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Biological Risk Assessment for Smallmouth bass (*Micropterus dolomieu*) and Largemouth bass (*Micropterus salmoides*) in British Columbia

Évaluation du risque biologique posé par l'achigan à petite bouche (*Micropterus dolomieu*) et l'achigan à grande bouche (*Micropterus salmoides*) en Colombie-Britannique

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ABSTRACT

We performed a qualitative risk assessment of the ecological and genetic impacts of the non-native smallmouth bass (*Micropterus dolomieu*) and largemouth bass (*Micropterus salmoides*), and their parasites, pathogens, and fellow travelers to native ecosystems in British Columbia. The basses are widely distributed in North America, and have been introduced into southern British Columbia. They were originally introduced into BC by government agencies, although their recent spread into new water bodies is by unauthorized means, mainly by angling enthusiasts. Smallmouth and largemouth bass are adaptable voracious littoral zone predators. Once they establish themselves in water bodies they present a high risk to native biota and often cause the extirpation of native fish species, primarily minnows. The risk is very high in small lakes and lower in larger water bodies which have less of the preferred habitat for the basses. The probability of widespread establishment once they have arrived in a water body was rated high to very high for five of the eight regions in BC. Because there are no members of the Centrarchid family native to BC, the potential genetic impact of establishment of the basses is very low. There were few published papers to inform our assessment of the potential impact of parasites, pathogens, and fellow travelers to native ecosystems in BC, however the risks were considered low.

RÉSUMÉ

Nous avons procédé à une évaluation qualitative du risque posé par les impacts écologiques et génétiques de l’achigan à petite bouche (*Micropterus dolomieu*) et de l’achigan à grande bouche (*Micropterus salmoides*) non indigènes ainsi que de leurs parasites, de leurs agents pathogènes et de leurs compagnons de route sur les écosystèmes de la Colombie-Britannique. Les achigans ont une vaste aire de répartition en Amérique du Nord et ont été introduits dans le sud de la Colombie-Britannique. À l'origine, ils ont été introduits en C.-B. par des organismes gouvernementaux, bien que leur propagation récente dans de nouveaux plans d'eau soit causée par des moyens illégaux, principalement par des amateurs de pêche à la ligne. Ces espèces d’achigan sont des prédateurs littoraux voraces qui s’adaptent facilement. Lorsqu'ils s'établissent dans un plan d'eau, ils posent un risque élevé pour le biote indigène et causent souvent le déclin des espèces indigènes de poissons, principalement les ménés. Le risque est très élevé dans les petits lacs et inférieur dans les plus grands plans d'eau, lesquels renferment moins d'habitats de prédilection de l’achigan. La probabilité d’établissement à grande échelle des achigans une fois leur arrivée dans un plan d'eau est considérée comme d’élevée à très élevée dans cinq des huit régions de la C.-B. Puisqu'il n'y a aucun membre indigène de la famille des centrarchidés en C.-B., l'impact génétique potentiel causé par l'établissement des achigans est très faible. Peu d’études publiées étaient disponibles pour documenter notre évaluation de l’impact potentiel causé par les parasites, les agents pathogènes et les compagnons de route de cette espèce sur l’écosystème de la C.-B.; cependant, le risque est considéré comme faible.

1.0 INTRODUCTION

The establishment of populations of non-native aquatic species can have very deleterious impacts on native fishes and other components of aquatic ecosystems. Although most non-native species are benign (Moyle and Light 1996a; Rahel 2002), those that do have impacts can create significant challenges for resource managers. These impacts include severe reductions or extirpations of native species (Dextrase and Mandrak 2006), reductions in the abundance or productivity of sport, commercial, or culturally important species and habitat alterations (Rahel 2002). Consequently invasive non-native species have been considered a threat to aquatic biodiversity that may rival habitat alteration and destruction (Light and Marchetti 2007).

While some of the more spectacular impacts of invaders in North America are the result of recent intercontinental introductions (e.g., zebra mussel, *Dreissena polymorpha*, round goby *Neogobius melanostomus*, Asian carp, *Hypopthalmichthys spp*.), there has been a much longer history of movements of fish species within the continent. These introductions have expanded the range of many species and contributed to a trend of homogenization of fish fauna in both the United States and Canada (Taylor 2004; Rahel 2007). Beginning in the mid 1800s fish were transported by train from east to west in the US and introduced to various waterbodies in the western States to satisfy demands by European settlers for fish that they had become familiar with in the eastern and Midwest regions. Additionally, water development projects in the west created reservoirs that were stocked with so-called “warmwater” fish such as bass (*Micropterus spp.*) to provide fishing opportunities. As a result the western states have the highest proportion of non-native species (exceeding 50% in some cases) compared to eastern regions (Rahel 2000). Deliberate fish movements westward have not been as actively pursued in Canada and the pattern of homogenization is less pronounced (Taylor 2004). Eastward introductions have usually involved salmonids (e.g., rainbow trout, *Oncorhynchus mykiss*) to diversify recreational fishing (Rahel 2000).

Enthusiasm of government agencies for stocking non-native fish species in western North American continued through the 1980s and contributed significantly to the spread of species such as the pikes (*Esox spp*.), walleye (*Sander vitreus*) and yellow perch (*Perca flavescens*) and various basses and other panfish (centrarchidae). The management of these introductions (largely to provide quality fisheries) has proven challenging and has lead to additional introductions, either of predators to control proliferate and stunted populations, or prey species to provide forage. These issues, as well as a greater understanding of and concern about the impacts of introduced species on native biota have lead to a more conservative approach in the past 20 years (Rahel 2000).

In British Columbia most agency-sponsored introductions have been salmonids for the purpose of recreation and commercial fishing. Brook char (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) have been introduced from outside of BC, and all *Oncorhynchus* spp*.* have been introduced or stocked in lakes and rivers to increase production. Authorized introductions of the warm-water species (prior to 1940) were very limited but resulted in the initial introductions of species such as smallmouth bass (*Micropterus dolomieu*) and pumpkinseed (*Lepomis gibbosus*) to BC (Hatfield and Pollard 2006).

While agency-lead stocking programs have taken a more conservative approach in recent years there has been in increase in the spread of a suite of non-native species in western North America through unauthorized introductions, presumably by anglers attempting to create or enhance sport fisheries. Often the species have spread beyond the initial point of introduction and have caused management agencies to put considerable effort into control measures

(McMahon and Bennett 1996). Most notable are the northern pike (*Esox lucius*) of Davis Lake, California, where agencies have expended upwards of $10M in repeated attempts to eradicate this invader (CDFG 2000).

This document considers the risk to aquatic communities in British Columbia posed by the potential expansion in range, largely by unauthorized introductions, of smallmouth bass and largemouth bass (*M. salmoides*). These species are native to North America, have been introduced and are established at numerous locations in the border states (Washington, Idaho, Montana). Both species are listed as among the most commonly introduced species in the United States by Rahel (2000).

1.1 THE RISK ASSESSMENT PROCESS

The format of the risk assessment for British Columbia follows the "National guidelines for assessing the biological risk of aquatic invasive species in Canada" (Mandrak and Cudmore 2006). This is a qualitative rating process that serves to summarize existing information and identify the relative risks posed by smallmouth and largemouth bass. Biological synopsis have been commissioned (Brown et al. 2008a, Brown et al. 2008b), which provide information on the species natural history, distribution, and documented instances where it has been shown to impact aquatic communities as an invasive species. A supporting document (Runciman and Leaf 2008) details known occurrences of each species in BC.

Risk ratings for the basses were determined by a workshop convened March 4-6, 2008 in Richmond, BC, that involved the authors, staff from the DFO Centre for Expertise for Aquatic Risk Assessment, and local and national experts on this species. This risk assessment is conducted at a relatively broad scale and is not intended to provide detailed information or advice for specific waterbodies or on impacts to individual populations or species. More detailed assessments are required in these cases; recent examples are available for northern pike in Alaska (SANPCC 2006) and California (CDFG 2000).

To accommodate regional differences in BC, we divided the province into 8 regions roughly patterned on those used by Taylor (2004; Figure 1.1). The regions take into account major drainage basins and differences in human population distribution. Statistics for the regions are provided in Table 1.2.

Table 1.2. The number of lakes and reservoirs and the size of each analysis region.

Region	Region Code	Number of lakes and reservoirs	Area (land) of the region (km^2)
Arctic drainage	AR	19 518	421 370
North Coast	NC	10 070	235 925
Central Coast	CC	9 147	85 535
Upper Fraser	UF	14 870	158 476
Lower Mainland	LM	1 631	38 753
Thompson	TH	5 443	55 777
Columbia	CO	3 796	136 943
Vancouver Island	VI	2 654	34 883

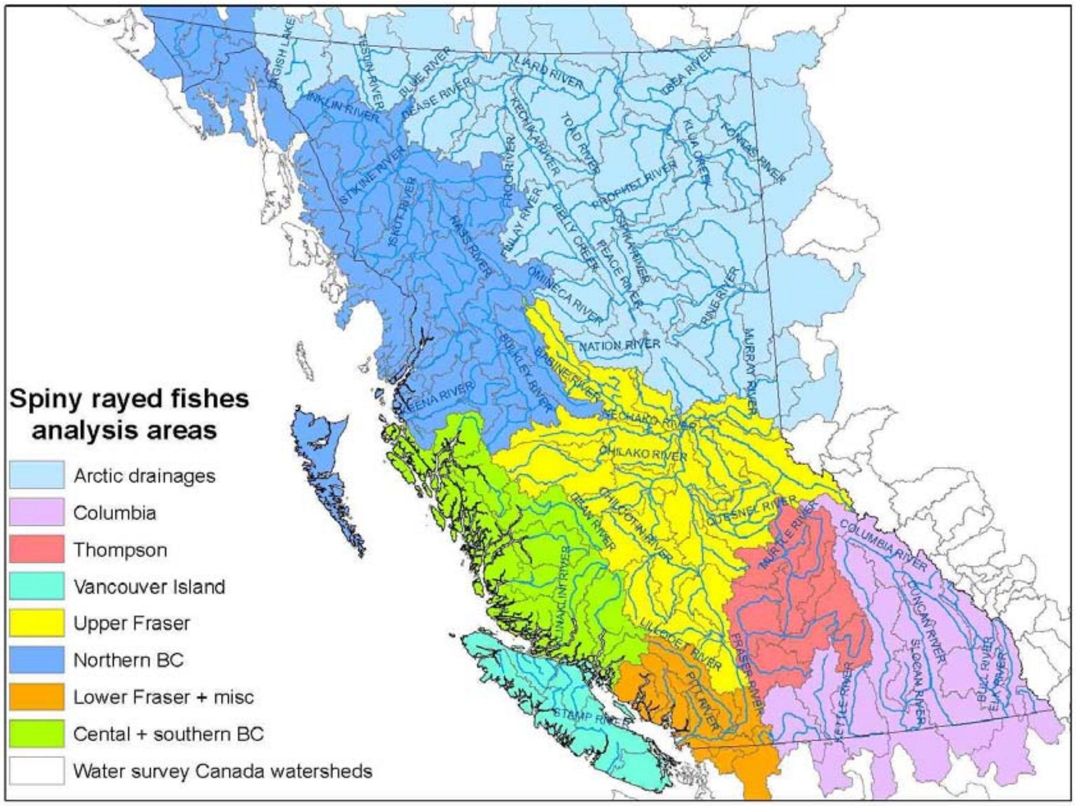


Figure 1.1. The eight analysis regions for use in the risk assessment process. The Arctic region includes headwater tributaries of both the Mackenzie and Yukon Rivers. The lower mainland region includes small transboundary basins and the Sunshine Coast/Whistler area.

1.2 ASSESSING RISK

The National Guidelines breaks the risk assessment into two steps: (1) estimation of the probability of establishment (defined as the sequence of arrival, survival, reproduction and spread), and (2) the determination of impact once introduced, in terms of its ecological and genetic impact on existing aquatic communities. These two analysis steps are conducted both for the species of interest, and are repeated for any pathogens or "fellow travelers" that may be associated with the invader. The evaluation of the probability of establishment or the consequences of introduction is based on qualitative constructed scales with a corresponding assessment of uncertainty.

The first component of the establishment process is the probability of arrival. If the species was already present within a region a risk rating was not needed and an 'A' was entered in the tables. Arrival in the region depends on the presence of populations in adjacent regions, the likelihood of spread (especially downstream) from adjacent regions, and the likelihood that the species would be spread by unauthorized introduction (depending on the history of introductions and human population density; Table 1.3).

