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Atlantic Salmon (*Salmo salar*) and Smallmouth Bass (*Micropterus dolomieu*) Interactions in the Magaguadavic River, New Brunswick

Interactions entre le saumon atlantique (*Salmo salar*) et l'achigan à petite bouche (*Micropterus dolomieu*) dans la rivière Magaguadavic (Nouveau-Brunswick)

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ABSTRACT

Data from 15 years (1994-2008) of backpack electrofishing surveys of juvenile Atlantic salmon habitat in the Magaguadavic River, New Brunswick were reviewed to document occurrences of smallmouth bass. We also examined datasets from salmon smolt monitoring stations (1999-2009) and from the head-of-tide fish ladder trap (1992-2008) in this river for captures of bass. Bass were found at 55% (N=23) of the juvenile salmon habitat sites. The species co-occurred with juvenile salmon at various electrofishing sites annually, except in 2001 and 2003. On average, the species co-occurred at 35% (range: 0 to 89%) of the electrofishing sites sampled over the 15 year period. Bass were found throughout most of the main stem riffle-run habitat and in 45% (N=15) of the tributaries sampled. In the tributaries, the majority of the bass were young of the year and 87% of those sites were within 100 metres of a lake, reservoir, or the river's main stem. Body sizes (lengths) were generally similar between salmon and bass at most electrofishing sites and salmon outnumbered bass in most cases. However, larger bass were found in the river's main stem and near commercial salmon hatcheries. Bass were found in 1st and 2nd order streams as small as 2 m wide. However, they did occur more frequently in 3rd to 5th order streams and they apparently avoided spring fed areas. Bass occasionally co-occurred with salmon smolts at trap sites during the spring monitoring periods, and were also captured at the head-of-tide fish ladder. In addition to smallmouth bass, one exotic largemouth bass (*M. salmoides*), the first record for this species in the Maritimes Provinces, was captured in the Magaguadavic system in 2006.

RÉSUMÉ

Nous avons examiné des données recueillies sur une période de 15 ans (1994-2008), grâce à des relevés menés au moyen d'appareils portatifs de pêche à l'électricité, concernant l'habitat du saumon atlantique juvénile dans la rivière Magaguadavic (Nouveau-Brunswick) afin de documenter les occurrences de l'achigan à petite bouche. Nous avons également examiné des ensembles de données provenant des stations de suivi de saumoneau du saumon (1999-2009) et des pièges de l'échelle à poissons située à la ligne extrême des eaux de marée (1992-2008) de cette rivière pour capturer l'achigan. L'achigan a été repéré sur 55 p. 100 (N=23) des sites correspondant à l'habitat du saumon juvénile. Chaque année, l'espèce cohabitait avec le saumon juvénile sur différents sites de pêche à l'électricité, sauf en 2001 et en 2003. En moyenne, les espèces cohabitaient sur 35 p. 100 (entre 0 et 89 p. 100) des sites de pêche à l'électricité échantillonnés pendant ces 15 ans. L'achigan se trouvait d'un bout à l'autre de la plupart des radiers et plats du bras principal et dans 45 p. 100 (N=15) des affluents échantillonnés. Dans les affluents, la majorité des achigans étaient des jeunes nés au cours de l'année, et 87 p. 100 des sites se trouvaient à moins de 100 m d'un lac, d'un réservoir ou du bras principal de la rivière. La taille du corps (longueur) des saumons et des achigans était généralement semblable sur la plupart des sites de pêche à l'électricité. Dans la plupart des cas, les saumons étaient plus nombreux que les achigans. Par contre, des achigans plus gros se trouvaient dans le bras principal de la rivière et à proximité des stations commerciales d'alevinage du saumon. Des achigans ont été repérés dans des cours d'eau de premier et de second ordre dont la largeur atteint à peine deux mètres. Cependant, ils se trouvaient plus fréquemment dans des cours d'eau de troisième à cinquième ordre et, apparemment, évitaient les zones alimentées par des sources. À l'occasion, l'achigan cohabitait avec le saumoneau sur les sites où se trouvaient des pièges pendant les périodes de suivi du printemps. On en a également capturé dans l'échelle à poissons située à la ligne extrême des eaux de marée. En plus de l'achigan à petite bouche, un achigan à grande bouche (*M. salmoides*) exotique, le premier spécimen de cette espèce enregistré dans les provinces maritimes a été capturé dans le système hydrographique de Magaguadavic en 2006.

