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Gulf Region
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POTENTIAL IMPACT OF SMALLMOUTH BASS INTRODUCTIONS ON ATLANTIC SALMON: A RISK ASSESSMENT

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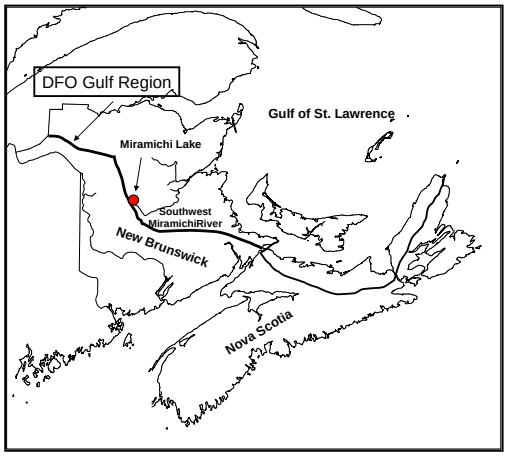

Figure 1: DFO Gulf Region and location of Miramichi Lake and the Southwest Miramichi River within the Maritime provinces.

Context :

In late September 2008, smallmouth bass (Micropterus dolomieu Lacepède) was discovered in a headwater lake in the Southwest Miramichi River (NB), the first known incidence of the species in this watershed. The Miramichi River and other rivers of the Gulf Region are recognized as the most productive Atlantic salmon (Salmo salar) rivers in the world. Smallmouth bass are recognized as an effective predator and competitor of other fish. The range has been extending into a large number of watersheds in Nova Scotia and New Brunswick with unauthorized introductions and natural dispersal as the vector in recent decades.

In response to numerous concerns,, DFO Fisheries and Aquaculture Management (FAM) requested science advice regarding the risks that the introduction and spread of smallmouth bass would pose to Atlantic salmon and other freshwater fish within the Miramichi River and within the Gulf Region rivers.

A risk analysis of smallmouth bass introductions and spread in British Columbia was conducted in early 2008. Information from that review as well as area specific information from the Maritime provinces was assembled and reviewed at a meeting of the Regional Advisory Process in Moncton (NB), January 27-28, 2009. The objectives of the meeting were: (1) to review the historical and current distribution of smallmouth bass, (2) its biology, habitat requirements and availability of habitat to smallmouth bass in the Maritime provinces, (3) to examine evidence for negative interaction between Atlantic salmon and smallmouth bass, (4) to conduct a risk assessment of smallmouth bass impacts on the ecosystem of the rivers of the Gulf Region, with a specific risk analysis of impacts to Atlantic salmon in the Southwest Miramichi River, and (5) to review options for and the effectiveness of mitigation measures for minimizing the risks associated with range extension of smallmouth bass. The risk assessment followed the guidelines established by the DFO Centre of Expertise for Aquatic Risk Assessment (CEARA) for assessing the biological risk of aquatic invasive species in Canada.

The advice from the meeting will be used by DFO FAM to decide on the course of action to take in response to the introduction of smallmouth bass in Miramichi Lake as well as for future incidents should they arise. Participants at the review were from DFO Science, DFO FAM, the provinces of New Brunswick and Nova Scotia, Aboriginal groups, Miramichi Watershed Management Committee members, NGOs and academia.

SUMMARY

- Smallmouth bass is not an endemic species in the Maritime provinces but they are presently known from 188 lakes/rivers of Nova Scotia and 69 lakes and 34 rivers in New Brunswick.
- Smallmouth bass are found in eight lakes in the Gulf Region and the latest introduction was confirmed in 2008 in Miramichi Lake, the first record from the Miramichi River.
- When smallmouth bass are introduced into a water body, they prey heavily on smaller fish, can out-compete other fish species, and can become a dominant component of the food web.
- There is a high likelihood of widespread establishment of smallmouth bass in the Southwest Miramichi River and in the Gulf Region rivers in general.
- Watersheds with a sequence of lakes within the main stems of rivers or in close proximity to main stems would provide a better environment for broad watershed establishment of smallmouth bass and negative interactions would be enhanced.
- The overall risk to the aquatic ecosystem is considered to be high in the lake environment; smallmouth bass is expected to become a dominant component of the food web and to cause significant reductions in existing biota. The uncertainty is low.
- The overall risk is considered to be moderate in the riverine environment; a measurable decrease in abundance of native populations is likely to occur in most locations due to the establishment of smallmouth bass. The uncertainty is high.
- Riverine habitat is used preferentially by Atlantic salmon. Although the overall risk to salmon is considered moderate in the riverine environment, none of the consequences of smallmouth bass introductions will be positive for Atlantic salmon.
- The highest probability of controlling or eradicating non-native species is through the use of multiple approaches. The likelihood of success of controlling and/or eradicating the target species is reduced when control and eradication actions are delayed.