Table 1.3. Constructed scale to guide the ranking of the probability of arrival of an invasive species into one of the analysis regions.

Element Rank	Descriptor
Very Low	No connected waterways, no nearby donor populations and/or little human influence in the region.
Low	Source populations not close and/or low human density.
Moderate	Some populations in adjacent regions and/or potential for human translocation.
High	Source populations common in adjacent region, recent history of introductions in adjacent regions.
Very High	Almost certain to occur: source populations upstream and likely to spread by natural means and/or a species that is commonly introduced by unauthorized means and has populations in nearby regions.

The second element is the survival and reproduction of the species. For smallmouth bass we used Habitat Suitability Modeling to predict the proportion of lakes that were suitable for the species for each region. That proportion was translated into ranks based on Table 1.4. Details of Habitat Suitability Modeling are provided in Section 2.

For largemouth bass, the Habitat Suitability Model did not predict the locations that the the species were expected to survive and reproduce, based on expert advice. Instead, the Atlas of Canada Growing Degree Days map was used to characterize the climatic conditions of the current distribution of largemouth bass in Canada. For each region of BC the proportion of the region that contained suitable climatic conditions for largemouth bass was estimated and translated into ranks based on Table 1.4. The details are provided in Section 2. Although there is a potential for climate change to alter the suitability of habitats in the future it was not considered in this analysis.

Table 1.4. Constructed scale for survival and reproduction based on habitat suitability modeling.

Element Rank	Habitat Suitability Score (0-100)
Very Low	≤ 1
Low	2-10
Moderate	11-50
High	51-80
Very High	>80

The final element of establishment of the species considers the spread of the species within the region once it is introduced. The evaluation is based on the combined effects of natural and human spread. We considered the degree of connectedness of suitable waterways within the region that would allow the species to spread naturally from its point of origin. Also included is the potential for spread by human vectors, most notably through inadvertent or deliberate introductions. The component related to human vectors is based on the human population size and/or the number of visitations of sport fishers to the region. The recent pattern of introductions influences this evaluation (Table 1.5).

Table 1.5. Constructed scale for the probability of spread once introduced into a region.

Element Rank	Descriptor
Very Low	No connected waterways of suitable habitats and little human influence in the region and/or sedentary species.
Low	Waterways not well connected or species unlikely to be introduced by humans.
Moderate	Can spread to adjacent waterways, but species may not be a successful colonizer. Limited interest in introduction of species.
High	Will likely spread to connected waterways and become established and/or species likely to be introduced at a number of locations or a number of times in the region.
Very High	Very well connected waterways and/or species has been noted to spread widely in other regions and/or human population density or visitations of sport fishers very high within the region.

The final element of the establishment rating is an overall consideration of the probability of the fish species, or its pathogens, parasites, or fellow travelers becoming widely established in each region once they have arrived (Table 1.6). This was based on an expert assessment of the probability of survival and reproduction as well as spread, and was guided by the definitions provided in Table 1.6.

Table 1.6. Constructed scale for the widespread establishment of a fish species or its pathogens, parasites, or fellow travelers within each region.

Element Rank	Descriptor
Very Low	Unlikely to become an invasive species in the region.
Low	Species will likely be restricted to isolated waterbodies within the region.
Moderate	Species may become established in a few watersheds within the region.
High	Species likely to become established at multiple locations within the region and concentrated in certain areas.
Very High	Likely to become widespread in the region, occupying many of the suitable lakes and rivers.

The evaluation of the magnitude of consequences considers the risk of the invasive species to Canadian biotic and abiotic resources (Mandrak and Cudmore 2006). The focus in this report is on native BC fishes and other biota, and includes species such as rainbow trout and salmon that may be enhanced (i.e. stocking and hatchery programs) for human use. No weighting or special consideration is given to specific species or populations at this level of review. Table 1.7 contains descriptors we used to guide us in determining the magnitude of the consequences of an introduction of an invasive species in both ecological and genetic terms.

Table 1.7. Constructed scale to guide the evaluation of the magnitude of the ecological or genetic consequences of an invasive fish species, their pathogens, parasites, and fellow travelers in a given water body or area.

Element Rank	Descriptor of impact
Very Low	Species integrates into aquatic community and has no discernable impact on existing biota or genetic exchange with native populations impossible.
Low	Native species are sometimes impacted by predation, competition, disease, or habitat alteration as a result of the invasion or genetic exchange with native populations highly unlikely.
Moderate	A measurable decrease in abundance of native populations is likely to occur in most locations or genetic exchange with native populations may occur in some instances and cause harm.
High	The invasive species becomes a dominant component of the food web and causes significant reductions in existing biota or genetic exchange with native populations likely to occur in some circumstances and cause harm.
Very High	Extirpation of native populations likely. Food webs are highly altered or genetic exchange is likely to be widespread or seriously deleterious.

The ecological impact assessment was done separately for small (<1000 ha) and large water bodies within BC.
Accompanying both the probability of introductions and magnitude of effects tables are assessments of the uncertainty associated with each determination. There are at least two components of uncertainty: the natural biological and ecological variability associated with stochastic events, and the scientific uncertainty resulting from a lack of evidence for a particular species. The uncertainty measure here focuses on scientific understanding (Table 1.8). We have taken an evidenced-based approach and assess risk by reviewing empirical information. Scientific uncertainty is lowest when there are studies on the target species in similar ecosystems, uncertainty is high when analogue species must be used or when impacts must be inferred from dissimilar or distant ecosystems or experiments.

Table 1.8. Constructed scale for the evaluation of uncertainty in the risk assessment ratings.

Rank	Interpretation of uncertainty
Very Low	Demonstrated: outcome known with certainty in BC.
Low	Similar: case studies in similar ecosystems for the target species.
Moderate	Expected: inferred from knowledge of the species in its native range.
High	Plausible: based on ecological principles, life histories, or experiments.
Very High	Unknown: little information to guide assessment.

Finally, the summary ranks for the probability of widespread establishment and the ecological or genetic consequences are combined in the following table to obtain an overall risk rating (Table 1.9). An ellipse was placed on the matrix based on the risk evaluation. The size of the ellipse was adjusted to reflect the uncertainty in the assessment. Separate ellipses were used in cases where there were differences within regions.

Table 1.9. Matrix for determining overall risk, where green indicates low risk, yellow indicates moderate risk, and the red region represents the conditions for a high risk designation (from Mandrak and Cudmore 2006).

Ecological or Genetic Consequences	Very High					
	High					
	Medium					
	Low					
	Very Low					
		Very Low	Low	Moderate	High	Very High
	Probability of Widespread Establishment					

2.0 HABITAT MODELLING

2.1 SMALLMOUTH BASS

2.1.1 Data sources

We obtained occurrence data for smallmouth from the Ontario Habitat Inventory Index which summarizes species occurrence, geographic location, physical habitat, and water chemistry for 7 567 Ontario lakes. The presence of each species was recorded in the same dataset. The Ontario dataset was randomly divided into training and validation datasets (80:20 ratio) with the same large-scale geographic coverage in both datasets.

We obtained data for the occurrences of thee species in lakes in British Columbia from Runciman and Leaf (2008). Physical habitat and water chemistry variables in BC were from the British Columbia Ministry of Environment. Mean monthly air temperature data were obtained from the WorldClim database (www.worldclim.org) and provided on a 30 arc seconds or about a 1 km resolution. The mean monthly air temperature data for lakes in Ontario and British Columbia was extracted using ESRI ArcGIS 9.1. Nineteen environmental predictor variables were used in a habitat suitability model for each species: lake perimeter (m), lake surface area (ha), maximum depth (m), elevation (m), surface pH, surface total dissolved solids concentration ($mg \cdot L^{-1}$), Secchi depth (m), and monthly mean air temperatures. Out of the 67 463 lakes and reservoirs in the BC Environment lake database, environmental variables that were the same as the Ontario dataset were available for 1 882 lakes.

2.1.2 Modeling

Multicollinearity between variables was evaluated using bivariate plots and correlation analyses prior to regression analyses to determine which variables should be retained. Additionally, variables were log transformed as necessary to satisfy the assumption of normality. Variables included in the models were: surface area, maximum depth, perimeter, elevation, Secchi depth, pH, total dissolved solids concentration and mean monthly air temperatures.

Stepwise multiple logistic regression models were constructed for Ontario lakes using the training dataset in SAS statistical software to evaluate the relationship between fish occurrence and physical habitat, water chemistry, and climatic predictor variables. In a logistic regression, response variables are subject to a logit transformation, whereas predictor variables are based on a linear combination using maximum likelihood (Olden and Jackson 2002). Significance values for predictor variables were set at a value of 0.05 to enter and remain in the model.

The logistic regression models were tested on the Ontario validation dataset. We also tested the logistic regression models on the British Columbia occurrence dataset. The use of large independent data sets is necessary in order to evaluate the model and determine its generality, although it has been traditionally rarely used in ecological studies (Pearce and Ferrier 2000; Ozesmi et al. 2006). Without proper validation, these models generally overestimate their predictive capability (Olden et al. 2002).

Finally, we applied the logistic regression models to all lakes in British Columbia to identify the potential occurrence of the two species. The models appeared to perform well for smallmouth bass and largemouth bass in BC. For each sub-sub-drainage area watershed the proportion of lakes (for which there was data) that calculated, using a minimum of 5 lakes in the basin. Results for smallmouth bass are presented in Section 3.

2.2 LARGEMOUTH BASS

Since the survival and reproduction of some species of fish is very temperature-dependent, the growing degree-day map was used to estimate the probabilities of survival and reproduction for largemouth bass. The Atlas of Canada Growing Degree-Days map (Canada. Natural Resources Canada. 2008. The Atlas of Canada: http://atlas.gc.ca Accessed on April 10, 2008) contains isoclines of the cumulative number of degree days for temperatures above 5 °C. The northern limit of the largemouth bass in eastern Canada followed the 1750 degree-day isocline and this isocline was used to visually evaluate the area within each BC analysis region that was suitable for the species.

3.0 SMALLMOUTH BASS

3.1 BACKGROUND AND BIOLOGY

The smallmouth bass (*Micropterus dolomieu*) Lacépède is a moderately large fish usually 203-380 mm in length (up to 350 mm FL in British Columbia; Scott and Crossman 1973; McPhail 2007). Within the Centrarchid family it is smaller only than the largemouth bass (*M. salmoides*). The body of the smallmouth bass is laterally compressed, although less so than the pumpkinseed, and it has an operculum that is bony to the edge and pointed but not formed into a flap, with a feint black spot near the tip. The lower jaw is slightly longer than the upper jaw and extends to the middle of the pupil. The mouth gape thus reaches close to the anterior portion of the eye (Scott and Crossman 1973; Wydoski and Whitney 2003; McPhail 2007). The smallmouth bass has two dorsal fins that are fused together, the first of which is spiny with the shortest spine at the point of fusion being greater than half the length of the longest spine (Scott and Crossman 1973; McPhail 2007). The adult smallmouth bass is variable in colour with two or three dark lines radiating backwards from the eye (McPhail 2007). For spawning males, the colours darken and for spawning females the colour pattern intensifies. Young smallmouth bass have radiating cheek stripes although they also have vertical bars along their midline and a distinctive orange mark on the base of the caudal fin.

Sexual maturity is usually attained at 3-5 years in males and 3-6 years in females (Scott and Crossman 1973; McPhail 2007). The breeding season begins in late spring and carries on through early summer when the water temperatures range between 13 and 20 °C. Male smallmouth bass exhibit a large degree of parental care, first creating a spawning nest with their caudal fins (a shallow saucer-shaped depression about 50-100 mm deep and 500 mm in diameter) in waters less than 1 m deep, and then guarding and fanning the eggs and larvae following mating (McPhail 2007). The male will not eat during this time although he will aggressively attack intruders in the nest pit. Nests are often located in quiet water over sand, gravel, or rocky bottoms of lakes and rivers near cover (large rocks, stumps, or logs) and are generally spaced out at densities of one every 15-50 m (Scott and Crossman 1973; McPhail 2007). Smallmouth bass are territorial and return to the same nest sites in subsequent years.

