ASSESSMENT OF ATLANTIC SALMON IN THE MIRAMICHI RIVER (NB), 1998 TO 2009

Context

The Miramichi River is considered to have the largest Atlantic salmon (*Salmo salar* L.) run of eastern North America. Commercial fisheries were permanently suspended in the Maritime provinces in 1984. Aboriginal fisheries were historically conducted almost exclusively in the Northwest Miramichi (exploitation also occurs in the Southwest Miramichi and estuarial waters of the Miramichi River, downstream of the confluence of the two branches) and are of a smaller scale than the recreational fishery. Recreational catches of salmon between 1991 and 1995, the most recent years of available information, averaged over 24,000 fish annually.

Annual assessments of the Atlantic salmon stock of the Miramichi River have been prepared since 1982. The status of the resource was assessed on the basis of whether the conservation requirement was attained/exceeded (Chaput et al. 2001). Since 2001, estimates of returns of salmon have been provided to user groups and managers but the data, methods, and results have not been peer reviewed or published.

The Miramichi Watershed Management Committee is interested in annual assessments of Atlantic salmon in the Miramichi River. In 2008, the assessment was provided but the estimates from the model used by DFO Science did not conform to the perceptions of the abundance of adult salmon that year. In response to low counts of small salmon at numerous monitoring facilities in 2009 and the discrepancies in perceptions from previous years, DFO Fisheries and Aquaculture Management (FAM) requested that the assessment model and the 2009 assessment be peer reviewed. DFO FAM has also asked whether the present management measures are sufficient to meet the objective of attaining the conservation requirements for the river. A special science response process was initiated to consider these questions.

The assessment model was considered adequate for estimating the returns of Atlantic salmon to the Miramichi River. Conservation requirements after fisheries have only been achieved once during the 1998 to 2009 period (range 68% to 104%). Total estimated losses of eggs due to fishing have averaged 8%, 53% of the loss is attributed to removals of large salmon. The scope for increasing egg depositions using more restrictive fisheries management is greater on the Northwest branch of the Miramichi. It is anticipated that the return of large salmon in 2010 will be less than 50% of the number required to achieve conservation.

Background

The Miramichi River is considered to have the largest Atlantic salmon (*Salmo salar* L.) run of eastern North America. There are two major branches: the Northwest Branch covers about 3,950 km^2 and the Southwest Branch about 7,700 km^2 of drainage area. The two branches drain into a common estuary and subsequently drain into the Gulf of St. Lawrence at latitude 47°N.

Two size groups of salmon are defined. The small salmon category consists of fish less than 63 cm fork length. These fish have usually spent only one full year at sea (one-sea-winter) prior to returning to the river. The large salmon category consists of fish greater than or equal to 63 cm fork length. This size group is generally referred to as multi-sea-winter or just salmon and contains varying proportions of one-sea-winter, two-sea-winter and three-sea-winter maiden (first time) spawners as well as salmon that have spawned previously.

In the context of the Miramichi, estimates of returns to each branch are desired. It is not possible to obtain absolute counts of salmon in the Miramichi due to its physical size. As a result, the use of partial capture techniques to sample the runs necessitates the use of mark and recapture methods to estimate run sizes.

Since 1992 and briefly over 1985 to 1987, returns of Atlantic salmon to the Miramichi River and to the Northwest and Southwest branches, were estimated from mark and recapture experiments. Capture and tagging operations occur at tidal trapnets and recaptures occur at tidal trapnets and opportunistically using other sampling gear at various locations upriver, including counting fences and directed sampling programs such as seining. Since 1994, a DFO operated trapnet located at Millerton is considered the index facility for the Southwest Miramichi whereas in the Northwest Miramichi, a DFO trapnet located at Cassilis has become the index trapnet since 1998.

Harvest data from the Miramichi are incomplete. First Nations' harvests from the trapnets are considered complete as the data are used in the assessment. However there are no harvest data from the aboriginal gillnet fisheries in the Miramichi (with the exception of a few years in the time series). As well, recreational catch data have not been available for the Miramichi River since 1997.

The conservation spawning requirement for the Miramichi River and each branch separately is based on an egg requirement of 2.4 eggs/m^2 of spawning and rearing habitat area (54.6 million m^2) (CAFSAC 1991). Based on average biological characteristics, the conservation requirements are about 16,000 large salmon for the Southwest Miramichi and 7,300 large salmon for the Northwest Miramichi (Chaput et al. 2001).

Analysis and Responses

Assessment data

The run of Atlantic salmon to the two main branches of the Miramichi River was monitored using estuary trapnets, of a T-trap design as used in the historical commercial salmon fishery and in the commercial gaspereau fishery. The DFO Science trapnet installed at Millerton is the index facility for the Southwest Miramichi whereas the DFO Science trapnet installed at Cassilis is the index facility for the Northwest Miramichi. These trapnets were installed and fished daily from the middle of May to the end of October and covered the period of migration of Atlantic salmon to the Miramichi River.

Mark and recapture experiments were used to estimate the returns of Atlantic salmon by size group. For 1998 to 2009, salmon were marked with individually numbered external tags at three estuary trapnet locations: at trapnets in the lower portion of the Southwest Miramichi by Eelground First Nation, at the DFO index trapnet at Millerton in the upper tidal portion of the Southwest, and at the DFO index trapnet at Cassilis in the upper tidal portion of the Northwest Miramichi. Salmon were sampled for recaptures at the three tagging locations as well as at the

Metepenagiag First Nation trapnets in the upper tidal portion of the Northwest Miramichi. Sampling for recaptures also occurred during the directed seining program sponsored by Miramichi Salmon Association in both the Northwest Miramichi and Southwest Miramichi in 2008 and 2009.

There are three headwater monitoring facilities in the Miramichi, two in the Southwest Miramichi River (Dungarvon, Juniper) and one in the Northwest Miramichi River (Northwest Miramichi). Two of these facilities are operated by the New Brunswick Department of Natural Resources and the third is sponsored and operated by the Miramichi Watershed Management Committee in collaboration with a private company (J.D. Irving Ltd.). Salmon are counted and contained in a holding pool during the summer months then released to continue migrations upstream in late fall. Counts of salmon are distinguished on the basis of size (small and large categories). The two Southwest Miramichi barriers began operations in 1981 and the Northwest Miramichi barrier began operation in 1988 (Table 1). Counts of large salmon in 2009 were within the range of other counts since 2000, whereas the counts of small salmon with the exception of the 2007 Dungarvon count, are the lowest during this period.

Other indicators of abundance include recreational catch data. The most complete time series was available from the Crown Reserve waters of the Northwest Miramichi (1969 to present) (Table 2). The Crown Reserve waters are stretches of river which are made available for angling by a draw system. Effort is limited on each stretch and angling parties complete angling creel forms of their activities (catch and effort). In 2009, both the fishing effort and catch of large salmon were the highest since 1984, whereas the catch of small salmon was the lowest of the time period (Table 2).

