson, en Nouvelle-Écosse. Rapp. tech. can. sci. halieut. aquat.3142: v + 45 p.

L'élaboration de protocoles d'élevage et de reproduction en captivité au Centre de biodiversité de Mersey de Pêches et Océans Canada, à Milton, en Nouvelle-Écosse, pour le corégone de l'Atlantique (*Coregonus huntsmani*) en voie de disparition a entraîné une augmentation de la descendance F1 qui est devenue trop importante par rapport aux besoins en matière de recherche. Il a été déterminé que l'empoisonnement expérimental pour évaluer la pertinence d'utiliser des poissons élevés en écloserie en tant qu'aide au rétablissement et pour élaborer des critères d'ensemencement et des critères d'habitats propices aux fins d'utilisation dans la détermination des plans d'eau receveurs représentait une meilleure utilisation des poissons excédentaires. En conséquence, 7 000 larves de corégone de l'Atlantique, 4 500 juvéniles et 396 adultes d'âge F1 ont été relâchés dans le lac Anderson (64 ha), dans le comté d'Halifax, en Nouvelle-Écosse. Selon les données disponibles, le lac avait été évalué comme pouvant convenir suivant l'application du Code national sur l'introduction et le transfert d'organismes aquatiques de 2003. La surveillance, principalement à l'aide de filets-trappes, de l'état général des poissons ensemencés et de la progéniture résultant du frai a été effectuée entre 2005 et 2010 et en 2012. Les corégones de l'Atlantique juvéniles mâles et femelles F1 ensemencés ont affiché une croissance corporelle et atteint la maturité sexuelle fin novembre – début décembre, ce qui correspond à la période de frai présumée des corégones de l'Atlantique sauvages. Cependant, aucun corégone de l'Atlantique qui serait le résultat du frai dans le lac n'a été observé. Il semble que les pertes de juvéniles ensemencés en raison de la prédation et peut-être de la famine ont été élevées. Aucune des larves relâchées dans le lac n'a été observée en 2009, 2010 et 2012 alors que les larves auraient dû être d'une taille permettant leur capture dans les filets-trappes. La qualité de l'eau et la composition de la nourriture de base du lac Anderson semblent convenir aux corégones de l'Atlantique juvéniles, mais il n'est pas certain qu'elles conviennent aux œufs et aux larves. L'abondance élevée d'ombles de fontaine piscivores dans les lacs qui abritent actuellement des corégones de l'Atlantique sauvages ainsi que les différences dans la composition des espèces entrant dans les assemblages de poissons indiquent que la structure trophique devrait être prise en compte lors de la sélection des lacs pouvant recevoir le corégone de l'Atlantique dans le but d'en étendre l'aire de répartition. L'harmonisation des densités de mise en charge et de la sélection des stades biologiques pour l'empoisonnement avec les utilisations pour établir des populations refuges d'autres espèces de corégonidés peut permettre d'accroître la probabilité qu'une activité de frai viable puisse découler de l'empoisonnement en corégones de l'Atlantique.

INTRODUCTION

The Atlantic whitefish (*Coregonus huntsmani*) is endemic to Canada (Scott 1987), and found only in the Province of Nova Scotia. It is considered to be anadromous by nature (Scott and Scott, 1988), however, only land-locked populations presently exist in the wild. Extant populations are confined to three small (16 km² surface area) semi-natural lakes in the Petite Rivière (Fig. 1), Lunenburg County that serve as the municipal water supply for the Town of Bridgewater (DFO 2004). Prior to September 2012, these lakes could not be accessed from the lower river and estuary because of the presence of an impassable dam across the outlet of Hebb Lake (Fig. 1) (Themelis et al. 2014), the lower most of the three lakes supporting wild Atlantic Whitefish.

Atlantic Whitefish have been listed and protected as endangered under the Canada *Species at Risk Act* (SARA) since June 2003. The overall goal of the recovery strategy (DFO 2006) developed for Atlantic Whitefish is to “*Achieve stability in the current population of Atlantic Whitefish in Nova Scotia, reestablishment of the anadromous form, and expansion beyond its current range*”. The capacity for this species to establish self-sustaining populations in any water body they do not presently occupy is poorly understood. Neither the life-history nor the habitat requirements for this species have been extensively investigated and inference based upon the demographics of the species is limited by their small historical area of occupancy (Petite Rivière, Lunenburg County and the Tusket-Annis rivers, Yarmouth County (Fig. 1) (Edge and Gilhen 2001; Bradford et al. 2004)).

The likelihood is low that range extension will occur through natural colonization of new habitat because the population is landlocked (DFO 2004). The stocking of eggs and/or fish produced through captive breeding of Atlantic Whitefish, into locations outside of their present area of occupancy is an option both to facilitate range extension and to develop anadromy (DFO 2004, 2006). Atlantic Whitefish stocking has never been attempted.

Atlantic Whitefish were successfully bred in captivity for the first time at the DFO Mersey Biodiversity Facility (MBF), Milton, N.S in December 2000 using five wild adults captured earlier in the year from within the Petite Rivière watershed (Whitelaw et al. 2015). The principle aim of the early captive breeding trials was to provide small numbers of eggs, larvae, and juveniles for research purposes. These life-stages were not readily available from the wild (Bradford et al. 2004) but were required to help complete descriptions of the Atlantic Whitefish life-history (Bradford et al. 2004; 2010; Hasselman et al. 2009), their ontogenetic development (Hasselman et al. 2007) and to develop taxonomic keys to aid in field identifications (Hasselman et al. 2009; Hasselman and Bradford 2012).

Modest collections from the wild continued into 2003 in order to maintain a captive population of ~30 mature adults (15 males: 15 females) at MBF (Whitelaw et al. 2015). These fish were used to produce eggs, larvae, and juveniles (Table 1) for use in experimental determination of their response (growth and survival) to a suite of water temperature, salinity, and pH regimes that are representative of conditions in southern uplands Nova Scotia river catchments and estuaries (see Cook et al. 2010, Cook 2012).

Year over year advances by MBF staff in increasing egg fertilization success and reducing mortality of age 0⁺ year old Atlantic Whitefish (Whitelaw et al. 2015) resulted in significant and accumulating surpluses of F1 fish (first generation resulting from parents bred in captivity) relative to research needs (Table 1). Trial releases of the surplus F1 Atlantic Whitefish into vacant habitat was chosen as an acceptable ethical and scientific use of the fish. It was recognized that releases over time might result in range extension of the species. However, it was equally recognized that releases of 'surplus' fish should not be equated with a stocking strategy designed to maximize the likelihood that self-sustaining populations could result from the activity.

Two locations were selected to receive F1 Atlantic Whitefish: the portion of the Petite Rivière lying below the (then) impassable Hebb Lake Dam, and Anderson Lake, Halifax County, NS (Fig. 2). The lower Petite Rivière site offered the potential to evaluate the response of the F1's to open access to tidal waters. Anderson Lake represented vacant lacustrine habitat wherein the outcomes of the stocking would be wholly dependent upon the response of the stocked fish to the lake habitat. Natural obstructions in the outlet stream from Anderson Lake negated any possibility of the stocked population establishing a connection with the outlet stream and the receiving tidal waters.

WHY ANDERSON LAKE

Fish assemblage and lake habitat information for Anderson Lake was gathered by DFO-Science during 2003 and 2004 as part of investigations into the effects of non-native Smallmouth Bass (*Micropterus dolomieu*) and Chain Pickerel (*Esox niger*) on native Nova Scotia fish assemblages (Bradford et al. 2004). At the times of the surveys Smallmouth Bass had been detected in Minamkeak and Hebb lakes (Fig. 1), the result of at least one unauthorized introduction (Bradford et al. 2004). Chain Pickerel had been illegally released into a number of river systems close to the Petite Rivière and there was concern they would appear with time in the Petite Rivière watershed. Anderson Lake was included in the survey as an example of a water body not impacted by either Smallmouth Bass or Chain Pickerel.

The surveys of the lake during 2003 and 2004 together with information reported from prior, cursory, surveys (Alexander 1972; Alexander et al. 1986) had suggested that the water chemistry and temperature of Anderson Lake was similar to that of the Petite Rivière and that the fish species present in Anderson Lake were conspecific with Atlantic Whitefish in the Petite Rivière. Furthermore, the later surveys had revealed the presence of a previously undocumented lacustrine population of Rainbow Smelt (*Osmerus mordax*), the young life-history stages of which could offer a potential pelagic food source to Atlantic Whitefish. Investigations of the trophic status of Atlantic Whitefish based upon analysis of stable oxygen and nitrogen isotopes (R.G. Bradford unpub. data) along with published descriptions of the land-locked Atlantic Whitefish diet (Edge and Gilhen 2001) had indicated that this species acquired a significant proportion of their food from the water column and were therefore more similar to ciscoes (the so-called lake herrings) than Lake Whitefish (*Coregonus clupeaformis*) in feeding habit.

Anderson Lake was accordingly considered as a potential recipient for F1 Atlantic Whitefish on the basis of habitat suitability. The limited accessibility of the lake (see below), together with the proximity of the lake to the Bedford Institute of Oceanography

(BIO) in Dartmouth, N.S. offered security and operational benefits, respectively. The candidacy of the lake was assessed following a risk assessment framework (DFO 2004) that borrowed evaluation criteria from the 2003 National Code on Introductions and Transfers of Aquatic Organisms (<http://www.dfo-mpo.gc.ca/science/enviro/ais-eae/code/Code2003-eng.pdf>). The first release of Atlantic Whitefish into Anderson Lake occurred on 4 November 2005.

This manuscript presents 1) a synthesis of the biological and environmental data that was gathered prior to and during Atlantic Whitefish F1 stocking activities that occurred during the years 2006, 2007, and 2008; and 2) fish assemblage data that was collected while monitoring the outcomes of the stocking during 2009, 2010, and 2012.

The fate of the surviving Atlantic Whitefish broodstock at Mersey Biodiversity Facility that were released into the lake on 5 November 2015 following the decision to close the facility is unknown, and not considered in this report.

DESCRIPTION OF ANDERSON LAKE

LOCATION AND PHYSICAL CHARACTERISTICS

Anderson Lake is an undeveloped and relatively inaccessible lake located in Dartmouth, NS south east of the Burnside Industrial Park (Fig.2). The lake has a total surface area of 0.62 km², a mean depth of 9.8 m and a maximum depth of 24.4 m. Total lake volume is approximately 6 million m³. The lake is predominantly groundwater fed with seasonal surface inflow and a single continuous outflow that leads into Wright's Cove in Bedford Basin via Little Lake and Wright's Brook. Anderson Lake and Little Lake are connected by a stream (Fig. 3) about 6 m in length with a total fall of < 1 m. Passage into Little Lake from Bedford Basin for species other than American Eel (*Anguilla rostrata*) is blocked by a 2 m high waterfall located about 100m below the lake. As well, Wrights Brook is extensively braided and completely overgrown with wetland vegetation in several low gradient sections (Alexander 1972). American Eel is the only diadromous species present in Anderson and Little lakes.

The northern arm and southeastern embayment of Anderson Lake contain extensive submerged boulder shelves of 2 m depth or less. The shoreline of the lake is dominated by bedrock outcrops and boulders. Emergent aquatic vegetation is sparse. Little Lake exhibits the same shoreline features as Anderson Lake but is shallower (<3 m maximum depth) and supports extensive submerged and emergent vegetation (Alexander 1972).

Anderson Lake was used for several decades as the water supply for the nearby Canadian Forces Base (CFB) Bedford until 1978. The short, approximately 10m long jetty (Fig. 3) that extends into the southwest portion of the lake is the only infrastructure that remains of a pump house that was removed in 1996. The shoreline is otherwise unaltered and the catchment area of the lake is completely forested. The lake edge is generally vegetated with low brush in areas where bedrock is not exposed.

HUMAN ACTIVITIES WITHIN THE ANDERSON LAKE CATCHMENT

The southwest portion of Anderson Lake, and all of Little Lake, is owned by the Department of National Defence (DND). The only access to the lake by motor vehicle is

located on DND lands and access is restricted and only with permission. The remainder of the lake catchment is owned by Dexter Construction Company Limited. The lake can be accessed by hikers and anglers on foot. The frequency of this is unknown. Rough paths occur on the east and west sides of the lake. Foot traffic through the southerly sections is discouraged by DND because of the possibility that Unexploded Ordinance (UXO) materials that were expelled from the CFB Bedford munitions depot via an explosion in 1945 remain in the catchment.

A diesel powered generator provided electricity to the pump house during the years the lake supplied water to the military base. Fuel leaks and spillages during refueling had the potential to contaminate the soil and the lake water. Coal was burned at the pump house and coal ash was discarded in the immediate vicinity of the pump house. Monitoring for contaminants, principally polycyclic hydrocarbons (PAHs) and heavy metals in the soils surrounding Anderson Lake, in lake water, lake sediments, and the tissues of resident fish species has been conducted on several occasions since 2000 (summarized in Jacques Whitford 2008). The presence of detectable levels of PAH's at the site of the decommissioned pump house resulted in the removal/replacement of surface soils in 2005. Concentrations of PAHs following soil remediation were within acceptable limits (Jacques Whitford 2008).

