Canadian Atlantic Fisheries Scientific Advisory Committee

Comit  scientifique consultatif des pches  canadiennes dans l'Atlantique

CAFSAC Research Document 89/75

CSCPCA Document de recherche 89/75

# AN ANALYSIS OF 1SW TO MSW SALMON RETURNS IN GULF OF ST. LAWRENCE RIVERS IN RELATION TO THE 1984-1988 SALMON MANAGEMENT PLAN

by

Michael Chadwick
Marine and Anadromous Fish Division
Gulf Fisheries Centre
Department of Fisheries and Oceans
P.O. Box 5030
Moncton, New Brunswick
E1C 9B6

**ABSTRACT**

The effectiveness of the 1984 Salmon Management Plan at increasing returns of MSW salmon was examined in rivers of the Gulf of St. Lawrence. An index using returns of 1SW salmon as a proportion of MSW salmon in the following year was calculated for early and late runs of seven rivers with counting traps, 1975-88. A multiplicative model was used to calculate a standardized annual index to compare years before and after 1984. The results indicated that a significantly greater proportion of MSW salmon returned in years after imposition of the plan in 1984. In addition, it was found that early-run stocks had significantly smaller proportions of MSW salmon compared to late-run stocks. This difference could be because of relatively lower fishing mortality on late-run stocks.

**RÉSUMÉ**

On a examiné l'efficacité du plan de gestion du saumon de 1984 au regard des montaisons accrues de redibermarins dans les rivières du golfe du Saint-Laurent. À cette fin, on a établi un indice fondé sur les remontées de saumons unibermarins, représentant une proportion des redibermarins de l'année suivante, pour les premières et les dernières montaisons dans sept rivières dotées de parcs de dénombrement, de 1975 à 1988. Un modèle multiplicatif a servi à calculer un indice annuel normalisé pour comparer les résultats d'avant et d'après 1984. Les chiffres obtenus ont révélé qu'une proportion nettement plus importante de redibermarins ont remonté les rivières dans les années qui ont suivi l'adoption du plan (1984). De plus, on a établi que dans les stocks des premières montaisons la proportion de redibermarins était nettement inférieure à celle des dernières montaisons. Cette différence pourrait s'expliquer par un taux de mortalité dû à la pêche relativement plus bas dans les dernières montaisons.

## 1. INTRODUCTION

Returns of 1SW salmon are used to predict returns of MSW salmon in the following year for stocks in Miramichi (Randall et al. 1989 a)), Restigouche (Randall et al. 1989 b)) and Margaree (Claytor and Chaput 1988) rivers. The models used in these predictions assume that the returns of MSW salmon are a constant proportion of 1SW salmon in the previous years. In 1984, major changes were imposed in the commercial and recreational fisheries of Atlantic Canada, Chadwick (1985), which drastically reduced the numbers of salmon taken in homewater fisheries. These changes would be expected to decrease the proportion 1SW/MSW. This paper examines the hypothesis that the proportion of 1SW to MSW salmon returning to rivers in the Gulf of St. Lawrence has changed since 1984.

## 2. METHODS

### 2.1 Grilse-salmon index

Returns of 1SW and MSW salmon were available for seven rivers in the Gulf of St. Lawrence, which had daily counts at upstream counting facilities. A total of 14 years of data were available. Data 1975-1983 were coded as pre-PLAN and those from 1984-1988, during the Salmon Management Plan, were coded as PLAN.

The grilse - salmon index was the ratio 1SW/MSW, where 1SW was the count of 1SW salmon in year i-1 and MSW (multi-seawinter) was the count of MSW salmon in year i. A high index, therefore, would indicate a high number of 1SW salmon relative to MSW salmon in the following year.

Migrations of salmon in many rivers in the Gulf of St. Lawrence occur in two seasons. The summer season extends from May to August with most fish entering the rivers in June and July. The fall season extends from September to November. In this analysis fish entering the rivers during these two time periods were treated separately.

A standardized index was calculated using the multiplicative model of Gavaris (1980). The basic assumption of this model is that the index is influenced by common environmental or fishery-related factors.