Models

The mark and recapture assessment models to estimate abundance of salmon were developed in a Bayesian framework which allowed the use of multiple indicators including catches at estuary trapnets, counts at headwater monitoring facilities, and focused sampling programs in river (seining). Two variations of the model were used. An annual model used only the data from the year of interest to estimate returns, while a hierarchical model used information from other years to help in the inference for the year of interest. The quantities of interest for the assessment were the annual returns of salmon by size group to the Northwest and Southwest branches and to the Miramichi River overall. The Bayesian models were run using Monte Carlo Markov Chain sampling with the Gibbs sampler in “OpenBugs”.

A key assumption of the mark and recapture models was that the probability of capture of tagged and untagged fish is independent and identical, within the season and within the different recapture and monitoring facilities in the different areas of the river. There were questions regarding whether this assumption was correct for the entire year, particularly for the early portion of the salmon run when catchability of salmon at the trapnets may be lower. This concern stemmed from the low catches at the trapnets early in the year while salmon were known to be present upriver of the traps during that same time period (from angling, First Nations catches, counts at headwater barriers). This effect may be more important in the Northwest Miramichi than the Southwest Miramichi. The consequence of this potential bias to the assessment may be that the abundance was underestimated but the magnitude of the bias was unknown. It was also assumed that the survival rate of tagged fish was the same from all tagging facilities. Notwithstanding these questions, the models were considered sufficient for the purpose of estimating the returns. Recommendations on further analyses to validate the assumptions and improve the model were discussed during the meeting and provided in a subsequent section (see Research Recommendations).

Of the two models, the hierarchical model is the preferred model over the annual model. The hierarchical model incorporates the data from the year of interest (2009 for example), as well as information about catchability that is available from previous years. As well, counts at the headwater monitoring facilities are included in the model and have some observation weight for the years when the mark and recapture experimental observations are weakly informative.

Assessment Results

The estimates of returns of small salmon and large salmon for the years 1998 to 2009 for the Miramichi River are provided in Table 3 and Figure 1. The returns by branch are provided in Table 3 and Figures 2 and 3.

Returns of large salmon to the entire Miramichi in 2009 were estimated to be 22,000 fish (95% Bayesian Credibility Interval (B.C.I.) of 17,400 to 28,800), equivalent to the estimated abundance in 2001 and 50% higher than in 2008 (Table 3; Fig. 1). The small salmon returns in 2009 were estimated at 12,400 fish (95% B.C.I. 9,300 to 16,600), 60% below 2008 and the lowest of the 1998-2009 time period (Table 3; Fig. 1).

Return estimates of large salmon in 2009 remained low (3,000 fish) in the Northwest Miramichi but were high in the Southwest Miramichi (18,700 fish) (Table 3; Figures 2, 3). Small salmon return estimates in 2009 were 3,000 fish in the Northwest and 9,300 fish in the Southwest, the lowest of the time series (1998 to 2009) in both branches (Table 3). The abundance in the Northwest Miramichi may be underestimated because some of the run may be missed by the assessment traps; as discussed above, catchability may be lower in the early part of the season. The run timing to the Northwest Miramichi is earlier than the Southwest Miramichi and the issue of missing some of the early run is considered more important on the Northwest branch.

The proportions of the total annual catches of small and large salmon at the index trapnets in the Northwest Miramichi and Southwest Miramichi which occurred before August 1 were exceptionally high in 2008 and 2009 (Figure 4). During 1998 to 2006, only 30% to 40% of the large salmon catches at the SW Millerton trapnet occurred before August 1, but this percentage increased steadily to 86% in 2009. The increase in the early-run proportion was also noted for the small salmon catch, which ranged from 30% to 55% during 1998 to 2006, but was almost 80% in 2009 (Figure 4). The timing of catches in the Northwest Miramichi has been more variable than in the Southwest Miramichi, but for 2007 to 2009, the proportion of the catch which occurred before August 1 was higher than most previous years (Figure 4). Most of the tag returns from the headwater barriers have traditionally been from fish that were tagged in the estuary prior to August 1, suggesting that the run of salmon at these headwater sites is mostly early-run fish.

Estimates of salmon which would have returned before August 1 to the Northwest and Southwest Miramichi (based on the proportion of the total catches at the trapnets which occurred early) are shown in Figure 5. For the Miramichi overall, the early run returns of small salmon in 2008 were indeed much higher than the previous three years but equally important early-run returns were estimated to have occurred in 2002 and 2004 (Figure 5). For the Northwest Miramichi, small salmon early-run returns in 2008 were estimated to have been much higher than in 2005 to 2007 but equal and higher returns were estimated to have occurred in many other years previously (Figure 5). For the Southwest Miramichi, small salmon early-run returns in 2008 were the highest of the 1998 to 2009 time period (Figure 5). Large salmon early-run returns to the Miramichi overall and to the Southwest Miramichi in 2009 were the highest of the time period and by a large amount (Figure 5). In the Northwest Miramichi, early run returns of large salmon in 2009 are among the highest of the time series, surpassed only by those of 1999 (Figure 5).

In summary, while the trapnets and headwater barrier fences experienced important periods of in-operation in 2008 which could have resulted in underestimates of the returns, the perceptions of strong runs of small salmon in 2008 could also be explained by a strong early run component (prior to Aug. 1). If the returns in 2008 and 2009 were dominated by early run fish, then the perceptions of anglers and from counts at barriers would be consistent with a strong return of small salmon in 2008 and a strong return of large salmon in 2009. The estimated early run returns indicate that this was indeed the case and the lower than expected estimate of the overall returns may in fact be closer to reality than has been previously concluded.

Escapement relative to conservation

Using the median estimates of the returns of small salmon and large salmon (Table 1) and the biological characteristics of the fish, salmon returns to the Miramichi in 2009 were sufficient to meet 97% of the conservation egg requirement. Over the period 1970 to 2009, the returns of salmon from all size groups were sufficient to have met or exceeded the conservation requirements repeatedly between 1970 and 1996 but have only been sufficient to meet or exceed conservation twice during the 1997 to 2009 period (range 74% to 112%) (Figure 6).

After correcting for the estimated removals in fisheries in 2009, the eggs which were estimated to have been spawned were 92% of the conservation requirement. Eggs in the escapement of salmon (all size groups) met or exceeded conservation every year between 1986 to 1996 but have only been sufficient to exceed conservation once since 1997 (range 68% to 104%) (Figure 6). At least 67% of conservation requirements have been met every year since 1984 (Figure 6).

Subject to the uncertainties on the abundance estimates to each branch, the escapement in the Southwest Miramichi in 2009 achieved 119% of the conservation requirements. For the Northwest Miramichi, the escapement was 34% of the conservation requirement. The Northwest Miramichi has met on average 50% (range 26% to 111%) of the conservation requirement during 2000 to 2009 whereas the Southwest Miramichi has averaged 103% (range 77% to 119%) of the conservation requirement during the same time period.

Expectations for 2010

It is anticipated that there will be a low return of large salmon in 2010 due to the exceptionally low return of small salmon in 2009. Since 1998, the ratio of 2SW returns to small salmon returns the previous year has averaged 0.38 (range of 0.24 to 0.47) which is equivalent to one 2SW salmon from every 2.6 small salmon the previous year (Figure 7). Including repeat spawners, on average 0.61 large salmon have returned for every small salmon the previous year (range of 0.42 to 0.77) (Figure 7). The most likely scenario in 2010 is for a low return of large salmon, in the order of 5,000 to 10,000 large salmon, or roughly 21% to 43% of the conservation requirement for the Miramichi overall.