Sampling within the lake of surface water, sediments and fish tissues in 2006 and 2007 revealed the presence of heavy metals in the lake water and both heavy metals and PAH in the lake sediments (ACER Environmental Services 2006). However, the heavy metals are thought to be naturally occurring (Acer Environmental Services 2006). Bio-assay testing indicated that the sediments were not toxic to zooplankton (ACER Environmental Services 2006). Copper, lead, and zinc levels were all above the reference zone background values but below the guideline levels that would raise safety concerns with human consumption of adult fish tissue or lake water (ACER Environmental Services 2006).

WATER QUALITY

Water quality in Anderson Lake was measured during 1971 (Alexander 1972; Alexander et al. 1986), 1991 and 2000 (Clement et al. 2007), 2003 (DFO, unpublished), and 2005-2006 (DFO unpublished). Surface water phosphate (0.004 mg/L (1991), 0.001 mg/L (2000)) and chlorophyll a (2.84 mg/L (1991), 4.46 mg/L (2000)) values indicate the lake is moderately mesotrophic (Clement et al. 2007). Vertical profiles indicate that the lake is well oxygenated (8-11 ppm) throughout the water column (Alexander 1972) even when strongly vertically stratified during summer (Fig. 4). Mean (± 1 standard deviation) water pH is 6.1 ± 0.4 but individual estimates have varied from 5.3 to 7.0 among years and among depths (Table 2; Fig.4). These data suggest that surface water pH has decreased with time from ~6.5 in 1971 to an average of 6.2 in the years 2003-2006 (Table 2).

Onset of stratification of the water column was evident in CTD casts during mid-May, 2006 (Figs. 5, 6). A CTD cast in August 2003 indicated that summer water surface temperatures can be as high as 23 °C and that water column stratification occurs at depths between 4 and 7 m (Fig. 4). CTD casts conducted in August, October and November 2005 also showed the presence of a thermocline at 4-7 m in summer-early

autumn conditions (Fig. 7) and that turnover of the water column occurred by November (Fig. 7). Water temperatures below the thermocline were typically < 9 °C (Figs. 4-7).

FISH ASSEMBLAGE PRIOR TO STOCKING ATLANTIC WHITEFISH

Anderson Lake has a lengthy and rather exotic history of having been stocked with non-native salmonids, beginning with the release of 75,000 Lake Trout (*Salvelinus namaycush*) during 1895-1896 and the release of 3,000 Rainbow Trout (*Oncorhynchus mykiss*) in 1899 (Alexander 1972). Neither species established self-sustaining populations in the lake. During the 1970's, Anderson Lake was included in a provincial experimental stocking program, receiving in 1975 a total of 1,963 Brook Trout (*Salvelinus fontinalis*) of 255 g average individual weight (Alexander 1976).

The species composition and biological traits of the native fish assemblage were not established prior to the stocking of the lake with salmonids. Few surveys were conducted after the release of Brook Trout and those that occurred were low effort, i.e., an overnight set with a multi-panel gillnet (mesh sizes from 1.3 to 6 cm). The gill net data suggested that the diversity of the native fish assemblage was low. White Suckers (*Catostomus commersoni*) were captured in late summer 1971 (Alexander 1972) and catches of Brook Trout, American Eel (*Anguilla rostrata*) and White Suckers were reported from gill netting activities conducted in 1984 (DFO unpublished data).

The fish assemblage of Anderson Lake was surveyed with gill nets in 2003 (Table 3) by DFO-Science for the reasons described above. Briefly, four 18 m long by 2 m deep multi-panel gillnets with mesh sizes 2.5, 3.8, 5.1, 6.3, 7.5, 8.8 cm were set on 3 July 2003 and allowed to soak overnight for a total soak time of 19 hours. Two gill nets were set perpendicular to the shore at a maximum depth of 3 m. The other two gill nets were set at depths of ≥7m (below the thermocline). One additional 18 m long by 2 m deep single panel gill net of 3.8 cm stretch mesh was deployed below the thermocline. This mesh size was employed because it had been shown to be an effective means to capture Lake Whitefish (*Coregonus clupeaformis*) in other Nova Scotia lakes (Bradford et al. 2004; Murray 2005). The capture of a single land-locked Rainbow Smelt (*Osmerus mordax*) in this net prompted a larger search effort for smelt on 20 August 2003. Five 18 m long by 2 m deep small mesh (1.3 cm to 1.9 cm) gill nets were fished overnight (soak time =19 h). Two nets were fished at the water surface over a water depth of 15m, two were set at 6.9 m, and one at 10m depth.

Gillnetting activities were repeated on 27 April, 2004 (Table 4). The composite catch revealed the presence of White Sucker, Brook Trout, Ninespine Stickleback (*Pungitius pungitius*), and Rainbow Smelt. White Sucker were the dominant catch (>80%) in nets set on the lake bottom in both years (Table 3, 4).

A Beamish trap (Beamish 1972) set during September-October 2005 prior to the release of Atlantic Whitefish was not effective in capturing fish (data not shown).

Minnow pots baited with canned salmon that were set opportunistically during July-August 2005 and 2006 contributed Banded Killifish (*Fundulus diaphanus*), Common Shiner (*Luxilus cornutus*), and Golden Shiner (*Notemigonus chryssoleucas*) to the species list for the lake. In total, eight fish species were collected from Anderson Lake (Table 5) prior to the first release of F1 Atlantic Whitefish on November 4, 2005.

METHODS

ATLANTIC WHITEFISH STOCKING

Table 6 summarizes the stocking dates, numbers of fish, average weights and distinguishing marks of fish released into Anderson Lake from 2005-2012. Table 7 summarizes the criteria used to identify the stocking year and age-at-capture (years) of Atlantic Whitefish sampled in Anderson Lake during the years 2007 to 2012.

The first release of captive bred and reared Atlantic Whitefish occurred on the afternoon of November 4, 2005 with the release of 1,500 unmarked age 1⁺ year old juveniles from the jetty that extends into Anderson Lake (Table 6, Fig. 3). A 3 m deep barrier net (2.5 cm stretch mesh) was installed across the inlet to Little Lake for about 10 days in order to discourage emigration from the lake during dispersal from the release site. The barrier net was similarly installed and maintained in every year during which age 1⁺ year old and older Atlantic Whitefish were released into the lake.

In 2006, the first of several stocking events occurred on April 24 with the release of 10 age 2⁺ years old fish carrying surgically implanted Vemco model V9-1L acoustic transmitters (see Cook et al. 2013) and 750 age 1⁺ year old adipose clipped juveniles. On April 26, a total of 5,000 post-yolk sac larvae (age 0⁺ year) were released in shallow water at various points around the lake in batches of approximately 1,000 fish. On May 23, 2006, an additional five age 2⁺ year old fish carrying acoustic transmitters were released. On October 16, 750 unmarked age 1⁺ year old juveniles were released.

In 2007, 750 age 1⁺ year old juveniles marked by removal of their entire adipose fin were released on May 1 along with 2,000 larval (age 0⁺ years) fish. Six age 2⁺ years old juveniles with surgically implanted acoustic transmitters were released on October 3, 2007, together with 750 age 1⁺ year old juveniles marked by partial removal of the adipose fin (a hole punch was used to remove the posterior portion of the adipose fin, hereafter referred to as a PAP).

In 2008, there was a single release of 212 age 4⁺ years old adults marked via injection of a visible implanted elastomer (VIE) into the left pectoral fins and 184 age 3⁺ years old adults marked with both a VIE on the left pectoral fin and a PAP.

The final release of fish into Anderson Lake occurred on November 5, 2012 when approximately 80 ages 5⁺ years and 6⁺ years fish were released. These were marked via injection of a pink VIE into their left pectoral fin.

FISH SAMPLING FOLLOWING STOCKING ATLANTIC WHITEFISH

A floating trap net (approximate dimensions 12 m long by 6 m wide by 3 m depth and constructed of knotless 3.8 cm stretched mesh) was deployed from 11-16 May, 2006 in 3 m of water about 9 m from the northwestern shore of Anderson Lake (Fig. 3, Table 8). The trap was oriented with the mouth facing, and aligned perpendicular to the shoreline, as was the case for all further trap net deployments irrespective of trap design. Because access to the lake through DND lands was restricted to between 0800h and 1500h for the duration of the study, the trap (and all subsequently deployed traps) was checked during the morning hours and re-set within this time frame.

The floating trap net proved to be ineffective at retaining Atlantic Whitefish because of their tendency to swim over the top rope whenever waves developed on the lake¹. On 6 June 2006, the trap was mounted on wooden pickets attached to a sunken 12 m by 6 m rebar frame to raise the top rope about 0.3 m above the water. The trap was fished a few days each week until June 28, 2006 when water temperatures rose to above 16 °C, the upper thermal limit for handling Atlantic Whitefish (Cook et al. 2010).

The trap net was reset in the same location on 15 November 2006 but on a rigid frame and fished about once or twice per week until 1 December, 2006.

Beginning in 2007, box trap nets constructed of knotless 2.5 cm stretch mesh were hung from the top rail of a floating frame with dimensions 7.3 m long by 3 m wide by .4 m deep (Fig. 8). These traps were constructed specifically to circumvent the difficulties associated with installing fixed frames upon the irregular and hard lake bottom and as well to prevent Atlantic Whitefish entering the trap from escaping over the top line. The first trap net deployed on 16 May 2007 and fished until 22 June 2007 (Table 8) was 3.7 m deep and was attached to a 30 m long leader (2.5cm stretch mesh) that extended to shore. Sampling resumed 8 November 2006 and continued to 30 November 2006 with a net of similar netting specifications and length-width dimensions but 4.5 m deep. The extra depth allowed the trap net to be installed 60 m from the shore with the foot rope of the net on the lake bottom. The attached leader (2.5 cm stretch mesh) extended to the shore. This trap net was adopted as the principle sampling platform in the years 2008-2010 and 2012 (no monitoring occurred during 2011). In an attempt to increase sampling effort during the fall of 2010, the shallower 3 m deep trapnet was installed on a second floating frame and set on a shoal that ran between the northern shore of the lake and an island (Fig. 3).

All fish were identified to species, measured to Fork Length (FL) and or Total Length (TL) and returned to the lake. External body scales were removed from Atlantic Whitefish and White Sucker prior to their release in order to allow for later age determination. Atlantic Whitefish and Brook Trout captured during autumn sampling activities were inspected for evidence of sexual maturation, principally the release of eggs or milt upon application of light pressure to the abdomen. Presence/absence of pearl organs on the exterior of Atlantic Whitefish was an additional indicator of sexual maturation among male Atlantic Whitefish following Edge (1987) and Edge et al. (1991).

RESULTS

CATCHES FOLLOWING STOCKING

2006

The trap net was fished on four days from 6 - 22 June and captured 31 Golden Shiners (7.8 ± 3.8 per day), 10 White Suckers (2.5 ± 2.5 per day), and three Atlantic Whitefish

¹ The same observation was made during the autumn of 2005 when the trap net was deployed in Milipisgate Lake, Petite Rivière (R.G. Bradford personal observation).

(0.8 ± 1.5 per day) (Table 9). The Atlantic Whitefish were all captured on 7 June and were likely members of the group released on 5 November 2005 (Table 6) as no surgical scars or adipose fin clips were observed.

In November 2006, the trap net was fished for five days and captured 20 (4.0 ± 1.9 per day) Brook Trout, 14 (2.8 ± 2.6 per day) White Sucker, and 7 (1.4 ± 0.9) Atlantic Whitefish (Table 10). The broad range in body size (15.6 cm - 25.9 cm FL, Table 10) and capture of both marked and un-marked Atlantic Whitefish indicated that these animals had originated from different release dates. The two individuals measuring 19.6 and 20.2 cm FL had no fin clips or surgical scars and were likely members of the cohort released on 16 October 2006 (average 18 cm FL, no clips). The two individuals measuring 19.8 and 21.7 cm FL had adipose clips and lengths similar to the fish released on 24 April 2006 (17 cm FL; Table 6). The two largest individuals with lengths of 24.0 cm FL and 25.9 cm FL had no adipose clips or scars and may have been from the 4 November, 2005 when the largest bodied group of unmarked fish (22 cm FL) was released (Table 6). The 15.6 cm FL individual captured on November 23 is difficult to assign to a probable stocking cohort because it was shorter than the average length of any group released. It may have been part of the group released on 24 April 2006, the only group with an average length under 20 cm (17 cm FL) but no adipose clip for this fish was recorded in the field notes.

2007

A total of 20 Atlantic Whitefish were captured during sampling in 2007, six from 15 May to 22 June and 14 from 9 - 30 November (Table 11). All of the fish captured during May and June were between 19.9 and 24.6 cm FL (Table 12) and were considered to be from the 4 November 2005 and/or the 16 October 2006 releases because no fin clips were observed (all fish released on 24 April 2006 were marked), and they were larger bodied than the ~15 cm FL fish released on 1 May 2007. Five of the six fish were skinny and had tattered caudal fins (Table 13). All of the 14 Atlantic Whitefish captured in the fall were 19.0 to 24.8 cm FL (Table 13) and represent multiple release events. None of the 15 cm FL fish released on 1 May 2007 was observed in 2007 trapnet catches.

