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# Assessment of Atlantic salmon (*Salmo salar*) to the Miramichi River (NB) for 1998 to 2009

# Évaluation du saumon atlantique (*Salmo salar*) de la rivière Miramichi (N.-B.) pour 1998 à 2009

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## ABSTRACT

The assessment of Atlantic salmon (*Salmo salar*) returns and escapement to the Miramichi River (NB) for 2009 with updated values for 1998 to 2008 are presented. A hierarchical Bayesian mark and recapture model which considers multiple indicators including catches at estuary trapnets, counts at inriver monitoring facilities, and directed inriver seining programs is used to estimate the annual returns of small salmon (<63 cm fork length) and large salmon (>= 63 cm fork length). The return of small salmon in 2009 (at about 12,000 fish) was the lowest level since 1971. The large salmon return, of about 22,000 fish, was among the highest values since 1998. Harvest data of small salmon and large salmon from both the aboriginal fisheries and the recreational fisheries are incomplete. Overall for the Miramichi, total losses of eggs due to assumed losses from fishing have averaged 8% over both size groups, 5% for large salmon and 20% for small salmon. The eggs in the returns to the Miramichi in 2009 were 97% of the conservation requirement and the eggs which were estimated to have been spawned were 92% of the conservation requirement. The returns of salmon 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 1997 to 2009. At least 67% of the conservation requirements have been met every year since 1984. The most likely scenario in 2010 is for a low return of large salmon, in the order of 5,000 to 10,000 fish, or roughly 21% to 43% of the conservation requirement for the Miramichi overall. A number of recommendations for further analyses and model development are made.

## RÉSUMÉ

L'évaluation pour 2009 et des révisions pour les années 1998 à 2008 des retours et des géniteurs de saumon atlantique (*Salmo salar*) de la rivière Miramichi (N.-B.) sont présentés. Un modèle bayésien hiéarchique de marquage et de recapture est utilisé pour évaluer les retours de petits saumons (<63 longueur à la fourche) et de grands saumons (>= 63 cm longueur à la fourche). Ce modèle utilise des indicateurs d'abondances provenant de captures dans des filets-trappes en estuaire, des décomptes à des barrières en rivière et des campagnes ciblées de captures à la senne. Les retours de petits saumons en 2009 ont été évalués à 12 000 poissons, le plus faible niveau depuis 1971. Les retours de grands saumons ont été évalués à 22 000 poissons ce qui est parmi les plus hauts niveaux depuis 1998. Les déclarations des récoltes de petits saumons et de grands saumons des pêches autochtones et récréatifs sont incomplètes. Pour l'ensemble de la rivière Miramichi, les pertes en oeufs attribuables aux niveaux de pêches présumés ont été en moyenne 8% des œufs dans les retours pour les deux groupes de tailles confondus, dont 5% pour les grands saumons et 20% pour les petits saumons. La quantité d'oeufs dans les retours de saumon en 2009 était équivalente à 97% des besoins de conservation tandis que la quantité d'œufs qui aurait été frayée se chiffrait à 92% des besoins de conservation. Durant les années 1970 à 1996, les retours de saumon atlantique, toutes tailles confondues, ont souvent été à des niveaux égaux ou supérieurs aux besoins de conservation. Cependant, les retours n'ont été égaux ou supérieurs aux besoins de conservation qu'à deux reprises durant 1997 à 2009. Depuis 1984, au moins 67% des besoins de conservation ont été comblés annuellement. Un faible retour de grands saumons de l'ordre de grandeur de 5 000 à 10 000 poissons est prévu en 2010, soit de 21% à 43% des besoins de conservation pour l'ensemble de la rivière Miramichi. Des recommandations d'analyses supplémentaires et de développements de modèles sont formulées.

# INTRODUCTION

The Miramichi River, located in central New Brunswick, has a maximum axial length of 250 km and drains an area of about 14,000 km$^2$ (Randall et al. 1989). There are two major branches: the Northwest Branch drains about 3,950 km$^2$ and the Southwest Branch about 7,700 km$^2$ of drainage area (Bousfield 1955). The two branches flow into a common estuary that subsequently enters the Gulf of St. Lawrence at latitude 47°N (Fig. 1). Tidal influence extends more than 30 km upstream of the confluence of the Northwest and Southwest branches of the river.

The Miramichi River is considered to have the largest Atlantic salmon (*Salmo salar* L.) run of eastern North America. Peak recreational catches of salmon were recorded in 1986 and 1988 at over 40,000 fish annually (Moore et al. 1995b). Recreational catches of salmon between 1991 and 1995, the most recent years of available information, averaged over 24,000 fish annually with about two-thirds of the catches occuring in the Southwest (Chaput et al. 2001). Aboriginal fisheries of a smaller scale than the recreational fishery, occur primarily in tidal waters of the Miramichi River (Chaput et al. 1998). Commercial salmon fisheries in the Maritime Provinces were closed in 1984 and have not been re-opened. Commercial harvests of salmon from the Miramichi River (including Miramichi Bay) exceeded 102,000 fish in 1967 (Chaput et al. 1998). Salmon originating from the Miramichi River were exploited extensively in several marine commercial fisheries in eastern Canada and at West Greenland (Saunders 1969).

Separate branch assessments were introduced in 1992 to account for some of the diverse characteristics of the runs in the Miramichi River (Saunders 1981) and for the differences in exploitation between the Northwest and Southwest branches. Historically, aboriginal fisheries were conducted almost exclusively in the Northwest Miramichi (exploitation also occurs in the estuarial waters of the Miramichi River, downstream of the confluence of the two branches) and recreational fisheries exploitation also differs between the Northwest and Southwest branches.

Temporal stock distinctiveness has been highlighted as an important component of the Atlantic salmon resource (Saunders 1967). For convenience, the early-run has been defined as salmon returning to the river up to August 31 whereas the late-run is considered to consist of salmon returning from September 1 onwards. Early runs and late runs have different composition in terms of small and large salmon proportions. The early runs in both branches are also exploited more heavily than the late runs (Randall et al. 1991).

For fisheries management purposes, two size groups of salmon are defined. The small salmon category consists of fish less than 63 cm fork length and are generally referred to as grilse. These fish have usually spent just over one full year at sea (one-sea-winter; 1SW) prior to returning to the river, but the size group may also contain a small proportion of two-sea-winter (2SW) salmon and salmon that have spawned previously. The large salmon category consists of fish greater than or equal to 63 cm fork length. This size group is also referred to as multi-sea-winter (MSW) or just salmon and contains varying proportions of 1SW, 2SW and three-sea-winter (3SW) maiden (first time) spawners as well as previous spawners (Moore et al. 1995a). Salmon which have spawned, have overwintered in fresh water, and are migrating seaward in the spring are referred to as kelts or black salmon, in contrast to bright salmon which are mature adult salmon moving into freshwater from the ocean.

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. Therefore partial capture techniques are used to sample the runs, and mark and recapture methods are used to estimate run sizes.

Annual assessments of the Atlantic salmon stock of the Miramichi River have been prepared since 1982 (Randall and Chadwick 1983a, b; Randall and Schofield 1987, 1988; Randall et al. 1985, 1986, 1989, 1990; Moore et al. 1991, 1992). The objectives of these assessments were to estimate the returns of salmon, the spawning escapement after removals and to compare the egg deposition with the conservation requirement for the river. The status of the resource was assessed on the basis of whether or not the conservation requirement was attained/exceeded. Since 1992, assessments of the returns of salmon to the Northwest and Southwest branches have been prepared (Courtenay et al. 1993; Chaput et al. 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001). Returns by size group to the whole river were partitioned into Northwest and Southwest Miramichi returns and in some cases into early and late run. The returns and escapements were estimated on a spatial and temporal scale corresponding to the available data. Since the 2001 assessment, estimates of returns of salmon have been provided to user groups and managers but the data, methods, and results have not been published.

In response to low counts of small salmon at numerous monitoring facilities in 2009 and the discrepancies in perceptions of abundance of salmon from previous years, DFO Fisheries and Aquaculture Management (FAM) requested that the assessment model and the 2009 assessment be peer reviewed. DFO FAM also asked whether the present management measures were sufficient to meet the objective of attaining the conservation requirements for the river.

## DESCRIPTION OF MARK AND RECAPTURE EXPERIMENTS

There are no impediments to migration of Atlantic salmon in the Miramichi River. Since 1992 and briefly during 1985 to 1987, returns of Atlantic salmon to the Miramichi River and to the Northwest and Southwest branches, have been estimated from mark and recapture experiments. All tagging operations occurred at trapnets operated in tidal waters (Fig. 1, 2). Recapture gear included trapnets also located in tidal waters, as well as the opportunistic use of other capture methods such as seining in freshwater holding pools.

### TRAPNETS

The trapnets used in the Miramichi are for the most part T-trap designs as used in the historical commercial salmon fishery and in the commercial gaspereau fishery. V-trap designs were used at the Northwest recapture traps in some years. The T-trap designs evolved to include a back-channel linking the upper and lower traps in the late 1990s. Specific details of the trapnets are provided in Appendix 1.

The trapnets are generally operated over the period of the return migration of Atlantic salmon, from the middle of May to late October. Since 1994, facility M26 (Millerton) is considered the index facility for the Southwest Miramichi whereas in the Northwest Miramichi, facility M05 (Cassilis) has been used as the index trapnet since 1998 (Fig. 2).

### Processing of catches at the trapnets

All fish captured at the trapnets were enumerated by species. Atlantic salmon were captured with a dipnet, placed in sampling boxes in water and measured for fork length (to the nearest 0.1 cm). Sex determination was made based on external characteristics and is considered unreliable prior to August. Wild fish were distinguished from hatchery-origin fish on the basis of the presence of the adipose fin, this fin having been removed prior to stocking on the majority of hatchery-produced juvenile salmon. Scale samples, for determination of age, were removed from the standard location (along the imaginary line joining the posterior of the dorsal fin and the anterior of the anal fin, two to four rows above the lateral line) from all large salmon and from varying proportions of small salmon. Scale samples were stored dry.

Prior to release, some Atlantic salmon were marked with individually numbered blue Carlin tags (dimensions 9.5 mm by 4.6 mm by 1.0 mm thick) attached to the back just anterior to the dorsal fin with narrow gauge stainless steel wire. In most years, some salmon were released back to the river untagged because of injuries, to reduce stress during warm water events, or as a result of a catch in excess of the daily allotment of tags to be placed on small salmon. In those cases, the caudal fin was hole punched prior to releasing the fish, with upper or lower caudal punches used to identify the branch in which the fish was captured. Caudal punching of the tail was restricted to the Northwest Cassilis trapnet (M05) and the Southwest Millerton trapnet (M26). Caudal punching of small salmon after a maximum number of 30 tags per day occurred in 2007 to 2009 and for large salmon in 2009.

All salmon sampled from the trapnets were examined for the presence of a Carlin tag or tail punch. In the case of marked fish, its tag number (Carlin-tagged fish only), caudal punch location (caudal-punched fish only), size (small or large based on length), and date and location of capture were recorded. Salmon were either released after sampling or retained if the sample was obtained from the food fishery harvests.

Food fishery catches at Eel Ground and Red Bank were sampled for number of salmon caught (by size) and number as well as sex of salmon harvested (by internal examination). Fish were examined for Carlin tags and when present the number was recorded prior to release or at sampling.

### Treatment of Data

All the data were entered in spreadsheets (Appendix 2). A coding hierarchy was derived for categorizing the fish sampled from the trapnets. The upper level (first letter) identifies whether a fish is returned to the river after sampling (R) or removed from the river (M) (Appendix 2). The secondary and tertiary levels identify whether the fish was sampled, tagged, carried a tag or the specifics of the removal from the river (Appendix 2).

Summaries by facility, size group and month of the catch, tagging and recapture histories were developed using SAS (SAS Institute 2008). The summary for 2009 is shown in Appendix 3.

## BARRIER FENCE MONITORING

There are three headwater protection barriers in the Miramichi, two in the Southwest Miramichi River (Dungarvon, Juniper) and one in the Northwest Miramichi River (Northwest Miramichi) (Fig. 1) (Madden et al. 1999). The two Southwest Miramichi barriers began operations in 1981 and the Northwest Miramichi began operation in 1988. Salmon are counted into a holding pool where they are held until late fall to continue migrations upstream. Counts of salmon are obtained by small salmon and large salmon categories (Table 1).

## ANGLING CATCHES

Angling regulations have changed over time. Since 1984, there is mandatory catch and release of all large salmon in the angling fisheries. Seasonal bag limits for small salmon have been reduced over time to eight since 1992 and daily retention was reduced from two to one in 1998.

Angling catches and effort have in the past been available from two sources: FISHSYS (mail-out survey of a portion of the angling license holders after the season) from the New Brunswick Department of Natural Resources and Energy (DNRE), and from the Government of Canada Department of Fisheries and Oceans (DFO) (Moore et al. 1995b). For the Miramichi River system, the DNRE estimates are considered to be more accurate than the DFO estimates (Randall and Chadwick 1983a). DFO estimates of catch, which have generally been lower than the DNRE estimates, were not collected after 1994. FISHSYS angling catch data were collected until 1997 (excl. 1996) but have not been collected since then. The catch and effort series beginning in 1984 (the year of introduction of mandatory catch and release of small salmon) are shown in Table 2.

The Crown Reserve waters angling data from the Northwest Miramichi have been collected since 1969 (B. Dubee, DNR) and the time series since 1984 is shown in 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 for their activities.

## MARK AND RECAPTURE MODELS

Spatially stratified mark and recapture models are used for estimating the returns of Atlantic salmon to the Miramichi. The spatial stratification is in terms of the Southwest and Northwest branches. The estimation is done independently for small salmon and large salmon. Returns to the branches are based on estimates from the index facilities in each branch.

The standard assumptions of mark and recapture experiments apply:

- probabilities of capture for tagged and untagged fish are independent and identical. For tagged fish, a 10% tagging and handling mortality is assumed (as in previous assessments, Chaput et al. 2001).
- the population is closed, i.e. all fish remain in the either the Northwest Miramichi or the Southwest Miramichi.

The trapping facilities are located in the Northwest and Southwest branches of the Miramichi River. The estimation of the returns to the Miramichi overall and to each branch is complicated by several factors including:

- movement of tagged fish between branches
- potentially different capture probabilities (or efficiencies) of the trapping gear (trapnets or seining programs) between the branches.

Annual and hierarchical Bayesian models were developed to account for the movements of tagged fish between the branches and for potentially differing efficiencies of the index and recapture facilities between the branches (Appendix 4). The annual models considered only the information available in a specific year. The hierarchical models considered information from previous years as well as information from the current year to estimate the parameters of interest. Exchangeability is an important assumption in the hierarchical model: it was assumed that the movement rate of tagged fish between branches, the efficiencies of the index trapnets, and the proportions of the returns which migrate to each of the headwater barriers were exchangeable among years, i.e., they may differ annually, but they originate from a common parameter-specific probability distribution. This assumption is used because the index trapnets in both branches were installed at the same location and operated using standard protocols every year. As such, annual trapnet efficiencies would be expected to be somewhat similar, but would also be expected to vary somewhat from year to year based on factors such as river discharge when salmon were migrating.

## MARK AND RECAPTURE DATA

### Data for 2008 and 2009

Salmon were tagged at three estuary trapnet locations in 2008 and 2009: in the lower portion of the Southwest Miramichi at the Enclosure Park (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 (Fig. 2; Tables 3, 4).

Salmon were sampled for recaptures at the three tagging locations as well as at the Red Bank First Nation trapnets in the upper tidal portion of the Northwest Miramichi (Fig. 2). Sampling for recaptures also occurred during the directed seining program sponsored by Miramichi Salmon Association in both the Northwest and Southwest Miramichi (Tables3, 4).

An annual Bayesian mark and recapture was used to estimate the returns to the Miramichi in 2008 and 2009 (Appendix 4). Three variations on the data inputs were considered:

1) using only samples and recaptures from the estuary trapnets
2) using only samples and recaptures from the seining activities
3) using samples and recaptures from the combined seining and estuary trapnets.

The Bayesian hierarchical model was also used. The variations on the data inputs and for estimation in the year of interest included:

1) using only samples and recaptures from the estuary trapnets over the time periods 1998 to 2008, 1998 to 2009 to estimate the annual returns for 2008 and 2009, respectively.
2) using samples and recaptures from the combined seining and estuary trapnets over the time periods 1998 to 2008, 1998 to 2009 to estimate the returns for 2008 and 2009, respectively.
3) using samples and recaptures from the combined seining and estuary trapnets and the counts at the headwater barriers over the time periods 1998 to 2008, 1998 to 2009 to estimate the annual returns for 2008 and 2009.
4) for the 2008 returns, using samples and recaptures from the estuary trapnets for the period 1998 to 2007 and
    a. using the estimated overall efficiencies of the index trapnets and the observed catches in 2008 to estimate the returns for 2008,

b. using the estimated overall proportions of the returns that are counted at the headwater barriers and the corresponding counts in 2008 to estimate the returns for 2008,
c. using the estimated overall proportions of the returns that are counted at the headwater barriers and the corresponding counts in 2008 as well as the estimated overall efficiencies of the trapnets and the trapnet catches in 2008 to estimate the returns for 2008.

5) for the 2009 returns, using samples and recaptures from the estuary trapnets and the seining for the period 1998 to 2008 and
   a. using the estimated overall efficiencies of the index trapnets and the observed catches in 2009 to estimate the returns for 2009,
   b. using the estimated overall proportions of the returns that are counted at the headwater barriers and the corresponding counts in 2009 to estimate the returns for 2009,
   c. using the estimated overall proportions of the returns that are counted at the headwater barriers and the corresponding counts in 2009 as well as the estimated overall efficiencies of the trapnets and the trapnet catches in 2009 to estimate the returns for 2009.

### Data for 1998 to 2009

The annual and hierarchical Bayesian models were applied to the data from 1998 to 2009 (Appendix 4; Tables 5, 6).

# RESULTS

The total number of tags applied to large salmon in the Miramichi River ranged from a low of 520 fish in 2008 to a high of 2,921 fish in 2001 (Table 5). For small salmon, the total number of tags applied ranged from a low of 974 fish in 2009 to a high of 3,767 fish in 2004 (Table 6). The total number of valid recaptures annually in the estuary trapnets ranged from 6 to 168 for large salmon (Table 5), and from 15 to 269 recaptures for small salmon (Table 6).

## MOVEMENT OF TAGGED FISH BETWEEN BRANCHES

Some fish tagged at the estuary trapnets were recaptured in the other branch. This phenomenon occurs for both small salmon and large salmon and there was a particularly important emigration of large salmon tagged in the Northwest Miramichi and recaptured in the Southwest Miramichi, based on both trapnet recaptures and from angler returns (Tables 5 to 8). The proportions of the tagged fish that remain in the branch in which they were tagged were estimated for each of the tagging locations based on the recovery information at the tidal trapnets. From most locations, the majority (> 80%) of the small salmon and large salmon remained in the branch in which they were originally tagged (Fig. 3). The proportion was highest for the Southwest Millerton trapnet for both small and large salmon (median values over 90% in all years) (Fig. 3). The proportions were lower for the Southwest Eelground trapnet which was located very close to the confluence of the two branches (Fig. 3). More large salmon tagged from the Northwest Miramichi at Cassilis switched branches than from either of the Southwest Miramichi locations or for small salmon (Fig. 3). These proportions of movements of tagged fish were estimated in the model and were used to adjust the tags available for recapture in each branch.

## PROPORTIONS OF RETURNS CAPTURED AT THE INDEX TRAPNETS

The probability of capture (overall parameter for all years) for large salmon was higher at the Cassilis trapnet than at the Millerton trapnet but efficiencies for small salmon were similar for the two branches (Figs. 4, 5). The probability of capture of small salmon (median = 0.09, CV = 34%) was estimated to be about twice that for large salmon (median = 0.05, CV = 53%) at the Millerton trapnet in the Southwest Miramichi (Fig. 4). This contrasted with the estimated efficiency of the Cassilis trapnet which was only slightly higher for small salmon (median = 0.10, CV = 28%) compared to large salmon (median = 0.09, CV = 47%) (Figs. 4, 5). There was more uncertainty in the estimates for large salmon than for small salmon, and more uncertainty in the Southwest relative to the Northwest.

Sparse data in some years provided little information about the proportions of the returns captured at the index trapnets in those years (Millerton for the SW Miramichi, Cassilis for the NW Miramichi) (Figs. 4, 5). The coefficient of variation (CV) of the annual estimates of the Millerton trapnet ranged from a low of 15% in 2000 to a high of 119% in 2008. The CVs of the efficiencies for large salmon ranged from 22% to 154%. The CVs of the annual estimates of the Cassilis index trapnet efficiencies for small salmon ranged from a low of 13% in 2000 to a high of 161% in 2008. A similar range of CVs was estimated for the large salmon at the Cassilis trapnet (27% to 164%). High uncertainty, expressed as a high CV value, corresponded to years with low numbers of recaptures.

The hierarchical model outputs had less uncertainty in the trapnet efficiency estimates for both small salmon and large salmon (Fig. 4, 5). The CVs for the Southwest Miramichi trapnet ranged from 12% to 20% for small salmon and 13% to 20% for large salmon. The CVs for the Northwest Miramichi trapnet efficiencies ranged from 9% to 22% for small salmon and from 19% to 33% for large salmon.

## PROPORTIONS OF RETURNS AT THE HEADWATER BARRIERS

The estimated proportions of the returns of small salmon and large salmon that ascended to the headwater barriers varied annually at all three sites with the greatest annual variation noted for small salmon at the NW Miramichi and SW Dungarvon barriers (CV = 54% for the overall proportion for both compared to 37% at the SW Juniper Barrier) (Fig. 6). For large salmon, the annual variation was highest in the NW Miramichi barrier (CV = 51%) followed by SW Dungarvon (CV = 45%) and least at the SW Juniper Barrier (CV = 25%) (Fig. 6).

## ESTIMATES FOR 2009

In 2009, a total of 974 small salmon and 1,174 large salmon (>= 63 cm fork length) were tagged (Table 3). Valid recaptures totaled 9 small salmon and 8 large salmon at the Red Bank trapnets in the Northwest Miramichi, 2 small salmon and 7 large salmon at the Cassilis trapnet in the Northwest, and 4 small salmon and 19 large salmon at the Millerton trapnet in the Southwest Miramichi (Table 3). Recaptures in the seining programs totaled 6 small salmon and 1 large salmon in the Northwest Miramichi, 11 small salmon and 20 large salmon in the Southwest Miramichi. In the seining operations, three small salmon and three large salmon sampled had an adipose-fin punch but did not carry a tag which indicated that the tag had been lost or removed. Overall, this represented tag loss proportions of 0.18 for small salmon and 0.14 for large salmon (Table 3).

Total first time catches at the estuary trapnets were 1,310 small salmon and 1,108 large salmon (Table 3). Total fish sampled during seining operations were 366 small salmon and 967 large salmon (Table 3).

Estimates for 2009 based on three variants of the annual model and four variants for the hierarchical model (using mark and recapture data including or excluding seining data for 2008 and 2009, and using only trapnet catches without M & R data for 2009, using only barrier counts without M & R data for 2009) for the Miramichi River are summarized in Figure 7 and Table 5.

The results for the Southwest and Northwest branches separately are shown in Table 6.

The estimates using the annual model were highly variable depending upon which data are included and all had large uncertainty, particularly for the large salmon (Table 9; Fig. 7). The full hierarchical model incorporates the data from the year of interest (2009 for example) and the information available from previous years. As well, counts at the headwater barriers are included in the hierarchical model and have some observation weight for the years when the mark and recapture experimental observations are weakly informative. The estimates from the hierarchical model, that incorporated all the data from all years, had the least uncertainty (Fig 7; Table 9). Over all combinations of estimates for small salmon in 2009, the median values were in the range of 10,000 to 14,000 fish, only the estimate using the seining M&R data was higher at about 17,500 (Table 9). For large salmon, the median estimates were all between 17,000 and 23,000 fish, only the seining data had an unbelievably high value of 55,000 fish (Table 9). For the separate branch estimates, there was the same congruence between most models, and the results of the model variant using only seining recapture data were much larger than all the other data variants (Table 10).

**ESTIMATES FOR 2008**

The mark and recapture data for 2008 are shown in Table 4 to 6.

Estimates for 2008 based on three variants of the annual model and four variants for the hierarchical model (using mark and recapture data including or excluding seining data for 2008, and using only trapnet catches without M & R data for 2008, using only barrier counts without M & R data for 2008) for the Miramichi River are summarized in Figure 8 and Table 11.

The results for the Southwest and Northwest branches separately are shown in Table 12.

The estimates using the annual models were highly divergent depending upon which data were included (trapnets only, seining only, or both), had large uncertainty, and differed the most from the estimates using the hierarchical model (Fig. 8). The annual model estimates using seining data only were not credible (Fig. 8; Table 11). The hierarchical model estimates were in the range of 30,000 small salmon and less than 10,000 large salmon (Table 11). When only barrier count data were considered, and to which were applied the overall proportions of the returns at the barriers (Fig. 6), the estimates of small salmon and large salmon were higher than the hierarchical models, by about 50%, but with very large uncertainty (Table 11). The same discrepancies between models were translated into the separate branch estimates (Table 12).
The 2008 sampling year was particularly problematic due to frequent washouts at the index trapnets and a very large washout at the SW Miramichi headwater barriers on Sept 29, 2008 (Fig. 9). The highest counts of small salmon occurred at the SW Juniper barrier the day of the washout. The model cannot reconcile this bias. As a result, estimating returns based on catches

and estimates of proportions of the runs at trapnets and barriers would result in underestimates of the returns.

## HIERARCHICAL MODEL ESTIMATES FOR 1998 TO 2009

The estimates of returns of small salmon and large salmon to the Miramichi River for the years 1998 to 2009 are in Table 13 and Figures 10 and 11. The returns by branch are provided in Table 13 and Figures 12 and 13. The hierarchical model is the preferred model. The separate branch estimates were more consistent with expectations based on relative size of the rearing area. The returns to the SW Miramichi were always larger than those to the NW Miramichi (1.5 to 4.8 times for small salmon; 1.8 to 6 times for large salmon) although in some years, the relative proportions of the returns to the SW Miramichi were much larger than would be expected a priori (Table 13).

Returns of large salmon to the Miramichi in 2009 were estimated to be 22,000 fish (95% B.C.I. 17,400 – 28,800), equivalent to the estimate for 2001, and 50% higher than in 2008 (Table 13; Fig. 10). The small salmon returns in 2009 were estimated at 12,400 fish (95% B.C.I. 9,300 – 16,600) 60% below 2008 and the lowest of the time series in the 1998 to 2009 time period (Table 13; Fig. 11).