INTRODUCTION

The Canadian Council of Fisheries and Aquaculture Ministers (CCFAM) developed the Aquatic Invasive Species Task Group to deal with the prevention of accidental introductions and to develop management plans designed to protect natural ecosystems from the harmful impacts of invasive species, consistent with the UN Convention on Biodiversity and the Canadian Biodiversity Strategy. The goal of the Canadian Action Plan to address the threat of aquatic invasive species (AIS) was to prevent the introduction of harmful AIS and to remediate the impact of those already in Canada. Aquatic invasive species were defined by CCFAM as:

> Fish, animal, and plant species that have been introduced into a new aquatic ecosystem and are having harmful impacts on the natural resources in the native aquatic ecosystem and/or the human use of the resource (CCFAM 2004).

The DFO Centre of Expertise for Aquatic Risk Assessment (CEARA) was established in 2006 to develop national standards for conducting biological risk assessments of AIS not authorized for introduction. Risk assessment of AIS is the process of characterizing the likelihood of a potential introduction and the magnitude of the consequences of that introduction, in either qualitative or quantitative terms. Likelihood of establishment and magnitude of impact are key criteria for

identifying invasive species that require enhanced management. Identifying the uncertainty associated with both the likelihood of introduction and the magnitude of biological consequences is a key component of the risk assessment.

Whether smallmouth bass (*Micropterus dolomieu)* qualifies as an invasive species and whether its spread into watersheds in the Gulf Region warrants new management measures depends upon the extent of the negative impact it may have on the native ecosystem. Smallmouth bass is not an endemic species in the Maritime provinces although the history of introduction in some watersheds dates back to about 1869. In the context of the discovery of smallmouth bass in Miramichi Lake in September 2008, the concern is to the impact the species may have on the native Atlantic salmon (*Salmo salar*) and brook trout (*Salvelinus fontinalis*) populations in the Miramichi River, species which contribute to important aboriginal and recreational fisheries, in addition to the overall aquatic ecosystem.

ASSESSMENT

The types of information required for a risk assessment includes biology and vectors. The biological information is used to identify the potential of the species encountering adequate biological and physical resources and its subsequent ability to survive, reproduce and spread. Information on vectors is used to assess the potential and likelihood of spread beyond the natural capacity of the species to expand its range.

Distribution, biology, and habitat requirements of smallmouth bass

Smallmouth bass, *Micropterus dolomieu* Lacepède (1802), is a member of the Order Perciformes, Family Centrarchidae, and is endemic to the fresh waters of eastern-central North America. The original Canadian distribution of smallmouth bass was restricted to the Great Lakes / St. Lawrence River system. The initial expansion of the smallmouth bass range took place in the mid-1800s, to central New York State through the Erie Canal. They were transplanted into the New England states in the late 1800s and spread into New Brunswick from Maine around 1869, in the St. Croix River watershed. They were deliberately introduced to more lakes in New Brunswick (NB) and into Nova Scotia (NS) from New Brunswick sources by public agencies between 1905 and 1953. Sanctioned and unsanctioned introductions in the first half of the 20th century contributed to the expanded range of smallmouth bass in the Maritime provinces but the last legal introductions date to 1948 for NB and 1984 for NS.

The recent continued expansion of the range of smallmouth bass in NB and NS is attributed primarily to illegal introductions but also by dispersal through connected waterbodies (Table 1). The species is presently known from 188 lakes/rivers in NS, and 69 lakes and 34 rivers in NB. Most of the watersheds colonized by smallmouth bass are located in the Bay of Fundy and Atlantic coast of NS drainages (Fig. 2). Smallmouth bass have been reported from eight lakes in the Gulf of St. Lawrence drainages; one in NB and seven in NS, all confirmed since 1998. Important smallmouth bass recreational fisheries have developed in NB and NS.

