ATLANTIC SALMON (*SALMO SALAR*) IN THE MAGAGUADAVIC RIVER NEW BRUNSWICK 1992 - 1997

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PREFACE

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1.0 ABSTRACT

The Magaguadavic River has become a North American index site for monitoring the interactions between wild and escaped cultured Atlantic salmon. Since 1992, the river has been followed to document changes in the proportions of wild and cultured Atlantic salmon entering the river. This report summarizes available information on the river.

Wild salmon returns have steadily declined from 293 in 1992 to 59 in 1997. Escapees composed from 34% to 90% of the annual salmon run. For wild salmon, males dominated the 1SW run and females dominated the MSW run. One sea winter to MSW wild salmon ratios shifted from 1:2 in the 1980s to 1:0.85 in the 1990s. Cultured salmon 1SW fish outnumbered the MSW salmon in all years. An increased number of escaped postsmolts entered the river beginning in 1994. Over 50% of postsmolts were precocious males during 1995 and 1997.

Only an estimated 11.2% (average 1992-1997) of the cultured salmon entering the river were considered to be sexually mature. All wild salmon were sexually mature, exhibiting secondary sexual characteristics by mid August.

No pathogenic bacterial or viral organisms were found in wild and cultured salmon tested during 1992-1996. However, in 1997 five of 34 cultured salmon tested were suspect for hemorrhagic kidney syndrome (HKS).

The 1992-1997 average egg deposition was only 40% of the conservation target set for the river. Cultured salmon contributed 14% of the average estimated egg deposition from 1992-1997.

Three non-indigenous species were recorded in the river: smallmouth bass, rainbow trout, and brown trout.

Juvenile anadromous salmon riffle habitat was identified and electrofished during 1994-1997. Juvenile salmon densities and relative abundance were low at most sites examined. Higher numbers of parr caught near salmon hatcheries may have been due to juvenile escapees. Smallmouth bass have colonized in several riffle areas of the watershed.

2.0 INTRODUCTION

The Magaguadavic River is the sixth largest river in New Brunswick. It originates in Magaguadavic Lake in the southwest part of the province and flows southeasterly 97 km to Passamaquoddy Bay (an offshoot of the Bay of Fundy) near St. George. There are 103 named tributaries and more than 55 lakes within a drainage area of 1812 km^2. A 13.4m high dam (built in 1903) located at the head of the tide is equipped with Francis runner-type turbines which generate 3.7 megawatts. A pool and weir fishway bypasses the dam for upstream fish passage. A sluiceway intended for downstream fish passage is situated adjacent to the penstock at the dam. Water storage reservoirs are located in Mill, Digdeguash, and Magaguadavic Lakes.

The Magaguadavic system supports a sport fishery for anadromous and landlocked Atlantic salmon, brook trout (*Salvelinus fontinalis*), and introduced smallmouth bass (*Micropterus dolomieui*). Also, non-indigenous sea-run brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) have been recorded in the river but their origin is unknown. A limited sport dipnet fishery occurs during the spring in Lake Utopia tributary streams for two populations of landlocked smelt (*Osmerus mordax*). A commercial fishery exists in the lower sections of the river for American eels (*Anguilla rostrata*) during their seaward migration in the fall. The spring run of alewives (*Alosa pseudoharengus*) is sometimes fished for lobster bait in the tidal waters.

The Magaguadavic River is situated near the centre of the New Brunswick Atlantic salmon aquaculture industry, and large numbers of escaped cultured salmon from sea-cages have entered the river in recent years. Three commercial salmon hatcheries that together produce about two million smolts for the sea-cages are located within the drainage, and high numbers of cultured juvenile salmon are suspected to be escaping from those sites. The Magaguadavic River has become a reference site in North America to study the potential impacts that cultured salmon have on wild stocks (Carr et al., 1997a). It serves to annually document the frequency and potential impacts of escapees entering the river from sea-cages and fresh water hatcheries. The Magaguadavic River is an ideal reference site because it has: logistical advantages such as efficient monitoring stations with easy access to determine the frequency of escapees from sea-cages and fresh water hatcheries; stock characteristics similar to other Bay of Fundy rivers; and some background data predating the arrival of the aquaculture industry.

Complete counts of the river's salmon run have been made in the fishway trap at the head of the tide since 1992 (Figure 1). Wild salmon ascend the river from June until early November. Spawning occurs from late October until mid November. Wild salmon spend 2 to 4 years in the river before they migrate to sea as smolt.

Information on the history and characteristics of the salmon run prior to the 1980s is sketchy. Total reported salmon returns to the river prior to the 1990s are presented in Figure 2.

More details on the history and characteristics of the salmon in the Magaguadavic River are found in Carr et al.(1997a).

3.0 METHODS

From 1992-1997 the fishway trap was operational from June until November, except in 1996 when monitoring did not begin until July. Wild salmon were distinguished from cultured escapees using external morphology and scale characteristics (Carr, 1995). The state of sexual maturity was determined based on visual inspection for secondary sexual characteristics.

Juvenile anadromous salmon rearing habitat was identified throughout the Magaguadavic watershed and electrofishing surveys were conducted at 26 different sites during 1994 to 1997. Criteria for site selection was determined from detailed stream surveys (Hooper et al., 1995) and accessibility with two-wheel drive vehicles. Surveys were done in August and September. Seven of the electrofishing sites sampled in 1996 and 1997 were near commercial salmon hatcheries (4 in Magaguadavic River, 2 in Linton Stream, and at Mill stream; Figure 1).