INTRODUCTION

Exotic (non-indigenous) species introductions can pose serious ecological and economic dangers (Pimental et al. 2000; MacIssac et al. 2002; ICES 2003). Invasions by exotics are widely considered the second most important threat to native biodiversity, after habitat destruction (Vitousek et al. 1997; Birdlife International 2000; UNEP 2002; Worm et al. 2006). Aquatic invasives are now a major threat to freshwater ecosystems, but our knowledge of aquatic regional biodiversity and the historic, current, and impending threats to freshwater ecosystems is limited. This hampers our ability to work towards protection and recovery of native species, distinct populations, and natural communities.

In New Brunswick, there have been multiple reports of exotic species invasions. Notable exotics include rainbow trout (*Oncorhynchus mykiss*), muskullenge (*Esox masquinongy)*, chain pickerel *(Esox niger)*, smallmouth bass (*Micropterus dolomieu*), and largemouth bass (*Micropterus salmoides*). The Magaguadavic River appears to be a particular magnet for exotic species introductions, both deliberate (legal and illegal) and inadvertent. This may be because, as the sixth largest river in New Brunswick, it is heavily used by people. Four exotic fishes have been recorded in the Magaguadavic watershed: smallmouth bass (stocked in the 1920s, see Catt 1949), rainbow trout (detected from 1983-2000 – no evidence for reproduction or self sustaining populations), largemouth bass (single specimen first recorded in 2006 – no subsequent reports), and chain pickerel (first recorded in 2003 – currently self sustaining populations in Magaguadavic Lake). These species are all voracious predators of other fishes, and are potential predators of Atlantic salmon (*Salmo salar*) and native brook trout (*Salvelinus fontinalis)*. Exotics can also compete for food and space with indigenous fauna, and displace other native species.

Smallmouth bass were introduced into Magaguadavic Lake in 1925 (Catt 1949; Figure 1). An unauthorized introduction by a private source stocked the lake with 143 broodstock originating from Spednic Lake, St. Croix River Watershed (Catt 1949). It took less than 16 years for bass to spread and populate the lower reaches of the Magaguadavic River, including Lake Utopia (Smith 1942). Federal government agencies subsequently stocked several lakes in New Brunswick and Nova Scotia with bass from the Magaguadavic watershed during the 1940s (Catt 1949). Additional information on the distribution, biology, and habitat requirements for smallmouth bass in the Maritimes is found in DFO (2009).

Smallmouth bass are now well established in the Magaguadavic watershed and support a recreational sport fishery in lakes and reservoir zones. This species normally resides in lakes and slow moving waters. However, since electrofishing surveys began in 1994 smallmouth bass have been detected in juvenile Atlantic salmon and brook trout habitat within the Magaguadavic system.

We review data on juvenile salmon and bass numbers found during backpack electrofishing surveys of Atlantic salmon habitats in the Magaguadavic River. These surveys were conducted annually from 1994 to 2008. We use the information to make inferences about the potential for interaction between the two species in this habitat. Datasets from salmon smolt monitoring surveys (1999-2009) and from the head-of-tide fish ladder monitoring station (1992-2008) in this river are also reviewed to document the captures of smallmouth bass.