Estimated returns of large salmon remained low (3,000 fish) in the Northwest Miramichi but were high in the Southwest Miramichi (18,700 fish) (Table 13; Fig. 12 and 13). Small salmon return estimates in 2009 were the lowest of the time series in both branches.

## PERCEPTIONS OF RETURNS IN 2008 AND 2009

The proportions of the total annual catches of small and large salmon at the index trapnets in the Northwest and Southwest Miramichi which occurred before August 1 were exceptionally high in 2008 and 2009 (Fig. 14). From 1998 to 2006, only 30% to 40% of the large salmon catches at the SW Millerton trapnet occurred before August 1 but this increased to almost 50% in 2007, to about 70% in 2008 and to 86% in 2009 (Fig. 14). The increase in the proportion early was also noted for the small salmon catch, ranging from 30% to 55% during 1998 to 2006 and then rising to 62% in 2007, 78% in 2008 and almost 80% in 2009 (Fig. 14). The change in timing of catches has not been as dramatic in the Northwest where there have been important variations in the proportions of the catch which occurred early (Fig. 14). In 2007 to 2009, the proportion of the catch which occurred early was much higher than the levels in most previous years with the exception of 1999 and 2002 when there were equally high proportions of the catch which occurred prior to August 1 at the NW Miramichi Cassilis trapnet (Fig. 14).

Over the years, the tag returns from the headwater barriers were mostly from fish which were tagged in the estuary prior to August 1: 83% (35 of 42) at the Northwest Barrier, 84% (91 of 108) for Dungarvon, 70% (136 of 195) for Juniper Barrier. These data suggest that the run of salmon at these headwater sites was mostly early-run fish. So if the returns in 2008 and 2009 were dominated by early run fish, then the perceptions of anglers and from counts at barriers were consistent with a strong return of small salmon in 2008 and a strong return of large salmon in 2009. The data suggest that this was indeed the case and the lower than expected estimate of the returns for the whole year may in fact be closer to the truth than has been previously concluded.

Estimates of salmon which would have returned by July 31 to the Northwest and Southwest Miramichi (based on the proportion of the total catches at the trapnets which occurred early) are shown in Figure 15. For the Miramichi overall, the early run returns of small salmon in 2008 were much higher than the previous three years but equally important early run returns were estimated to have occurred in 2002 and 2004 (Fig. 15). 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 (Fig. 15). For the Southwest Miramichi, small salmon early run returns in 2008 were the highest of the 1998 to 2009 time period (Fig. 15). Large salmon early run returns to the Miramichi and to the Southwest Miramichi in 2009 were the highest of the time period and by a large amount (Fig. 15). 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 (Fig. 15).

Therefore, although the trapnets and headwater barrier fences experienced important periods of in-operation in 2008 and this 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 July 31) in that year, and for which a fall-run did not materialize.

## BIOLOGICAL CHARACTERISTICS

Preliminary ageing of large salmon scale samples for 2009 indicates that 68% of the large salmon were maiden 2SW salmon (208 of 311 samples). In previous years, repeat spawners had comprised an increasingly important proportion of the large salmon category at over 30% annually (Fig. 16).

In 2009, small salmon fork lengths averaged 55.4 cm (std. dev. = 2.78, N = 1,297) and large salmon fork lengths averaged 75.9 cm (std. dev. = 7.39, N = 1,086). These lengths are similar to those of recent years (Fig. 17).

Similarly, small salmon were characterized as 91% male (579 of 634) and large salmon were characterized as 77% female (830 of 1,073) in 2009, values within the ranges observed since 1992 (Fig. 18).

When converted to eggs per fish using the fecundity relationship of Randall (1989), the large salmon in 2009 contributed fewer eggs per fish than in recent years, due to the relatively smaller size (more 2SW fish) and the slightly lower proportion female (Fig. 19).

## REMOVALS

Harvest data for the Miramichi are incomplete. First Nations harvests from the trapnets are considered complete and the data are used in the assessment. However there are no harvest data from any of gillnet fisheries in the Miramichi. As well, recreational data have not been available for the Miramichi River since 1997. 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).
- Losses from angling were assumed to be 25% of the returns of small salmon and 0.9% (30% catch rate and 3% catch and release mortality) of the returns of large salmon to the Miramichi River (based on estimated returns by size group and estimated angling catches for 1984 to 1995; Moore et al. 1995b, Chaput et al. 1996).

- This indicates a loss from fishing of about 820 large salmon and 4,600 small salmon in 2009.

## ESTIMATES OF ESCAPEMENT RELATIVE TO CONSERVATION FOR 1970 TO 2009

The conservation spawning requirements for the Miramichi River and its two branches are based on a measure of wetted area (Amiro 1983) for juvenile production and an egg deposition rate of 240 eggs per 100 m² (CAFSAC 1991; Chaput et al. 2001). 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.

| | | | Fish required | |
|---|---|---|---|---|
| | Habitat area (million $m^2$) | Egg requirement (millions) | Large salmon | Small salmon |
| Miramichi River | 54.6 | 132 | 23,600 | 22,600 |
| Main Miramichi | 1.1 | 3 | 554 | 531 |
| Southwest Miramichi | 36.7 | 88.1 | 15,730 | 15,063 |
| Northwest Miramichi | 16.8 | 40.3 | 7,316 | 7,006 |

Using the median estimates of the returns of small salmon and large salmon (Table 13), the biological characteristics, and the estimates of removals, the eggs which could have been returned (i.e., before removals) to the Miramichi in 2009 were 97% of conservation and the eggs which were estimated to have been spawned (after removals) were 92% of the conservation requirement. Over the period 1970 to 2009, the returns of salmon 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 1997 to 2009 (Fig. 20). 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 (Fig. 20). At least 67% of conservation requirements have been met every year since 1984 (Fig. 20).

## 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 (Fig. 21). 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 21). Considering large salmon returns (which would include 2SW, 3SW and 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 21). 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. (Fig. 21).

## CONCLUSIONS

The hierarchical model is considered to be the most appropriate model for estimating returns to the two branches and overall to the Miramichi River.

The seining activities in 2009 provided informative data for the assessment of the returns, but if used alone, resulted in suspect estimates for large salmon. There are no indications from the barrier counts in 2009 that salmon returns could have been in the order of 50,000 fish. Counts at the barriers in 2009 were improved from 2008 but higher values have been recorded in the previous two decades at all three barriers (Table 1).

For 2009, the results indicate that the small salmon returns (at about 12,000 fish) were the lowest of the 1998 to 2009 time series and the lowest value since 1971. The large salmon returns of about 22,000 fish were near the conservation requirement for the river, and were among the highest values since 1998 (equal to that of 2001).

Separate branch estimates showed a much higher relative (expected 2:1 for SW:NW based on habitat area for production) return of both small salmon and large salmon in the Southwest Miramichi compared 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.

Small salmon returns in both branches in 2009 were the lowest since 1998. The low returns estimated for 2009 are confirmed by the low escapement at the barrier fences: 2$^{nd}$ lowest of the time series for SW Dungarvon, lowest since 1984 for the SW Juniper, and the lowest of the time series for the NW Miramichi barrier (Table 1). Trends in the Crown Reserve angling catches for the NW Miramichi were similar to the patterns above, the lowest catch of small salmon of the time series was in 2009 (Table 2) whereas large salmon catches in 2009 were the highest of the time series.

Harvest data of small salmon and large salmon are incomplete from both the First Nations FSC fisheries and the recreational fisheries. The assumed values for these 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 were assumed to occur in the First Nations FSC fisheries (95%) whereas the losses in the Southwest Miramichi were due to recreational fishing.

Overall for the Miramichi, total losses of eggs due to fishing have averaged 8% over both size groups, 5% for large salmon and 20% for small salmon.

### UNCERTAINTIES AND RECOMMENDATIONS FOR FURTHER WORK

A key assumption of the mark and recapture models is that the probability of capture of tagged and untagged fish is independent and identical, throughout the season and at the different recapture and monitoring facilities in the different areas of the river. This assumption may not be valid, particularly for the early portion of the salmon run when catchability of salmon at the trapnets may be lower. Evidence for this comes 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, gaspereau fishery trapnets, First Nations catches, counts at headwater barriers).

This potential bias to the assessment would lead to an underestimate of abundance but the magnitude of the bias is not known. This effect may be more important in the Northwest Miramichi than the Southwest Miramichi. In some years, there may be sufficient tagging and recapture data by month to examine the validity of the assumption but the issue of low catchability at the start of the year is difficult to resolve due to a lack of data.

It is also assumed that the survival rate of tagged fish is the same from all tagging facilities, and is the same in all years. Again, the validity of this assumption could be examined by comparing recapture rates of fish from the facilities. For example, in the seining program in 2009, there were 16 recaptures of large salmon tagged from the SW Millerton trapnet (out of 537 fish tagged) compared to only one recapture from the 440 fish tagged at the SW Eelground trapnet which initially suggests that the probability of a tagged fish from the Eelground trapnets was much lower than that of a tagged salmon from the Millerton trapnet, possibly due to lower survival of tagged fish from the Eelground trapnet. Yet there were 19 recaptures of large salmon from the SW Eelground trapnet at the SW Millerton trapnet so the survival rate at least up to the upper estuary trapnet was good. Such comparisons should be done within a formal model structure.

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. The collection of harvest data from all the fisheries should be a priority initiative for management.

Following on the regional science peer review of March 3, 2010 (DFO 2010), a number of recommendations for further analyses were made:

- 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 when the data are sufficient, examine the assumption of similar probability of capture between tagged and untagged fish. In some years, the trapnets at Red Bank were installed on both sides of the river in the Northwest Miramichi and this could be used to examine the assumption that fish captured and tagged from a trapnet on one side of the river redistribute themselves within the river before they encounter the recapture gear.
- The historical time series for the Miramichi should be re-analyzed using the hierarchical model. The time series from 1984 to the present could be examined first as it represents the years post commercial fishery closure.
- Consider using angling data from the two branches for the years when they are available (1984 to 1995, 1997). The model should incorporate the information on effort to estimate exploitation rates.
- Angling data from the Northwest Miramichi crown reserve should be included as the time series is more complete and extends to the present. The model should incorporate the information on effort to estimate exploitation rates.
- The headwater barrier data should be more appropriately treated as an index of escapement rather than returns. In the absence of angling data post 1997, the exploitation rates and harvests would have to be estimated from the historical data and applied to the

years when the angling data are missing. The collection of angling statistics should be a priority for the watershed group.

- The headwater barrier data should be more appropriately treated as an index of early run escapement rather than total escapement. The proportion early run for the whole year would be derived from 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.

The time series of juvenile abundance surveys for the Miramichi should be analysed and when combined with the recent efforts to estimate smolt production from the branches may provide insights into the factors contributing to annual variability in abundance of Atlantic salmon. On the basis of the estimated smolt run size in 2008 from the Southwest Miramichi (Miramichi Salmon Association, unpubl. data), the cause of the low return of small salmon in 2009 was more likely attributable to poor marine survival rather than low freshwater production.

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## REFERENCES


Amiro, P.G. 1983. Aerial photographic measurement of Atlantic salmon habitat of the Miramichi River, New Brunswick. Can. Atl. Fish. Sci. Adv. Commit. Res. Doc. 83/74.

Bousfield, E.L. 1955. Some physical features of the Miramichi estuary. J. Fish. Res. Bd. Canada, 12: 342-361.

CAFSAC. 1991. Quantification of Conservation for Atlantic Salmon. Can. Atl. Fish. Sci. Adv. Commit. Adv. Doc. 91/16.

Chaput, G., D. Moore, M. Biron, and R. Claytor. 1994. Stock status of Atlantic salmon (*Salmo salar*) in the Miramichi River, 1993. DFO Atl. Fish. Res. Doc. 94/20.

Chaput, G., M. Biron, D. Moore, B. Dube, M. Hambrook, and B. Hooper. 1995. Stock status of Atlantic salmon (*Salmo salar*) in the Miramichi River, 1994. DFO Atl. Fish. Res. Doc. 95/131.

Chaput, G., M. Biron, D. Moore, B. Dube, C. Ginnish, M. Hambrook, T. Paul, and B. Scott. 1996. Stock status of Atlantic salmon (*Salmo salar*) in the Miramichi River, 1995. DFO Atl. Fish. Res. Doc. 96/124.

Chaput, G., D. Moore, J. Hayward, C. Ginnish, B. Dubee, and M. Hambrook. 1997. Stock status of Atlantic salmon (*Salmo salar*) in the Miramichi River, 1996. DFO Atl. Fish. Res. Doc. 97/20.

Chaput, G., D. Moore, J. Hayward, C. Ginnish, and B. Dubee. 1998. Stock status of Atlantic salmon (*Salmo salar*) in the Miramichi River, 1997. DFO Can. Stock Assess. Secr. Res. Doc. 98/34.

Chaput, G., D. Moore, J. Hayward, J. Shaesgreen, and B. Dubee. 1999. Stock status of Atlantic salmon (*Salmo salar*) in the Miramichi River, 1998. DFO Can. Stock Assess. Secr. Res. Doc. 99/049.

Chaput, G., D. Moore, J. Hayward, J. Shaesgreen, and B. Dubee. 2000. Stock status of Atlantic salmon (*Salmo salar*) in the Miramichi River, 1999. DFO Can. Stock Assess. Secr. Res. Doc. 2000/004.

Chaput, G., D. Moore, J. Hayward, J. Sheasgreen, and B. Dubee. 2001. Stock status of Atlantic salmon (Salmo salar) in the Miramichi River, 2000. Can. Sci. Advi. Secr. Res. Doc. 2001/008

Courtenay, S.C., D.S. Moore, R. Pickard, and G. Nielsen. 1993. Status of Atlantic salmon in the Miramichi River in 1992. DFO Atl. Fish. Res. Doc. 93/56.

DFO. 2010. Assessment of Atlantic salmon in the Miramichi River (NB), 1998 to 2009. DFO Can. Sci. Advis. Sec. Sci. Resp. 2010/005.

Madden, G.A., P.J. Cronin, B.L. Dubee, P.D. Seymour, and E.J. LeBlanc. 1999. Using artificial barriers to protect and enhance Atlantic salmon. NB Dept. of Natural Resources Management Report 99-01-E.

Moore, D.S., G. Chaput, and R. Pickard. 1995a. The effect of fisheries on the biological characteristics and survival of mature Atlantic salmon (*Salmo salar*) from the Miramichi River. *In* E.M.P. Chadwick [ed.] Water, science, and the public: the Miramichi ecosystem. Can. Spec. Publ. Fish. Aquat. Sci. No. 123.

Moore, D.S., B. Dubee, B. Hooper, and M. Biron. 1995b. Angling catch and effort for the Miramichi River from 1969 to 1994. DFO Atl. Fish. Res. Doc. 95/4.

Moore, D.S., S.C. Courtenay, R. Claytor, and R. Pickard. 1992. Status of Atlantic salmon in the Miramichi River during 1991. Can. Atl. Fish. Sci. Adv. Commit. Res. Doc. 92/38.

Moore, D.S., S. Courtenay, and P.R. Pickard. 1991. Status of Atlantic salmon in the Miramichi River during 1990. Can. Atl. Fish. Sci. Adv. Commit. Res. Doc. 91/8.

Randall, R.G. 1989. Effect of sea age on the reproductive potential of Atlantic salmon (*Salmo salar*) in eastern Canada. Can. J. Fish. Aquat. Sci. 46: 2210-2218.

Randall, R.G. and E.M.P. Chadwick. 1983a. Assessment of the Miramichi River salmon stock in 1982. Can. Atl. Fish. Sci. Adv. Commit. Res. Doc. 83/21.

Randall, R.G. and E.M.P. Chadwick. 1983b. Biological assessment of Atlantic salmon in the Miramichi River, N.B., 1983. Can. Atl. Fish. Sci. Adv. Commit. Res. Doc. 83/83.

Randall, R.G., E.M.P. Chadwick, and E.J. Schofield. 1985. Status of Atlantic salmon in the Miramichi River, 1984. Can. Atl. Fish. Sci. Adv. Commit. Res. Doc. 85/2.

Randall, R.G., E.M.P. Chadwick, and E.J. Schofield. 1986. Status of Atlantic salmon in the Miramichi River, 1985. Can. Atl. Fish. Sci. Adv. Commit. Res. Doc. 86/2.

Randall, R.G., D.M. Moore, and P.R. Pickard. 1990. Status of Atlantic salmon in the Miramichi River during 1989. Can. Atl. Fish. Sci. Adv. Commit. Res. Doc. 90/4.

Randall, R.G., M.F. O'Connell, and E.M.P. Chadwick. 1989. Fish production in two large Atlantic coast rivers: Miramichi and Exploits, p. 92-308. *In* D.P. Dodge [ed.] Proceedings of the International Large River Symposium. Can. Spec. Publ. Fish. Aquat. Sci. No. 106.

Randall, R.G., P.R. Pickard, and D. Moore. 1989. Biological assessment of Atlantic salmon in the Miramichi River, 1988. Can. Atl. Fish. Sci. Adv. Commit. Res. Doc. 89/73.

Randall, R.G., J.A. Wright, P.R. Pickard, and W.G. Warren. 1991. Effect of run timing on the exploitation by anglers of Atlantic salmon in the Miramichi River. Can. Tech. Rep. Fish. Aquat. Sci. 1790. 46 p.

Randall, R.G. and E.J. Schofield. 1987. Status of Atlantic salmon in the Miramichi River, 1986. Can. Atl. Fish. Sci. Adv. Commit. Res. Doc. 87/5.

Randall, R.G. and E.J. Schofield. 1988. Status of Atlantic salmon in the Miramichi River, 1987. Can. Atl. Fish. Sci. Adv. Commit. Res. Doc. 88/49.

Rivot, E. and E. Prévost. 2002. Hierarchical Bayesian analysis of capture–mark–recapture data. Can. J. Fish. Aquat. Sci. 59: 1768–1784.

Saunders, R.L. 1967. Seasonal pattern of return of Atlantic salmon in the Northwest Miramichi River, New Brunswick. J. Fish. Res. Bd. Canada 24: 21-32.

Saunders, R.L. 1969. Contributions of salmon from the Northwest Miramcihi River, New Brunswick, to various fisheries. J. Fish. Res. Bd. Canada 26: 269-278.

Saunders, R.L. 1981. Atlantic salmon (*Salmo salar*) stocks and management implications in the Canadian Atlantic Provinces and New England, USA. Can. J. Fish. Aquat. Sci. 38: 1612-1625.

***Table 1.*** *Counts of small salmon and large salmon at the three headwater protection barriers in the Miramichi River, 1981 to 2009.*

| | Large salmon | | | Small salmon | | |
|---|---|---|---|---|---|---|
| Year | Northwest | Dungarvon | Juniper | Northwest | Dungarvon | Juniper |
| 1981 | | 112 | 54 | | 550 | 671 |
| 1982 | | 122 | 282 | | 483 | 621 |
| 1983 | | 126 | 219 | | 330 | 290 |
| 1984 | | 93 | 297 | | 315 | 230 |
| 1985 | | 162 | 604 | | 536 | 492 |
| 1986 | | 174 | 1,138 | | 501 | 2,072 |
| 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 | 1371 |
| 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 from the Northwest and Southwest Miramichi Rivers, 1984 to 2009. Effort is in units of rod days.*

| | Southwest Miramichi | | | Northwest Miramichi | | | Northwest Crown Reserve | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Small | Large | Effort | Small | Large | Effort | Small | Large | Effort |
| 1984 | 12,827 | 4,858 | 40,330 | 5,964 | 2,828 | 16,505 | 1,240 | 229 | 2,179 |
| 1985 | 9,008 | 6,522 | 38,769 | 9,430 | 3,098 | 23,041 | 1,563 | 206 | 2,269 |
| 1986 | 16,616 | 10,379 | 41,113 | 9,537 | 3,836 | 25,355 | 1,676 | 156 | 2,456 |
| 1987 | 13,670 | 9,844 | 42,115 | 7,095 | 2,088 | 22,891 | 1,072 | 88 | 1,839 |
| 1988 | 20,753 | 6,986 | 55,612 | 9,833 | 3,082 | 25,186 | 1,860 | 102 | 2,432 |
| 1989 | 16,814 | 9,123 | 51,008 | 7,568 | 2,805 | 22,104 | 1,595 | 127 | 2,535 |
| 1990 | 14,547 | 7,029 | 86,700 | 6,825 | 2,229 | 35,654 | 1,587 | 144 | 2,502 |
| 1991 | 8,244 | 4,614 | 74,714 | 3,056 | 1,533 | 34,641 | 612 | 77 | 2,395 |
| 1992 | 14,522 | 7,682 | 84,376 | 6,960 | 1,794 | 37,263 | 1,423 | 94 | 2,364 |
| 1993 | 10,727 | 5,945 | 77,929 | 6,171 | 2,186 | 39,912 | 1,426 | 135 | 2,432 |
| 1994 | 7,072 | 3,261 | 73,905 | 4,131 | 1,868 | 39,471 | 1,234 | 130 | 2,342 |
| 1995 | 3,828 | 2,519 | 22,532 | 1,705 | 627 | 10,930 | 523 | 88 | 1,773 |
| 1996 | | | | | | | 1,301 | 131 | 2,607 |
| 1997 | 7,440 | 3,646 | 48,785 | 4,052 | 1,432 | 23,549 | 868 | 115 | 2,494 |
| 1998 | | | | | | | 1,044 | 125 | 2,488 |
| 1999 | | | | | | | 514 | 68 | 2,177 |
| 2000 | | | | | | | 949 | 93 | 2,619 |
| 2001 | | | | | | | 555 | 119 | 2,298 |
| 2002 | | | | | | | 836 | 66 | 2,566 |
| 2003 | | | | | | | 650 | 174 | 2,601 |
| 2004 | | | | | | | 569 | 74 | 2,565 |
| 2005 | | | | | | | 598 | 112 | 2,637 |
| 2006 | | | | | | | 767 | 99 | 2,579 |
| 2007 | | | | | | | 586 | 125 | 2,574 |
| 2008 | | | | | | | 1,685 | 135 | 2,558 |
| 2009 | | | | | | | 445 | 235 | 2,755 |

***Table 3.*** *For 2009, tagging and recapture matrices by size group of salmon for all sampling facilities. Shaded values are recaptures of fish at the same location where they were tagged or returns from angling and these are not used in the mark and recapture model. Recaptures shown are for valid recaptures for the mark and recapture experiment, i.e. first occurrence of the tagged fish at that facility originating from another facility.*

| **Small salmon** | | Recaptured in | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Northwest Miramichi | | | | | Southwest Miramichi | | | |
| Tagged at | Tags placed | NW Cassilis | NW Red Bank | NW Seining | NW Barrier | Angling | SW Millerton | SW Seining | SW Barrier | Angling |
| NW Cassilis | 255 | *16* | 8 | 4 | 0 | 5 | 0 | 0 | 0 | 0 |
| SW Eelground | 38 | 1 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 2 |
| SW Millerton | 681 | 1 | 1 | 0 | 0 | 3 | *40* | 10 | 6 | 20 |
| Tag scarred fish | | 0 | 0 | 2 | 0 | | 2 | 1 | 0 | |
| First time catch | | 270 | 91 | 125 | 315 | | 949 | 241 | 207 | |

| **Large salmon** | | Recaptured in | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Northwest Miramichi | | | | | Southwest Miramichi | | | |
| Tagged at Northwest | Tags placed | NW Cassilis | NW Red Bank | NW Seining | NW Barrier | Angling | SW Millerton | SW Seining | SW Barrier | Angling |
| NW Cassilis | 197 | *9* | 5 | 1 | 0 | 2 | 0 | 0 | 0 | 0 |
| SW Eelground | 440 | 6 | 1 | 0 | 0 | 3 | 19 | 1 | 0 | 4 |
| SW Millerton | 537 | 1 | 2 | 0 | 0 | 0 | *14* | 16 | 0 | 8 |
| Tag scarred fish | | 1 | 0 | 0 | 0 | | 3 | 3 | 0 | |
| First time catch | | 204 | 80 | 98 | 207 | | 824 | 869 | 234 | |

***Table 4.*** *For 2008, tagging and recapture matrices by size group of salmon for all sampling facilities. Shaded values are recaptures of fish at the same location where they were tagged or returns from angling and these are not used in the mark and recapture model. Recaptures shown are for valid recaptures for the mark and recapture experiment, i.e. first occurrence of the tagged fish at that facility originating from another facility.*

| **Small salmon** | | Recaptured in | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Northwest Miramichi | | | | | Southwest Miramichi | | | |
| Tagged at | Tags placed | NW Cassilis | NW Red Bank | NW Seining | NW Barrier | Angling | SW Millerton | SW Seining | SW Barrier | Angling |
| NW Cassilis | 677 | *47* | 12 | 2 | 2 | 14 | 6 | 0 | 1 | 4 |
| SW Eelground | 79 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| SW Millerton | 966 | 1 | 2 | 0 | 0 | 2 | *36* | 3 | 13 | 22 |
| Tag scarred fish | | | | 2 | | | | 0 | | |
| First time catch | | 704 | 105 | 347 | 1094 | | 1485 | 510 | 1743 | |

| **Large salmon** | | Recaptured in | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Northwest Miramichi | | | | | Southwest Miramichi | | | |
| Tagged at Northwest | Tags placed | NW Cassilis | NW Red Bank | NW Seining | NW Barrier | Angling | SW Millerton | SW Seining | SW Barrier | Angling |
| NW Cassilis | 121 | *5* | 1 | 0 | 0 | 3 | 3 | 0 | 0 | 0 |
| SW Eelground | 118 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 |
| SW Millerton | 281 | 1 | 0 | 0 | 0 | 0 | *11* | 1 | 3 | 1 |
| Tag scarred fish | | | | 0 | | | | 0 | | |
| First time catch | | 124 | 15 | 104 | 164 | | 298 | 237 | 818 | |