Impacts of management measures on attainment of conservation

Harvests of salmon were incomplete from both the First Nations Food, Social, and Ceremonial (FSC) fisheries as well as from the recreational fisheries. In the absence of complete harvest data, the following annual (1998 to 2009) assumptions were made:

- For the First Nations FSC fisheries, it was assumed that the harvest of large salmon was 600 fish, about 90% of the allocations in the fishery agreements. The annual harvest of small salmon was assumed equal to the reported harvests from the trapnets (range 794 to 2,568 fish).
- For the recreational fishery, the losses of large salmon were estimated using an assumed catch rate of 30% with a 3% mortality from catch and release. Based on these values, losses of large salmon are just under 1% of the annual returns of large returns. For small salmon, the harvests were assumed to be 25% of the estimated returns annually.

Conservation requirements for the Miramichi, after fisheries, have only been achieved once in the past ten years (range of 69% to 104%) (Figure 6). The assumed harvests from all fisheries resulted in a loss of about 30% of the eggs from small salmon in the Southwest Miramichi and 40% of the eggs from small salmon in the Northwest Miramichi. For large salmon, assumed harvests represented about 15% of the eggs in the returns for the Northwest Miramichi and less than 2% of the eggs in the returns of the Southwest Miramichi. The majority of the large salmon losses in the Northwest Miramichi are assumed to occur in the First Nations FSC fisheries (90% or more) whereas the losses in the Southwest Miramichi are due to recreational fishing.

Even in the absence of fisheries, conservation requirements would have been met only twice in the last ten years (range 74% to 112%) (Figure 6). Overall for the Miramichi, total assumed losses of eggs due to fishing have averaged 8% (range of 5% to 14%) over both size groups; 53% (annual range 27% to 75%) of that due to fishing losses of large salmon. These levels are an indication of the extent to which egg depositions can be increased using more restrictive fisheries management. The scope for increased egg depositions is greater on the Northwest Miramichi where the losses relative to returns have averaged 21% from all the fisheries and size groups, compared to 5% for the Southwest Miramichi.

Sources of Uncertainty

Harvest data from the Miramichi are incomplete. First Nations' harvests from the trapnets are considered complete as the data are used in the assessment, however the harvest data from the gillnet fisheries are incomplete. As well, recreational catch data have not been available for the Miramichi River since 1997. As a result, values from the past must be assumed for these harvests and then used to assess the attainment of conservation requirements for the river. If actual harvests were greater than the values assumed, the attainment of conservation was overestimated and if the harvests were less, then the impacts of fisheries were overestimated.

Particularly in recent years, low numbers of small salmon have been tagged at some locations and there has been reduced fishing effort at some trapnet recapture facilities, as they function primarily as food fishery traps. The low number of tagged fish available for recapture and the lower number of recaptures realized results in less precise and potentially biased assessments.

The 2008 assessment may be biased due to frequent washouts at the index trapnets and a very large washout at the Southwest Miramichi monitoring facilities on Sept 29, 2008. The model could not reconcile these biases. Returns will be underestimated when based exclusively on catches and estimated proportions of the runs at trapnets and barriers from previous years, however, this was not the case for 2008 and 2009 when mark and recapture data were also available.

Recent efforts to estimate smolt production from the branches should be reviewed and used to assess the factors which contribute to annual variability in abundance of Atlantic salmon. On the basis of the estimated smolt run in 2008 from the Southwest Miramichi, the cause of the low return of small salmon in 2009 was more likely attributable to poor marine survival rather than low freshwater production.

Research Recommendations

The working document detailing the data, model and analyses which was reviewed should be upgraded to a research document as the level of information that was used for the peer review is too large to be captured in the science response advisory report.

The historical time series of returns which has been published in previous assessments should be reexamined. The perception of stock status for the Miramichi is in large part driven by the high return estimates of the late 1980s and early 1990s, particularly 1992. The 1992 assessment estimates have always been troubling; in the absolute scale of the estimated returns, in the sudden rise and drop over a three year period, and relative to the lack of coherence with other rivers of eastern Canada. The time series from 1984 to the present could be examined first as it represents the years post commercial fishery closure in the Maritime provinces.

An evaluation of the mark and recapture program should be done to determine where effort should be focused to most benefit the assessment (that is, more effort in tagging or more effort in recovery).

A number of recommendations for further work on the mark and recapture model and its assumptions were proposed:

- Use tag return information from angling to estimate the movement of tagged fish between the two branches, in addition to the trapnet data as presently used.
- For the years where the data are sufficient, examine the assumption of similar probability of capture between tagged and untagged fish. In some years, the trapnets at Metepenagiag were installed on both sides of the river and this could be used to examine the assumption that fish captured and tagged from a trapnet on a fixed side of the river redistribute themselves within the river before they encounter the recapture gear.
- Consider the headwater barrier data as an index of escapement rather than returns.
- Consider the headwater barrier data as an index of early run escapement rather than escapement for the whole year. The proportion early run for the whole year would be derived from the timing at the estuary trapnet catches. This may not be feasible for the longer time series however, as branch specific trapnet information is not available prior to 1992.
- Explore model options for temporal stratification relative to the assumption of catchability at trapnets being independent of run-timing.
- When there are incomplete count data associated with washouts during high discharge periods, explore options for correcting the gaps based on timing of catches in-season.
- Evaluate the long term series of juvenile data, with standardization for habitat type sampled, which may provide another indicator of the relative level of escapement estimated from the model, albeit retrospectively.

Conclusions

The estimate of the small salmon returns in 2009 (12,400 fish) is the lowest of the 1998 to 2009 time series and based on values recorded in previous assessments, it is the lowest value since 1971 (Chaput et al. 2001) The large salmon return of about 22,000 fish equates to 97% of the conservation requirements for the river, among the highest values since 1998.

Separate branch estimates show a much higher relative return of both small salmon and large salmon in the Southwest Miramichi relative to the Northwest Miramichi. Returns of large salmon to the Southwest Miramichi in 2009 were the highest since 1998. Returns of large salmon to the Northwest Miramichi were 18% below the average return from 1998 to 2008. There are uncertainties regarding the estimates of abundance particularly in the Northwest Miramichi related to the very early (late May to mid-June) run portion which may be inadequately sampled by the assessment trapnets.

Small salmon returns in both branches in 2009 were the lowest since 1998. The low returns of small salmon estimated for 2009 and the higher returns of large salmon relative to recent years are consistent with the counts at the headwater monitoring facilities; for example, small salmon were the 2nd lowest of the time series at Southwest Dungarvon, lowest since 1984 at the Southwest Juniper, and the lowest of the time series for the Northwest Miramichi barrier; for large salmon, counts were among the highest values in the recent time period. Crown reserve angling catches for the Northwest Miramichi were consistent with the patterns above, the lowest catch of small salmon of the time series whereas large salmon catches were the highest of the time series.