Table 1. History of spread of smallmouth bass, based on new locations confirmed by time period, in the Maritime provinces and the Gulf Region .

	Maritime provinces			Gulf Region	
	New Brunswick		Nova Scotia	New Brunswick	Nova Scotia
Time period	Lakes	Rivers	Lakes and rivers	Lakes	Lakes
1869 - 1900	5	4	0		
1901 - 1951	8		8		
1952 - 1980	16		42		
1981 - 1993	19	30	30		
1994 - 2008	21		108	1	7
Total	69	34	188	1	7

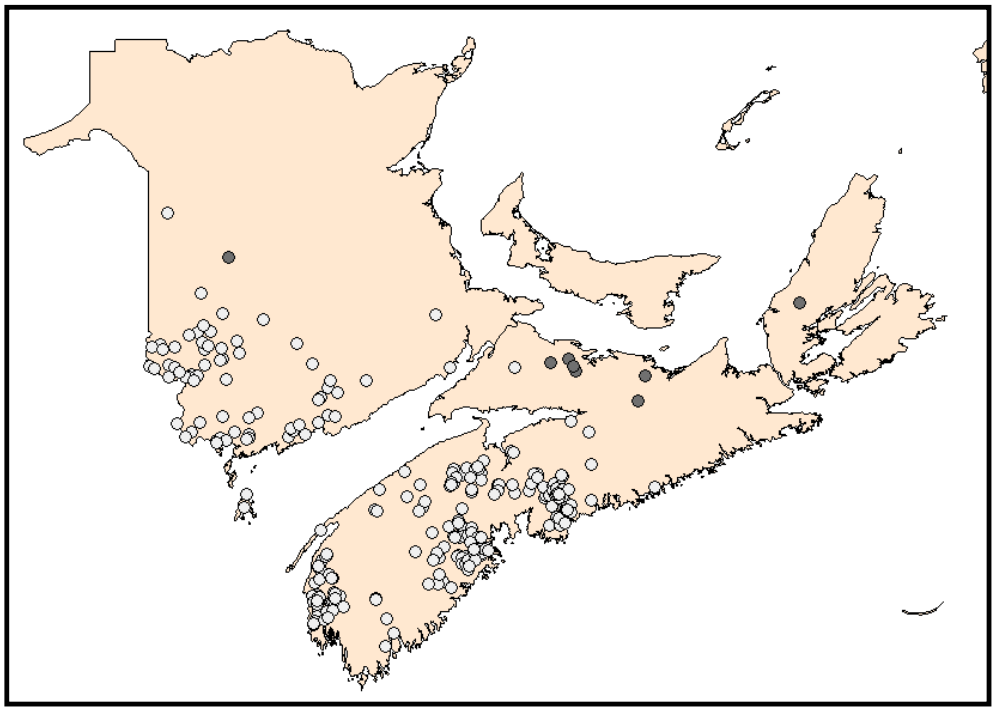

Figure 2. Confirmed distribution of smallmouth bass in the Maritime provinces. Distribution in the Gulf Region is shown by dark grey symbols.

Biology

Smallmouth bass is a medium body-sized fish with fork length of the largest animals typically less than 50 cm and whole weights typically less than 2 kg; the Canadian angling record smallmouth bass measures 61.6 cm. The maximum age reported for the Maritimes is 22 years. Sexual maturity is reached typically at ages > 5 years but mature 3 year old fish have been recorded in some growth-stunted populations in NS. Reproduction occurs in spring and male bass provide a large degree of parental care. Females produce from a few thousand up to 20,000 (depending on female body size) adhesive demersal eggs released in nests constructed by males. Males guard the nests as well as embryos and swim-up fry until the latter disperse from the nest. By the end of the first growing season, young-of-the-year bass can attain lengths

of 40 to 100 mm. Adults prefer the inshore rocky or large woody debris habitat areas of lakes and in areas of moderate current over rocky or gravel substrates in rivers.