Captured parr, smallmouth bass, and trout were anaesthetized, weighed and measured, had a sample of scales taken, and released. Salmon fry were classified as 0+ fish $\leq$ 6.0 cm forklength, and parr were larger than 6.0 cm. Density estimates were calculated at selected sites for juvenile salmon and non-indigenous smallmouth bass in 1995 and 1997 using the Peterson mark-recapture method. Relative abundance (number of fish caught per 100 seconds electrofishing time) of salmon, smallmouth bass, and brook trout were also recorded at various sites throughout the watershed (Figure 1).

4.0 RESULTS

Numbers of wild salmon steadily decreased from 1992 to 1997 (Figure 3). Escapees composed from 34% (1992) to 90% (1994/95) of the annual adult run. In 1997, the numbers of both wild and cultured escapees that entered the Magaguadavic River were the lowest since 1992. However, escapees were still 67% of the total number of salmon captured at the fishway.

4.1 Wild returns

Counts of wild salmon have declined from 293 in 1992 to 59 in 1997 (Figure 3). Total wild returns in 1997 were only 36% of the average 1992 to 1996 returns.

Wild salmon returned to the river from June through October, and numbers peaked in July or August (from 1992-1997) (Figure 4).

One sea winter wild salmon outnumbered MSW wild salmon in 5 of the 6 years considered and the percent of 1SW salmon is trending up (Figure 5a). The 1SW to MSW ratios have shifted from 1:2 in the 1980s (1983-1988, Carr et al., 1997a) to 1:0.85 in the 1990s (1992-1997).

Males dominated the 1SW salmon run with a 1992-1997 average of 61% males and 39% females (Table 1). Females dominated the MSW salmon averaging 83% of the run during the six years considered (Table 2). MSW female percentages peaked at 100% in 1997 and were as low as 50% in 1995.

The 1992-1997 average lengths for both 1SW and MSW wild females were slightly larger than males (Tables 1 and 2). No difference in overall lengths of 1SW and MSW salmon were observed among the years considered. Average 1992 to 1997 forklengths for 1SW and MSW wild salmon were 56.8 $\pm$ 3.37cm and 77.0 $\pm$ 4.42cm, respectively (Tables 1 and 2).

Information on the wild salmon repeat spawners over the period 1992-1997 is given in Table 3. The 6 year average of repeat spawners in the wild salmon run was 7%.

4.2 Cultured Escapees

The number of escapees entering the river have ranged from 119 (1997) to a peak of 1198 in 1994 (Figure 3). A sea-cage failure in 1994 in Passamaquoddy Bay resulted in the escape of an estimated 20,000 fish. This probably accounts for the increased numbers of cultured salmon entering the Magaguadavic River in 1994 and 1995.

The number of escapees captured in 1997 was the lowest in 6 years. At the same time the sea-cage sites were operating at their highest ever recorded production levels. Unintentional releases of cultured salmon from the salmon aquaculture industry may be declining as improvements are made in securing cage sites from predators and storms, and as cage technologies improve.

Cultured escapees entered the river later than wild fish in all years and their numbers peaked in either September or October (Figure 4).

One sea winter fish outnumbered MSW fish for the escaped cultured salmon (Figure 5b). Increased numbers of escaped postsmolts have been observed in the river since the introduction of a brackish water cage site at the mouth of the Magaguadavic River in 1994 (Table 4).

The size of escaped salmon will vary depending on time of escape from cages. The overall 1992 to 1997 average forklengths for 1SW and MSW cultured salmon were 60.3 $\pm$ 5.44 cm and

73.0 ± 5.98 cm, respectively (Tables 5 and 6). The 1992-1997 average forklength for escaped postsmolts was 30.5 ± 6.22 cm (Table 4). There were more female than male 1SW salmon trapped at the fishway each year (Table 5). The average sex ratio of MSW escapees was 51% females to 49% males (Table 6).

Males were slightly larger than females each year for both 1SW and MSW cultured fish. The 1992-1997 average forklengths for 1SW male and female salmon were 61.3 ± 5.49 cm and 59.9 ± 5.33 cm, respectively. The 1992-1997 average forklengths for MSW male and female fish were 73.3 ± 6.19 cm and 73.2 ± 5.69 cm, respectively.

There were two escaped MSW cultured salmon repeat spawners: one male in 1992, and one female in 1994.

4.3 Tagging

Adult salmon captured in the fishway of the Magaguadavic River were Floy tagged every year except 1994 and 1995. In 1995, 218 cultured salmon were tagged in the operculum with strap tags and released below the fishway trap. In 1997, 77 cultured salmon were floy tagged and released at various sites in Passamaquoddy Bay to determine if they home to the Magaguadavic River or enter the river at random.

Recaptures are shown in Table 7. Two male wild salmon were initially mis-identified and released at sea in 1997 but returned to the fishway trap two and six days after release. One male escapee released at the mouth of the river in 1997 returned to the fishway after two days. None of the other 1997 tagged fish were seen again.

4.4 State of Maturity

All wild fish exhibited secondary sexual characteristics by mid-August and were considered to be sexually maturing. However, most escaped cultured salmon lacked the appearance of secondary sex characteristics. Internal examination of gonads from 60 cultured salmon in 1994 and gonadal sex steroid profiles from 62 escapees in 1995 confirmed 100% of the fish (lacking secondary sexual characteristics) to be sexually immature (Carr et al., 1997b; Lacroix et al., 1997).

The reliability of visually sexing escaped salmon based on body characteristics was evaluated for 19 escaped cultured salmon in 1997. All maturing fish (one male and one female) were accurately sexed. By contrast, 24% of the remaining, non-maturing fish were mis-identified. Here the inability to accurately distinguish between sexes prior to the appearance of secondary sexual characteristics may result in incorrect estimations of egg depositions. A more reliable

method is needed to sex salmon prior to the appearance of secondary sexual characteristics so that more accurate estimated egg depositions may be computed.