***Table 5.*** *Capture, mark and recapture data for large salmon, 1998 to 2009.*

| | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Fish tagged** | | | | | | | | | | | | |
| SW Eelground (Slow) | 309 | 347 | 355 | 704 | 231 | 345 | 338 | 190 | 210 | 289 | 118 | 440 |
| SW Millerton (SMid) | 354 | 403 | 382 | 1271 | 494 | 1050 | 972 | 705 | 1005 | 581 | 281 | 537 |
| NW Cassilis (NMid) | 210 | 274 | 275 | 946 | 182 | 335 | 351 | 387 | 205 | 347 | 121 | 197 |
| **Tag recaptures** | | | | | | | | | | | | |
| RSLowSMid | 5 | 15 | 9 | 57 | 12 | 17 | 13 | 11 | 10 | 1 | 1 | 19 |
| RSLowNMid | 1 | 1 | 9 | 20 | 1 | 2 | 7 | 4 | 3 | 6 | 0 | 6 |
| RSLowNHigh | 1 | 13 | 5 | 7 | 1 | 0 | 2 | | 0 | 0 | 0 | 1 |
| RSMidNMid | 1 | 0 | 2 | 12 | 5 | 10 | 9 | 8 | 7 | 2 | 1 | 1 |
| RSMidNHigh | 0 | 1 | 1 | 4 | 4 | 5 | 2 | | 0 | 1 | 0 | 2 |
| RNMidSMid | 2 | 2 | 3 | 35 | 0 | 9 | 4 | 2 | 4 | 12 | 3 | 0 |
| RNMidNHigh | 4 | 27 | 20 | 33 | 13 | 18 | 20 | | 0 | 14 | 1 | 5 |
| **First time catch at trapnets** | | | | | | | | | | | | |
| FTSMid (Millerton) | 363 | 436 | 395 | 1352 | 510 | 1080 | 1040 | 750 | 1047 | 613 | 298 | 824 |
| FTNMid (Cassilis) | 217 | 280 | 277 | 983 | 188 | 339 | 358 | 417 | 210 | 365 | 124 | 204 |
| FTNHigh (Redbank) | 69 | 592 | 636 | 561 | 160 | 169 | 285 | | 11 | 205 | 15 | 80 |
| **Counts at barriers** | | | | | | | | | | | | |
| Dungarvon | 163 | 185 | 130 | 111 | 107 | 158 | 185 | 300 | 217 | 88 | 131 | 234 |
| Juniper | 698 | 698 | 725 | 904 | 546 | 920 | 764 | 673 | 829 | 783 | 692 | 889 |
| NWMiramichi | 289 | 387 | 217 | 202 | 121 | 186 | 167 | 262 | 214 | 166 | 164 | 207 |
| **Catches by season at DFO index trapnets (E is <= July 31; L is > July 31)** | | | | | | | | | | | | |
| SWMillE (Millerton) | 119 | 171 | 124 | 432 | 172 | 377 | 378 | 264 | 342 | 299 | 205 | 715 |
| SWMillL (Millerton) | 244 | 265 | 271 | 920 | 338 | 703 | 662 | 486 | 705 | 314 | 93 | 109 |
| NWCassE (Cassilis) | 73 | 155 | 85 | 179 | 120 | 104 | 124 | 119 | 29 | 201 | 79 | 148 |
| NWCassL (Cassilis) | 144 | 125 | 192 | 804 | 68 | 235 | 234 | 298 | 181 | 164 | 45 | 56 |
| **Recaptures in the seine** | | | | | | | | | | | | |
| RSLowSSeine | | | | | | | | | | | 0 | 1 |
| RSLowNSeine | | | | | | | | | | | 0 | 0 |
| RSMidSSeine | | | | | | | | | | | 1 | 16 |
| RSMidNSeine | | | | | | | | | | | 0 | 0 |
| RNMidSSeine | | | | | | | | | | | 0 | 0 |
| RNMidNSeine | | | | | | | | | | | 0 | 1 |
| **Total catch in seining** | | | | | | | | | | | | |
| FTSSeine | | | | | | | | | | | 237 | 869 |
| FTNSeine | | | | | | | | | | | 104 | 98 |
| **Tag loss data for seining** | | | | | | | | | | | | |
| Fish with tags | | | | | | | | | | | 1 | 18 |
| Fish with tag scars | | | | | | | | | | | 0 | 3 |

***Table 6.*** *Capture, mark and recapture data for small salmon, 1998 to 2009.*

| | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Fish tagged** | | | | | | | | | | | | |
| SW Eelground (SLow) | 508 | 790 | 1065 | 613 | 625 | 499 | 514 | 109 | 175 | 95 | 79 | 38 |
| SW Millerton (SMid) | 1148 | 898 | 1431 | 1140 | 1587 | 1320 | 2138 | 1518 | 1948 | 1054 | 966 | 681 |
| NW Cassilis (NMid) | 745 | 794 | 1070 | 734 | 1127 | 594 | 1115 | 783 | 644 | 799 | 677 | 255 |
| **Tag recaptures** | | | | | | | | | | | | |
| RSLowNMid | 5 | 10 | 22 | 13 | 13 | 3 | 11 | 1 | 3 | 1 | 0 | 1 |
| RSLowNHigh | 4 | 20 | 28 | 7 | 10 | 3 | 10 | NA | 0 | 0 | 0 | 0 |
| RSLowSMid | 39 | 41 | 55 | 51 | 49 | 42 | 34 | 15 | 12 | 3 | 3 | 4 |
| RSMidNMid | 9 | 4 | 10 | 8 | 10 | 16 | 19 | 10 | 27 | 4 | 1 | 1 |
| RSMidNHigh | 1 | 3 | 2 | 7 | 17 | 4 | 5 | NA | 1 | 3 | 2 | 1 |
| RNMidSMid | 9 | 7 | 12 | 19 | 20 | 6 | 13 | 13 | 9 | 4 | 6 | 0 |
| RNMidNHigh | 18 | 95 | 140 | 52 | 46 | 22 | 73 | NA | 10 | 59 | 12 | 8 |
| **First time catch at trapnets** | | | | | | | | | | | | |
| FTSMid (Millerton) | 1158 | 924 | 1442 | 2223 | 2787 | 2230 | 2957 | 2475 | 2636 | 1354 | 1485 | 949 |
| FTNMid (Cassilis) | 758 | 835 | 1090 | 914 | 1687 | 636 | 1262 | 943 | 659 | 893 | 704 | 270 |
| FTNHigh (Redbank) | 246 | 1329 | 2018 | 829 | 970 | 304 | 1140 | | 83 | 412 | 105 | 91 |
| **Counts at barriers** | | | | | | | | | | | | |
| Dungarvon | 592 | 378 | 372 | 295 | 287 | 389 | 559 | 441 | 468 | 195 | 664 | 207 |
| Juniper | 981 | 566 | 1202 | 729 | 1371 | 912 | 1368 | 853 | 853 | 945 | 1087 | 242 |
| NWMiramichi | 1038 | 708 | 456 | 344 | 595 | 478 | 723 | 735 | 469 | 460 | 1094 | 315 |
| **Catches by season at DFO index trapnets (E is <= July 31; L is > July 31)** | | | | | | | | | | | | |
| SWMillE (Millerton) | 354 | 493 | 679 | 1128 | 1533 | 1042 | 1566 | 1174 | 1426 | 838 | 1143 | 749 |
| SWMillL (Millerton) | 804 | 431 | 763 | 1025 | 1185 | 1140 | 1344 | 1273 | 1210 | 515 | 342 | 200 |
| NWCassE (Cassilis) | 442 | 662 | 610 | 305 | 1364 | 347 | 658 | 417 | 204 | 579 | 559 | 205 |
| NWCassL (Cassilis) | 316 | 173 | 480 | 588 | 300 | 270 | 574 | 515 | 455 | 314 | 145 | 65 |
| **Recaptures in the seine** | | | | | | | | | | | | |
| RSLowSSeine | | | | | | | | | | | 0 | 0 |
| RSLowNSeine | | | | | | | | | | | 0 | 0 |
| RSMidSSeine | | | | | | | | | | | 3 | 10 |
| RSMidNSeine | | | | | | | | | | | 0 | 0 |
| RNMidSSeine | | | | | | | | | | | 0 | 0 |
| RNMidNSeine | | | | | | | | | | | 2 | 4 |
| **Total catch in seining** | | | | | | | | | | | | |
| FTSSeine | | | | | | | | | | | 502 | 241 |
| FTNSeine | | | | | | | | | | | 347 | 125 |
| **Tag loss data for seining** | | | | | | | | | | | | |
| Fish with tags | | | | | | | | | | | 5 | 14 |
| Fish with tag scars | | | | | | | | | | | 2 | 3 |

***Table 7.*** *Returns of tags from small salmon angled in the Northwest and Southwest branches of the Miramichi River relative to the branch in which the fish were originally tagged, 1998 to 2009.*

| Tag_Species | 1733 | Small salmon | | |
|---|---|---|---|---|
| | | | | |
| | | Recaptured in | | |
| Tag year | Tag_branch | Northwest | Southwest | Grand Total |
| 1998 | Northwest | 24 | 6 | 30 |
| | Southwest | 6 | 72 | 78 |
| 1998 Total | | 30 | 78 | 108 |
| 1999 | Northwest | 11 | 0 | 11 |
| | Southwest | 0 | 5 | 5 |
| 1999 Total | | 11 | 5 | 16 |
| 2000 | Northwest | 32 | 6 | 38 |
| | Southwest | 4 | 98 | 102 |
| 2000 Total | | 36 | 104 | 140 |
| 2001 | Northwest | 14 | 2 | 16 |
| | Southwest | 7 | 49 | 56 |
| 2001 Total | | 21 | 51 | 72 |
| 2002 | Northwest | 28 | 7 | 35 |
| | Southwest | 13 | 87 | 100 |
| 2002 Total | | 41 | 94 | 135 |
| 2003 | Northwest | 17 | 0 | 17 |
| | Southwest | 8 | 68 | 76 |
| 2003 Total | | 25 | 68 | 93 |
| 2004 | Northwest | 14 | 5 | 19 |
| | Southwest | 2 | 84 | 86 |
| 2004 Total | | 16 | 89 | 105 |
| 2005 | Northwest | 5 | 5 | 10 |
| | Southwest | 1 | 47 | 48 |
| 2005 Total | | 6 | 52 | 58 |
| 2006 | Northwest | 12 | 1 | 13 |
| | Southwest | 5 | 49 | 54 |
| 2006 Total | | 17 | 50 | 67 |
| 2007 | Northwest | 19 | 1 | 20 |
| | Southwest | 3 | 42 | 45 |
| 2007 Total | | 22 | 43 | 65 |
| 2008 | Northwest | 14 | 4 | 18 |
| | Southwest | 2 | 22 | 24 |
| 2008 Total | | 16 | 26 | 42 |
| 2009 | Northwest | 5 | 0 | 5 |
| | Southwest | 3 | 23 | 26 |
| 2009 Total | | 8 | 23 | 31 |

***Table 8.*** *Returns of tags from large salmon angled in the Northwest and Southwest branches of the Miramichi River relative to the branch in which the fish were originally tagged, 1998 to 2009.*

| Tag_Species | 1734 | Large salmon | | |
|---|---|---|---|---|
| Sum of Freq. | | Recaptured in | | |
| Tag year | Tag_branch | Northwest | Southwest | Grand Total |
| 1998 | Northwest | 2 | 1 | 3 |
| | Southwest | 0 | 7 | 7 |
| 1998 Total | | 2 | 8 | 10 |
| 1999 | Northwest | 1 | 0 | 1 |
| | Southwest | 0 | 0 | 0 |
| 1999 Total | | 1 | 0 | 1 |
| 2000 | Northwest | 3 | 4 | 7 |
| | Southwest | 1 | 6 | 7 |
| 2000 Total | | 4 | 10 | 14 |
| 2001 | Northwest | 3 | 3 | 6 |
| | Southwest | 1 | 22 | 23 |
| 2001 Total | | 4 | 25 | 29 |
| 2002 | Northwest | 2 | 3 | 5 |
| | Southwest | 2 | 10 | 12 |
| 2002 Total | | 4 | 13 | 17 |
| 2003 | Northwest | 2 | 4 | 6 |
| | Southwest | 3 | 27 | 30 |
| 2003 Total | | 5 | 31 | 36 |
| 2004 | Northwest | 1 | 7 | 8 |
| | Southwest | 2 | 16 | 18 |
| 2004 Total | | 3 | 23 | 26 |
| 2005 | Northwest | 1 | 2 | 3 |
| | Southwest | 0 | 11 | 11 |
| 2005 Total | | 1 | 13 | 14 |
| | Northwest | 0 | 0 | 0 |
| 2006 | Southwest | 0 | 12 | 12 |
| 2006 Total | | 0 | 12 | 12 |
| 2007 | Northwest | 0 | 2 | 2 |
| | Southwest | 0 | 14 | 14 |
| 2007 Total | | 0 | 16 | 16 |
| 2008 | Northwest | 3 | 0 | 3 |
| | Southwest | 1 | 1 | 2 |
| 2008 Total | | 4 | 1 | 5 |
| 2009 | Northwest | 2 | 0 | 2 |
| | Southwest | 3 | 12 | 15 |
| 2009 Total | | 5 | 12 | 17 |

***Table 9.*** *Estimates of returns of small salmon and large salmon to the Miramichi River in 2009. Row in bold characters is the selected model and data combination for assessment.*

| Miramichi overall | | Median (95% credibility interval) | |
|---|---|---|---|
| Model | Variant | Small salmon | Large salmon |
| Annual | M&R Trapnet only | 11,100 (5,400 – 41,200) | 17,600 (11,900 – 27,200) |
| | M&R Seine only | 17,500 (9,700 – 33,600) | 55,400 (27,700 – 84,900) |
| | M&R Trapnet and seine | 9,700 (4,700 – 24,200) | 16,800 (11,500 – 18,700) |
| | | | |
| **Hierachical (1998-2009)** | M&R Trapnet only | 11,500 (8,500 – 16,600) | 18,500 (14,700 – 24,500) |
| | **M&R Trapnet and seine** | **12,400** (9,300 – 16,600) | **21,900** (17,400 – 28,800) |
| With all data (up to 2008) | Using only trapnet catches | 14,400 (7,100 – 51,800) | 22,600 (7,500 – 141,000) |
| | Using only barrier counts | 12,400 (5,800 – 54,300) | 20,400 (9,100 – 68,700) |

***Table 10.*** *Estimates of returns of small salmon and large salmon to the Southwest and Northwest branches of the Miramichi River in 2009. Row in bold characters is the selected model and data combination for assessment.*

| **Southwest Miramichi** | | Median (95% credibility interval) | |
|---|---|---|---|
| Model | Variant | Small salmon | Large salmon |
| Annual | M&R Trapnet only | 8,000 (2,300 – 38,600) | 13,900 (6,300 – 24,500) |
| | M&R Seine only | 10,500 (5,500 – 22,300) | 27,100 (15,400 – 47,000) |
| | M&R Trapnet and seine | 5,900 (1,300 – 20,900) | 13,200 (3,400 – 20,800) |
| | | | |
| **Hierachical (1998-2009)** | M&R Trapnet only | 8,600 (5,600 – 13,800) | 15,800 (12,000 – 21,800) |
| | **M&R Trapnet and seine** | **9,300** (6,500 – 13,300) | **18,700** (14,300 – 25,600) |
| With all data (up to 2008) | Using only trapnet catches | 6,700 (4,600 – 38,400) | 19,300 (5,400 – 122,000) |
| | Using only barrier counts | 11,000 (2,600 – 19,700) | 16,800 (6,600 – 52,000) |

| **Northwest Miramichi** | | Median (95% credibility interval) | |
|---|---|---|---|
| Model | Variant | Small salmon | Large salmon |
| Annual | M&R Trapnet only | 2,800 (1,400 – 6,100) | 3,400 (1,400 – 8,700) |
| | M&R Seine only | 6,100 (2,400 – 19,300) | 26,200 (4,900 – 200,000) |
| | M&R Trapnet and seine | 3,300 (700 – 8,900) | 3,400 (900 – 11,000) |
| | | | |
| **Hierachical (1998-2009)** | M&R Trapnet only | 2,700 (1,900 – 4,200) | 2,700 (1,700 – 4,400) |
| | **M&R Trapnet and seine** | **3,000** (2,100 – 4,600) | **3,000** (1,900 – 5,000) |
| With all data (up to 2008) | Using only trapnet catches | 2,500 (900 – 16,700) | 1,600 (400 – 24,400) |
| | Using only barrier counts | 4,800 (1,200 – 43,900) | 2,400 (600 – 26,400) |

***Table 11.*** *Estimates of returns of small salmon and large salmon to the Miramichi River in 2008. Row in bold characters is the selected model and data combination for assessment.*

| Miramichi overall | | Median (95% credibility interval) | |
|---|---|---|---|
| Model | Variant | Small salmon | Large salmon |
| Annual | M&R Trapnet only | 42,900<br>(21,400 – 103,800) | 16,900<br>(7,300 – 57,400) |
| | M&R Seine only | 196,000<br>(74,000 – 500,000) | 128,000<br>(25,000 – 471,000) |
| | M&R Trapnet and seine | 50,400<br>(25,200 – 108,000) | 12,800<br>(6,500 – 25,600) |
| | | | |
| **Hierachical**<br>**(1998-2008)** | M&R Trapnet only | 30,000<br>(23,000 – 41,000) | 13,200<br>(9,300 – 18,900) |
| | **M&R Trapnet and seine** | **29,600**<br>(22,100 – 42,100) | **9,400**<br>(7,000 – 13,200) |
| With all data (up to 2007) | Using only trapnet catches | 24,000<br>(13,100 – 60,300) | 8,100<br>(3,400 – 42,800) |
| | Using only barrier counts | 47,100<br>(24,900 – 145,000) | 15,700<br>(9,000 – 40,600) |

***Table 12.*** *Estimates of returns of small salmon and large salmon to the Southwest and Northwest branches of the Miramichi River in 2008. Row in bold characters is the selected model and data combination for assessment.*

| **Southwest Miramichi** | | Median (95% credibility interval) | |
|---|---|---|---|
| Model | Variant | Small salmon | Large salmon |
| Annual | M&R Trapnet only | 38,200 (15,300 – 100,200) | 9,800 (2,200 – 39,200) |
| | M&R Seine only | 110,000 (33,600 – 389,000) | 59,000 (10,000 – 371,000) |
| | M&R Trapnet and seine | 28,700 (4,600 – 98,400) | 9,200 (1,200 – 21,700) |
| | | | |
| **Hierachical (1998-2008)** | M&R Trapnet only | 22,700 (16,100 – 34,000) | 11,200 (7,200 – 16,700) |
| | **M&R Trapnet and seine** | **20,500** (14,700 – 31,600) | **8,300** (6,000 – 12,200) |
| With all data (up to 2007) | Using only trapnet catches | 16,500 (6,900 – 50,000) | 6,200 (2,000 – 38,600) |
| | Using only barrier counts | 25,900 (11,700 – 63,500) | 12,000 (6,300 – 26,000) |

| **Northwest Miramichi** | | Median (95% credibility interval) | |
|---|---|---|---|
| Model | Variant | Small salmon | Large salmon |
| Annual | M&R Trapnet only | 4,400 (1,900 – 9,300) | 5,200 (300 – 34,500) |
| | M&R Seine only | 65,000 (16,000 – 256,000) | 35,300 (2,400 – 270,000) |
| | M&R Trapnet and seine | 18,300 (3,600 – 43,400) | 2,400 (200 – 15,600) |
| | | | |
| **Hierachical (1998-2008)** | M&R Trapnet only | 7,100 (5,000 – 11,100) | 1,900 (1,000 – 4,200) |
| | **M&R Trapnet and seine** | **8,300** (5,000 – 17,100) | 1,000 (500 – 2,300) |
| With all data (up to 2007) | Using only trapnet catches | 6,900 (3,200 – 17,000) | 1,400 (500 – 6,700) |
| | Using only barrier counts | 18,700 (5,300 – 109,000) | 3,100 (900 – 20,800) |

***Table 13.*** *Estimates of returns of small salmon and large salmon to the Miramichi River (upper table) and to the Southwest Miramichi (middle table) and 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 |

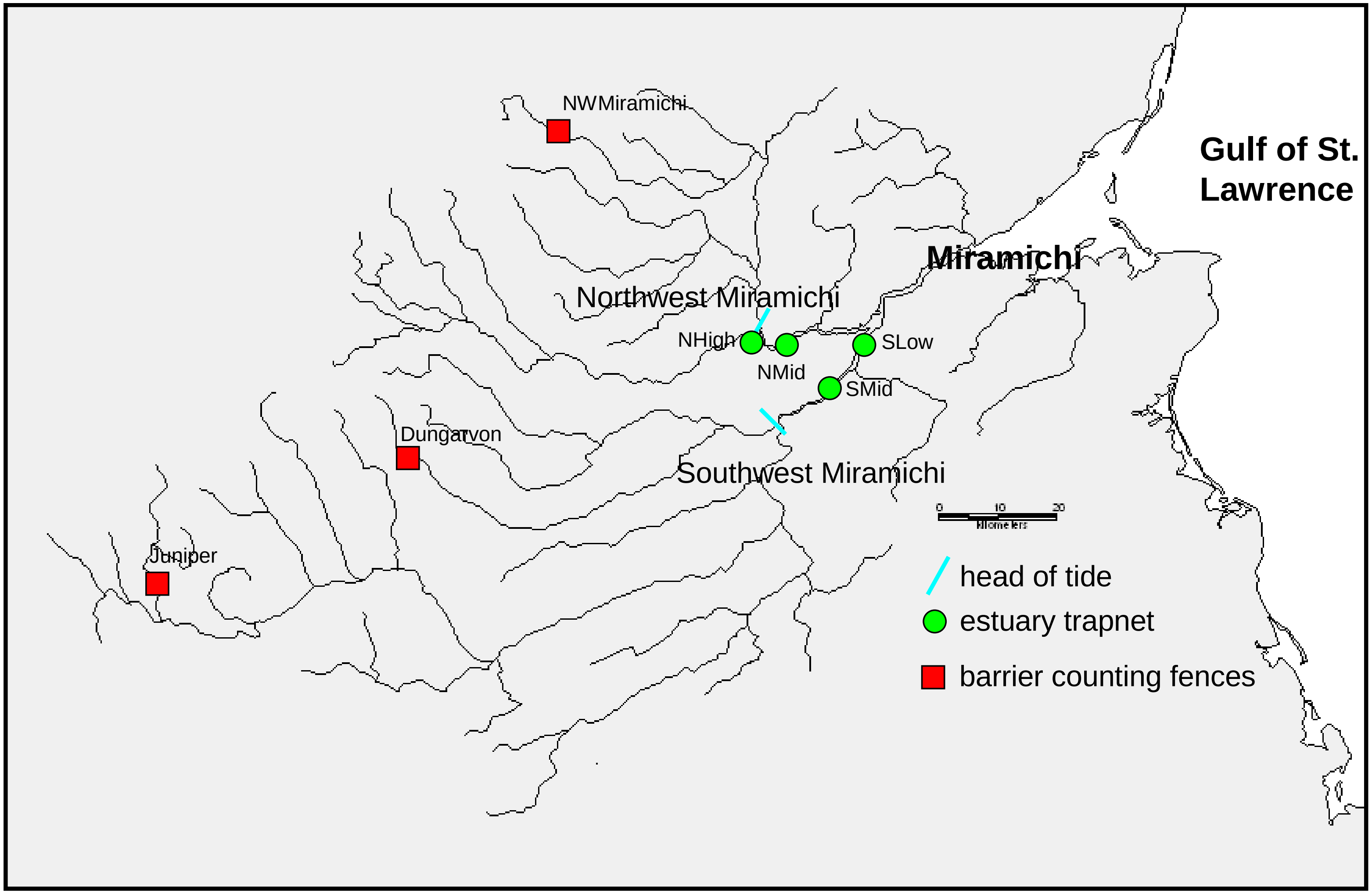



***Figure 1.*** *The Miramichi River watershed showing the location of estuary trapnets and headwater counting facilities.*

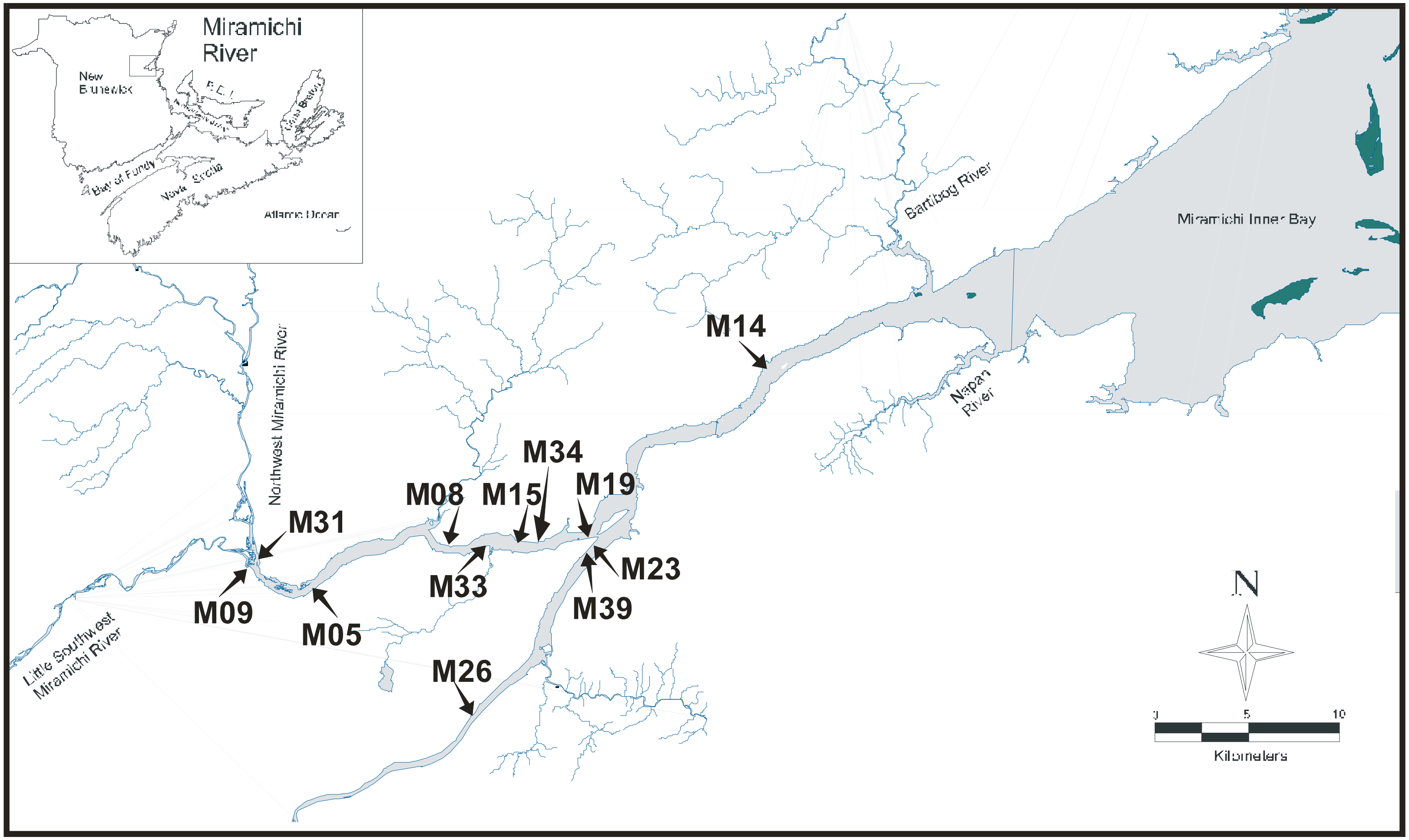



***Figure 2.*** *Location of tidal trapnets (facilities) in the Northwest and Southwest branches of the Miramichi River. See Appendix 1 for details of trapnet facilities.*