Depending on female size, smallmouth bass produce typically 2 000 to 20 000 (roughly 15 000 per kg of female) adhesive, demersal eggs that are 1.2-2.5 mm diameter (Scott and Crossman 1973; McPhail 2007). They release them in batches and sometimes in more than one male's nest (Scott and Crossman 1973). The eggs are usually attached to clean stones near the centre of the nest and have been known to hatch in roughly 10 days at 12 °C or 3 days at 25 °C (McPhail 2007). After hatching the male continues to guard the fry for up to one month before they leave the nest. Interesting to note is that a portion of the smallmouth bass population does not breed every year (McPhail 2007).

Growth of the juveniles is fast with young-of-the-year reaching 50-100 mm in length by the end of their first growing season (Scott and Crossman 1973; McPhail 2007). The juveniles grow steadily each year until they reach sexual maturity, at which time growth slows (McPhail 2007). Dunlop and Shuter (2006) found a significant positive relationship between air temperature and early growth although growth in later years was less influenced by climate. By age 7, the smallmouth bass of many populations have reached roughly 350 mm and most smallmouth bass caught by anglers are in the range of 200-380 mm (Scott and Crossman 1973). The maximum age attained by smallmouth bass in Canada appears to be 15 years and the maximum known length for a 13 year old female in Canada was 584 mm FL (Scott and Crossman 1973).

Adult smallmouth bass are usually found in clear lakes and rivers (McPhail 2007). In lakes they are usually found in inshore rocky areas and in rivers they use areas of moderate current over rock or sand substrates. During daylight hours the smallmouth bass are strongly associated with shelter including piles of rocks or submerged logs. In the summer smallmouth bass may have separate home ranges between night and day. When the water temperatures are high they tend to shift from shallow feeding areas to deeper water where it is cooler. In the fall when water temperatures fall below roughly 15 °C, they move into deep water and when it reaches 4 °C they aggregate near the bottom, cease feeding, become very inactive, and live on their summer stores (Scott and Crossman 1973; McPhail 2007). In the spring when temperatures reach 8.5 °C they resume their feeding activities (Scott and Crossman 1973). The preferred temperature for smallmouth bass in their native range in summer ranges from 17-28 °C (Scott and Crossman 1973; McPhail 2007) and their movements have been shown to maintain this preferred temperature range (Scott and Crossman 1973). The upper lethal temperature, determined experimentally was found to be 35 °C.

Juvenile smallmouth bass have roughly the same habitats as the adults although they tend to occupy shallower water. After leaving the nest, young-of-the-year move into shallow, calm, vegetated margins of lakes and streams. In British Columbia, most of the smallmouth bass populations were introduced into lakes and so are rarely found in rivers (McPhail 2007). The lakes that they occupy are generally small to medium sized and relatively shallow. When they co-occur with largemouth bass the two species segregate similarly to within their natural range, with smallmouth bass in cooler, sand or rock bottomed areas with submerged cover and largemouth bass with warmer soft bottomed, weedy bays.

Smallmouth bass are a littoral zone predator (Vander Zanden et al. 2004; Dunlop and Shuter 2006). In the words of J.D. McPhail (2007), "Smallmouth bass are noted for their voracious appetites". Prey selection for the smallmouth bass is particularly influenced by fish age and prey availability (Scott and Crossman 1973; McPhail 2007). There is an increase in the size of prey from plankton, to aquatic insects, to fish (including smaller smallmouth bass: Clady 1974) and crayfish as the size of the smallmouth bass increases (Scott and Crossman 1973). In Ontario lakes insects replace plankton at the size of about 20 mm, and there is a shift to fishes and crayfish once they reach 50 mm. In most habitats, crayfish make up the largest portion of the diet (60-90% by volume), followed by fishes (10-30%), and aquatic and terrestrial insects (0-10%; Johnson et al. 1977). Other prey items include frogs, tadpoles, fish eggs, and plant materials. In the British Columbia interior, adults fed mainly on fish (particularly redside shiners (*Richardsonius balteatus),* peamouth (*Mylocheilus caurinus),* and chiselmouth (*Arocheilus alutaceus*)), as well as macroinvertebrates, mainly crayfish (McPhail 2007). Adult smallmouth bass on Vancouver Island primarily consumed crayfish and odonate nymphs.

Across its range 114 parasites, including 12 protozoans, 49 trematodes, 12 cestodes, 13 nematodes, 9 acanthocephalans, 9 leeches, 1 mollusc, and 9 crustaceans have been identified in smallmouth bass (Hoffman 1967). Of these parasites, three are of most concern: black-spot and yellow grub which deteriorate the appearance of the fish and make it less palatable to humans; and the bass tapeworm *Proteocephalus ambloplitis* which can cause sterility or seriously affect reproduction in the smallmouth bass (Scott and Crossman 1973). None of these is however harmful to humans.

The trematode, *Nezpercella lewisi*, is an intestinal parasite of native northern pikeminnow (*Ptychocheilus oregonensis*) that also infects smallmouth bass in Idaho (Schell 1976). It was found to infect the fry of pikeminnow, redside shiner, longnose dace (*Rhynichthys cataractae*), and torrent sculpin (*Cottus rhotheus*) but not the speckled dace (*Rhynichthys osculus*).

Another parasite, the small (0.6-1.0 mm) parasitic copepod *Neoergasilus japonicus* which is native to eastern Asia, was found in pumpkinseed, largemouth bass, yellow perch, and fathead minnow (*Pimephales promelas*) in Lake Huron in 1994 (Hudson and Bowen 2002). By 2001 seven additional species (including smallmouth bass) were found with the parasite in this lake. The parasite can swim well, can be found on a variety of hosts (from cyprinids to percids and centrarchids to ictalurids), and is able to move from one host to another easily. This may explain how this copepod appears to have dispersed over long distances quite quickly, spreading across Europe in 20 yr and moving into North America over 10 yr. The mode of transport and introduction into the Great Lakes is probably by exotic fish species associated with the fish husbandry industry, the aquaculture trade, or bait releases. The ecological impact of the non-native parasite is unknown, although they appeared to reduce growth in some species of fish.

3.2 KNOWN DISTRIBUTION

The native range of the smallmouth bass included the fresh waters of eastern central North America (Scott and Crossman 1973). It extended from southern Quebec west to mid Minnesota, southeast to Georgia, and west to Oklahoma (Wydoski and Whitney 2003). Beginning in the mid-1800's, the range began to expand due to human influence and now covers most places in the United States and many places in England, Europe, Russia, and Africa (Scott and Crossman 1973). In the 1990s it has spread through highland lakes of Japan and it is in the process of becoming established there (Iguchi et al. 2004a). In Canada, smallmouth bass now occurs in southern Nova Scotia, southern and western New Brunswick, southern Quebec, through Ontario and Manitoba and central Saskatchewan, and southern British Columbia (Scott and Crossman 1973).

In British Columbia the smallmouth bass has spread from the US through the Columbia River system and has been introduced to Saltspring Island and southern Vancouver Island by direct introductions (Table 3.1; Figure 3.1). It is now also present in the Kootenays and most of the lowland lakes of the Okanagan system as well as many lakes in southern Vancouver Island. There was also a recent unauthorized introduction into the middle Fraser River system in the Quesnel area.

Table 3.1: Counts of waterbodies containing introduced smallmouth bass, by region, in British Columbia, from Runciman and Leaf (2008).

	Region						
Category	Vancouver Island	Lower Mainland	Upper Fraser	Thompson	Columbia	Arctic	C and N Coast
Confirmed	50	2	4	1	12	0	0
Unconfirmed	3	0	0	1	1	0	0

Figure 3.1: Distribution of known (confirmed) occurrences of smallmouth bass in British Columbia (data from Runciman and Leaf 2008).

3.3 POTENTIAL DISTRIBUTION

The habitat suitability model for smallmouth bass used five variables for the majority of each of the lakes in British Columbia: surface area, maximum depth, and September, October, and November air temperature. All other variables were rejected based on the initial assessment.

The variables with the highest contribution to the final model to predict the suitability of lakes in BC were September air temperature, lake area, and October air temperature.

The model validation based on the independent data set of smallmouth bass occurrences in BC found a good predictive accuracy, with 28 out of 37 invaded lakes successfully predicted as suitable. The model results suggest that the majority of lakes in southern British Columbia would be suitable for smallmouth bass (Table 3.2). The percent suitability for the Central Coast is likely too high because there was a lack of data on Central Coast lakes to include in the model (note the grey areas in Figure 3.2).

Table 3.2. Predictions of the percent of the lakes within each region that would sustain a population of smallmouth bass based on the Habitat Suitability Model (n=1882 lakes).

	Region							
	Vancouver Island	Lower Mainland	Upper Fraser	Thompson	Columbia	Arctic	Central Coast	North Coast
Suitability	64	84	54	66	68	29	64	42

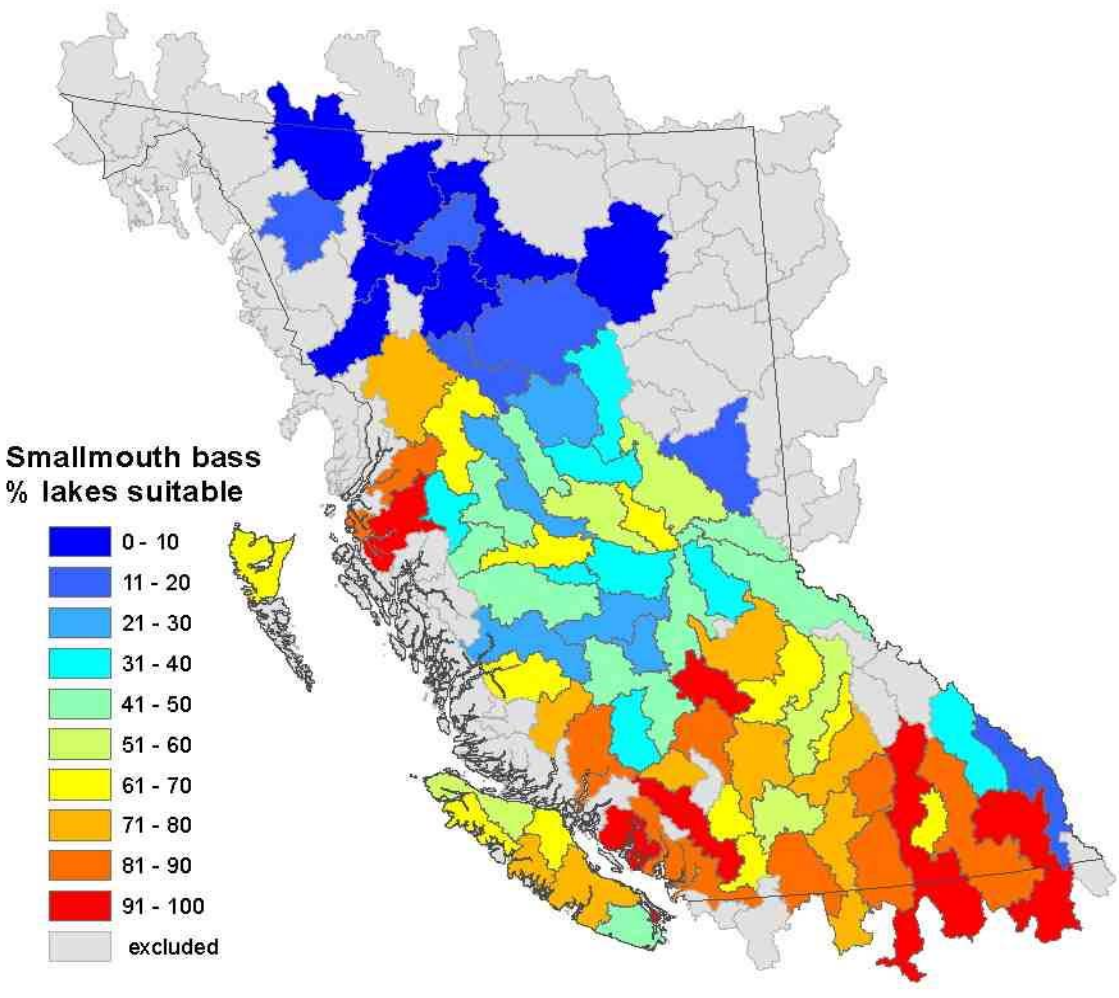


Figure 3.2. The potential distribution of smallmouth bass in British Columbia based on the results of the Habitat Suitability Model that indicate the proportion of the lakes in the region that would sustain a population (n=1882 lakes). Watersheds with ≥ 5 lakes with data are included.