Smallmouth bass consume a wide range of invertebrate and vertebrate prey, prey type being influenced by fish length, age and prey availability. They are also known to be cannibalistic. Where available, crayfish can comprise an important component of the diet.

Habitat requirements

In its native range, smallmouth bass inhabit primarily larger (> 40 ha) mesotrophic (clean, clear) lakes with average depths > 9 m. Shallow, cobble to gravel substrate in littoral zones are important for both spawning and rearing. Bass are also found in wider mid-order rivers or streams of moderate current, of gradient less than 0.5%, substrates of silt, sand gravel and deeper pools. In NS, smallmouth bass have been reported from lakes ranging between 4 and 5,700 ha, and mean depths of 3.4 m. In NB, smallmouth bass have only been reported in lakes of 5 to 7,000 ha and maximum depths > 3 to 41 m. Smallmouth bass also exist in many NB and NS rivers, including in NB the St. Croix, Magaguadavic, Musquash rivers, much of the lower Saint John River flowing waters and along its mainstem.

Although smallmouth bass are generally confined to fresh water, they may move into low salinity areas of tidal rivers for short periods of time. In their native range, smallmouth bass can be found in the upper reaches of estuaries of larger rivers.

Smallmouth bass prefer water temperatures in summer of 17-28ºC with an upper lethal temperature of 35ºC. They may not feed actively until temperature reaches about 8.5ºC and cessation of feeding typically occurs when temperatures drop below 7-10^{O}C although there is evidence of feeding activity at colder temperatures in the Maritimes and northeast US (smallmouth bass are reportedly caught by ice fishermen). Spawning typically occurs when temperatures exceed 15ºC. The weight of evidence indicates that northern distribution of smallmouth bass is limited by temperature. Length of the growing season determines the size of juveniles entering their first winter which is positively correlated with over-winter survival. Achieving a minimum body size is critical for their first winter survival and it appears that 50 mm is the minimum for the Maritimes. The July mean air temperature threshold of 18ºC has been used as one measure to delineate the limit of smallmouth bass range in Ontario.

Risk assessment of smallmouth bass impacts

The risk assessment was conducted according to the guidelines provided by the DFO Centre of Expertise for Aquatic Risk Assessment (CEARA). The risk assessment consists of two components: (1) estimation of the probability of establishment (defined as the sequence of arrival, survival and reproduction, and spread), (2) once introduced, the determination of its ecological impact on the aquatic community.

The first component of the risk assessment is conducted sequentially. The first element is assessing the likelihood of arrival of the introduced species for the area of interest. The second element, survival and reproduction, is assessed in the context of the non-native species having arrived. Finally the third element, spread, is assessed conditional on the non-native species having arrived, and survived and reproduced.

The ecological impacts assessment is provided for the aquatic ecosystem with special consideration for Atlantic salmon. The assessment is conducted for the rivers of the Gulf Region, and specifically for the Southwest Miramichi River. The time frame chosen for the

assessment of impacts is 10 years, equivalent to about two generations time for smallmouth bass.

An assessment of the uncertainty for the likelihood ranks is also provided. Uncertainty can arise at two levels: (1) the natural variability, (2) scientific uncertainty resulting from a lack of evidence. Scientific uncertainty is lowest when there are studies on the target species in similar ecosystems, and uncertainty is high when analogue species must be used or when impacts must be inferred from dissimilar or distant ecosystems or experiments.

Probability of the organism arriving, colonizing, and maintaining a population

Arrival

The first introduction of smallmouth bass to New Brunswick (NB) occurred around 1869 as fish dispersed within the St. Croix River (border river) from the State of Maine (USA). The first successful introduction in Nova Scotia (NS) in 1942 was deliberate and intended to provide recreational fishing opportunities. In many lakes and rivers of the Maritime provinces, smallmouth bass encountered suitable habitat features to allow the introduced fish to survive and establish reproductive populations. Smallmouth bass are presently confirmed in 188 lakes/rivers in NS and 69 lakes and 34 rivers in NB. Bass are known to be in eight Gulf Region lakes. An illegal introduction of smallmouth bass is the vector for the presence of the fish in Miramichi Lake (Southwest Miramichi River). Confirmed in September 2008, the time of arrival of smallmouth bass in Miramichi Lake is uncertain. Bass removed from the lake and the outlet in 2008 included young-of-the-year (YOY) (14 fish, ranging in length from 55 to 88 mm), and two fish measuring 235 and 284 mm.

