A Preliminary Assessment of Smallmouth Bass in the Beaver Creek System, 2007 - 2008

Final reporting requirements of HCTF Project File 5-211: Assessment and control of invasive smallmouth bass in the Beaver Creek / Quesnel River watersheds

Prepared by
Lita Gomez M.Sc. , Project Biologist, BC Conservation Foundation

Tom Wilkinson, Fisheries Biologist, Fish and Wildlife Branch

Ministry of Environment
Cariboo Region
400-640 Borland
Williams Lake, BC

November 26th, 2008

Habitat Conservation Trust Fund

BRITISH COLUMBIA The Best Place on Earth | Ministry of Environment

Acknowledgements

Thank you to the British Columbia Conservation Foundation and Conservation Corps., Northern Shuswap Tribal Council, Fisheries and Oceans, the Fisheries Department at the Williams Lake Ministry of Environment office and volunteers, for their assistance in the field and in the lab. This includes Cheryl Meshue and the Northern Shuswap Tribal Council Fisheries crew, Steve Ratko, Lisa Christie, Cathy MacPherson, Hayes Zirnhelt, Lynn Avis, Martin King, Allan Moreau, Devon Kvist, Mike Ramsay, Rob Dolighan, Skip Rimmer, Lee Williston, Cheryl Williston, Tyler Weir and Dan Lirette. Thank you to Tom Brown with the Department of Fisheries and Oceans, and the Pacific Biological Station Sclerochronology Lab for ageing the smallmouth bass. John Bell from the Ministry of Environment Kootenays, supplied quatrefoil traps. Scott Silvestri, Ministry of Environment Nanaimo, supplied length and weight data for smallmouth bass from lakes on Vancouver Island. The Ministry of Environment, Interior Region, provided ongoing support and advice: Steve Maricle, Linda Ritchie, Andrew Klassen, Dave Pehl and Tammy Kendall. Thank you to the Provincial Invasive Fish team for their overall support and help with the development of outreach materials. Provincial Invasive Aquatic Species Coordinators, Sue Pollard and Matthias Herborg provided guidance through the project. David Southgate with the Department of Fisheries and Oceans was a great help with outreach and coordination. Gord Sterritt (NSTC Fisheries Manager) ensured that First Nations participated in this project. Partnerships between the Ministry of Environment, the Northern Shuswap Tribal Council, British Columbia Conservation Foundation and Fisheries and Oceans Canada were supported by funding from the Habitat Conservation Trust Fund, the Pacific Salmon Foundation, Fraser Basin Council, BC Conservation Corp, Fisheries and Oceans Canada, Ministry of Environment and the Invasive Alien Species Partnership Program, a government of Canada initiative.

Habitat Conservation Trust Fund

Funding for this project was provided by HCTF

Table of Contents

List of Tables

List of Figures

Executive Summary

Smallmouth bass were illegally introduced to the Beaver Creek system approximately six years ago and currently occupy 55 km of the Beaver Creek system, from its confluence with the Quesnel River upstream through a chain of six lakes. Bass are efficient predators of other fish and can cause severe impacts on native aquatic communities and biodiversity (Brown et al., 2008). It is likely that bass will disperse from the system and will be illegally introduced to other systems. There are serious implications should the species become widely established in the Cariboo, considering the high annual value of recreational fisheries and the important First Nations and commercial salmon stocks.

The Ministry of Environment (Cariboo Region) has taken the lead on dealing with the Beaver Creek bass issue. Funding has been previously secured from several partners, including HCTF, and project implementation has been carried out by MOE, DFO, BC Conservation Foundation and Northern Shuswap Tribal Council Fisheries Crew. Provincial policy directs the Ministry to eradicate newly discovered populations of illegally introduced invasive fish when feasible. A leading North American expert in eradication methods conducted a site assessment and concluded that treatment of Beaver Creek with a piscicide is technically possible. The eradication program would require an assessment of technical, social and economic considerations and presently, no decision has been made regarding eradication. Since bass pose a very high risk to many systems in the Cariboo, the Ministry has submitted for funds that would allow efforts to control and contain the bass population to continue.

INTRODUCTION

Invasive species are recognized as the second greatest threat to biodiversity, after habitat loss (Wilcove et al., 1998). Invasive fish species have devastating impacts to ecosystems when introduced outside their native range. (MacRae and Jackson, 2001; Findlay et al., 2000; Lepak et al., 2006; Vander Zanden et al., 1999). Threats posed by invasive fish should illicit comparable attention to those posed by human disturbance. A quarter of fish in the western United States are non native, and invasive fish are present in twice as many fish bearing streams as streams classified as disturbed by human activities (Schade and Bonar, 2008).

After initial introductions by Government Agencies of non-native fish species in the early 1900's and subsequent illegal liberations, there has been an increasing awareness by fisheries managers of the lasting impacts that non-native fish have on native ecosystems. With this awareness comes a desire to minimize threats posed by non-native fish. In BC, the Ministry of Environment is developing a provincial approach for managing non-native fish and has recently developed policy to help better direct management actions (*Management of un-authorized introductions of non-native freshwater fish species* # 3-2-01.03). Fisheries and Oceans has assembled risk assessments and detailed synopses that address the distribution, natural history, use by humans and impacts associated with introductions for 7 invasive fish in BC.

In 2006, an invasive population of smallmouth bass (*Micropterus dolomieu)* was found in the Beaver Creek system, near Williams Lake BC (Figure 1). This was the first occurrence of invasive fish in the Cariboo Region and the Ministry of Environment played a key role in initiating a rapid-response to the issue. Specifically, the Ministry of Environment began to assess the ecology, identify effective control techniques and address the potential for illegal re-introductions through public education.

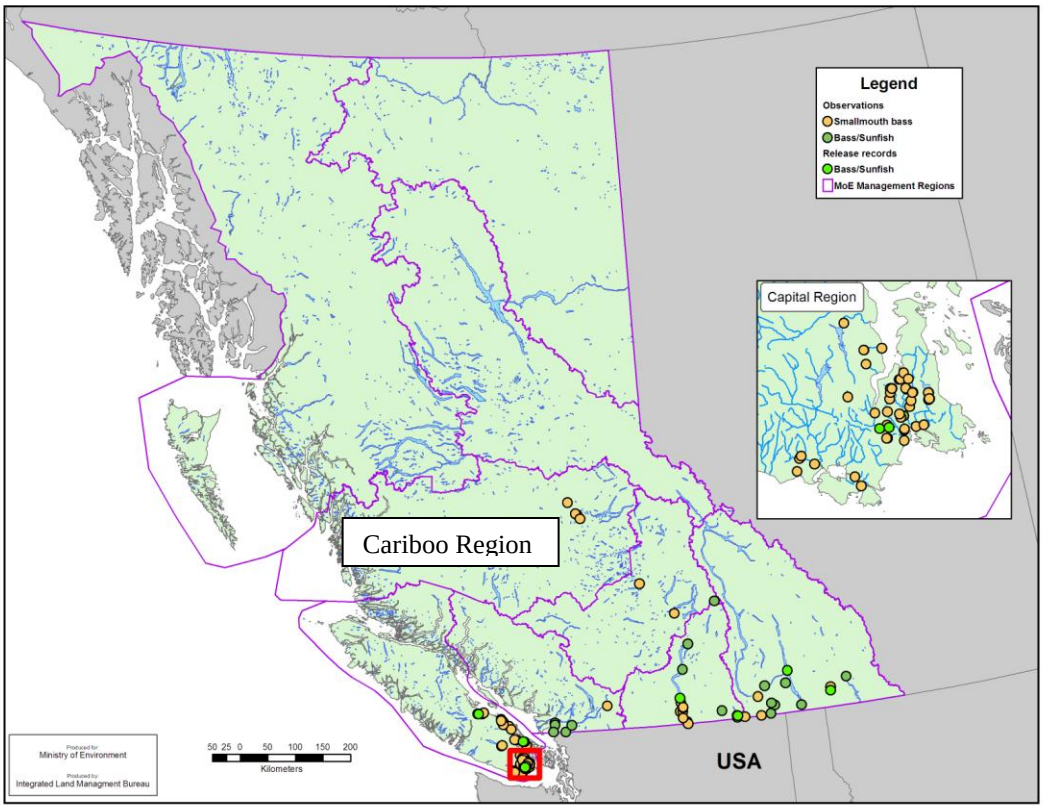

Figure 1. Locations of smallmouth bass in BC (yellow points) and Ministry of Environment regional boundaries (outlined in purple, Hatfield and Pollard, 2006).

The Beaver Creek system supports diverse fish and wildlife communities. The lower 29 kilometres of the system, known as the lower beaver valley corridor ecosystem, supports abundant fish and wildlife diversity including at least 7 blue listed and 1 red listed species. There is a clear appreciation by beaver valley residents, ranchers, woodlot licensees and guide outfitters for this unique ecosystem, the wildlife diversity and aesthetic qualities it supports (Zirnhelt and Case, 1998). One threatened fish species is known to occur in the Beaver Creek system (mid-Fraser River coho salmon (*Oncorhynchus kisutch*)).

The Quesnel River supports populations of rainbow, bull and lake trout, mountain whitefish, pink, sockeye, chinook and coho salmon and provides spawning habitat to some of the largest salmon runs in BC. The Quesnel River drains Quesnel Lake which supports a 1.5 million dollar per year recreational fishery and contains a genetically unique population of resident rainbow trout. The river has recently experienced a

significant increase in angling pressure and draws over half of its anglers from BC (Carlson et al., 2008).