As modified from Gavaris (1980), the model is:

$$(G/S) = br_1 \times \ldots \times br_j \times ba_1 \times \ldots \times ba_i \times bs_1 \times \ldots \times bs_k \times E \times \epsilon$$

Where $(G/S)$ = any grilse to salmon ratio

$br_j$ = river effects in river j

$ba_i$ = year effects in year i

$bs_k$ = season effects in season k

E = environmental or fishery-related factors

$\epsilon$ = error

By choosing a reference such as:

$$(G/S)r = br_1 \times ba_1 \times bs_1 \times E \times \epsilon$$

E can be removed from the equation:

$$\frac{(G/S)}{(G/S)r} = \frac{br_1 \times \ldots \times br_j \times ba_1 \times \ldots \times ba_j \times bs_1 \times \ldots \times bs_k \times E \times \epsilon}{br_1 \times ba_1 \times bs_1 \times E \times \epsilon}$$

and

$$(G/S) = (G/S)r \times br_2 \times \ldots \times br_i \times ba_2 \times \ldots \times ba_i \times bs_2 \times \ldots \times bs_k \times \epsilon$$

with the (G/S) index transformed into natural logarithms, the regression can be solved with least squares.

$$\ell n\ (G/S) = \ell n\ (G/S)r + \ell n\ br_2 + \ell n\ br_j + \ell n ba_2 + \quad + \ell n ba_i + \ell n bs_2 + \quad \ell n bs_k + \epsilon$$

The general model is:

$$\ell n(G/S) = \ell n\ ((G/S)r) + \Sigma[\ell n(P_{ij})X_{ij}] + \epsilon$$

Where (G/S)r = reference index

$P_{ij}$ = relative importance of group $_j$ and factor $_i$

$X_{ij}$ = dummy variable (1 when data are present, 0 if not)

The hypothesis that the grilse salmon index had not changed since the advent of the 1984 Salmon Management Plan was tested by comparing pre-PLAN to PLAN years.

## Results and Discussion

The initial model with all seven rivers (Table 1) provided a good fit to the data and explained 72% of the variation in the index. However, there was a trend in the residuals for two rivers and a second model using only five rivers (Nepisiguit, Millbank, Bartholomew, Mitis, and Margaree) was calculated. A large negative residual was also removed. This value was the 1985 count of late run grilse as a proportion of 1986 counts of late run salmon at Millbank. The revised model indicated that all effects were highly significant (Table 2).

The retransformed index for early-run stocks was three times greater than late-run stocks (Table 2); that is, late-run stocks comprised proportionately more MSW salmon. It can be assumed that the difference between early and late run stocks was due to fishing and not to natural mortality. This assumption can be made because it is likely that sex ratio and fecundity of early and late-run stocks are equal and that their natural mortality rates are also equal.

The significant year effects were used to identify highs and lows on grilse-salmon index and to measure the success of the 1984 Salmon Management Plan. The coefficients indicated that the index was highest in 1981, 1982, 1983, and 1987, and lowest in 1978, 1979, 1984, 1985, and 1986 (Table 2)

An analysis comparing pre-PLAN and PLAN indicated that coefficients for these years were significantly different (Table 3). the retransformed coefficients indicated that the number of MSW salmon relative to grilse had increased by 60% during the plan. It was noteworthy, however, that the five-year management plan appeared to have been effective in these rivers in only four out of five years, the index in 1987 was one of the highest over the 14 year time period, which indicated salmon returns were low.

The results indicate that returns of MSW salmon have increased relative to those of 1SW salmon during PLAN compared to pre-PLAN years. A significant correlation between Labrador commercial catch of small salmon in the year previous to MSW returns suggests that reduced catches from 1983-1985 were one reason for increased MSW returns from 1984-1986 (Randall and Chadwick 1989). However, hook-and-release requirements for MSW salmon suggest that the selective removal of 1SW salmon, in recreational fisheries prior to enumeration at some of the counting facilities used in the data set, likely also increased MSW returns relative to 1SW salmon. Future analyses of grilse-salmon returns should examine these last two points in more detail.

## REFERENCES

Chadwick, E.M.P. 1985. Fundamental research problems in the management of Atlantic salmon, Salmo salar L, in Atlantic Canada. J. Fish Biology. 27/Supplement : 9-25.

Claytor, R.R., and G.J. Chaput. 1988. Assessment of Atlantic salmon (Salmo salar) in the Margaree River, 1988. CAFSAC. Res. Doc. 88/75, 43 p.

Gavaris, Stratis. 1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. Can. J. Fish. Aquat. Sci. 37: 2272-2275.

Randall, R.G., and E.M.P. Chadwick. 1989. Preseason forecasting of MSW salmon returns to the Miramichi River. CAFSAC Res. Doc. in preparation.

Randall, R.G., G. Landry, A. Madden, and P.R. Pickard. 1989. Status of Atlantic salmon in the Restigouche River, 1989. CAFSAC Res. Doc. in preparation.