3.4 AQUATIC ORGANISM ECOLOGICAL AND GENETIC RISK ASSESSMENT

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

Smallmouth bass are considered to be an excellent game fish with more fight per kg than most other freshwater game fish (Wydoski and Whitney 2003). They can provide a spectacular aerial display when hooked and provide a better fight than the largemouth bass. Thus, the addition of angling opportunities is the reason for most of the introductions of this fish beyond its native range, either authorized or unauthorized. Once introduced into an area, the smallmouth bass is able to spread to other areas by natural dispersal.

Climatic factors were found to explain the general distribution of smallmouth bass (Johnson et al. 1977). The specific wintering temperatures between 2-6 °C did not influence the mortality rates of age 0+ smallmouth bass between 55-107 mm total length although long fish survived better than shorter ones (Oliver et al. 1979). Thus, smallmouth bass in good summer growing conditions are likely not to be limited by cold winter temperatures. However, low winter oxygen levels may limit centrarchid survival as it appeared to do so in small Wisconsin lakes (Tonn and Magnuson 1982).

The concordance between climate and growth of smallmouth bass was lower for introduced populations in North America than within the native range of the species (Dunlop and Shuter 2006). As distance from the center of a species distribution increases, the populations tend to experience more stressful environmental conditions and often exist at their physiological limits. Moyle and Light (1996b) found in California streams that if the abiotic factors were good for an exotic species that it was likely to successfully establish itself regardless of the biota already present. The environmental challenges faced by invaders in their study areas mainly consisted of the timing and intensity of in-river flow events.

The movement into British Columbia from the United States occurred by natural dispersal through the Columbia River system (Scott and Crossman 1973). The date of first purposeful introduction into British Columbia is as early as 1901, when the Dominion Fisheries Department introduced smallmouth bass into Christina Lake in the Kootenays and Florence and Langford lakes on Vancouver Island (McPhail 2007). The stock for these introductions came from Ontario. In 1908, smallmouth bass were taken from Christina Lake and introduced into Moyie Lake, also in the Kootenay system, and in 1920, they were transplanted from Langford Lake to St. Mary Lake on Saltspring Island. Later, in the 1960s smallmouth bass were found in Osoyoos Lake, and were assumed to have arrived from Washington by natural dispersal. In 1987, more fish were taken from Christina Lake and transplanted into Vaseux and Skaha lakes in the southern Okanagan system. Today, smallmouth bass occur in most of the lowland lakes in the Okanagan system as well as many lakes on southern Vancouver Island (Table 3.1; Figure 3.1). There was also a recent unauthorized introduction into the middle Fraser River system in the Quesnel area. This may have serious consequences for the ecologically, culturally, commercially, and recreationally important Fraser River Pacific salmon populations as they are likely able to spread through the Fraser system (McPhail 2007).

Since smallmouth bass are found in the many locations in the Columbia and Vancouver Island Regions and in 1-3 locations in the Lower Mainland, Thompson, and Upper Fraser Regions today, the probability of arrival is not provided (Table 3.3). The probability of survival and reproduction in these regions is based on the Habitat Suitability Model (Table 3.2; Table 3.3) and is found to be high for the Columbia, Vancouver Island, Thompson, and Upper Fraser Regions and very high for the Lower Mainland Region.

Smallmouth bass invading new habitats are able to feed on a wide range of prey and show adaptability to various feeding environments (Iguchi et al. 2004a). The large amount of parental care increases the probability of smallmouth bass introduced into a new area becoming established (Hatfield and Pollard 2006). However, the reproductive behaviour of smallmouth bass requires specific conditions and if those conditions are not met it may prevent its establishment. It is hypothesized that a failure in brooding may lead to unsuccessful establishment (Iguchi et al. 2004b). These factors are not taken into account in the Habitat Suitability Model and may have a modifying affect on the probability of survival and reproduction.

3.4.2 The probability spread.

Mainly due to unauthorized introductions by anglers as well as natural dispersal, the smallmouth bass have an ability to increase their geographic range in the years to come (Vander Zanden et al. 2004). Smallmouth bass are adept at dispersing throughout drainage systems (Vander Zanden et al. 1999) and their habitat includes both lakes and rivers which allows them to spread easily throughout a watershed with the correct environmental conditions. However, smallmouth bass are territorial and often return to the same nest site year after year (Scott and Crossman 1973), which may limit their spread. Outside of the spawning season, most mark and recapture studies have shown them to move less than 0.8-8 km from their place of capture. However, some may migrate greater distances, which would enable them to disperse to other water bodies from their present distribution. Where the smallmouth bass have been introduced into small lakes without connection to other water bodies, the spread to other areas from the source would depend on the unauthorized transport and release by sport fishing enthusiasts with the purpose of creating new populations for fishing opportunities. This type of spread is most likely to occur in areas of high population density or visitor numbers.

The probability of spread within each of the regions in BC is based on past incidences of spread in the region, the human population or frequency of visitations of sport fishers to the area, as well as the connectedness of the waterbodies within the region. The probability of spread for these reasons is predicted to be very high for the Lower Mainland and Vancouver Island Regions (Table 3.3). The uncertainty is low for the Lower Mainland and very low for Vancouver Island. The probability is high for the Upper Fraser, Thompson, and Columbia Regions, and is due mainly to the connectedness of drainages and high human visitation.

3.4.3 Final rating: widespread establishment of smallmouth bass.

Table 3.3. The probability of arrival, survival and reproduction, spread, and widespread establishment once arrived (WEOA) of the smallmouth bass in the eight regions of British Columbia with the associated uncertainties. 'A' indicates that the bass has already arrived in the region.

	Vancouver Island		Lower Mainland		Upper Fraser		Thompson		Columbia		Arctic Drainage		Central Coast		North Coast	
Element	Prob	Unc	Prob	Unc	Prob	Unc	Prob	Unc	Prob	Unc	Prob	Unc	Prob	Unc	Prob	Unc
Arrival	A	A	A	A	A	A	A	A	A	A	VL	H	M	M	L	M
Survival & Repro	H	M	VH	L	H	M	H	M	H	M	M	H	M	H	M	H
Spread	VH	VL	VH	L	H	L	H	L	H	VL	L	H	L	M	M	M
WEOA	VH	M	VH	L	H	M	H	M	H	M	M	H	M	H	M	H

3.4.4 Estimate the ecological impact on native ecosystems.

There is a vast amount of evidence, a lot of it indirect, that shows that in lakes where smallmouth bass have been introduced, there is a local extinction of small native prey fish. In the small, lowland Vancouver Island, BC lakes with introduced smallmouth bass, most have lost their stickleback (*Gasterosteus* spp.) and peamouth (*Mylocheilus caurinum*) populations (McPhail 2007). MacRae and Jackson (2001) found that in small lakes in central Ontario species richness (diversity) did not differ, however, the species composition in lakes with smallmouth bass were dominated by large-bodied centrarchids in contrast to small-bodied species, primarily cyprinids that were found in lakes without smallmouth bass. The presence of smallmouth bass led to the extirpation of many small-bodied species, particularly fathead minnow, brook stickleback (*Culaea inconstans*), pearl dace (*Margariscus margarita*), and *Phoxinus* spp. Large-bodied species, including creek chub (*Semotilus atromaculatus*), white sucker (*Catostomus commersoni*), and yellow perch were able to coexist with smallmouth bass populations. Other species, while coexisting with smallmouth bass, had much reduced abundance relative to lakes without smallmouth bass. They also found that lakes with less complexity (and prey refuge), including those that have highly developed shorelines, with woody debris and aquatic vegetation removed, were more likely to have reduced populations of small-bodied fish. This suggests that those lakes in the areas of high human density will likely have higher impacts on the native populations of small-bodied fish as a result of introduction of smallmouth bass.

In a survey of the fish assemblages in over 190 northeastern United States lakes Whittier et al. (1997) and Whittier and Kincaid (1999) found that lakes with *Micropterus* species were most likely to have lower native species richness. They also noted that minnow species declined with increased human activity even in the absence of predators (Whittier et al. 1997). This further suggests that lakes with introduced predators near human settlements would likely experience a larger impact.

In small temperate lakes of the Adirondacks with top piscivores, dominated by introduced species such as smallmouth bass, largemouth bass, and northern pike (*Esox lucius*), the native minnow richness was reduced by two thirds from those lakes without piscivores (Findlay et al. 2000). As well, the average minnow richness varied with the number if predators present. There is strong evidence that the creek chub, blacknose dace (*Rhinichthys atratulus*), northern redbelly dace (*Phoxinus eos*), and common shiner (*Notropis cornutus*) were less likely to be present in lakes with predators present, and that the same may be true for pearl dace (*Semotilus margarita*), although the evidence is not as strong. Only 2 of the 13 species of minnows appeared to not be affected by the piscivore presence, and both were introduced species (bluntnose minnow (*Pimephales notatus*) and golden shiner (*Notemigonus crysoleucas;* Findlay et al. 2000).

Predation is a major factor determining the fish communities in small lakes of Alberta. Lakes with piscivores were found to have reduced minnow diversity (Robinson and Tonn 1989). In northern Wisconsin lakes, minnows were either absent or their abundance was low in lakes with littoral piscivores, including centrarchids and pike (Tonn and Magnuson 1982). In those lakes where winterkill excluded northern pike and centrarchids, the minnows and mudminnows were common. In the 1930s, the diversity of minnows in Adirondack lakes to which bass were absent was much greater than in those lakes where bass had been introduced (Findlay et al. 2000). As well, Chapleau et al. (1997) found that there was reduced minnow richness in small lakes of Gatineau Park, Quebec that had introduced piscivores (mainly smallmouth bass and northern pike). However, they were not able to find a difference in minnow richness in large lakes, suggesting there may be an effect of low habitat heterogeneity increasing vulnerability to predation in the smaller lakes (Findlay et al. 2000).

Thus, there is a large body of evidence that the introduction of top predators including smallmouth bass puts native minnow populations at high risk of extirpation, especially in small lakes for which all of the above studies are focused on. Thus, the introduction of the smallmouth bass to lakes (especially small temperate ones) in British Columbia represents a very high probability of risk for small native (especially soft-finned) fish species. The uncertainty for this is very low due to the large amount of evidence, including evidence within BC. The impact is likely to be highest for those lakes with large human impact due to habitat alteration in the littoral zone, including the Lower Mainland, Vancouver Island, and Upper Fraser Regions. The impact is also likely to be higher for small shallow lakes and possibly not as high for large lakes, although there is little data on large lakes.

In addition to the local extinctions of littoral prey fish, in many areas of Washington, smallmouth bass have been found to prey on salmonids (Wydoski and Whitney 2003). This may have significance for the Fraser system since smallmouth bass were recently introduced into the Quesnel area. Predation on salmonids can be very heavy (Wydoski and Whitney 2003). In the Columbia River near Richland, Washington, juvenile chinook salmon comprised 59% of the diet of the smallmouth bass. In the Lake Washington Ship Canal in May and June juvenile salmonids comprised 38% of smallmouth bass diets. The number of smallmouth bass in the Yakima River in 1999 increased from 8 066 in mid-March to 35 378 by the second week of June (Pearsons 2000 as in Wydoski and Whitney 2003). This increase is believed to be a result of immigration from the Columbia River in time for the smolt migration. These smallmouth bass consumed an estimated 171 071 salmonid smolts (primarily fall chinook salmon).
Other studies showed predation on juvenile salmonids but to a smaller degree. In the Columbia River, introduced smallmouth bass feed on peamouth and northern pikeminnow (*Ptychocheilus oregonensis*) and of the salmonids, chinook salmon smolts comprised 10% of bass diets by frequency. In the John Day Reservoir (Columbia River), only 4% of the diet of smallmouth bass during the period of salmon smolt migration (1983-1986) were salmonids, which was substantially lower than the other predators that were present (northern pikeminnow, walleye, *Stizostedion vitreum*, and channel catfish, *Ictalurus puntatus*; Poe et al. 1991). Based on the numbers of smallmouth bass and the consumption rate Rieman et al. (1991) estimated that they consumed 9% of the 2.7 million salmonids lost to predation. In Lake Washington, smallmouth bass were not found to have a large impact on sockeye salmon (*O. nerka*) populations (Fayram and Sibley 2000). This could have resulted from the low overlap in the habitat of the pelagic sockeye and littoral smallmouth bass.