Large salmon	Small salmon

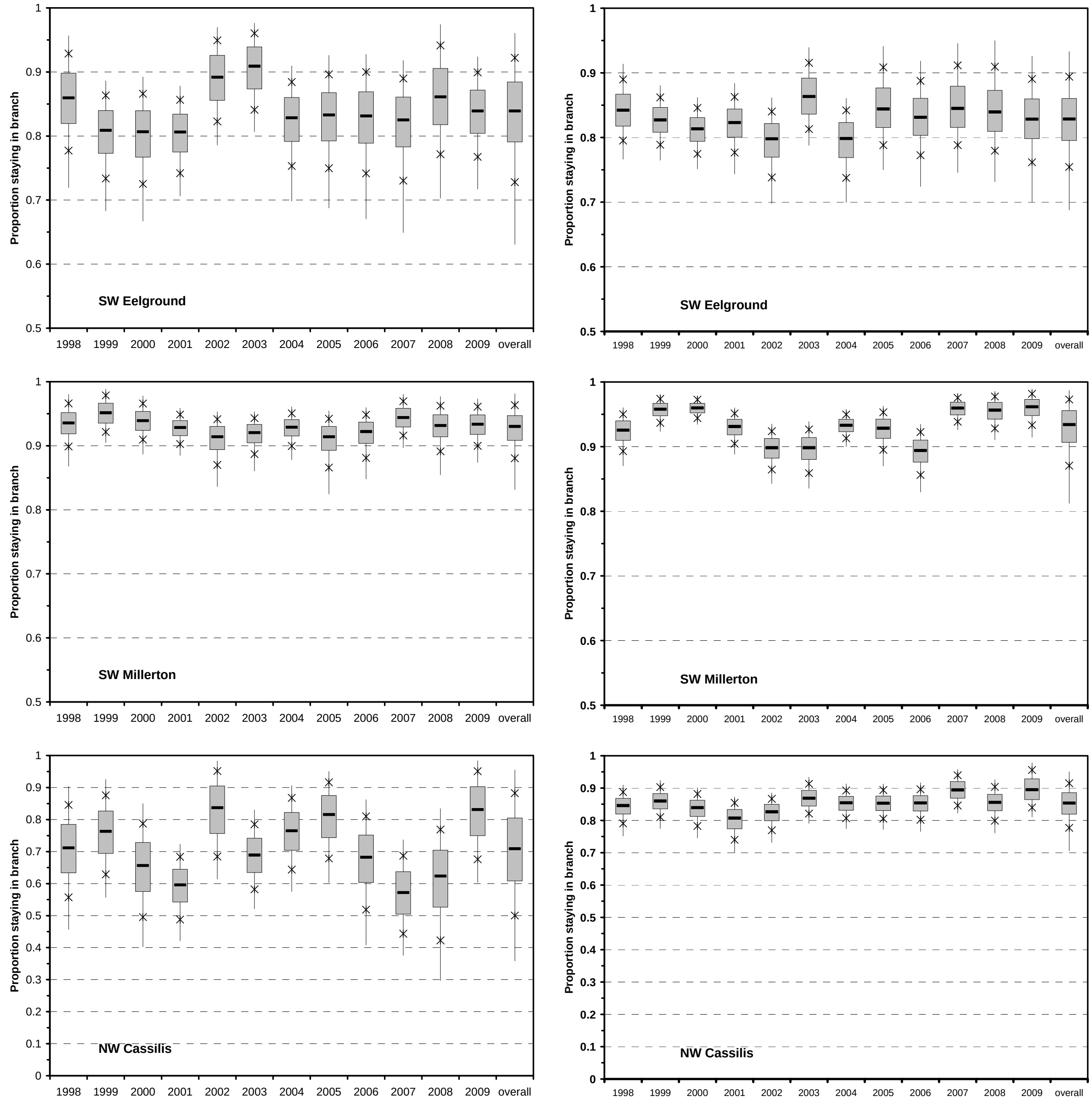



***Figure 3.*** *Proportion of tagged fish staying in the branch in which they were tagged for the three trapnet facilities in the Miramichi River. Large salmon (left panel) and small salmon (right panel). Box plots are interpreted as follows: vertical line is the 95% B.C.I. range, the stars are the 80% B.C.I. range, the box is the interquartile range and the horizontal line is the median.*

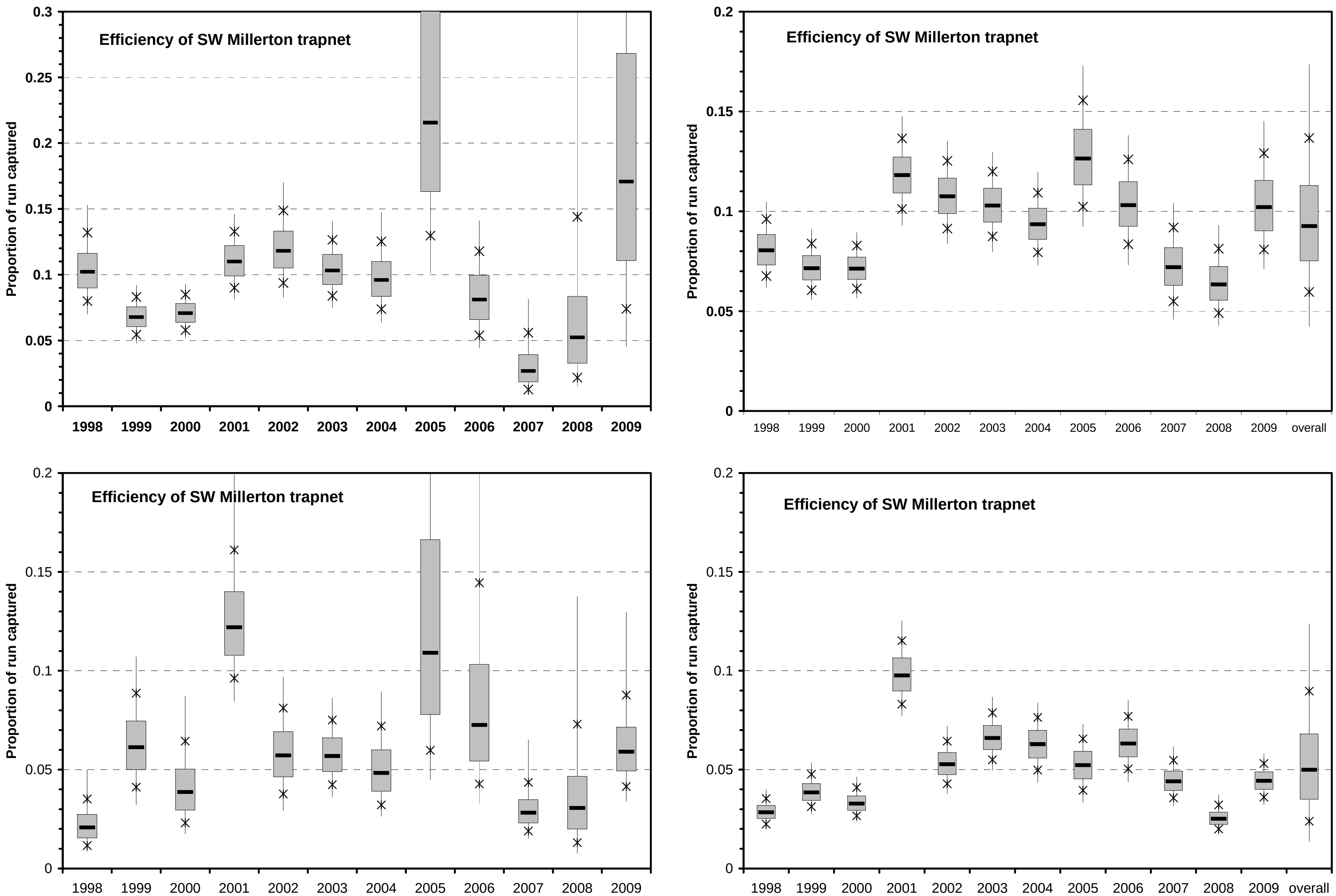



***Figure 4.*** *Estimated efficiencies of the Southwest Miramichi* <u>*Millerton trapnet*</u> *for small salmon (upper panel) and for large salmon (lower panel) based on an annual model (left panels) and the hierarchical model (right panels). Box plots are interpreted as in Figure 3.*

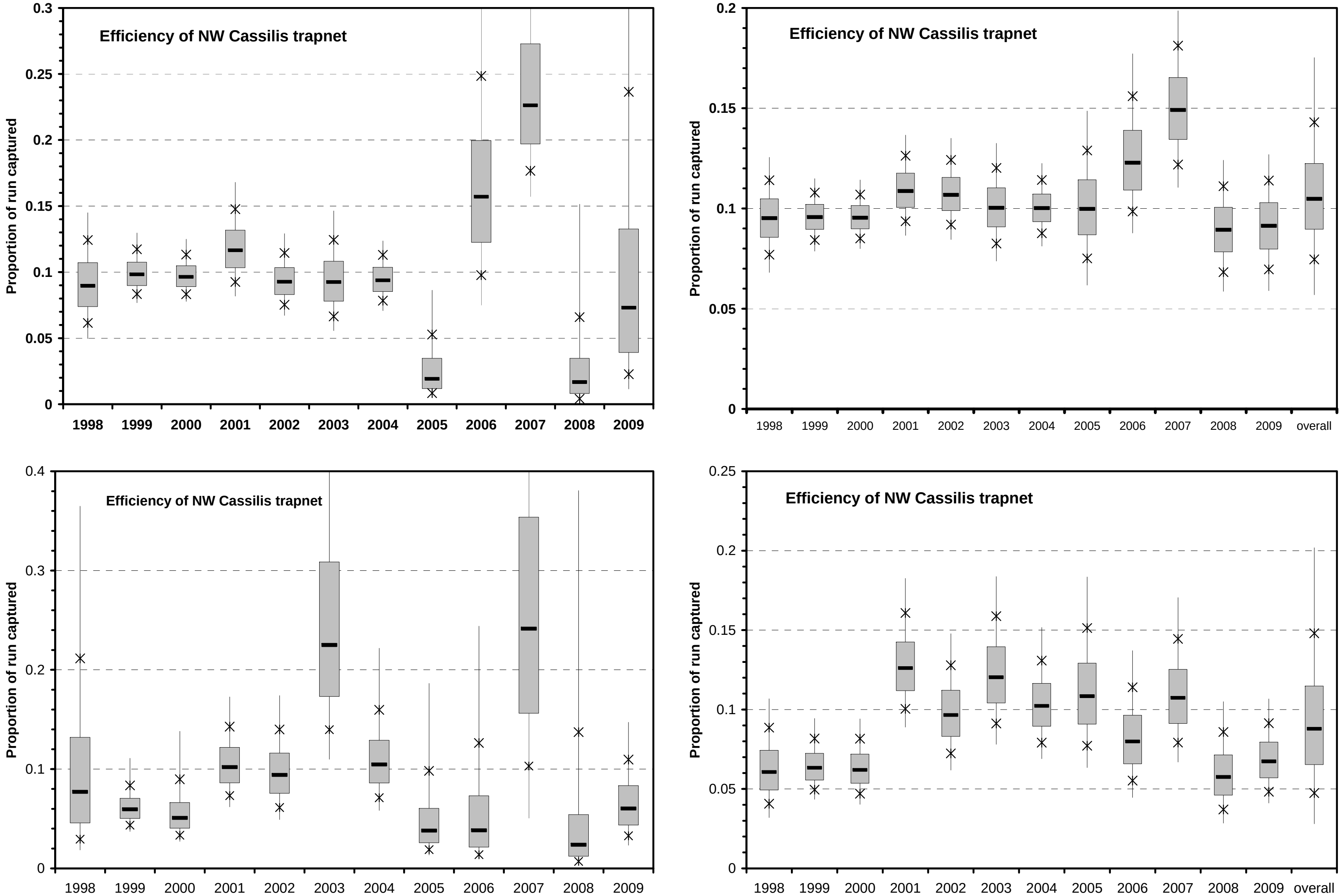



***Figure 5.*** *Estimated efficiencies of the Northwest Miramichi* <u>*Cassilis trapnet*</u> *for small salmon (upper panel) and for large salmon (lower panel) based on an annual model (left panels) and the hierarchical model (right panels). Box plots are interpreted as in Figure 3.*

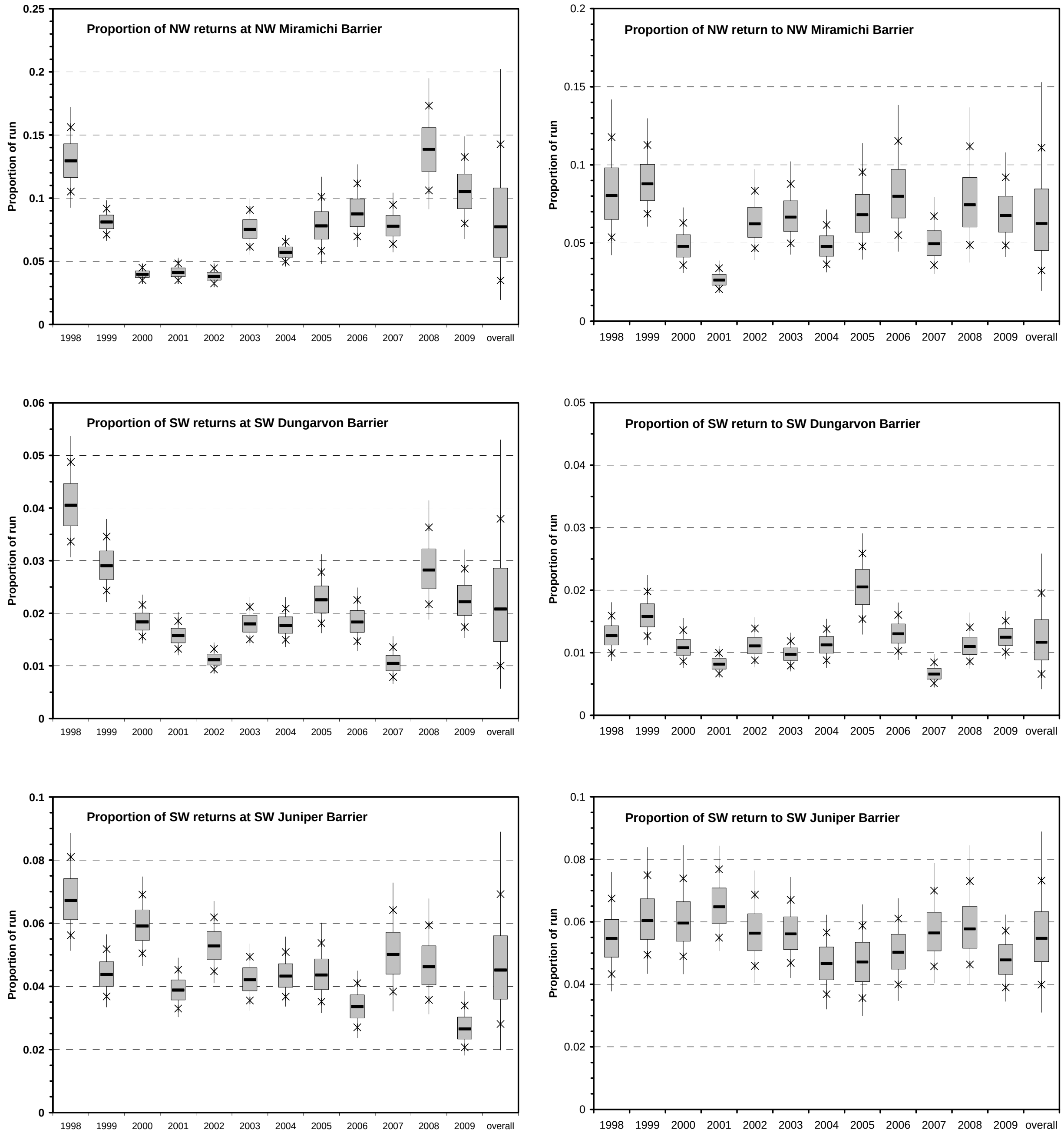



***Figure 6.*** *Estimated proportions of branch specific runs of small salmon (left panels) and large salmon (right panels) which are counted at the headwater protection barriers: Northwest Miramichi (upper), Southwest Miramichi Dungarvon Barrier (middle) and Southwest Miramichi Juniper Barrier (lower). Box plots are interpreted as in Figure 3.*

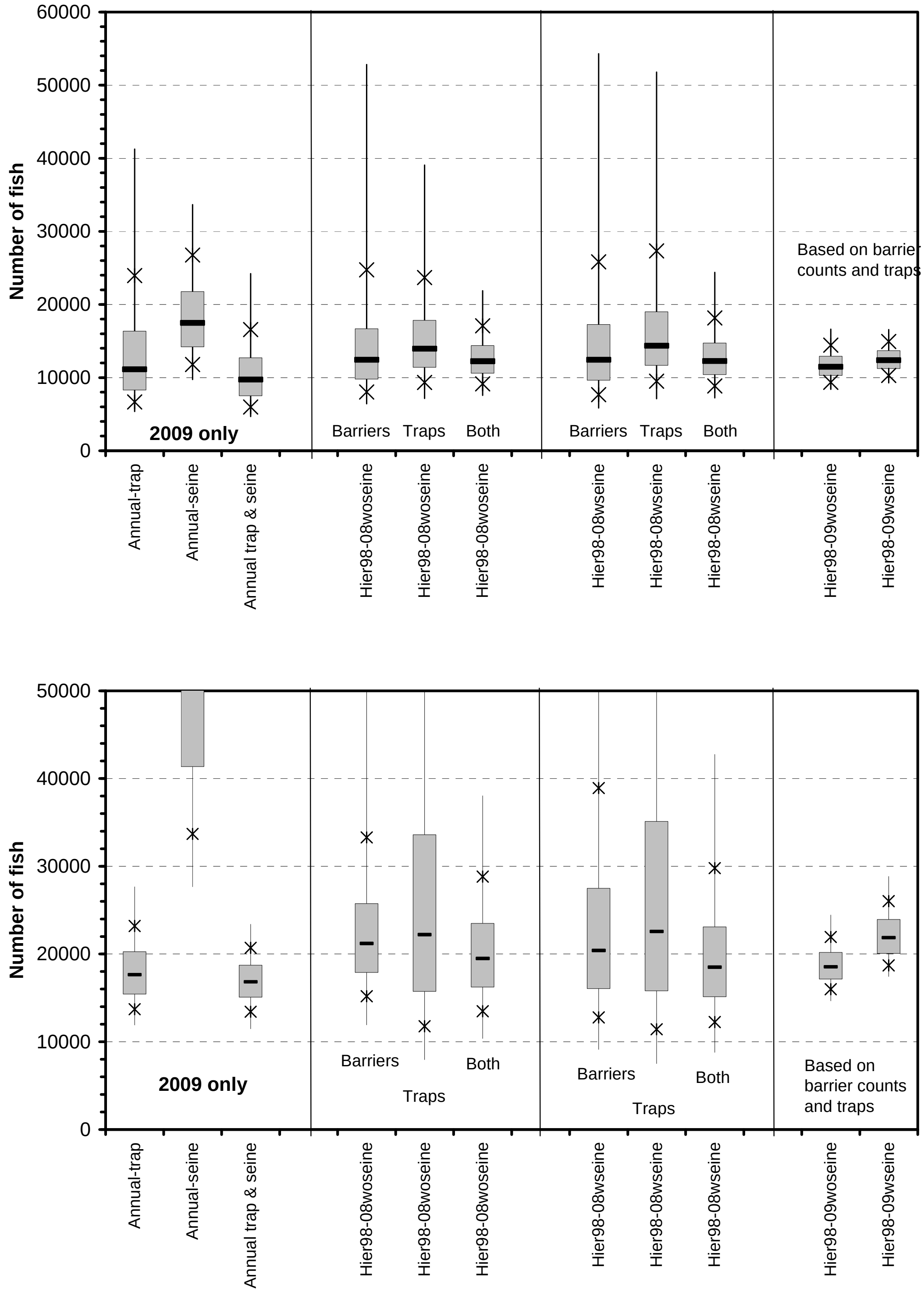



***Figure 7.*** *Estimated returns of small salmon (upper panel) and large salmon (lower panel) to the Miramichi River for 2009 for various combinations of the data and the models. Box plots are interpreted as in Figure 3.*

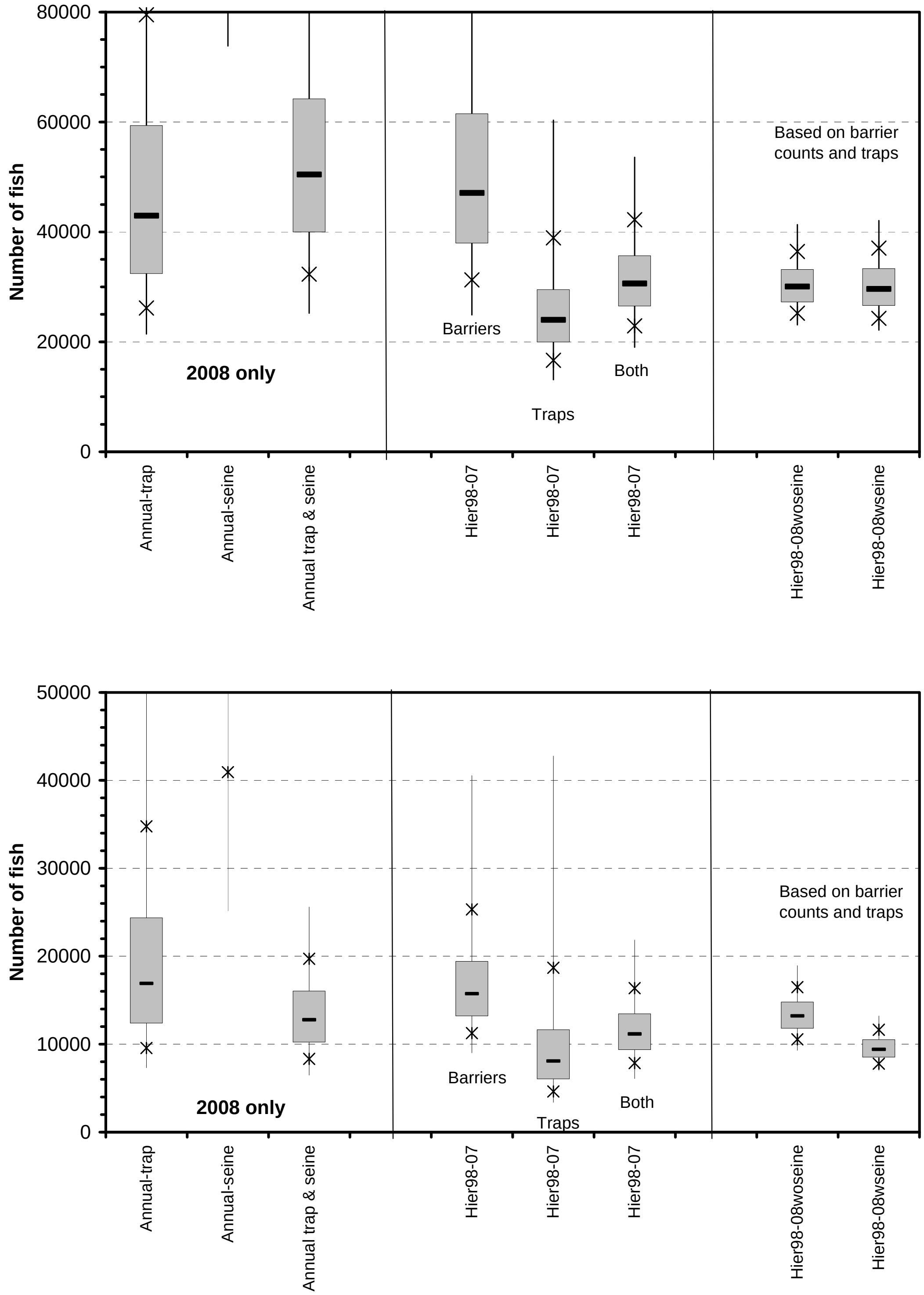



***Figure 8.*** *Estimated returns of small salmon (upper panel) and large salmon (lower panel) to the Miramichi River for 2008 for various combinations of the data and the models. Box plots are interpreted as in Figure 3.*