2008

A total of 18 Atlantic Whitefish were trapped from 21 October 21 to 14 November, prior to release of hatchery reared fish. Fourteen of these captures did not display adipose clips or surgical scars (Table 14) and were between 21 and 24.2 cm FL. The other four fish had adipose clips and were between 21.2 and 21.5 cm FL (Table 14). Forty of the 44 fish caught on 28 November three days after the release of 396 VIE marked Atlantic Whitefish on 25 November displayed VIE marks (Table 14). This was the largest daily catch of Atlantic Whitefish in any year. Ten of the 14 Atlantic Whitefish caught during sampling from 3 -17 December were PAP and VIE marked (Table 14). The other 4 were between 22.7 and 23.6 cm FL. The length range of the sampled population was 21.2 cm FL – 31.6 cm FL (Table 12, Fig 9) as would be anticipated with the presence by introduction of multiple cohorts of fish into the lake.

2009

Trapping from 12 November to 2 December captured 42 Atlantic Whitefish ranging from 23 - 33.7 cm FL. The suite of marks exhibited by the catch indicated that fish aged 3⁺, 4⁺ and 5⁺ years were all represented in the catches (Table 15). Ten fish had a PAP mark indicating they were from the 3 October 2007 release. Seven fish had VIE markings indicating that they were released in 2008. The length frequency distribution of the sampled catch (Fig. 9) indicated that the fish were overall larger-bodied than those sampled during 2007 and 2008 which suggested that at least some members of the stocked population had realized somatic growth since their release.

2010

A total of 41 Atlantic Whitefish were captured from 2 November to 9 December by the 4.5 m deep trapnet (Table 9). Of these, 24 (60%) were from the cohort released in 2006 (Table 14). Fifteen (38%) had been released in 2007 (Table 14). Only one of the fish released in 2008 (VIE marked) was recaptured (Table 14). Both the minimum body length represented in the catch (25.7 cm FL) and average length of the catch (28.2 cm FL) were greater than those observed in the previous years of sampling (Fig. 9) which further suggested that Atlantic Whitefish were able to accrue annual somatic growth.

2012

Only two Atlantic Whitefish were captured during 17 days of fishing from 2 November to 15 December 2012 (Table 11). These were 34 and 36 cm FL (Fig. 9) and had no observable fin clips or VIE marks. Assuming no regeneration of adipose fins, the fish may have been in the lake since 2006 when the last group of unmarked age 1+ fish were released. None of the fish from the 2008 or 2012 releases (all VIE marked) were observed.

CONTRIBUTION OF ATLANTIC WHITEFISH TO THE FISH ASSEMBLAGE

Stocked Fish

Daily catches of Atlantic Whitefish tended to be low on average (2 fish per day or less in all years, (Table 11) and infrequent in all years (Appendix 1) with zero catches recorded on more than 60% of the 96 total sampling days during the years 2007-2010 and 2012 (Fig. 10). However, the frequency distribution of the daily catch rates for stocked Atlantic Whitefish is consistent with the results of trap net-based monitoring activities of wild Atlantic Whitefish in the Petite Rivière lakes where zero catches were recorded more on more than 80% of the 65 days of sampling (Fig. 10; source Edge 1987, DFO unpublished data). On the days that fish were captured, ≤ 3 Atlantic Whitefish per day were recorded 57% and 67% percent of the time in Anderson Lake and the Petite Rivière lakes, respectively.

The proportion of the catch represented by Atlantic Whitefish differed markedly between Anderson Lake and the Petite Rivière lakes. Stocked Atlantic Whitefish represented more than 20% of the fish sampled from Anderson Lake during the years 2007-2010 and was less than 10% (7%) only during 2012 (Table 16). Wild Atlantic Whitefish did not

exceed 19% of the catches sampled from the Petite Rivière lakes in any year, irrespective of method of capture (trap net, gill net) (Table 16, Fig. 11).

A comparison of the fish species composition compiled from multiple years of sampling in Anderson Lake and the Petite Rivière lakes affirms that Rainbow Smelt are found in the Anderson Lake but not the Petite Rivière watershed (Tables 16 and 17). Brown Bullhead Catfish (*Ictalurus nebulosus*), White Perch (*Morone americana*), and Yellow Perch (*Perca flavescens*) which are common in the Petite Rivière lakes appeared to be absent from Anderson Lake. Brook Trout are present but not abundant in Petite Rivière lakes (Table 17), in sharp contrast to their general status within Anderson Lake (Table 11). White Sucker was a common component of sampled catches in both locations (Tables 11 and 17).

None of the 7,000 larvae released into the lake (5,000 in 2006, 2,000 in 2007; Table 7) were observed in the later years of sampling (i.e., 2009, 2010, 2012). These appear to not have survived. Based on the observed minimum length of capture in the trapnets (Fig. 9), these would have been susceptible to capture when they reached a body length of approximately 15 cm FL.

Progeny of Stocked Fish

The length frequency distribution of the sampled catch exhibits a progressive increase in body size during the years that monitoring occurred (Fig. 9). Smaller bodied fish which would indicate that spawning may have occurred successfully and that a portion of the progeny survived to be susceptible to capture (assumed to be at a body length of ~15 cm FL) do not appear in the time series with time (Fig. 9). Sexually mature Atlantic Whitefish were first observed in the sampled catch in 2008 (see below) which could have resulted in the availability of progeny to capture during 2010 at the latest. Progeny from these adults would have been available to capture by 2010. Any progeny that may have resulted from spawning would therefore have existed at a level of abundance that could not be detected with the sampling platforms deployed to monitor Atlantic Whitefish status.

SEXUAL MATURATION AND SPAWNER SUCCESS

A total of 40 stocked Atlantic Whitefish exhibited signs of sexual maturation (Table 18) during November-December sampling, all years combined. Of these, 21 fish possessed pearl organs around the head area, an indication of sexual maturation in males but not necessarily females (Edge and Gilhen 2001). An additional 17 fish were assessed to be mature males on the basis of expression of milt (Table 18), but trap records are unclear whether all of these fish possessed pearl organs. Two stocked Atlantic Whitefish released eggs under slight pressure (Table 18) suggesting a sex ratio of 19 males per female (assuming only males possessed pearl organs). However, males represented slightly less than ½ (48%) of all fish ≥25 cm FL (n =80), the minimum observed length of sexually mature fish which suggests that sexually mature female fish were represented in the catch but not identifiable. The tendency for the few (n =2) ripe females to be sampled during early December (Table 18) suggests differing maturation schedules between sexes with females achieving full sexual maturation later than males.

No sexually mature fish were observed during 2007. The number of mature fish sampled per year was 4, 17, 19, and 2 for the years 2008, 2009, 2010, and 2012 respectively.

DISCUSSION

No progeny of Atlantic Whitefish stocked during the years 2005-2008 were observed during the years (2009, 2010, and 2012) that they would have been susceptible to capture in the trap nets. Whether failure to spawn, or low spawn viability, or failure of the post-emergence life-stages to survive to the size/age of recruitment to the sampling gear contributed to their apparent absence is not known. However, there were several outcomes or inferences from the outcomes of the stocking activity that yielded useful insights concerning the spawning potential of F1 Atlantic Whitefish, the potential effects of protracted captive rearing (e.g., >1 year) on survivability of F1 released to the wild, stocking strategies, and habitat suitability. These are discussed below in the context of a contribution to the biology of Atlantic Whitefish and as considerations for future stocking activities intended to aid survival or recovery through range extension.

Spawner Potential of Captive-Bred Donor Stock

Observable numbers of both male and female stocked juvenile F1 Atlantic Whitefish exhibited body growth and attained sexual maturation in vacant lacustrine habitat. The seasonal timing of their maturation is consistent with a spawning period of late November inferred for wild Atlantic Whitefish (Edge and Gilhen 2001, COSEWIC 2010)) and with the December-January spawning period observed for both wild-caught and captive reared adult Atlantic Whitefish at the MBF (Whitelaw et al. 2015). These outcomes support the further consideration of captive-bred Atlantic Whitefish as donor stock for aiding species survival or recovery through range extension (DFO 2006).

However, there were indications that the mortality rate of captive reared juveniles was high once introduced to Anderson Lake, with a number of factors contributing to the loss of fish with time.

Effects of Protracted Captive Rearing

Observations of the general condition of the stocked fish at their time of capture indicated that many fish did not succeed in transitioning to foraging in the wild whereas others maintained the appearance of good health, e.g., the observations during 2007 as recorded in Table 13 and were able to survive for two or more years following their release into the lake (Tables 14 and 15). Habituation of the fish to husbandry (e.g., a scheduled, monotonous and liberal feeding regime) from the time of first feeding through to release as age 1⁺ year or age 2⁺ years juveniles, may have contributed to what had the appearance of a high level of naïvety with respect to foraging ability.

Furthermore, predation on Atlantic Whitefish by avian predators, principally a family unit of osprey (*Pandion halieatus*) nesting on a small island in Anderson Lake, was observed frequently, by a number of project participants, in the years that stocking occurred. Of particular interest is that the birds were frequently observed to pluck

Atlantic Whitefish from the water by swooping down to the lake surface at a low angle of attack rather than via the high-angle-of-approach dive to capture prey that is characteristic of the species. These observations suggest that some of the stocked juvenile F1 Atlantic Whitefish remained near the lake surface. Consistent with the inference of a high rate of loss from avian predation, Cook et al. (2013) estimated that 10 of 15 (67 %) F1 Atlantic Whitefish released into the lake with implanted acoustic transmitters during April-May, 2006 were lost within 31 days of release, always during daylight, and usually either shortly after sunrise or shortly before sunset. In contrast, only one of the 16 wild Atlantic Whitefish implanted with acoustic transmitters was interpreted to be lost to predation in Hebb Lake (Cook et al. 2013). Further, the tracked population in Anderson Lake was slow to disperse from the release site and remained at the surface for extended periods of time (Cook et al. 2013).

Whether the practice of delivering feed to the fish while in captivity at the water surface rather than throughout the water column contributed to an apparent protracted association of the fish with the lake surface following their release is not known. But the cumulative information from observation and acoustic tracking indicate that captive husbandry practices have the potential to affect post-release mortality from starvation and predation.

Stocking Strategy

The life-stage (larval, juvenile and adult) composition and schedule for releases of Atlantic Whitefish into Anderson Lake were set to manage the accumulation of fish that were surplus to research purposes. Considerations did not extend to either the life-stages best suited for release, or the number required per release, or the duration (years) of stocking that could have contributed to improved likelihood that self-sustaining populations would result from stocking. The net outcome of the stocking activity was that F1 Atlantic Whitefish survived to sexual maturity with no indication that progeny resulted from any spawning activity within the lake. Although this outcome was encouraging, it was the result of stocking fish in numbers that were high relative to the native fish assemblage (F1 Atlantic Whitefish represented on average $32\% \pm 23\%$ of annual sampled fish assemblage and relative to the contribution of wild Atlantic Whitefish to the fish assemblages of the Petite Rivière lakes ($\leq 19\%$; Table 17). The density of the stocked juvenile fish may have exceeded the availability of forage within the lake which may explain in part the poor condition of some the fish (Table 13).

Stocking as a conservation tool to establish new populations of Nearctic coregonid fish species does not appear to have been attempted anywhere in North America.

Supplemental stocking of Lake Whitefish (*C. clupeaformis*) has occurred since 1982 to improve the status of the population that exists in Lake Simcoe, Ontario (Lasenby et al. 2001). There are anecdotal reports that populations of Cisco (*Coregonus artedii*) were established in previously vacant habitat during the 19th century following the stocking of larvae to develop commercial fisheries in Indiana (Frey 1955) and Illinois (Burr and Page 1986). In contrast, there are no indications that any of the extensive stockings of Lake Whitefish from federal Canadian hatcheries during the years 1878-1914 (Bradford and Mahaney 2004) resulted in the development of any self-sustaining Lake Whitefish

populations, including within the Province of Nova Scotia (Murray 2005) which received millions of eggs and larvae for distribution (Bradford and Mahaney 2004).

Stocking of Palearctic coregonid species, namely *Coregonus lavaretus* and *Coregonus albula*, with the objective of establishing refuge populations, has been practiced in recent decades within the British Isles with some success, or with a high expectation of success (see Winfield et al. 2012, Thomas et al. 2013 and Adams et al. 2014). These initiatives, summarized in Table 19, included transplants of wild-caught adults, and distributions of eggs and/or larvae produced from captive breeding. No F1 juveniles were released (Table 19). In contrast, any Atlantic Whitefish of adult age placed into Anderson Lake up to 2008 were F1's bred and reared in captivity and no eggs were distributed (Table 6, Fig. 13). Future Atlantic Whitefish stocking initiatives should consider releasing fish to the wild at the earliest possible life stage to help reduce the risk of domestication selection (Jones et al. 2006).

With respect to the release of coregonid larvae, it is of interest to note that the surface area of Anderson Lake lies within the range of surface areas of the lakes stocked with larvae in the British Isles (Table 19). However, the total number of Atlantic Whitefish larvae ($n = 7,000$) released was comparatively low on a per unit area (ha) basis (Fig. 13). Future Atlantic Whitefish stocking initiatives should consider evaluating the outcomes of stocking larvae in densities that more closely align with those that resulted in survival to sexual maturation and viable spawning among other coregonid species introduced into vacant lacustrine habitat.

