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Status of Atlantic Salmon (*Salmo salar* L.) in Gander River, Notre Dame Bay (SFA 4), Newfoundland, 1996

by

M. F. O'Connell, D. G. Reddin, and E.G.M. Ash
Science Branch
Department of Fisheries and Oceans
P.O. Box 5667
St. John's, Newfoundland A1C 5X1

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Abstract

The status of Atlantic salmon in Gander River in 1996 was determined using counts of small and large salmon from a counting fence located on the main stem just above head of tide, recreational fishery data, and biological characteristics information. The assessment was also conducted in relation to the commercial salmon fishery moratorium which entered its fifth year in 1996. The number of small salmon retained in the recreational fishery in 1996 was the highest since 1985; effort expenditure was the highest in the time series. The river received 124% of its conservation egg requirement in 1996, the third time since the start of the moratorium that the requirement was met; in excess of 90% of requirement was achieved in 1994 and 1995. Only 36-44% of conservation requirement was met during the pre-moratorium period 1989-91. There were significant increases in returns of small and large salmon during the moratorium (1992-96) over returns during pre-moratorium years 1989-91. However, proportions of large salmon and proportions of repeat spawning grilse in the small salmon category did not change significantly from pre-moratorium levels. Weights and lengths of small salmon observed during the moratorium increased significantly over those prior to the moratorium but there was no significant difference in condition index. There was a significant decline in estimated total population sizes of small salmon during the period 1974-96. Recruitment during 1989-96 was among the lowest in the time series. The number of recruits per spawner in 1996 was the highest since 1988. It is anticipated that returns of small salmon in 1997 will be in excess of conservation requirement. For the years 1994-96, of the small salmon examined, 6.9-16.1% possessed net marks; 5.9-46.1% of large salmon were marked.

Résumé

L'état du saumon de l'Atlantique de la rivière Gander en 1996 a été déterminé à partir du dénombrement des petits et gros saumons réalisé à une barrière située sur le cours principal de la rivière tout juste en amont de la limite de la marée, de données de la pêche récréative et de paramètres biologiques. L'évaluation a aussi été réalisée dans le contexte du moratoire de la pêche commerciale qui en était à sa cinquième année en 1996. Le nombre de petits saumons conservés par les pêcheurs récréatifs en 1996 est le plus élevé noté depuis 1985 et l'effort de pêche a été le plus important de toute la série. La ponte a correspondu à 124 % du besoin de conservation. Il s'agit de la troisième fois que les besoins ont été satisfaits depuis le début du moratoire. L'objectif a été atteint à plus de 90 % en 1994 et 1995. L'objectif de conservation n'avait été atteint que de 36 à 44 % pendant la période 1989-1991 précédant le moratoire. Les remontées de petits et de gros saumons ont été de beaucoup plus importantes pendant le moratoire (1992-1996) que pendant la période pré-moratoire de 1989-91. La proportion de gros saumons et de madeleinaux ayant déjà frayé, dans la catégorie des petits saumons, ne différait cependant pas de façon appréciable de celle de la période d'avant le moratoire. Le poids et la longueur des petits saumons ont augmenté de façon appréciable pendant le moratoire, mais l'indice de condition ne différait pas de façon significative. L'effectif estimé de la population totale a diminué de façon appréciable au cours de la période 1974-1996. Le recrutement de la période 1989-1996 est l'un des plus faibles de la série. Le nombre de recrues par géniteur en 1996 compte parmi les plus élevés depuis 1988. On prévoit que les remontées de petits saumons de 1997 seront supérieures aux besoins de la conservation. Au cours de la période 1994-1996, de 6,9 à 16,1 % des petits saumons présentaient des marques de filet, et de 5,9 à 46,1 % des gros saumons avaient été marqués.

Introduction

The Gander River, with a drainage area of 6,398 km^2 (Porter *et al.* 1974), is the third largest in insular Newfoundland. The river is located in Salmon Fishing Area (SFA) 4 (Notre Dame Bay) (Fig. 1). In addition to being one of the most important Atlantic salmon angling rivers in insular Newfoundland, the river has historically supported a relatively large angler guiding and outfitting industry.

In response to concerns from angler groups that returns to the river were declining, the Department of Fisheries and Oceans in cooperation with the Gander Rod and Gun Club and the Gander Bay-Hamilton Sound Development Association, initiated a 3-year study to determine the status of the Gander River Atlantic salmon population in 1989. The results of this study (O'Connell and Ash MS 1992) showed that for the period 1989-91, Gander River received only 36-44% of its conservation egg requirement.

In this paper we examine the status of Atlantic salmon in Gander River in 1996, the fifth year of the five-year commercial salmon fishery moratorium. Anticipated impacts of the moratorium on the Gander River Atlantic salmon population include: increases in the numbers of small and large salmon returning to the river and in the percentage of conservation requirement achieved; increases in the proportion of large salmon; changes in biological characteristics, e.g., increases in weight, length, and condition. These aspects are compared for two time periods, moratorium (1992-96) and pre-moratorium (1984-91). The pre-moratorium period selected corresponds to the years of a major management plan introduced in 1984 (O'Connell *et al.* 1992a; May 1993; Mullins and Caines MS 1994), which was modified in 1990 and 1991 to include a commercial fishery quota in each SFA (O'Connell *et al.* MS 1992b). Elements of this management regime continued into the moratorium years. All the above measures were aimed at increasing river escapements. Also, a moratorium on the Northern Cod Fishery was implemented in early July of 1992, which should have resulted in the elimination of by-catch in cod fishing gear. The cod moratorium continued in 1996.

Counts obtained from a counting fence are used in conjunction with recreational fishery data and biological characteristics data to calculate total river returns and egg deposition. Status of stock is evaluated against a conservation egg requirement (calculated in terms of fluvial and lacustrine habitats) derived for Gander River. An analysis of trends in the numbers of small salmon recruits and spawners for 1974-96 is provided as well as anticipated adult returns in 1997.

Management Measures Since 1992

The introduction of the five-year moratorium on the commercial fishery in insular Newfoundland in1992 was a major change in the management of Atlantic salmon. The moratorium was coupled with a commercial license retirement program. A quota on the number of fish that could be retained in the recreational fishery was introduced in each SFA in 1992 and 1993. The quota was assigned for each SFA as a whole and not administered on an individual river basis. Only hook-and-release fishing was permitted after the quota was caught.

Recreational fishery quotas were eliminated in 1994. In place of quotas, for insular Newfoundland, the season bag limit for retained small salmon was lowered from eight to six fish, three to be caught prior to July 31 and three after that date. Hook-and-release fishing only was permitted after the bag limit of three was reached in each time period. These measures remained in effect in 1995 and 1996. As in previous years, retention of large salmon was not permitted in insular Newfoundland. There was a fall hook-and-release fishery in the main stem of the Gander River below Gander Lake in 1995 (September 9-October 8) and 1996 (September 3-September 29).