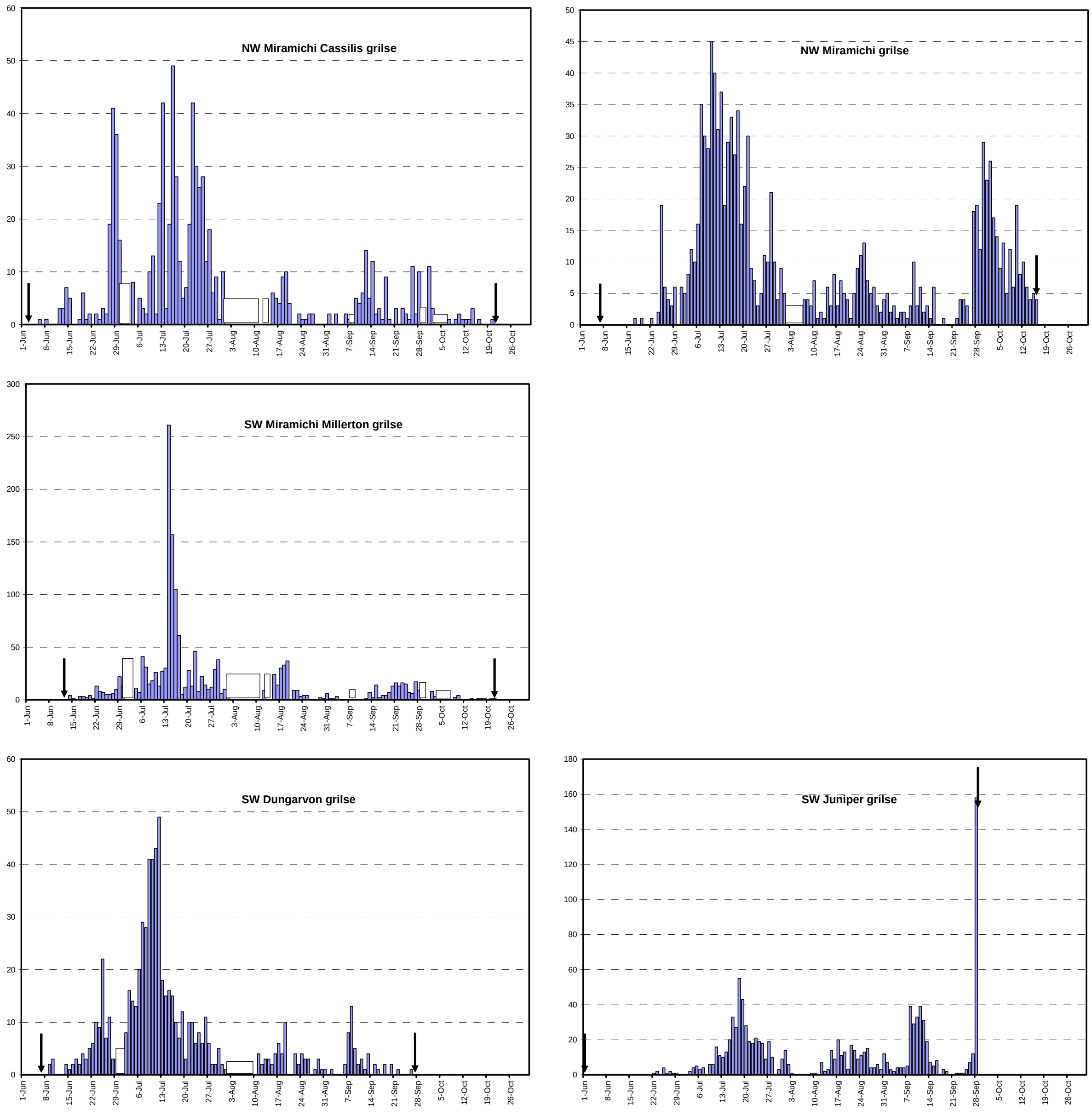



***Figure 9.*** *Daily counts of fish at the trapnets and the headwater barriers of the Miramichi in 2008. Arrows indicate the first and last dates of operation for the facilities. Washout periods are indicated using white rectangles.*

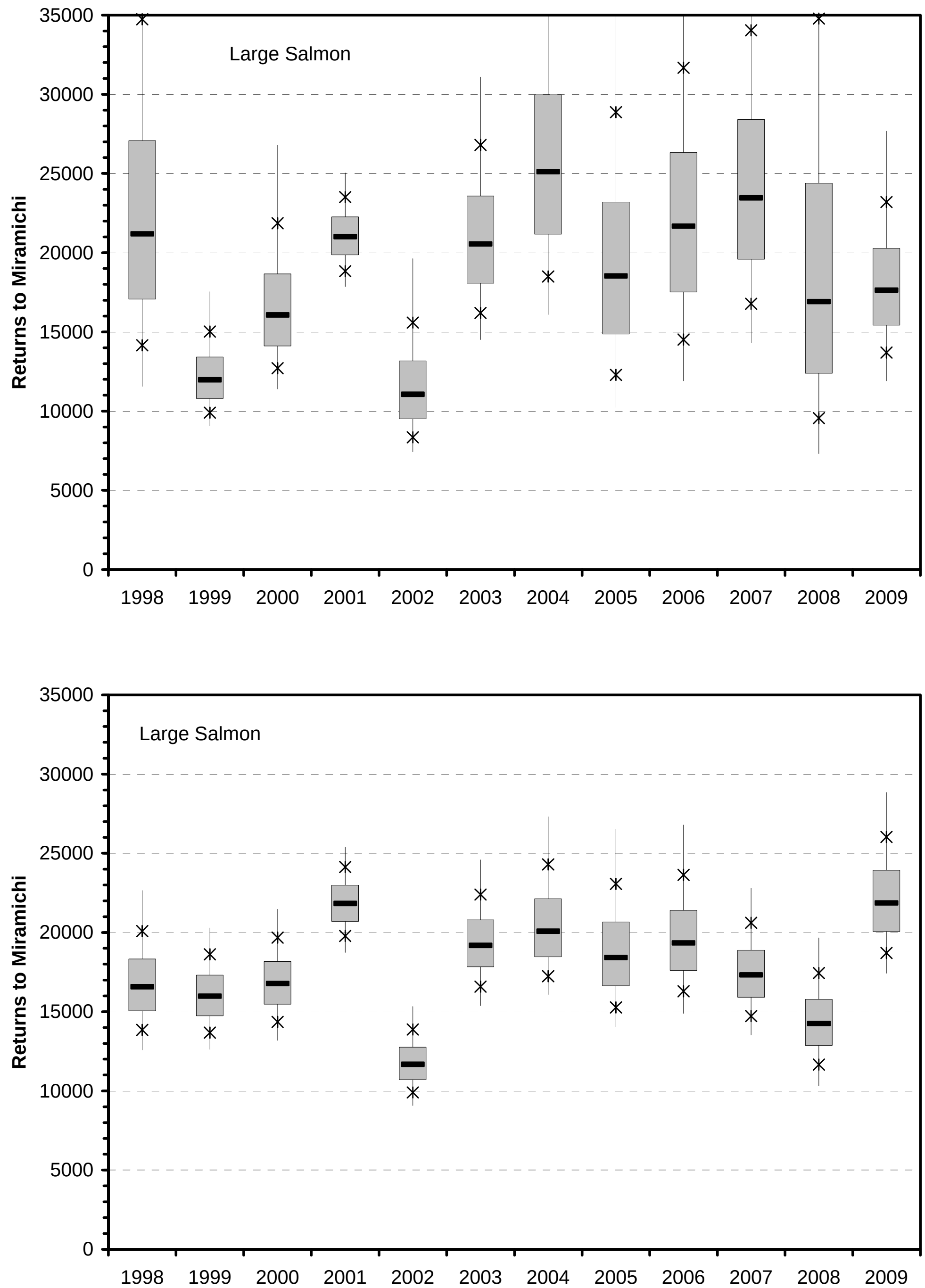



***Figure 10.*** *Estimates of returns of large salmon to the Miramichi River for 1998 to 2009 based on an annual model (upper panel) and a hierarchical model (lower panel). Box plots are interpreted as in Figure 3.*

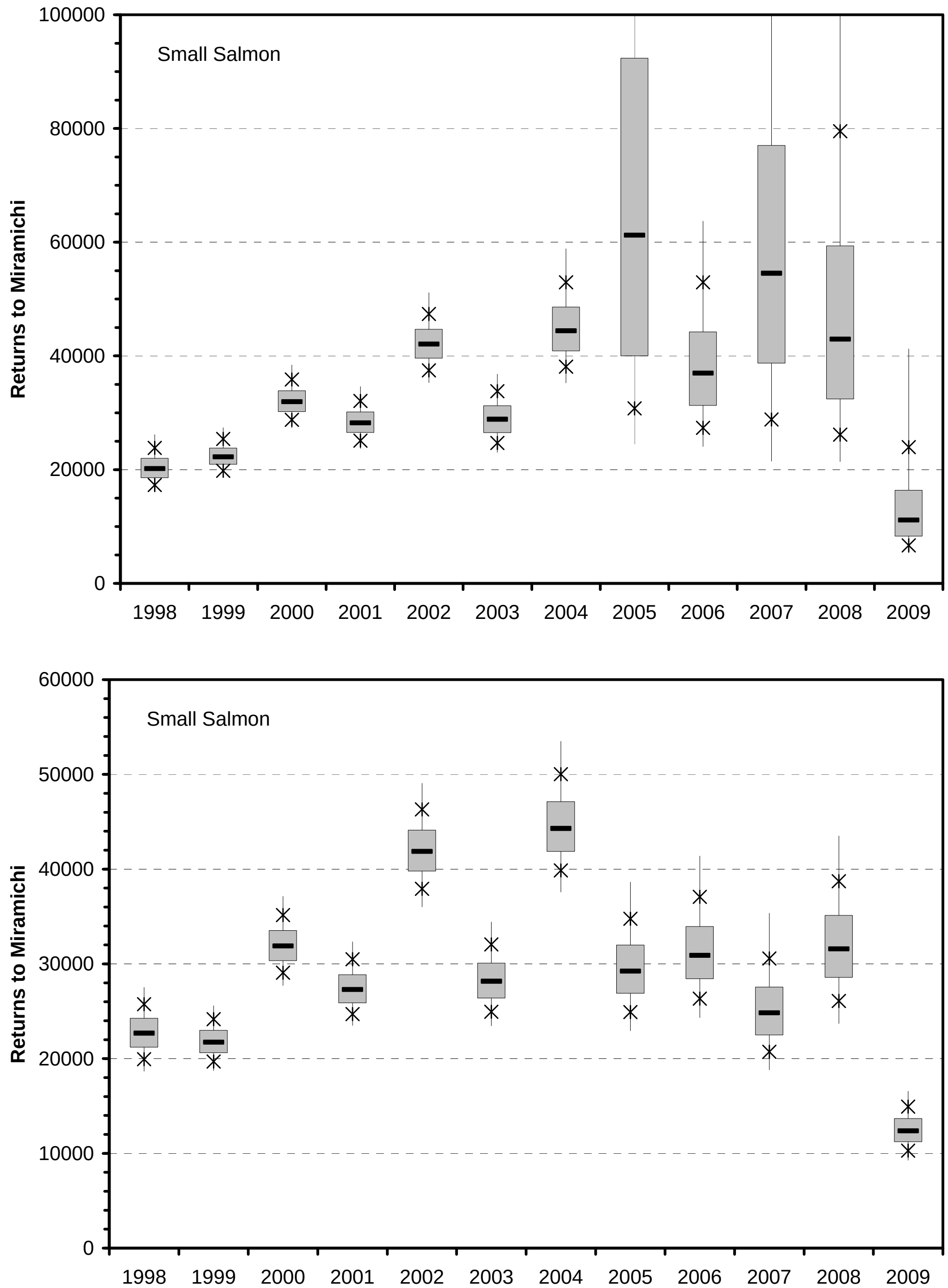



***Figure 11.*** *Estimates of returns of small salmon to the Miramichi River for 1998 to 2009 based on an annual model (upper panel) and a hierarchical model (lower panel). Box plots are interpreted as in Figure 3.*

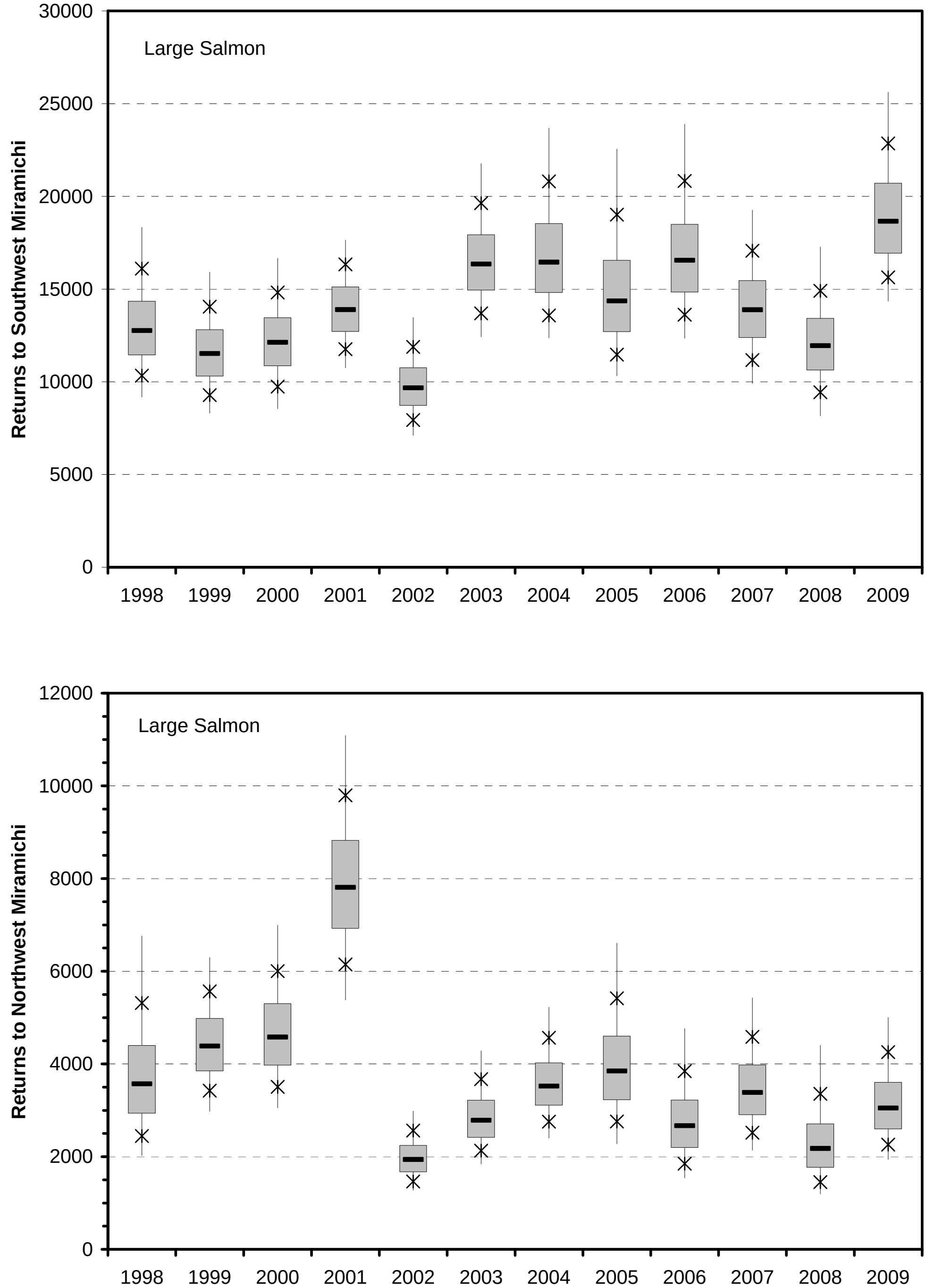



***Figure 12.*** *Estimates of returns of large salmon to the Southwest Miramichi River (upper panel) and to the Northwest Miramichi River (lower panel) for 1998 to 2009 based on the hierarchical model. Box plots are interpreted as in Figure 3.*

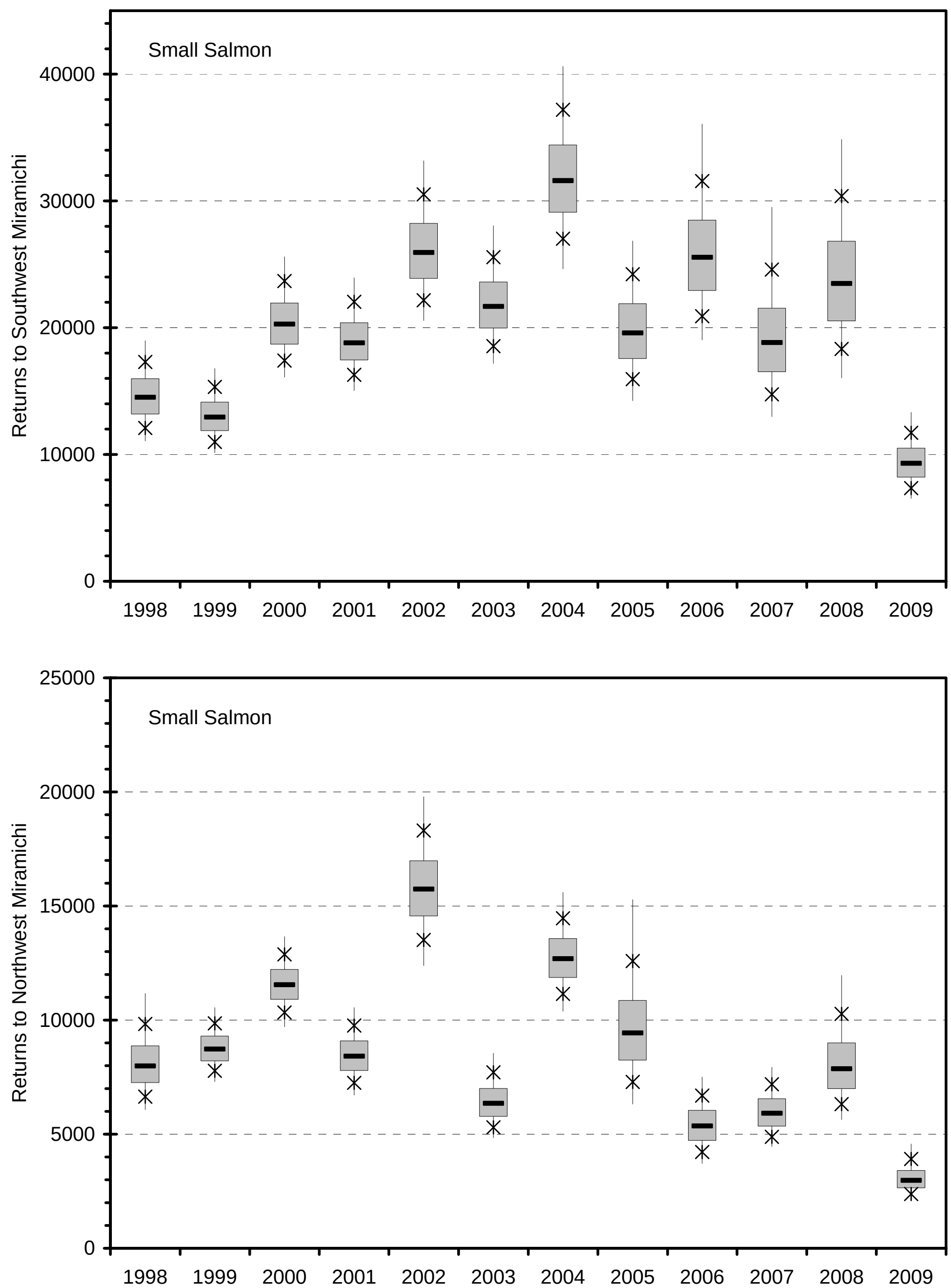



***Figure 13.*** *Estimates of returns of small salmon to the Southwest Miramichi River (upper panel) and to the Northwest Miramichi River (lower panel) for 1998 to 2009 the hierarchical model. Box plots are interpreted as in Figure 3.*

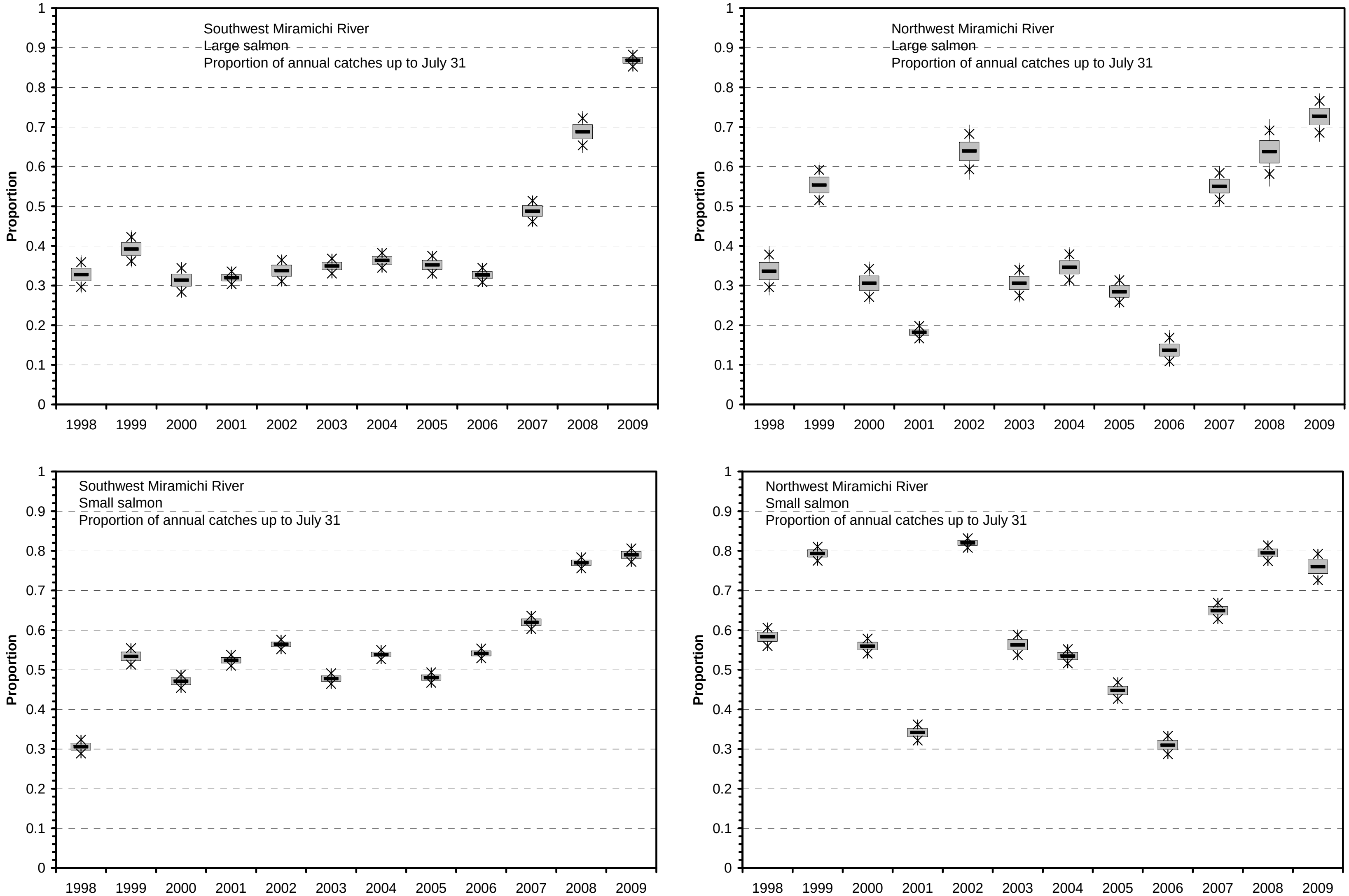



***Figure 14.*** *Proportion of trapnet catches of large salmon (upper panels) and small salmon (lower panel) which occurred before August 1 for the Southwest Millerton trapnet (left panels) and the Northwest Cassilis trapnet (right panels) for 1998 to 2009. Box plots are interpreted as in Figure 3.*

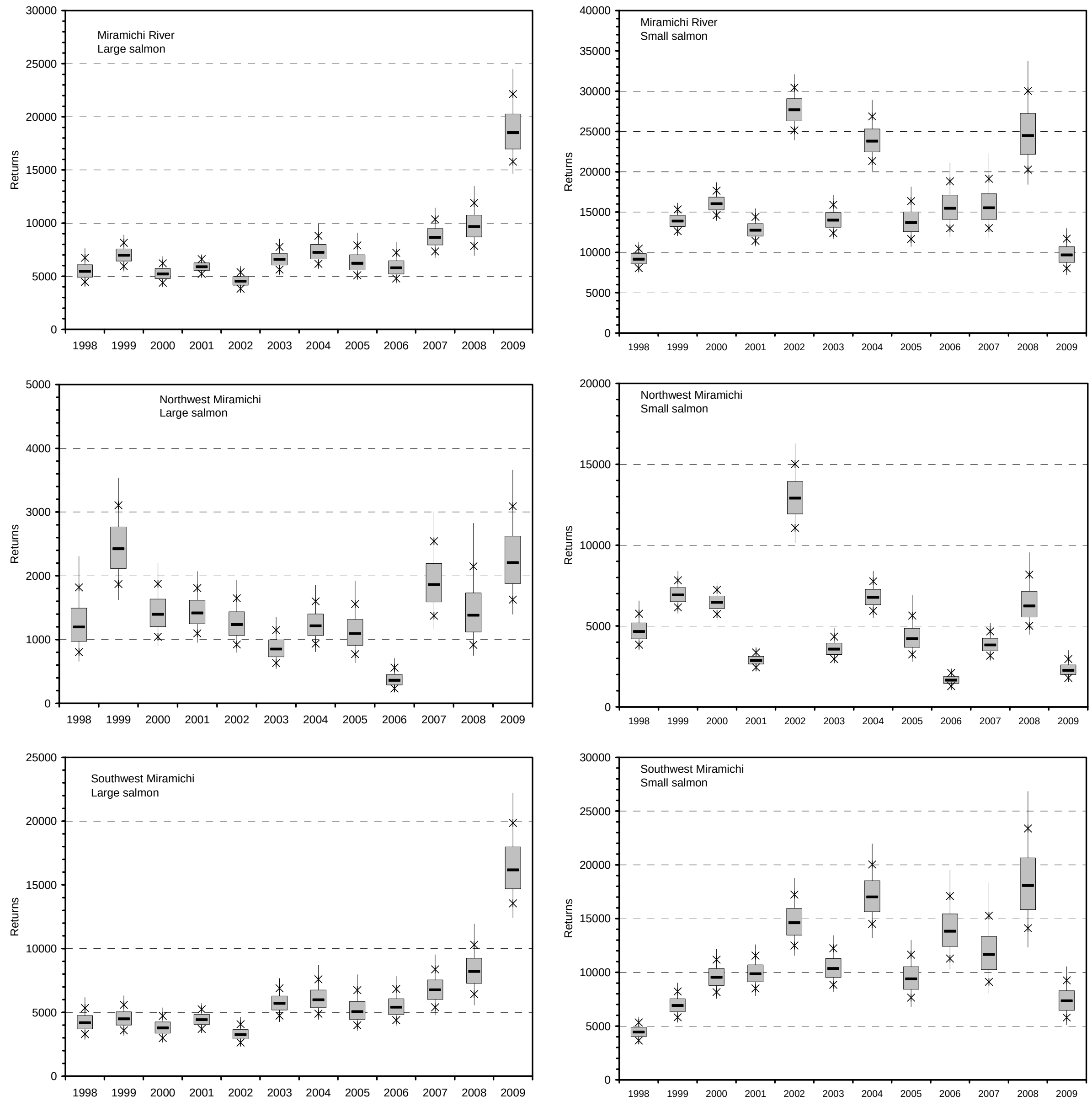



***Figure 15**. Estimated early run (up to and including July 31) returns of large salmon (left panels) and small salmon (right panels) to the Miramichi River (upper panels), to the Northwest Miramichi River (middle panels) and to the Southwest Miramichi River (lower panels) for 1998 to 2009. Box plots are interpreted as in Figure 3.*