The introduction of smallmouth bass in Washington has altered the suite of predators there. In the Brownlee Reservoir on the Snake River the native pikeminnow population was reduced to almost nothing in 1969 after the introduction of smallmouth bass in 1962 (Wydoski and Whitney 2003). As well, in the Yakima River, following the introduction of smallmouth bass the amount of predation on salmonids appeared to be unchanged. The difference was that smallmouth bass replaced pikeminnow as the dominant predator (Fritts and Pearsons 2006). The specific life history type of salmonid that was preyed upon most heavily switched from spring chinook and coho to ocean type chinook, as they were smaller and were consumed by the large abundance of younger smallmouth bass. Part of the reason for this switch is that smallmouth bass become piscivorous 2-3 years earlier than the pikeminnow and were found to be able to consume salmonids up to 56.6% of their length.

Vander Zanden et al. (1999) found that in the presence of the non-native predators (smallmouth bass and rock bass), the littoral prey fish diversity and abundance was lower than in uninvaded in Canadian lakes. Aside from the effect on the prey fish, the native top predator, lake trout (*Salvelinus namaycush*) was found to have a reduced trophic position in lakes with these invaders, indicating changes to food web configuration. The lake trout had shifted from consuming littoral fish (which were reduced in abundance and diversity) to consuming zooplankton. These results have implications for the growth and condition of native predators. For northern North American temperate lakes similar results were obtained except that in some cases lake trout were buffered from the impact of smallmouth bass in lakes that contained pelagic prey fishes (Vander Zanden et al. 2004).

Because of the above evidence, the magnitude of the ecological impact to small warmwater lakes and other small water bodies is considered to be very high and with a very low degree of uncertainty. For large water bodies, the smallmouth bass only lives in shallow bays, and so their population is not likely to be very high. However, smallmouth bass have been known to cause a large amount of predation in deep channels that do not have a large amount of preferred habitat. Therefore, the ecological impact in large water bodies is considered to be high, however, the degree of uncertainty is moderate.

3.4.5 Genetic impacts on local self-sustaining stocks or populations.

The smallmouth bass in the wild is known to hybridize with the spotted bass, *M. punctulatus* in Missouri (Scott and Crossman 1973) and the Guadalupe bass *M. treculi* and northern and Florida largemouth bass in Texas (Pierce and Van Den Avyle 1997). The spotted bass and Guadalupe bass are not currently present in British Columbia so hybridization with this species in BC is unlikely. As well, the spotted bass, Guadalupe bass, and largemouth bass are not native to BC (Scott and Crossman 1973) and so hybridization with them does not pose a genetic risk to native populations. In fact, all centrarchids (sunfish, bass, and crappie) in BC are introduced because tectonic and glacial onset eliminated the ancient ones from the northwest of North America (McPhail 2007). Therefore the magnitude of the genetic impact of smallmouth bass on native populations is very low with a low degree of uncertainty.

3.4.6 Final rating: ecological and genetic consequences

Table 5.4. The magnitude of the ecological and genetic consequences and the related uncertainties for introduced smallmouth bass in British Columbia.

	British Columbia	
Element	Magnitude	Uncertainty
Ecological Consequence: Small Water Bodies	Very High	Very Low
Ecological Consequence: Large Water Bodies	High	Moderate
Genetic Consequence	Very Low	Low

3.4.7 Estimating aquatic risk potential for smallmouth bass.

The summary ranks for the probability of widespread establishment (introduction, survival, reproduction, and spread; Table 3.3) and the ecological and genetic consequences (Table 3.4) are combined in the following tables to obtain an overall risk rating (Table 5a, 5b, 5c).

Table 3.5a: Matrix for determining overall ecological risk for small water bodies, where green indicates low risk, yellow indicates moderate risk, and the red region represents the conditions for a high risk designation. The size of the ellipse represents the amount of uncertainty.

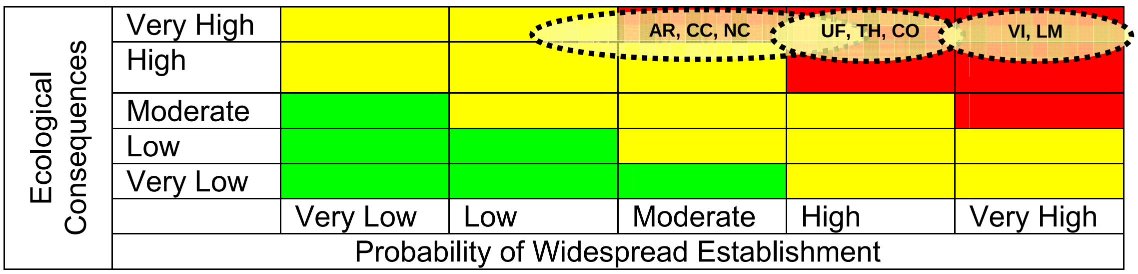


Table 3.5b: Matrix for determining overall ecological risk for large water bodies, where green indicates low risk, yellow indicates moderate risk, and the red region represents the conditions for a high risk designation. The size of the ellipse represents the amount of uncertainty.

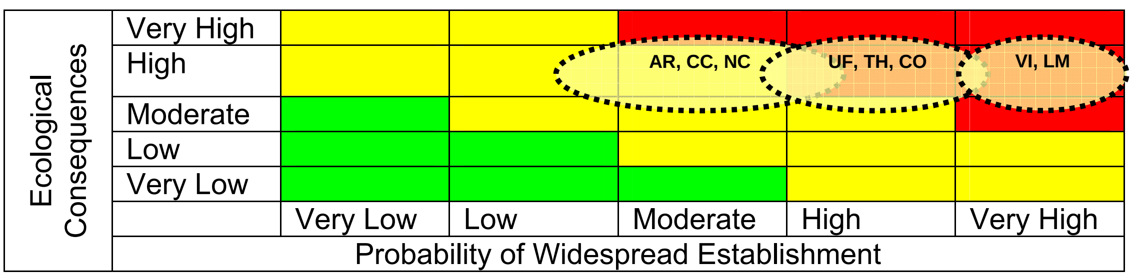
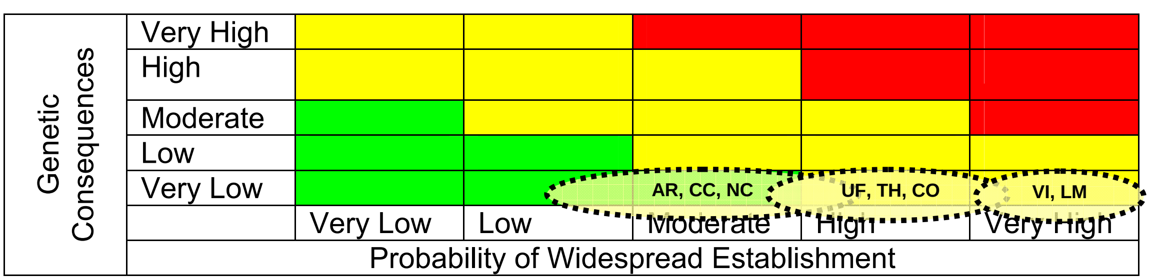


Table 3.6: Matrix for determining overall genetic risk, where green indicates low risk, yellow indicates moderate risk, and the red region represents the conditions for a high risk designation. The size of the ellipse represents the amount of uncertainty.



3.5 PATHOGEN, PARASITE, OR FELLOW TRAVELER ECOLOGICAL AND GENETIC RISK ASSESSMENT

3.5.1 The probability that a pathogen, parasite, or fellow traveler may be introduced along with the potential invasive species and become established.

The primary mode of introduction of smallmouth bass and their pathogens, parasites, and fellow travelers into new lakes in British Columbia results from unauthorized introductions from nearby water bodies. With this method of introduction, the smallmouth bass that are transferred are likely to take with them pathogens, parasites, or other fellow travelers that already exist in BC.

The potential future distribution of the smallmouth bass identified above (Table 3.2; Figure 3.2) was based on a habitat model that uses the conditions in lakes that support smallmouth bass in eastern Canada to predict which lakes in BC would support smallmouth bass. Thus, it is likely that the conditions that would support the smallmouth bass would also support the common parasites that smallmouth bass carry, which are known to be numerous (see Section 3.1). Thus, if there were introductions of smallmouth bass into BC water bodies from sources inside or outside of BC, then there would be potential for the viability of the pathogens, parasites, or fellow travelers. Whether a parasite carried along with smallmouth bass would be able to infect the native species depends on the life history and host specificity of the parasite. The information on this specific to smallmouth bass is not available at this time.

If there were to be an introduction of a parasite along with smallmouth bass into water bodies with existing populations of smallmouth bass, the risk of spread would be very high. The smallmouth bass is often found in high densities and the higher the density the faster the spread of parasites. As well, the parental care by the male smallmouth bass may increase the spread of the parasite to the offspring due to close contact with the juvenile fish. However, since smallmouth bass are not native to BC this is not a risk to native populations.
Therefore, because the smallmouth bass carries a large number of parasites, some of which may not be specific to smallmouth bass, the probability of establishment is moderate. The uncertainty is high due to low amount of information to guide the assessment.

Table 3.7 Probability and uncertainty for the establishment of parasites, pathogens, and/or fellow travelers from introduced smallmouth bass in British Columbia.

	British Columbia	
Element	Probability	Uncertainty
Establishment	Moderate	High

3.5.2 Ecological and genetic impacts of pathogens, parasites, and fellow travelers on native ecosystems both locally and within the region.

One study showed that the smallmouth bass is known to host 114 parasites over its whole range (Hoffman 1967). It is not known which of these parasites the smallmouth bass that are introduced into BC are known to carry and which would have other hosts that are native to BC. However there was one study in the 1950s (Bangham and Adams 1954) that showed that 80% of the smallmouth bass in Christina Lake (Kettle River Drainage), BC were infected with four different species of parasites. This is much lower than in their native range, as smallmouth bass in Wisconsin carried 24 different parasites and those in Lake Huron carried 30. The major parasites for smallmouth bass in British Columbia are: *Proteocephalus* sp., *Rhabdochona* sp.,

Ergasilus caeruleus (Margolis and Arthur 1979; McDonald and Margolis 1995) and an unnamed cestode (Bangham and Adams 1954).
Thus, the ecological impact of these parasites is likely varied and difficult to quantify. However, since there has been no literature on disease outbreaks in BC from any of the parasites, the impact that they would have is likely low (because native species may sometimes be impacted by the parasites). The uncertainty is high as the impact is only plausible based on the absence of literature on the topic. The magnitude of the genetic impact of these parasites is low as native species of parasites may sometimes be impacted by the parasites. The uncertainty is very high as there is little information to guide the assessment.

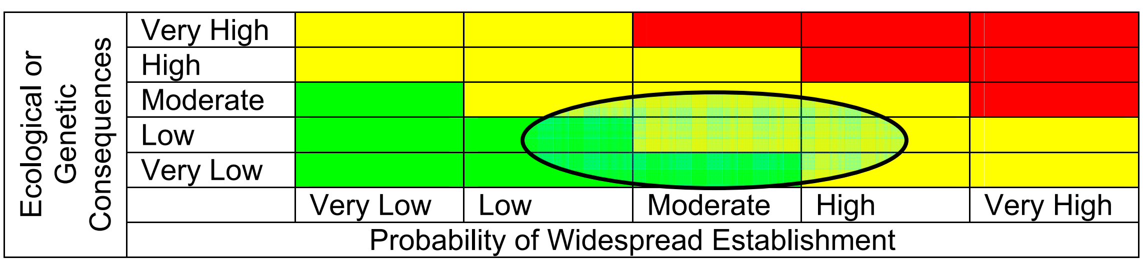
Table 3.8 Estimated ecological and genetic consequences of the introduction of parasites, pathogens, or fellow travelers from introduced smallmouth bass populations.

	British Columbia	
Risk Component	Magnitude	Uncertainty
Ecological	Low	High
Genetic	Low	Very High

3.5.3 The aquatic risk potential for pathogen, parasite or fellow traveler.

The summary ranks for the probability of widespread establishment (Table 3.7) and the ecological and genetic consequences (Table 3.8) of parasites, pathogens, and/or fellow travelers of smallmouth bass are combined in the following table to obtain an overall risk rating (Table 3.9).

