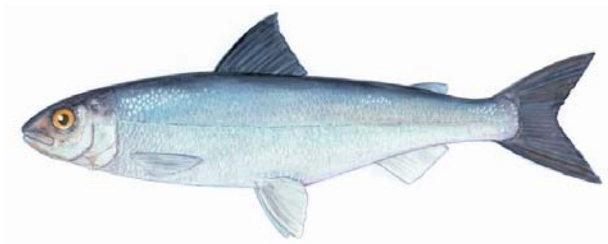
RECOVERY POTENTIAL ASSESSMENT FOR ATLANTIC WHITEFISH (*COREGONUS HUNTSMANI*)



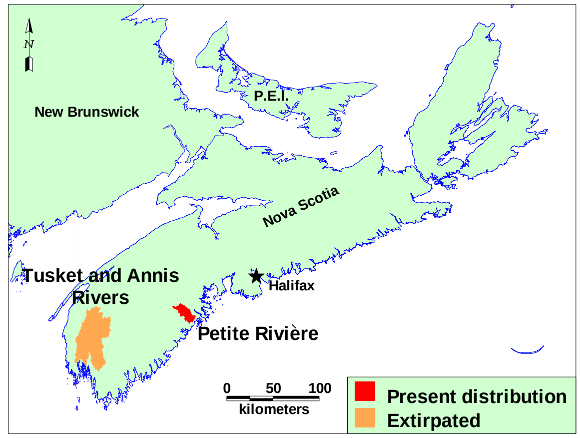


Figure 1: Atlantic whitefish distribution.

Context:

Atlantic whitefish (Coregonus huntsmani) are designated as "endangered" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and are listed on Schedule 1 of the Species at Risk Act (SARA). The prohibitions associated with SARA came into force in June 2004. A Recovery Potential Assessment was undertaken 24-25 March 2009 to provide information and advice on current status and trends, the impact of human activities on the species, possible alternatives and management measures to mitigate these impacts, and their potential for recovery. This Recovery Potential Assessment, which replaces the previous Allowable Harm Assessment (DFO 2004), is intended to consolidate new information on Atlantic whitefish in preparation for reassessment by COSEWIC, to support decisions on permitting of incidental harm, and to support ongoing recovery planning efforts as described in the current Recovery Strategy (DFO 2006).

SUMMARY

- The absolute abundance of wild Atlantic whitefish is unknown but is considered to be low. They are currently thought to be restricted to the Petite Rivière watershed, with reproduction occurring primarily within the approximately 16 km^2 combined area of Minamkeak, Milipsigate, and Hebb lakes.

- Atlantic whitefish survival depends upon its continued production within Minamkeak, Milipsigate, and Hebb lakes; thus, this habitat is considered necessary for its survival and subsequent recovery. There is no evidence to suggest that any part of this small area is not utilized by Atlantic whitefish, and further habitat fragmentation or loss of function should be avoided.

- At present, information about past abundance or productivity of Atlantic whitefish populations is not sufficient to form a basis for establishing watershed-specific abundance recovery targets or the number of populations required to ensure long-term viability.

- The minimum census population size required to maintain genetic diversity is estimated to be in the vicinity of 550 – 2,000 mature individuals. An interim watershed specific abundance target above the mid-point of this range (e.g., above 1,275 mature individuals) is proposed.

- There are reasons to expect that establishing several populations in diverse habitats, i.e., in several watersheds as a distribution target, will increase the probability that the species will be self-sustaining in the long term.

- Both the proposed interim watershed specific abundance target and distribution target will need to be revisited once knowledge about the dynamics of the recovering species is obtained.

- Current potential sources of direct mortality for Atlantic whitefish include: bycatch in recreational angling and other fisheries, entrainment of fish into water intakes, and removals or mortality from sampling for scientific purposes. Current indirect sources of mortality and impacts to habitat currently include: fluctuations in lake levels from municipal water drawdown or irrigation; acidification from acid run-off or acid rain; activities causing increased siltation, eutrophication, or substrate alteration; and barriers to fish passage. Unauthorized introduction and spread of non-native fish species (e.g., smallmouth bass, chain pickerel) may pose competitive, disruptive, or predation risks for Atlantic whitefish.

- A number of measures have already been put in place to mitigate threats to the existing population of Atlantic whitefish. However, the potential for survival of this population may be higher if fish passage and anadromy is an option within the Petite Riviére, and abundance of smallmouth bass within Minamkeak, Milipsigate, and Hebb lakes is managed. The overall survival and recovery of Atlantic whitefish requires enabling anadromy and range extension outside the Petite Rivière lakes.