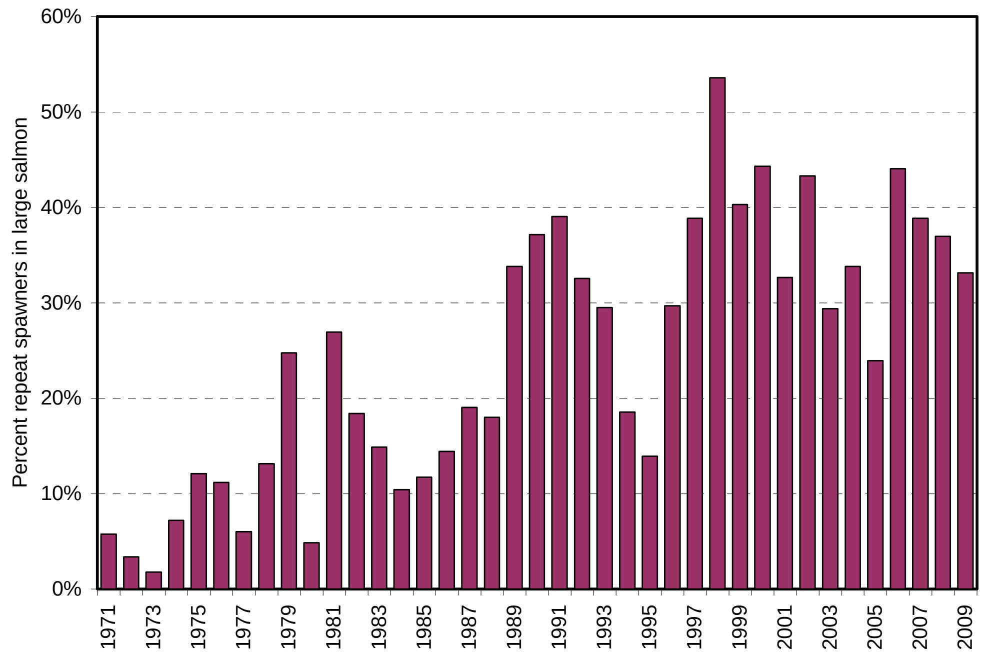



***Figure 16.*** *Repeat spawner composition (percent of number) in the large salmon category from the Miramichi River, 1970 to 2009.*

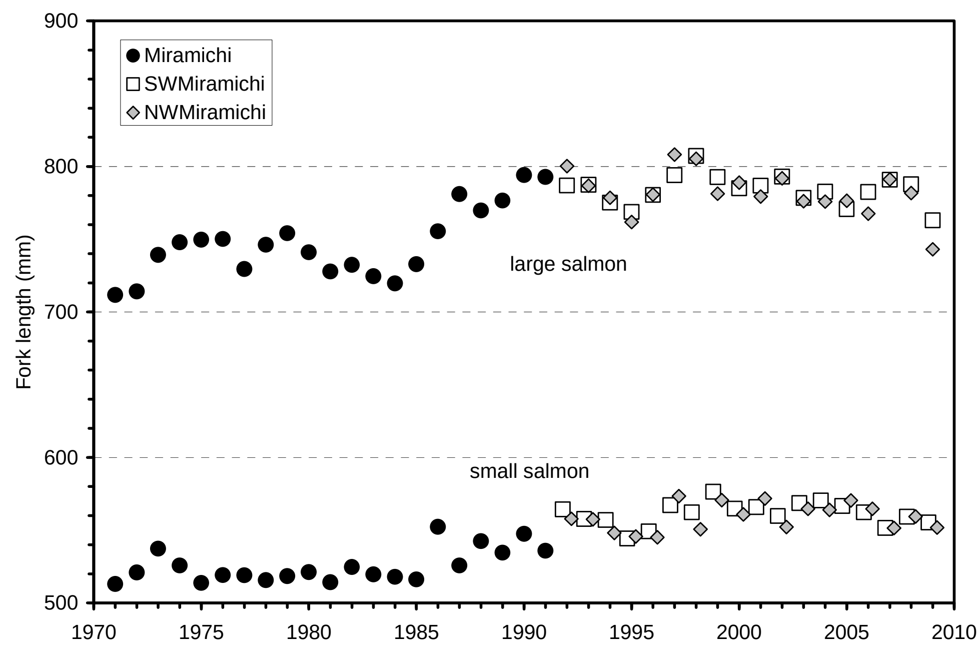



***Figure 17.*** *Mean fork length (mm) of small salmon and large salmon from the Miramichi River and the two main branches, 1970 to 2009.*

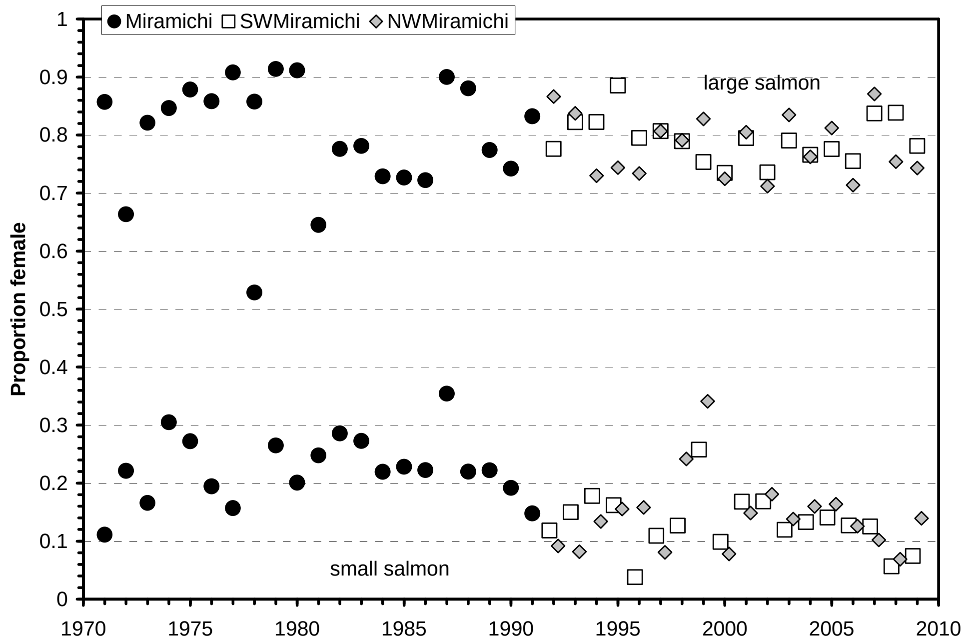



***Figure 18.*** *Proportion female by size group (small salmon, large salmon) from the Miramichi River and the two main branches, 1970 to 2009.*

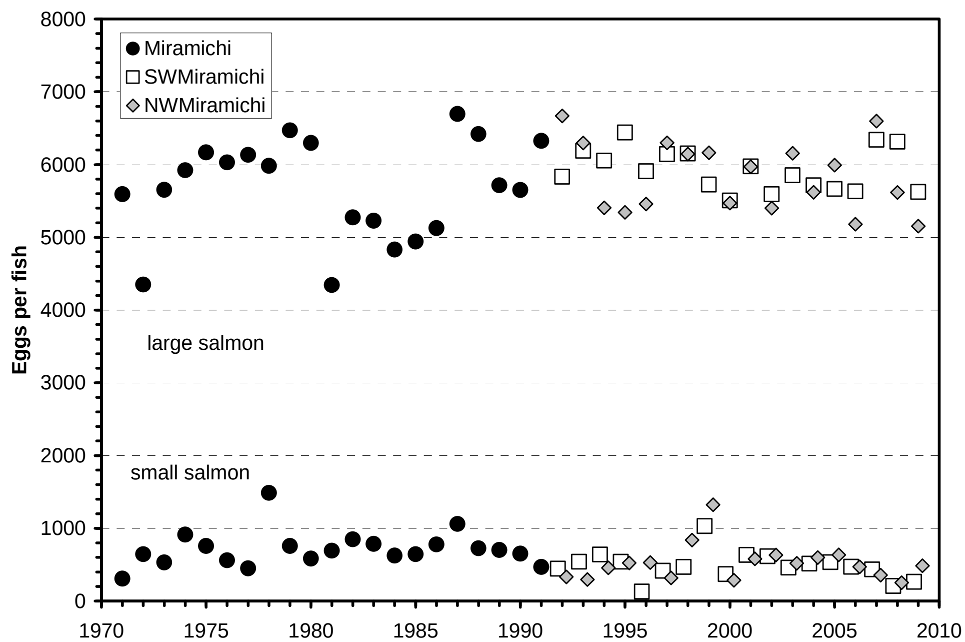



***Figure 19.*** *Eggs per fish by size group (small salmon, large salmon) from the Miramichi River and the two main branches, 1970 to 2009.*

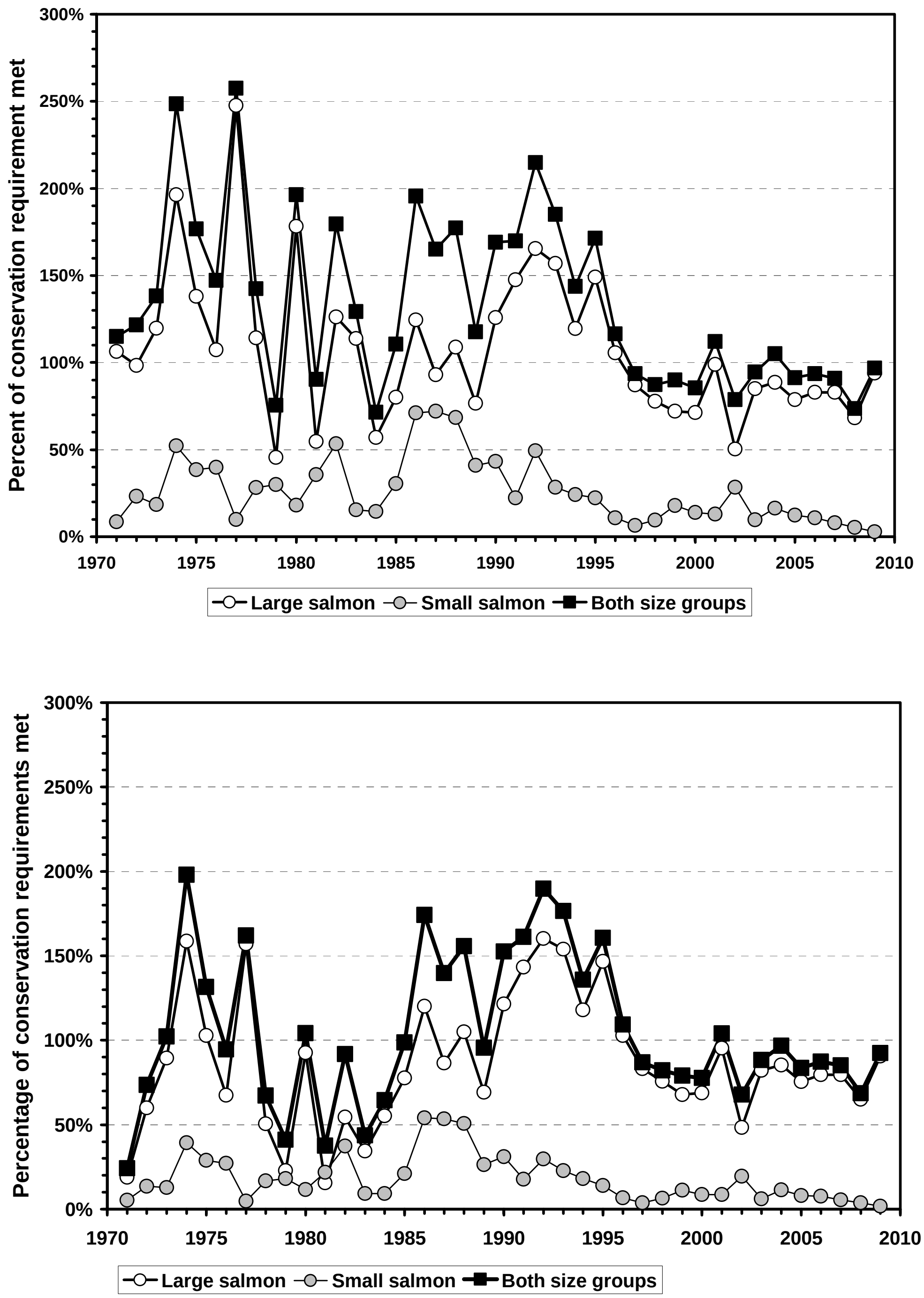



***Figure 20.*** *Percentage of conservation requirements (240 eggs per 100 m$^2$) met for the Miramichi River in the returns (upper panel) and in the escapement (lower panel) for 1970 to 2009.*

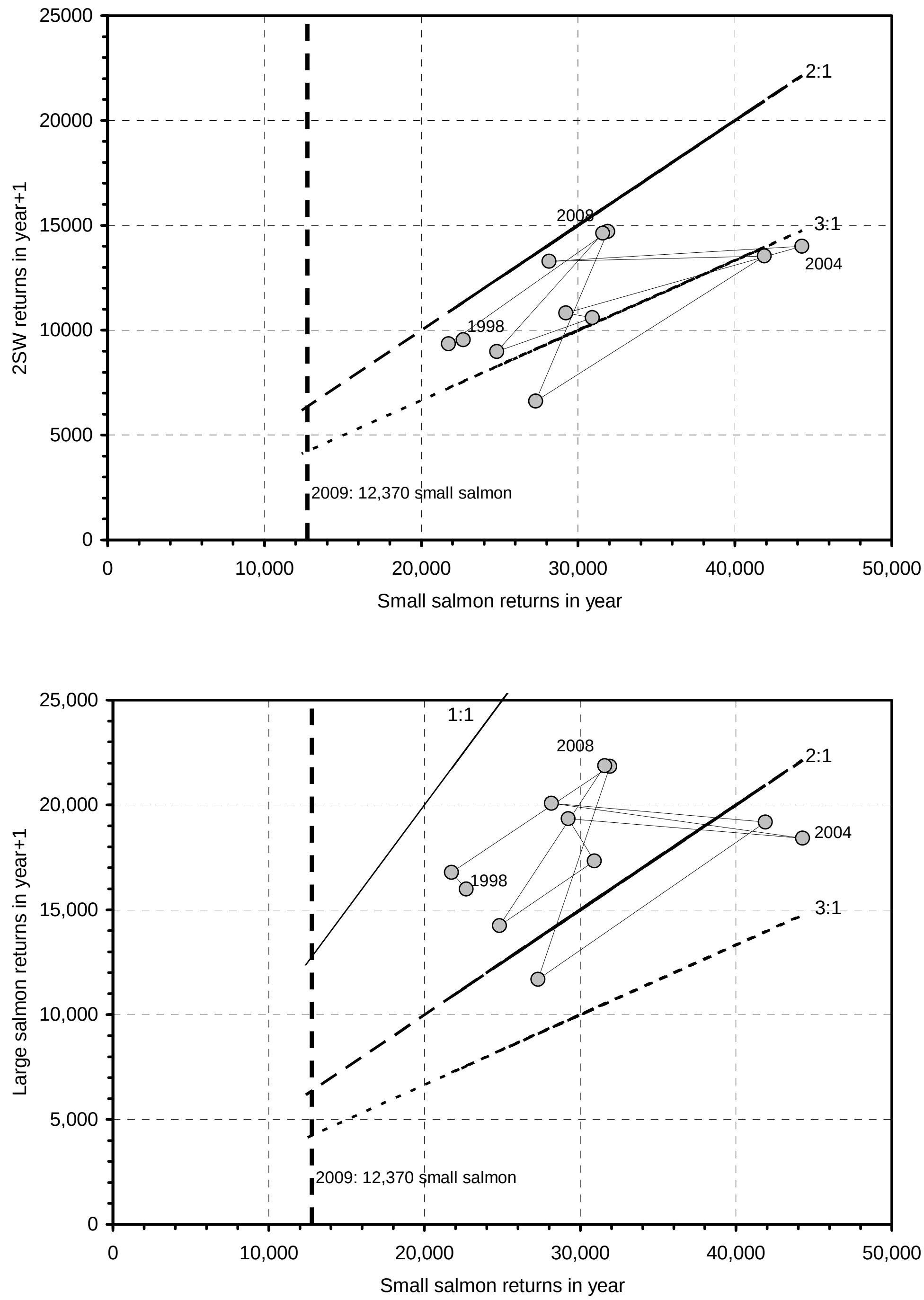



***Figure 21**. Association between small salmon returns in a given year and 2SW returns in the following year (upper panel) and large salmon returns in the following (lower panel) for the small salmon return years 1998 to 2008.*

## APPENDIX 1. DETAILS OF THE TRAPNET INSTALLATIONS IN THE MIRAMICHI RIVER (FROM FIGURE 2).

M23 (SWEE) – Southwest Miramichi Enclosure trapnet

This facility is a T-trap design and is located about 1.1 km above the confluence of the Northwest and Southwest Miramichi branches, less than 100 m downstream of the railway bridge, on the north bank of the Southwest Miramichi (47º 15.6’ N; 66º 19.5’ W). Since 1998, Eel Ground First Nation staff have been the lead operators. The trapnet and leader are made of 5 cm knotted twine (to more effectively fish gaspereau) with a back channel linking the upstream and downstream compartments. The leader extends to shore. The depth of water at the trap varies between 4 and 6 m with a tidal amplitude of less than 2 m. Within season, the nets are occasionally brailed for cleaning.

M39 (SWEFF) – Southwest Eel Ground Food Fishery trapnet

This facility, operated by Eel Ground First Nation, is situated on the north bank of the Southwest Miramichi, upstream of facility M23 and about 500 m upstream of the railway bridge crossing the Southwest Miramichi (46º 57.2’ N; 65º 35.7’ W). The trapnet is of similar design to the Southwest Miramichi Enclosure trapnet (facility M23).

M26 (SWM) – Southwest Miramichi Millerton trapnet

The Southwest Miramichi Millerton index trapnet is situated about 11 km upstream of the confluence of the Northwest and Southwest Miramichi, on the north bank of the Southwest Miramichi (46º 52.9’ N; 65º 39.6’ W). It was first installed in 1994 and the lead operator of the facility is Science Branch of the Department of Fisheries and Oceans (DFO).The entire trap is constructed of 5.08 cm knotless nylon mesh and the leader is constructed of 15.2 cm polypropylene knotted mesh. A back channel to improve the retention of salmon in the trapnet was installed after the 2000 season.

M05 (CU) – Northwest Miramichi at Cassilis trapnet

The Northwest Miramichi adult trapnet at Cassilis is located 16.3 km above the confluence of the Northwest Miramichi, on the south side of the river (46º 56.2’ N; 65º 46.7’ W). The lead operator of this facility has been DFO. It is a standard commercial T-trapnet of identical design to the Southwest Miramichi Millerton trapnet (M26). There is a back channel linking the downstream and upstream traps. The entire trap is constructed of 5.08 cm knotless nylon mesh and the leader is constructed of 15.2 cm polypropylene knotted mesh but mesh sizes has been reduced in recent years to 10 cm polypropylene knotted mesh to reduce the meshing of large salmon. The location was originally selected for the installation of a smolt sampling and marking trapnet. The same frame is used for the smolt trapnet and the adult trapnet. During 1998 to 2006, the adult trapnet is installed after the completion of the smolt monitoring program, generally no later than June 15. The smolt trapnet has the leader on the downstream side of the door whereas the leader is on the upstream side of the door for the adult trapnet. Smolt trapping operations ended in 2006. This trapnet has become the primary index and tagging trapnet for the Northwest Miramichi.

M09, M31 (RBNW, RBLSW) – Red Bank First Nation trapnets

The Little Southwest Miramichi (heading primarily in a westerly direction) branches off the Northwest Miramichi (heading north) at the community of Red Bank First Nation and Sunny Corner (New Brunswick). The food fishery trapnets at Red Bank First Nation are located within the general area of the confluence, on opposite banks (46º 56.9' N; 65º 49.3' W). They are operated by Red Bank First Nation with opportunistic assistance in the installation and operation by DFO. The Northwest Miramichi Red Bank trapnet (M31) has been consistently located on the east bank of the Northwest Miramichi above the bridge linking New Brunswick provincial highway routes 420 and 425. Various locations upstream of the bridge (within 1 km of the bridge) were explored with the location fixed since 1998. The LSW Miramichi Red Bank trapnet (M09) was initially installed less than 100 m above the bridge on the west bank of the river but was moved and is presently situated less than 100 m below the bridge on the left bank. Trapnet configurations have also changed. Between 1992 and 1998, V-type design trapnets were used. The box portion of the trap was constructed of 5.7 cm knotless nylon mesh. Downstream-angled leaders extended from the downstream facing door of the trap. The trapnet and leader frames were constructed of metal rebar with wood crosspieces and brail. The trap itself was entirely constructed of 5.5 cm knotless nylon and leaders were of varying dimensions, generally greater than 5 cm but less than 15 cm. Since 1999, a conventional "T-trap" design, identical to the trap used at Cassilis in the Northwest Miramichi (Facility M05), has been used. The traps have a back channel and are constructed of 5.08 cm knotless nylon and leaders are 15 cm knotted polypropylene. The river is entirely fresh water at that location but tidal fluctuations of up to 1.5 m do occur. The traps were installed in depths varying between 2 and 3 m (at low tide). These traps are the primary recapture facilities for the Northwest Miramichi.

## APPENDIX 2. DATA ENTRY CODES.

The salmon data were processed to develop the tagging, recapture and catch matrices. Four summary categories were required.

1) fish CAPTURED for the first time (equivalent to unmarked): This includes any fish that is seen for the first time at the specific trapnet. Codes in this category include: R, RS, RI, RL, RT, RPU, RPL, RTP, M, MF, MM, MFRP, MZ, MB. Depending upon the facility, this could also include codes RRPU, RRPL, RRPUT, RRPLT.
2) fish TAGGED: This category includes the fish which are marked with Carlin tags and released back to the river. It also includes the first observation at one of the trapnets of a salmon tagged in a previous year in the Miramichi returning to the river for a second or subsequent spawning. Codes in this category include RT, RTP, RRT, RRPUT, RRPLT.
3) fish RECAPTURED: This includes fish which carry a Carlin tag. Codes in this category include RR, MR, MFR, MMR. In the case of a salmon tagged in a previous year and seen for the second time in the year of interest, the recapture would have been coded RR. Only fish with recorded tag numbers are included in this category.
    - Multiple recaptures in the same year at the tagging or other facilities are a frequent event. Recaptured fish are assigned a secondary designation based on the number of times the tagged fish is seen in the year of interest. Specifically, a tagged fish seen for the first time at a given facility is considered to be a valid recapture (First). A tagged fish seen for the second time at the same facility is not considered to be a valid recapture (Previous).
4) Some fish are not assigned to any category (OTHER) and are excluded from the summations. For example, a fish which has a tagging scar has been seen before and therefore is excluded from the CAPTURED category. It cannot be assigned to a specific facility on first capture and it is therefore also excluded from the RECAPTURED category. Fish with tagging scars are infrequent (see for example Appendix 2 in Chaput et al. 2001 and Appendix 3 in this report). Caudal fin-punched recaptured fish can be categorized as to the marking facility but not the date. They are excluded from the CAPTURE and RECAPTURE categories at the marking facility but are included in the CAPTURE category at other facilities. Codes in this category include RRL and could include RRPU, RRPL, RRPUT, RRPLT.

| Heading | Definition |
|---|---|
| River | Numerical number to identify river |
| Area | Facility code |
| Time | Start time of trapnet fishing operation |
| DD | Day |
| MM | Month |
| YY | Year |
| Species | Code for a particular species |
| Tag # | Tag number (Carlin or other tag) |
| Size | S = large salmon (>= 63 cm), G = small salmon (< 63 cm) |
| FL | Fork Length (mm) |
| Sex | M = male, F = female, U = unknown |
| Or | W = wild, A = Adipose clip, U = unknown |
| SS | Scale sampled (Y or N) |
| FS | Fish status (see below) |
| Freq | Frequency (number of fish for this row of data) |
| LocTagged | Location Tagged - Where fish was originally tagged. |
| TgDD | Original tag day |
| TgMM | Original tag month |
| TgYY | Original tag year |
| COMMENT | |

| Fish Status (FS) | Status definition |
|---|---|
| R | Released, unsampled |
| RS | Released, sampled |
| RI | Released, injury |
| RL | Released, lost (fish escaped before sampling) |
| RT | Released, tagged (usually also sampled) |
| RPU | Released, punched, Upper Caudal fin |
| RPL | Released, punched, Lower Caudal fin |
| RTP | Released, tagged previous year (1st time caught this year) |
| RR | Released, recapture |
| RRT | Released, recapture, tagged again due to tag loss (either in net or tagging scar) |
| RRL | Released, recapture, lost (no tag number recorded before release) |
| RRPU | Released, recapture, punched upper caudal |
| RRPL | Released, recapture, punched lower caudal |
| RRPUT | Released, recapture, punched upper caudal, tagged. |
| RRPLT | Released, recapture, punched lower caudal, tagged |
| | |
| M | Mortality - in trapnet |
| MF | Mortality, food |
| MM | Mortality – meshed on leader |
| MR | Mortality, recapture from trap |
| MFR | Mortality, food, recapture |
| MFRP | Mortality, food, recapture of fish tagged in previous year(s) |
| MMR | Mortality, recapture, meshed on leader |
| MZ | Research removal |
| MB | Broodstock removal |

# APPENDIX 3. THE CATCHES AND FATES OF SMALL SALMON CAPTURED AND TAGGED FROM THE TIDAL TRAPNETS OF THE SOUTHWEST MIRAMICHI RIVER IN 2009.