Conservation requirements for the Miramichi, after fisheries, have only been achieved once in the past ten years (68% to 104%). Overall for the Miramichi, total assumed losses of eggs due to fishing have averaged 8% over both size groups, 53% of the loss due to removals of large salmon. These levels are an indication of the extent to which egg depositions can be increased using more restrictive fisheries management. The scope for increased egg depositions is considered greater on the Northwest Miramichi where the losses are in the order of 21% of the returns, 69% of these from large salmon losses.

It is anticipated that there will be a low return of large salmon in 2010 due to the exceptionally low return of small salmon in 2009. The most likely scenario in 2010 is for a low large salmon return, in the order of 5,000 to 10,000 large salmon, or roughly 21% to 43% of the conservation requirement for the Miramichi overall.

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Sources of Information

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Appendices

Table 1. *Counts of large salmon and small salmon at the three headwater protection barriers of the Miramichi River, 1984 to 2009.*

	Large salmon			Small salmon		
		Southwest Miramichi			Southwest Miramichi	
Year	Northwest	Dungarvon	Juniper	Northwest	Dungarvon	Juniper
1984		93	297		315	230
1985		162	604		536	492
1986		174	1,138		501	2072
1987		202	1,266		744	1,175
1988	234	277	929	1,614	851	1,092
1989	287	315	731	966	579	969
1990	331	318	994	1,318	562	1,646
1991	224	204	476	765	296	495
1992	219	232	1,047	1,165	825	1,383
1993	216	223	1,145	1,034	659	1,349
1994	228	155	905	673	358	1,195
1995	252	95	1,019	548	329	811
1996	218	184	819	602	590	1,388
1997	152	115	519	501	391	566
1998	289	163	698	1,038	592	981
1999	387	185	698	708	378	566
2000	217	130	725	456	372	1,202
2001	202	111	904	344	295	729
2002	121	107	546	595	287	1,371
2003	186	158	920	478	389	912
2004	167	185	764	723	559	1,368
2005	262	300	673	735	441	853
2006	214	217	*829*	469	468	*860*
2007	166	88	783	460	195	945
2008	164	131	692	1,094	673	1,083
2009	206	234	889	315	207	242

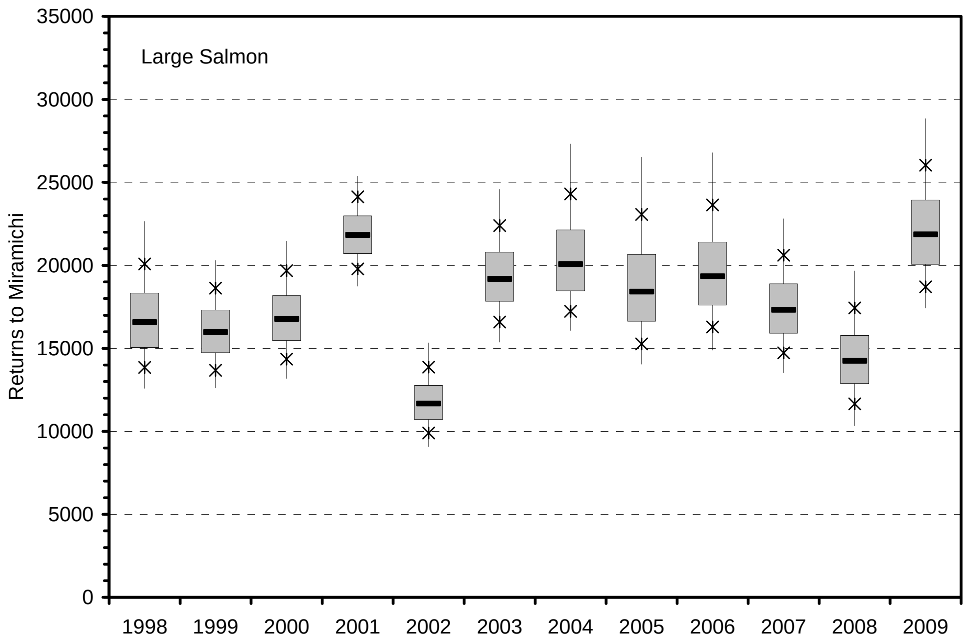
Table 2. *Angling catches by size group and effort (rod day) from the Crown Reserve waters of the Northwest Miramichi, 1984 to 2009.*

	Northwest Crown Reserve		
Year	Small	Large	Effort
1984	1240	229	2179
1985	1563	206	2269
1986	1676	156	2456
1987	1072	88	1839
1988	1860	102	2432
1989	1595	127	2535
1990	1587	144	2502
1991	612	77	2395
1992	1423	94	2364
1993	1426	135	2432
1994	1234	130	2342
1995	523	88	1773
1996	1301	131	2607
1997	868	115	2494
1998	1044	125	2488
1999	514	68	2177
2000	949	93	2619
2001	555	119	2298
2002	836	66	2566
2003	650	174	2601
2004	569	74	2565
2005	598	112	2637
2006	767	99	2579
2007	586	125	2574
2008	1685	135	2558
2009	445	235	2755

Table 3. *Estimates (median and 95% Bayesian Credibility Interval) of returns of large salmon and small salmon to the Miramichi River (upper table), to the Southwest Miramichi (middle table), and to the Northwest Miramichi (lower table) based on the hierarchical model for 1998 to 2009.*

Miramichi River						
	Large Salmon			Small salmon		
Year	median	95% B.C.I.		median	95% B.C.I.	
1998	16,570	12,590	22,650	22,680	18,670	27,510
1999	15,980	12,610	20,300	21,730	18,740	25,580
2000	16,780	13,190	21,470	31,890	27,710	37,110
2001	21,830	18,740	25,380	27,290	23,490	32,320
2002	11,680	9,069	15,330	41,880	36,010	49,060
2003	19,180	15,380	24,580	28,160	23,460	34,420
2004	20,070	16,080	27,320	44,280	37,580	53,490
2005	18,410	14,040	26,530	29,220	22,930	38,630
2006	19,340	14,890	26,790	30,900	24,330	41,390
2007	17,320	13,530	22,810	24,820	18,810	35,360
2008	14,250	10,330	19,660	31,580	23,720	43,500
2009	21,860	17,430	28,840	12,370	9,288	16,560
Southwest Miramichi River						
	Large Salmon			Small salmon		
Year	median	95% B.C.I.		median	95% B.C.I.	
1998	12,770	9,184	18,330	14,520	11,070	18,970
1999	11,520	8,316	15,920	12,950	10,130	16,780
2000	12,130	8,548	16,660	20,280	16,100	25,590
2001	13,890	10,760	17,640	18,800	15,040	23,930
2002	9,673	7,114	13,470	25,930	20,570	33,160
2003	16,350	12,430	21,770	21,670	17,180	28,040
2004	16,450	12,370	23,680	31,600	24,640	40,610
2005	14,360	10,320	22,550	19,580	14,250	26,850
2006	16,550	12,350	23,890	25,560	19,040	36,070
2007	13,880	9,912	19,260	18,830	12,980	29,500
2008	11,950	8,160	17,280	23,490	16,040	34,850
2009	18,660	14,340	25,610	9,298	6,526	13,330
Northwest Miramichi River						
	Large Salmon			Small salmon		
Year	median	95% B.C.I.		median	95% B.C.I.	
1998	3,570	2,024	6,760	7,987	6,070	11,170
1999	4,386	2,977	6,296	8,731	7,304	10,550
2000	4,579	3,052	6,991	11,550	9,709	13,660
2001	7,809	5,379	11,090	8,417	6,713	10,550
2002	1,937	1,275	2,983	15,740	12,390	19,790
2003	2,786	1,841	4,286	6,351	4,833	8,546
2004	3,522	2,401	5,224	12,690	10,390	15,600
2005	3,848	2,278	6,605	9,440	6,323	15,280
2006	2,665	1,539	4,763	5,360	3,714	7,508
2007	3,384	2,140	5,426	5,915	4,459	7,939
2008	2,178	1,192	4,403	7,867	5,635	11,970
2009	3,049	1,937	5,000	2,975	2,133	4,572