Survival and reproduction

Climate in the Maritime provinces is diverse. Mean annual air temperatures at selected stations range from 3.2 to 7.0ºC (Fig. 3). Mean air temperatures in Sept. to Nov. range from 5.4 to 9.6ºC. The success of smallmouth bass colonization may be restricted by the length of the growing season which would affect YOY overwinter survival.

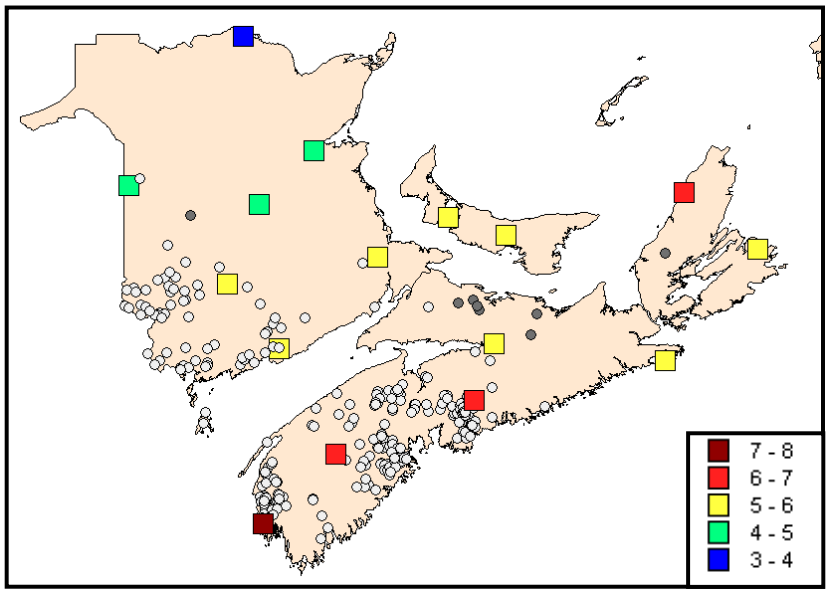

Figure 3. Smallmouth bass distribution in the Maritime provinces and mean annual air temperature (ºC) at selected weather stations in the Maritime provinces.

Multiple years of reproduction of smallmouth bass have been confirmed in Lake Ainslie (NS), although perceived failures have also been noted. In many parts of NB and NS, populations of smallmouth bass are established, thriving, and providing recreational fishing opportunities, though most are in areas with mean annual temperatures greater than 5ºC.

Miramichi Lake is in a moderately cool region of NB with mean annual air temperature of 4 to 5ºC. YOY smallmouth bass were observed in the fall 2008 in Miramichi Lake suggesting that successful breeding and reproduction occurred in the spring of 2008. The YOY measured between 55 and 88 mm in length, which would favour overwinter survival.

Spread

In the Gulf Region, the risk of smallmouth bass transfer by people between watersheds is high because of the extensive road network. Within watersheds, smallmouth bass can spread naturally both upstream and downstream through the riverine habitats and colonize other lakes in the watershed as well as suitable habitat in the river itself. In the absence of human intervention, smallmouth bass could potentially move between rivers in the Gulf of St. Lawrence, in particular those that empty into common estuaries of low salinity.

There is a high likelihood of natural downstream dispersal of smallmouth bass from Miramichi Lake. Although the Southwest Miramichi River does not have any intermittent lakes within its main stem, there are areas of slower current such as pools, bogans and deadwater streches within the main stem. There are numerous lakes in the tributaries. The closest lakes potentially accessible to smallmouth bass from Miramichi Lake would require a 13 km downstream displacement into and down the Southwest Miramichi River followed by a 17 km upstream migration to the lakes in McKiel Brook. Constraints to natural dispersal do not apply to illegal introductions by humans.

Overall, there is a high probability of widespread establishment (species likely to become established at multiple locations within the region and concentrated in certain areas) of smallmouth bass in the Southwest Miramichi River and in Gulf Region rivers in general (Table 2). The uncertainty is considered low, based on the history of spread and colonization of smallmouth bass in the Maritime provinces.