Visual evaluations for state of sexual maturity for escaped cultured salmon were recorded each year except in 1992 and 1993. We assumed that the proportions of sexually mature and immature fish in 1992 and 1993 were similar to those in 1994-1997. The state of sexual maturity for 1992 and 1993 escaped cultured salmon was calculated using the average 1994-1997 proportions of sexual mature and immature fish for each age class (postsmolt, 1SW, MSW).

Only 11.1% of cultured salmon from the 1992-1997 average were considered to be sexually mature (Table 8). As few as 3.3% in 1994 and as many as 46.2% in 1997 were considered sexually mature (Table 8, Figure 6).

An increased frequency of escaped cultured postsmolts were observed in the river beginning in 1994, after the establishment of a brackish water rearing site near the mouth of the Magaguadavic River. Sexually precocious males comprised over 50% of the postsmolts in 1995 and 1997 (Table 8).

4.5 Removals

Wild and escaped cultured salmon were removed from the Magaguadavic River during 1992-1997 for broodstock, experimental, or disease screening purposes (Figure 7).

4.5.1 Wild

Table 9 presents the numbers of 1SW and MSW wild salmon that were recorded as in-river mortalities or taken for broodstock (1996/97). Some of the dead fish were taken to the New Brunswick Department of Fisheries and Aquaculture (NBDFA) for pathological examinations (see disease screening, below).

4.5.2 Broodstock collections

In 1996, 7 wild salmon were removed for broodstock. Fish were spawned in November and six surviving kelt were then released into the Magaguadavic estuary. An estimated 10,000 eggs were fertilized and incubated at Connors Brothers Lake Utopia hatchery. Fry and parr were subsequently released into selected habitat within the Magaguadavic watershed in 1997. In 1997, all fish destined for broodstock died as a result of water circulation failure in the holding tanks at ASF prior to scheduled spawning.

4.5.3 Cultured

Numbers of escaped cultured salmon removed from the river are given in Table 10. A total of 219 fish were screened for pathogens, and an additional 295 escapees were tagged and re-released below the fishway trap or at sea to determine if they would return to the river. The purpose of this study was to determine whether escapees randomly enter the Magaguadavic River or "home" to the river. The "other " category in Table 10 refers to the following: in 1994 and 1995 122 fish were tested for state of sexual maturity (Carr et al., 1997b; Lacroix et al., 1997); 146 fish were provided to the Aboriginal Food Fishery in 1994; 15 fish were tested for presence of antibiotic residues in 1994 and 1995; the remaining fish were disposed of at the N.B. Department of Fisheries and Aquaculture.

4.6 Disease Screening

A total of 13 wild and 158 cultured salmon were tested for pathogens at the Department of Fisheries and Aquaculture from 1992 to 1997. All wild fish were found dead in the river. By contrast, escapees were either found dead in the river, or deliberately sacrificed for disease tests.

Six wild salmon showed no pathogens. *Aeromonas* was detected in 4 wild fish. Two *Pseudomonas* cases and one *Vibrio* case were also reported for wild salmon.

Pathology examinations for all cultured salmon tested from 1992-1996 detected either no or non-pathogenic pathogens (Table 11). However, 5 of 34 cultured salmon examined in 1997 were suspect for HKS (Hemorrhagic Kidney Syndrome) based on pathologies observed in post mortem exams. *Aeromonas* and *Pseudomonas* are considered non-pathogenic. They are not the primary cause of mortalities but are signs of stress. *Edwardsella tarda* is a bacteria associated with sewage and elevated water temperatures.

Tissue samples of kidney, spleen, gills, and pyloric caeca were extracted from escapees in 1995 (61) and 1997 (19), and sent to the Department of Fisheries and Oceans for more intensive virus screening. All tests were negative, including those for the HKS virus in 1997. Unfortunately, the 19 fish tested did not include the five individuals whose post mortem exams were suspect for HKS. Four of the suspect HKS cases showed symptoms of aeromonas.

In 1994 and 1995, 5 and 10 cultured salmon, respectively, were screened at NBDFA for antibiotic residues (oxytetracycline, trimethoprim, ormetropin,and sulphadimethoxine). The levels were less than 50 parts per billion (ppb). The alert level established by Health and Welfare and Fisheries and Oceans is 100ppb for all residues mentioned above.

4.7 Other species captured in fishway trap

Species other than anadromous Atlantic salmon captured in the fishway trap from 1992-1997 included other salmonids, cluepeids, and centrarchids (Table 12). All rainbow trout captured were removed from the river. Rainbows were examined for bacterial pathogens and HKS in 1997 and tests were negative. All other species were released into the river.

Captured smallmouth bass and landlocked salmon had most probably spilled over the dam during high water discharges. Some landlocks identified by fin clips in 1996 had originally been released by New Brunswick Department of Natural Resources and Energy in various lakes throughout the Magaguadavic watershed.

Alewives returned to the river during May and June each year. Their juveniles left the river during August and September.

5.0 ESTIMATION OF ESCAPEMENTS

5.1 Conservation Requirements

An interim required deposition of 1.35 million eggs is based on an estimated 563,000 m^2 of juvenile rearing substrate and a deposition of 2.4 eggs/m^2 (Anon MS 1978). Spawners required to obtain those eggs were estimated at 140 1SW and 230 MSW salmon. Measurements from orthophotographic maps and air photos (Amiro 1993) estimate 9.33 million m^2 of available habitat (>0.125 gradient). Once ongoing ground surveys are completed and integrated into the data base a more accurate estimate of rearing habitat will be available.

5.2 Calibration of egg depositions

5.2.1 Wild

We used the 1992-1995 average sex ratios of 60% males and 40% females for 1SW fish and applied it to fish of unknown sexes in 1996 and 1997. The 1992-1995 average MSW sex ratios were 18% males and 82% females and the undetermined sexes in 1996 were adjusted similarly.