- Activities to establish the anadromous form of Atlantic whitefish will need to consider the above cited sources of direct and indirect mortality, as well as the direct impact of passage through hydroelectric turbines, indirect effects of water management for hydroelectric generation, and native fish species (e.g., brook trout) recreational angling fishery enhancement activities.

- The recovery of Atlantic whitefish is considered to be both biologically and technically feasible. However, the time to recovery will be dependent both upon the current status of the remaining population and the timing/extent of human intervention.

- At a minimum, future monitoring activities should aim to establish whether Atlantic whitefish continue to produce new individuals annually in Minamkeak Lake, determine the response of Atlantic whitefish in Milipsigate Lake to a likely increase in smallmouth bass abundance, and establish indices of current status within Hebb Lake in advance of smallmouth bass becoming established.

BACKGROUND

Rationale for Assessment

When the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses an aquatic species as threatened or endangered, and the Governor in Council lists the species as one of these designations under the *Species at Risk Act (SARA)*, the Minister of DFO is required to undertake a number of actions. Many of these actions require scientific information, including the current status and trends of the species, the threats to its survival or recovery, and the feasibility of its recovery. Scientific advice on at-risk species is developed through a Recovery Potential Assessment (RPA).

Atlantic whitefish was designated as endangered at the species level by COSEWIC in 1984. It was reassessed by COSEWIC in 2000, at which time its endangered status was re-confirmed. Atlantic whitefish has been listed (thus protected) on Schedule 1 of *SARA* since its enactment, and a Recovery Strategy for this species was published in 2007 (DFO 2006). Atlantic whitefish will be up for reassessment by COSEWIC in 2010. This Recovery Potential Assessment is intended to consolidate new information on Atlantic whitefish in preparation for reassessment by COSEWIC, to support decisions on permitting of incidental harm, and to support recovery planning efforts.

Species Biology and Ecology

Atlantic whitefish, a species endemic to Nova Scotia, is a member of the family Salmonidae, and belongs to the subfamily Coregoninae. Recent genetic analyses of nuclear and mitochondrial DNA[1] supports the distinctiveness of Atlantic whitefish from other coregonid species including lake whitefish (C. *clupeaformis*) and Lake Ontario cisco (C. *artedii*). Analysis of microsatellites did not detect genetic differentiation among the populations of Atlantic whitefish within Minamkeak, Milipsigate and Hebb lakes and indicated low overall genetic diversity.

Atlantic whitefish can occur as either anadromous or freshwater resident populations. Former anadromous adults were typically larger (up to 50 cm in fork length [FL] and 3.6 kg in weight) than of freshwater resident specimens (usually less than 30 cm in FL). The maximum age for individuals in the existing wild population is estimated to be 4-5 years. The age at first maturity is 2 years.

Atlantic whitefish spawning has never been observed in the wild and spawning locations are unknown. Historical data indicates that gravid anadromous Atlantic whitefish ascended the Tusket River during late September to November. Both wild-caught lake resident Atlantic whitefish and their progeny raised to maturity in captivity spawn from late November to early January. Fecundity of Atlantic whitefish sampled from the lakes and reared in captivity varied from 1,500 extruded eggs per female at 25 cm FL to about 10,000 extruded eggs per female at 45 cm FL. Egg production per anadromous female is therefore expected to be greater than per land-locked female by up to a factor of approximately 4. Under culture, fertilized eggs are demersal and slightly adhesive. Larvae hatch after 260 ± 5.5 incubation degree days, which corresponds to an April-May hatch period in most mainland Nova Scotian rivers. Metamorphosis to juveniles begins around 30-days post hatch and at 3.1 cm to 4.9 cm total length. Atlantic whitefish appear to mature at a FL of approximately 20 cm and as early as age 2^+ years.

Adult Atlantic whitefish feed on a wide variety of aquatic organisms. Stomach analyses of fish from the Petite Rivière lakes indicated a diet that included aquatic insects and small fish but not benthic

[1] Neighbour joining analysis of 12 microsatellite loci and mitochondrial cytochrome oxydase subunit 1.

organisms. Atlantic whitefish captured in the marine environment contained shrimp, amphipods, fish and marine worms.

ASSESSMENT

Trends and Current Status

The historical range of Atlantic whitefish is known to have included the Tusket and Petite Rivière watersheds (Figure 1) and their adjacent estuaries and bays, but is expected to have extended to other watersheds in Nova Scotia (based on demographics, the characteristics of watersheds and the distribution of co-occurrent anadromous species). By the mid-twentieth century, reported occurrences were limited to the Tusket and Annis rivers and the Petite Rivière. There have been no sightings of Atlantic whitefish from the Tusket and Annis rivers since 1982, and the population is considered to have been extirpated from this system. No sightings of Atlantic whitefish were reported in the most recent systematic survey of the Tusket-Annis conducted in 2001 and 2002. There have been no reported sightings of wild Atlantic whitefish from other areas. The current range of wild Atlantic whitefish is thought to be restricted to the Petite Rivière watershed, with reproduction occurring primarily within the 16 km^2 combined area of Minamkeak, Milipsigate, and Hebb lakes (Figure 2).