Table 2. Summary of the probability of arrival, survival and reproduction, spread and the overall likelihood of widespread establishment once arrived (WEOA) of smallmouth bass in the Gulf Region and outside Miramichi Lake to the Southwest Miramichi River in particular. WEOA is considered as a separate assessment and is not a roll-up of the other elements.

	Gulf Region		**Southwest Miramichi River**	
Element	Probability	Uncertainty	Probability	Uncertainty
Arrival	Arrived	NA	Arrived	NA
Survival & reproduction	HIGH	MODERATE	HIGH	MODERATE
Spread	HIGH	LOW	HIGH	LOW
WEOA	HIGH	LOW	HIGH	LOW

Ecological impact

The ecological impact of smallmouth bass in lake ecosystems is expected to high (defined as the introduced species becomes a dominant component of the food web and causes significant reductions in existing biota). The ecological impacts in riverine environments is expected to be

moderate (defined as a measurable decrease in abundance of native populations likely to occur in most locations) (Table 3).

Table 3. Summary of the probability of ecological impacts of smallmouth bass introductions for lakes and riverine habitats.

Ecological impact	Gulf Region		Southwest Miramichi River	
	Probability	**Uncertainty**	**Probability**	**Uncertainty**
Lakes	HIGH	LOW	HIGH	LOW
Riverine	MODERATE	HIGH	MODERATE	HIGH

Reports on the impacts of smallmouth bass introductions to aquatic ecosystems are dominated by observations from lakes and reservoirs. When smallmouth bass are introduced into a water body, they prey heavily on smaller fish and may become a dominant component of the food web, particularly in systems of low biological and physical complexity. Smallmouth bass introductions often result in shifts in forage fish assemblages manifested as declines in abundance and reduced species diversity. In most Maritime rivers inhabited by Atlantic salmon, there are relatively few fish species, and habitats for smallmouth bass would most probably be restricted to the slow and deeper waters of large rivers.

As most of the established populations in the Maritime provinces are in lakes, other fish species that utilize this habitat to complete their life cycle are likely to be the most impacted. Predation would be on all life stages of small-bodied fish (for ex. cyprinids) and juvenile stages of large fish such as anadromous clupeids, salmonids, catostomids, percids, and others. Competition for prey is also important in the lake dwelling species. Of the salmonids, brook trout and lake trout populations in lakes would be most at risk of negative impacts from smallmouth bass.

The overall risk of negative interactions between Atlantic salmon and smallmouth bass will be watershed specific. Watersheds with a sequence of lakes within the main stems or in close proximity to and accessible from main stems would provide a better environment for broad watershed establishment of smallmouth bass and negative interactions would be enhanced.

As habitat in rivers is spatially more complex than in lakes, the impact of smallmouth bass on the ecosystem in rivers is expected to be less severe than in lakes (Table 3).

Few studies have been conducted on the interactions between smallmouth bass and Atlantic salmon. Although direct competitive interactions between juvenile smallmouth bass and juvenile Atlantic salmon in streams has not been demonstrated, it is likely because river habitat used by juvenile smallmouth bass potentially overlaps with that of Atlantic salmon juveniles. Recent studies indicate that competition is most likely to occur between young-of-the-year of both species, which can occupy similar habitats. The period of maximum interaction is likely to be mid to late summer when water levels are low, fishes are concentrated, and warm temperatures increase the thermal stress on Atlantic salmon.

Juvenile salmon as fry or parr are the most vulnerable stages to predation. There is opportunity for predation on salmon smolts by smallmouth bass, especially in rivers which have lakes or reservoirs that must be traversed by Atlantic salmon smolts. Impediments to migration as would occur at barriers (i.e. dams) and spillage over dams may make salmon smolts more vulnerable to predation, including by smallmouth bass.

Minimal interactions are expected between smallmouth bass and adult salmon. Due to their large body size, they are not a potential prey item, but there may be competition for space in holding pools between salmon and large smallmouth bass.

Overall Risk Assessment of Smallmouth Bass to Atlantic Salmon

The summary ranks for the probability of widespread establishment and the ecological impacts to Atlantic salmon are combined to obtain an overall risk rating. The result is presented in a "risk matrix" with the form and size of the ellipses reflecting the uncertainty associated with the risk assessment rank. Green indicates low risk, yellow indicates moderate risk, and the red region represents the conditions for a high risk designation (Fig. 4).