5.2.2 Escapees

The 1SW sex ratios from 1995-1997 were adjusted after applying the 1992-1994 average of 64% females and 36% males to the undetermined 1SW sexes. The 1992-1994 average MSW sex ratios of 34% males and 66% females were used to calibrate the undetermined MSW sexes.

5.2.3 Estimated Egg Yield

Once the total female escapement was determined for each of the years, the mean length-fecundity relationship for St. John River salmon ($Y=430.19e^{0.03605x}$, Marshall and Penney MS 1983) was used to estimate potential egg deposition from the fish passed through the fishway. Table 13 presents the potential spawners and estimated egg depositions from 1992 to 1997. The egg requirements were not met nor were the escapements of large and small salmon met in any of the years considered (Table 13, Figure 8 and 9).

The average estimated egg deposition from 1992-1997 was 541,848 eggs (Table 13), of which 14% was contributed by cultured escapees. The 1992-1997 average egg deposition is 40% of target level. The wild egg deposition declined steadily from 1992-1996 but was slightly higher in 1997 compared to the previous two years. The higher estimated yield in 1997 was because of the increased number of MSW spawners (Figure 9). No male MSW wild salmon were recorded in

the river in 1997. The estimated egg deposition in 1997 was only 11.7% of the required target. No cultured escapees were released into the river in 1997.

The highest contribution of estimated escapee spawners was in 1996 when 32.9% were considered to be sexually mature (Table 13). It was the only year in which cultured salmon had the potential to contribute more eggs than wild salmon (Figure 8).

6.0 JUVENILE DENSITIES

6.1 Stocking Program

Salmon fingerlings and parr were released as part of an enhancement program in 1997. The juveniles released were offspring of wild broodstock collected from the river in 1996. Below are listed the sites and estimated number of fish released per site.

Site	No. Fish Released
Piskahegan Stream	200
Kedron Stream	200
Lake Stream	200
Mouth of Davis Brook (Mag. River)	200
Upstream of Second Falls (Mag. River)	100
Grassy Islands (Mag. River)	300
Davis Brook	200
Pomeroy Bridge (Mag. River)	300
Flume Ridge (Mag. River)	300
Turnover Island (Mag. River)	300
below Graveyard Pool (Mag. River)	300

6.2 Density Estimates

The densities of salmon (fry and parr) and smallmouth bass per $100m^2$ at selected sites, are given in Table 14. The overall salmon densities were low in most sampled areas, with the exception of parr in Linton and Kedron Streams in 1997. Salmon were stocked in those two sites

in June 1997. Most of those salmon, when released, were larger than the 6.0 cm upper limit used as a break between 0+ and 1+ juvenile salmon. Fry densities were less than those for parr at all sites, except at the mouth of Davis Brook, where densities were the same. The salmon parr density near Cook's hatchery was higher than at most other sites, which suggests the hatchery may be leaking salmon. The presence of smallmouth bass in riffle areas may also add to the stress on salmon populations.

6.3 Relative Abundance

The number of juvenile salmon (fry, parr, fry and parr), smallmouth bass, and brook trout caught per 100 seconds of electrofishing time in riffle areas of the Magaguadavic watershed from 1994 to 1997 are given in Tables 15 and 16. The numbers of juvenile salmon were low throughout the watershed. Fewer fry were found than were parr. The number of fry decreased at all stations during the sampling years, with the exception of 3 sites: the Piskahegan, Kedron, and Lake Streams. Those sites were stocked with wild fingerlings in late June 1997.

Salmon fry and parr caught near hatcheries may have been escapees. In 1996 and 1997, 50% and 67% of the sample stations in the Magaguadavic River, respectively, were near commercial salmon hatcheries (Figure 1). The second highest frequency of parr captures was recorded in Mill Stream. The number of parr caught increased in Linton Stream in 1996 where 50% of the sample sites were near a hatchery.

Smallmouth bass have invaded salmon riffle habitat throughout most of the Magaguadavic watershed. They were found in 15 of the 26 sites electrofished. Bass were most common near salmon hatcheries. Brook trout were present only in a few areas. The trout were most common in smaller streams with abundant shade and cover.

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8.0 REFERENCES

Anonymous. 1978. Biological Conservation Subcommittee Report. Prep. For Atlantic Salmon Review Task Force. 203p.

Amiro, P.G. 1993. Habitat measurement and population estimation of juvenile Atlantic salmon (*Salmo salar*). *In* Production of juvenile Atlantic salmon, *Salmo salar*, in natural waters. pp.81-97. Ed. By R.G. Gibson and R.E. Cutting. Canadian Special Publication of Fisheries and Aquatic Sciences 118.

Carr, J. 1995. Interactions between wild and aquaculture Atlantic salmon in the Magaguadavic River, New Brunswick. M.Sc. Thesis, University of New Brunswick, Fredericton: 77 pp.

Carr, J.W., J.M. Anderson, F.G. Whoriskey and T. Dilworth. 1997a. The occurrence and spawning of cultured Atlantic salmon (*Salmo salar*) in a Canadian river. ICES J. Mar. Sci. 54:1064-1073.

Carr, J.W., G.L. Lacroix, J.M. Anderson and T. Dilworth. 1997b. Movements of non-maturing cultured Atlantic salmon (*Salmo salar*) in a Canadian river. ICES J. Mar. Sci. 54:1082-1085.

Table 1. Numbers, percentages, and mean lengths (X in cm, with standard deviations = SD) of 1SW wild Atlantic salmon in Magaguadavic River from 1992 to 1997. Sexes were determined from secondary sexual characteristics.