Figure 1. *Estimates of returns of large salmon (upper panel) and small salmon (lower panel) to the Miramichi River for 1998 to 2009, based on the Bayesian hierarchical model. Box plots are interpreted as follows: vertical line is the 95% credibility interval range, the stars define the 80% credibility interval range, the shaded rectangles are the interquartile range (50% credibility interval range) and the vertical dash is the median value.*



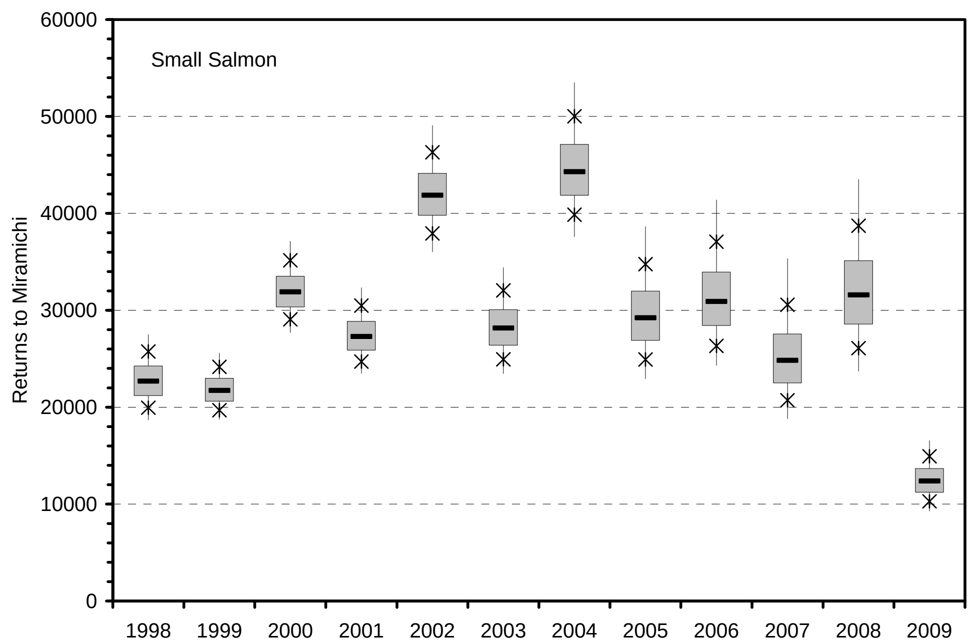


Figure 2. *Estimates of returns of large salmon (upper panel) and small salmon (lower panel) to the Southwest Miramichi River, 1998 to 2009, based on the hierarchical model. Box plots are interpreted as in Figure 1.*

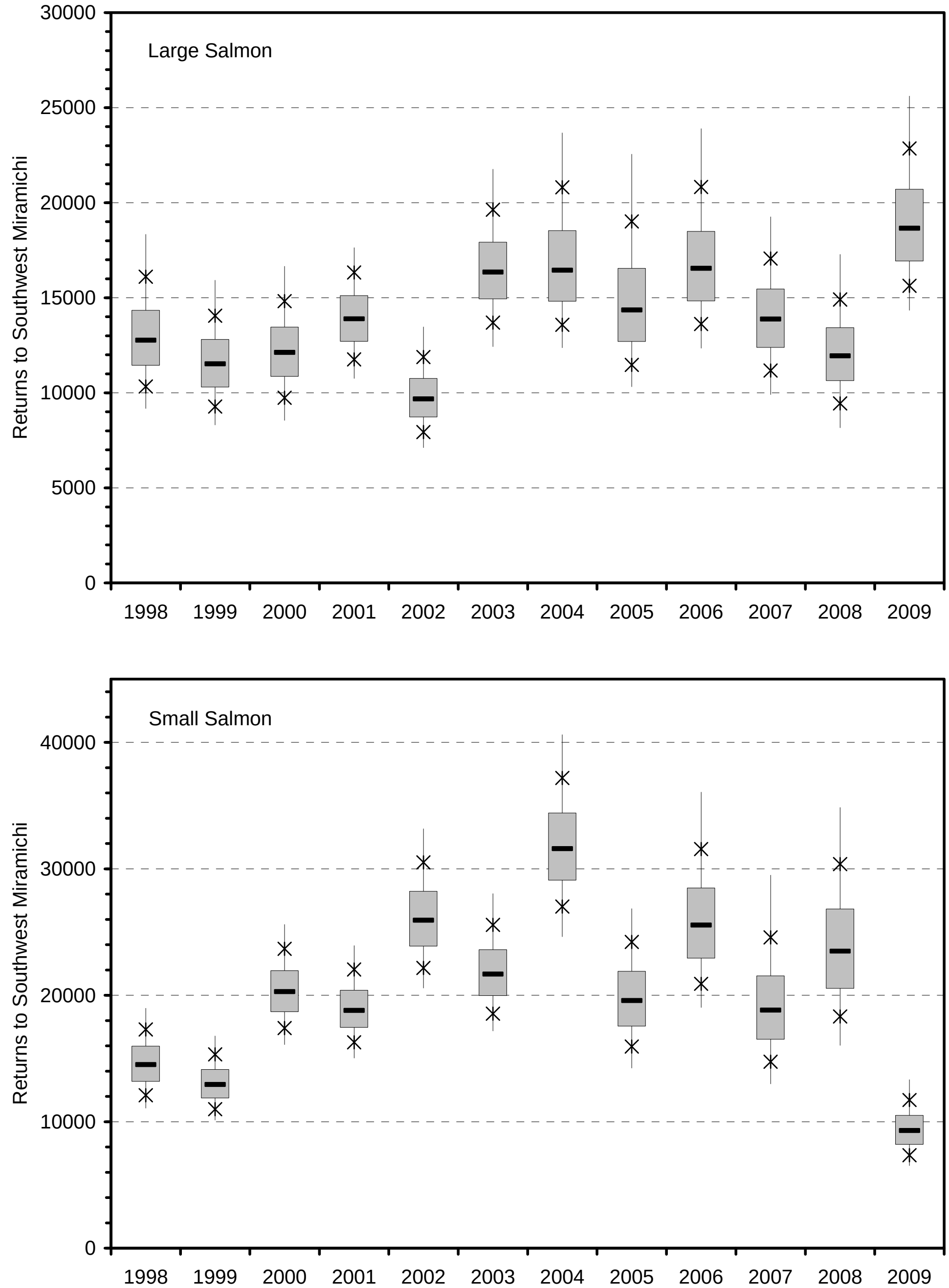
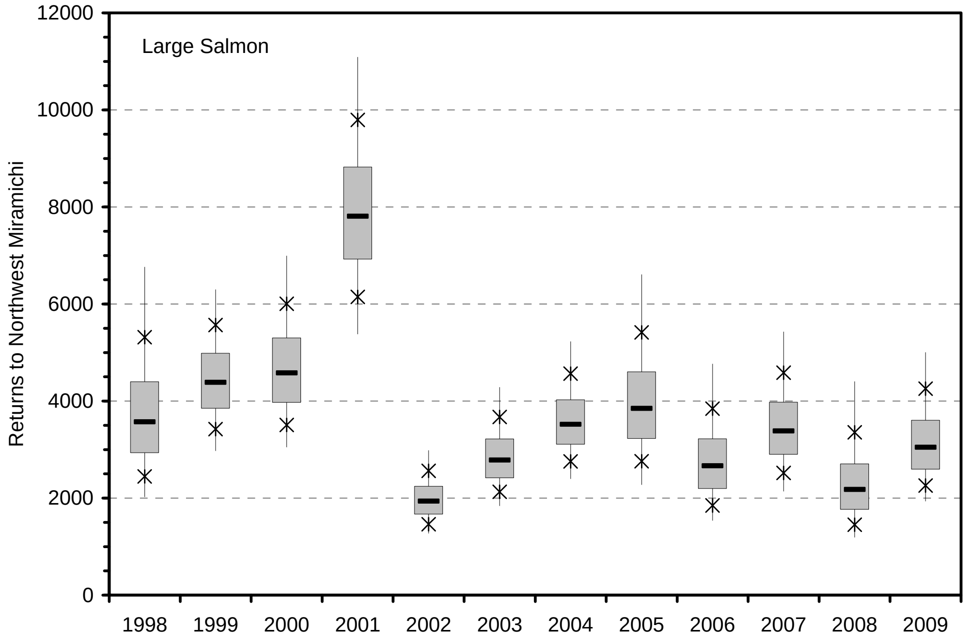