METHODS

Accessible juvenile salmon rearing habitat has been identified throughout the Magaguadavic River watershed, and 42 open monitoring stations were established for backpack electrofishing surveys. In 1994 and 1995, reconnaissance surveys were conducted at several sites to provide a species inventory. From 1996 to 2008, electrofishing was conducted primarily to enumerate juvenile salmon for stock assessments and to document juvenile salmon escapees from commercial fish hatcheries within the watershed (Carr et al. 1997; Carr and Whoriskey 2006). The number of sites electrofished each year ranged from 10 to 35. Surveys were conducted from late July to late September. Although the primary focus was on Atlantic salmon, at a minimum, the occurrence of all other fish species captured was recorded at each electrofishing station. Habitats electrofished were deliberately biased towards riffle and run areas with suitable rock substrate for juvenile Atlantic salmon (Symonds and Heland 1978; Morantz et al. 1987). Electrofishing Site Habitat Assessment Forms were filled out for each electrofishing station. Habitat measurements included stream type (i.e. riffle, run, pool, etc.), substrate (rock, rubble, gravel, etc.), embeddedness, woody debris, site dimensions, depth, flow, water temperature, bank stability, and vegetation.

In all years, captured juvenile salmon were anaesthetized, weighed, and measured (fork length) prior to release. From 1994 to 2000, smallmouth bass were weighed and measured (total length) prior to release. Bass that measured < 100 mm were considered to be age 0+. Catches per unit effort (CPUE) (1994 – 2000) were calculated as the number of smallmouth bass or juvenile salmon caught per 100 seconds of fishing time. Salmon and bass densities per $100m^2$ could be determined for a small fraction of sites. Density estimates (Zippin 1958) were obtained through repeated passes of the electrofishing equipment over the same area. No differences ($P>0.05$) were found in CPUE for salmon and bass numbers among the seven years examined (1994 to 2000). Thus, data for these years were pooled. From 2000 to 2008, only the presence or absence of bass was recorded at each site.

Monitoring was also conducted for salmon smolts and adults. From 1999 to 2006 (except in 2004) Atlantic salmon smolts were captured and enumerated using a rotary screw trap operated in the spring (April to June). The trap (E.G. Solutions Inc, Oregon, USA; refer to Chaput and Jones 2004 for description of screw trap) was situated in the river's main stem at Lee Settlement, 24 km above the head-of-tide dam (Figure 1). Smolts and all other fish species captured were also counted at the downstream fish passage facility at the head-of-tide dam from 1999 to 2009. Finally, fish ascending the Magaguadavic River (from the estuary) were enumerated at the head-of-tide pool and weir fish ladder from 1992 to 2008. More information on the head-of-tide Atlantic salmon monitoring stations can be found in Carr et al. (1997) and Carr and Whoriskey (2006, 2008).

RESULTS

Bass captures at juvenile salmon electrofishing stations

Bass were recorded at 23 (55%) of the 42 juvenile salmon habitat stations sampled between 1994 and 2008 in the Magaguadavic River watershed. At those sites, bass were found in 14 of 15 years (Table 1). On average, the species co-occurred with Atlantic salmon at 35% (range: 0 to 89%) of the sites sampled over the 15 year period (Table 1).

Bass were found at all but two sample sites (IDs 11 and 29 in Figure 1) in the Magaguadavic River's main stem from Magaguadavic Lake to the head-of-tide dam (Figure 1). However, those two sites were only sampled once during the 15-year period (ID 11: 1994 and ID 29: 1995). Bass were found at 87% (N=13) of the sites sampled in tributaries, and most tributary sites with bass were located within 100 m of a lake, reservoir, or the river's main stem. The other two tributary sites where bass were captured were within 1500 m of a reservoir or the main stem.

In tributary sites devoid of bass, the distance from lakes, river's main stem or reservoir zones was as follows: >3 km (N= 9), 1.5 km (N=1), and <0.5 km (N=4), respectively. No bass were found upstream of inaccessible fish passage barriers (N=3 sites).

No trends over time in the presence of bass were observed at individual sample sites during the study period. For instance, at most sites sampled over several years, there was at least one year in which no bass were recorded (Table 1). Seven sites where bass were recorded had only been sampled once during the 15-year period (Table 1). The three sites with the most frequent annual detections of bass were situated near commercial salmon hatcheries. At those sites bass occurred in at least five consecutive years from 1996 to 2001 (Table 1).