Year	Male			Female			Undetermined		Combined	
	Tot	%	X ± SD	Tot	%	X ± SD	Tot	X ± SD	Tot	X ± SD
1992	87	56	56.9 ± 2.75	68	44	57.8 ± 3.15			155	57.3 ± 2.96
1993	64	57	57.0 ± 3.18	48	43	56.3 ± 4.33			112	56.7 ± 3.73
1994	48	68	57.5 ± 3.47	23	32	58.6 ± 4.56			71	57.9 ± 3.89
1995	34	69	55.4 ± 2.64	15	31	55.6 ± 2.83			49	55.5 ± 2.70
1996	24	75	56.2 ± 3.15	8	25	56.1 ± 2.21	16	55.7 ± 3.16	48	56.1 ± 2.89
1997	20	63	56.1 ± 3.50	12	37	56.1 ± 1.93	3	57.6 ± 0.46	35	56.2 ± 2.85
92-95	233	60	56.9 ± 3.08	154	40	57.2 ± 3.88			387	56.9 ± 3.42
92-96	257	61	56.8 ± 3.09	162	39	57.2 ± 3.74	16	55.7 ± 3.16	435	56.9 ± 3.41
92-97	277	61	56.7 ± 3.12	174	39	57.2 ± 3.82	19	56.0 ± 2.99	470	56.8 ± 3.37

Table 2. Numbers, percentages, and mean lengths (X in cm, with standard deviations = SD) of MSW wild Atlantic salmon in Magaguadavic River from 1992 to 1997. Sexes were determined from secondary sexual characteristics.

Year	Male			Female			Undetermined		Combined	
	Tot	%	X ± SD	Tot	%	X ± SD	Tot	X ± SD	Tot	X ± SD
1992	23	17	76.6 ± 3.71	115	83	77.7 ± 4.43			138	77.5 ± 4.34
1993	17	14	76.6 ± 4.90	108	86	77.6 ± 4.11			125	77.5 ± 4.24
1994	9	15	76.2 ± 5.13	51	85	76.6 ± 5.07			60	76.6 ± 5.08
1995	15	50	75.8 ± 2.83	15	50	74.8 ± 3.27			30	75.3 ±3.46
1996	2	18	77.8 ± 0.75	9	82	74.9 ± 2.83	10	77.6 ± 4.00	21	76.5 ± 3.60
1997	0	0		24	100	76.6 ± 2.97			24	76.6 ± 2.97
92-95	64	18	76.1 ± 4.81	289	82	77.3 ± 4.44			355	77.1 ± 4.53
92-96	66	18	76.1 ± 4.75	298	82	77.2 ± 4.42	10	77.6 ± 4.00	374	77.1 ± 4.49
92-97	66	17	76.1 ± 4.75	322	83	77.2 ± 4.33	10	77.6 ± 4.00	398	77.0 ± 4.42

Table 3. Numbers and percent of total male and female wild salmon repeat spawners that entered the fishway (at the head of the tide) of the Magaguadavic River during 1992 to 1997.

Year	Sex		
	male	female	Percent returns
1992	2	8	7
1993	2	9	9
1994	0	3	5
1995	1	0	3
1996	0	1	5
1997	0	1	4
average 1992 -1997	1	4	7

Table 4. Numbers, percentages, mean lengths (X in cm, with standard deviations = SD) of postsmolt escaped cultured Atlantic salmon in Magaguadavic River from 1992 to 1997. Sexes were determined from secondary sexual characteristics.

Year	Male		Female		Undetermined		Combined	
	Tot	X ± SD	Tot	X ± SD	Tot	X ± SD	Tot	X ± SD
1992	1	28.0	0		2	35.5 ± 4.00	3	33.0 ± 4.81
1993	8	31.2 ± 6.43	0				8	31.2 ± 6.43
1994	1	32.0	0		58	32.5 ± 4.62	59	32.5 ± 4.58
1995	30	24.8 ± 4.60	0		23	30.2 ± 7.08	53	27.2 ± 6.39
1996	13	29.4 ± 7.72	11	36.2 ± 4.13	22	33.9 ± 4.62	46	33.2 ± 5.93
1997	23	25.5 ± 3.23	0		14	33.0 ± 5.62	37	28.3 ± 5.63
92-95	40	26.4 ± 5.61	0		83	32.0 ± 5.53	123	30.1 ± 6.15
92-96	53	27.1 ± 6.33	11	36.2 ± 4.13	105	32.4 ± 5.31	169	31.0 ± 6.24
92-97	76	26.6 ± 5.63	11	36.2 ± 4.13	119	32.4 ± 5.35	206	30.5 ± 6.22

Table 5. Numbers, percentages, mean lengths (X in cm, with standard deviations = SD) of 1SW escaped cultured salmon in Magaguadavic River from 1992 to 1997. Sexes were determined from secondary sexual characteristics.

Year	Male			Female			Undetermined		Combined	
	Tot	%	Ave ± SD	Tot	%	X ± SD	Tot	X ± SD	Tot	X ± SD
1992	34	41	58.2 ± 4.31	49	59	57.1 ± 4.86			83	57.5 ± 4.68
1993	9	9	59.3 ± 5.23	87	91	57.3 ± 4.77			96	57.4 ± 4.85
1994	394	37	61.8 ± 4.26	665	63	60.5 ± 4.21			1059	61.0 ± 4.27
1995	184	44	61.5 ± 7.58	242	56	60.4 ± 7.68	65	56.8 ± 3.99	491	60.4 ± 7.40
1996	57	34	59.1 ± 4.31	112	66	59.1 ± 4.43	5	57.8 ± 5.13	174	59.0 ± 4.42
1997	18	34	61.4 ± 5.57	35	66	57.7 ± 5.11	6	56.8 ± 7.14	59	58.7 ± 5.78
92-95	621	37	61.5 ± 5.54	1043	63	60.0 ± 5.41			1729	60.4 ± 5.50
92-96	678	37	61.3 ± 5.49	1155	63	59.9 ± 5.33	70	57.5 ± 4.71	1903	60.3 ± 5.43
92-97	696	37	61.3 ± 5.49	1190	63	59.9 ± 5.33	76	57.5 ± 4.77	1962	60.3 ± 5.44

Table 6. Numbers, percentages, mean lengths (X in cm, with standard deviations = SD) of MSW escaped cultured Atlantic salmon in Magaguadavic River from 1992 to 1997. Sexes were determined from secondary sexual characteristics.