Fisheries and Oceans conducted a risk assessment to assess the probability of bass establishment and to determine the impact of smallmouth bass once introduced, in terms of its ecological and genetic impact on existing aquatic communities risk and to the environment (Fisheries and Oceans, 2008). The magnitude of ecological consequences that smallmouth bass will have on small lakes (<1000 ha) was rated as very high. This rating indicates that extirpation of native populations is likely. Food webs will become highly altered or genetic exchange is likely to be widespread or seriously deleterious (Fisheries and Oceans, 2008). Smallmouth bass are known to consume salmonids; however, the impact of predation on salmon abundance remains unclear (*reviewed in* Brown et al., 2008).

Issue

Smallmouth bass (*Micropterus dolomieu*) are not native to British Columbia and have been illegally introduced to the Beaver Creek system near Williams Lake. Bass are a top predator: they prey on other fish and when introduced outside their native range can have devastating impacts on native biodiversity including sport, commercial and culturally important species. There is a high probability that once bass spread by natural dispersal and introduction by anglers they will become widely established in the Cariboo.

Objectives

The main objective of this two year preliminary assessment was to assess the scope of the issue, improve knowledge of the biodiversity in Beaver Creek, determine management options and implement short term measures to control / contain bass until and a long-term plan can be implemented.

METHODS

Distribution and dispersion

Angling and gillnet sets occurred throughout the smallmouth bass range and allowed a comparison of abundance as indexed by mean catch per unit effort (CPUE). Angling occurred throughout the summer and targeted habitat types known to be used by mature smallmouth bass. These habitats included gravel shoreline habitats, areas with submerged logs and wood debris and sheltered waters. Shoreline habitat was angled during early summer and deeper habitats were targeted later in the season. During the spawning season, shoreline habitat was surveyed for bass nests by a 2 person crew. One crew member operated the boat while the other scanned littoral habitat for nests. To maximize visibility of nests, most surveys occurred during calm weather conditions and both members wore polarized sunglasses. In 2007, nests were counted each time that they were found to have been reconstructed. In 2008, nests were marked with a unique identifier. Once a nest was detected, the crew would try to angle the male bass from the nest. Crews using seine nets and a backpack electrofisher successfully removed male bass guarding nests on several occasions, in 2008. Sediment was then kicked over the nests in an attempt to kill eggs / larva and prevent further nesting activity. Angler effort was measured as the amount of time spent angling. Angling and nest surveys occurred at the same time, therefore, angler effort had to be estimated as a portion of an angler day. It was estimated that approximately four hours were actually spent angling for each day that angling occurred. Gillnets were set for approximately 2 hour sets in 2007 and 2008. Gillnets were found to be ineffective at capturing bass due to the abundance non target species in 2007, therefore, fewer nets were set in 2008. In 2007, 46 sinking gillnets were set in six lakes. In 2008, eight floating gillnets and 14 sinking gillnets were set. In order to determine potential out-migration of bass from Beaver Creek, gill nets were drifted through the mouth pool (confluence with Quesnel River) and the 7 km falls pool on June 20, July 4 and July 11, 2008.

Targeted removal

Once it was determined that smallmouth bass were most abundant in Beaver Lake, other techniques, including destruction of nests, trapnets, seine nets, dip netting, quatrefoil larval traps, and minnow traps were used in an attempt to remove as many bass as possible. Three trapnets were set in Beaver Lake in 2007. In 2008, one trapnet was set at the trapnet site that caught the most bass in 2007.

In July 2008, crews observed a large number of young-of-the-year in Beaver Lake. Young typically were associated with structure (i.e. wood debris) in shallow areas which made netting the young particularly challenging. Nets set in areas with wood debris would allow the young to escape between the nets and debris. Young at one site; however, consistently aggregated in exposed shallow water (<1m depth). The only available cover was from a downed log in deeper water (>1m depth). A fine-sized mesh net was set along the lake bottom at this site 4 times in July and August, 2008. After approximately 1 hour, crews would lift each end of the net at the same time while bringing the catch to shore. Because aggregations of young were only visible during calm weather, and could only be netted in areas that lacked cover, the effectiveness of this technique was limited to a single location and 4 sampling events. Larva were also dip-netted from nests when possible. The number of larva removed per dip-netting event was extrapolated from counting a portion of the catch and estimated to be approximately 100 individuals per event.

Quatrefoil (light) traps have been used successfully to catch larval smallmouth bass in other systems (Bell, J pers. com.). Light traps are constructed from Plexiglas and Styrofoam floats. A single light stick, activated at dusk, is placed in the centre of the quatrefoil traps to attract larval fish over night. Traps are removed the following morning and checked for fish. Five light traps were set each night in Beaver Lake on June 26, 27 and July 9, 2008.

Twenty minnow traps were set three times in Beaver Lake in late June, 2008. Minnow traps were baited with cat food during the first 2 sets and with roe during the final set.

Biological characteristics

Smallmouth bass were retained for analysis of biological characteristics. Fork length and weight were measured, the condition of bass was calculated, diet composition was assessed and fish were identified as male or female. Otoliths and / or scales were collected from all smallmouth bass and the Pacific Biological Research Station sclerochronology lab used the burnt otolith section method to age a sample of smallmouth bass caught each year.

In order to assess how smallmouth bass were doing in the Beaver Creek system, the length at age and condition of bass from Beaver Creek were compared with data from populations in the United States and southern BC. Length at age was compared from a sample of bass aged by the Pacific Biological research Centre to bass from Lake Sammamish and Lake Whatcom, Washington (Brown et al. 2008). Length and weight data from smallmouth bass in 11 lakes on Vancouver Island were compared with data from bass captured from the Beaver system.

The average fork length of immature and mature bass (fork length >20cm) was compared between years. Because different techniques were used to capture immature bass between years, comparisons may be more a reflection of technique than of population characteristic.

Biodiversity

Sinking gillnets and electrofishing were used to sample many of the native fish species in the Beaver Creek system. The average catch per unit effort of gillnet sets was used as a rough indication of the relative abundance of each fish species in the lake. Limited effort was made in 2007 to catch mature burbot in Beaver Lake with 5 hoop traps. Electrofishing confirmed the presence of littoral species and young age classes and visual surveys were carried out to document spawning activity. Preliminary auditory surveys were carried out at the end of May, 2008 to document the presence of amphibians in the upper section of Beaver Creek.

RESULTS

Distribution and dispersion

In 2007, 66 smallmouth bass were angled and in 2008, 84 were angled from the Beaver Creek system. Bass were angled from three lakes: Lake George, Beaver Lake and Chambers Lake. The average catch per unit effort for smallmouth bass was highest in Beaver Lake in both years (Table 1).

Table 1. Catch per unit effort (±sd) of anglers on 7 lakes in the Beaver Creek system in 2007 and 2008.

	2007		2008	
Lake	**Average CPUE of bass (± sd)**	**Total angling hours**	**Average CPUE of bass (± sd)**	**Total angling hours**
Beaver	0.50 ± 0.58	103.08	1.03 ± 2.39	190.98
Chambers	0.00	16.00	0.07 ± 0.09	9.83
George	0.18 ± 0.37	23.42	0.00	8.00
Joan	0.00	8.00		
McCauley	0.00	8.16	0.00	18.50
Opheim	0.00	4.95	0.00	10.00
Robert	0.00	0.50	0.00	0.00

The first 2 bass caught in the system were by 2 anglers at the mouth of Beaver Creek in 2006. Since then, no smallmouth bass have been captured by crews angling on Beaver Creek. Seven and a half hours were spent angling from 7 km falls to the mouth of Beaver creek in 2008 and three and half were spent there in 2007. Beaver Creek was angled for 8 hours in 2007 and was not angled in 2008. No bass were caught in the gill net sets at the mouth (confluence with Quesnel River) or 7 km pool in 2008.

A total of 3083 fish were caught in gillnets in 2007 and 2008. Only twenty five of the fish caught were smallmouth bass. Other non-target species included suckers (LSU,CSU,SU), whitefish (MW), northern pike minnow (NSC), redside shiners (RSC), rainbow trout (RB), kokanee (KO) and peamouth chub (PPC, Table 2).

Table 2. Total number of fish caught in sinking gillnets set in seven Beaver Creek lakes in 2007 and 2008.

LSU	CSU	SU	WF	NSC	SMB	RSC	RB	KO	PPC
145	288	63	87	1017	25	29	135	21	1273

The CPUE of all fish species was greatest in Opheim Lake and lowest in McCauley Lake. Smallmouth bass were gillnetted from Beaver Lake and Opheim Lake and were most abundant in Beaver Lake (Table 3).

Table 3. Catch per unit effort of sinking gillnet samples taken from seven lakes in the Beaver Creek system in 2007 and in 2008.

Lake	# sets	Average set time (± sd)	Average CPUE of all fish (± sd)	Average CPUE of bass (± sd)
Beaver	25	2.20 ±0.85	22.36 ±25.62	0.40±0.51
Chambers	3	1.55 ±0.25	13.85 ±17.32	0
George	11	2.27 ±0.60	19.40 ±17.69	0
Joan	1	2.00	26.50	0
McCauley	8	1.80 ±0.81	3.09 ±2.01	0
Opheim	7	1.59 ±0.49	64.52 ±32.72	0.26±0.46
Robert	5	1.45 ±0.40	49.40 ±33.15	0

Targeted removal

The average distance of nests from shore was 4 m, the average depth was 83 cm and these values did not differ between years (Distance from shore: $W_{2,57} = 474$, P= 0.28; depth: $t_{82} = 1.1$, P = 0.28). In 2007, 70 nests (including nests that were reconstructed) were observed and 'destroyed' between June 1st and July 19th. Because nests were not marked in 2007, some were likely tallied several times. Most nests occurred in Beaver Lake (Beaver Lake: 61, Joan Lake: 1, Lake George: 7, Beaver Creek between Opheim and Chambers: 1). Eggs were found in 17 nests and no larva were found. In 2008, nests were individually marked and tallied only once. Forty two nests were found and 'destroyed' (41 in Beaver Lake, 1 in Lake George). Eggs were found in 15 of the nests (36%). Larva were observed for the first time in the system between June 19th and July 28th in 18 (43%) nests. Of the nests that were revisited after the nest had been 'destroyed', one still contained eggs and three still contained larva.