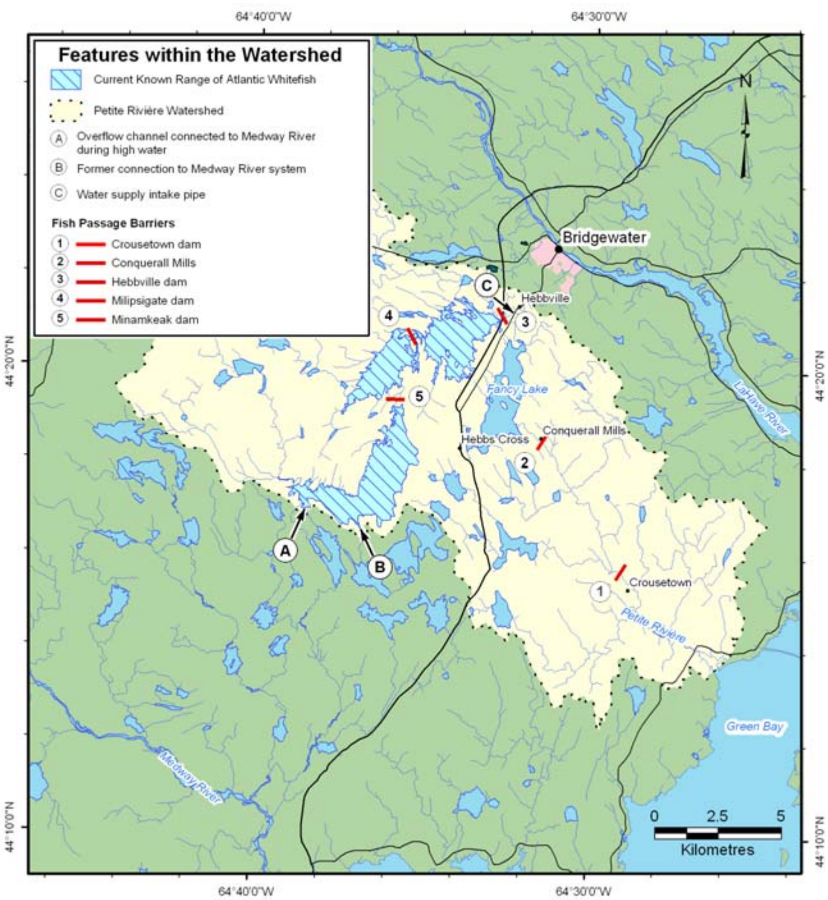


Figure 2. Map of the Petite Rivière watershed.

The absolute abundance of wild Atlantic whitefish is unknown, as the variety of techniques used to sample the species have not always been effective (Table 1), but is considered to be low. Atlantic whitefish were present in the years that they were last sampled (Hebb and Milipsigate lakes in

2007, and Minamkeak Lake in 2004). Atlantic whitefish were observed below the Milipsigate Dam in 2008. A recreational angler reported that one Atlantic whitefish had been angled and released in June 2004 below the Hebbville Dam.

Table 1. Number of Atlantic whitefish sampled since 2000 by location, year and sampling method. Blank cells indicate no effort.

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Petite Rivière Estuary	0 (framed trapnet)								
Below Hebb Lake Dam									0 (framed trapnet)
Hebb Lake	1 (seine)							24 (floating trapnet)	
Above Hebb Lake (Milipsigate Dam)	78 (seine, angling)	5 (trapnet, /angling)		1 (angling)		4 (angling)	19 (seine, angling)	29 (seine, angling)	
Milipsigate Lake				7 (trapnet)			0 (trapnet)		
Minamkeak Lake					19 (gillnet)				

Note: Table does not include casual observations, such as the fish observed below the Milipsigate Dam in 2008 or the fish that was angled and released below the Hebbville Dam in 2004.

Habitat Requirements and Residence

Atlantic whitefish are currently thought to be restricted to Petite Rivière watershed, with reproduction occurring primarily within the approximately 16 km^2 combined area of Minamkeak, Milipsigate, and Hebb lakes. Atlantic whitefish survival presently depends upon its continued production within these lakes (i.e., this habitat is considered necessary for its survival and subsequent recovery). The utilization of the various habitats within these lakes by the different life-history stages of Atlantic whitefish is not well understood, but sampling to date has shown that they occur throughout the lakes and the streams that connect the three lakes (e.g., eggs are demersal, juveniles were sampled in the shallows, adults and subadults are pelagic). There is no evidence to suggest that any part of this small area is not utilized by Atlantic whitefish, and further habitat fragmentation or loss of function should be avoided.