Methods

The location of the counting fence is shown in Fig. 1. Recreational catch and effort information and counts of adult salmon in 1996 were compared to two pre-salmon moratorium means (1984-89 and 1986-91) and to the 1992-95 mean during the moratorium. The 1984-89 mean corresponds to years under the major management changes in the commercial fishery in the Newfoundland Region, cited above. The 1986-91 mean incorporates the quota years of 1990 and 1991. The mix of management measures in effect during 1984-89 on the one hand and the imposition of commercial quotas in 1990 and 1991 on the other, should be kept in mind when making evaluations based on the 1986-91 mean.

ADULT SALMON COUNTING EQUIPMENT

Counts of Adult Atlantic salmon were obtained with a positive image closed-circuit television (CCTV) system, which was operated in the boat passage in the counting fence, and by viewing VTR tapes. Visual counts were simultaneously conducted in the boat passage and these corroborated the CCTV counts. Counts were also obtained with a conventional adult trap installed in the counting fence.

RECREATIONAL FISHERY DATA

Catch and effort data from the recreational fishery in Gander River were collected by Department of Fisheries and Oceans (DFO) Officers and processed by DFO Science Branch personnel. Procedures for the collection and compilation of recreational fishery data are described by Ash and O'Connell (1987). The year 1987 was not included in the means because portions of the river were closed to angling for an extensive period due to drought conditions.

BIOLOGICAL CHARACTERISTICS

Biological characteristics information on adult Atlantic salmon in Gander River was obtained by sampling recreational catches. Information used in the calculation of egg deposition (mean weight and proportion female) and for the comparsion of biological characteristics during and prior to the moratorium for fish < 63 cm in length (small salmon) is shown in Table 1. Because the sample sizes for weight and proportion female in 1987 were small, the means for the pre-moratorium years 1984-91 were used to calculate egg deposition in that year.

A mean weight of 3.13 kg and a proportion of female value of 0.77 (O'Connell *et al.* 1997a) was used to calculate egg deposition for fish ≥ 63 cm in length (large salmon) for all years.

Fecundity was determined from ovaries collected in the recreational fishery. Ovaries were stored in Gilson's fluid until ovarian tissue had broken down after which time eggs were transferred to 10% formalin. Eggs, which for the most part were in early stages of development, were counted directly. The following annual relative fecundity (eggs/kg) values were available for small salmon for Gander River:

Year	Eggs/kg	N
1984	1,811	60
1985	1,524	73
1986	1,656	34
1987	1,811	13
1988	2,020	31
1989	1,989	29
1990	1,739	128
1992	1,831	77
1993	1,638	25
Mean	1,752	470

The mean for all years combined was used in 1987, 1991, and 1994-96. The same relative fecundity values were used for both small and large salmon.

TOTAL RIVER RETURNS, SPAWNING ESCAPEMENT, AND EGG DEPOSITION

Calculations were performed for small and large salmon separately. Total egg deposition was obtained by summing depositions for small and large salmon.

<u>Total River Returns</u>

Total river returns (TRR) was calculated as follows:

$$TRR = RC_b + C + HRM_b \qquad (1)$$

where,

RC_b = recreational catch below counting fence

C = count of fish at counting fence

HRM_b = hook-and-release mortalities (10% of hook-and-release fish) below counting fence in 1993-96

A partial count of small and large salmon was obtained at the counting fence in 1992. High water levels caused a delay in counting fence installation until July 1. During the period of delay, fish were counted upriver at the Salmon Brook fishway and also there were some angling catches. The numbers of small and large salmon entering Gander River prior to July 1 in 1989 and 1990 represented on average 4.8% and 7.5% of the total counts. The total counts of small and large salmon for 1992 were adjusted using these percentages and daily counts estimated as the the product of the average proportion of total count (for 1989-90) on a daily basis and estimated total count. Information for 1991 was not used because in that year timing of adult migration was later than in 1989 and 1990 (O'Connell and Ash MS 1992). A similar approach was used to adjust the counts of small and large salmon at the Salmon Brook fishway in 1990. In that year, counts were not obtained during the last two weeks of the run prior to the cessation of counting operations because of extremely low water conditions. The average percentage of small and large salmon counted at the fishway up to August 16 during the period 1984-91 (exclusive of 1987) was 95 and 90.

Spawning Escapement

Spawning escapement (SE) was calculated as follows:

$$SE = FR - RC_a - HRM_a \qquad (2)$$

where,

FR = fish released from counting fence

RC_a = recreational catch above counting fence

HRM_a = hook-and-release mortalities (10% of hook-and-release fish) above counting fence in 1993-96

Egg deposition

Egg deposition (ED) was calculated as follows:

$$ED = SE \times PF \times RF \times MW \qquad (3)$$

where,

SE = number of spawners

PF = proportion of females

RF = relative fecundity (No. eggs/kg)

MW = mean weight of females

The phenomenon of atresia occurs in Atlantic salmon in insular Newfoundland (O'Connell and Dempson MS 1997). Since the egg deposition calculations above were based on eggs in early stages of development, they should be regarded as potential egg depositions.

CONSERVATION EGG DEPOSITION AND SPAWNER REQUIREMENTS

The conservation egg deposition and spawner requirements for Gander River were developed by O'Connell and Dempson (MS 1991). The egg requirement for classical fluvial parr rearing habitat (Elson 1957) was 240 eggs/100 m^2 (Elson 1975); the requirement for lacustrine habitat was 368 eggs/ha (O'Connell and Dempson 1995). **It should be noted that Gander Lake was not included in the calculation of the egg deposition requirement.**

Accessible rearing habitat and conservation egg and spawner requirements in terms of fluvial and lacustrine habitats were as follows:

	Lacustrine	**Fluvial**	**Total**
Accessible habitat	21,488 ha	159,560 units	
Eggs (No. x 10^6)	7.917	38.294	46.211
Small salmon (No.)	3,739	18,089	21,828

The adult conservation spawning requirement was calculated in terms of small salmon only. Egg deposition from large salmon was considered as a buffer.

NUMBERS OF RECRUITS AND SPAWNERS, 1974-96, AND ANTICIPATED RETURNS IN 1997

It is possible to retrospectively estimate total population size of small salmon (or total number of small salmon recruits), prior to any exploitation, in rivers with counting facilities and to use the ratio of recruits to spawners to estimate anticipated returns one year in advance. A calculation of anticipated total returns (small plus large salmon) is also possible. Details of the calculations are presented below.