Table 3.9: Matrix for determining overall risk of pathogens, parasites, and/or fellow travelers of smallmouth bass. Green indicates low risk, yellow indicates moderate risk, and the red region represents the conditions for a high risk designation. The solid ellipse represents the ecological and genetic consequences of establishment.



4.0 LARGEMOUTH BASS

4.1 BACKGROUND AND BIOLOGY

The largemouth bass (*Micropterus salmoides*) Lacépède is a moderately large fish usually 203-380 mm in length (up to 500 mm FL in British Columbia) with coarse scales and well-developed spines (Scott and Crossman 1973; McPhail 2007). Within the Centrarchid family it is the largest species. Its body is laterally compressed, although less so than the smallmouth bass. It has an operculum that is bony to the edge and pointed but not formed into a flap, with a vague dark spot near the tip. The lower jaw is slightly longer than the upper jaw and extends to a point behind the hind margin of the eye (McPhail 2007). The mouth gape thus reaches to the middle of the eye (Scott and Crossman 1973; Wydoski and Whitney 2003). The largemouth bass has two dorsal fins that are fused together. The first is spiny and there is a deeper notch than seen with the smallmouth bass between it and the second soft-rayed dorsal fin. The adult largemouth bass is bright green to olive coloured on its dorsal surface, lighter green to golden on its sides, and has a white underside (Scott and Crossman 1973). For spawning males, the colours darken and during spawning season the sexes can be distinguished. Young largemouth bass have a dark midlateral stripe extending from the snout to the base of the caudal fin (McPhail 2007). Sexual maturity is usually attained in Canadian populations at 3-4 years in males and 4-5 years in females (Scott and Crossman 1973; McPhail 2007).

Females spawn yearly up until the age of about 12 years. The breeding season begins in late spring once the water temperatures reach roughly 15 °C and has been shown to carry on through mid-summer in temperatures of 16.7-18.3 °C. Male largemouth bass exhibit a large degree of parental care, first creating a spawning nest with their caudal fins (a shallow saucer-shaped depression about 25-200 mm deep and 610-950 mm diameter: McPhail 2007) in waters less than 1 m deep, and then guarding and fanning the eggs and larvae following mating (Scott and Crossman 1973; McPhail 2007).

The male will continue to eat during this time, but at a much reduced rate. He will also aggressively attack intruders in the nest pit. Nests are often located in quiet water over sand (rarely) or soft mud of lakes and river sloughs in submerged vegetation including reeds, bulrushes, or water lilies. They are also often located near cover including stumps or logs. The bottom of the nest often includes the exposed roots of submerged vegetation, and nests are generally spaced out at densities of one every 2-10 m (Scott and Crossman 1973; McPhail 2007).

Largemouth bass are territorial and there is evidence that they return to the same nest sites every year. When largemouth bass and smallmouth bass co-occur the largemouth bass spawns earlier since the shallower areas of high vegetation warm to the optimal temperature earlier than the deeper rocky areas used by the smallmouth bass (Scott and Crossman 1973).

Depending on female size, largemouth bass produce typically 2 000 to over 100 000 (4 000 - 15 000 per kg of female) adhesive, demersal eggs that are roughly 1.5-2 mm in diameter (Scott and Crossman 1973; McPhail 2007). They release them in batches and sometimes in more than one male's nest. The eggs are often laid over the entire bottom and lip of the nest, less compactly than with the smallmouth bass (Scott and Crossman 1973). The eggs have been found to hatch in roughly 13 days at 10 °C or 3 days at 28 °C (McPhail 2007). After hatching the male continues to guard the schools of fry for up to one month before they leave the nest at about 25-30 mm. There is typically a low survival rate of the eggs and only 5-10 reach 254 mm length (Scott and Crossman 1973). Perturbations to water temperature, wind, waves, and predation limit the success of the hatch and this as well as growth and survival in the first year determine year class strength which can vary greatly interannually. Interesting to note is that largemouth bass may spawn more than once in a summer (McPhail 2007).

Growth of the juveniles is fast with young-of-the-year reaching 50-130 mm in length by the end of their first growing season (Scott and Crossman 1973; McPhail 2007). The juveniles grow steadily each year until they reach sexual maturity at which time growth slows (McPhail 2007). Although it depends on environmental conditions, it takes the largemouth bass roughly 2 years to reach 200 mm and 5-6 years to reach about 350 mm, which is the most common range of lengths for sport caught fish (Scott and Crossman 1973). Females grow faster and reach a larger final size than males. The maximum known age attained by largemouth bass is 23 years and the maximum length recorded is 827 mm for one caught in Georgia, where growing seasons are longer than in Canada. In British Columbia the oldest largemouth bass was 12 years and the length of this fish is unknown (McPhail 2007).

Largemouth bass are usually found in warm (25-28 °C), shallow lakes, shallow bays of larger lakes, and less frequently large, slow-moving rivers (Scott and Crossman 1973; McPhail 2007). In the summer, adults are found in the upper levels of the water column near soft substrates in areas with dense beds of emergent and subemergent vegetation. In British Columbia, the largemouth bass populations exist primarily in shallow, warm-water lakes, and they rarely succeed in large oligotrophic lakes (McPhail 2007). In BC and in their natural range, the habitats of the largemouth and smallmouth basses rarely overlap, even when they co-occur: largemouth bass are found in the warmer, soft-bottomed, weedy bays and smallmouth bass in the cooler, sand or rock bottomed areas associated with cover. However, this association of largemouth bass with aquatic vegetation is flexible as in California it was shown that they are able to do well in fluctuating reservoirs lacking aquatic plants (Wydoski and Whitney 2003).

Largemouth bass establish home ranges that are small in the summer although can be adjusted to accommodate changes in foraging density and have been seen to range up to 8 km. When the water temperatures are high in the summer they tend to remain in shallow feeding areas and rest in the shade of aquatic or terrestrial vegetation (Scott and Crossman 1973). In the fall when water temperatures fall below roughly 10 °C, they move into deep water and foraging and other activity decreases. This is in contrast to smallmouth bass, which cease feeding and other activity at colder temperatures. In the spring largemouth bass return to shallower water and resume their normal feeding activities prior to spawning (McPhail 2007). Juvenile largemouth bass have roughly the same habitats as the adults although in summer they form small schools and cruise closer to shore and in shallower water than solitary adults (Wydoski and Whitney 2003; McPhail 2007). After leaving the nest, young-of-the-year move into shallow, calm, often vegetated margins of lakes.

Largemouth bass are able to tolerate higher water temperatures than the smallmouth bass (Scott and Crossman 1973). In the field, the preferred temperature ranged from 26.6-27.7 °C, although their preference has experimentally been determined to be 30-32 °C, depending on the acclimation temperature. The upper lethal temperature exhibits geographic variation and was determined to be 28.9 °C in British Columbia for a population acclimated at 20-21 °C (Black 1953) and 36.4 °C in other areas when acclimated at 30 °C. (Scott and Crossman 1973). The largemouth bass however has a low tolerance for low oxygen and in an experiment they were found to avoid levels of 1.5 mg/litre or lower. This and the fact that they are closely associated with weeds often subjects them to winterkill and sometimes also summerkill (from a reduction in oxygen due to the decay of plant matter).

Largemouth bass are known for their voracious appetites and adults are largely piscivorous littoral predators (Scott and Crossman 1973; McPhail 2007). Prey selection for the largemouth bass is particularly influenced by fish age and prey availability. There is an increase in the size of prey from plankton, to aquatic insects, to fish (including smaller largemouth bass) as well as crayfish and other macroinvertebrates as the size of the largemouth bass increases. Other prey items for adults include frogs, worms, and large insect nymphs. A shift to piscivory starts early at 40-80 mm TL and the proportion of fish in the diet increases with increased size (McPhail 2007). The specific fishes consumed depend on the availability of individuals of appropriate size. In their native range, largemouth bass diets include gizzard shad (*Dorosoma cepedianum*), carp, bluntnose minnow (*Pimephales notatus*), silvery minnow (*Hybognathus amarus*), golden shiner (*Notemigonus crysoleucas*), yellow perch, pumpkinseed, bluegill (*L. macrochirus*), silversides

(*Menidia rnenidia*), and other largemouth bass (Scott and Crossman 1973). In their native range, young largemouth bass are also preyed upon by other fish that share their habitat, including walleye, yellow perch, northern pike and various birds. Larger largemouth bass usually escape predation due to their large size, spines, and swimming speed.

Over 103 parasites including 13 protozoans, 45 trematodes, 11 cestodes, 14 nematodes, 5 acanthocephalans, 4 leeches, 1 mollusc, and 10 crustaceans have been identified in largemouth bass (Hoffman 1967). Of these parasites, three are of most concern for both the largemouth and smallmouth bass: black-spot and yellow grub which deteriorate the appearance of the fish and make it less palatable to humans, and the bass tapeworm *Proteocephalus ambloplitis* which can cause sterility or seriously affect reproduction (Scott and Crossman 1973). None of these is harmful to humans.

Another parasite, the small (0.6-1.0 mm) parasitic copepod *Neoergasilus japonicus* which is native to eastern Asia, was found in largemouth bass, pumpkinseed, yellow perch, and fathead minnow in Lake Huron in 1994 (Hudson and Bowen 2002). By 2001 seven additional species (including smallmouth bass) were found with the parasite in this lake. The parasite can swim well, can be found on a variety of hosts (from cyprinids to percids and centrarchids to ictalurids), and is able to move from one host to another easily. This may explain how this copepod appears to have dispersed over long distances quite quickly, spreading across Europe in 20 yr and moving into North America over 10 yr. The mode of transport and introduction into the Great Lakes is probably by exotic fish species associated with the fish husbandry industry, the aquaculture trade, or bait releases. The ecological impacts of the non-native parasite are unknown, although it appears to reduce growth in some species of fish.

The largemouth bass virus (LMBV), an iridovirus, is the cause of a newly recognized disease in wild largemouth (reviewed by Grizzle and Brunner 2003). It is the only virus known to cause a fatal condition in largemouth bass. It is difficult to diagnose as it does not cause obvious external lesions. It was first isolated in 1991 in Florida and is now found in several waterbodies in the eastern United States. Within the known range of the virus, most populations are either not infected or infected at a low prevalence. The disease caused by LMBV occurs in the summer and primarily in largemouth bass greater than 30 cm TL. The virus causes fish to lose their equilibrium after which they are found floating on the surface. Diseased fish may have lesions on their swim bladders and there is often a thick yellow or brown exudate in the swim bladder indicating previous hemorrhage (Hanson et al. 2001). In some instances large fish kills have occurred (thousands of fish), however in other cases, populations of largemouth bass and other fish species are infected and do not show signs of the disease. In locations where there have been fish kills there have not been any subsequent kills, possible resulting from immunity developed in the largemouth bass population.

No other fish species have been found to express the disease, although several centrarchids and chain pickerel (*E. niger*) can carry LMBV without becoming diseased. The virus can reproduce in various cell lines including cyprinid, ictalurid, and salmonid cells. In one study (Hanson et al. 2001) sympatric white bass (*Morone chrysops*), white crappies (*Pomoxis annularis*), bluegills, and gizzard shad were found to be negative for the virus.

Largemouth bass can be infected either through the water or through eating infected prey items (reviewed by Grizzle and Brunner 2003). Because it can be transported in water or by other fish species as carriers of the infection, the proposed route of transfer from one area to another is through the water and fish, for example in live wells of fishing vessels or by private or government stocking of fish.

4.2 KNOWN DISTRIBUTION

The native range of the largemouth bass includes the fresh waters of the lower Great Lakes south to Florida and east of the Appalachian Mountains from Florida to Virginia (Scott and Crossman 1973; McPhail 2007). On the west side of the Appalachians, the range extends from Minnesota to the Gulf Coast and northeastern Mexico. Largemouth bass have been introduced into the cool waters of North America as well as other continents (McPhail 2007). In Canada it now occurs in the St. Lawrence River and its tributaries and in southern Manitoba (Scott and Crossman 1973). An introduction in Saskatchewan in 1950 failed to produce a viable population. Beginning in the 1800's, the range began to expand via introductions into western North America (McPhail 2007). They can now be found in California, Idaho, Washington, Oregon, and southern British Columbia (Table 4.1; Figure 4.1).

The largemouth bass has spread into British Columbia from the US through the Columbia River and other transboundary rivers and streams and it has spread into other areas of BC by direct introductions. The entire range of this species is now almost equal to that of the smallmouth bass (Scott and Crossman 1973).