The characteristics of suitable spawning habitat are not known, although it appears as though Atlantic whitefish in the Petite Rivière spawn in the lakes, as is common for both lake whitefish and cisco. The habitat preferences of immature Atlantic whitefish are not well understood. A single immature Atlantic whitefish was intercepted with a beach seine within the shallows of Hebb Lake during June 2000, and several immature whitefish were captured in a 5 m deep floating trapnet installed in Hebb Lake in 2007. The marine habitat preferences of anadromous Atlantic whitefish are not known, although their documented occurrence in locations as distant as Hall's Harbour, Nova Scotia indicates that they are not wholly resident within estuaries.

Many of the rivers in Nova Scotia that are thought to have supported Atlantic whitefish populations at one time were naturally acidic to some degree. Paleolimnilogical records and ongoing water quality monitoring indicate that the three Petite Rivière lakes still possessing Atlantic whitefish have consistently maintained a mean annual pH greater than 5.6. Controlled experiments have shown that a pH of less than 5.0 can decrease the survival of Atlantic whitefish eggs, whereas a pH of less than 4.5 decreased survival of larvae and juveniles. Fertilized eggs are not salt tolerant, and Atlantic whitefish are therefore considered to be obligate freshwater spawners. Salinity tolerance of Atlantic whitefish increases with ontogenetic development such that survival at the time of larval hatch decreases from 100% in freshwater to 93 and 91% in 15 and 30 ppt, whereas both juveniles and adults tolerate 30 ppt. Atlantic whitefish can grow at temperatures between 11.7ºC and 24.0ºC, with optimum growth at 16.5ºC.

SARA defines residence as, "*a dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating*." The available information indicates that the concept of residence does not apply to Atlantic whitefish.

Recovery Targets

Recovery targets are used to assess progress towards the recovery goal. The current goal of the Atlantic whitefish Recovery Strategy is "*to achieve stability in the current population of Atlantic whitefish in Nova Scotia, re-establishment of the anadromous form, and expansion beyond its current range*" (DFO 2006).

For both anadromous and fresh water resident populations where there is an expectation that straying among water bodies is low, the recovery targets could be specified for a set of watersheds in which populations would be recovered, as well as an abundance target for each population. At present, information about past abundance or productivity of Atlantic whitefish populations is not sufficient to form a basis for establishing watershed-specific abundance targets or the number of populations required to ensure long-term viability, although there is information that can guide these decisions.

Watershed-Specific Abundance Targets

The minimum population size needed to maintain genetic diversity can be used as a coarse abundance target. This value can be estimated from the effective population size[2] required to maintain genetic diversity and the ratio of the effective population size (N_e) to the census population size (N_{census}), neither of which is known for Atlantic whitefish. An effective population size of 500 mature individuals is thought to be sufficient to maintain genetic diversity in many vertebrate species and could be assumed as a proxy for Atlantic whitefish. A review of N_e/N_{census} ratios for salmonids showed this ratio to be typically in the vicinity of 0.26 to 0.88, and these values could be assumed to be a rough approximation of the range of this ratio for Atlantic whitefish. Taken together, these ratios would place the minimum census population size required to maintain genetic diversity in the vicinity of 550 – 2,000 mature individuals. Atlantic whitefish are thought to be at low abundance, exhibit evidence of undergoing or having undergone a genetic bottleneck (which would lower the N_e /N_{census} ratio), and are at-risk from catastrophic events and/or environmental variability. For these reasons, an interim watershed specific abundance target above the mid-point of this range (e.g., above 1,275 mature individuals) is proposed. This target will need to be revisited once knowledge about the dynamics of the recovering species is obtained.

Number of Watershed-Specific Populations Required for Recovery

With only limited information about the past distribution of Atlantic whitefish, any watershed within Nova Scotia could be considered a potential candidate for Atlantic whitefish introduction, particularly watersheds lying within the bounds of their known former range. There is uncertainty about the

[2] N_e - the number of mature individuals in an ideal population that would lose genetic variation due to drift or inbreeding at the same rate as the number of reproducing adults in the real population under consideration.

number, location and size of populations required to ensure the long-term viability of the species. There are several reasons based on fish life-history to expect that establishing several populations in diverse habitats, i.e., in several watersheds as a distribution target, will increase the probability that the species will be self-sustaining in the long term.