There was some evidence of other bass taking over nest sites once the original bass was removed. For two nests that contained eggs and the guarding bass were removed, another bass was seen near the nest again, but no new eggs had been laid. One nest never contained eggs, but a bass was observed actively guarding it. Attempts to remove larva from nests were never 100% effective. Subsequent surveys of these nests always yielded more larva.

In 2007, 27 smallmouth bass were caught in three trapnets in Beaver Lake. A single trapnet was set in 2008 at the trapnet site that caught the most bass in 2007 and only one smallmouth bass was caught. In 2007, 124 young of the year were electrofished from Beaver Lake, and five from Lake George. Due to equipment failure and subsequent shortage of availability, electrofishing in 2008 was limited and occurred only in Beaver Lake. Beaver Lake was electrofished three times and 23 young of the year were captured. In 2008, approximately 1000 young of the year were captured by seining and 700 by dip netting. Six northern pike minnow, four redside shiners and no smallmouth bass were captured in minnow traps and approximately 120 larval bass and four northern pike minnow were captured in light traps in 2008.

Biological characteristics

Biological data reflects the characteristics of the bass captured, not the characteristics of the bass population. The 2 most frequent size classes of bass captured in 2007 and in 2008 were 3-9 cm long and 23-34 cm long. The biggest bass captured was a female, 44 cm fork length and 1641 g. More males were captured than females in both years (*2007* females 44, males 87; *2008* females 56, males 64; $X^2_1 = 3.9$, P = 0.047); however, the sex of young was not determined. Stomach contents of the bass examined contained insects and fish and the smallest bass to consume another fish was 4.5 cm fork length.

In 2007, most of the mature bass that were aged were 3+ and in 2008, most were 4+ (Figure 2), indicating a strong brood year in 2004. A distinctive group of three bass were aged to be 10+. No bass in 2007 or 2008 were found in the 6, 7, 8 or 9 year classes. It is believed that the 10+ bass were part of the original illegal stocking which could have occurred in 2003; first major spawning by the illegally introduced bass appears to have

occurred in 2004. Age class 0+ and 1+ (Beaver Creek 3rd generation) in 2008 were likely offspring of the original introduction and age 3+ and 4+ second generation bass.

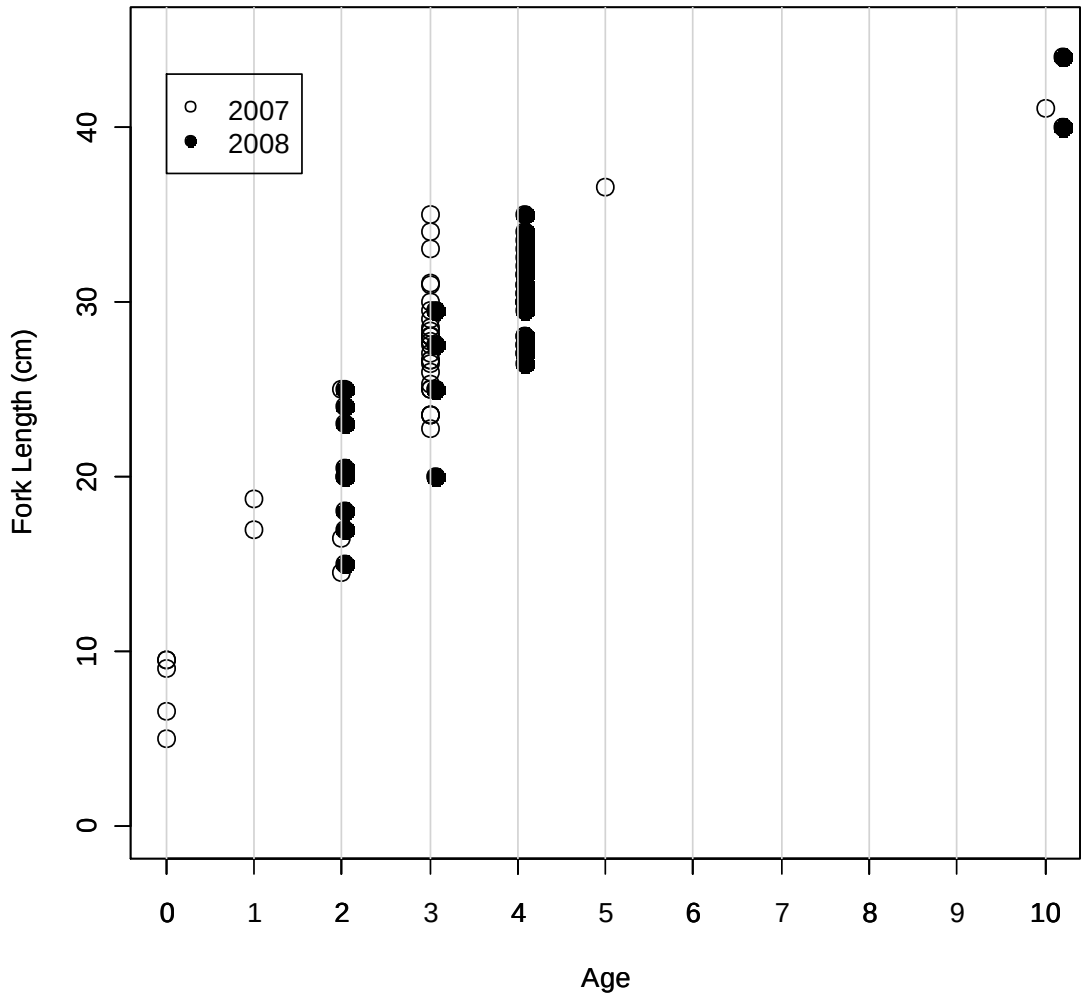

Figure 2. Length at age of a sample of smallmouth bass from Beaver Creek. Ages are in one year increments: 2008 data points have been offset slightly for visual purposes.

The length at age for a sub-sample of Beaver Creek bass was compared with data from smallmouth bass in Lake Sammamish and Lake Whatcom. Growth rates of smallmouth bass in Lake Sammamish were considered exceptional and growth rates of bass from Lake Whatcom were considered average (*reviewed in* Brown et al. 2008). Length at age for bass in Beaver Creek was consistent with data from other populations

(Figure 3).

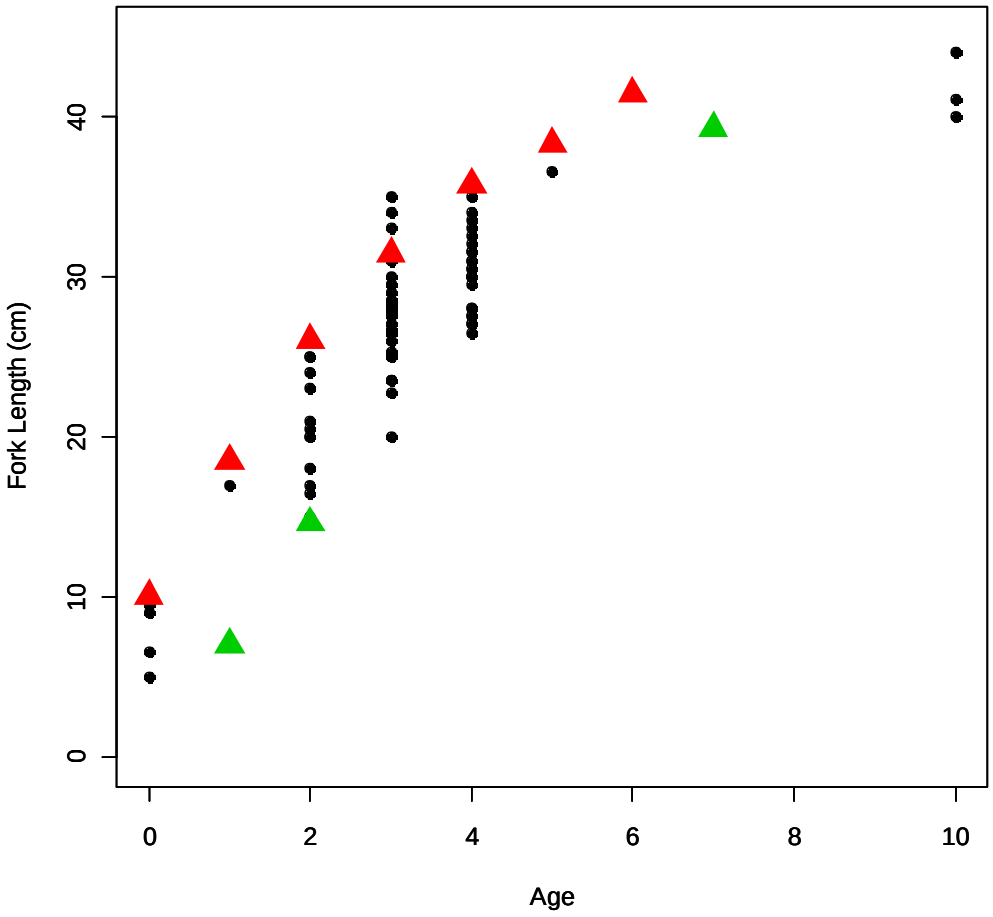

Figure 3. Length at age of a sample of smallmouth bass from Beaver Creek in 2007 and 2008, Lake Sammamish (red points) and Lake Whatcom (green points).

The length and weight data for Beaver Creek bass was compared with data from smallmouth bass in 11 Vancouver Island Lakes (Figure 4).

.