Randall, R.G., D.S. Moore, and P.R. Pickard. 1989. Status of Atlantic salmon in the Miramichi River, 1989. CAFSAC Res. Doc. in preparation.

**Table 1. A summary of counts of 1SW salmon (grilse) and MSW salmon at selected rivers in Gulf of St. Lawrence.**

| | | RUN | | | |
|---|---|---|---|---|---|
| | | EARLY | | LATE | |
| | | STAGE | | STAGE | |
| | | GRILSE | SALMON | GRILSE | SALMON |
| | | COUNT | COUNT | COUNT | COUNT |
| | YEAR | SUM | SUM | SUM | SUM |
| BARTHOLOMEW RIVER | 80 | 105 | 28 | 198 | 104 |
| | 81 | 336 | 9 | 285 | 91 |
| | 82 | 209 | 29 | 136 | 154 |
| | 83 | 221 | 40 | 134 | 71 |
| | 84 | 141 | 78 | 332 | 143 |
| | 85 | 96 | 30 | 251 | 369 |
| | 86 | 143 | 14 | 672 | 486 |
| | 87 | 423 | 17 | 427 | 330 |
| | 88 | 464 | 53 | 1178 | 384 |
| MADELEINE RIVER | 76 | 109 | 161 | . | . |
| | 77 | 75 | 72 | . | . |
| | 78 | 52 | 378 | . | . |
| | 79 | 90 | 62 | . | . |
| | 80 | 78 | 82 | . | . |
| | 81 | 310 | 147 | . | . |
| | 82 | 256 | 322 | . | . |
| | 83 | 86 | 177 | . | . |
| | 84 | 74 | 392 | . | . |
| | 85 | 148 | 310 | . | . |
| | 86 | 345 | 455 | . | . |
| | 87 | 381 | 976 | . | . |
| | 88 | 497 | 790 | . | . |
| MARGAREE RIVER | 74 | 34 | 30 | 26 | 77 |
| | 75 | 14 | 4 | 22 | 60 |
| | 76 | 43 | 9 | 53 | 73 |
| | 77 | 37 | 53 | 32 | 87 |
| | 78 | 9 | 20 | 16 | 138 |
| | 79 | 532 | 21 | 65 | 60 |
| | 80 | 100 | 2 | 67 | 138 |
| | 81 | 729 | 29 | 170 | 110 |
| | 82 | 602 | 65 | 89 | 114 |
| | 83 | 37 | 45 | 31 | 104 |
| | 84 | 81 | 27 | 67 | 94 |
| | 85 | 116 | 144 | 107 | 168 |
| | 86 | 196 | 269 | 99 | 414 |
| | 87 | 268 | 123 | 85 | 285 |
| | 88 | 287 | 293 | 148 | 287 |
| MILLBANK TRAP | 74 | 2948 | 864 | 1090 | 927 |
| | 75 | 2954 | 628 | 594 | 580 |
| | 76 | 4072 | 641 | 867 | 302 |
| | 77 | 1249 | 1189 | 256 | 745 |
| | 78 | 1150 | 535 | 118 | 158 |
| | 79 | 2157 | 257 | 343 | 61 |
| | 80 | 1802 | 837 | 337 | 256 |
| | 81 | 2020 | 173 | 154 | 26 |
| | 82 | 2593 | 392 | 72 | 16 |
| | 83 | 770 | 226 | 40 | 19 |
| | 84 | 879 | 257 | 131 | 76 |
| | 85 | 901 | 287 | 11 | 24 |
| | 86 | 1324 | 345 | 439 | 124 |
| | 87 | 1146 | 223 | 126 | 68 |
| | 88 | 884 | 173 | 944 | 152 |
| MITIS RIVER | 74 | 34 | 70 | . | . |
| | 75 | 66 | 124 | . | . |
| | 76 | 93 | 117 | . | . |
| | 77 | 66 | 90 | . | . |
| | 78 | 77 | 92 | . | . |
| | 79 | 291 | 119 | . | . |
| | 80 | 193 | 313 | . | . |
| | 81 | 268 | 128 | . | . |
| | 82 | 114 | 431 | . | . |
| | 83 | 46 | 123 | . | . |
| | 84 | 316 | 181 | . | . |
| | 85 | 181 | 360 | . | . |
| | 86 | 616 | 368 | . | . |
| | 87 | 224 | 532 | . | . |
| | 88 | 481 | 308 | . | . |
| NEPISIGUIT RIVER | 81 | 225 | 27 | 50 | 9 |
| | 82 | 522 | 180 | 475 | 199 |
| | 83 | 154 | 202 | 150 | 92 |
| | 84 | 744 | 193 | 213 | 218 |
| | 85 | 395 | 508 | 114 | 313 |
| | 86 | 835 | 564 | 573 | 381 |
| | 87 | 871 | 449 | 880 | 921 |
| | 88 | 593 | 458 | 1824 | 1401 |
| UPSALQUITCH RIVER | 80 | 796 | 798 | 65 | 100 |
| | 81 | 660 | 373 | 135 | 107 |
| | 82 | 648 | 409 | 139 | 180 |
| | 83 | 354 | 221 | 68 | 78 |
| | 84 | 403 | 461 | 114 | 208 |
| | 85 | 565 | 377 | 169 | 144 |
| | 86 | 1408 | 853 | 330 | 313 |
| | 87 | 1162 | 494 | 395 | 506 |
| | 88 | 746 | 372 | 401 | 607 |