First, there is habitat variability (e.g., pH; stream gradient; presence, amount and accessibility of lake habitat; thermal characteristics) within the former range of Atlantic whitefish. Establishing populations in watersheds that represent the full breadth of conditions that Atlantic whitefish can tolerate could potentially increase their biological diversity and with time increase genetic variation (through local adaptation), thereby enhancing the capacity of the species to respond to future environmental change.

Second, increasing the number of populations being used to maintain local variations decreases the risk of extirpation as a result of catastrophic events. Replication of habitat conditions described under the first point is desirable.

Third, other things being equal, larger populations have lower extinction risks than smaller populations and these tend to occur in larger watersheds. Watershed size or some other proxy for habitat amount should be considered when selecting locations for establishing additional populations.

Fourth, at present the importance of straying and mixing among populations for maintaining Atlantic whitefish populations is not known. However, metapopulation structure is an important consideration in the conservation of salmonids generally, and it acts to increase regional persistence particularly when straying "rescues" a local population from extirpation. As a result, the probability of long-term persistence of Atlantic whitefish would be expected to increase as the number of watersheds in which Atlantic whitefish are recovered is increased.

Finally, as was the case with the watershed-specific abundance target, the distribution target will need to be revisited once knowledge about the dynamics of the recovering species is obtained.

Threats, Alternatives and Mitigation Measures

The reasons for the historical decline in Atlantic whitefish are not known with certainty, but they are thought to have included the construction of barriers to migration. Most of the principal rivers and streams of southwestern Nova Scotia have been dammed to some extent since the time of European colonization. A 1926 census of dams showed that, in total, 92 dams were recorded as present on 33 southwestern Nova Scotia drainages bounded by the Annapolis River to the south and the Sackville River to the east in that year. The average year of construction for 73 of the dams was 1882 (± 35.3 years), with the oldest being constructed in 1802. The construction date for most of the dams on the Petite and Tusket rivers pre-dated the proclamation of the *Fisheries Act* in 1868; the lower most dam on the Annis River was constructed in 1869.

The recent (1982) probable extirpation of Atlantic whitefish from the Tusket watershed was attributed to a combination of habitat loss and degradation from river acidification (acid rain), ineffective fish passage around dams, introduction of exotic species, and unregulated fishing.

Current and potential threats to Atlantic whitefish are summarized in Appendix 1. Current potential sources of direct mortality for Atlantic whitefish (i.e., threats to the existing population of Atlantic whitefish within the Petite Rivière watershed) include: bycatch in recreational angling and other fisheries, entrainment of fish into water intakes, and removals or mortality from sampling for scientific purposes (including recovery efforts). Current indirect sources of mortality and impacts to habitat include: fluctuations in lake levels from municipal water drawdown or irrigation; acidification from acid run-off or acid rain; activities causing increased siltation, eutrophication, or substrate alteration; and barriers to fish passage. Unauthorized introduction and spread of non-native fish species (e.g., smallmouth bass, chain pickerel) may pose competitive or predation risks and is also a major concern for Atlantic whitefish.

Future Atlantic whitefish populations, should they be established in other watersheds, may face additional threats beyond those described above. For example, installation and use of commercial fishing gear could result in direct by-catch mortality. Stocking densities associated with recreational angling fishery enhancement activities could pose a competitive or predation risk. As well, the presence of hydroelectric facilities, the presence of dams, habitat alteration or barriers to fish passage generally could result in mortality, injury or unsuccessful migration of established Atlantic whitefish.

A number of measures have already been put in place to mitigate threats to the existing population of Atlantic whitefish. These measures include changes in fisheries regulations that make directed fishing for Atlantic whitefish illegal, as well as current prohibitions (by variation order) on recreational angling from April 1 to June 30th in the inland waters of Minamkeak, Milipsigate, and Hebb lakes and the thoroughfares joining them. Only unbaited lures and artificial flies are permitted during the open angling season from July 1 to September 30. One gillnet fisher was relocated from the Petite Rivière estuary. As well, monitoring protocols have been adopted that minimize handling of Atlantic whitefish when water temperatures are over 16ºC to reduce handling mortality. Screening of the existing municipal water intake is thought to be effective at preventing entrainment of Atlantic whitefish of all sizes. Aquaculture containment protocols are being developed and improved to minimize escapees (e.g., of rainbow trout and Atlantic salmon).

Additional mitigation measures and alternatives that could be used to minimize threats to existing and future Atlantic whitefish populations are provided in Appendix 1.