Habitat Suitability

The extent of occurrence of Atlantic Whitefish was reduced to three small semi-natural lakes within the Petite Rivière by the time efforts to define the attributes of important habitat as required under SARA were initiated (DFO 2006). Habitat variability within this highly restricted range is low relative to the remainder of the Southern Uplands of Nova Scotia, the likely historical area of occupancy for Atlantic Whitefish (DFO 2009). The habitat of the extant population is unlikely to be representative of all habitats that did, and could once more, sustain viable populations (DFO 2009). The response of the stocked F1 Atlantic Whitefish to the chemical, physical, and biological properties of Anderson Lake is therefore of importance to understanding the habitat requirements for the species and to the selection of future candidate stocking sites. Range extension, a core element of recovery for Atlantic Whitefish, is not likely to occur through natural colonization of new habitat (DFO 2004) and some form of supportive breeding and/or rearing will be necessary.

There are no indications that the water quality of Anderson Lake is unsuitable for Atlantic Whitefish. Both the mean (± 1 SD) water pH of 6.1 ± 0.4 and measured minimum (pH = 5.3; Table 2) are higher than the pH shown experimentally to reduce the survival of Atlantic whitefish eggs (pH = 5.0) and larval/juveniles (pH = 4.5) (DFO 2009). Juvenile F1 Atlantic Whitefish survived to overwinter, increased in body size and attained sexual maturation within the lake. Further, the minimum (11.7°C) and maximum (24.0°C) water temperatures for growth exist within Anderson Lake and the temperature (16.5°C) associated with optimum growth (Cook et al. 2010) exists, under well-oxygenated conditions, at a depth of approximately 5 m during summer thermal stratification. Poor

or inadequate water quality, therefore, does not appear to be the cause of the failure to capture stocked larvae at a later age and the absence of progeny resulting from spawning by stocked fish. These outcomes may be associated with the low density of stocked larvae (relative to the densities that have resulted in production of viable adult coregonid fishes elsewhere (see Stocking Strategy) and low spawner production relative to requirements for survival of wild-spawned larvae through to sexual maturation. Whether the kind of habitat required during onset of first feeding or at a later stage of physiological development is absent in Anderson Lake is not known.

Differences in the native fish assemblages of Anderson Lake and the Petite Rivière lakes that support wild Atlantic Whitefish are of interest. Brook Trout were the second most abundant fish captured in Anderson Lake which implies a high level of piscivory. This species is rare in the fish collections from the Petite Rivière lakes, to the extent they might be considered of rare occurrence in the lakes (Table 18). Both White Perch and Yellow Perch are common in the Petite Rivière lakes but absent from Anderson Lake. These differences may be associated with the presence of lacustrine Rainbow Smelt in Anderson Lake, whose appearance, via introductions, in Laurentian Basin lakes has negatively affected Yellow Perch status in some, but not all water bodies (Mercado-Silva et al. 2005, Rooney and Paterson 2009). Interactions between White Perch and Rainbow Smelt have not been extensively investigated beyond the observation that Rainbow Smelt comprise a component of the diet of White Perch (Evans and Loftus 1987).

Yellow Perch are present in a number of mainland Nova Scotia lakes that support native lacustrine Rainbow Smelt (Lochaber Lake and Gillis Lake, Antigonish County; Beaver Dam Lake and Pringle Lake, Guysborough County; and Shubenacadie-Grand Lake, Halifax County (Alexander et al. 1986) but not in others (Newville Lake, Cumberland County; Unnamed Lake, Guysborough County (Alexander et al. 1986)). White Perch are conspecific with Rainbow Smelt in Newville Lake, Cumberland County, Pringle Lake and Unnamed Lake, Guysborough County, Shubenacadie-Grand Lake, Halifax County, and Unnamed Lake, Pictou County (Alexander et al. 1986). Whether Rainbow Smelt, which were initially thought of as a potential pelagic food source for stocked Atlantic Whitefish (see Introduction) could negatively affect the outcome of stocking activities remains unknown but warrants further evaluation.

Foraging and Foraging Behaviour

Stocked juvenile F1 Atlantic Whitefish frequently attempted to predate on shiners while the trap nets were being fished (Table 13 contains an observation during 2007). These observations are consistent with the documented feeding habits of both land-locked and anadromous wild Atlantic Whitefish (Edge 1987).

Foraging by Atlantic Whitefish on aquatic insects at the water surface was observed during early summer, 2007 along a seam of wind-driven current that was generated downwind from a point of land (R.G. Bradford and D.M Campbell, personal observation). In this instance an estimated 10-20 fish were observed removing small flies along the length of the current seam. The fish foraged both with and against the direction of the surface current flow. This foraging behaviour, not previously documented for either wild or cultured Atlantic Whitefish continued for the duration of

the hour long observation period. Available information therefore indicates that cultured fish, once habituated to a wild setting, possess the capacity to forage on a diversity of prey that is comparable to wild fish (Edge 1987) and using tactics that may or may not be used by extant wild fish.

Recreational Angling Effects

A few anecdotal reports from recreational anglers fishing for Brook Trout using a variety of terminal tackle (artificial flies, lures, bait) plus reports of poached Atlantic Whitefish indicated that the stocked fish were susceptible to capture via angling. Mortality resulting from catch-release and poaching may have occurred but to an unknown extent.

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TABLES

Table 1. Summary of the number of Age 0+ Atlantic Whitefish required to support research by year and the size of the surplus of fish by age class that resulted from captive breeding and rearing at the Mersey Biodiversity Facility.

Year	Number of Age 0 ⁺ Fish for Research			Number of Surplus Fish		
	Eggs	Larvae	Juveniles	Age 0 ⁺	Age 1 ⁺	≥Age 2 ⁺
2004	2,500	1,000	4,000	4,200	0	0
2005	3,000	1,000	0	21,000	2,500	0
2006	0	0	0	10,000	16,000	2,250

Table 2. pH levels in Anderson Lake at surface, intermediate and bottom depths (m) in 1971 and 2003-2006.

Depth (m)	Oct 20, 1971	Aug 21, 2003	Aug 9, 2005	Oct 6, 2005	Nov 29, 2005	May 18, 2006	June 20, 2006	Aug 9 2006
0	6.5	6.1	5.9	6.6	6.0	6.9	6.8	5.9
1.5	7	6.1	5.9	6.3	6.4	6.2	6.3	5.9
5.3	6.5	5.9	6.1	6.6	-	6.1	6.2	5.9
12.2	6	5.3	5.6	6.1	-	6.2	6.3	5.6
Bottom	6	5.3	5.5	6.2	-	6	6.2	5.5
Depth at Bottom	15.3	15.3	12.5	19.2	-	14.8	14.8	12.5

Table 3. Set and haul back dates and times, soak times (hours), depth of set (m) and catch (numbers) by species per mesh size from experimental single and multi-panel gillnets set in Anderson Lake during 2003. All nets were 3 m deep by 18 m long (dash indicates species not caught; p indicates proportion of total catch).

Set		Haul Back		Soak	Net type	Depth (m)	Mesh size (cm)	Species			
Date	Time	Date	Time	Time (h)				White Sucker	Brook Trout	Rainbow Smelt	Ninespine Stickleback
July 3 2003	15:00	July 4 2003	10:00	19	Multi-panel	≤3m	2.5	1	-	-	-
							3.8	1	-	-	-
							5.1	1	-	-	-
							6.4	1	1	-	-
							7.6	5	4	-	-
July 3 2003	15:00	July 4 2003	10:00	19	Multi-panel	≤3m	2.5	-	-	-	-
							3.8	-	-	-	-
							5.1	7	-	-	-
							6.4	-	-	-	-
							7.6	3	-	-	-
July 3 2003	15:00	July 4 2003	10:00	19	Multi-panel	>7	8.9	1	-	-	-
							2.5	-	-	-	-
							3.8	-	-	-	-
							5.1	-	-	-	-
							7.6	-	-	-	-
July 3 2003	15:00	July 4 2003	10:00	19	Multi-panel	>7	8.9	-	-	-	-
							2.5	-	-	-	-
							3.8	-	-	-	-
							5.7	2	-	-	-
							8.9	-	-	-	-
July 3 2003	15:00	July 4 2003	10:00	19	Single Panel	>7	3.8	-	-	1	-
Aug. 20 2003	15:00	Aug. 21 2003	10:00	19	Single Panel	10	1.9	-	-	-	-
Aug. 20 2003	15:00	Aug. 21 2003	10:00	19	Single Panel	6.9	1.3	-	-	-	-
Aug. 20 2003	15:00	Aug. 21 2003	10:00	19	Single Panel ¹	0	1.3	-	-	5	-
Aug. 20 2003	15:00	Aug. 21 2003	10:00	19	Single Panel ¹	0	1.9	-	-	-	-
Aug. 20 2003	15:00	Aug. 21 2003	10:00	19	Single Panel	6.9	1.3	-	-	12	-
Aug. 20 2003	15:00	Aug. 21 2003	10:00	19	Single Panel	7.6	1.9	-	-	-	-
Totals								22	5	18	0
p(Totals)								0.49	0.11	0.40	0.00

¹ Set to fish at the surface at a location with a bottom depth of 15m.

Table 4. Set and haul back dates and times, soak times (hours), depth of set (m) and catch (numbers) by species per mesh size from experimental single and multi-panel gillnets set in Anderson Lake during 2004. All nets were 3 m deep by 18 m long. The net fished on the surface was set on an anchor at a water depth of 11m (dash indicates species not caught; p indicates proportion of total catch).

								Species			
Set		Haul Back		Soak		Depth	Mesh	White	Brook	Rainbow	Ninespine
Date	Time	Date	Time	Time (h)	Net type	(m)	size (cm)	Sucker	Trout	Smelt	Stickleback
April 27 2004	14:00	April 28 2004	9:00	19	Multi-panel	Surface	1.0	-	-	-	-
							1.6	-	-	-	-
							1.9	-	-	2	-
					Multi-panel	≤3m	2.5	-	-	-	-
							3.8	-	-	-	-
							5.1	1	-	-	-
							2.5	-	-	-	-
							3.8	-	-	-	-
							5.1	1	-	-	-
							6.4	14	-	-	-
April 27 2004	14:00	April 28 2004	9:00	19	Multi panel	≤3m	1.0	-	-	-	1
							1.6	-	-	-	1
							1.9	-	-	-	-
							2.5	-	-	-	-
							3.8	-	-	1	-
							5.1	-	-	-	-
April 27 2004	14:00	April 28 2004	9:00	19	Multi panel	≤3m	2.5	-	-	-	-
							3.8	-	-	-	-
							5.1	-	-	-	-
							6.4	7	-	-	-
Totals								23	0	3	2
p(Totals)								0.82	0.00	0.11	0.07

Table 5. List of species documented to occur within Anderson Lake prior to introduction of Atlantic Whitefish and method of sampling.

Species	Gear
American Eel	Minnow Trap
Banded Killifish	Minnow trap
Brook Trout	Gill net
Common Shiner	Minnow trap
Golden Shiner	Minnow trap
Nine-Spine Stickleback	Minnow trap/Gill net
Rainbow Smelt	Gill net
White Sucker	Gill net

Table 6. Stocking dates and biological traits for Atlantic Whitefish from 2005-2012. (VIE = Visible Implant Elastomer).

Release Date		Age (Years)/Stage	Number Released	Density (Fish/ha)	Production Year	Average		Identifying Marks
Year	Day-Month					Weight (g)	Length (cm)	
2005	4 November	1 ⁺ Juvenile	1,500	23.4	2003	125	22	None
2006	24 April	2 ⁺ Juvenile	10	0.2	2003	150	24	Acoustic Tag
	24 April	1 ⁺ Juvenile	750	11.7	2004	50	17	Full Adipose Clip
	26 April	0 ⁺ Larvae	5,000	78.1	2005	0.01	1.5	None
	23 May	2 ⁺ Juvenile	5	0.1	2003	150	24	Acoustic Tag
	16 October	1 ⁺ Juvenile	750	11.7	2004	70	18	None
2007	1 May	1 ⁺ Juvenile	750	11.7	2005	40	15	Full Adipose Clip
	1 May	0 ⁺ Larvae	2,000	31.3	2006	0.01	1.5	None
	3 October	1 ⁺ Juvenile	6	0.1	2005	50	17	Acoustic Tag
	3 October	1 ⁺ Juvenile	750	11.7	2005	50	17	Adipose Punch
2008	25 November	3 ⁺ Adult	184	2.9	2004	210	26	Adipose Punch, Left Pectoral VIE Red
	25 November	4 ⁺ Adult	212	3.3	2003	260	30	Left Pectoral VIE Red
2012	5 November	5 ⁺ and 6 ⁺ Adult	80	1.3	2005 2006	300	32	Left Pectoral VIE Pink

Table 7. Summary of criteria used to identify stocking year and age-at-capture (years) of Atlantic Whitefish sampled from Anderson Lake during the years 2007-2012.