| Southwest Miramichi - Small Salmon | | Southwest Food/Science Lower | | | | Southwest Food/Science Upper | | | | Millerton Trapnet - Southwest Miramichi | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | July | August | Sept. | Total | July | August | Sept. | Total | June | July | August | Sept. | Oct. 1-15 | >Oct. 15 | Total |
| | **Tags Placed** | . | 6 | 4 | **10** | 1 | 15 | 12 | **28** | 27 | 455 | 78 | 103 | 17 | 1 | **681** |
| **Mortalities recovered upriver (in freshwater)** | | | | | | | | | | | | | | | | |
| Northwest | | . | . | . | **0** | . | . | . | **0** | . | . | . | . | . | . | **0** |
| Southwest | | . | . | . | **0** | . | . | . | **0** | . | . | . | . | . | . | **0** |
| **Unmarked fish recovered at facility above** | | 172 | 30 | 4 | **206** | 470 | 87 | 12 | **569** | 28 | 721 | 78 | 104 | 17 | 1 | **949** |
| **Mortalities at facility above** | | . | 1 | . | **1** | . | . | . | **0** | . | 2 | . | . | . | . | **2** |
| **Fish with tagging scars recovered at facility above** | | . | . | . | **0** | . | . | . | **0** | . | . | . | 2 | . | . | **2** |
| **Recaptured fish lost before reading tag number at facility above** | | . | . | . | **0** | . | . | . | **0** | . | . | . | . | . | . | **0** |
| **Recoveries of tags placed at facility above** | | | | | | | | | | | | | | | | |
| **Northwest Cassilis Trapnet** | | 0 | 0 | 1 | **1** | 0 | 0 | 0 | **0** | 0 | 1 | 0 | 0 | 0 | 0 | **1** |
| | June | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | July | . | . | . | 0 | . | . | . | 0 | . | 1 | . | . | . | . | 1 |
| | August | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | Sept. | . | . | 1 | 1 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | Oct. 1-15 | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | > Oct. 15 | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| **Red Bank Trapnets** | | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 1 | 0 | 0 | 0 | 0 | **1** |
| | June | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | July | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | August | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | Sept. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | Oct. 1-15 | . | . | . | 0 | . | . | . | 0 | . | 1 | . | . | . | . | 1 |
| **Southwest Food/Science Lower** | | 0 | 0 | 0 | **0** | 0 | 1 | 0 | **1** | 0 | 2 | 2 | 0 | 0 | 0 | **4** |
| | June | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | July | . | . | . | 0 | . | . | . | 0 | . | 1 | . | . | . | . | 1 |
| | August | . | . | . | 0 | . | 1 | . | 1 | . | 1 | 2 | . | . | . | 3 |
| | Sept. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | Oct. 1-15 | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| **Southwest Food/Science Upper** | | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 1 | 6 | 1 | 0 | 0 | 0 | **8** |
| | June | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | July | . | . | . | 0 | . | . | . | 0 | 1 | 5 | . | . | . | . | 6 |
| | August | . | . | . | 0 | . | . | . | 0 | . | 1 | 1 | . | . | . | 2 |
| | Sept. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | Oct. 1-15 | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| **Southwest Millerton Trapnet** | | 0 | 0 | 0 | **0** | 0 | 4 | 0 | **4** | 1 | 25 | 3 | 11 | 0 | 0 | **40** |
| | May | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | June | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | July | . | . | . | 0 | . | . | . | 0 | 1 | 22 | . | . | . | . | 23 |
| | August | . | . | . | 0 | . | 2 | . | 2 | . | 1 | 2 | . | . | . | 3 |
| | Sept. | . | . | . | 0 | . | 2 | . | 2 | . | 2 | . | 9 | . | . | 11 |
| | Oct. 1-15 | . | . | . | 0 | . | . | . | 0 | . | . | 1 | 2 | . | . | 3 |
| | > Oct. 15 | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| **Barrier Fences** | | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 6 | 0 | 0 | 0 | 0 | **6** |
| NW Miramichi | June-Aug. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | Sept.-Oct. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| Catamaran | June-Aug. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | Sept.-Nov. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| Dungarvon | June-Aug. | . | . | . | 0 | . | . | . | 0 | . | 4 | . | . | . | . | 4 |
| | Sept.-Oct. | . | . | . | 0 | . | . | . | 0 | . | 2 | . | . | . | . | 2 |
| Clearwater Brook | June-Aug. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | Sept.-Nov. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| Burnthill Brook | June-Aug. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | Sept.-Nov. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| SW Miramichi | June-Aug. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | Sept.-Oct. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| **Broodstock Seining** | | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 1 | 9 | 0 | 0 | 0 | 0 | **10** |
| | Southwest | . | . | . | 0 | . | . | . | 0 | 1 | 9 | . | . | . | . | 10 |
| | Northwest | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |

## APPENDIX 3 (CONTINUED). THE CATCHES AND FATES OF LARGE SALMON CAPTURED AND TAGGED FROM THE TIDAL TRAPNETS OF THE SOUTHWEST MIRAMICHI RIVER IN 2009.

| Southwest Miramichi - Large Salmon | | Southwest Food/Science Lower | | | | Southwest Food/Science Upper | | | | Millerton Trapnet - Southwest Miramichi | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | July | August | Sept. | Total | July | August | Sept. | Total | June | July | August | Sept. | Oct. 1-15 | >Oct. 15 | Total |
| | **Tags Placed** | 115 | 21 | 2 | **138** | 249 | 46 | 7 | **302** | 13 | 420 | 25 | 63 | 16 | 0 | **537** |
| **Mortalities recovered upriver (in freshwater)** | | | | | | | | | | | | | | | | |
| Northwest | | . | . | . | **0** | . | . | . | **0** | . | . | . | . | . | . | **0** |
| Southwest | | . | . | . | **0** | . | . | . | **0** | . | . | . | . | . | . | **0** |
| **Unmarked fish recovered at facility above** | | 153 | 21 | 2 | **176** | 470 | 49 | 7 | **526** | 16 | 699 | 28 | 64 | 17 | 0 | **824** |
| **Mortalities at facility above** | | 4 | . | . | **4** | 2 | 1 | . | **3** | 2 | 5 | 2 | . | . | . | **9** |
| **Fish with tagging scars recovered at facility above** | | . | . | . | **0** | . | . | . | **0** | . | 2 | . | . | . | 1 | **3** |
| **Recaptured fish lost before reading tag number at facility above** | | . | . | . | **0** | . | . | . | **0** | . | . | . | . | . | . | **0** |
| **Recoveries of tags placed at facility above** | | | | | | | | | | | | | | | | |
| **Northwest Cassilis Trapnet** | | 3 | 0 | 0 | **3** | 2 | 1 | 0 | **3** | 0 | 1 | 0 | 0 | 0 | 0 | **1** |
| | June | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | July | 3 | . | . | 3 | 2 | . | . | 2 | . | . | . | . | . | . | 0 |
| | August | . | . | . | 0 | . | 1 | . | 1 | . | . | . | . | . | . | 0 |
| | Sept. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | Oct. 1-15 | . | . | . | 0 | . | . | . | 0 | . | 1 | . | . | . | . | 1 |
| | > Oct. 15 | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| **Red Bank Trapnets** | | 0 | 0 | 0 | **0** | 1 | 0 | 0 | **1** | 0 | 2 | 0 | 0 | 0 | 0 | **2** |
| | June | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | July | . | . | . | 0 | 1 | . | . | 1 | . | 1 | . | . | . | . | 1 |
| | August | . | . | . | 0 | . | . | . | 0 | . | 1 | . | . | . | . | 1 |
| | Sept. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | Oct. 1-15 | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| **Southwest Food/Science Lower** | | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| | June | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | July | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | August | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | Sept. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | Oct. 1-15 | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| **Southwest Food/Science Upper** | | 0 | 0 | 0 | **0** | 2 | 2 | 0 | **4** | 0 | 2 | 0 | 0 | 0 | 0 | **2** |
| | June | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | July | . | . | . | 0 | 2 | . | . | 2 | . | 2 | . | . | . | . | 2 |
| | August | . | . | . | 0 | . | 2 | . | 2 | . | . | . | . | . | . | 0 |
| | Sept. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | Oct. 1-15 | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| **Southwest Millerton Trapnet** | | 5 | 0 | 0 | **5** | 13 | 0 | 1 | **14** | 0 | 9 | 1 | 4 | 0 | 0 | **14** |
| | May | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | June | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | July | 5 | . | . | 5 | 12 | . | . | 12 | . | 8 | . | . | . | . | 8 |
| | August | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | Sept. | . | . | . | 0 | . | . | 1 | 1 | . | . | . | 4 | . | . | 4 |
| | Oct. 1-15 | . | . | . | 0 | 1 | . | . | 1 | . | 1 | 1 | . | . | . | 2 |
| | > Oct. 15 | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| **Barrier Fences** | | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| NW Miramichi | June-Aug. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | Sept.-Oct. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| Catamaran | June-Aug. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | Sept.-Nov. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| Dungarvon | June-Aug. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | Sept.-Oct. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| Clearwater Brook | June-Aug. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | Sept.-Nov. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| Burnthill Brook | June-Aug. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | Sept.-Nov. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| SW Miramichi | June-Aug. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| | Sept.-Oct. | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |
| **Broodstock Seining** | | 1 | 0 | 0 | **1** | 0 | 0 | 0 | **0** | 2 | 14 | 0 | 0 | 0 | 0 | **16** |
| | Southwest | 1 | . | . | 1 | . | . | . | 0 | 2 | 14 | . | . | . | . | 16 |
| | Northwest | . | . | . | 0 | . | . | . | 0 | . | . | . | . | . | . | 0 |

## APPENDIX 3 (CONTINUED). THE CATCHES AND FATES OF SMALL SALMON CAPTURED AND TAGGED FROM THE TIDAL TRAPNETS OF THE NORTHWEST MIRAMICHI RIVER IN 2009.

| Northwest Miramichi - Small Salmon | | Cassilis Trapnet - Northwest Miramichi | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | June | July | August | Sept. | Oct. 1-15 | >Oct. 15 | Total |
| | **Tags Placed** | 12 | 180 | 23 | 28 | 12 | 0 | **255** |
| **Mortalities recovered upriver (in freshwater)** | | | | | | | | |
| Northwest | | . | . | . | . | . | . | **0** |
| Southwest | | . | . | . | . | . | . | **0** |
| **Unmarked fish recovered at facility above** | | | | | | | | |
| | | 13 | 192 | 23 | 28 | 14 | 0 | **270** |
| **Mortalities at facility above** | | | | | | | | |
| | | . | 1 | . | . | 1 | . | **2** |
| **Fish with tagging scars recovered at facility above** | | | | | | | | |
| | | . | . | . | . | . | . | **0** |
| **Recaptured fish lost before reading tag number at facility above** | | | | | | | | |
| | | . | . | . | . | . | . | **0** |
| **Recoveries of tags at facility** | | | | | | | | |
| **Northwest Cassilis Trapnet** | | 0 | 9 | 1 | 3 | 3 | 0 | **16** |
| | June | . | . | . | . | . | . | 0 |
| | July | . | 7 | . | . | . | . | 7 |
| | August | . | 1 | . | . | . | . | 1 |
| | Sept. | . | . | 1 | 2 | . | . | 3 |
| | Oct. 1-15 | . | 1 | . | 1 | 2 | . | 4 |
| | > Oct. 15 | . | . | . | . | 1 | . | 1 |
| **Red Bank Trapnets** | | 0 | 6 | 1 | 1 | 0 | 0 | **8** |
| | June | . | . | . | . | . | . | 0 |
| | July | . | 3 | . | . | . | . | 3 |
| | August | . | 2 | 1 | . | . | . | 3 |
| | Sept. | . | 1 | . | . | . | . | 1 |
| | Oct. 1-15 | . | . | . | 1 | . | . | 1 |
| **Southwest Food/Science Lower** | | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| | June | . | . | . | . | . | . | 0 |
| | July | . | . | . | . | . | . | 0 |
| | August | . | . | . | . | . | . | 0 |
| | Sept. | . | . | . | . | . | . | 0 |
| | Oct. 1-15 | . | . | . | . | . | . | 0 |
| **Southwest Food/Science Upper** | | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| | June | . | . | . | . | . | . | 0 |
| | July | . | . | . | . | . | . | 0 |
| | August | . | . | . | . | . | . | 0 |
| | Sept. | . | . | . | . | . | . | 0 |
| | Oct. 1-15 | . | . | . | . | . | . | 0 |
| **Southwest Millerton Trapnet** | | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| | May | . | . | . | . | . | . | 0 |
| | June | . | . | . | . | . | . | 0 |
| | July | . | . | . | . | . | . | 0 |
| | August | . | . | . | . | . | . | 0 |
| | Sept. | . | . | . | . | . | . | 0 |
| | Oct. 1-15 | . | . | . | . | . | . | 0 |
| | > Oct. 15 | . | . | . | . | . | . | 0 |
| **Barrier Fences** | | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| NW Miramichi | June-Aug. | . | . | . | . | . | . | 0 |
| | Sept.-Oct. | . | . | . | . | . | . | 0 |
| Catamaran | June-Aug. | . | . | . | . | . | . | 0 |
| | Sept.-Nov. | . | . | . | . | . | . | 0 |
| Dungarvon | June-Aug. | . | . | . | . | . | . | 0 |
| | Sept.-Oct. | . | . | . | . | . | . | 0 |
| Clearwater Brool | June-Aug. | . | . | . | . | . | . | 0 |
| | Sept.-Nov. | . | . | . | . | . | . | 0 |
| Burnthill Brook | June-Aug. | . | . | . | . | . | . | 0 |
| | Sept.-Nov. | . | . | . | . | . | . | 0 |
| SW Miramichi | June-Aug. | . | . | . | . | . | . | 0 |
| | Sept.-Oct. | . | . | . | . | . | . | 0 |
| **Broodstock Seining** | | 1 | 3 | 0 | 0 | 0 | 0 | **4** |
| | Southwest | . | . | . | . | . | . | 0 |
| | Northwest | 1 | 3 | . | . | . | . | 4 |

## APPENDIX 3 (CONTINUED). THE CATCHES AND FATES OF LARGE SALMON CAPTURED AND TAGGED FROM THE TIDAL TRAPNETS OF THE NORTHWEST MIRAMICHI RIVER IN 2009.

| Northwest Miramichi - Large Salmon | | Cassilis Trapnet - Northwest Miramichi | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | June | July | August | Sept. | Oct. 1-15 | >Oct. 15 | Total |
| | **Tags Placed** | 18 | 125 | 15 | 16 | 23 | 0 | **197** |
| **Mortalities recovered upriver (in freshwater)** | | | | | | | | |
| Northwest | | . | . | . | . | . | . | **0** |
| Southwest | | . | . | . | . | . | . | **0** |
| **Unmarked fish recovered at facility above** | | | | | | | | |
| | | 20 | 128 | 17 | 16 | 23 | 0 | **204** |
| **Mortalities at facility above** | | | | | | | | |
| | | 1 | . | 1 | . | . | . | **2** |
| **Fish with tagging scars recovered at facility above** | | | | | | | | |
| | | . | . | . | 1 | . | . | **1** |
| **Recaptured fish lost before reading tag number at facility above** | | | | | | | | |
| | | . | . | . | . | . | . | **0** |
| **Recoveries of tags at facility** | | | | | | | | |
| **Northwest Cassilis Trapnet** | | 0 | 1 | 2 | 5 | 1 | 0 | **9** |
| | June | . | . | . | . | . | . | 0 |
| | July | . | . | . | . | . | . | 0 |
| | August | . | 1 | . | . | . | . | 1 |
| | Sept. | . | . | 1 | 2 | . | . | 3 |
| | Oct. 1-15 | . | . | 1 | 3 | 1 | . | 5 |
| | > Oct. 15 | . | . | . | . | . | . | 0 |
| **Red Bank Trapnets** | | 0 | 3 | 0 | 1 | 1 | 0 | **5** |
| | June | . | . | . | . | . | . | 0 |
| | July | . | 3 | . | . | . | . | 3 |
| | August | . | . | . | . | . | . | 0 |
| | Sept. | . | . | . | 1 | . | . | 1 |
| | Oct. 1-15 | . | . | . | . | 1 | . | 1 |
| **Southwest Food/Science Lower** | | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| | June | . | . | . | . | . | . | 0 |
| | July | . | . | . | . | . | . | 0 |
| | August | . | . | . | . | . | . | 0 |
| | Sept. | . | . | . | . | . | . | 0 |
| | Oct. 1-15 | . | . | . | . | . | . | 0 |
| **Southwest Food/Science Upper** | | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| | June | . | . | . | . | . | . | 0 |
| | July | . | . | . | . | . | . | 0 |
| | August | . | . | . | . | . | . | 0 |
| | Sept. | . | . | . | . | . | . | 0 |
| | Oct. 1-15 | . | . | . | . | . | . | 0 |
| **Southwest Millerton Trapnet** | | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| | May | . | . | . | . | . | . | 0 |
| | June | . | . | . | . | . | . | 0 |
| | July | . | . | . | . | . | . | 0 |
| | August | . | . | . | . | . | . | 0 |
| | Sept. | . | . | . | . | . | . | 0 |
| | Oct. 1-15 | . | . | . | . | . | . | 0 |
| | > Oct. 15 | . | . | . | . | . | . | 0 |
| **Barrier Fences** | | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| NW Miramichi | June-Aug. | . | . | . | . | . | . | 0 |
| | Sept.-Oct. | . | . | . | . | . | . | 0 |
| Catamaran | June-Aug. | . | . | . | . | . | . | 0 |
| | Sept.-Nov. | . | . | . | . | . | . | 0 |
| Dungarvon | June-Aug. | . | . | . | . | . | . | 0 |
| | Sept.-Oct. | . | . | . | . | . | . | 0 |
| Clearwater Brool | June-Aug. | . | . | . | . | . | . | 0 |
| | Sept.-Nov. | . | . | . | . | . | . | 0 |
| Burnthill Brook | June-Aug. | . | . | . | . | . | . | 0 |
| | Sept.-Nov. | . | . | . | . | . | . | 0 |
| SW Miramichi | June-Aug. | . | . | . | . | . | . | 0 |
| | Sept.-Oct. | . | . | . | . | . | . | 0 |
| **Broodstock Seining** | | 0 | 1 | 0 | 0 | 0 | 0 | **1** |
| | Southwest | . | . | . | . | . | . | 0 |
| | Northwest | . | 1 | . | . | . | . | 1 |

**APPENDIX 4. MARK AND RECAPTURE MODELS APPLIED TO THE MIRAMICHI ADULT SALMON DATA.**

The models are developed in a Bayesian framework in which posterior probability distributions for the quantities of interest are derived from prior probability distributions (either uninformative in the case of the annual model, or derived from other years in hierarchical model) and the observed data via their likelihood (the probability of the data given the model and its associated parameter estimates). The models for estimating returns of adult salmon are presented in Figures A4-1 and A4-2. Acronyms, observations, likelihoods and priors are described in Tables A4-1 to A4-4.

The quantities of interest for the assessment are the annual returns of salmon by size group to the Northwest and Southwest branches (TotSW; TotNW) and to the Miramichi River overall. This cannot be measured directly as there is no complete enumerating system on this river. Expert opinion provides a range for the possible run sizes to this river based on wetted area for juvenile production and an assumed population dynamic for salmon. Based on average biological characteristics, the conservation requirements are about 16,000 large salmon for the Southwest Miramichi and 7,300 fish for the Northwest Miramichi. Recruits per spawner of 5:1 would be very high production for Atlantic salmon and a return of 100,000 large salmon could be considered an upper limit for the Miramichi. Catches of small salmon at trapnets are generally higher than for large salmon and returns of 200 to 300 thousand small salmon would be an upper limit to the maximum returns expected in each branch. The Southwest Miramichi has twice the juvenile production area of the Northwest Miramichi and returns to the former are expected to be about twice those of the latter.

Uninformative uniform prior distributions were chosen for the returns of small salmon and large salmon to each branch:

| Branch | Size group | Distribution | Lower | Upper |
|---|---|---|---|---|
| Southwest | Small | Uniform | 1,000 | 500,000 |
| | Large | Uniform | 1,000 | 200,000 |
| Northwest | Small | Uniform | 100 | 300,000 |
| | Large | Uniform | 100 | 100,000 |

The observed data consist of several indicators of salmon abundance in Miramichi including, catches at estuary trapnets, counts at headwater protection barriers, and focused sampling programs in river (seining) in 2008 and 2009. All of these are partial counts that are indicative of, but not equal to, the total returns. The objective is to estimate the raising factors for these indicators to the total returns of salmon.

The indicators of abundance for the Miramichi were modelled as having come from a binomial process with the number of successes (samples or catches) dependent on the number of trials (total run of fish to the river) and the probability of success (the proportion of the total run which is sampled or caught) (Table A4-2 to A4-4).

For the annual model, uninformative priors are used for the proportion parameters, modelled independently as beta(1,1). This gives a uniform distribution over the range 0 to 1.

The purpose of the hierarchical model is to borrow information from other years to help in inference for the year of interest. In the following simple example:
$[catch_i \mid p_i, N_i] \sim binomial(p_i, N_i)$

the probability of having observed $catch_i$ given the probability of capture in year i and the run size in year i is binomial with parameters $p_i$, $N_i$

$p_i$ ~ beta(a, b)

$p_i$ is beta distributed with parameters a and b

$p_i$ is the "true" probability of capture (trapnet efficiency) in year i and the $p_i$'s are a random sample (over years) from a common distribution. The trapnet efficiencies are assumed to be similar but not identical. The beta(a,b) prior describes the distribution of fishing efficiency among the years. A joint probability model for the entire set of parameters ($p_i$,a, b) is developed and prior distributions are assigned to a and b.

Rather than setting priors directly on a and b, priors were set on the mean and variance of the Beta(a, b) distribution (Rivot and Prevost 2002). After alternate variable transformation, an uninformative prior distribution which is essentially uniform over the interval 0 to 1 for the $p_i$'s is obtained from:

E ~ beta(1.5,1.5)

u~ beta(1, 10)

$a_i$ = E (1 – u) / u

$b_i$ = (1 – E) * (1 – u) / u

$p_i$ ~ beta($a_i$, $b_i$)

Both annual and hierarchical models were applied to the data for 1998 to 2009. Acronym definitions for the data are provided in Table A4-1 and the assumed distributions for these data are provided in Table A4-2.

In the annual model, the barrier count data are not informative because the proportion of the run which goes to the barriers is estimated from the run size which is derived from the mark and recapture data. In the hierarchical model, the barrier data are used and an overall proportion of the run which goes to the barriers can be estimated over all the years with mark and recapture data. The overall proportion can then be applied to the years when no mark and recapture data are available.

The models were run using Monte Carlo Markov Chain with the Gibbs sampler in "OpenBugs". An initial run of 50,000 was used for the "burn-in" period and an additional 100,000 simulations were performed and the results from every tenth simulation (n = 10,000) were retained to describe the marginal posterior distributions for the parameters of interest. Two chains were run to check for convergence using the tools in OpenBugs. Based on these diagnostics, convergence appeared to have been achieved (Fig. A4-5). Model fits were examined by comparing the observations to the predicted distributions. There were generally weak correlations between the model parameters (Table A4-5).

Fits of data to the model

The fits to the observations of the annual and the hierarchical model formulations are presented for the recaptures for small and large salmon at the estuary trapnets (Fig. A4-3, A4-4). Posterior distributions for the predicted recaptures were obtained from the marginal distributions conditional on the parameters and the data. For example, the posterior distribution of the predicted recaptures at the Southwest Millerton trapnet of fish marked at the Southwest Eelground trapnet (pred.RSLowSMid) were derived from the following:

```
(pred.RSLowSMid | EFSMid, ESLowS, 0.9, MSLow)
pred.RSLowSMid ~ bin(EFSMid, MSLowS)
        MSLowS ~ bin(ESLowS, MSLow2)
        MSLow2 ~ bin(0.9, MSLow)
```

The fit to the observations was slightly better for the annual model compared to the hierarchical model but most of the observed recaptures were within the interquartile range of the posterior distributions of the predicted recaptures (Fig. A4-3, A4-4). There was only one instance (large salmon recaptures of SW Eelground tags at SW Millerton in 2007) when the observed value was not within the 95% credibility interval of the posterior distribution of the predicted (Fig. A4-3).