Measures to Increase Productivity or Survivorship

Atlantic whitefish appear to exhibit enhanced growth, the capacity to live as long as eight years, and a four fold increase in egg production when introduced into culture. Culture in turn appears able to replicate the general body size traits of the now extirpated anadromous Tusket River population, which suggests that there are demonstrable benefits to productivity and survivorship by re-establishing anadromous populations. The observed tolerance of early-life stage Atlantic whitefish to broad ranges of water salinity, temperature, and pH indicates that establishing both anadromous runs and lake resident populations is biologically feasible and potentially feasible in a broad range of river drainages.

Recovery Potential

The recovery of Atlantic whitefish is considered to be both biologically and technically feasible. However, the time to recovery will be dependent both upon the current status of the remaining population and the timing/extent of human intervention.

Available information indicates that the lake resident Atlantic whitefish in the Petite Rivière watershed are small bodied, short lived (maximum observed age of 4-5 years) and, therefore, of limited individual reproductive capacity within their present range. While these features appear to have been relatively constant over the past several decades, the continuing survival of this population under current conditions is uncertain given the absence of information that new individuals are produced annually in Minamkeak Lake and indications that smallmouth bass are now reproducing in Minamkeak and Milipsigate lakes. The potential for survival of this population may be higher if fish passage and anadromy is an option within the Petite Rivière, and abundance of smallmouth bass within Minamkeak, Milipsigate, and Hebb lakes is managed.

The overall survival and recovery of Atlantic whitefish requires enabling anadromy and range extension outside the Petite Rivière lakes. Techniques have been developed at the Mersey Biodiversity Facility that allows the species to be successfully spawned and reared in captivity. Direct transplants from the existing population to new locations may also be an option, provided it can be demonstrated that the extant population can withstand removals of individuals in the numbers required to support natural production elsewhere. Experimental trials have shown that the existing Atlantic whitefish population maintains its salinity tolerance and capacity for anadromy, can tolerate a range of pH ranges that it does not presently experience, and is reasonably tolerant of a range of temperatures. Recent experimental releases of captive reared Atlantic whitefish into Anderson Lake and the lower Petite Rivière have shown that cultured fish can survive for at least a year and realize growth in the wild.

Research and Monitoring

At a minimum, future monitoring activities should aim to establish whether Atlantic whitefish continue to produce new individuals annually in Minamkeak Lake, determine the response of whitefish in Milipsigate Lake to a likely increase in smallmouth bass abundance, and establish indices of current status within Hebb Lake in advance of colonization by smallmouth bass. Monitoring would provide time series that could be used to evaluate recovery, including estimates of effective population size. Additional research and monitoring may include assessment or determination of:

Status

- population size (quantitative assessment);
- age composition and age at maturity, and growth and mortality on an inter-annually consistent basis;
- effects of current human activities on Atlantic whitefish survival; and,
- fish passage requirements, including an increased understanding of how trophic structuring within the lakes might respond to the presence of other fish species that do not occur there presently.

Habitat

- specific habitat requirements as they relate to spawning, incubation, rearing, foraging, and thermal refugial requirements;
- scope for negative interaction with smallmouth bass at all life-history stages;
- seasonal area of occupancy of Atlantic whitefish;
- identification and mapping of habitat features; and,
- habitat suitability within candidate stocking sites.

Captive Rearing

- nutritional, husbandry, and space requirements to maintain Atlantic whitefish in captivity;
- likelihood that domestication selection will occur within Atlantic whitefish spawned and reared in captivity; and,
- trophic niche selection of cultured fish as they naturalize to the waterbodies they are stocked into.

Sources of Uncertainty

Aging protocols for Atlantic whitefish remain in development, which limits the scope of interpretation of their seasonal growth, life-span in the wild, and maturation.

CONCLUSIONS AND ADVICE

The absolute abundance of wild Atlantic whitefish, a species endemic to Nova Scotia, is unknown but is considered to be low. They are currently thought to be restricted to the Petite Rivière watershed, with reproduction occurring primarily within the approximately 16 km^2 combined area of Minamkeak, Milipsigate, and Hebb lakes. There have been no sightings of Atlantic whitefish from the Tusket and Annis rivers since 1982, and the population is considered to have been extirpated from this system.

Atlantic whitefish survival depends upon its continued production within Minamkeak, Milipsigate, and Hebb lakes; thus, this habitat is considered necessary for its survival and subsequent recovery. The utilization of the various habitats within these lakes by the different life-history stages of Atlantic whitefish is not well understood, but sampling to date has shown that they occur throughout the lakes and the streams that connect the three lakes. There is no evidence to suggest that any part of this small area is not utilized by Atlantic whitefish, and further habitat fragmentation or loss of function should be avoided.