Numbers of bass and juvenile salmon were low at most sites (Tables 2 and 3). At electrofishing sites where bass and salmon co-occurred (from 1994 to 2000), salmon outnumbered bass 81% (N=32) of the time. Bass outnumbered salmon at six (19%) sites. However, no significant differences in abundance (densities per $100m^2$ and captures per 100 seconds of electrofishing) were found between salmon and bass at sites where they co-occurred (P>0.05).

The differences in bass and salmon densities (and CPUE) between small (<= 5 m width) and large (>= 20 m width) tributaries were not significant (P>0.05). At sites <= 5 m wide, the median salmon and bass densities were 6.1 and 5.3 fish per $100m^2$, respectively (Table 2). At sites >= 20 m wide, the median salmon and bass densities were 9.2 and 12.0 fish per $100m^2$, respectively (Table 2). At sites <= 5 m wide, the median number of salmon and bass captured per 100 seconds of fishing time was 0.23 and 0.12, respectively (Table 3). At sites >= 20 m wide, the median number of salmon and bass captured per 100 seconds of fishing time was 0.64 and 0.21, respectively (Table 3). No differences were found for captures of salmon and bass between sites where they co-occurred and where no overlap occurred (P>0.05, see Table 3).

Age 0+ (total lengths <100 mm) smallmouth bass were found at all sites (N=14) sampled between 1994 and 2000. Larger bass were found at two tributary sites (<= 5 m wide) situated adjacent to commercial salmon hatcheries, and in two sites in the main stem (IDs 16,20,36,40; see Figure 1). Maximum total lengths for bass captured during our work were 201 mm for tributaries <= 5 m wide, and 295 mm in the main stem (>= 20 m wide). At sites where larger bass were found, salmon sizes (fork length) ranged from 72 – 200 mm (<= 5 m wide tributaries) and from 50 – 183 mm (>= 20 m wide main stem).

The sizes of fish captured in tributaries (<= 5 m wide) distant from commercial salmon hatcheries ranged from 35 to 96 mm for bass and from 44 to 199 mm for salmon. Sizes of bass (age 0+) and salmon captured in wider reaches (>= 20 m wide) ranged from 49 to 95 mm and 45 to 175 mm, respectively.

We observed no differences in habitat characteristics between sites where bass were present and absent. Bass were found in 1st to 5th order streams, although 87% (N=20) of the sites they occupied were in 3rd to 5th order reaches. No bass were found in cool water (spring fed) streams. Median water depth at sites where bass were found was 0.35 m (range: 0.16 - 0.60 m).

Other fish species captured during the 15 year sampling period included various cyprinids, brook trout, American eel (*Anguilla rostrata*), white sucker (*Catostomus commersonii)*, sculpin (*Cottus cognatus*), stickleback, *(Gasterosteus aculeatus)*, burbot (*Lota lota*), sunfish (*Lepomis gibbosus)*, and yellow perch *(Perca flavescens)*. There were no trends in the occurrence of other species in habitats where bass were present or absent.

Bass captures at salmon smolt and adult sample stations

Smallmouth bass were captured with salmon smolts periodically during spring sampling periods. Most bass captured in the rotary screw trap and downstream fish passage facility at the head-of-tide dam during the spring smolt migration exceeded 150 mm in size. In 2009, we observed a 330 mm bass consume an 180 mm salmon smolt in the Magaguadavic River's head-of-tide downstream fish bypass facility.

Occasionally, bass were captured at the head-of-tide fish ladder trap (Figure 1). Most captures at the fish ladder occurred shortly after spillage events associated with freshets. Sizes of smallmouth bass captured at the head-of-tide dam ranged from 150 mm to 390 mm.

Largemouth bass captures

A 380 mm (total length) largemouth bass (*M. salmoides*) was recorded at the head-of-tide fish ladder trap on 11 July, 2006. This was the first record of largemouth bass in the Maritime provinces. The specimen was taken to the NB Museum.