Mark type	Code	Age (years) at release	Stock Date	Age of stocked fish during year				
				2007	2008	2009	2010	2012
No mark	0	1 ⁺	2005	3	4	5	6	8
No mark	0	1 ⁺	2006	2	3	4	5	7
No mark	0	0 ⁺ (larvae)	2006	1	2	3	4	6
No mark	0	0 ⁺ (larvae)	2007	0	1	2	3	5
Full adipose clip	1	1 ⁺	2006	2	3	4	5	7
Full adipose clip	1	1 ⁺	2007	1	2	3	4	6
Posterior Adipose punch	2	1 ⁺	2007	1	2	3	4	6
Posterior Adipose punch and Left Pectoral VIE Red	3	3 ⁺	2008	2	3	4	5	7
Left pectoral VIE red	4	4 ⁺	2008	3	4	5	6	8
Acoustic transmitter	9	1 ⁺	2007	1	2	3	4	6
Acoustic transmitter	9	2 ⁺	2006	3	4	5	6	8

Table 8. Deployment dates, locations, and number of days fished by year for trap nets in Anderson Lake (n: number).

Year	Trap design	Net Depth (m)	Dates of Operation	Location coordinates		Days Fished (n)
				Latitude (degree N)	Longitude (degrees W)	
2006	Floating	3	May 11-16	44.7247	-63.6251	4
2006		3	June 6 - 28	44.7276	-63.6250	4
2006	Fixed frame	3	November 16 - December 1	44.7276	-63.6250	5
2007	Floating frame	3	May 14 - June 22	44.7276	-63.6250	28
2007	with box net	4.5	November 8 - 30	44.7276	-63.6250	11
2008		4.5	October 2 – December 17	44.7276	-63.6250	35
2009		4.5	November 3 – December 2	44.7276	-63.6250	22
2010		4.5	November 3 – December 2	44.7276	-63.6250	30
2010		3	November 9- December 12	44.7289	-63.6195	22
2012		4.5	October 22- December 12	44.7276	-63.6250	22

Table 9. Daily catch by species with a floating trapnet that was fished in Anderson Lake between 1 June – 30 June, 2006 (n: number; StanDev: standard deviation).

	Atlantic Whitefish	Brook Trout	White Sucker	Golden Shiner ¹
Date Fished	n	n	n	n
June-01-06	0	0	3	11
June-01-07	3	0	1	4
June-01-13	0	0	4	11
June-01-22	0	0	2	5
Total	3	0	10	31
Mean Catch/Day	0.8	0	2.5	7.8
StanDev Catch/Day	1.5		1.3	3.8

¹most had become entangled in the netting of the trap

Table 10. Daily catch (numbers) and mean body size of fish species sampled with a fixed-frame trap net fished in Anderson Lake from November 15 – December 1, 2006 (Min =Minimum length, Max =Maximum length, StanDev= Standard Deviation).

Date Fished	Atlantic Whitefish					Brook Trout					White Sucker				
	Fork Length (cm)					Fork Length (cm)					Fork Length (cm)				
	n	Mean	StanDev	Min	Max	n	Mean	StanDev	Min	Max	n	Mean	StanDev	Min	Max
16-Nov	0					5	34.2	10.2	16.8	42.7	0				
17-Nov	1	21.7				6	23.9	8.9	16.0	36.0	5	21.5	3.3	16.9	26.0
23-Nov	2			15.6	20.2	2			33.8	40.2	0				
24-Nov	2			19.8	25.9	5	34.4	5.3	30.3	43.5	4	29.0	9.5	16.1	38.1
01-Dec	2			19.6	24.0	2			34.3	39.1	5	27.5	3.3	22.5	31.1
Total	7	21.0	3.3	15.6	25.9	20	31.7	8.9	16.0	43.5	14	25.8	6.2	16.1	38.1
Mean Catch/Day	1.4					4.0					2.8				
StanDev Catch/Day	0.9					1.9					2.6				

Table 11. Summary of sampling dates and total numbers of fish sampled with a trap net hung on a floating frame trapnet in Anderson Lake from 2007-2012 (StanDev: standard deviation).

Year	Trap Depth (m)	Period of Operation		Days Fished	Catch Summary	Species						Daily Total
		Beginning	End			American Eel	Atlantic Whitefish	Brook Trout	Shiner	Rainbow Smelt	White Sucker	
2007	3	15-May	22-Jun	19	Total	3	6	46	5	1	104	165
					Average	0.16	0.32	2.42	0.26	0.05	5.47	8.68
					StanDev	0.50	0.95	3.56	0.45	0.23	5.93	8.56
					Total	1	14	14	2	2	7	40
2008	4.5	09-Nov	30-Nov	7	Average	0.14	2.00	2.00	0.29	0.33	1.00	5.71
					StanDev	0.38	2.58	2.24	0.49	0.52	1.15	2.87
					Total	9	32	58	6	1	41	149
					Average	0.25	0.89	1.61	0.17	0.03	1.14	4.14
2009	4.5	02-Nov	02-Dec	22	StanDev	0.60	1.65	2.10	0.70	0.17	2.11	4.48
					Total	0	44	13	0	2	5	64
					Average		2.00	0.59	0.00	0.09	0.23	2.91
					StanDev		2.74	1.01	0.00	0.29	0.61	3.38
2010	3.0	09-Nov	10-Dec	22	Total	0	0	2	2	9		13
					Average			1.00	1.00	1.50		0.59
					StanDev			0.00	0.00	0.55		0.8
					Total	0	41	20	2	1	78	142
2012	4.5	23-Oct	12-Dec	14	Average		1.37	0.67	0.07	0.03	2.60	4.73
					StanDev		3.29	1.27	0.25	0.18	6.09	8.28
					Total	0	2	12	1	2	10	27
					Average		0.14	0.86	0.07	0.14	0.71	1.93
					StanDev		0.36	0.95	0.27	0.36	0.83	1.27

Table 12. Average fork length (cm) of fish sampled with a floating frame trap net in Anderson Lake by year for 2007-2012 (FL – Fork Length (cm, dash indicates species not observed)).

Species	Attribute	2007	2008	2009	2010	2012
Atlantic Whitefish	FL mean	22.0	23.5	26.5	28.2	35.3
	FL range	19.9-26.2	21.2-31.6	23-33.7	25.7-31.6	34.4-36.2
	number	20	32	42	41	2
Brook Trout	FL mean	21.1	27.9	28.4	26.8	28.2
	FL range	12.7-44.5	13.4-38.8	14.9-42.5	13.4-41.5	11.3-43.4
	number	60	58	13	22	12
American Eel	FL mean	48.2	43.1	-	-	-
	FL range	48.6-53.3	40.4-50	-	-	-
	number	4	9	-	-	-
Rainbow Smelt	FL mean	13.6	16.4	12.0	10.2	12.3
	FL range	9.4-21.8	16.4	10.5-13.4	9.1-11.6	11.6-13.0
	number	3	1	2	2	2
White Sucker	FL mean	22	26.8	24.9	25.1	23.1
	FL range	11.0-37.1	15.9-40.4	22.4-26.5	17.1-33.5	21.2-25.7
	number	111	41	5	78	10
Shiner	FL mean	8.0	8.1	-	8.0	9.4
	FL range	7.5-8.5	7.7-8.7	-	7.5-8.8	-
	number	7	6	-	4	1

Table 13. Observations recorded during sampling concerning the appearance of Atlantic Whitefish captured during 2007.

Date Fished	Fork Length (cm)	Notes
May 29	24.2	No comments noted
June 5	19.9	skinny, tattered caudal, worst shape of all Whitefish collected on this date
June 5	23.0	skewed muscle development at caudal
June 5	24.6	tattered caudal, skinny
June 5	22.7	Healthy
June 20	26.2	Attempting to eat a shiner, thin, tattered caudal fin
Nov 9	23.8	Not clipped
Nov 9	22.8	Adipose notch
Nov 9	24.8	Not clipped
Nov 22	24.8	Rough shape, fin notched
Nov 22	20.6	Not clipped
Nov 22	22.3	Not clipped
Nov 29	20.9	Fin clipped but not full adipose clip, no gonads, skinny
Nov 30	19.2	Not clipped, small
Nov 30	19.0	Clip growing back, small
Nov 30	22.1	Not clipped
Nov 30	21.2	Part of a clip
Nov 30	19.1	Clipped, skinny
Nov 30	20.6	Recent looking clip
Nov 30	19.2	Recent looking clip, small

Table 14. Dates of capture of Atlantic Whitefish and marks observed (full clip – adipose fin removed, PAP – hole punched in posterior region of adipose fin; PAP+VIE – both posterior punch and VIE dye mark on left pectoral fin; VIE - VIE dye mark on left pectoral fin; dash indicates not observed).

		No Clip	Full Clip	PAP	PAP+VIE	VIE	Daily Total
Year	Code	0	1	2	3	4	
2007	29-May	1	-	-	-	-	1
	05-Jun	4	-	-	-	-	4
	20-Jun	1	-	-	-	-	1
	09-Nov	2	1	-	-	-	3
	22-Nov	2	1	-	-	-	3
	29-Nov	0	1	-	-	-	1
	30-Nov	2	5	-	-	-	7
2007 Total		12	8	0	0	0	20
2008	21-Oct	5	-	-	-	-	5
	22-Oct	2	-	-	-	-	2
	23-Oct	2	3	-	-	-	5
	13-Nov	1	-	-	-	-	1
	14-Nov	4	1	-	-	-	5
	28-Nov	3	1	-	-	40	44
	03-Dec	0	-	-	-	2	2
	04-Dec	2	-	-	-	2	4
	05-Dec	-	-	-	-	4	4
	12-Dec	1	-	-	-	2	3
	15-Dec	1	-	-	-	0	1
2008 Total		21	5	0	0	50	76
2009	12-Nov	6	1	0	0	-	7
	13-Nov	2	-	1	0	-	3
	17-Nov	1	-	1	1	-	3
	18-Nov	1	-	1	2	-	4
	20-Nov	1	-	1	0	-	2
	24-Nov	3	-	1	1	-	5
	25-Nov	4	-	3	0	2	9
	26-Nov	4	-	0	0	-	4
	27-Nov	1	-	0	1	-	2
	01-Dec	1	-	1	-	-	-
	02-Dec	-	-	1	-	-	-
2009 Total		24	1	10	5	2	42

		No Clip	Full Clip	PAP	PAP+VIE	VIE	Daily Total
Year	Code	0	1	2	3	4	
2010	02-Nov	-	-	1	0	-	1
	06-Nov	10	-	5	0	-	15
	08-Nov	4	-	2	0	-	6
	12-Nov	0	-	0	1	-	1
	18-Nov	4	-	4	0	-	8
	24-Nov	1	-	1	0	-	2
	02-Dec	3	-	1	0	-	4
	03-Dec	1	-	1	0	-	2
	09-Dec	1	-	0	0	-	1
2010 Total		24	0	15	1	0	40
2012	22-Nov	1	-	-	-	-	1
	28-Nov	1	-	-	-	-	1
2012 Total		2	0	0	0	0	2

Table 15. Atlantic Whitefish recaptures in 2009. Codes are 0: no marks; 1: full adipose clip; 2: posterior adipose punch; 3: posterior adipose punch and left pectoral VIE Red; 4: Left pectoral VIE red; 9: acoustic transmitter; dash indicates none caught.

Date	Code					Total
	0 (Ages 4-5)	1 (Age 4)	2 (Age 3)	3 (Age 4)	4 (Age 5)	
12-Nov	6	1	-	-	-	7
13-Nov	2	-	1	-	-	3
17-Nov	1	-	1	1	-	3
18-Nov	1	-	1	2	-	4
20-Nov	1	-	1	-	-	2
24-Nov	3	-	1	1	-	5
25-Nov	4	-	3	-	2	9
26-Nov	4	-	-	-	-	4
27-Nov	1	-	-	1	-	2
1-Dec	1	-	1	-	-	-
2-Dec	-	-	1	-	-	-
Total	24	1	10	5	2	42

Table 16. Proportion of the annual trap net catches in Anderson Lake per fish species captured, years 2007-2010 and 2012 (Average = average catch for all years combined, StDev =Standard Deviation).

Year	Date	Species					
		American Eel	Atlantic Whitefish	Brook Trout	Shiner	Rainbow Smelt	White Sucker
2007		0.03	0.35	0.35	0.05	0.05	0.18
2008		0.06	0.21	0.39	0.04	0.01	0.28
2009		0.00	0.69	0.20	0.00	0.03	0.08
2010		0.00	0.29	0.14	0.01	0.01	0.55
2012		0.00	0.07	0.44	0.04	0.07	0.37
Average		0.02	0.32	0.31	0.03	0.03	0.29
StDev		0.03	0.23	0.13	0.02	0.03	0.18

Table 17. Number of fish per species by gear type (method) for each year that sampling occurred within Minamkeak Lake, Milipsigate Lake and Hebb Lake (Petite Rivière). The proportion of the catch (p) represented by wild Atlantic Whitefish is shown for each sampling event.