Figure 3. *Estimates of returns of large salmon (upper panel) and small salmon (lower panel) to the Northwest Miramichi River, 1998 to 2009, based on the hierarchical model. Box plots are interpreted as in Figure 1.*



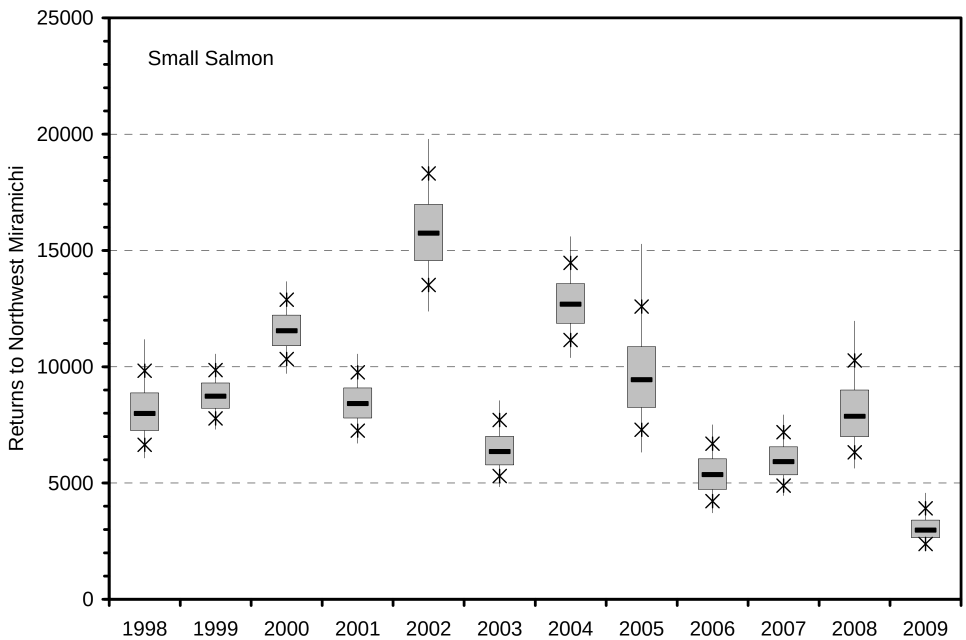


Figure 4. *Proportion of trapnet catches of large salmon (upper panels) and small salmon (lower panels) which occurred before August 1 at the Southwest Millerton trapnet (left panels) and the Northwest Cassilis trapnet (right panels) for 1998 to 2009. Box plots are interpreted as in Figure 1.*