Fertilized eggs are not salt tolerant, and Atlantic whitefish are therefore considered to be obligate freshwater spawners. The marine habitat preferences of anadromous Atlantic whitefish are not known, although their documented occurrence in locations as distant as Hall's Harbour, Nova Scotia indicates that they are not wholly resident within estuaries. The available information indicates that the concept of residence does not apply to Atlantic whitefish.

The current goal of the Atlantic whitefish recovery strategy is "*to achieve stability in the current population of Atlantic whitefish in Nova Scotia, re-establishment of the anadromous form, and expansion beyond its current range*" (DFO 2006). At present, information about past abundance or productivity of Atlantic whitefish populations is not sufficient to form a basis for establishing watershed-specific abundance recovery targets or the number of populations required to ensure long-term viability; however, the minimum census population size required to maintain genetic diversity is estimated to be in the vicinity of 550 – 2,000 mature individuals. Given that Atlantic whitefish are thought to be at low absolute abundance, are undergoing or have undergone a genetic bottleneck, and are at-risk from catastrophic events and/or environmental variability, an interim watershed specific abundance target above the mid-point of this range (e.g., above 1,275 mature individuals) is proposed. There are reasons to expect that that establishing several populations in diverse habitats, i.e., in several watersheds as a distribution target, will increase the probability that the species will be self-sustaining in the long term. Both the proposed interim watershed specific abundance target and distribution target will need to be revisited once knowledge about the dynamics of the recovering species is obtained.

Current potential sources of direct mortality for Atlantic whitefish include: bycatch in recreational angling and other fisheries, entrainment of fish into water intakes, and removals or mortality from sampling for scientific purposes. Current indirect sources of mortality and impacts to habitat include: fluctuations in lake levels from municipal water drawdown or irrigation; acidification from acid run-off or acid rain; activities causing increased siltation, eutrophication, or substrate alteration; and barriers to fish passage. Unauthorized introduction and spread of non-native fish species (e.g., smallmouth bass, chain pickerel) may pose competitive, disruptive, or predation risks for Atlantic whitefish.

A number of measures have already been put in place to mitigate threats to the existing population of Atlantic whitefish. However, the potential for survival of this population may be higher if fish passage and anadromy is an option within the Petite Rivière, and abundance of smallmouth bass within Minamkeak, Milipsigate, and Hebb lakes is managed. The overall survival and recovery of Atlantic whitefish requires enabling anadromy and range extension outside the Petite Rivière lakes.

Activities to establish the anadromous form of Atlantic whitefish will need to consider the above cited sources of direct and indirect mortality, as well as the direct impact of passage through hydroelectric turbines, indirect effects of water management for hydroelectric generation, and native fish species (e.g., brook trout) recreational angling fishery enhancement activities.

The recovery of Atlantic whitefish is considered to be both biologically and technically feasible. However, the time to recovery will be dependent upon the current status of the remaining population and the timing/extent of human intervention.

At a minimum, future monitoring activities should aim to establish whether Atlantic whitefish continue to produce new individuals annually in Minamkeak Lake, determine the response of whitefish in Milipsigate Lake to a likely increase in smallmouth bass abundance, and establish indices of current status within Hebb Lake in advance of smallmouth bass becoming established. Monitoring would provide time series that could be used to evaluate recovery, including estimates of effective population size.

OTHER CONSIDERATIONS

Efforts to establish anadromous runs of Atlantic whitefish should take into account changes in marine environmental conditions, particularly within nearshore areas that historical evidence suggests were occupied by the species.

In efforts to re-establish anadromy in Atlantic whitefish through improvements to fish passage, potential ecological interactions with other diadromous species should be considered. Efforts to establish anadromy on the Petite Rivière watershed should consider the potential effects on the existing wild population.

Activities (e.g., research and mitigation) conducted in relation to Atlantic whitefish should be considered within the context of the broader watershed community.

SOURCES OF INFORMATION

DFO. 2004. Allowable Harm Assessment for Atlantic Whitefish. DFO Can. Sci. Advis. Sec. Stock Status Rep. 2004/052.

DFO. 2006. Recovery Strategy for the Atlantic Whitefish (*Coregonus huntsmani*) in Canada. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa.

Appendix 1

Summary of human activities that may contribute to total mortality or harm to Atlantic whitefish. Activities are categorized by sector and current threats (not potential threats) have been assigned a relative rank effect (1=highest, 2=moderate, 3=lowest). The cause and effect on survival of each is indicated. Alternatives to the activity and possible mitigative measures are indicated. Current threat is one that affects the existing population within Petite Riviere. Potential threat is one that may affect new or expanded populations.