Table 4.1: Counts of waterbodies containing introduced largemouth bass, by region, in British Columbia, from Runciman and Leaf (2008).

	Region						
Category	Vancouver Island	Lower Mainland	Upper Fraser	Thompson	Columbia	Arctic	C and N Coast
Confirmed	2	50	0	1	39	0	0
Unconfirmed	1	0	0	0	12	0	0

Figure 4.1 Distribution of known (confirmed) occurrences of largemouth bass in British Columbia (data from Runciman and Leaf 2008). Note that one of the points in the Thompson Region is a misidentification.

4.3 POTENTIAL DISTRIBUTION

The potential distribution of largemouth bass in British Columbia was determined from the degree-day map (Figure 4.2). Areas with >1750 degree-days were considered most suitable for largemouth bass and regions >1500 DD and <1750 DD were considered less suitable.

Figure 4.2. The Atlas of Canada Growing Degree Days map. The regions with >1750 DD were considered to have lakes most suitable for largemouth bass.

4.4 AQUATIC ORGANISM ECOLOGICAL AND GENETIC RISK ASSESSMENT

4.4.1 The probability of the organism arriving, colonizing and maintaining a population.

Largemouth bass are considered to be a good game fish with tender flesh although are less popular as a sport fish than the smallmouth bass (Scott and Crossman 1973; Wydoski and Whitney 2003). The addition of angling opportunities is the reason for most of the introductions of this fish beyond its native range, either authorized or unauthorized. Once introduced into an area, the largemouth bass is able to spread to other areas by natural dispersal.

Largemouth bass invading new habitats are able to feed on a wide range of prey and show adaptability to various feeding environments. Their spread throughout South Korean river systems in the last decade results from their consumption of native fish species (Jang et al. 2006). Largemouth bass are highly piscivorous and start consuming fish at a small size and this may reinforce the dietary flexibility and contribute to its success as an invader. The major reason the largemouth bass has had success in spreading through the Japanese Islands is attributed to its strong predator performance (Takamura 2007). Aside from its diet of fish, the largemouth bass's tolerance for high temperatures and slight turbidity, and its fast growth rate increase the probability that introduced bass will become established (Scott and Crossman 1973).

Parental care (lasting up to a month) likely increases the probability of establishment (Hatfield and Pollard 2006). However, the reproductive behaviour of largemouth bass requires specific conditions and if those conditions are not met it may prevent its establishment. Water temperature at spawning time, wave action, nest desertion, parasite sterility, and availability of food for newly rising fry are more operative in controlling recruitment than is predation or competition (Scott and Crossman 1973). Thus in water bodies where there is little access to the types of habitat required for nest building and reproduction, or the types of prey for the young, the risk of establishment of largemouth bass may be lower than predicted by environmental data.

The tendency for largemouth bass to exist in shallow warm-water lakes and its inability to thrive in large oligotrophic lakes (McPhail 2007) may alter the probability of survival and reproduction. Largemouth bass are sensitive to low oxygen levels and are susceptible to winterkill (Scott and Crossman 1973; Tonn and Magnuson 1982) and that may exclude them from the interior portions of some of the more northern regions.

In the late 19th and early 20th centuries, the US Government and European settlers stocked lakes and rivers in the western US with many non-native fishes including largemouth bass (Bonar et al. 2005). The fish's subsequent movement and introductions has resulted in a broad spread of the fish throughout the Pacific Northwest. In Washington state, largemouth bass are now present in 85% of lowland warmwater lakes with public access (n=421). They are also present in 84% of the same type of lakes in Oregon (n=179), and 74% of those in the eight northernmost counties of California state (n=19; Bonar et al. 2005).

The spread of largemouth bass into British Columbia from the United States likely occurred by natural dispersal through the Columbia River system (Scott and Crossman 1973; Figure 4.1). In British Columbia, largemouth bass are currently found in lakes and ponds of the upper Columbia and Kootenay drainage systems, the lower Fraser Valley, and the Okanagan River system (McPhail 2007). Most populations likely arrived through natural dispersal from Idaho and Washington. Introductions into the northwestern United States began in 1890 (Wydoski and

Whitney 2003), and the first BC specimen was recorded from Vaseux Lake in the Okanagan system in 1909 (McPhail 2007). Largemouth bass were then recorded in the Kootenay River system in 1921. The upper Columbia River system lake populations appear to have resulted from unauthorized introductions in the 1950s or 1960s. More recently largemouth bass have been transplanted into limited locations within the Okanagan and Kootenay regions. Evidence suggests that dispersal into the lower Fraser Valley was through the Sumas River system sometime in the 1970s. The largemouth bass is currently established in the Sumas River, Silvermere, and Hatzic lakes, and sloughs associated with the Fraser River.

There are multiple occurrences of largemouth bass in four of our eight Regions in BC - the Lower Mainland, Thompson, Vancouver Island, and Columbia Regions (Table 4.1; Figure 4.1) – and therefore the probability of arrival there is not provided (Table 4.3). The probability of arrival to the Upper Fraser Region is high due to the moderate human population density/visitations and the proximity to existing populations of largemouth bass. The uncertainty is low (Table 4.3). The probability of arrival is very low for the Artic Drainage and low for the Central and North Coast Regions due to the low number of human vectors and distance from existing populations. The uncertainty is high for Arctic and moderate for the Central and North Coast Regions

The probability of survival and reproduction for the eight regions was based on the growing degree-days map for BC (Figure 4.2) and is provided in below (Table 4.3).

<u>4.4.2 The probability of spread.</u>

The main modes of spread for the largemouth bass today in BC are through natural dispersal from existing locations and unauthorized introductions by sport fishers. Largemouth bass live in rivers as well as lakes and that increases their ability to spread throughout a watershed. In the words of Don McPhail (2007), ‘little can be done to control their spread once they are introduced into an open system like the lower Fraser River’. Largemouth bass are territorial and this may limit their spread. A mark recapture study showed that they had relatively small home ranges and were quite sedentary in the summer, fall, and winter - 59% of fish were recaptured near the site of tagging (Wydoski and Whitney 2003). However, some of the largemouth bass were shown to travel greater distances - 25% were recaptured within 5-10 km, and one fish was recaptured 40 km from the site of tagging. Some individuals moved to another part of the water body and established a new home range.

The factors affecting our assessment of the potential spread of largemouth bass by unauthorized introductions include the number of sport fishers that inhabit or visit the locations where the populations exist and the locations where they may be introduced as well as the connectivity of the waterbodies in the region. For these reasons the probability of largemouth bass spreading in the regions that they are already found is very high (Vancouver Island and Lower Mainland) and high (Thomson and Columbia; Table 4.3).

4.4.3 Final rating: widespread establishment of largemouth bass.

Table 4.3. The probability of arrival, survival and reproduction, spread, and widespread establishment once arrived (WEOA) of the largemouth bass in the eight regions of British Columbia with the associated uncertainties. 'A' indicates that the bass has already arrived in the region.

	Vancouver Island		Lower Mainland		Upper Fraser		Thompson		Columbia		Arctic Drainage		Central Coast		North Coast	
Element	Prob	Unc	Prob	Unc	Prob	Unc	Prob	Unc	Prob	Unc	Prob	Unc	Prob	Unc	Prob	Unc
Arrival	A	A	A	A	H	L	A	A	A	A	VL	H	L	M	L	M
Survival & Repro	H	L	VH	VL	M	H	H	M	M	M	VL	M	L	H	L	H
Spread	VH	L	VH	VL	H	L	H	L	H	VL	L	H	L	M	L	M
WEOA	VH	L	VH	VL	H	H	H	M	H	M	L	H	L	H	L	H

4.4.4 The ecological impact on native ecosystems locally and within the region.

The largemouth bass is a voracious, mainly piscivorous yet opportunistic littoral predator and it has been calculated to require 4 kg of food to produce 1 kg of fish (3.5:1 in smallmouth bass; Scott and Crossman 1973). There is a vast amount of evidence that shows that lakes where largemouth bass exist there are local extinctions of small prey fish, primarily cyprinids. In small temperate lakes of the Adirondacks with top piscivores dominated by introduced species such as largemouth bass, smallmouth bass, and northern pike, the native minnow richness (diversity) was reduced by two thirds from those lakes without piscivores (Findlay et al. 2000). The average minnow richness also varied with the number of predators present. Creek chub (*Semotilus atromaculatus*), blacknose dace (*Rhinichthys atratulus*), northern redbelly dace (*Phoxinus eos*), and common shiner were less likely to be present in lakes with predators present, and the same may be true for pearl dace (*Semotilus margarita*), although the evidence is not as strong. Only 2 of the 13 species of minnows appeared to not be affected by the piscivore presence, and both were introduced species.

In small lakes of Alberta, predation is a major factor determining fish communities with lakes containing piscivores having reduced minnow diversity (Robinson and Tonn 1989). In northern Wisconsin lakes, minnows were either absent or their abundance was low in lakes with littoral piscivores, including centrarchids and pike (Tonn and Magnuson 1982). In those lakes where winterkill excluded northern pike and centrarchids, the minnows and mudminnows were common. In the 1930s, the diversity of minnows in Adirondack lakes to which bass (*Micropterus* spp.) were absent was much greater than in those lakes where bass had been introduced (Findlay et al. 2000). In Japanese farm ponds (some of which are hundreds of years old) that had been invaded by largemouth bass and bluegill sunfish the mean number of native fish species was three times lower than in ponds without the exotic fish (Yonekura et al. 2004). For the remaining native fish species, their abundance was much lower than in uninvaded ponds. In fact, in ponds with both largemouth bass and bluegill, no other fish species existed.

In surveys of over 190 northeastern United States lakes, lakes with *Micropterus* species were most likely to have the greatest reduction in native species richness (Whittier et al. 1997; Whittier and Kincaid 1999). They also noted that minnow species declined with increased human activity even in the absence of predators. They suggested that the decline was due to the destruction of the littoral habitat including removal of submerged logs and aquatic plants (Whittier et al. 1997). This suggests that in lakes with both introduced predators and habitat alterations native fishes would likely experience a larger impact from predators due to low prey refuges.

Predatory success decreases as habitat complexity increases, and Savino and Stein (1982) found that with high macrophyte density, predation success of largemouth bass on bluegill sunfish (*Lepomis macrochirus*) decreased to near zero. The bluegill is a fish that freezes and hides when it sees a predator and the reduction in predation success was likely due to decreased visual contact with the prey species under conditions of high macrophyte density. However, fathead minnows, an alternative prey fish, continued to move in the presence of largemouth bass and were not as protected from predation by the dense macrophyte beds (Savino and Stein 1989). This behavioural difference in the minnow (as well as not having a size refuge from predation) may explain why this species (and cyprinids in general) are more vulnerable to predation by largemouth bass than the bluegill (Takamura 2007).

A dome-shaped relationship was also found between the abundance of largemouth bass and the density of macrophytes in lakes (reviewed by Takamura 2007). The initial rise in the largemouth bass abundance with macrophyte density was suggested to be related to increased prey density. However, the decline in largemouth bass abundance (or productivity) at higher macrophyte density was found to be due to the increased refuges for prey. This suggests that the impact of largemouth bass predation is likely to be highest for those lakes with moderate human impact due to habitat alteration in the littoral zone.

In addition to the local extinctions of littoral prey fish, in many areas of Washington, largemouth bass have been found to prey on salmonids (Wydoski and Whitney 2003). In Lake Sammamish the diet of largemouth bass was 42% salmonids. Other prey included sculpins (15%), crayfish (5%), and other fish species (23%). In a shallow lake system in Oregon, the introduction of largemouth bass in 1971 reduced levels of coho salmon for the next 15 years (Reimers 1989 as in Bonar et al. 2005). Natural production of coho salmon in this system became isolated to the streams because of bass predation in the lake. Bonar et al. (2005) examined the diet of 10 introduced species in three shallow lakes in the Pacific Northwest that provided rearing environment for wild coho (*O. kisutch*), and found that largemouth bass were responsible for 98% of the predation on coho. Predation impacts to coho salmon appeared greater when a small run of salmon passed through a lake with a large littoral area and many largemouth bass, compared to the case with a large run passing through a small lake. Very few salmon were eaten by the other introduced species. Juvenile coho salmon growth in the lake was higher than in the neighbouring streams leading Bonar et al. (2005) to conclude that the introduced species did not compete with coho for food enough to limit their growth. However, coho in lakes are often larger than in streams.