Since the implementation of the commercial fishery moratorium in 1992, the total number of small salmon recruits (TNR) for Gander River was considered to be equivalent to TRR (equation 1). Prior to 1992, TNR was calculated using a commercial fishery exploitation rate (μ_c) of 0.60 (Anon. MS 1990) according to the equation

$$TNR = TRR/(1 - \mu_c) \qquad (4)$$

For the period 1974-88, i.e., prior to the counting fence, TRR was calculated as the ratio of total recreational catch (RC_t) and the average recreational fishery exploitation rate (μ_r) for the period 1989-91 (prior to recreational quotas) of 0.158, or

$$TRR = RC_t/\mu_r \qquad (5)$$

Age composition of Gander River smolts (data for all years combined N = 1543) was adjusted to reflect only the 3+ and 4+ age groups, i.e., the minimal numbers of 2+ and 5+ year old smolts present were not considered; the resultant proportions of 3+ and 4+ smolts were 0.37 and 0.63. The ratio of recruits to spawners (R/S) was calculated incorporating smolt age composition of small salmon according to the equation

$$R/S = [(TNR_{i+5} \times 0.37) + (TNR_{i+6} \times 0.63)]/SE_i \qquad (6)$$

where,

TNR_{i+5} and TNR_{i+6} = small salmon recruits in years i+5 and i+6
SE_i = spawning escapement (small salmon) in year i

Anticipated returns of small salmon (AR_s) in 1997 was calculated as the product of the average R/S and SE for each smolt-age grouping separately and then summed. The average R/S for 1993-96 was used for both the 3+ and 4+ smolt-age groups. The equation to derive AR_s was as follows:

$$AR_s = (R/S\_3+_i \times SE_{i-5}) + (R/S\_4+_i \times SE_{i-6}) \qquad (7)$$

where,

R/S_3+_i and R/S_4+_i = number of small salmon recruits per spawner with smolt ages 3+ and 4+ in 1997 (year i)
SE_{i-5} and SE_{i-6} = spawning escapement (small salmon) in years i-5 and i-6

A similar calculation was performed with the minimum and maximum R/S corresponding to the mean for each smolt-age grouping to obtain an estimate of the range of anticipated returns.

Anticipated total returns (AR_t), or the sum of small and large salmon, was determined as follows:

$$AR_t = AR_s/P\_AR_s \qquad (8)$$

where,

P_AR_s = mean proportion of small salmon in escapements for 1993-96

A measure of the precision of estimates of anticipated returns of small salmon for 1995 (O'Connell *et al.* MS 1995) and 1996 (O'Connell *et al.* MS 1996) was obtained by comparison to actual returns for 1995 and 1996.

ANALYSIS TO DETECT RECRUITMENT OVERFISHING

Anon. (MS 1994) defined recruitment overfishing as a level of fishing mortality that reduces the ability of a population to persist, more specifically, the failure of a cohort of spawners to replace itself as a result of fishing. One way to evaluate Atlantic salmon stocks in terms of recruitment overfishing is through the examination of spawner-to-spawner relationships. Estimated numbers of spawners obtained from parental cohorts of small salmon were traced backward, beginning with the estimate of the number of spawners for the current year. Data sets were examined to see if numbers of spawners, which were made up of a range of chronological ages, were sufficient to replace the weighted sum of spawning parents of the same sea age. The appropriate weighting for historical spawners was determined from the average smolt-age distribution. This technique, demonstrating the use of the necessary lags and river-age distributions, is found in Anon. (MS 1994).

NET MARKS

Small and large salmon enumerated at the adult trap installed in the counting fence were examined for net marks in 1994-96. Optical properties of the CCTV system precluded examination for net marks on fish moving through the boat passage. The periods of examination were: July 8-August 16 in 1994; June 17-July 5 in 1995; June 17-August 4 in 1996.

IMPACTS OF THE MORATORIUM

Total returns of small and large salmon, proportion of large salmon, proportion of repeat spawning grilse in the small salmon category, and weight and length of small salmon (sexes combined plus unsexed fish) for the moratorium period 1992-96 were compared to that of the the pre-moratorium period 1984-91using the Wilcoxon two-sample test (Z) in the NPAR1WAY Procedure of SAS (SAS Institute 1985).

Adjusted mean weight standardized to length as a covariate (both variables ln transformed) was used as a measure of condition following the general linear model approach outlined in Dempson *et al.* (1994) and Winters and Wheeler (1994). Analyses comparing the moratorium and pre-moratorium periods were carried out using the GLM Procedure of SAS (SAS Institute 1985).

Results

Recreational Fishery

Catch and effort data are presented in Appendix 1. Catches for all years prior to 1992 represent retained catch for the entire angling season. Total catch for 1996 (retained plus released fish), effort, and catch per unit of effort (CPUE) are compared to years prior to 1992 and 1992-95. There was no estimate of released fish during the period of retention of catch in 1992 which could impact on comparisons. Calculation of CPUE in terms of retained fish only was not possible since effort figures apply to both retained and released fish collectively.

Total catch of small salmon (retained plus released fish) in 1996, the highest since 1981, increased over 1995 (29%), and exceeded the 1992-95 (moratorium) mean (53%). The catch in 1996 also increased over the pre-moratorium means, 1984-89 (78%) and 1986-91 (141%). Effort in 1996, the highest in the time series, was similar to 1995, but increased over the 1984-89 (48%), 1986-91 (67%), and 1992-95 (27%) means. CPUE in 1996 increased over 1995 (26%) and the 1984-89 (21%), 1986-91 (48%), and 1992-95 (21%) means. Comparison of 1994-96 retained catch with that of 1992 and 1993 provides an indication of the effectiveness of the elimination of quotas in 1994 on maintaining catch at 1992 and 1993 SFA quota levels. The number of small salmon retained in 1996, the highest since 1985, increased over 1994 (40%) and 1995 (15%) and the quota years of 1992 (135%) and 1993 (134%); the catch also increased over the means: 1984-89 (28%); 1986-91 (74%); 1992-95 (64%).

In the fall hook-and-release fishery in 1996, 128 small and 17 large salmon were released; effort expended was 231 rod days. In 1995, 30 small and 9 large salmon were released with an effort expenditure of 158 rod days.

Counts at Counting Fence and Fishway

In 1996, the counting fence on the main stem of the Gander River operated from May 31 to August 26. Counts for the period 1989-96 were as follows (see also Fig. 2):

Year	Small salmon	Large salmon	Prop. large
1989	7,743	473	0.055
1990	7,520	508	0.063
1991	6,445	670	0.094
1992	18,179[1]	4,162[1]	0.186[1]
1993	25,905	1,734	0.062
1994	18,080	1,072	0.056
1995	22,002	1,121	0.048
1996	23,665	1,753	0.069

[1]Adjusted count (see text)

The count of small salmon in 1996, the second highest of the moratorium years, increased over 1995 by 8%. The count of large salmon increased over 1995 (56%) and was the second highest of the moratorium years. The proportion of large salmon in 1996 increased over that of 1995 (44%) and was the second highest of the moratorium period.

Counts of small and large salmon at the fishway located in Salmon Brook tributary for the period 1974-96 are shown in Table 2 and Fig. 2. The count of small salmon in 1996 decreased from 1995 (41%) and the 1984-89 (12%) and 1992-95 (29%) means but increased over the 1986-91 (32%) mean. The count of large salmon in 1996 was the second highest on record; it decreased from 1995 (10%) but increased over the 1984-89 (405%), 1986-91 (751%), and 1992-95 (13%) means. The proportion of large salmon for Salmon Brook in 1996 was 11% which compares to 7% in 1995 and 2, 2, and 7% for the 1984-89, 1986-91, and 1992-95 means, respectively.