						Species									
Water Body	Study	Year	Beginning Day of Year	Method	Soak Time (d)	Atlantic Whitefish		White Sucker	Brown Bullhead	White Perch	Yellow Perch	American Eel	Shiner	Brook Trout	Smallmouth Bass
						n	p(Catch)		Catfish						
Minamkeak	Edge 1987	1982	11-Nov	Gill Net	3.0	5	0.07	26	4	20	15	0	0	0	0
	DFO Unpublished	2003	04-Nov	Trammel Net	2.6	0	0.00	30	15	7	0	0	0	0	1
	DFO Unpublished	2004	05-May	Gill Net	0.7	11	0.11	19	4	64	1	0	0	0	0
	DFO Unpublished	2009	01-Oct	Trap Net	13.0	4	0.02	4	120	52	0	4	0	0	0
Milipsigate	Edge 1987	1982	19-Sep	Gill Net	1.5	3	0.04	7	5	50	2	0	0	0	0
			20-Sep	Gill Net	1.5	2	0.01	34	2	123	8	0	0	0	0
			23-Sep	Gill Net	1.5	4	0.05	2	3	65	11	0	0	0	0
			07-Nov	Gill Net	1.5	2	0.01	43	0	91	12	2	0	0	0
	DFO Unpublished	2003	29-Oct	Trap Net	7.0	17	0.18	7	0	60	0	12	0	0	0
	DFO Unpublished	2009	20-Oct	Trap Net	10.0	1	0.02	0	3	51	0	0	0	0	0
Hebb	Edge 1987	1982	12-Nov	Gill Net	2.0	8	0.06	21	0	88	8	0	0	0	0
	Edge 1987	1983	22-May	Gill Net	4.8	13	0.19	21	2	32	0	0	0	0	0
	DFO Unpublished	2007	24-May	Trap Net	14.0	3	0.01	1	0	546	12	6	1	1	0
	DFO Unpublished	2007	03-Oct	Trap Net	11.0	1	0.01	0	25	88	6	7	11	0	0
	DFO Unpublished	2007	09-Oct	Trap Net	10.0	19	0.10	0	11	128	9	15	2	0	0

Table 18. Number of stocked Atlantic Whitefish by day of year (all years combined) that exhibited externally traits for sexual maturation. Maturing fish possessed pearl organs associated with sexual maturation by males. Mature fish expressed either milt (male) or eggs (female). The number of fish greater than the minimum observed length of sexually mature fish (≥ 25 cm FL) by calendar day is shown. Analogous data for wild Brook Trout sampled from Anderson Lake are provided for comparison.

Calendar Day	Catch ≥25 cm FL	Atlantic Whitefish						Brook Trout			
		Maturing	Male		Female		Total Mature (n)	Male		Female	
			Mature	Spent	Mature	Spent		Mature	Spent	Mature	Spent
02-Nov	1						0				
06-Nov	15	3					3				
08-Nov	6	1					1				
12-Nov	5	2					2				
13-Nov	3		2				2				
14-Nov	2						0				
17-Nov	1		1				1				
18-Nov	12	6					6				
20-Nov	1		1				1				
22-Nov	1	1					1				
23-Nov							0				
24-Nov	6	1	4				5			1	1
25-Nov	7		3				3				
26-Nov	4		2				2				
27-Nov	2		1				1				
28-Nov	2	1	1				2				
29-Nov							0				2
01-Dec	2		1				1				
02-Dec	5	4			1		5				
03-Dec	2	2					2				
04-Dec							0			1	
05-Dec							0				
09-Dec	1				1		1				
12-Dec	2		1				1				

Table 19. Summary of stocking activities initiated to establish refuge populations of three species of coregonid fishes. The number of fish by life-stage in total number and relative to the surface area of the recipient water bodies is shown. The outcome is as reported in the source literature.

Number Stocked by Life-Stage															
Location	Species	Recipient Water Body	Area (ha)	Adults			Eggs	Larvae	Juveniles	Stocking Density (n/ha)				Outcome	Source
				Total	Male	Female				Adults	Eggs	Larvae	Juveniles		
British Isles	C. lavaretus	Llyn Arenig	35	416	366	50	81,300	0	0	12	2,317			adults	Thomas et al. 2013
		Loch Sloy	100	85			0	12,227	0			123		population	Thomas et al. 2013
		Carron Valley	300	0			0	13,123	0			45		population	Thomas et al. 2013
	C. albula	Loch Skeen	28	0			47,500	17,500	0		1,704	628		population	Winfield et al. 2008
		Daer Reservoir	202	0			32,300	12,800	0		161	64		uncertain	Adams et al. 2014
		Sprinkling Tarn	2	25			134,480	0	0	11	58,471				Adams et al. 2014
		Loch Valley	34	0			70,000	0	0		2,072			uncertain	Adams et al. 2014
	Nova Scotia	C. huntsmani	Anderson Lake	62	396			0	7,000	4,521	6	0	113	73	

FIGURES

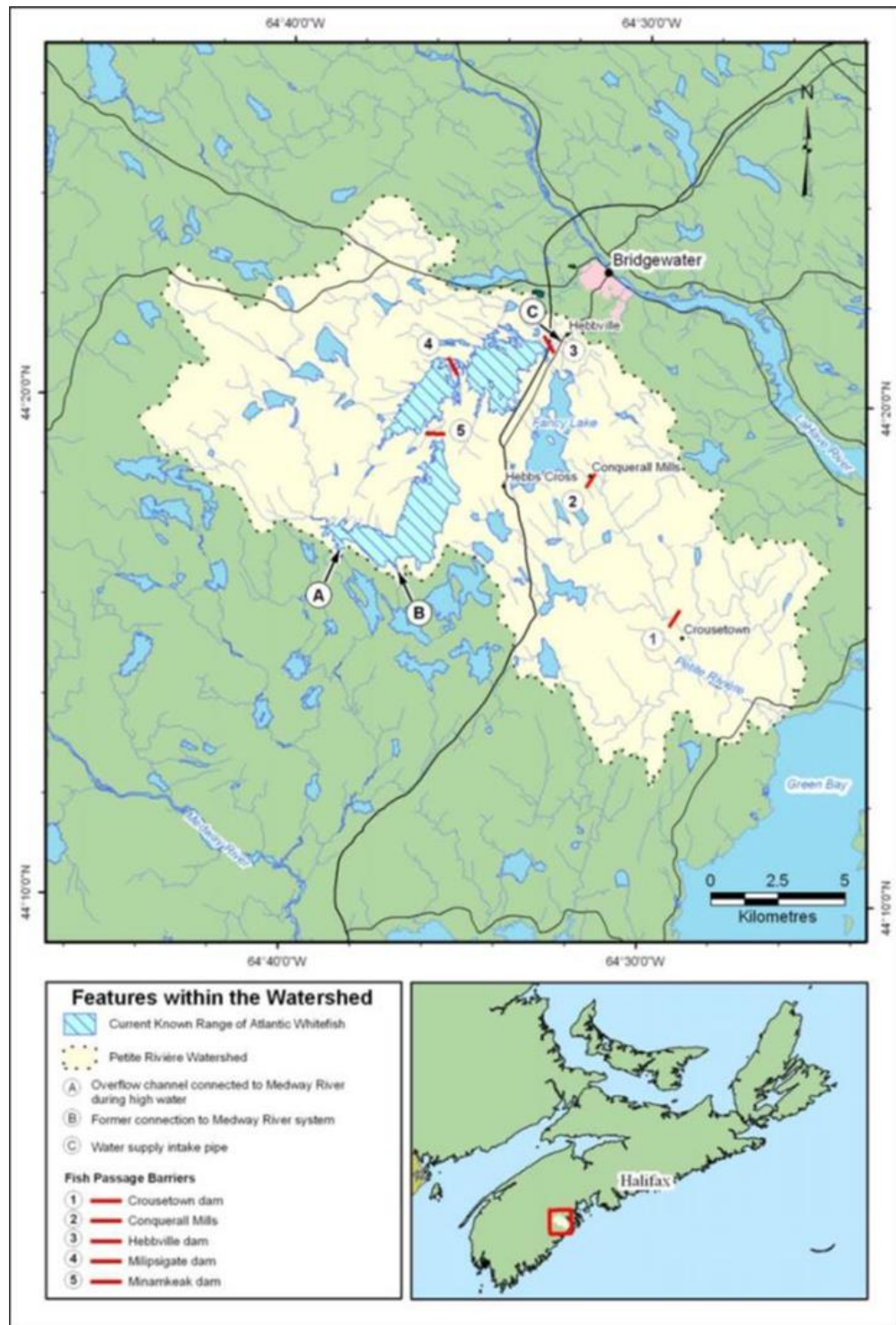


Figure 1. Map of the Petite Rivière, Lunenburg County, Nova Scotia showing the lakes (shaded) that support land-locked populations of Atlantic Whitefish and the location of the Hebb Lake Dam.



Figure 2. Location of Anderson Lake relative to Bedford Basin).



Figure 3. Satellite view of Anderson Lake and Little Lake showing locations of trapnets and jetty where fish were released. (Image generated using Google Earth).

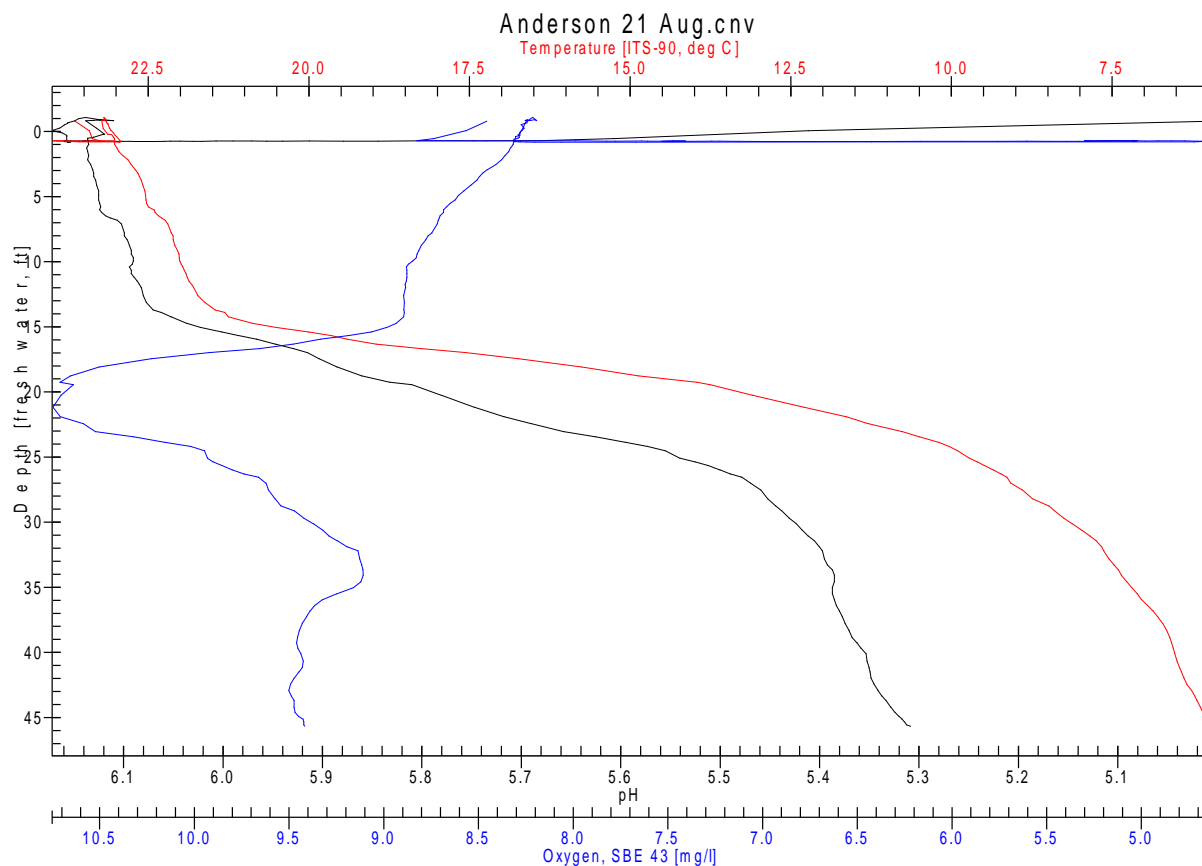


Figure 4. Temperature (C) (red line), oxygen content (mg/l) (blue line) and pH (black line) profiles of water column in Anderson Lake on August 21, 2003.