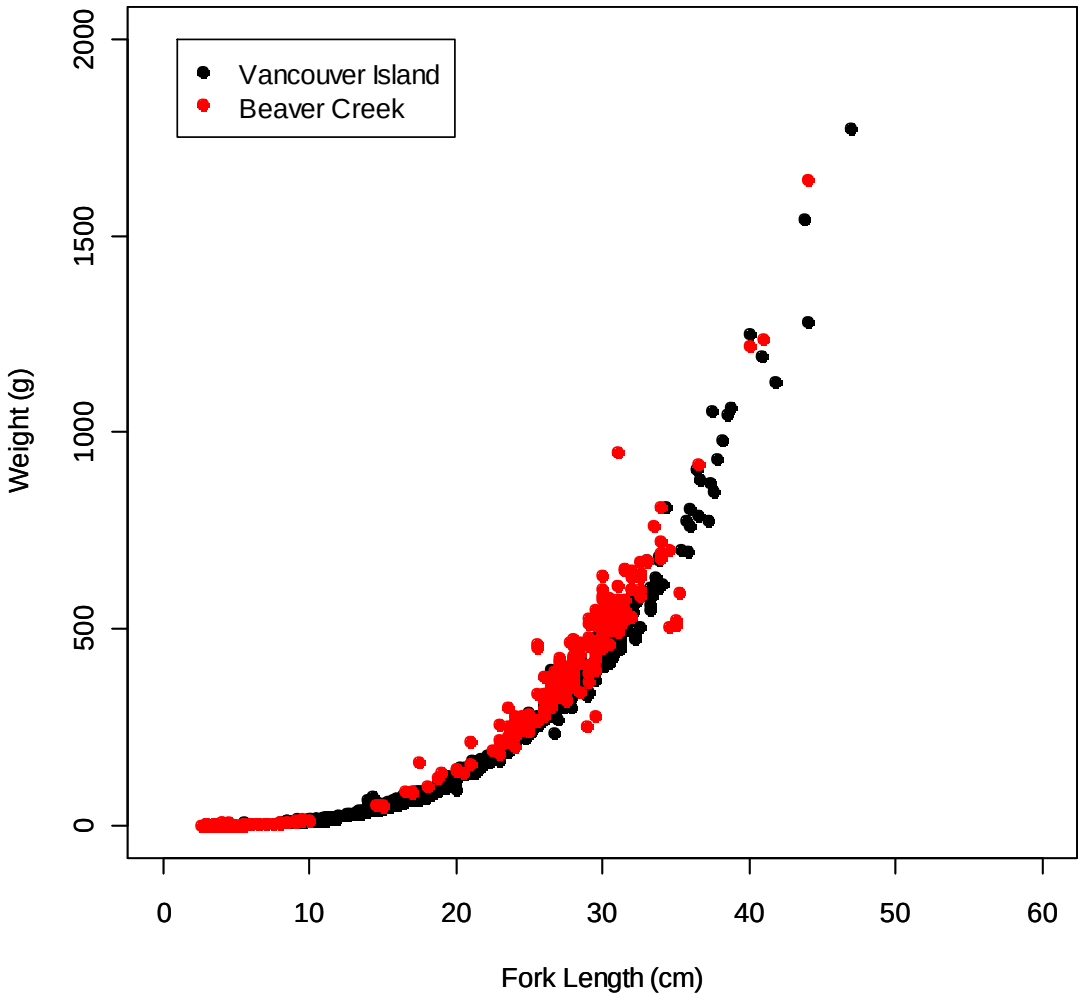

Figure 4. Length and weight relationship of smallmouth from Beaver Creek (red points) and from lakes on Vancouver Island.

Because only limited data from sub adult bass from Vancouver Island was available, the condition of mature (FL > 200mm) bass was compared between sites. The fitted regression lines suggest that mature smallmouth bass in the Beaver Creek system are of greater condition than mature bass from lakes on Vancouver Island (Figure 5).

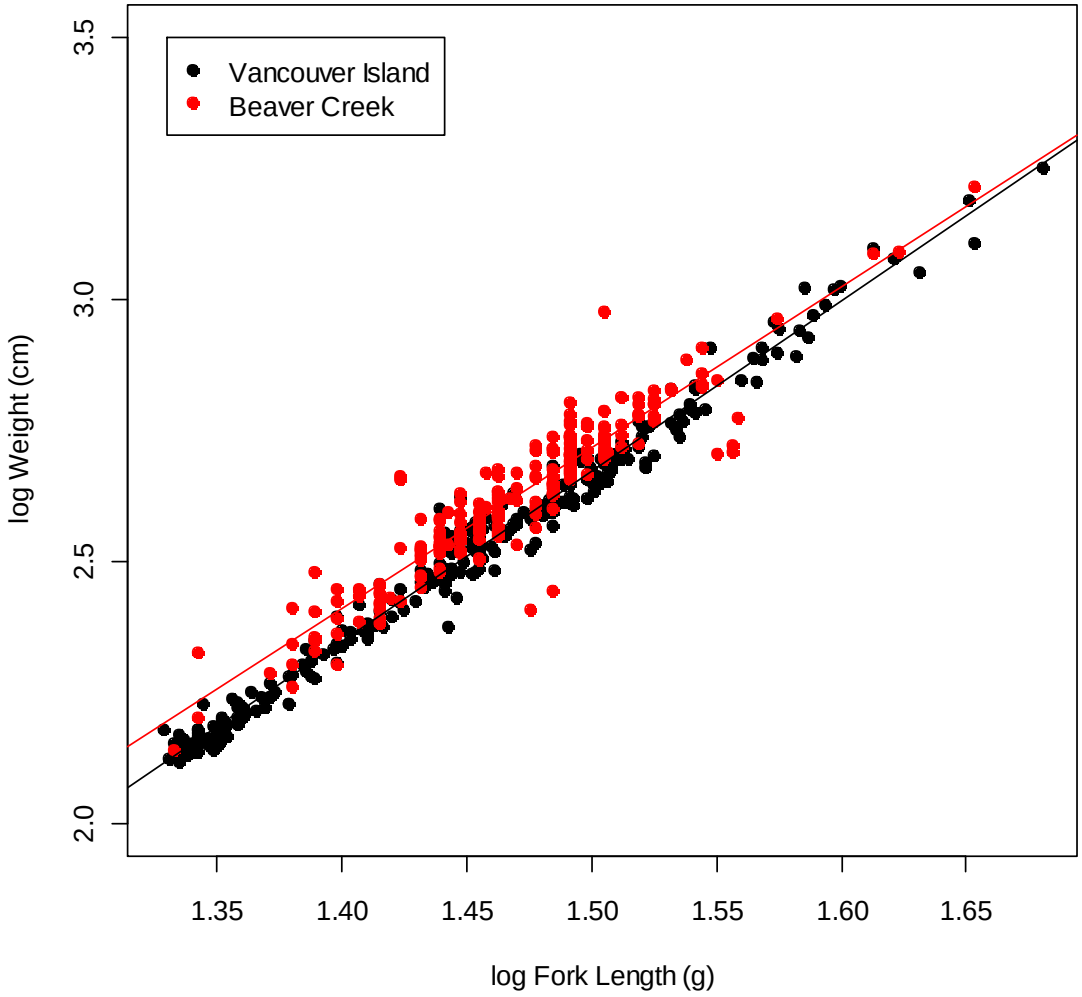

Figure 5. Condition of mature (FL>200mm) smallmouth bass from Beaver Creek (red points) and from lakes on Vancouver Island (black points).

The size of bass captured differed between years. From 2007 to 2008, the median fork length of immature bass went from 6.5 to 4.0 cm and the fork length of mature bass went from 27 to 30cm (*mature bass*: $W_{234} = 2808$, $P < 0.0001$, *immature bass*: $W_{237} = 9691.5$, $P<0.0001$). Larger, mature bass and smaller immature bass were caught in 2008 (Figure 6).