Fig. 3 shows the cumulative percentage of small salmon counted at the counting fence by day for 1989-96. The days are standardized for all years and the date on which the first fish was counted is denoted by an arrow. The earliest date on which the median count occurred was in 1996, just a few days ahead of 1995. The latest median date was in 1991.

Total River Returns, Spawning Escapement, and Percentage of Conservation Requirement Achieved

Total river returns, spawning escapements, potential egg depositions, and percentage of coservation egg requirement achieved for Gander River in 1989-96 are presented in Table 3. The percentage of conservation egg requirement achieved for 1989-96 is also shown in Fig. 4. Less than 50% of conservation requirement was achieved for small salmon in terms of egg deposition prior to the moratorium. During the moratorium, target conservation egg requirement was achieved in 1992, 1993, and 1996, although the years 1994 and 1995 were close to requirement at 91 and 95%. The requirement for small salmon was met only in 1993.

Trends in Total Numbers of Recruits and Spawners

The estimated number of small salmon recruits and corresponding number of spawners for each year-class are shown in Table 4 and Fig. 5A. Estimated refers to years prior to 1992. There was a lot of variability in recruitment from a given spawning escapement. The ratio of total number of small salmon recruits to spawners (R/S) increased in 1996 and was the second highest observed (Fig. 5B). There was no identifiable overall trend in numbers of small salmon spawners (Fig. 5C). Expressing conservation spawning requirement in terms of small salmon (horizontal line in Fig. 5C), it is evident that requirement was met or close to being met in 1979, 1981, and 1993. Numbers of spawners in 1992-96 compare well with higher values in the past, particularly the late 1970s and early 1980s, and represent a substantial improvement over the lows observed for 1989-91. Recruitment in 1996 improved over 1995 but remained similar to the low levels observed since 1989. There was a significant decline ($r^2 = 0.42$; $df = 21$; $P < 0.01$) in the total number of small salmon recruits for Gander River since 1974 (Fig. 5D).

Anticipated Returns in 1997

The estimated number of small salmon recruits anticipated for 1997, based on the average R/S for each smolt-age grouping, is approximately 29,640; corresponding low and high values are approximately 16,080 and 39,580 (Table 4 and Fig. 5D). The anticipated number of small salmon returns in 1997 based on the mean is well above conservation requirement (Fig. 5C). An idea of the precision of these estimates can be obtained by examining the differences between estimated and observed returns for 1995 and 1996 shown in Table 4. The variability described in Fig. 5A must be kept in mind with respect to estimates of anticipated returns.

Recruit Overfishing

During the commercial fishery moratorium years 1992-96, estimated numbers of small salmon spawners in Gander River were above the replacement (diagonal) line but remained below conservation requirement (horizontal) line for all years except 1993 and 1981. The three years immediately preceeding the moratorium, 1989-91, were well below the replacement line and conservation requirement.

Net Marks

The numbers of small and large salmon examined for net marks and the numbers and percentages bearing net marks in 1994-96 were as follows:

Year	Small salmon (No.)			Large salmon (No.)			Total (No.)		
	Examined	Marked	%	Examined	Marked	%	Examined	Marked	%
1994	223	36	16.1	10	1	10.0	233	37	15.9
1995	233	16	6.9	13	6	46.1	246	22	8.9
1996	407	52	12.8	34	2	5.9	441	54	12.2

The highest percentage of small salmon with net marks occurred in 1994 while for large salmon it occurred in 1995. For small and large salmon combined (total), the highest incidence of net marks was encountered in 1994.

Impacts of the Moratorium

The results of statistical analysis on data for the factors presented in Tables 1 and 3, comparing the moratorium period (1992-96) with the pre-moratorium period (1984-91), are summarized as follows:

Factor	Z	P
Total river returns (No.) - small salmon	-2.09	0.0369
- large salmon	-2.09	0.0369
Proportion of large salmon	0.00	0.9999
Proportion of repeat spawning grilse	0.15	0.8835
Whole weight (kg)	6.59	0.0001
Fork length (cm)	7.83	0.0001

There were significant increases in returns of small and large salmon during the moratorium over pre-moratorium years. However, the proportion of large salmon in total returns and the proportion of repeat spawning grilse in the small salmon category did not change significantly ($P > 0.05$). Weight and length (for sexes combined plus unsexed fish) increased significantly over pre-moratorium years.

Individual regressions of ln whole weight on ln fork length for the moratorium and pre-moratorium periods were as follows:

Pre-moratorium: $\ln Y = 2.6972 \ln X - 16.4093$ $r^2 = 0.6965$ $P = 0.0001$ df = 888

Moratorium: $\ln Y = 2.8373 \ln X - 17.2856$ $r^2 = 0.4213$ $P = 0.0001$ df = 567

The overall general linear model with separate slopes ($r^2 = 0.5571$; $P = 0.0001$) showed there was no significant difference in slopes ($F = 1.09$; $P = 0.2974$). Therefore the common slope model was used to test for difference in adjusted means. The adjusted mean (ln scale) for the moratorium period (0.5167; SE = 0.0082) was not significantly different ($F = 0.11$; $P = 0.7452$) from the pre-moratorium mean (0.5133; SE = 0.0066); r^2 for the common slope model was 0.5568 ($P = 0.0001$).

Discussion

In the present assessment, biological characteristics information was updated and applied on an individual year basis to a larger extent than previously, when there was greater reliance on default values. Consequently, the percentage of conservation egg requirement achieved for each year since 1989 has changed from that reported in previous documents (see O'Connell *et al.* MS 1996). Also, for the first time, a factor of 10% for hook-and-release mortality was applied in the calculation of total river escapements and spawning escapements for the years 1993-96, the only years with sufficient information on numbers of released fish. The mortality rate of 10% was arbitrarily chosen. Brobbel *et al.* (1996) reported a mortality rate of 12% for bright Atlantic salmon angled to exhaustion under controlled conditions in the Miramichi River, New Brunswick. These mortalities occurred within 12 hours and mean water temperature during the angling period was 16 °C.

As anticipated, with the closure of the commercial salmon fishery, there were significant increases in the numbers of small and large salmon entering Gander River during moratorium years compared to pre-moratorium years. Conservation egg requirement was achieved in three of the five moratorium years and nearly so in the remaining two years. It was anticipated that the removal of size-selective commercial fishing gear would have resulted in an increase in the proportion of large salmon during the moratorium. This did not occur in the case of Gander River, which is contrary to results obtained for other rivers in northern and eastern Newfoundland (O'Connell *et al.* MS 1997b; O'Connell and Reddin MS 1997). Commercial fishing gear was also a source of mortality for repeat spawning grilse; however, no increases in returns were noted for these fish. Other anticipated results of the removal of commercial fishing gear were increases in size (mean weight and mean length) and improved condition. With respect to condition, it was felt that commercial gear selectively removed the better conditioned or more robust fish. There were significant increases in weight and length of small salmon during the moratorium, but the condition index remained essentially the same.