The overall risk to the aquatic ecosystem of the Southwest Miramichi and to rivers in Gulf Region is different for lakes and riverine habitats (Fig. 4). The risk in the lake environment is expected to be high whereas in riverine habitat, the risk is expected to be moderate. Riverine habitat is used preferentially by Atlantic salmon and the risk to salmon of smallmouth bass introductions would have the same risk score as for the riverine ecosystem. There is a high probability of widespread establishment once arrived in both the Southwest Miramichi River and the Gulf Region rivers but a moderate ecological impact. There is more uncertainty in the probability of widespread establishment for the Southwest Miramichi River; this is related to the uncertainties about the suitability of riverine habitat for survival and reproduction as well as the uncertainty of the natural rate of spread into the lakes of the tributaries of the main stem. Unauthorized human introductions could accelerate the anticipated natural spread and establishment of smallmouth bass in the Southwest Miramichi River, and in other rivers in the Gulf Region.

Southwest Miramichi River and Gulf Region

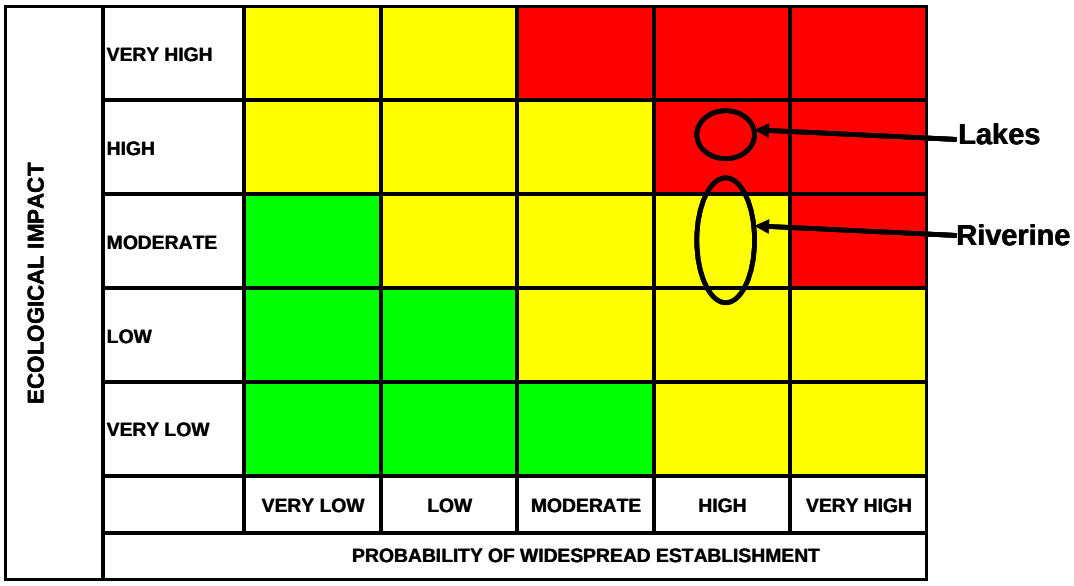

Figure 4. Overall risk of smallmouth bass introductions on the aquatic ecosystem of the Southwest Miramichi River and to the Gulf Region rivers. The risk is considered to be high (red) in lake environments and moderate (yellow) in river environments.

Evaluation of mitigation measures for minimizing risks of impacts of smallmouth bass on Atlantic salmon

A broad range of methods have been used in efforts to contain the spread, to control the abundance, and to eradicate introduced non-native species. The review of methods focused on quantifying the effectiveness of the measures at attaining their objective and the consequences to other components of the ecosystem when these measures are applied. A review of options is presented specifically for the case of the smallmouth bass introduction in Miramichi Lake.

Evaluation of mitigation measures for smallmouth bass in Miramichi Lake

The extensive experience of numerous agencies in many countries indicates that the highest probability of controlling or eradicating non-native species is through the use of multiple approaches. The likelihood of controlling and/or eradicating smallmouth bass is reduced when actions are delayed due to the increased opportunity for smallmouth bass to become more widely dispersed.