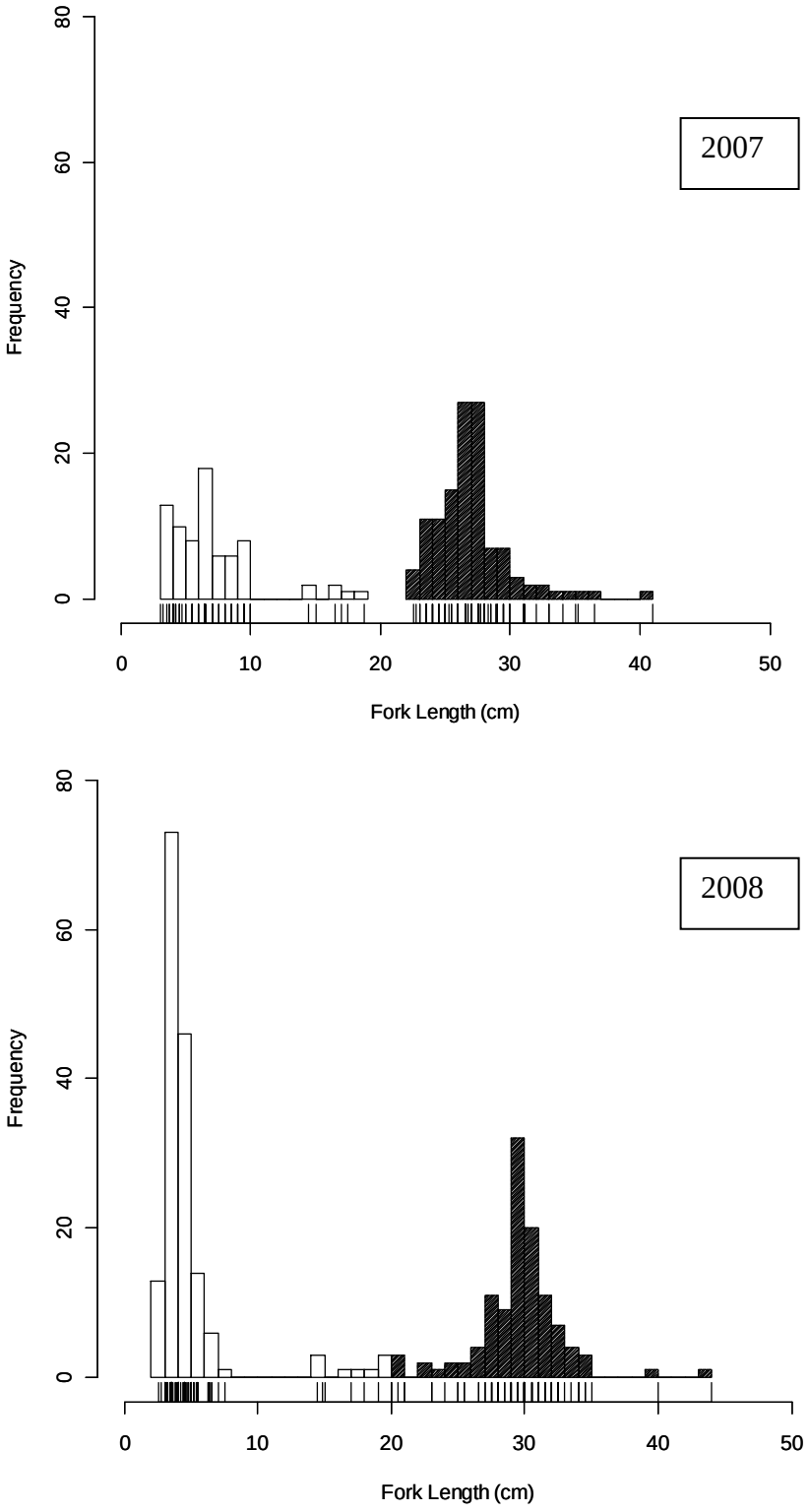

Figure 6. Fork length (cm) of mature smallmouth bass (hatched bars) and immature smallmouth bass (open bars) caught in 2007 and 2008 from Beaver Creek.

Biodiversity

A variety of native fish species were found in the Beaver Creek system including the redside shiner (*Richardsonius balteatus*), peamouth (*Mylocheilus caurinus*), longnose sucker (*Catostomus catostomus*) and largescale sucker (*Catostomus macrocheilus*), northern pikeminnow (*Ptycheilus oregonensis*), rainbow trout (*Oncorhynchus mykiss*), lake whitefish (*Coregonus clupeaformis*), burbot (*Lota lota*), and kokanee (*Oncorhynchus nerka*). A set of falls located approximately 7 km upstream from the confluence of Beaver Creek and the Quesnel River limits the upstream distribution of pink, chinook and coho salmon. The greatest catch per unit effort of any species was for peamouth chub in Roberts Lake and the lowest catch per unit effort for all species was in McCauley Lake (Figure 7). No mature burbot were caught in gillnets or in hoop traps.

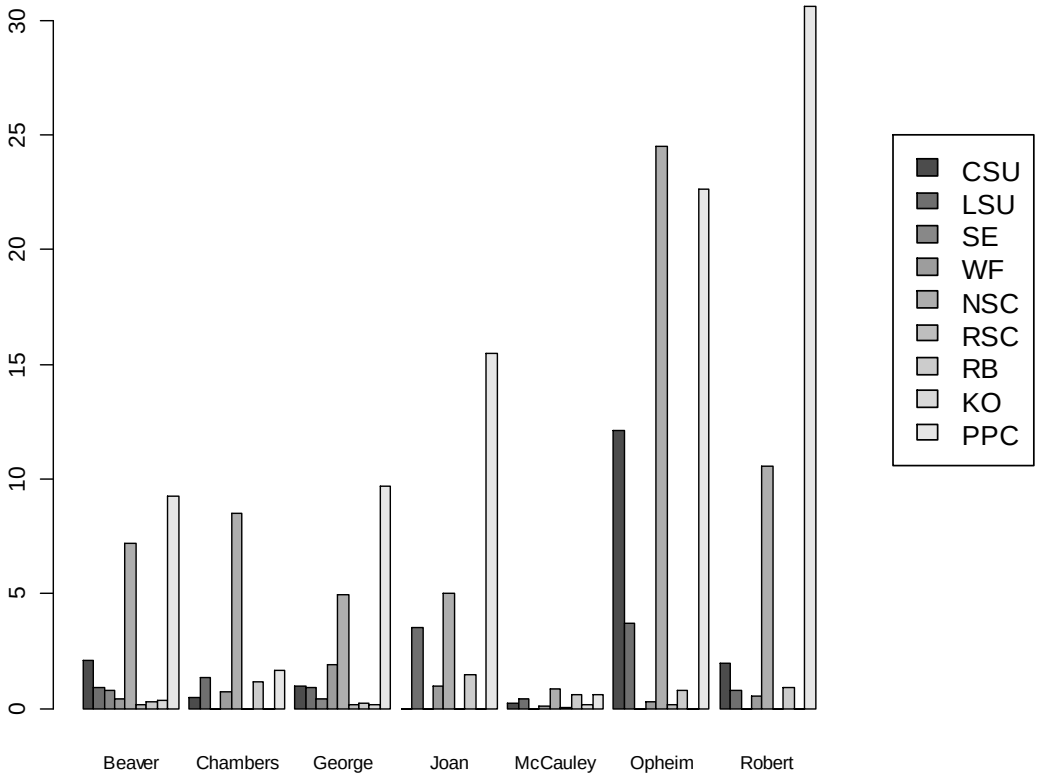

Figure 7. The average catch per unit effort of native fish species caught in sinking gillnets in 2007 and 2008.

Electrofishing was carried out at 12 locations in the Beaver Creek system and 12 species were detected (Table 4). Chinook salmon fry were fished from all areas below the 7 km falls (Figure 8: A-E). This indicates that adult chinook are able to move upstream of the small falls (Figure 8: C) located several kilometres up from the outlet of Beaver Creek.

Table 4. Total number of fish by species and location electrofished from the Beaver Creek system in 2007 and 2008. See Figure 8 for specific A-E site locations.

Location	L	LNC	CC	RB	CH	PPC	SU	CSU	BB	NSC	RSC	SMB
Beaver	0	0	0	0	0	2	15	3	40	33	89	147
Beaver Creek: above bridge, mouth (C)	1	0	0	1	28	0	6	0	0	1	2	0
Beaver Creek: below 7 km falls (D)	0	0	0	13	4	0	13	0	0	6	11	0
Beaver Creek: below bridge, mouth (B)	0	1	0	0	30	0	1	0	0	0	0	0
Beaver Falls (E)	0	0	0	5	3	0	4	2	0	3	16	0
Beaver Mouth (A)	4	24	5	5	37	0	7	0	0	0	1	0
Chambers	0	0	0	0	0	0	0	0	0	2	2	0
George	0	0	0	0	0	1	8	0	6	12	4	5
Joan	0	0	0	0	0	0	0	0	0	0	2	0
Opheim	0	0	0	0	0	0	4	0	16	1	0	0
Quesnel River	0	0	0	0	0	0	0	0	0	0	0	0
Robert	0	0	0	0	0	0	0	0	0	0	0	0
Grand Total	**5**	**25**	**5**	**24**	**102**	**3**	**58**	**5**	**62**	**58**	**127**	**152**

L=lamprey; LNC=longnose dace; CC=sculpins; RB=rainbow trout; PPC=peamouth chub; SU=sucker; CSU=large scale sucker; BB=burbot; NSC=northern pike minnow; SMB=smallmouth bass