It was not possible to meaningfully compare biological charcateristics of large salmon before and during the moratorium because of insufficient sample sizes. This stems largely from the fact that the retention of large salmon in the recreational fishery has been prohibited since 1984. Sampling of large salmon at the counting fence has been kept to a mimimum in order to minimize the risk of mortality to this valuable component of the stock.

The estimated total population size of Gander River small salmon since 1989 has been quite low compared to the late 1970s and early 1980s. Had there been a commercial fishery in 1992-96, total river returns and spawning escapements would probably have continued at the low levels indicative of the period 1989-91. Anticipated returns of small salmon in 1996, based on the average R/S for 1992-95 was approximately 15,200 with corresponding low and high estimates of 9,060 and 21,090. The actual return of small salmon was 23,946. Another estimate of returns for 1996 was made based on the R/S value for 1995 and this was 21,000 small salmon, much closer to the actual result. The R/S value for 1995 had improved considerably over the previous several years, probably due in part to increased marine survival. The prediction for 1996 using the 1995 value assumed sea survival would remain the same. The above analysis was based on fixed parameter values (smolt-age composition and commercial and recreational fishery exploitation rates) and assumes constant natural survival rates both in freshwater and in the sea. The use of constants in the prediction of adult returns is risky since the parameters are most likely subject to annual variability. For instance, smolt-to-adult survival has been shown to be highly variable in Northeast Brook, Trepassey (SFA 9) and Conne River (SFA 11) (O'Connell *et al.* MS 1997). Each of these rivers, Rocky River (SFA 9), and Campbellton River (SFA 4) showed an increase in smolt-adult survival in 1996 over 1995. Western Arm Brook (SFA 14A) showed a decline from 1995, but survival for 1995 was the highest since 1983 and that of 1996 the second highest. An estimate of returns of small salmon based on juvenile population estimates as indicative of abundance predicts conservation requirement will be exceeded in 1997 (Ryan *et al.* MS 1997).

Gander River smolts characteristically have a modal smolt age of 4+ years. Increased returns of adults with a smolt age of 3+ years, the progeny of increased numbers of spawners in the first year of the moratorium in 1992, are expected in 1997. The magnitude of these returns will depend on the strength of the 3+ age component. The first year of major returns will be in 1998 when the 4+ smolt-age component from the 1992 spawning and the the 3+ smolt-age component from the 1993 spawning are recruited. This expectation assumes that overall survival will not fall below that currently being observed.

The objective of implementing SFA quotas on the retention of small salmon in the recreational fishery was to constrain catches to levels observed just prior to the moratorium, with the intent of not reallocating catch from the commercial fishery to the recreational fishery. This was also the objective of the split seasonal bag limit (three fish prior to and after July 31) since historically the major proportion of total seasonal catch has been taken prior to July 31. Quotas were effective in this regard but the split season was not as successful as anticipated. In 1992 and 1993, quotas constrained the retention of small salmon in the recreational fishery to around 1,200 each year. By comparison, in 1994, 1995, and 1996, the numbers of small salmon retained increased to 2,122, 2,598, and 3,009, respectively. The angling exploitation rate was 0.116 in 1994, 0.117 in 1995, and 0.13 in 1996, which compares to 0.070 and 0.049 in 1992 and 1993. The increased exploitation was most likely a function of the removal of quotas. Had the split season not been in place however, catches could have been much higher.

The occurrence of net marks was likely the result of encounters with illegal and legal fishing gear in coastal waters and illegal gear in the river below the counting fence. It is not possible to accurately estimate the extent of such removals. Therefore total returns considered in the context of being equivalent to total production during the moratorium have to be regarded as minimum values.

Cautions associated with the parameter values used to calculate the conservation egg requirement have been discussed previously by O'Connell and Dempson (1995) and will not be dealt with here. In the above analysis, total conservation egg requirement came from small salmon and the contribution from large salmon was considered as a buffer. Recently, managers have expressed an interest in setting conservation requirements for both small and large salmon. Using the biological characteristics information and relative proportions of small and large salmon presented above and computational formulae presented in O'Connell *et al.* (MS 1997a), it is possible to derive a conservation requirement for each component for Gander River. These separate requirements have to be viewed from both the biological and operational perspectives. On the biological side, the proprotion of eggs to come from each component should reflect natural stock characteristics. This may not be readily defined due to potential modifications in proportions resulting from decades of size-selective commercial fisheries. On the operational side, Fig. 7 gives an idea of the outcome of selecting various proportions of the conservation egg requirement to come from small salmon on the proportionate contributions required from large salmon in order to achieve conservation egg requirement. By selecting a percentage contribution for small salmon and locating the corresponding point on the small salmon curve, then drawing a line from this point vertically to meet the curve for large salmon, the number of small and large salmon corresponding to the point on each curve can be read from the y-axis. The tradeoff between each component in numbers needed to meet egg requirement is quite apparent. However, the question of whether a particular choice of proportions is biologically appropriate for the population and the long-term biological consequences of such a choice still has to be considered.

Acknowledgements

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Table 1. Biological characteristics data for female small salmon and with sexes combined plus unsexed fish by year and for pre-moratorium (1984-91) and moratorium (1992-96) periods for Gander River (SFA 4), Newfoundland. WW = whole weight (kg); FL = fork length (cm); RS = repeat spawning grilse.

	Sexes combined plus unsexed								Females						%	
Year	$\bar{X}$ WW	SD	N	$\bar{X}$ FL	SD	N	% RS	N	$\bar{X}$ WW	SD	N	$\bar{X}$ FL	SD	N	Female	N
1984	1.54	0.35	109	51.3	3.80	109	2.8	3	1.54	0.39	71	51.1	3.89	71	65	71
1985	1.62	0.33	111	51.0	3.66	113	1.8	2	1.63	0.34	82	51.0	3.59	84	74	84
1986	1.61	0.35	51	52.1	3.27	51	11.8	6	1.76	0.30	32	53.1	2.90	32	82	32
1987	1.49	0.37	19	50.6	3.50	19	0.0	0	1.47	0.40	15	49.8	3.45	15	79	15
1988	1.63	0.33	40	52.6	3.56	40	5.0	2	1.61	0.33	33	52.4	3.74	33	83	33
1989	1.60	0.38	187	52.8	4.11	186	9.4	17	1.66	0.39	89	53.5	4.13	88	83	89
1990	1.80	0.47	245	53.7	4.07	245	5.4	13	1.84	0.48	170	54.0	4.24	170	73	170
1991	1.70	0.46	142	52.8	3.93	141	0.7	1	1.66	0.47	110	52.3	3.90	109	85	110
1992	1.80	0.44	149	54.3	3.80	172	0.0	0	1.78	0.44	87	54.6	4.02	108	65	109
1993	1.86	0.41	144	55.1	3.98	145	5.6	8	1.85	0.39	73	55.0	3.28	73	70	73
1994	1.75	0.49	196	53.6	4.18	196	7.5	13	1.83	0.46	101	54.1	4.25	101	73	101
1995	1.73	0.51	76	52.5	4.73	73	2.7	2	1.72	0.51	48	52.1	5.13	46	66	48
1996	1.95	0.57	105	54.6	4.40	120	5.9	7	1.95	0.56	68	54.6	4.35	71	70	71
Pre-moratorium																
1984-91	1.66	0.42	904	52.5	4.01	904	4.9	44	1.69	0.431	602	52.6	4.10	602	77	604
Moratorium																
1992-96	1.81	0.48	670	54.1	4.209	706	4.4	30	1.83	0.47	377	54.3	4.22	399	69	402

Table 2. Counts of small and large salmon at Salmon Brook fishway, 1974-96. Partial counts are in parentheses and are not included in means. Adjusted counts are bold and in italics.