Physical barriers would be the most effective immediate measure for containing the spread of smallmouth bass out of Miramichi Lake (Table 4). Barrier design must consider the life stages which are to be contained and for young-of-the-year fish, a fine mesh barrier would be required. Barriers can restrict movements of native fishes between the lake and river environments.

Control measures such as intensive fishing in Miramichi Lake to remove adult and juvenile stages of smallmouth bass will require sustained effort and this is not expected to result in eradication of smallmouth bass from the lake.

Eradication through chemical treatment would provide a high probability of complete removal in Miramichi Lake, however, if smallmouth bass have spread downstream into the main stem of the Southwest Miramichi River, the potential for complete eradication is lost. Even in closed systems, chemical treatment is not always 100% effective and it has the most negative consequences on the non-targeted native species. Directed rescue of native fishes from the lake prior to chemical treatment, with option for re-stocking after the lake is reclaimed, may mitigate these effects.

CONCLUSIONS AND ADVICE

Smallmouth bass are now found in 20 of 46 primary watersheds in NS and 35 of 54 primary and secondary drainage basins in NB. Four of ten watersheds in the Gulf Region NS have smallmouth bass compared to one of thirty primary and secondary drainage basins in the Gulf Region NB. All introductions into the Gulf Region waters have occurred by unauthorized transfers, despite the extensive publicity in the provincial angling summaries, distributed with each angling licence in the Maritime provinces, describing the harm associated with unauthorized transfer of live fish between watersheds.

The overall risk to the aquatic biota in lakes is considered to be high with low uncertainty. The overall risk for riverine environments is considered to be moderate but with high uncertainty. There is high uncertainty in the riverine assessment because: (1) there are few studies on the suitability of habitat in rivers like the Southwest Miramichi to accommodate smallmouth bass, and (2) there are few studies on direct interactions between smallmouth bass and Atlantic salmon to inform the assessment of ecological impacts.

Although the overall risk to salmon is considered moderate for the Southwest Miramichi River, none of the consequences of bass introductions will be positive for Atlantic salmon.

A range of containment/control/eradication options, including their effectiveness and impacts on the ecosystem components, were reviewed in the general context of non-native fish introductions and specifically for Miramichi Lake.

Based on the extensive experience of numerous agencies in many countries, the highest probability of controlling or eradicating non-native species is through the use of multiple approaches. The likelihood of controlling and/or eradicating smallmouth bass is reduced when actions are delayed. This is due to the increased opportunity for smallmouth bass to become more widely dispersed.

Table 4. Summary of the effectiveness, constraints, collateral effects and effects on habitat of containment, control or eradicate measures identified as most suitable for management of non-native fish species.

	Effectiveness	Constraint	Effects on non-target species	Effects on habitat
Containment				
Physical barrier	o Can be 100% but fish size dependent o Difficult to contain early life stages	o Size specific o Requires regular maintenance	o Can restrict movements of native species	o Minor localized habitat effects dependent upon scale of operation
Control				
Directed removals (electrofishing, netting, angling,…)	o Can reduce abundance o Does not eradicate o Does not eliminate potential for spread	o Requires sustained intensive effort over many years	o Can be minimized	o Minimal
Eradication				
Poisons	o Most likely to be close to 100% effective	o Case specific effort required o Probability of success depends upon complexity of lake characteristics	o Will eradicate all susceptible non-target aquatic organisms, o Severe impact on ecosystem in the absence of preparatory rescue	o Minimal

OTHER CONSIDERATIONS

The risk assessment was conducted using a time frame for potential impacts of 10 years. This time frame may not be sufficient to characterize the risks associated with natural dispersal and colonization. It can take several generations before populations become established and impacts are manifested. The more time populations of introduced species have to adapt and colonize river and lake systems, the more likely it is that they will spread through connected waterways and be integrated into the ecosystem.

As of November 2008, smallmouth bass were only captured within the first 300 m of the lake outlet stream. The abundance of smallmouth bass in Miramichi Lake needs to be quantified and more importantly the current extent of dispersal from Miramichi Lake needs to be confirmed. This information could influence both the choice of remedial measures and the likelihood of success of meeting the desired control objectives for the smallmouth bass introduction in Miramichi Lake.

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