Year	Male			Female			Undetermined		Combined	
	Tot	%	X ± SD	Tot	%	X ± SD	Tot	X ± SD	Tot	X ± SD
1992	17	27	79.5 ± 6.41	45	73	76.3 ± 6.51			62	77.2 ± 6.65
1993	14	28	76.0 ± 4.32	36	72	72.9 ± 4.24			50	73.8 ± 4.47
1994	35	43	75.4 ± 6.09	47	57	73.8 ± 5.82			82	74.5 ± 5.82
1995	113	72	71.3 ± 5.49	43	28	70.3 ± 4.38	12	66.5 ± 2.65	168	70.7 ± 5.22
1996	3	17	74.4 ± 2.55	15	83	71.3 ± 5.18	2	80.2 ± 1.30	20	72.6 ± 5.37
1997	6	33	75.4 ± 4.28	12	67	72.4 ± 3.75	5	68.7 ± 3.51	23	72.4 ± 4.47
92-95	179	51	73.2 ± 6.27	171	49	73.4 ± 5.81	12	66.5 ± 2.65	362	73.1 ± 6.09
92-96	182	49	73.3 ± 6.23	186	51	73.2 ± 5.79	14	68.5 ± 5.41	382	73.1 ± 6.06
92-97	188	49	73.3 ± 6.19	198	51	73.2 ± 5.69	19	68.5 ± 4.98	405	73.0 ± 5.98

Table 7. Summary of recaptured wild and escaped cultured salmon released in the Magaguadavic River, below the fishway trap, or at sea.

Recap. Year	Origin	Release site	Release date	Recapture site	Recapture date	Recapture observations
1995	culture	above fishway trap	July 18/95	67km upstream of release	Aug/12/95	found dead 25 days after release - fungal infection
1996	wild	above fishway trap	July 96	81km upstream of release.	Oct 3/96	caught and released by fly fisherman
1996	culture	above fishway trap	July 15/96	fishway trap	Aug 19/96	Must have passed through downstream sluice after release into the river before it returned as a maturing male
1996	culture	below fishway trap	Sept 29/95	fishway trap	Sept 11/96	tagged as a sexually immature fish in 1995. Returned as a mature male 347 days after release.
1996	wild landlocked	above fishway	July 96	Lake Utopia	Aug 96	
1997	wild	Chamcook Harbour (10km from mouth of Mag. River	Sept 17/97	fishway trap	Sept 19/97	
1997	wild	Ovenhead (3km from mouth of Mag. River	Sept 17/97	fishway trap	Sept 23/97	
1997	cultured	mouth of Mag. River (8.4km downstream of fishway)	Sep 17/97	fishway trap	Sept 19/97	

Table 8. Numbers of sexually mature and immature escaped cultured Atlantic salmon captured in the fishway (at the head of the tide) of the Magaguadavic River from 1992 - 1996. Mature postsmolts are precocious males that escaped from brackish water aquaculture facilities situated in the Magaguadavic estuary.

YEAR	AGE	MATURE	IMMATURE	Total	Percent mature
1992	Postsmolt	1	2	3	33.3
	1SW	5	78	83	6.0
	MSW	13	49	62	21.0
	Total	**19**	**129**	**148**	**12.8**
1993	Postsmolt	2	6	8	25.0
	1SW	7	89	96	7.3
	MSW	11	39	50	22.0
	Total	**20**	**134**	**154**	**13.0**
1994	Postsmolt	0	59	59	0
	1SW	32	1027	1059	3.0
	MSW	7	75	82	8.5
	Total	**39**	**1161**	**1200**	**3.3**
1995	Postsmolt	29	24	53	54.7
	1SW	29	462	491	5.9
	MSW	16	152	168	9.5
	Total	**74**	**638**	**712**	**10.4**
1996	Postsmolt	8	38	46	17.4
	1SW	54	120	174	31.0
	MSW	17	3	20	85.0
	Total	**79**	**161**	**240**	**32.9**
1997	Postsmolt	22	15	37	59.5
	1SW	12	47	59	20.3
	MSW	21	2	23	91.3
	Total	**55**	**64**	**119**	**46.2**

92-97	**Total**	**286**	**2287**	**2573**	**11.1**

Table 9. Wild fish removals. Summary of the wild 1SW and MSW salmon recorded as either in-river mortalities or taken as broodstock from 1992 - 1997.

Year	1992	1993	1994	1996	1997	
	in-river	in-river	in-river	broodstock	in-river	broodstock
1SW	3	1	0	4	1	3
MSW	4	1	1	3	2	5
Total	7	2	1	7	3	8

Table 10. Summary of escaped postsmolt, 1SW, and MSW cultured salmon removed from the Magaguadavic River following their capture in the fishway trap at the head of the tide. Fish were screened for disease, re-released, or used for other purposes such as aboriginal food fishery, maturity studies, or disposed of.

Year	Age	Disease screening	Re -released	Other	Total
1993	Postsmolt	1	0	0	1
	1SW	0	0	0	0
	MSW	1	0	0	1
1994	Postsmolt	1	0	32	33
	1SW	22	0	450	472
	MSW	0	0	0	0
1995	Postsmolt	1	52	0	53
	1SW	120	138	100	358
	MSW	39	28	26	93
1997	Postsmolt	0	36	1	37
	1SW	27	26	6	59
	MSW	7	15	1	23

Table 11. Results of bacteriology cultures of escaped cultured salmon captured at fishway trap in Magaguadavic River from 1993 - 1997. Tests were conducted at the N.B. Department of Fisheries and Aquaculture.