Year	Small salmon	Large salmon
1974	857	9
1975		
1976		
1977		
1978	755	52
1979	(404)	(6)
1980	997	15
1981	2459	33
1982	1425	18
1983	978	12
1984	1081	38
1985	1663	26
1986	1064	12
1987	493	9
1988	1562	24
1989	596	24
1990	***345***	***8***
1991	245	2
1992	1168	101
1993	1560	87
1994	968	83
1995	1600	125
1996	946	112
$\bar{X}$ 84-89	1076.5	22.2
95% LCL	572.9	11.2
95% UCL	1580.1	33.2
N	6	6
$\bar{X}$ 86-91	717.5	13.2
95% LCL	190.5	3.7
95% UCL	1244.5	22.6
N	6	6
$\bar{X}$ 92-95	1324.0	99.0
95% LCL	835.4	68.8
95% UCL	1812.6	129.2
N	4	4

Table 3. Total river returns, spawning escapements, and percentage of conservation requirement achieved in terms of small salmon and eggs for Gander River, 1989-96.

Year	Total returns (No.)		Prop.	Spawning escapement (No.)		Egg deposition (Millions)		% cons. req. achieved		Eggs per
	Small	Large	Large	Small	Large	Small	Large	Small	Eggs	240 sq. m
1989	7743	473	0.0576	6570	473	18.005	2.264	30.1	44	127
1990	7740	508	0.0616	6585	508	15.381	2.126	30.2	38	110
1991	6745	670	0.0904	5565	670	13.757	2.825	25.5	36	104
1992	18179	4180	0.1869	17143	4180	36.317	18.422	78.5	118	343
1993	26205	1734	0.0621	24739	1725	52.477	6.800	113.3	128	372
1994	18273	1072	0.0554	16106	1068	37.697	4.504	73.8	91	264
1995	22266	1121	0.0479	19606	1114	38.994	4.696	89.8	95	274
1996	23946	1753	0.0682	20822	1746	49.796	7.362	95.4	124	358

Table 4. Data used to estimate total recruits and anticipated returns in 1997 for Gander River.
Smolt age distribution is 37% 3+ & 63% 4+. Recruit years are in brackets (3+ & 4+).

Spawning Year i(i+5,i+6)	Total river escapement Year i	Total recruits Year i	Spawning escapement Year i	Recruits 3+ i+5	Recruits 4+ i+6	Recruits Total	No. of recruits per spawner (R/S ratio) 3+ i+5	R/S 4+ i+6	R/S Total	Return yr
74 (79 & 80)	14367	35918	12100	24583	26556	51139	2.0317	2.1947	4.2264	3.1779
	18835	47088	15863	15596	45636	61232	0.9832	2.8769	3.8601	4.9949
76 (81 & 82)	15025	37563	12654	26802	21691	48493	2.1180	1.7141	3.8322	2.7674
	14361	35903	12095	12739	20266	33005	1.0533	1.6756	2.7288	2.3457
78 (83 & 84)	21089	52723	17761	11902	20215	32117	0.6701	1.1382	1.8083	1.6686
	26576	66440	22382	11872	33473	45346	0.5304	1.4955	2.0260	2.8799
80 (85 & 86)	16861	42153	14200	19659	23535	43194	1.3844	1.6574	3.0418	2.2238
	28975	72438	24403	13822	14394	28216	0.5664	0.5898	1.1563	1.3187
82 (87 & 88)	13772	34430	11599	8454	26775	35229	0.7288	2.3084	3.0373	3.7595
	12867	32168	10837	15725	12195	27920	1.4511	1.1254	2.5765	1.7880
84 (89 & 90)	12835	32088	10810	7162	12191	19353	0.6626	1.1277	1.7903	1.5277
	21253	53133	17899	7160	10623	17783	0.4000	0.5935	0.9935	1.0893
86 (91 & 92)	14943	37358	12585	6239	11453	17692	0.4958	0.9100	1.4058	1.7839
	9139	22848	7697	6726	16509	23235	0.8739	2.1449	3.0188	2.8221
88 (93 & 94)	17000	42500	14317	9696	11512	21208	0.6772	0.8041	1.4813	1.8331
	7743	19358	6570	6761	14026	20787	1.0291	2.1349	3.1640	3.3859
90 (95 & 96)	7740	19350	6585	8238	14911	23149	1.2510	2.2644	3.5153	3.8380
	6745	16863	5565	8757			1.5736			
92 (97 & 98)	18179	18179	17143							
	26205	26205	24739							
94 (99 & 00)	18273	18273	16106							
	22266	22264	19606							
96 (01 & 02)	23946	23668	20822							
98 (03 & 04)										

Anticipated returns 97 based on 1993-96 mean

	R/S ratios 3+	R/S ratios 4+	Number of small 3+	Number of small 4+	Number of small Total	Total 1.10
Mean	1.1327	1.8371	19418	10223	29641	32477
Hi	1.5736	2.2644	26976	12601	39578	43364
Low	0.6772	0.8041	11609	4475	16084	17623

Comparison of observed & expected in 95-96

Year	R/S ratio 3+	R/S ratio 4+	Number of small 3+	Number of small 4+	Estimated small	Observed small	Difference (Obs-Est)	%
95*	0.8601	1.2863	5664	8451	14115	22266	8151	37
96**	0.9578	1.4985	5330	9868	15198	23946	8748	37
							Mean diff	37

* From O'Connell et al. (MS 1995)