In Lake Washington, in the late 1960s salmonids were found to make up 14% of the diet of largemouth bass (Wydoski and Whitney 2003). Sculpins made up the largest portion of the largemouth bass diet (45% by volume), and crayfish and other crustaceans (25.6%), minnows (mainly peamouth and northern pikeminnow; 12%) and insects (0.6%) were also consumed.

Stocking programs for trout fry in small and medium sized western Washington lakes that contained largemouth bass failed to produce sport fisheries (Bonar et al. 2005). When the lakes were stocked with trout > 150 mm, the programs were more successful since the trout were large enough to escape predation. In some Washington lakes trout can co-occur with largemouth bass due to habitat segregation (Wydoski and Whitney 2003). The trout are found in deeper water below the thermocline where the temperature is more suitable in summer, while largemouth bass are restricted to the warmer littoral zone. A similar result was found for deep systems such as the Columbia River Reservoir and Lake Washington – salmon were able to avoid predation due to spatial separation of the largemouth bass and the juvenile salmon (Bonar et al. 2005). The reduction in the amount of littoral zone habitat to support largemouth bass populations in these deeper systems may also have had an effect. Therefore, it appears that the risk of largemouth bass to salmonid and trout populations is higher in small lakes than in larger lakes or rivers.

Largemouth bass predation can also have an impact on other trophic levels besides preyfish (Mittelbach et al. 1995). In a Michigan lake where the top predator, largemouth bass was eradicated in 1978 and then reintroduced in 1986, several changes in the community occurred. Once the predator was reintroduced, the bass population increased, planktivore numbers decreased by two orders of magnitude, large zooplankton, including the cladoceran (water flea) *Daphnia* began to dominate the zooplankton, and the small-bodied cladocerans virtually disappeared. Total zooplankton biomass increased 10 fold and water clarity increased (due to the decrease in phytoplankton density). In another whole-lake manipulation study similar results were found (Carpenter et al. 1987). With the reintroduction of largemouth bass and a manual reduction in planktivore numbers there was an increase in zooplankton biomass, with a shift from a copepod/rotifer assemblage to a cladoceran assemblage. There was also a reduction in algal biomass and a continuous decline in primary productivity. In these reintroduction experiments species extinctions did not occur, likely because the species that existed were accustomed to coexistence with the largemouth bass.

Thus, there is a large body of evidence that the introduction of top predators such as largemouth bass puts native minnow populations at high extinction risk and can cause other alterations to the ecosystem, especially in small lakes that were the subject of the afore-mentioned studies. The introduction of the largemouth bass to lakes (especially small temperate ones) in British Columbia represents a very high probability of ecological impact for small native (especially soft-finned) fish species. The uncertainty for this is low due to the large amount of evidence from areas outside of BC. The impact is likely to be highest for those lakes or other water bodies with moderate human impact due to habitat alteration in the littoral zone, including the Lower Mainland, Vancouver Island, Thompson, and Upper Fraser Regions. The impact is also likely to be lower for large water bodies. Findlay et al. (2000) suggest that there may be an effect of low habitat heterogeneity increasing vulnerability to predation in the smaller lakes. As well, large largemouth bass do poorly in large oligotrophic lakes in BC so their ecological impact in those types of lakes would be lower (McPhail 2007). Therefore, the ecological impact in large lakes is considered to be moderate, however, the degree of uncertainty is high.

Kootenay Lake is a large oligotrophic lake in BC and has largemouth bass although the numbers are very low (Jeff Burrows, BC Ministry of Environment, Fish and Wildlife Branch, Kootenay Region, personal communication). Most of the lake is unsuitable habitat for bass, being deep pelagic and cold. They can however be found in the protected bays where shallower warm water exist. Because of their rarity, they appear to have a very low impact on fish and other trophic levels as a result of predation and competition.

4.4.5 Genetic impacts on local self-sustaining stocks or populations.

In Japanese freshwaters largemouth bass hybridize with a subspecies of the largemouth bass, the Florida bass (*M. floridanus*; Takamura 2007). This species does not exist in BC and is not native to BC (Scott and Crossman 1973) and so hybridization with it does not pose a genetic risk to native populations. The largemouth bass in the wild is not known to hybridize with any species that is native to British Columbia. In fact, all centrarchids (sunfish, bass, and crappie) in BC are introduced because tectonic and glacial onset eliminated the ancient ones from northwest of North America (McPhail 2007). Therefore the magnitude of the genetic impact of largemouth bass on native populations is very low with a low degree of uncertainty.

4.4.6 Final rating: ecological and genetic consequences.

Table 4.4. The magnitude of the ecological and genetic consequences and the related uncertainties for introduced largemouth bass in British Columbia.

	British Columbia	
Element	Magnitude	Uncertainty
Ecological Consequence: Small Water Bodies	Very High	Low
Ecological Consequence: Large Water Bodies	Moderate	High
Genetic Consequence	Very Low	Low

4.4.7 Estimating aquatic risk potential for largemouth bass.

The summary ranks for the probability of widespread establishment (introduction, survival, reproduction, and spread; Table 4.3) and the ecological and genetic consequences (Table 4.4) are combined in the following tables to obtain an overall risk rating (Table 5a, 5b, and 5c).

Table 4.5a: Matrix for determining overall ecological risk for small water bodies, where green indicates low risk, yellow indicates moderate risk, and the red region represents the conditions for a high risk designation. The size of the ellipse represents the amount of uncertainty.

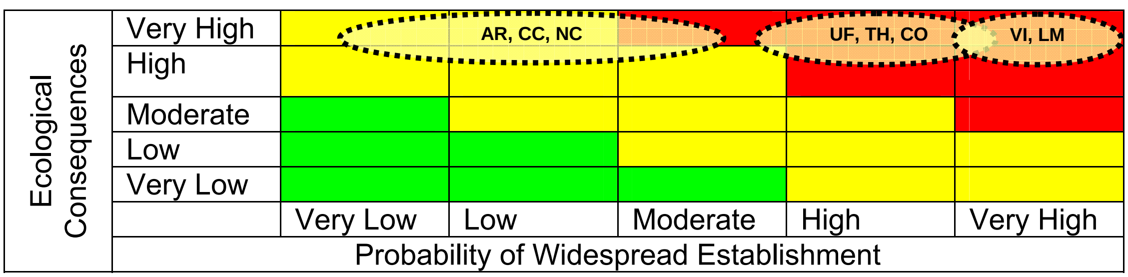


Table 4.5b: Matrix for determining overall ecological risk for large water bodies, where green indicates low risk, yellow indicates moderate risk, and the red region represents the conditions for a high risk designation. The size of the ellipse represents the amount of uncertainty.

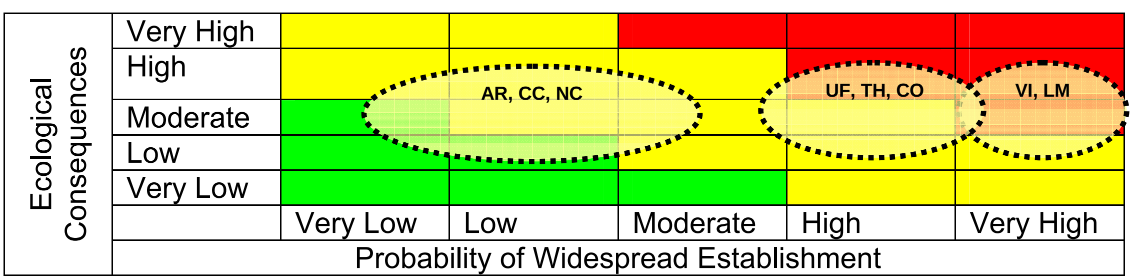


Table 4.6: Matrix for determining overall genetic risk, where green indicates low risk, yellow indicates moderate risk, and the red region represents the conditions for a high risk designation. The size of the ellipse represents the amount of uncertainty.

Genetic Consequences	Very High					
	High					
	Moderate					
	Low					
	Very Low		AR, CC, NC		UF, TH, CO	VI, LM
		Very Low	Low	Moderate	High	Very High
		Probability of Widespread Establishment				

4.5 PATHOGEN, PARASITE, OR FELLOW TRAVELER ECOLOGICAL AND GENETIC RISK ASSESSMENT

4.5.1 The probability that a pathogen, parasite, or fellow traveler may be introduced along with the potential invasive species and become established.

The primary mode of introduction of largemouth bass into new water bodies in British Columbia results from unauthorized introductions from nearby water bodies. With this method of introduction, the largemouth bass that are transferred are likely to take with them pathogens, parasites or other fellow travelers that already exist in BC. There are no published reports of specific outbreaks of disease caused by the introduction of largemouth bass in BC. There may be a risk of fellow travelers being brought along with the largemouth bass used for unauthorized introductions; however, this has not been documented.

The potential future distribution of the largemouth bass identified above (Figure 4.2) was based on growing degree-days. It is likely that the conditions that would support the largemouth bass would also support the common parasites that largemouth bass carry, which are known to be numerous. Thus, if there were introductions of largemouth bass into BC water bodies from sources inside or outside of BC, then there would be potential for the viability of the parasites, pathogens, and/or fellow travelers. Whether a parasite or pathogen carried along with largemouth bass would be able to infect native species depends on the life history and host specificity of the parasite or pathogen. The information on this specific to largemouth bass is not available at this time. The probability of establishment of parasites, pathogens, or fellow travelers of introduced largemouth bass therefore is moderate with a high degree of uncertainty.

Table 4.6. Probability and uncertainty for the establishment of parasites, pathogens, and/or fellow travelers from introduced largemouth bass in British Columbia.

	British Columbia	
Element	Probability	Uncertainty
Establishment	Moderate	High

4.5.2 The ecological and genetic impacts of pathogens, parasites, and fellow travelers on native ecosystems both locally and within the region.

It is not known which parasites the largemouth bass that are introduced into BC are carrying and which would have other hosts that are native to BC. Thus, the ecological impacts of these parasites are likely varied and difficult to quantify. The largemouth bass virus (LMBV) is at times fatal to the bass. It has been shown to be carried by other centrarchids and chain pickering, however, not cause disease in those species. None of these species is native to BC and so LMBV does not appear to cause an ecological impact to native populations. As well, the virus is currently found only in the eastern part of North America. However, it is possible that if LMBV is transported to BC that it may be able to infect native species, as was suggested by the reproduction in cell lines of salmonids and cyprinids (see above). However, it is unlikely that infection with the virus would result in disease in the native species as no species other than largemouth bass has become diseased through infection.

Since there has been no literature on disease outbreaks in BC from any of the parasites, the ecological impact that they would have is likely low (because native species may sometimes be impacted by the parasites). The uncertainty is high as the impact is only plausible based on the absence of literature on the topic. The magnitude of the genetic impact of these parasites is low as native species of parasites may sometimes be impacted by the parasites. The uncertainty is very high as there is little information to guide the assessment.

Table 4.7. Estimated ecological and genetic consequences of the introduction of parasites, pathogens, or fellow travelers from introduced largemouth bass populations.

	British Columbia	
Risk Component	Magnitude	Uncertainty
Ecological	Low	High
Genetic	Low	Very High

4.5.3 Aquatic Risk Potential for Pathogen, parasite or fellow traveler.

The summary ranks for the probability of widespread establishment (Table 4.6) and the ecological and genetic consequences (Table 4.7) of parasites, pathogens, and/or fellow travelers of largemouth bass are combined in the following table to obtain an overall risk rating (Table 4.8).

Table 4.8: Matrix for determining overall risk of pathogens, parasites, and/or fellow travelers of largemouth bass. Green indicates low risk, yellow indicates moderate risk, and the red region represents the conditions for a high risk designation. The solid ellipse represents the ecological and genetic consequences of establishment.

Ecological or Genetic Consequences						
	Very High					
	High					
	Medium					
	Low					
	Very Low					
		Very Low	Low	Moderate	High	Very High
	Probability of Widespread Establishment					

5.0 CONCLUSIONS

Smallmouth and largemouth bass represent a significant risk to native biota in British Columbia. With their adaptability they have a potential to spread by natural and human activities and there is a significant likelihood of these fish becoming widespread in British Columbia. The basses can have large impacts on native biota in small lakes and thus were considered to be of very high risk. Their impact in large lakes may be lower as they are usually limited to the littoral zone, although localized effects may occur. There is considerable uncertainty about their impact in large water bodies.

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