Year	Total	No pathogens	*Aeromonas*	*Pseudomonas*	*Vibrio*	*Edwardsella tarda*
1993	2	1	1	0	0	0
1994	23	22	4	0	2	0
1995	99	74	13	11	0	1
1997	15	4	10	0	1	0

Table 12. Total numbers (N) of species other than anadromous Atlantic salmon captured in the fishway trap from 1992 - 1997. Mean lengths (X, in cm) and standard deviations (SD) are given for each species except alewives.

Species		Year					
		1992	1993	1994	1995	1996	1997
alewives	N	? X 10^4	? X 10^4	? X 10^4	? X 10^4	? X 10^4	? X 10^4
landlocked salmon	N	0	0	0	0	48	2
	X					40.6	38.7
	SD					3.43	.15
rainbow trout	N	0	0	7	3		
	X			50.5	44.7	0	2
	SD			5.40	12.0		50.8
							6.30
brown trout	N	9	2	2	11	0	0
	X	41.5	42.0	41.0	37.6		
	SD	3.10	11.5	1.50	5.10		
smallmouth bass	N	0	0	10	7	1	0
	X			30.4	32.2	30.0	
	SD			6.7	8.0		

Table 13. Escapement of wild and escaped cultured Atlantic salmon in the Magaguadavic River during 1992 - 1997. Numbers of spawners are based on fish classed as sexually mature, and total egg deposition is based on sex ratio, mature female fork length, and fecundity for age classes 1SW and MSW for wild and cultured spawners. Mature postsmolts are all precocious males that escaped from brackish water sites. The mean length-fecundity relationship for St. John River salmon ($Y=430.19e^{0.03605x}$, Marshall and Penney MS 1983) was used to estimate potential egg deposition. The conservation requirement is 1.35 million eggs.

	Wild			Cultured						Combined					
Yr	Total spawners	Percent females	Total eggs	Total	Total mature	Percent mature	Percent females	Postsmolt mature	Total eggs	Total escapement	Total spawners	Percent females	Percent cultured spawners	Total eggs	Percent of conserv. level
92	286	61.5	1014007	148	19	12.8	63.2	1	70712	434	305	61.6	6.2	1084719	80.3
93	254	66.0	912214	152	21	13.8	66.7	3	68021	386	255	66.3	8.2	980234	72.6
94	130	56.2	425979	695	31	4.5	35.5	0	54125	825	161	52.2	19.3	480104	35.6
95	79	38.0	143575	208	45	21.6	46.7	0	86143	287	124	41.1	36.3	229718	17.0
96	62	45.2	140623	240	79	32.9	55.7	8	178370	302	141	51.1	56.0	318993	23.6
97	48	62.5	157322	0	0	0	0	0	0	48	48	62.5	0	157322	11.7
avg 92-97	143.2	57.3	465620	2240.5	32.5	11.3	43.2	2	76229	380.3	172.3	55.8	21	541848	40.1

Table 14. The densities of salmon (fry and parr) and smallmouth bass per $100m^2$ at various stations in the Magaguadavic watershed, 1995, 1997. Peterson mark-recapture estimates were used to determine densities. NS = present, but density was not estimated.

Site	Year	Density per $100m^2$		
		fry	parr	bass
Pomeroy Bridge (Magaguadavic River)	1995	0	0.1	ns
Mouth of Davis Brook (Magaguadavic River)	1995	0.5	0.5	ns
Flume Ridge (Magaguadavic River)	1995	0.4	0.7	ns
Bonny River	1995	2.0	9.5	ns
NE Branch Magaguadavic River	1995	0	3.4	3.4
Linton Stream	1995	0	3.4	ns
Linton Stream	1997	3.8	55.0	ns
Kedron Stream	1997	8.6	28.4	ns
Piskahegan Stream	1997	3.8	3.8	ns
Cooks Hatchery (Magaguadavic River)	1997	0.6	11.3	12.0

Table 15. Number of juvenile Atlantic salmon (fry, parr, fry and parr), smallmouth bass, and brook trout caught per 100 seconds of electrofishing in riffle areas of the Magaguadavic watershed from 1995 to 1997. Fry were classified as 0+ salmon less than 6 cm forklength. N= number of stations fished. Species not found at a site were not listed. Trout are all brook trout.

Magaguadavic River

	1995				1996				1997			
	fry	parr	fry & parr	bass	fry	parr	fry & parr	bass	fry	parr	fry & parr	bass
X	0.3	0.33	0.63	0.43	0.05	0.73	0.78	0.13	0.03	1.33	1.37	1.47
Median	0.3	0.3	0.9	0.05	0.05	0.65	0.7	0.1	0	1.2	1.2	1.9
Sd	0.24	0.21	0.38	0.17	0.05	0.49	0.51	0.12	0.05	0.9	0.95	1.07
Range	0-0.6	0.1-0.6	0.1-0.9	0.2-0.6	0-0.1	0.2-1.5	0.2-1.6	0-0.3	0-0.1	0.3-2.5	0.3-2.6	0-2.5
N	3	3	3	3	8	8	8	8	3	3	3	3