** From O'Connell et al. (MS 1996)

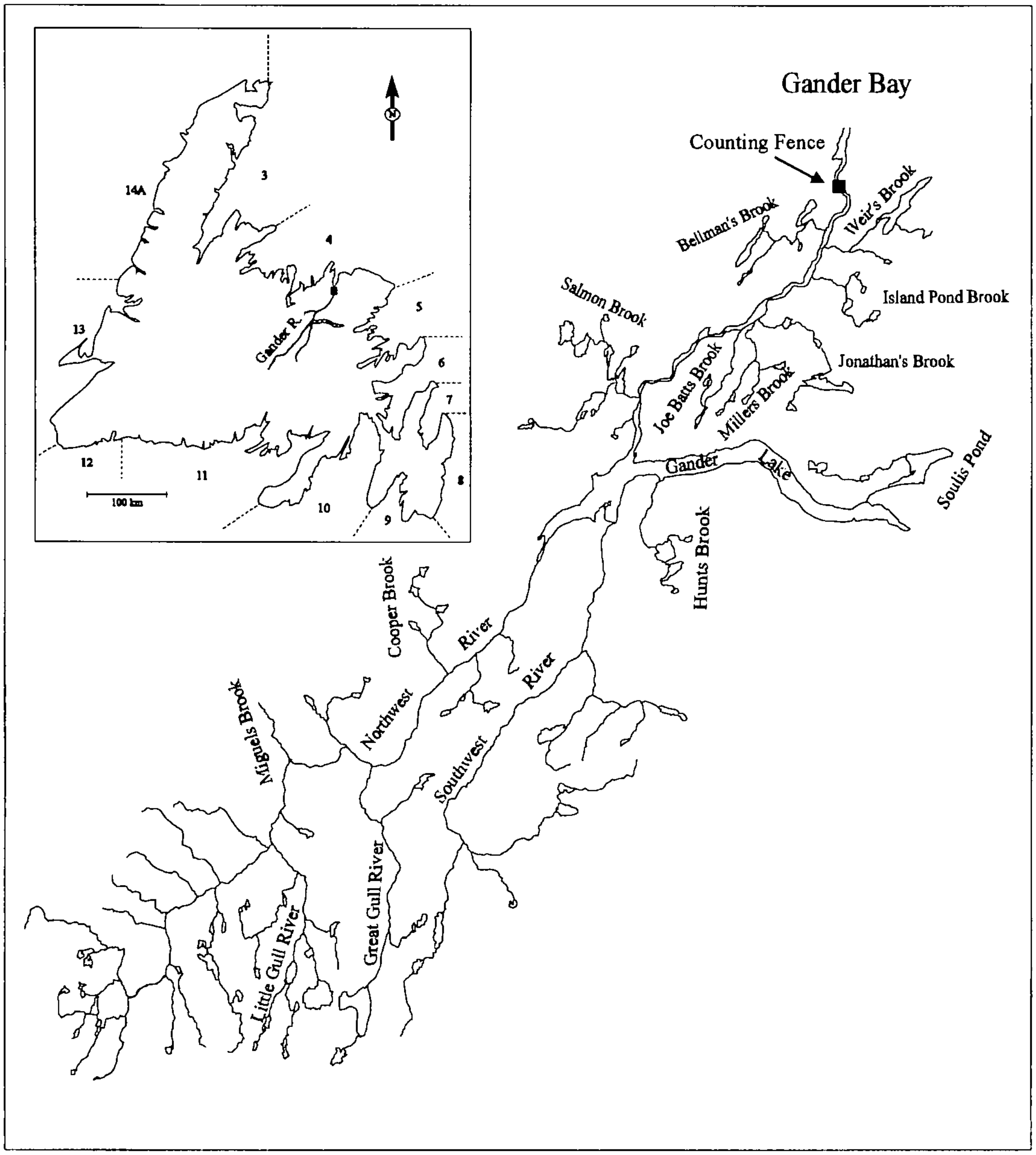

Fig. 1. Map showing the Gander River watershed and location of the counting fence (square symbol). Inset shows the Salmon Fishing Areas in Newfoundland and the location of Gander River.

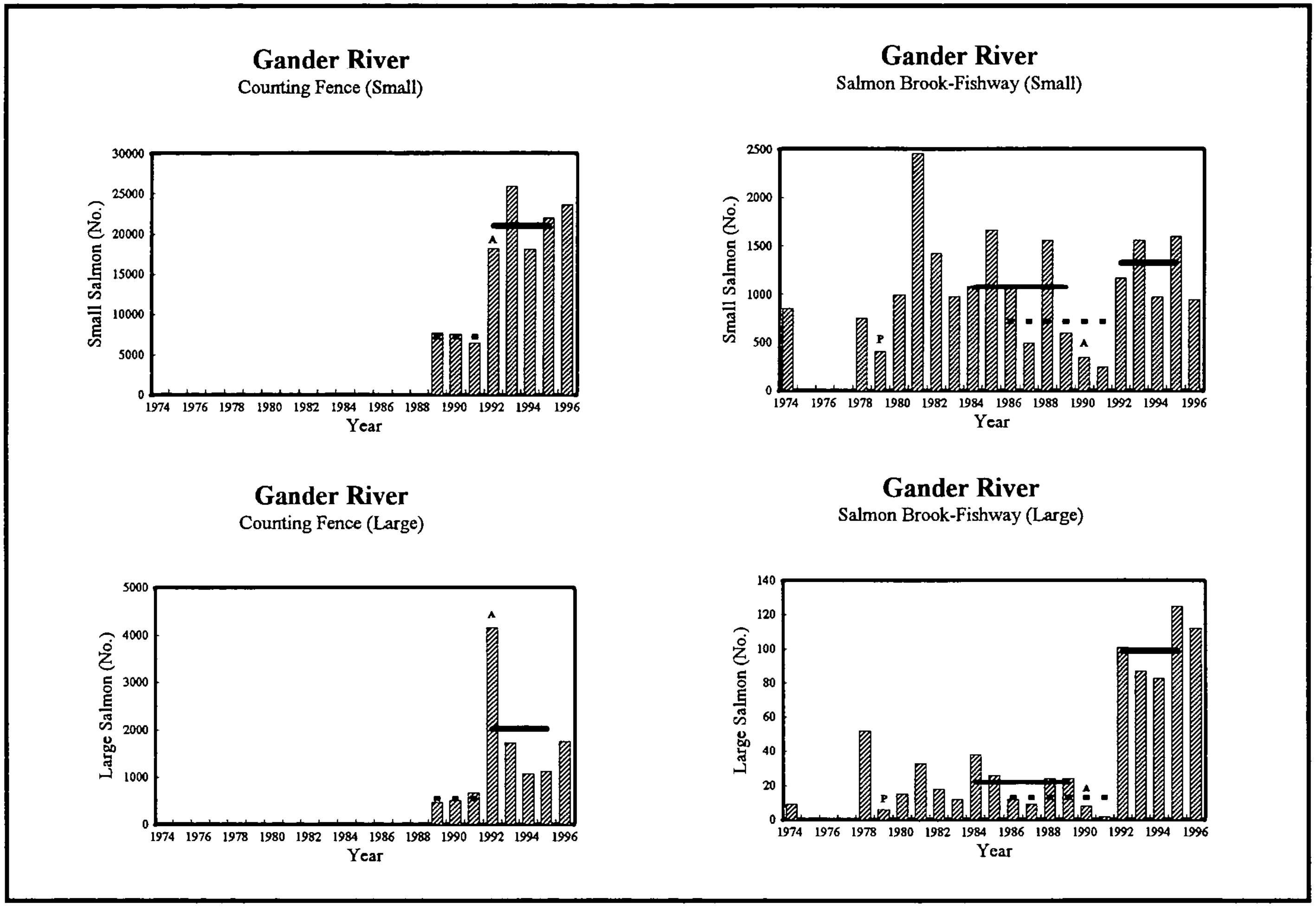

Fig. 2. Counts of small and large salmon at the Gander River counting fence and at the fishway located on the Salmon Brook tributary, 1974-96. The thin solid horizontal line represents the 1984-89 mean, the broken line the 1986-91 mean, and the thick solid line the 1992-95 mean. A = adjusted count; P = partial count, not included in the means.