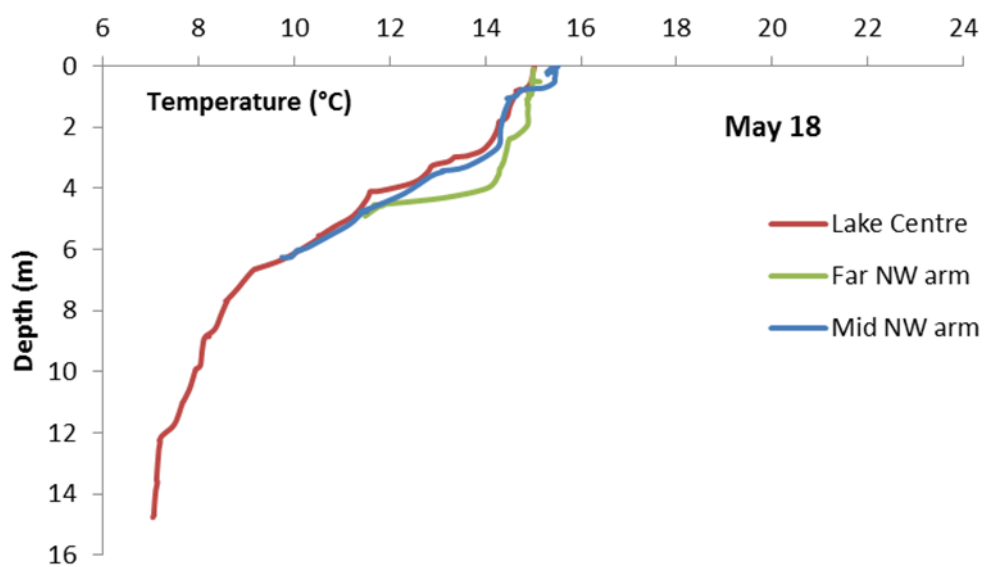


Figure 5. Temperature (°C) profile at the centre of Anderson Lake and two near-shore locations on May 18, 2006.

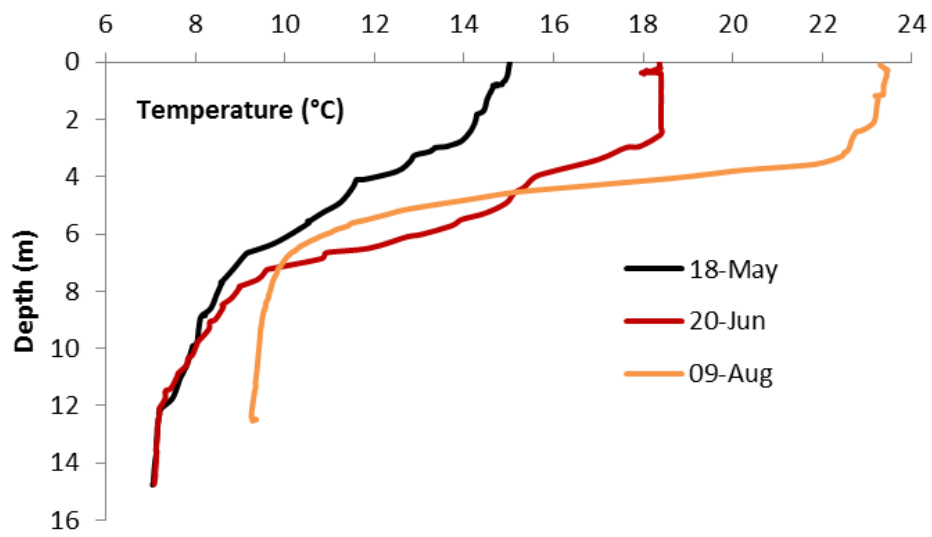


Figure 6. Temperature profile of the water column at the centre of Lake Anderson in the summer and fall of 2006.

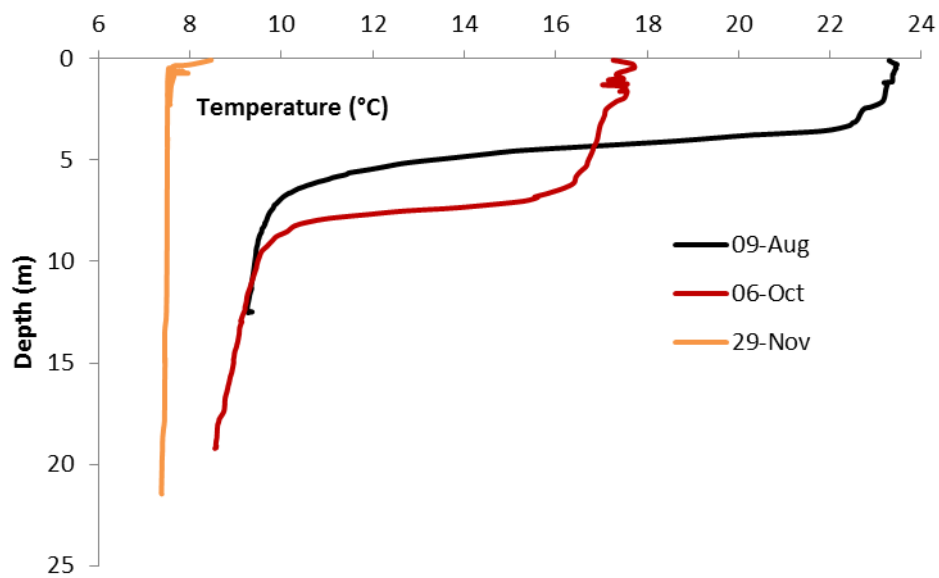


Figure 7. Temperature (°C) profiles of water column of Anderson Lake in summer and fall of 2005.



Figure 8. View of the floating frame trap net while set in Anderson Lake during 2007. White rectangle in satellite image of Anderson Lake shows the trap net location during the years 2006-2012 (satellite image generated using Google Earth).

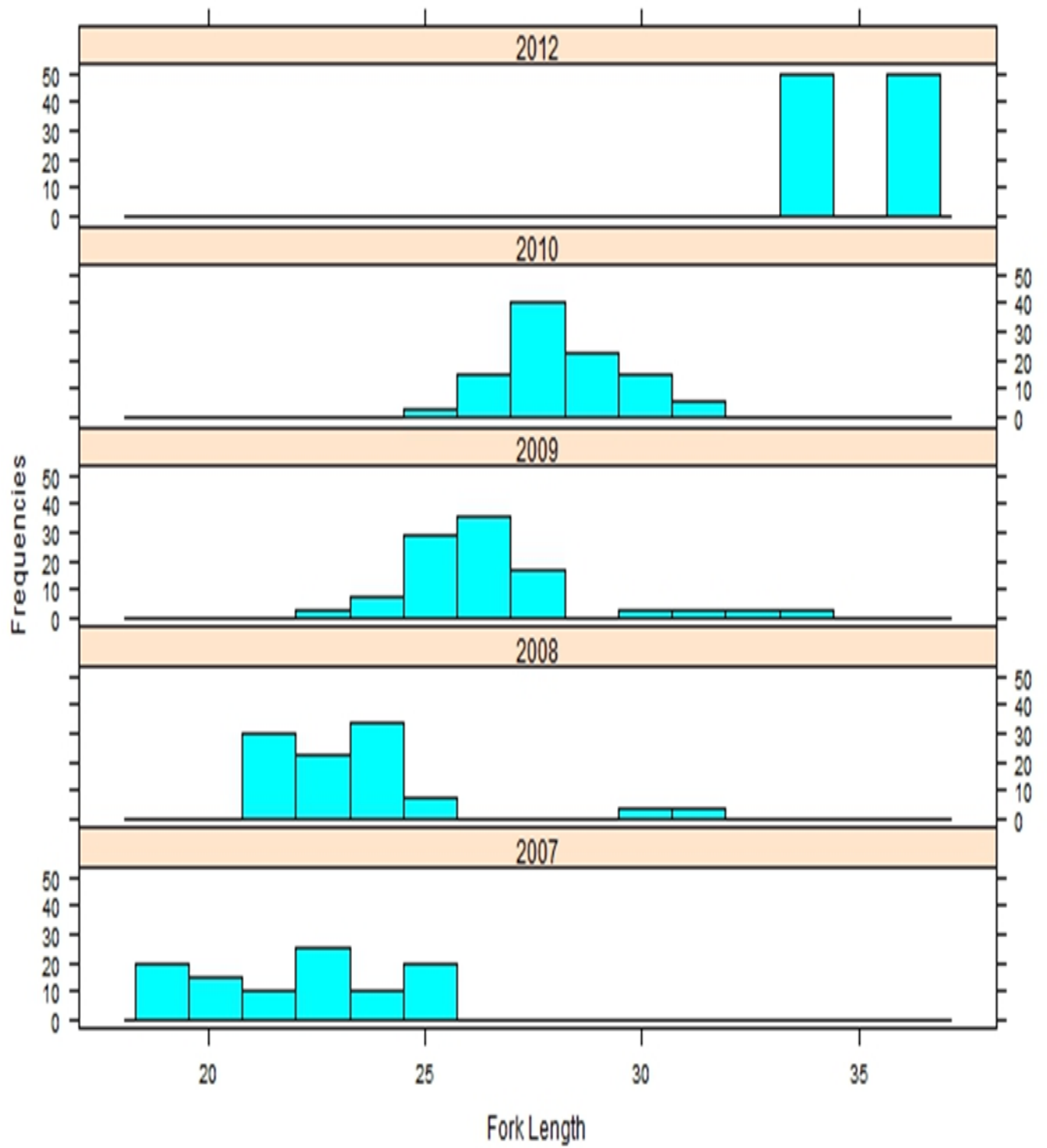


Figure 9. Proportion at length (Fork Length (cm)) of Atlantic Whitefish caught by trapnet in Anderson Lake in 2007 to 2012 (no sampling occurred in 2011).

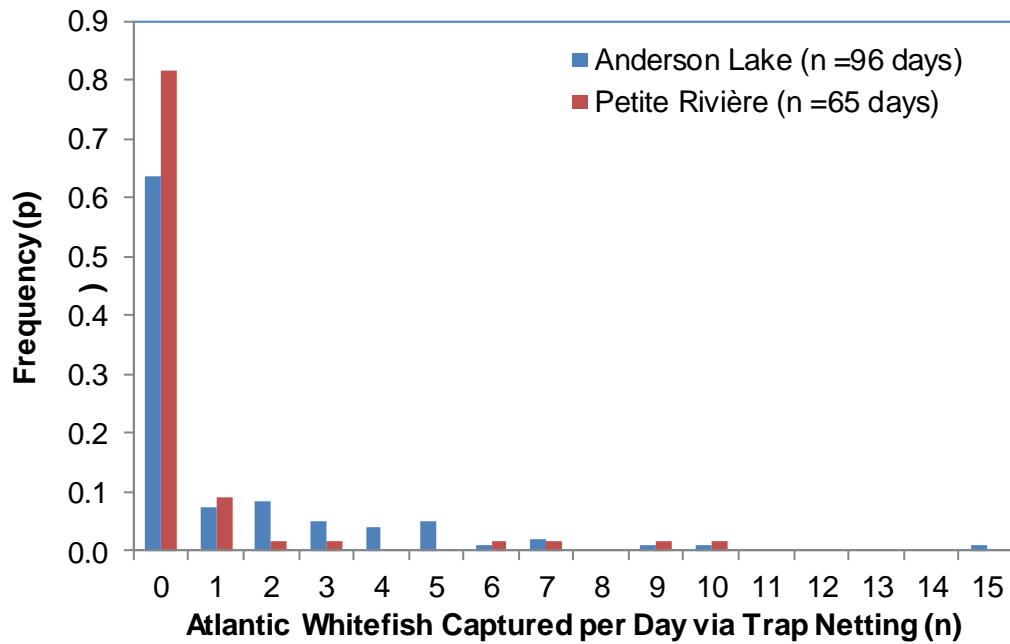


Figure 10. Frequency distribution (p) of daily catches (n) of Atlantic Whitefish with trap nets set in Anderson Lake during autumn sampling in the years 2007-2010 and the Petite Rivière lakes that support Atlantic Whitefish in the years 2003, 2007, and 2009.

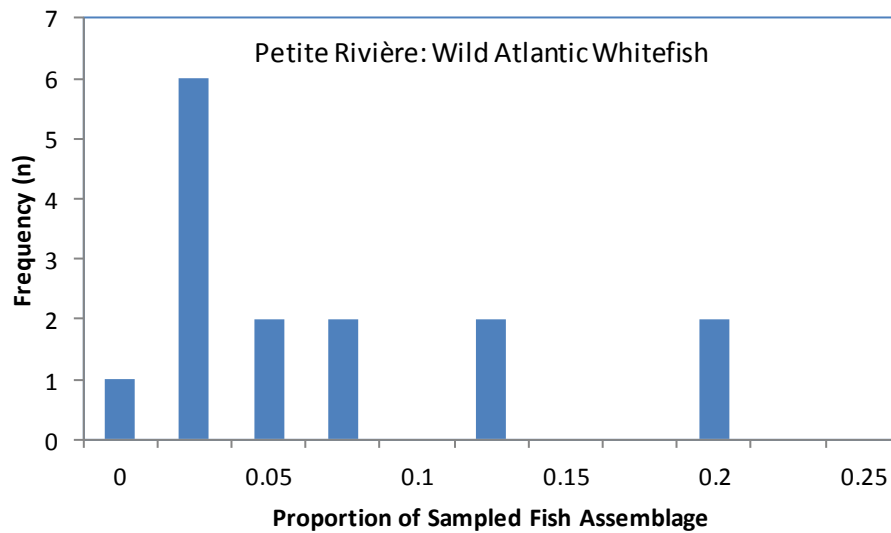


Figure 11. Proportion of gill net and trap net catches consisting of wild Atlantic Whitefish in the Petite Rivière lakes. The data are extracted from Table 17).