Linton Stream

	1994				1995			1996				1997				
	fry	parr	fry & parr	bass	parr	bass	trout	fry	parr	fry & parr	bass	fry	parr	fry & parr	bass	trout
X								0.02	0.77	0.79	0.13	0.02	0.37	0.39	0.51	0.
Median	0.03	0.07	0.10	0.03	0.33	0.16	0.04	0	0.82	0.87	0	0	0.38	0.43	0.14	0
Sd								0.04	0.42	0.42	0.23	0.02	0.05	0.06	0.61	0.(
Range								0-.09	.13-1.29	.13-1.29	0-.53	0-.05	.3-.43	.3-.43	.02-1.38	0-.
N	1	1	1	1	1	1	1	4	4	4	4	3	3	3	3	3

Table 15 (cont d)

Kedron Stream

	1994			1995			1996			1997		
	fry	parr	fry & parr	fry	parr	fry & parr	fry	parr	fry & parr	fry	parr	fry & parr
X	1.58	1.69	3.28	0.78	2.50	3.28	0.14	0.55	0.69	1.25	3.86	5.11
Median							0.14	0.55	0.69			
Sd							0.14	0.12	0.26			
Range							0-0.28	0.43-0.66	0.43-0.94			
N	1	1	1	1	1	1	2	2	2	1	1	1

Davis Brook

	1994			1996			1997		
	fry	parr	fry & parr	fry	parr	fry & parr	fry	parr	fry & parr
X				0.05	1.12	1.17	0	1.03	1.03
Median	0.53	0.79	1.32	0.05	1.12	1.17			
Sd				0.05	0.08	0.04			
Range				0-0.09	1.04-1.2	1.2-1.13			
N	1	1	1	2	2	2	1	1	1

Table 16. Number of juvenile Atlantic salmon (fry, parr, fry and parr), smallmouth bass, and brook trout caught per 100 seconds of electrofishing time at stations of the Magaguadavic watershed, 1994 - 1997. Fry were classified as 0+ salmon less than 6 cm forklength (ages have not been determined from scales).

	Bonny River					**Piskahegan River**					**NE Branch Magaguadavic River**			
	fry	parr	fry & parr	bass	trout	fry	parr	fry & parr	bass	trout	fry	parr	fry & parr	bass
1994	0.68	0.53	1.2	0.11	0.10	0.40	0.30	0.69	0.49	0.10	0.13	1.98	2.11	0.92
1995	0.39	1.69	2.1	0	0.10	1.16	1.16	2.32	0	0	0	0.70	0.70	0.54
1996	0	0.58	0.58	0	0.07	0	0.74	0.74	0	0	0	1.49	1.49	0
1997	0	0.15	0.15	0.15	0.15	1.20	1.51	2.71	0.16	0.05	NS	NS	NS	NS

	Lake Stream					**McDougall Inlet**					**Cox Stream**			
	fry	parr	fry & parr	bass	trout	fry	parr	fry & parr	bass	trout	fry	parr	fry & parr	trout
1994	0	0	0	0.55	0.08	0	0.35	0.35	0	0	0	0.59	0.59	1.58
1995	0	0	0	0	0.78									
1996	0	0	0	0	0.22	0	0.05	0.05	0	0.05	0	0.16	0.16	1.32
1997	0.73	0.97	0.24	0	0.85									

Site	Year	fry	parr	fry & parr	bass	trout
Colonel Stream	1996	0.10	0.30	0.40	0	2.09
Deadwater Stream	1996	0	0.55	0.55	0	1.66
Lower Trout Brook	1996	0	0.56	0.56	0	.47
Mill Stream	1996	0	0.59	0.59	0	.12
Mill Stream	1997	0	2.23	2.23	1.95	0

Figure 1. Map of Magaguadavic River showing the locations of electrofishing sites and commercial salmon hatcheries.

1. Magaguadavic River (Cook Hatchery, 2 sites)
2. Magaguadavic River (HWY 3 bridge, 2 sites)
3. North East Branch Magaguadavic River
4. Mouth of Davis Brook
5. Davis Brook (2 sites)
6. Lower Trout Brook
7. Deadwater Stream
8. Cox Stream
9. Magaguadavic River (Flume Bridge)
10. Magaguadavic River (Pomeroy Bridge)
11. Kedron Stream (2 sites)
12. Piskahegan Stream
13. Lake Stream
14. Magaguadavic River (Turnover Island)
15. Bonny River
16. Linton Stream (4 sites)
17. Mill Stream
18. McDougall Inlet
19. Colonel Stream

Figure 2. The total numbers of Atlantic salmon recorded annually in the fishway near the mouth of the Magaguadavic River prior to 1992. The 1SW and MSW salmon proportions are given in some years.

Figure 3. The (a) total numbers and (b) percent of wild (shaded) and cultured (hatched bars) Atlantic salmon recorded in the fishway near the mouth of the Magaguadavic River from 1992-1997.

Figure 4. The monthly total numbers of wild (shaded) and cultured (hatched bars) Atlantic salmon recorded in the fishway near the mouth of the Magaguadavic River during (a) 1992, (b) 1993, (c) 1994, (d) 1995, (e) 1996, and (f) 1997.

Figure 5. The percent of postsmolt, 1SW, and MSW (a) wild and (b) cultured Atlantic salmon recorded in the fishway near the mouth of the Magaguadavic River from 1992-1997.

Figure 6. The percent of sexually mature and immature cultured Atlantic salmon recorded in the fishway near the mouth of the Magaguadavic River from 1992-1997.

Figure 7. The percent of wild and cultured Atlantic salmon removed (for broodstock, experimental, disease screening, or found dead) from the Magaguadavic River from 1992-1997.

Figure 8. The estimated egg deposition for wild and cultured Atlantic salmon in the Magaguadavic watershed from 1994-1997. The length fecundity relationship for St. John River salmon (Marshall and Penny, 1983) was used to estimate potential egg deposition. The conservation requirement of 1.35 million eggs is shown.

Figure 9. The numbers of female 1SW and MSW (a) wild and (b) cultured salmon potential spawners in the Magaguadavic watershed from 1992-1997.