DISCUSSION

Smallmouth bass are widely distributed throughout the Magaguadavic River watershed. They are present in most lakes and along the river's main stem. Bass, particularly young of the year, are found in riffle and run habitats throughout the river's main stem and, in many instances, co-occur with juvenile Atlantic salmon. The same is true in tributaries, although most occurrences in those areas are limited to regions near lakes, reservoirs, or the river's main stem.

Bass absence from some stations may have resulted from low sampling efforts (i.e. only one year of sampling). Frequently, at sites where sampling occurred in multiple years, bass were not taken in one or more years. This was likely the reason why bass were not found in two main stem sampling stations that were sampled in a single year. Most tributary stations that were devoid of bass were located more than 3 km from sites thought to be suitable for adult bass and their reproduction (i.e. lake, river's main stem, or reservoir zone). Dispersing juvenile bass would have had to navigate through shallow and faster waters to reach these riffle zones. Physical restrictions may limit young of the year bass from moving long distances through fast waters to reach upper tributary zones. Adult bass are capable of moving upstream through greater velocities, as demonstrated by their capture at the head-of-tide fish ladder (13.4m high dam). Another possibility limiting bass occurrence at various sites might be abiotic factors such as water temperature, although this is speculative.

No systematic differences were evident among habitat types or fish species where bass were present versus sites devoid of bass. This is probably not surprising since the habitat sampled in this study was biased towards juvenile Atlantic salmon rearing areas. Bass apparently did avoid spring fed areas and were found most frequently in higher order (wider) streams.

Annual detections of bass were sporadic at most sites. The exception was sites near commercial salmon hatcheries, where bass were recorded in up to seven consecutive years. Several factors may influence bass occurrence on an annual basis, including food availability, predation, water temperatures, ice scouring, and freshet events. Size and abundance of bass at the end of the first growing season may also influence bass survival (Oliver et al. 1979; Shuter and Post 1990).

Smallmouth bass found in main stem juvenile salmon rearing habitats at times were more numerous and larger than salmon. Larger bass were also captured during the spring along with smolts in the rotary screw trap and at the head-of-tide dam. Large bass are predators during the outmigration of salmon smolts in the spring. Bass could therefore negatively affect salmon during one of their most vulnerable life stages.

Bass sizes in tributaries were restricted to young of the year except for those adjacent to fish hatcheries. Their co-occurrence with similar sized juvenile salmon in riffle habitats might offer a potential for competition for food or shelter, however, this seems unlikely in this watershed during this sample period given the low numbers of both species.

The higher numbers and larger sizes of bass near hatcheries might have been due to an abundance of food, notably escaped juvenile salmon, from hatchery operations. The hatcheries were also located near preferred adult bass habitat (lakes, main stem). Juvenile salmon found near those sites were thought to be escapees (Carr and Whoriskey 2006).

Bass captures in the smolt wheel and at the head-of-tide traps suggest that displacements of the species might be common during freshets. Therefore, bass inhabiting lakes connected to a river system could easily be displaced downstream, especially during high flows. Bass are a resilient species and can adapt to many habitat types, including prime juvenile Atlantic salmon rearing habitat.

Atlantic salmon numbers in the Magaguadavic River were at all time lows during the sampling period. Thus, competition for food and space between bass and salmon may not have been a major factor. Also, juvenile salmon outnumbered bass 81% of the time when they co-occurred. So despite the desperately low population numbers, salmon do not appear to have been displaced by bass, possibly indicating an advantage to salmon when they are in their preferred habitats. However, bass are opportunistic predators and their presence in juvenile salmon habitat should not be taken lightly, especially if restoration efforts are underway to rebuild salmon populations. One possible method to displace young of the year bass from riffle habitat might be to stock larger parr in areas known to be occupied by bass.

Finally, bass introductions into salmon rivers should be avoided, as there are no identified scenarios in which the introduction of bass is positive for salmon. Salmon waters are vulnerable to colonization by exotic predators. Bass were introduced in the Magaguadavic River more than 90 years ago, and it took this species less than 16 years to spread throughout the system (Smith 1942). Another exotic, the muskellunge, took less than 18 years to expand its range from a headwater lake to tidal waters in the St. John River system (Stocek et al. 1999).