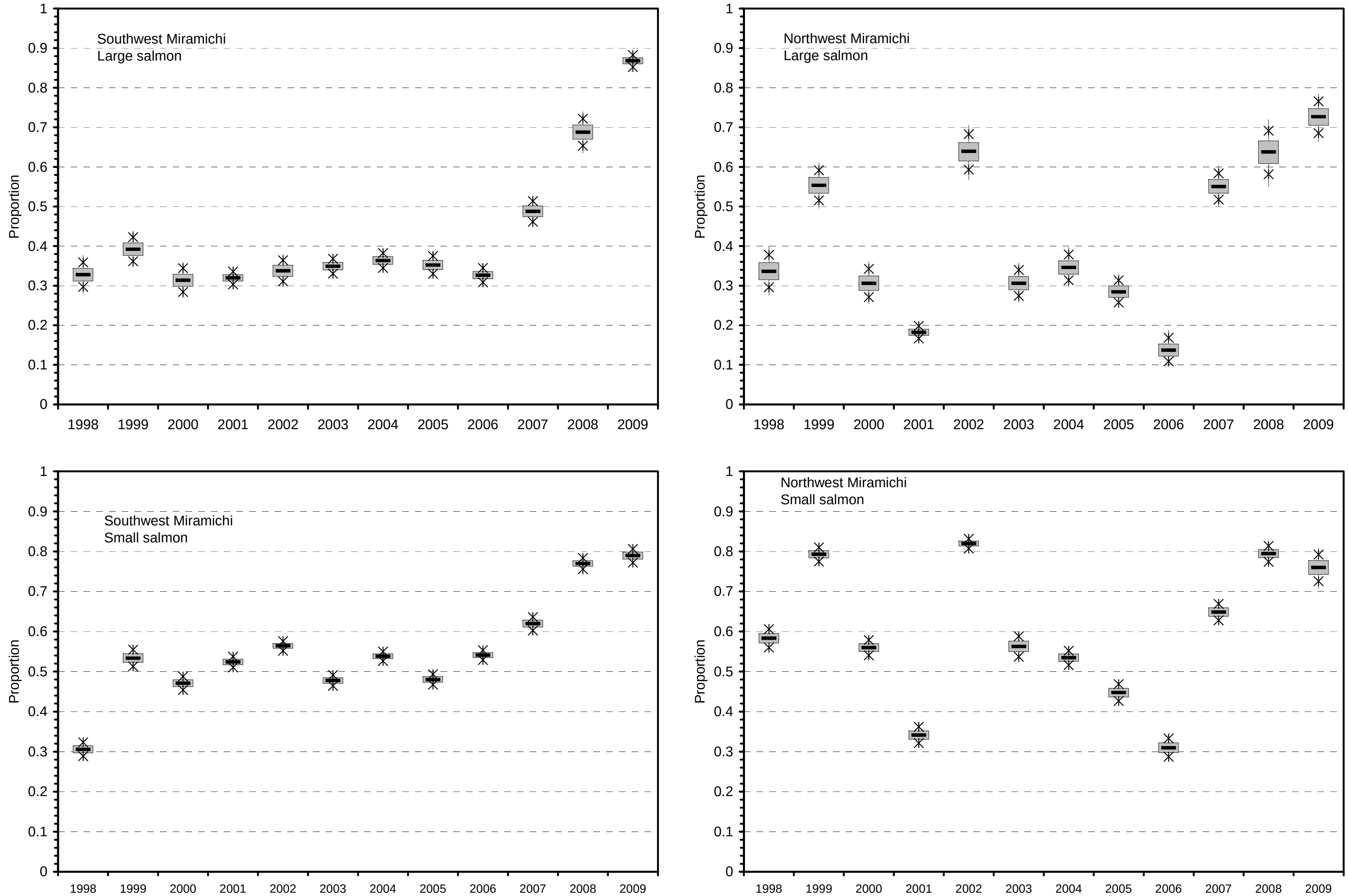


Figure 5. Estimates of early-run (before August 1) returns of large salmon (left panels) and small salmon (right panels) to the Miramichi River (upper), Southwest Miramichi (middle) and Northwest Miramichi (lower), 1998 to 2009. Box plots are interpreted as in Figure 1.

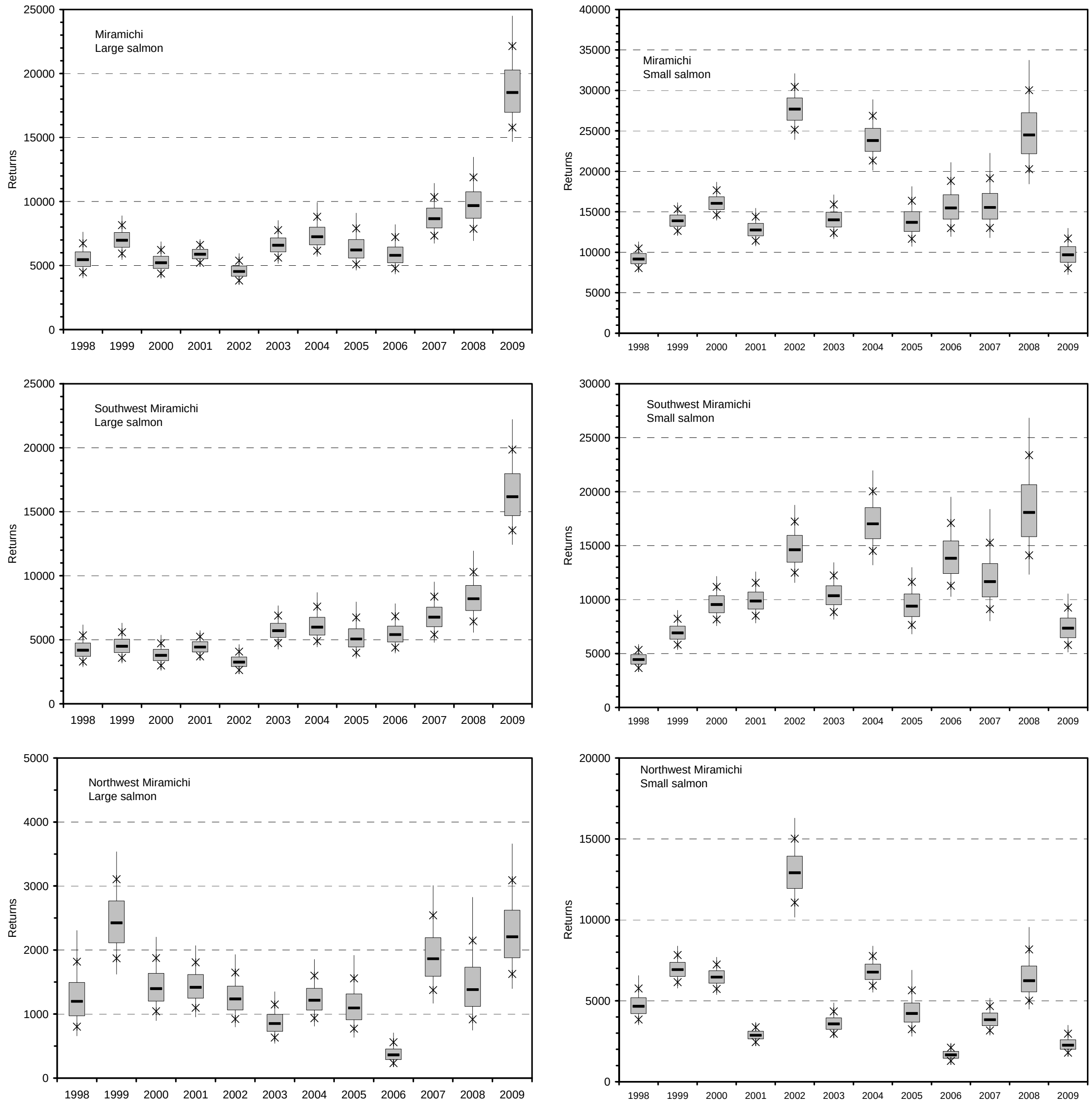
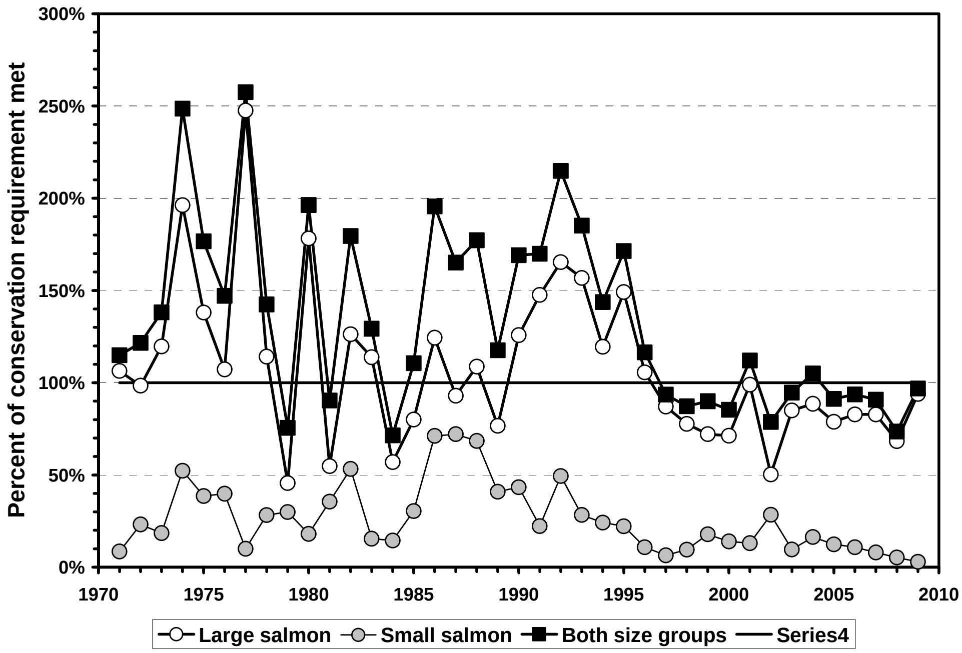