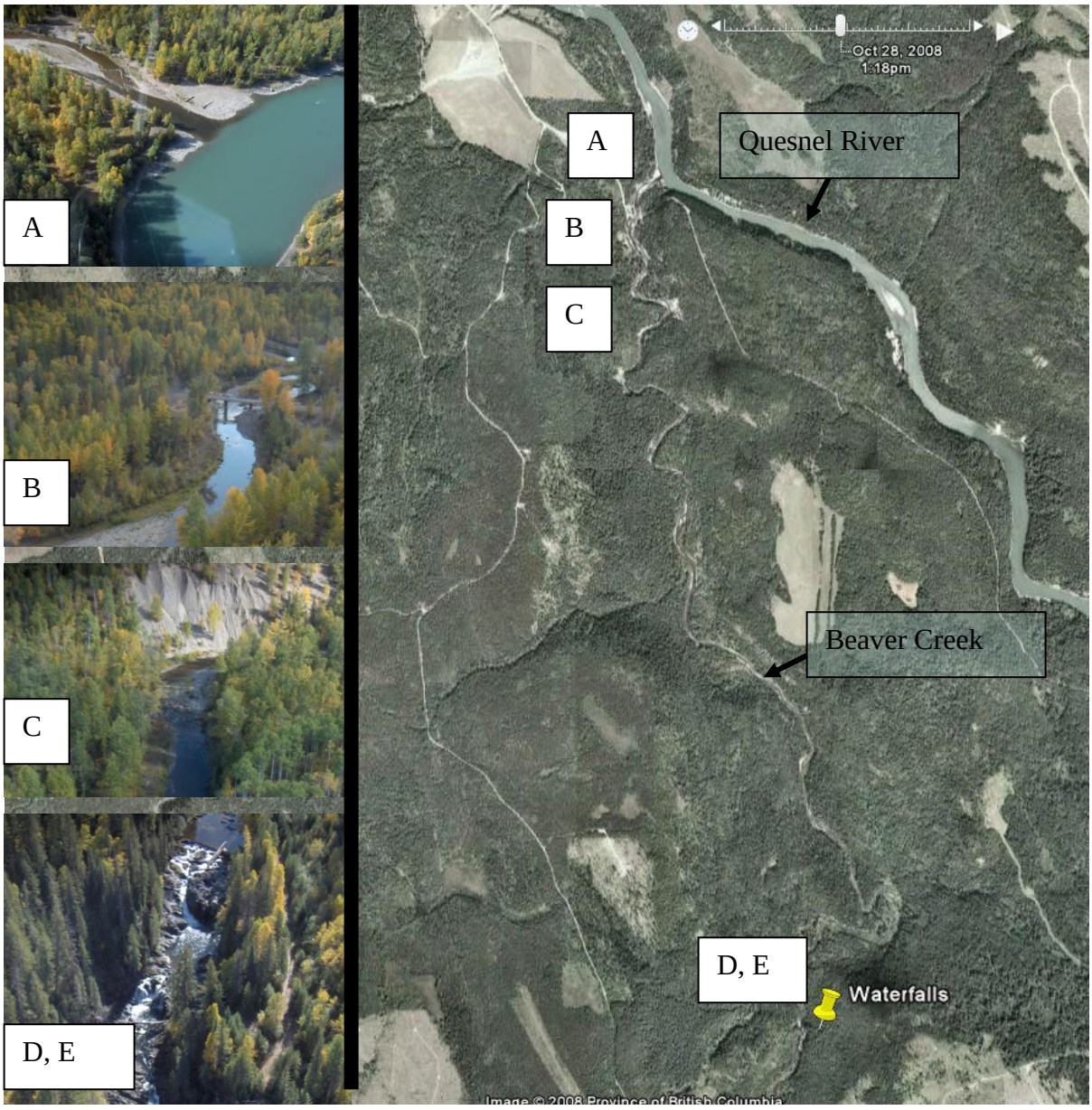

Figure 8. Locations of electrofishing in the lower reaches of Beaver Creek. Letters correspond with Table 4.

The lower reaches of Beaver Creek were visually surveyed several times during the fall of 2007. Pink salmon spawning activity was observed from the small set of falls (Figure 8, "C") down to the outlet at the Quesnel River on September 28th and October 3rd, 2007. Approximately 223 live pink salmon were tallied during the last survey. Kokanee spawning activity and reds were observed between Lake George and Beaver

Lake on September 24th, 2007. Amphibian species detected during auditory surveys included the western toad (*Bufo boreas*) and the pacific treefrog (*Hyla regilla*).

DISCUSSION

Results from this multi-year project have greatly improved our understanding of the issues and challenges that we can expect while managing this illegally-introduced population of smallmouth bass. We now have a better understanding of the scope of the issue, biodiversity in the Beaver Creek system, and potential impacts of control efforts on bass population growth.

The Beaver Creek system supports a substantial amount of diversity: 14 species of native fish and 2 species of amphibians were detected. More work is needed to document the diversity of amphibian species and the abundance of native fish in streams. For amphibians, auditory surveys should occur earlier in the year to detect the wood frog (*Rana sylvatica*) and time-constrained searches should also be carried out later in the summer. For streams, fish should be surveyed with minnow traps, and streams should be surveyed to identify spawning locations and number of spawners.

Smallmouth bass have been found in the mainstem Beaver Creek downstream of Lake George and are most abundant in Beaver Lake. Bass have not been found at the outlet since 2006 and more effort is needed in the future to monitor this area for out-migrants. It is expected that the relatively cold waters of the Quesnel River discourage bass from leaving Beaver Creek at times of the year. However, during the spring and fall, the temperatures of Beaver Creek and the Quesnel River are similar and there is no reason to believe that bass would not spread to other systems via the Quesnel River.

There are several possible explanations for the increase in young of the year observed in 2008. Fewer nests were found and destroyed in 2008 because they were harder to detect. Lake water appeared darker and nests were not cleared of as much sediment as they were in 2007. Thus, more eggs may have survived to hatch. More mature females spawned in 2008 than in 2007. Female bass typically mature at age 4+; in 2007, 34% of bass caught were female and the most frequent age class was 3+, in 2008, 47% of bass caught were female and the most frequent age class was 4+. Thus, there likely were more eggs fertilized in 2008 than in 2007.

Length at age data and condition values suggest that smallmouth bass are doing well in the Beaver Creek system. The population should be expected to increase until it reaches carrying capacity. Removing the standing crop of bass may do little to slow this increase. In fact, it may actually result in an increase in population growth rate, similar to the desired increase in sustained yield harvesting (Caughley and Sinclair, 1994). Even under intensive removal efforts, the number of young of the year can remain constant over time (Weidel et al. 2007) due to a release from competition (Zipkin et al., 2008).

Gillnets are not effective at removing bass because of non-target taxa. Less than one percent (25/3083) of the fish caught in sinking gillnets were smallmouth bass. Control efforts in the future should focus on removal of immature age classes to prevent overcompensation and gillnets should only be used as a means of assessing biodiversity of other fish species.

There are several techniques that might improve the capture success of young in the future. Additional minnow traps could be set at various times of the year with other types of bait (Region 3 suggests cheese strings). Traps constructed from mesh, rather than metal could be set. Larval traps should be picked up earlier in the morning: though larva were observed near one of the light traps at 10:00 am, no larva were in the trap. This could indicate that traps should be picked up earlier or that unless the trap is set directly on a nest, the light trap will not be effective. Finally, an electrofishing boat would significantly increase the number of young removed from the system (Weidel et al. 2007).

MANAGEMENT OPTIONS

Options to manage the population of smallmouth bass can be divided into three categories 1) long-term containment and control, 2) eradication with piscicide and 3) no action by government.

Long term containment and control

One of the first reactions from anyone that learns of an illegal introduction of invasive alien fish is to suggest possible measures to eliminate or reduce the population including biological and physical control activities. The Ministry of Environment carried out an assessment of options to control alien fish in BC and established that there currently are no developed methods for the biological control (species specific virus, introduction of predators, introduction of sterile fish, pheromones) of alien invasive fish in BC. Developing such methods would be costly and would not guarantee eradication of the population (Ritchie 2006).

Mechanical removal (nets, explosives, electricity, dewatering and increased angling pressure) is not effective at eradicating non-salmonids from large water bodies, but can be used to significantly reduce fish abundance. Intensive efforts over the past two years to remove northern pike from the Kootenay region were successful, likely because pike were detected soon after their introduction and had not become established. A suite of mechanical removal strategies, including, electrofishing, detonation cord and nets was unsuccessful at controlling an invasive population of northern pike in California. During three years of intensive removal efforts, the abundance of pike in Lake Davis increased (California Department of Fish and Game 2003).

Even in situations where mechanical removal appears to decrease the abundance of invasive fish populations, compensatory strategies, including higher fecundity at low population density, can produce a population made up of the youngest age classes (Zipkin 2008). The abundance of smallmouth bass in an Adirondack lake was reduced by 90% with a boat electroshocker during a 6 year study; however, the abundance of immature fish actually increased during that time.

The aim of a long term program to control the abundance of smallmouth bass in the Beaver Creek system would be to minimize the effect of smallmouth bass on native fish and to prevent range expansion. Actions and objectives to meet this goal include:

- Reduce the bass population by targeted removal of pre-reproductive age groups over a 5 year period to increase abundance of native littoral fish
- Assess the effectiveness of removal techniques by measuring the relationship that removing large numbers of bass from the system has on native fish abundance
- Minimize range expansion by removing smallmouth bass from the lower reaches of Beaver Creek
- Continue to monitor abundance and presence of native species in the Beaver Creek system

Whether this program is effective at minimizing range expansion depends on the age class of the dispersers. Mature smallmouth bass typically maintain constant home-ranges and exhibit fidelity to nest sites (Todd and Rabeni, 1989, Ridgeway et al. 1991). This could be tested in the Beaver Creek system using mark-recapture techniques and radio-telemetry to track the movements of both mature and immature age classes over time.

An intensive long-term program to control the abundance of bass and minimize the potential for range expansion would cost approximately $500,000 in the first year and $100,000+ each subsequent year. To be effective, the control program would require specific electrofishing equipment for all types of habitat (boat, barge, backpack) as well as helicopter or air boat access to remote areas. The project would have to continue indefinitely. Even with ongoing long term control activities, invasive fish may spread downstream and threaten native biodiversity, anadromous salmon stocks, First Nation, commercial and recreational values. In addition, the remaining bass in the Beaver Creek would provide a source for illegal transportation to adjacent waterbodies.

Funding for the program will require partnership agreements but, because of the high continuous cost and large initial outlay, the Provincial and Federal Governments will have to take a significant funding role.

Containment

Barriers have been successfully used to contain invasive fish (Ritchie, 2006). Smallmouth bass have been found throughout the Beaver Creek system upstream to Lake George. Several sub-drainages of the Beaver Creek system do not presently contain bass but are expected to be populated as bass spread upstream. To prevent upstream movement of bass, barriers should be installed at three key locations in the Beaver Creek watershed (Figure 9). These three portions of the watershed represent approximately 2/3^{rds} of the 1600 km^2 Beaver Creek watershed.