Activity	Sector	Rank Effect for Current Threats	Cause	Effect	Current (C) or Potential (P) Threat	Alternatives	Mitigation
Bycatch	Recreational angling	3	Capture on hook and line	Handling mortality	C	Other recreational activities or other areas	Varied season closures or gear restrictions.
	Commercial fishing	3	Capture in licensed gears	Entanglement, entrapment, handling mortality	C	Relocate fishery	Varied closures; relocations; live captured gear types to enable live release
Detrimental fishing effects on habitat	Commercial fishing		Physical presence of gear	Alteration of supporting habitat	P	Regulate fishing practices; relocate fishery	
				Barrier to passage	P	Regulate change to fishing practices	Ensure water flow around structures
Direct mortality under permit	Hydroelectric generation		Passage through turbines, ineffective fish passage facilities	Mortality, injury, delayed or unsuccessful migration	P	Alternative energy sources	Effective fish passage facilities operations
	Municipal water extraction	3 (based on current screening)	Intrusion of fish into water intakes	Mortality, injury	C	Alternative sources of water	Effective screening; regulating depth of intake
	Irrigation	3	Entrainment of fish	Mortality, loss from spawning population	C	Alternative water supply	Effective screening; regulating depth of intake; timing of intake; storage facilities; indirect withdrawl techniques, e.g., a “Groundwater Under the Direct Influence of surface water” well
Detrimental habitat alterations	Hydroelectric generation		Dewatering of habitat, reduced forage base	Mortality, reduced production	P	Alternative energy sources	Regulate reservoir operations; maximum draw downs; ramping timing and durations
	Presence of dams	1	Barriers to fish passage	Prohibits life-cycle closure	C	Depends on purpose of dam; relocation and/or removal of activity	Provide adequate upstream and downstream passage; water use management
		Unknown	Physical structure	Alters habitat type	C	Depends on purpose of dam; relocate activity	No known mitigation for habitat alterations
	Urbanization	1	Shoreline alteration, domestic waste leachate	Habitat alteration, reduced water quality	C	Watershed management	Setbacks; compliance monitoring and enforcement

Activity	Sector	Rank Effect for Current Threats	Cause	Effect	Current (C) or Potential (P) Threat	Alternatives	Mitigation
	Municipal water storage / drawdown	3	Dewatering of habitat, water level fluctuations; reduced forage base	Reduced production	C	Alternative water supply	Regulate reservoir operations
	Irrigation	3	Reduced river discharge	Possible loss of habitat	C	Alternative water supply	Control rate / quantity of water extraction; water conservation; timing of intake; storage facilities; indirect withdrawl techniques, e.g., a GUDI well (see irrigation mitigation above)
	Mines/quarries	2-3 (depending on conditions)	Acid run-off	Acid toxicity, pollution	C	Relocate activity	Treatment of runoff; reclamation of existing quarries
	Forestry	2-3	Damage to riparian zone, stream crossings	Increased siltation, flow alterations	C	Relocate activity	Setbacks; alternative forest harvest practices; compliance monitoring / enforcement
	Agriculture	3	Erosion / runoff	Eutrophication	C	Relocate activity	Setbacks; limit soil exposure; reduce use of chemicals
Scientific research	Assessment and research	3	Removals; Handling mortality	Reduced production	C	Non-invasive monitoring techniques; remote sensing; modeling	Modification of handling protocols, e.g., no handling over 16ºC
	Recovery efforts		Removals	Reduced production	P		Captive breeding
Non-domestic air pollutants	Acid precipitation	3 (natural buffering capacity of system and tolerance of species)	River acidification	Acid toxicity	C		Liming
Introductions and transfers	Illegal introductions	1	Spread or introduction of non-native species	Competition, predation, displacement, community shift	C		Regulation to control transfer among water bodies; control / removals; improved education
	Recreational fishery enhancement	Unknown	Spread or introduction of native species		C	Other recreational activities or other areas	Risk framework; control; removals
	Aquaculture	Unknown	Escapees, disease		C	Land-based operations	Containment; removals

FOR MORE INFORMATION

Contact: Rod Bradford
Fisheries and Oceans Canada
Population Ecology Division
Bedford Institute of Oceanography
1 Challenger Drive, Dartmouth, N.S., B2Y4A2

Tel: (902) 426-4555
Fax: (902) 426-1862
E-Mail: bradfordr@mar.dfo-mpo.gc.ca

This report is available from the:

Centre for Science Advice (CSA)
Maritimes Region
Fisheries and Oceans Canada
Box 1006, Stn. B203
Dartmouth, Nova Scotia
Canada B2Y 4A2

Telephone: 902-426-7070
Fax: 902-426-5435
E-Mail: XMARMRAP@mar.dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas

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