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Table 1. Annual occurrence of smallmouth bass (b) and juvenile Atlantic salmon (s) at the 23 electrofishing stations in the Magaguadavic watershed where bass were found between 1994 and 2008. The percent occurrence of bass per site over the entire sampling period is given. Blank = not sampled, ø = no salmon or bass present.

Map ID	Yrs. Fished	Bass Freq.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
1	1	100%			b												
2	1	100%			b												
3	1	100%			b												
4	13	62%			b s	b s	b s	b s	b s	bs	b s	s	s	ø	s	b s	s
5	13	77%			b s	b s	b s	b s	b s	b	ø	s	b s	bs	b s	b s	s
6	14	43%	b s	b s	s		b	ø	ø	ø	ø	ø	b	bs	ø	b s	s
9	11	55%		b s	b s		b			b	s	ø	ø	s	ø	b	b s
10	9	22%					ø			ø	s	ø	ø	s	ø	b	b s
14	1	100%	b s														
16	6	33%		b s	b s				ø	ø	ø	s					
20	13	54%		b s	b s	bs	b s		ø	ø	ø	ø	b	ø	ø	b	bs
23	3	33%	ø								b	ø					
24	14	29%	b s	s	s	b s		s	ø	ø	ø	ø	ø	ø	ø	b	b s
25	5	20%			b					ø	ø	ø	ø				
26	4	25%	b s		ø					ø						s	
30	15	7%	b	ø	ø	s	ø	ø	ø	ø	ø	ø	s	s	ø	s	s
32	13	15%	b s	s	s	b s	ø			ø	ø	ø	s	ø	ø	s	s
33	1	100%	b														
34	1	100%	b														
35	1	100%	b s														
36	13	54%			b s	b s	b s	b s	b s	s	s	s	b s	s	s	b	ø
37	14	43%	b s	b s	s	b s		s	b s	s	ø	ø	s	bs	s	ø	bs
40	12	67%			s	b s	b s		b s	bs	b s	s	s	b	ø	b s	bs
Total sites fished annually			11	8	17	9	10	7	10	15	16	15	13	12	12	13	12
Percent Bass annually			91	63	59	89	70	43	50	26	19	0	30	33	8	69	42
Percent only Bass annually			27	0	24	0	20	14	0	13	6	0	15	8	0	38	0
Percent Bass & Salmon annually			64	63	35	89	50	29	50	13	13	0	15	25	8	31	42

Table 2. Juvenile salmon and smallmouth bass densities (fish per 100 m^2) in the Magaguadavic River drainage at sites where the species occurred from 1995 to 2000.

Stream Width	No. of Sites	Salmon		Bass	
		Median	Range	Median	Range
<= 5 m	6	6.1	2.9 – 12.2	5.3	1.2 - 35.1
>= 20 m	3	9.2	1.0 – 12.5	12.0	2.3 - 14.9

Table 3. Juvenile salmon and smallmouth bass captures per 100 s fishing time in the Magaguadavic River drainage from 1994 to 2000.

		<= 5 m Width			>= 20 m Width		
		No. of sites	Median	Range	No. of Sites	Median	Range
Co-occur	Bass	13	0.12	0.01-1.95	13	0.21	0.08-2.67
	Salmon	13	0.23	0.04-2.23	13	0.64	0.07-3.10
No overlap	Bass only	6	0.24	0.19-1.44	2	0.62	0.03-1.21
	Salmon only	41	0.58	0.05-3.55	12	0.54	0.11-4.04

Figure 1. Map of Magaguadavic River Watershed showing the 42 electrofishing stations sampled between 1994 and 2008. Circled numbers indicate sites where bass were found. The head-of-tide dam and smolt wheel monitoring sites are shown. Map IDs 4, 36, and 40 are adjacent to commercial salmon hatcheries. Map IDs 17, 21, and 22 are upstream of natural barriers.