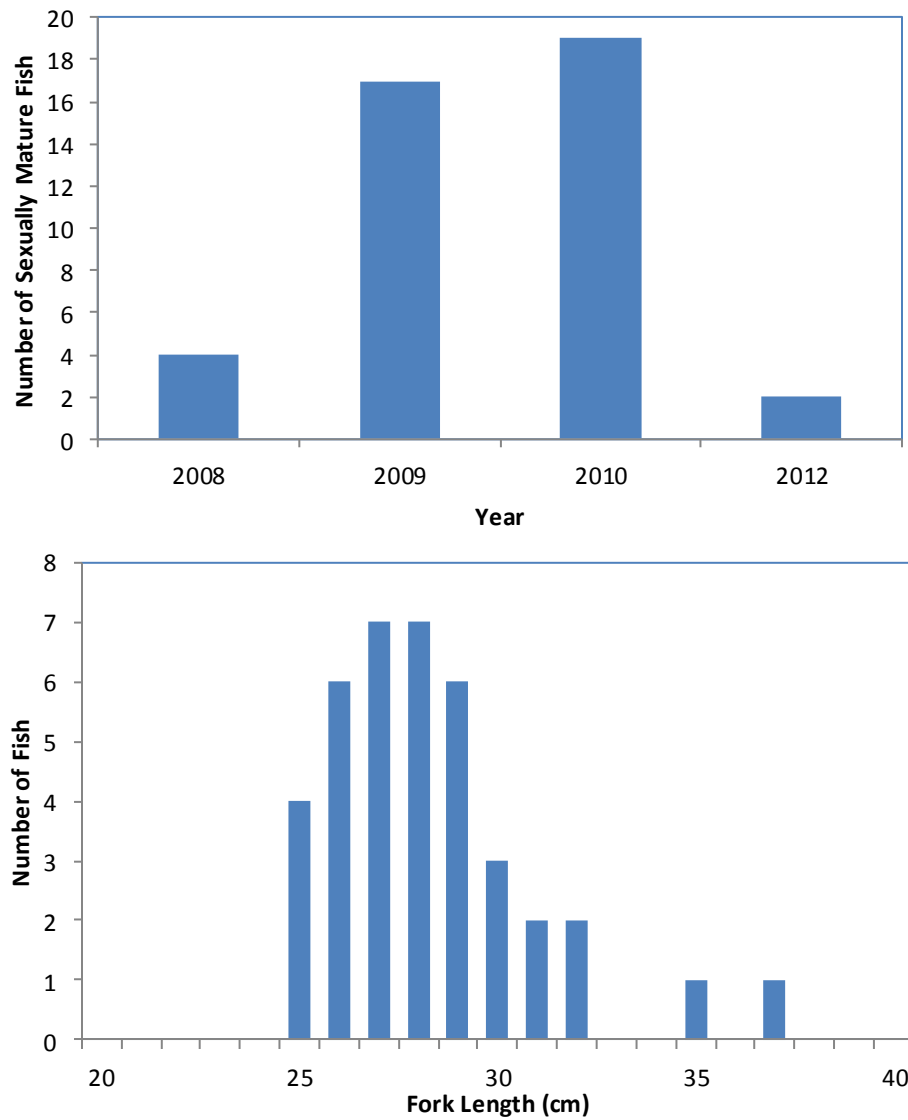


Figure 12. Number of Atlantic Whitefish sampled per year that exhibited external characters consistent with sexual maturation (upper panel) and their fork length (cm) frequency distribution, all years combined (lower panel).

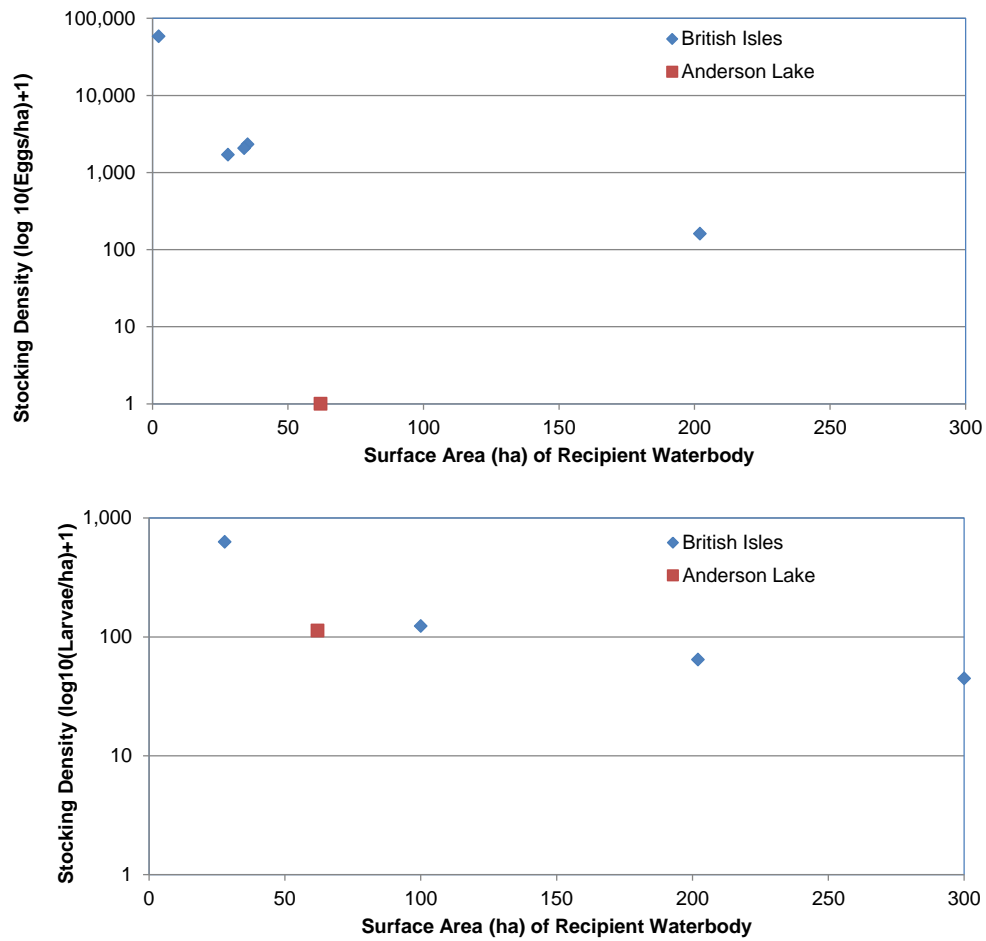


Figure 13. Comparison of stocking densities per ha ($\log_{10} n+1$) of coregonid eggs (upper panel) and larvae (lower panel) released with the objective of establishing reproducing populations in a number of lakes located in the British Isles (diamond) and Anderson Lake (square).

APPENDIX 1

Appendix 1. Trap net catches By Species (Years 2007-2010, 2012)

Year	Date	Trap Depth (m)	Species					Daily Total		
			American Eel	Atlantic Whitefish	Brook Trout	Shiner	Rainbow Smelt		White Sucker	
2007	15-May	3				1			1	
	17-May				1				1	
	18-May					1			1	
	25-May						1		1	
	29-May			1	11			6	18	
	30-May		2		12			16	30	
	31-May				3	1		9	13	
	01-Jun				4			22	26	
	05-Jun			4	3			5	12	
	06-Jun				3			6	9	
	07-Jun				1	1		9	11	
	08-Jun							8	8	
	12-Jun				5			4	9	
	13-Jun		1		1			10	12	
	14-Jun				2				2	
	15-Jun							2	2	
	20-Jun				1		1	3	5	
	21-Jun							3	3	
	22-Jun							1	1	
	Total			3	6	46	5	1	104	165
	Average			0.16	0.32	2.42	0.26	0.05	5.47	8.68
	StanDev			0.50	0.95	3.56	0.45	0.23	5.93	8.56
	09-Nov	4.5		3				2	5	
	15-Nov		1			1		1	3	
	16-Nov				1				1	
	22-Nov			3	1		1	3	8	
	23-Nov				6		1		7	
	29-Nov			1	4	1		1	7	
	30-Nov			7	2				9	
	Total			1	14	14	2	2	7	40
	Average			0.14	2.00	2.00	0.29	0.33	1.00	5.71
	StanDev			0.38	2.58	2.24	0.49	0.52	1.15	2.87

Year	Date	Trap Depth (m)	Species					Daily Total
			American Eel	Atlantic Whitefish	Brook Trout	Shiner	Rainbow Smelt	White Sucker
2008	29-Sep	4.5						
	30-Sep							
	01-Oct							
	02-Oct		1		1	1		3
	03-Oct				1	1		3
	06-Oct							
	07-Oct				5	4		10
	08-Oct		1					1
	09-Oct		1		2			3
	14-Oct							1
	15-Oct				1			4
	16-Oct		1		3			4
	21-Oct			5	3			10
	22-Oct		3	2	4			10
	23-Oct			5	3			14
	03-Nov							
	04-Nov				1			2
	05-Nov				2			2
	13-Nov			1	3			8
	14-Nov			5				5
	18-Nov							
	19-Nov		1		9			10
	20-Nov				6			8
	21-Nov				3			3
	25-Nov							
	26-Nov							
	27-Nov							
	28-Nov ¹			5	2			11
	02-Dec							
	03-Dec			2	2			10
	04-Dec		1	2	3		1	3
	05-Dec			1				2
	11-Dec							
	12-Dec			3	4			1
	15-Dec			1				1
	16-Dec							1
	Total		9	32	58	6	1	41
	Average		0.25	0.89	1.61	0.17	0.03	1.14
	StanDev		0.60	1.65	2.10	0.70	0.17	2.11

¹40 Atlantic Whitefish released into the lake on 25 November were captured but not used to calculate total and average catch

	Date	Trap Depth (m)	Species						Daily Total
			American Eel	Atlantic Whitefish	Brook Trout	Shiner	Rainbow Smelt	White Sucker	
2009	02-Nov	4.5							
	03-Nov								
	04-Nov								
	05-Nov					1			1
	06-Nov				1				1
	09-Nov								
	10-Nov				2				2
	12-Nov			7					7
	13-Nov			3					3
	16-Nov								
	17-Nov			3	4				7
	18-Nov			4	1				5
	19-Nov				1				1
	20-Nov			2					2
	23-Nov								
	24-Nov			5	1				6
	25-Nov			10	1		1	1	13
	26-Nov			5					5
	27-Nov			2				2	4
	30-Nov								
01-Dec			2	2			2	6	
02-Dec			1					1	
	Total		0	44	13	0	2	5	64
	Average			2.00	0.59	0.00	0.09	0.23	2.91
	StanDev			2.74	1.01	0.00	0.29	0.61	3.38

	Date	Trap Depth (m)	Species					Daily Total
			American Eel	Atlantic Whitefish	Brook Trout	Shiner	Rainbow Smelt	White Sucker
2010	01-Nov	4.5						
	02-Nov			1	5			28
	03-Nov				1			14
	04-Nov							12
	05-Nov							
	06-Nov			15	3	1		5
	07-Nov							
	08-Nov			6	4			10
	09-Nov							5
	10-Nov							
	11-Nov							
	12-Nov			1	2			
	15-Nov							
	16-Nov							1
	17-Nov				1			
	18-Nov			9				
	19-Nov							1
	22-Nov							
	23-Nov				1			
	24-Nov			2		1		
	25-Nov							
	26-Nov				1			
	30-Nov							
	01-Dec						1	
	02-Dec			4				
	03-Dec			2				
	07-Dec							
	08-Dec				1			
	09-Dec			1	1			1
	10-Dec							1
	Total		0	41	20	2	1	78
	Average			1.37	0.67	0.07	0.03	2.60
	StanDev			3.29	1.27	0.25	0.18	6.09
	09-Nov	3.0						
	10-Nov							
	11-Nov							
	12-Nov					1		
	15-Nov							
	16-Nov					1	1	
	17-Nov				1			
	18-Nov							
	19-Nov						2	
	22-Nov							
	23-Nov							
	24-Nov				1			
	25-Nov						2	
	26-Nov							
	30-Nov							
	01-Dec						1	
	02-Dec							
	03-Dec							
	07-Dec							
	08-Dec						2	
	09-Dec						1	
	10-Dec							
	Total		0	0	2	2	9	13
	Average				1.00	1.00	1.50	0.59
	StanDev				0.00	0.00	0.55	0.8

Year	Date	Trap Depth (m)	Species					Daily Total	
			American Eel	Atlantic Whitefish	Brook Trout	Shiner	Rainbow Smelt		White Sucker
2012	23-Oct	4.5			1				1
	24-Oct							2	2
	25-Oct				2			2	4
	30-Oct				3			1	4
	01-Nov				1			2	3
	02-Nov				2	1		1	4
	20-Nov							1	1
	22-Nov			1				1	2
	23-Nov				1				1
	28-Nov			1					1
	06-Dec						1		1
	07-Dec				1				1
	11-Dec				1				1
	12-Dec						1		1
	Total			0	2	12	1	2	10
Average				0.14	0.86	0.07	0.14	0.71	1.93
StanDev				0.36	0.95	0.27	0.36	0.83	1.27