***Appendix Table A4-1.*** *Acronym definitions for the observations in the annual and hierarchical Miramichi salmon models, 1998 to 2009. Subscripts for year and size group are dropped for convenience.*

**<u>Observations</u>**

**Counts at headwater protection barriers**

| | |
|---|---|
| NNWMir | Count of fish at the NW Miramichi barrier |
| NJunip | Count of fish at the SW Miramichi Juniper barrier |
| NDung | Count of fish at the SW Miramichi Dungarvon barrier |

**Catches in estuary trapnets and in seining operations**

| | |
|---|---|
| FTSMid | Catches (first time) at SW Miramichi Millerton trapnet |
| FTNMid | Catches (first time) at the NW Miramichi Cassilis trapnet |
| FTNHigh | Catches (first time) at the NW Miramichi Red Bank trapnets |
| FTSSeine | Catches in seining operations in the SW Miramichi |
| FTNSeine | Catches in seining operations in the NW Miramichi |

**Marked fish at trapnets**

| | |
|---|---|
| MSLow | Fish tagged at SW Eelground trapnets |
| MSMid | Fish tagged at SW Millerton trapnet |
| MNMid | Fish tagged at NW Cassilis trapnet |

**Recaptures of previously tagged fish in estuary trapnets**

| | |
|---|---|
| RSLowSMid | Recaptures of fish tagged at SW Eelground traps to SW Millerton trap |
| RNMidSMid | Recaptures of fish tagged at NW Cassilis trap to SW Millerton trap |
| RSLowNMid | Recaptures of fish tagged at SW Eelground traps to NW Cassilis trap |
| RSMidNMid | Recaptures of fish tagged at SW Millerton trap to NW Cassilis trap |
| RSLowNHigh | Recaptures of fish tagged at SW Eelground traps to NW RedBank trap |
| RSMidNHigh | Recaptures of fish tagged at SW Millerton trap to NW RedBank trapnets |
| RNMidNHigh | Recaptures of fish tagged at NW Cassilis trap to NW RedBank trapnets |

**Recaptures of previously tagged fish in seining operations**

| | |
|---|---|
| RSLowSSeine | Recaptures of fish tagged at SW Eelground traps to SW seining |
| RSMidSSeine | Recaptures of fish tagged at SW Millerton trap to SW seining |
| RNMidSSeine | Recaptures of fish tagged at NW Cassilis trap to SW seining |
| RSLowNSeine | Recaptures of fish tagged at SW Eelground trapnets to NW seining |
| RSMidNSeine | Recaptures of fish tagged at SW Millerton trap to NW seining |
| RNMidNSeine | Recaptures of fish tagged at NW Cassilis trap to NW seining |

***Appendix Table A4-2.*** *Probability distributions assumed for the likelihoods of observations in the annual and hierarchical Miramichi salmon models, 1998 to 2009. Subscripts for year and size group are dropped for convenience.*

**<u>Likelihoods for observations</u>**

| | |
|---|---|
| NJunip | ~ bin(pJunip, TotSW) |
| NDung | ~ bin(pDung, TotSW) |
| NNWMir | ~ bin(pNWMir, TotNW) |
| | |
| FTSMid | ~ bin(EFSMid, TotSW) |
| FTNMid | ~ bin(EFNMid, TotNW) |
| FTNHigh | ~ bin(EFNHigh, TotNW) |
| | |
| RSLowSMid | ~ bin(EFSMid, MSLowS) |
| RNMidSMid | ~ bin(EFSMid, MNMidS) |
| RSLowNMid | ~ bin(EFNMid, MSLowN) |
| RSMidNMid | ~ bin(EFNMid, MSMidN) |
| RSLowNHigh | ~ bin(EFNHigh, MSLowN) |
| RSMidNHigh | ~ bin(EFNHigh, MSMidN) |
| RNMidNHigh | ~ bin(EFNHigh, MNMidN) |
| | |
| RSLowSSeine | ~ bin(EFSSeine, MSLowS2) |
| RSMidSSeine | ~ bin(EFSSeine, MSMidS2) |
| RNMidSSeine | ~ bin(EFSSeine, MNMidS2) |
| RSLowNSeine | ~ bin(EFNSeine, MSLowN2) |
| RSMidNSeine | ~ bin(EFNSeine, MSMidN2) |
| RNMidNSeine | ~ bin(EFNSeine, MNMidN2) |

***Appendix Table A4-3.*** *Acronym definitions of parameters of interest and their corresponding priors. Subscripts for year and size group are dropped for convenience.*

| | | |
|---|---|---|
| TotSW | Returns to the SW Miramichi<br>Prior: uniform(min, max) | |
| TotNW | Returns to the NW Miramichi<br>Prior: uniform(min, max) | |
| pJunip | Proportion Juniper counts of returns to SW Miramichi<br>prior: beta(a, b) | |
| pDung | Proportion Dungarvon counts of returns to SW Miramichi<br>prior: beta(a, b) | |
| pNWMir | Proportion NW Miramichi barrier counts of returns to NW Miramichi<br>prior: beta(a, ) | |
| ESLowS | Probability of fish tagged in SW Eelground traps staying in SW Miramichi<br>Prior: beta(a, b) | |
| ESMidS | Probability of fish tagged in SW Millerton trap staying in SW Miramichi<br>Prior: beta(a, b) | |
| ENMidN | Probability of fish tagged in NW Cassilis trapnet staying in NW Miramichi<br>Prior: beta(a, b) | |
| EFSMid | Efficiency of SW Millerton trapnet<br>Prior: beta(a, b) | |
| EFNMid | Efficiency of NW Cassilis trapnet<br>Prior: beta(a, b) | |
| EFNHigh | Efficiency of NW RedBank trapnets<br>Prior: beta(a, b) | |
| EFSSeine | Efficiency of SW seining program<br>Prior: beta(1,1) | |
| EFNSeine | Efficiency of NW seining program<br>Prior: beta(1,1) | |
| tagretain | proportion of tags which are retained and available for recapture by seining<br>~ beta(a,b) | |
| | For 2008, | a = 6 (tags retained), b = 2 (tag scars) for small and large salmon |
| | For 2009, | a = 14, b = 3 for small salmon<br>a = 18, b = 3 for large salmon |

<u>For annual model:</u>

a = 1
b = 1

<u>For hierarchical model:</u>

a = E (1 – u) / u
b = (1 – E) * (1 – u) / u
E ~ beta(1.5,1.5)
U ~ beta(1, 10)

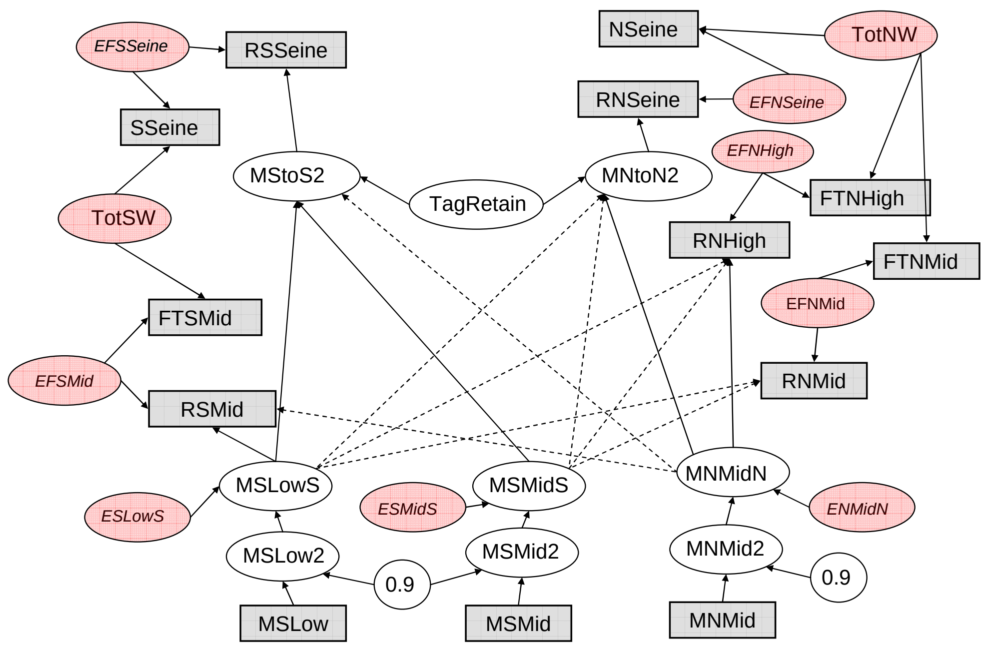
***Appendix Table A4-4.*** *Acronym definitions of latent variables and their corresponding likelihoods. Subscripts for year and size group are dropped for convenience.*

**<u>Latent variables</u>**

| | |
|---|---|
| MSLow2 | Tags available from SW Eelground after correcting for tagging and handling mortality<br>~ bin(0.9, MSLow) |
| MSMid2 | Tags available from SW Millerton after correcting for tagging and handling mortality<br>~ bin(0.9, MSMid) |
| MNMid2 | Tags available from NW Cassilis after correcting for tagging and handling mortality<br>~ bin(0.9, MNMid) |
| MSLowS | Tagged fish from SW Eelground traps available for recapture at traps in SW<br>~ bin(ESLowS, MSLow) |
| MSLowN | Tagged fish from SW Eelground traps available for recapture at traps in NW<br>= MSLow – MSLowS |
| MSMidS | Tagged fish from SW Millerton trap available for recapture at trasp in SW<br>~ bin(ESMidS, MSMid) |
| MSMidN | Tagged fish from SW Millerton trap available for recapture at traps in NW<br>= MSMid - MSMidS |
| MNMidN | Tagged fish from NW Cassilis trap available for recapture at traps in NW<br>~ bin(ENLowN, MNLow) |
| MNMidS | Tagged fish from NW Cassilis trap available for recapture in SW traps<br>= MNMid - MNMidN |
| | |
| MSLowS2 | Tagged fish from SW Eelground traps available for recapture in seining in SW<br>~ bin(tagretain, MSLowS) |
| MSLowN2 | Tagged fish from SW Eelground traps available for recapture in seining in NW<br>~ bin(tagretain, MSLowN) |
| MSMidS2 | Tagged fish from SW Millerton trap available for recapture in seining in SW<br>~ bin(tagretain, MSMidS) |
| MSMidN2 | Tagged fish from SW Millerton trap available for recapture in seining in NW<br>~ bin(tagretain, MSMidN) |
| MNMidN2 | Tagged fish from NW Cassilis trap available for recapture in seining in NW<br>~ bin(tagretain, MNMidN) |
| MNMidS2 | Tagged fish from NW Cassilis trap available for recapture in seining in SW<br>~ bin(tagretain, MNMidS) |
| | |
| TotMir | Returns to the Miramichi River<br>= TotSW + TotNW |

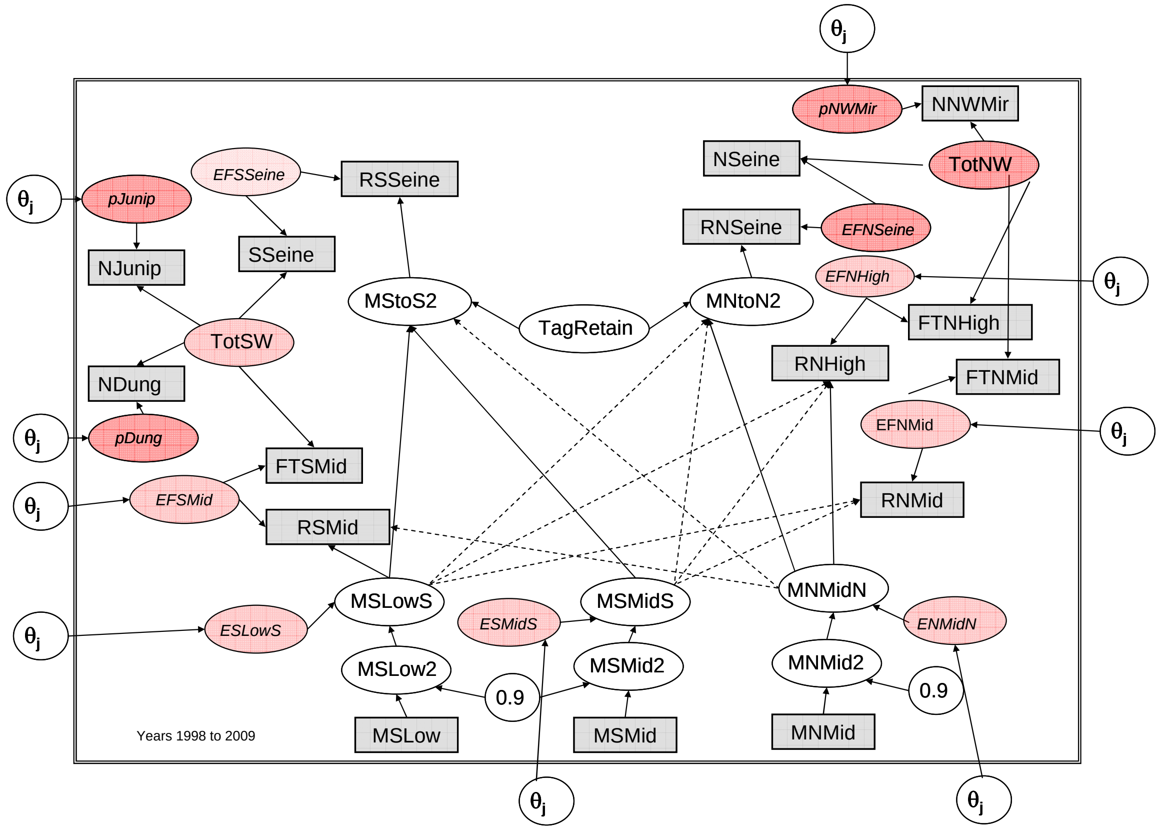
*Table A4-5. Correlations of model parameters for the small salmon hierarchical model.*

| Year | TotN TotS | ENMidN ESLowS | ENMidN ESMidS | ESLowS ESMidS | EFNMid EFSMid | pDung pNWMir |
|---|---|---|---|---|---|---|
| 1994 | -0.482 | -0.046 | -0.023 | 0.338 | -0.062 | -0.427 |
| 1995 | -0.417 | -0.054 | -0.026 | 0.417 | -0.036 | -0.366 |
| 1996 | -0.437 | -0.046 | -0.025 | 0.224 | -0.045 | -0.393 |
| 1997 | -0.289 | -0.051 | -0.012 | 0.191 | -0.029 | -0.260 |
| 1998 | -0.306 | -0.145 | -0.059 | 0.177 | -0.194 | -0.276 |
| 1999 | -0.310 | -0.176 | -0.088 | 0.160 | -0.186 | -0.293 |
| 2000 | -0.258 | -0.235 | -0.103 | 0.213 | -0.171 | -0.218 |
| 2001 | -0.249 | -0.230 | -0.156 | 0.281 | -0.206 | -0.193 |
| 2002 | -0.261 | -0.247 | -0.151 | 0.300 | -0.199 | -0.243 |
| 2003 | -0.198 | -0.127 | -0.090 | 0.295 | -0.162 | -0.186 |
| 2004 | -0.208 | -0.164 | -0.115 | 0.290 | -0.163 | -0.193 |
| 2005 | -0.049 | -0.080 | -0.038 | 0.151 | -0.049 | -0.058 |
| 2006 | -0.110 | -0.112 | -0.094 | 0.269 | -0.086 | -0.104 |
| 2007 | -0.101 | -0.077 | -0.057 | 0.108 | -0.058 | -0.088 |
| 2008 | -0.065 | -0.084 | -0.024 | 0.087 | -0.029 | -0.066 |
| 2009 | -0.066 | -0.044 | -0.017 | 0.060 | -0.025 | -0.054 |



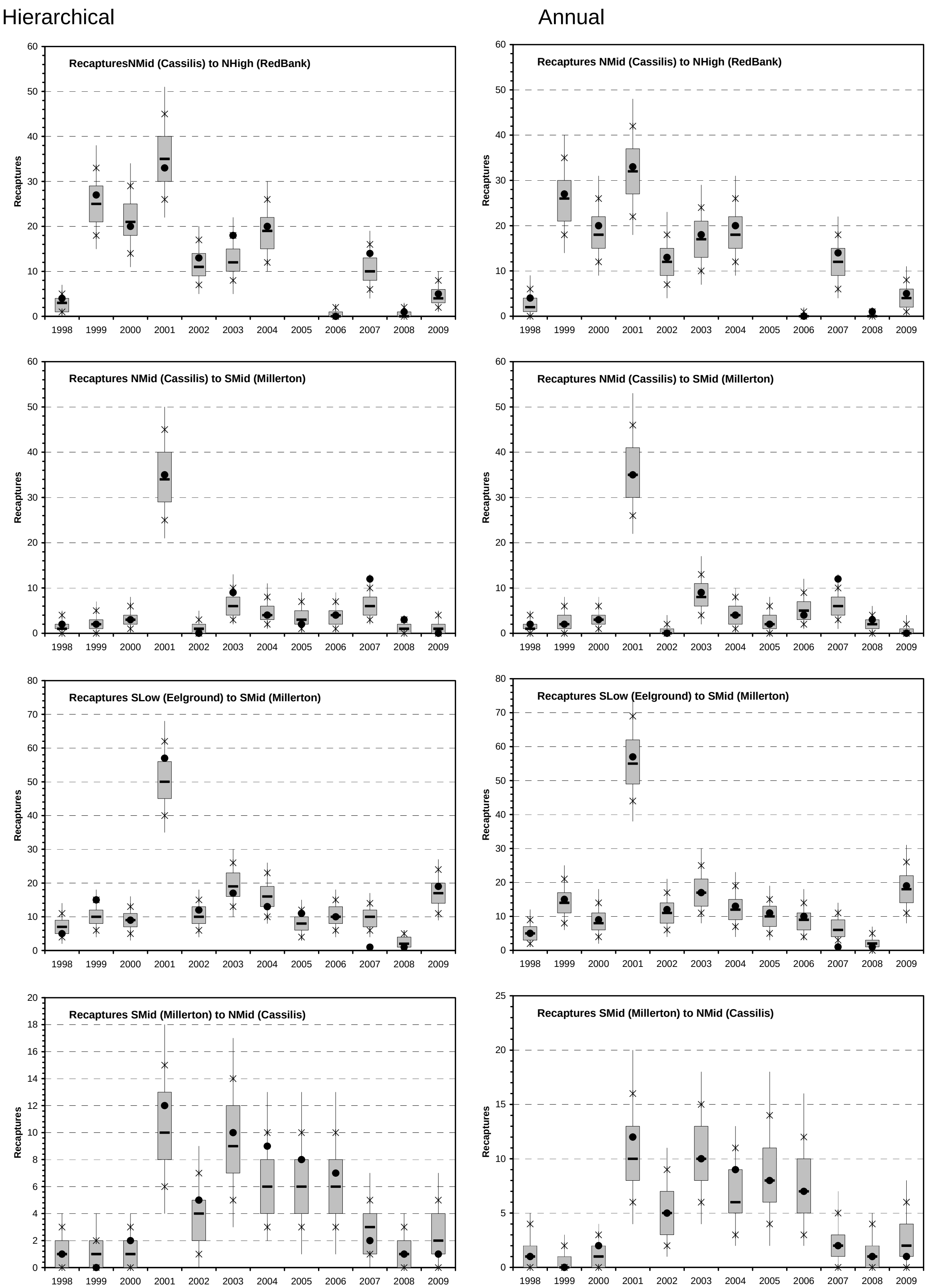

| | | | |
|---|---|---|---|
| MSLow, MSMid, MNMid | Tags placed at SW Eelground traps, SW Millerton trap, NW Cassilis trap, respectively | RSMid, RNMid, RNHigh | Recaptures of tagged fish originating from another trapnet |
| MSLow2, MSMid2, MNMid2 | Tags adjusted for 10% tagging and handling mortality | FTSMid, FTNMid, FTNHigh | Catches (first time) of fish at the three trapnets, respectively |
| ESLowS, ESMidS, ENMidN | Probability of a fish tagged in a branch staying in that branch for recapture, relative to each tagging location | EFSMid, EFNMid, EFNHigh | Efficiency of the trapnets at capturing salmon for each trapnet respectively |
| MSLowS, MSMidS, MNMidN | Tags remaining in the branch where they were tagged for each of the three tagging locations | | |
| MStoS2, MNtoN2 | Tagged fish staying in the Southwest or Northwest branches and available for recapture by seining | RSSeine, RNSeine | Valid recaptures of tagged fish at the Southwest and Northwest seining operations |
| TagRetain | Probability of a tagged retaining its tag to recapture by seining | EFSSeine, EFNSeine | Efficiency of the seining operations in the Southwest and Northwest branches, respectively |
| SSeine, NSeine | Catches (first time) of fish for the Southwest and Northwest seining operations, respectively | TotSW, TotNW | Returns of fish to the Southwest and Northwest branches, respectively |

***Appendix Figure A4-1.*** *Directed Acyclical Graph of the annual model (example for 2009 is shown). Items in grey rectangles are the observations, the items in red ellipses are the unknowns to be estimated by the model, and the items in clear ellipses are latent variables. Ellipses for priors of the parameters of interest are not shown for clarity.*

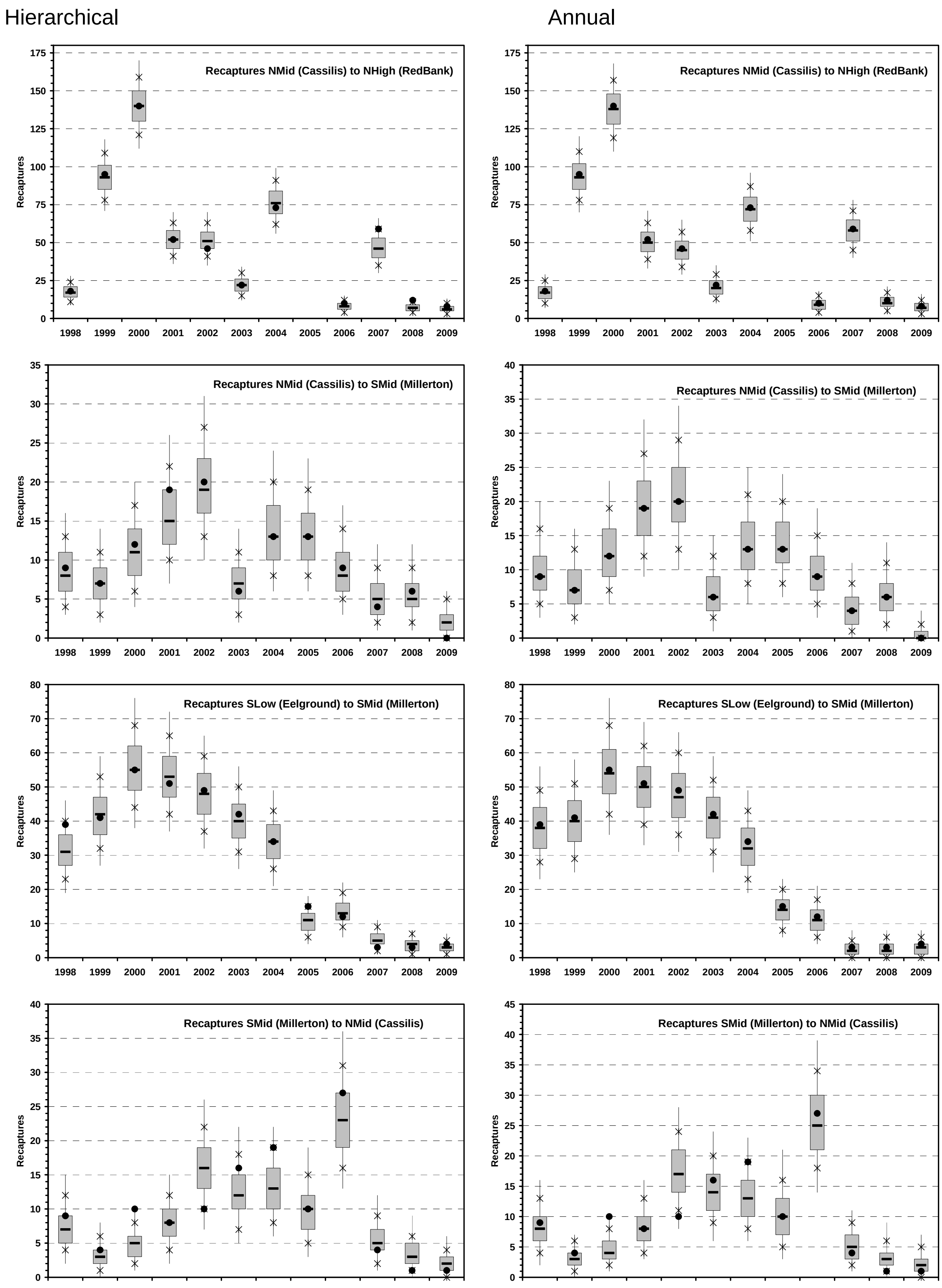



| | | | |
|---|---|---|---|
| NDung, NJunip, NNWMir | Annual counts at the three headwater barriers (Dungarvon, Juniper, NWMiramichi, respectively) | pDung, pJunip, pNWMir | Annual proportions of the respective branch returns of fish that go to the barriers |
| $\theta_j$ | Overall parameters (called hyperparameters) for the components (j) which are estimated in the model. | | |

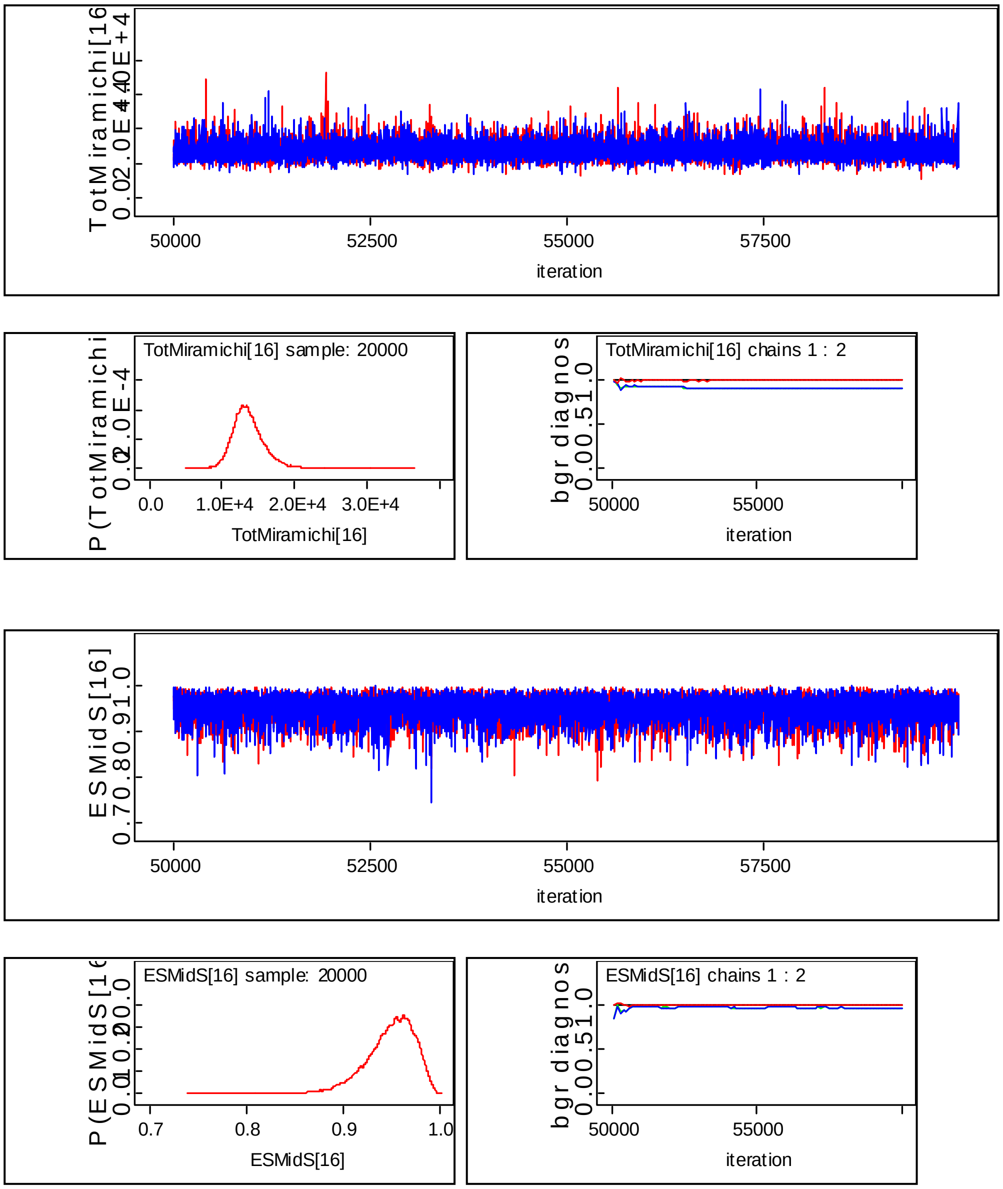
***Appendix Figure A4-2.*** *DAG of the hierarchical model (1998 to 2009). Items in grey rectangles are the observations, items in red ellipses are the unknowns to be estimated by the model. Items in white ellipses are the latent variables and the white circles identify the hyperparameters for the variables of interest. Acronyms are as in Figure A4-1 with additions above..*




***Appendix Figure A4-3.*** *Predicted (box plots) versus observed (solid points) recaptures of large salmon based on the hierarchical (left panels) and the annual model (right panels), 1998 to 2009. Box plots are interpreted as in Figure 3.*




***Appendix Figure A4-4.*** *Predicted (box plots) versus observed (solid points) recaptures of small salmon based on the hierarchical (left panels) and the annual model (right panels), 1998 to 2009. Box plots are interpreted as in Figure 3.*




***Appendix Figure A4-5.*** *Diagnostics for assessing convergence of the Bayesian hierarchical model. Shown are the history of the MCMC draws from the posterior, the smoothed posterior distribution of the parameter, and Gelman-Rubick convergence plot. Selected parameters and variables are: Estimated returns to the Miramichi for 2009 (TotMiramichi) (upper three plots), and the efficiency of the SW Millerton trapnet (ESMiDS) (lower three plots).*