**Table 2. Results of revised multiplicative model.**

| | |
|---|---|
| Multiple R | 0.863 |
| Multiple R squared | 0.744 |

**ANALYSIS OF VARIANCE**

| SOURCE VARIATION | DF | SUM OF SQUARES | MEAN SQUARES | F-VALUE | P |
|---|---|---|---|---|---|
| Intercept | 1 | 1.637E1 | 1.637E1 | | |
| Regression | 18 | 9.103E1 | 5.057E0 | 12.771 | <.001 |
| River | 4 | 5.208E1 | 1.302E1 | 32.877 | <.001 |
| Season | 1 | 2.499E1 | 2.499E1 | 63.110 | <.001 |
| Year | 13 | 2.190E1 | 1.684E0 | 4.253 | <.001 |
| Residuals | 79 | 3.128E1 | 3.960E-1 | | |
| TOTAL | 98 | 1.387E2 | | | |

**REGRESSION COEFFICIENTS**

| CATEGORY | CODE | COEFFICIENT | NO. OBS. |
|---|---|---|---|
| Reference | Millbank<br>Early run<br>1975 | 1.817 | 98 |
| River | Nepisiguit | -1.247 | 14 |
| | Bartholomew | -0.232 | 16 |
| | Margaree | -1.313 | 27 |
| | Mitis | -2.084 | 14 |
| Season | Late run | -1.094 | 42 |
| Year | 1976 | -0.263 | 5 |
| | 1977 | -0.295 | 5 |
| | 1978 | -0.407 | 5 |
| | 1979 | -0.527 | 5 |
| | 1980 | -0.317 | 4 |
| | 1981 | 0.718 | 7 |
| | 1982 | 0.427 | 9 |
| | 1983 | 0.747 | 9 |
| | 1984 | -0.627 | 9 |
| | 1985 | -0.187 | 9 |
| | 1986 | -0.729 | 8 |
| | 1987 | 0.209 | 9 |
| | 1988 | -0.208 | 9 |

**Table 3. Results of regression of multiplicative model for 1984-88 management plan.**

| | |
|---|---|
| Multiple R | 0.780 |
| Multiple R squared | 0.609 |

**ANALYSIS OF VARIANCE**

| SOURCE VARIATION | DF | SUM OF SQUARES | MEAN SQUARES | F-VALUE | P |
|---|---|---|---|---|---|
| Intercept | 1 | 1.637E1 | 1.637E1 | | |
| Regression | 6 | 7.445E1 | 1.241E1 | 23.590 | <0.001 |
| River | 4 | 5.671E1 | 1.418E1 | 26.954 | <0.001 |
| Season | 1 | 2.519E1 | 2.519E1 | 47.896 | <0.001 |
| Plan | 1 | 2.313E0 | 5.313E0 | 10.101 | <0.001 |
| Residuals | 91 | 4.787E1 | 5.260E-1 | | |
| TOTAL | 98 | 1.387E2 | | | |

**REGRESSION COEFFICIENTS**

| CATEGORY | CODE | COEFFICIENT | NO. OBS. |
|---|---|---|---|
| Reference | Millbank<br>Early run<br>1975-83 | 1.901 | 98 |
| River | Nepisiguit | -1.032 | 14 |
| | Bartholomew | 0.036 | 16 |
| | Margaree | -1.310 | 27 |
| | Mitis | -2.097 | 14 |
| Season | Late run | -1.096 | 42 |
| Year | 1984-88 | -0.490 | 44 |