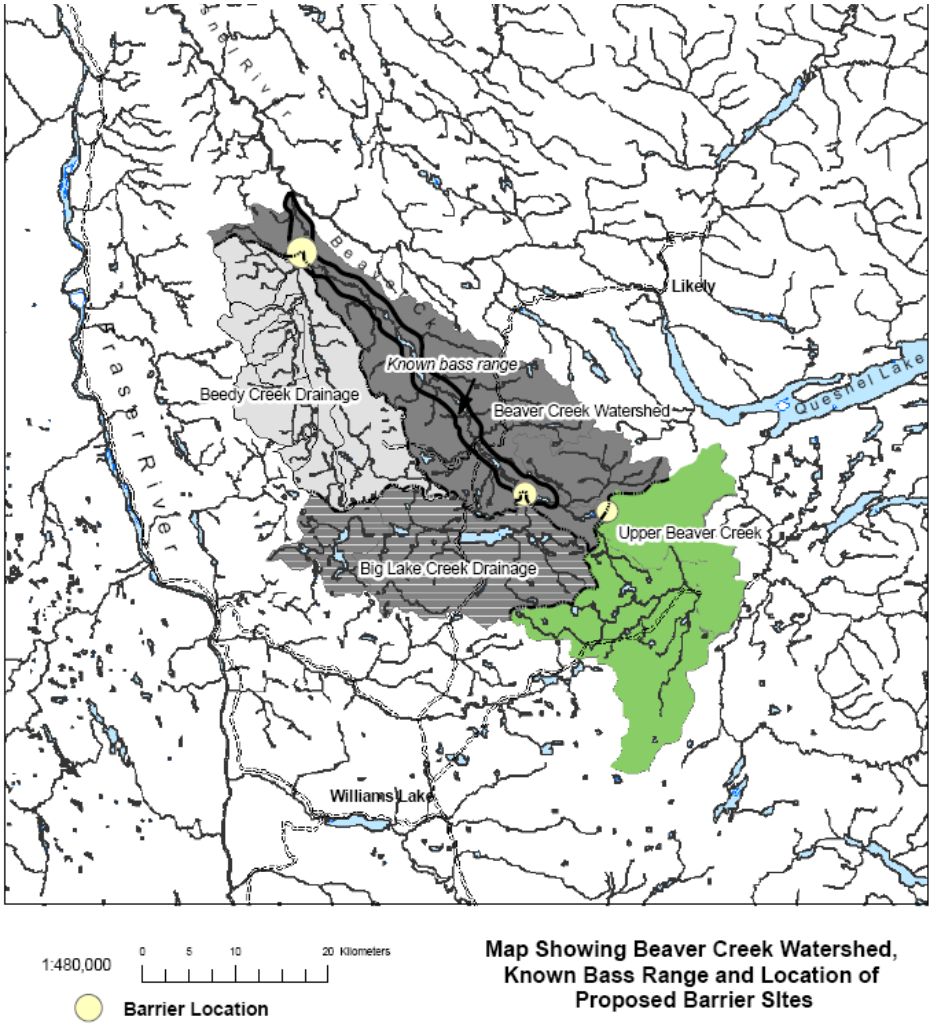

Figure 9. Proposed locations for in-stream barriers.

Preventing upstream movement of bass into these sections is vital to long term efforts to control / contain or eradicate bass in the Beaver Creek watersheds. Smallmouth bass are not aggressive swimmers and a structure with a jumping height of 46 cm will prevent upstream movement (B. Finlayson pers. com.). On the Beaver Creek system, the barriers would provide a vertical height of at least 50 cm to ensure upstream movement is stopped for all flow levels. An effective design (B. Finlayson, pers. com) is shown below (Figure 10).

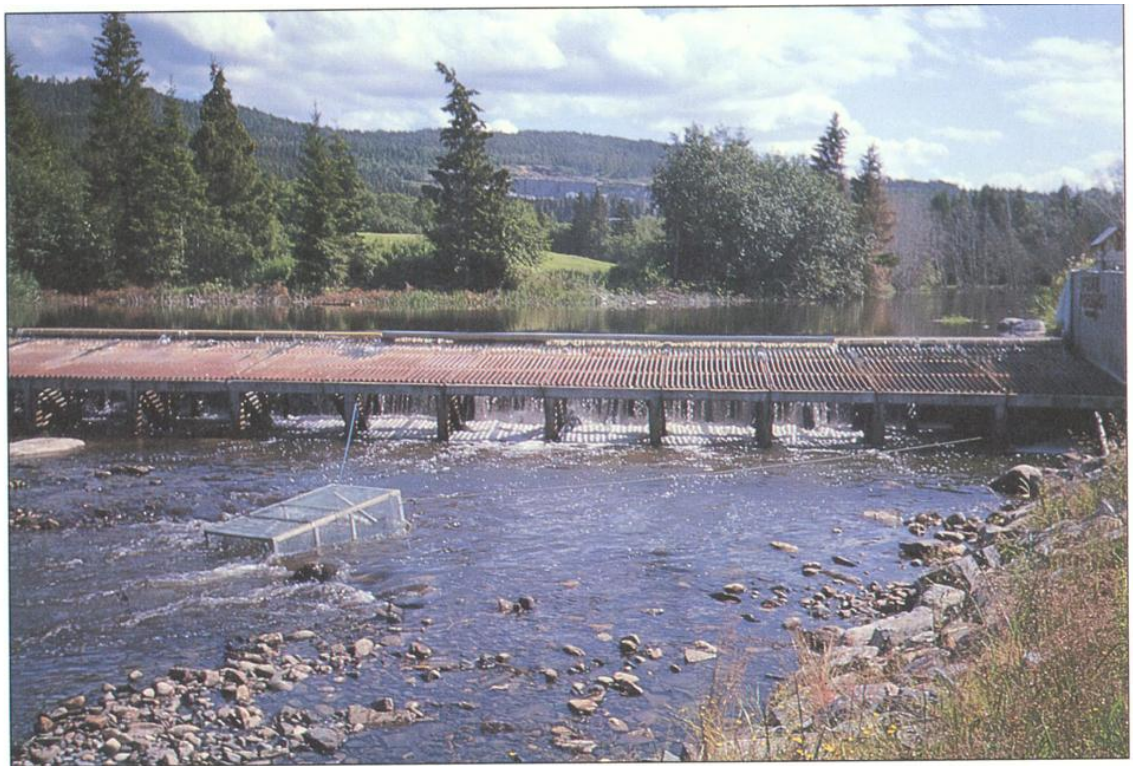

Figure 10. Potential design for in-stream barrier to prevent upstream movement of fish.

These barriers have been identified by the Ministry as a priority, especially at the location on Beaver Creek where low gradient and no natural obstructions allow for easy bass passage. Any increase in the range will require additional effort to deal with the Beaver bass population.

The effectiveness of barriers would be assessed by monitoring upstream waters for the presence of bass. Smaller tributaries, that presently contain an in-stream structure that will prevent upstream movement by bass, are shown below (Figure 11).

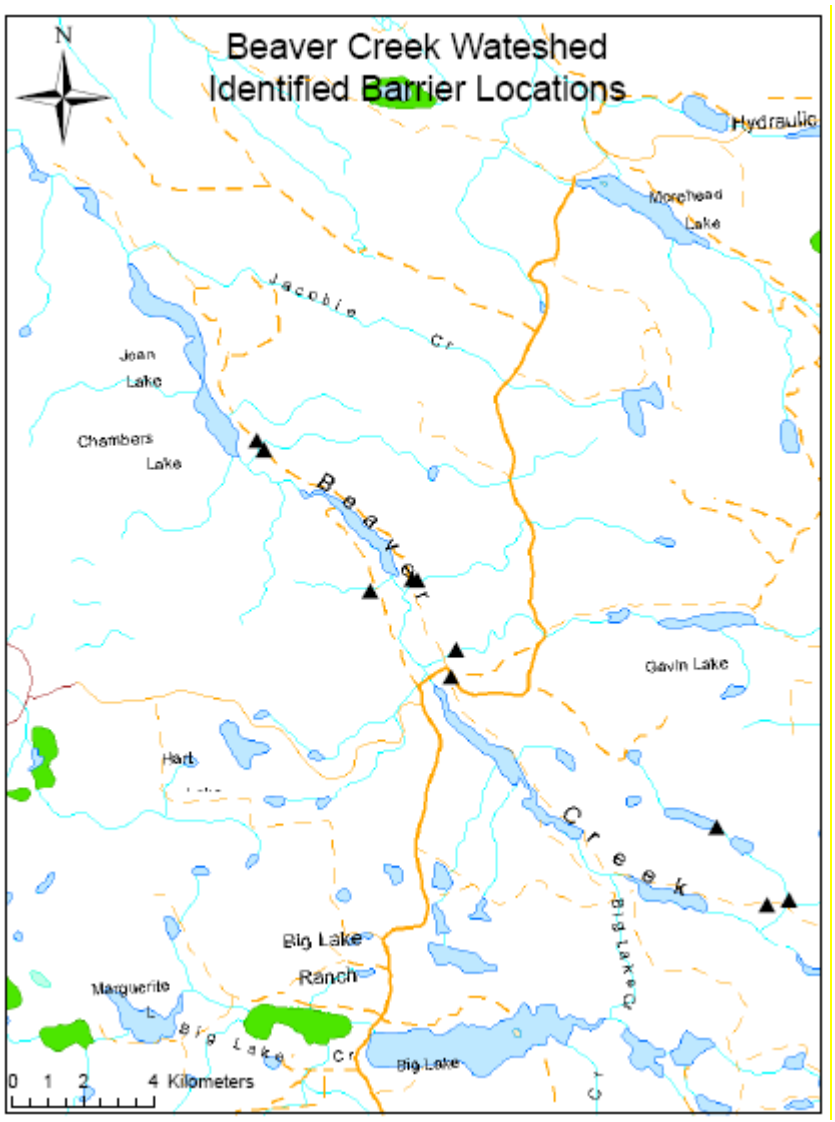

Figure 11. In-stream barriers that already occur in tributaries to the Beaver Creek system.