Figure 6. *Percentage of conservation requirements (240 eggs per 100 m²) achieved for the Miramichi River in the returns (upper panel) and in the escapement (lower panel) for 1970 to 2009.*



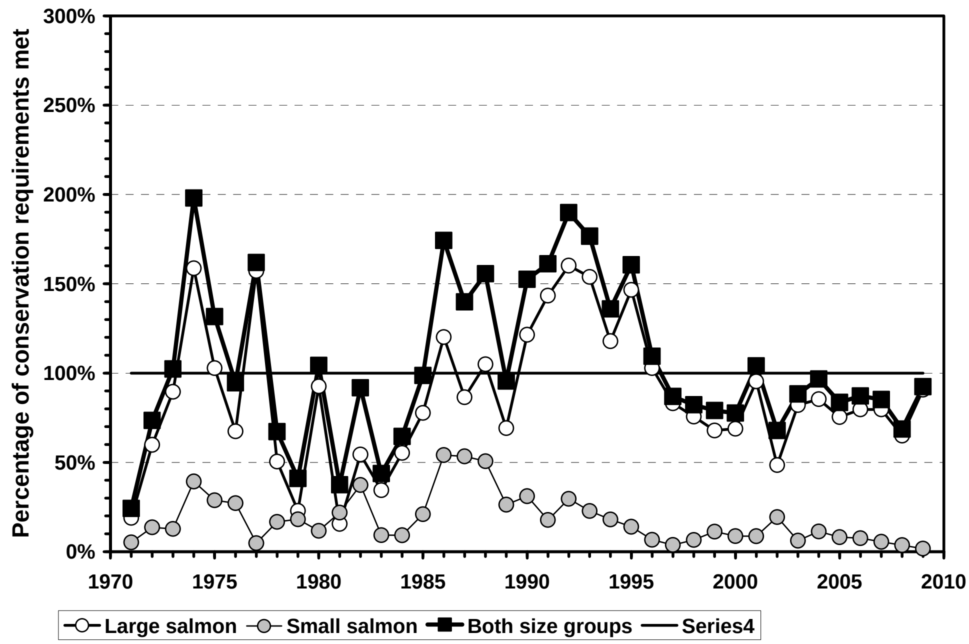
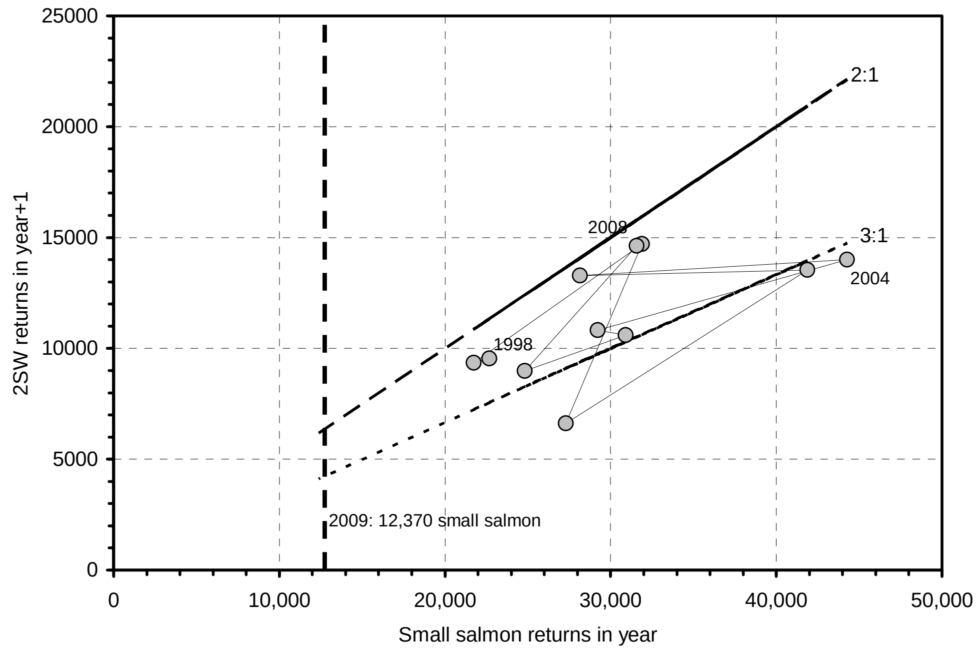
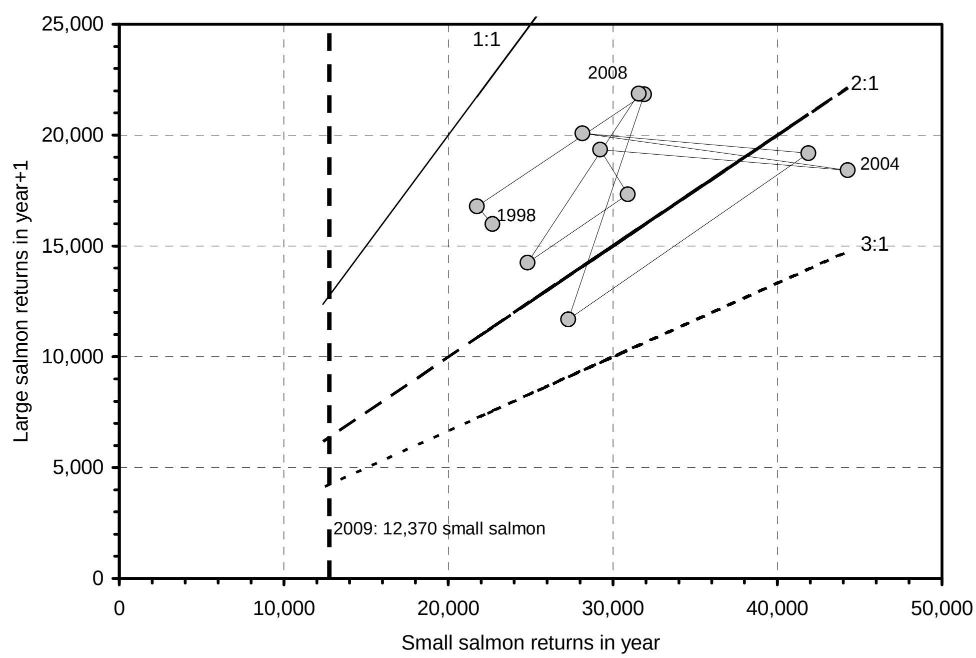


Figure 7. *Association between small salmon returns in year and 2SW returns in year+1 (upper panel) and to large salmon returns in year+1 (lower panel) for the small salmon return years 1998 to 2008.*





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