Downstream spread of bass to the Quesnel and Fraser River could impact salmonid populations (McPhail, 2007) and diverse fisheries values. Installation of an electric barrier at the outlet of Beaver Creek is not currently considered to be a feasible solution for preventing downstream range expansion due to high peak flows during spring runoff (Beaver Creek can reach peak flows of 60 m^3/sec). Lack of easily obtainable power at the mouth and high construction, maintenance and operation costs would require a substantial budget, yet not guarantee successful containment of bass in Beaver Creek. However, correspondence is ongoing with Smith-Root Inc. (a producer of

electric fish barriers) to obtain a formal assessment of the logistics of installing an electric fish barrier on Beaver Creek.

To minimize downstream range expansion, bass should be removed from the lower reaches of Beaver Creek using standard techniques (i.e. nets, electroshocker, angling). Nest surveys should be carried out during spawning season from 7 km falls downstream to the outlet (Figure 7 : *section* D,E *to section* A). If spawning activity is detected, efforts to remove sub-adults should be intensified (i.e. electrofisher boat nest destruction / removal).

Eradication with piscicide

To date, the only reliable method to completely eradicate smallmouth bass from the Beaver Creek system is with piscicide. There are numerous, long-term benefits associated with a chemical eradication program. Chemical eradication of an invasive fish population would remove the threat to salmon stocks and other fish species in the Quesnel and Fraser River watersheds and remove a potential source population for further, illegal introductions. Eradicating the population of bass would also remove the continuous threat to native biodiversity in the Beaver Creek system. This action is consistent with Provincial Policy (*Management of un-authorized introductions of non-native freshwater fish species* # 3-2-01.03) which states that newly discovered populations of invasive fish should be eradicated when feasible.

To our knowledge, a chemical rehabilitation of magnitude required in Beaver Valley has never been carried out in British Columbia. In the United States; however, there have been several, successful large-scale chemical rehabilitations. One of the largest occurred in Strawberry Valley, Utah in 1990 (Lentsch et al. 2001). A total of 161 miles of stream (volume of 300,000 acre-feet) was treated with 875,000 lbs of powdered rotenone and 4,000 gallons of 5% liquid rotenone.

Another large-scale treatment occurred at Lake Davis in California. Brian Finlayson, with the California Department of Fish and Game, played a lead role in efforts to eradicate invasive northern pike (*Esox lucius*) from Lake Davis. B. Finlayson also instructs a course on planning and executing successful rotenone and antimycin projects.

Because of his extensive experience on how to plan and effectively use piscicide to meet fisheries management objectives, B. Finlayson was consulted to assist with a preliminary assessment of the Beaver Creek system to determine whether treatment with piscicide was technically possible (Gomez and Wilkinson, in prep). Finlayson confirmed that eradication by chemical treatment is a technically-sound management option for the Beaver Creek system at this time. Finlayson also noted that if an eradication program is to occur, it should begin soon; otherwise, the continued expansion of the bass population will decrease the odds of successful eradication.

The preliminary assessment indicated that approximately $2,500,000 would be required to purchase the Rotenone product needed to eradicate the entire Beaver Creek main stem from George Lake to the mouth (six lakes and 23 km of stream). An additional $2,500,000 would be required to undertake the eradication, bringing the total cost to $5 million. It would be a technically challenging initiative. Such a program will require a commitment from Federal and Provincial Governments as well as partnership funding groups. Until a decision is provided by Ministry of Environment and Fisheries and Oceans Canada Executives as to the likely hood of funding an eradication program, efforts must continue to control and contain the Beaver Creek bass population.

No action by government

The short-term economic savings of doing nothing to manage the bass population will result in a loss of native biodiversity in the Beaver Creek system in the long term and will maintain a source population of smallmouth bass that can be moved illegally to adjacent systems. The population will threaten anadromous salmon stocks in the Quesnel and Fraser drainages and this could result in loss of recreation, commercial and First Nation fisheries and employment. Provincial policy indicates that lakes that become infested with invasive fish in the future must be closed to angling to provide a deterrent.

In order for the Cariboo region to effectively move forward with this initiative, funds must be secured so that the Ministry of Environment and its partners can continue to address this concern. This is a challenging issue that requires ongoing support and

cooperation from the public, funding partners, Fisheries and Oceans, and the Ministry. There are three options for managing smallmouth bass in Beaver Creek and all have positive and negative implications to a variety of social, economic and biological values. Urgent action is needed: the opportunity has nearly passed to eradicate this newly-discovered invasive population before it spreads to other waterbodies.

Outreach

Public education and outreach activities that reduce the chance of invasion are essential to reducing the number of illegal introductions that occur in the future (Finnoff et al 2007) and support from the public is critical to moving forward effectively with this project. In 2007, efforts began to inform the general public of the issues surrounding illegal introductions of invasive fish. Over 50 informative signs were posted at fishing lake recreation sites, boat launches and Provincial Parks in the Cariboo region and another 50+ will be distributed in 2009. Brochures, developed with input from Fisheries and Oceans, were distributed to local retailers, and several articles were published in the local newspaper and magazines. Presentations were delivered to diverse audiences including Nature Centres, Rod and Gun Clubs, Ministry divisions, Members of the Legislative Assembly, and Resource Management groups. One open house and presentation was delivered to Beaver Valley residents and another is scheduled to occur in February 2009. The public must continue to be informed of the issues that surround illegal introductions of invasive fish. Information should be distributed once a comprehensive public involvement plan is developed.

REFERENCES

Brown, T. G., B. Runciman, and S. Pollard. 2007. Biological synopsis of smallmouth bass in British Columbia. Can Manuscript Rep Fish Aquat Sci XXXX: vii + 76 p.

California Department of Fish and Game. 2003. Managing northern pike at Lake Davis, a plan for year 2000: three year report. Portola, CA. Pp24

Carlson, D., J. Holmes and R. Holmes. 2008. Quesnel river creel survey 2007.

Caughley, G. and A. Sinclair. 1993.Wildlife ecology and management. Blackwell Science, Ontario. Pp331.

Dunlop, E., J. Orendorff, B. Shuter, F. Helen Rodd and M. Ridgway. 2005. Diet and divergence of introduced smallmouth bass (*Micropterus dolomieu*) populations. Canadian Journal of Aquatic Science. 62: 1720-1732

Findlay, C., G. Bert, and L. Zheng. 2000. Effect of introduced piscivores on native minnow communities in Adirondack lakes. Canadian Journal of Fisheries and Aquatic Science.57. 570-580.

Finnoff, D., J. Shogren, B. Leung and D. Lodge. 2007. Take a risk: preferring prevention over control of biological invaders. Ecological economics. 62: 216-222

Fisheries and Oceans Canada: Tovey, C., M. Bradford and L. Herborg. 2008. Biological Risk Assessment for Smallmouth Bass (*Micropterus dolomieu*) and Largemouth bass (*Micropterus salmoides*) in British Columbia. Canadian Science Advisory Secretariat.

Gomez, L. and T. Wilkinson. *In prep.* Eradication of smallmouth bass with piscicide in the Beaver Creek system: A preliminary technical assessment. Ministry of Environment, Williams Lake, BC

Hatfield, T. and S. Pollard. 2006. Non-native freshwater fish species in British Columbia. Biology, biotic effects, and potential management actions. Report prepared for Freshwater Fisheries Society of British Columbia, Victoria, BC.

Lentsch L., Thompson, C. and R. Spateholts. 2001. Overview of large-scale chemical treatment success story: Strawberry Valley, Utah. Pages 63-80 *in* L. Cailteux, L. DeMong, B.J. Finlayson, W. Horton, W. McClay, R.A. Schnick, and C.

Thompson, editors. Rotenone in fisheries management: Are the rewards worth the risks? American Fisheries Society, Trends in Fisheries and Management 1, Bethesda, Maryland.

Lepak, J., C. Kraft, and B. Weidel. 2006. Rapid food web recovery in response to removal of an introduced apex predator. Canadian Journal of Aquatic Science. 63:569-575.

MacRae P.S.D. and D.A. Jackson. 2001. The influence of smallmouth bass (Micropterus dolomieu) predation and habitat complexity structure of littoral zone fish assemblages. Canadian Journal of Fisheries and Aquatic Science. 58: 342-351.

McPhail, J. 2007. The freshwater fishes of British Columbia. University of Alberta Press, Manitoba. Pp620.

Ridgway, M., J. MacLean and J. MacLeod. 1991. Nest-site fidelity in a centrarchid fish, the smallmouth bass (*Micropterus dolomieu*). Canadian Journal of Zoology. 69:3103-3105.

Ritchie, L. 2006. Options for Control of Alien Species in British Columbia, Ministry of Environment, Kamloops, BC

Schade, C. and S. Bonar. 2005. Distribution and abundance of non-native fishes in streams of the western United States. North American journal of fisheries management.25, 1386-1394.

Todd, B. and C. Rabeni. 1989. Movement and habitat use by stream-dwelling smallmouth bass. Transactions of the American fisheries society, 118(3):229-242.

Weidel, B. D. Josephson and C. Kraft.2007. Littoral fish community response to smallmouth bass removal from an Adirondack lake.Trans.Am.Fish.Soc.136:778-789.

Wilcove, D., D. Rothstein, J. Dubow, A. Phillips, E. Losos. 1998. Quantifying Threats to Imperilled Species in the United States. *BioScience*, Vol. 48,(8): 607-615.

Vander Zanden, M., J. Casselman, and J. Rasmussen.1999. Stable isotope evidence for the food web consequences of species invasions in lakes. Nature. 401:464-467.

Zipkin, E., P. Sullivan, E. Cooch, C. Kraft, B. Shuter and B. Weidel. 2008. Over compensatory response of a smallmouth bass population to harvest: release from competition? Can.J.Fish.Aquat.Sci.65:2279-2292

Zirnhelt, N. and R. Case. 1998. Lower beaver valley corridor ecosystem: meeting CCLUP targets. A submission to sub-regional planning and lakes classification under the Cariboo Chilcotin land-use plan (CCLUP). Pp 37.