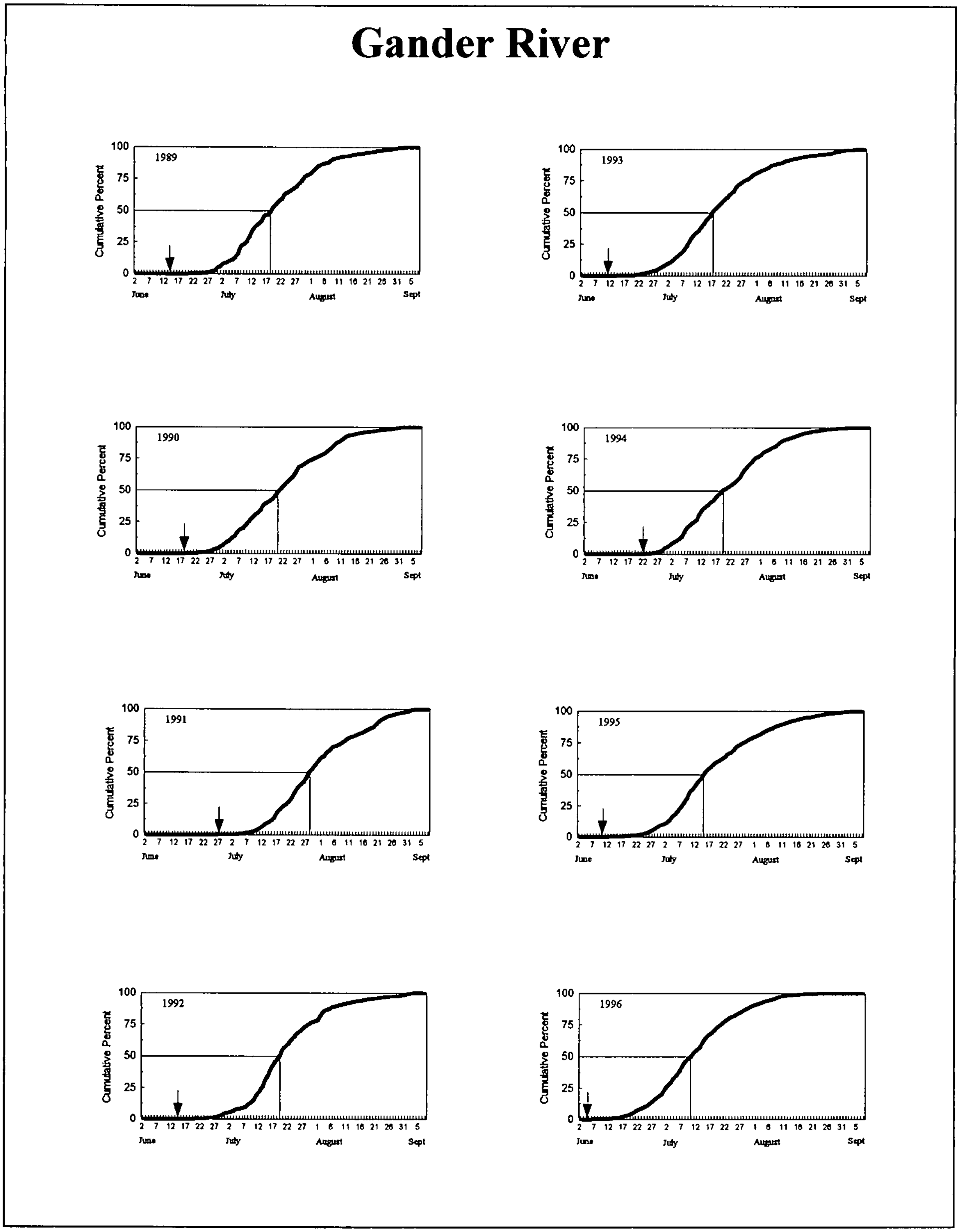

Fig. 3. Cumulative percentage of small salmon counted by day for Gander River in 1989-96. Days are standardized for all years and the date on which the first fish was counted is denoted by an arrow.

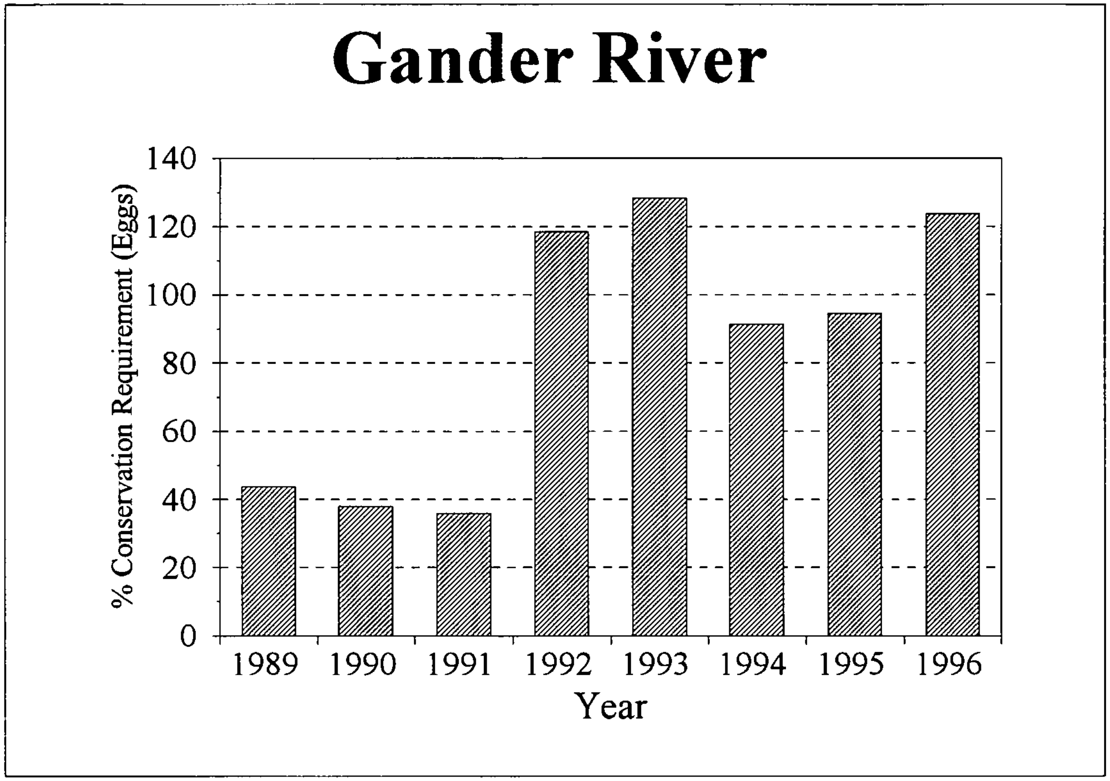

Fig. 4. Percentage conservation egg requirement achieved for Gander River, 1989-96.

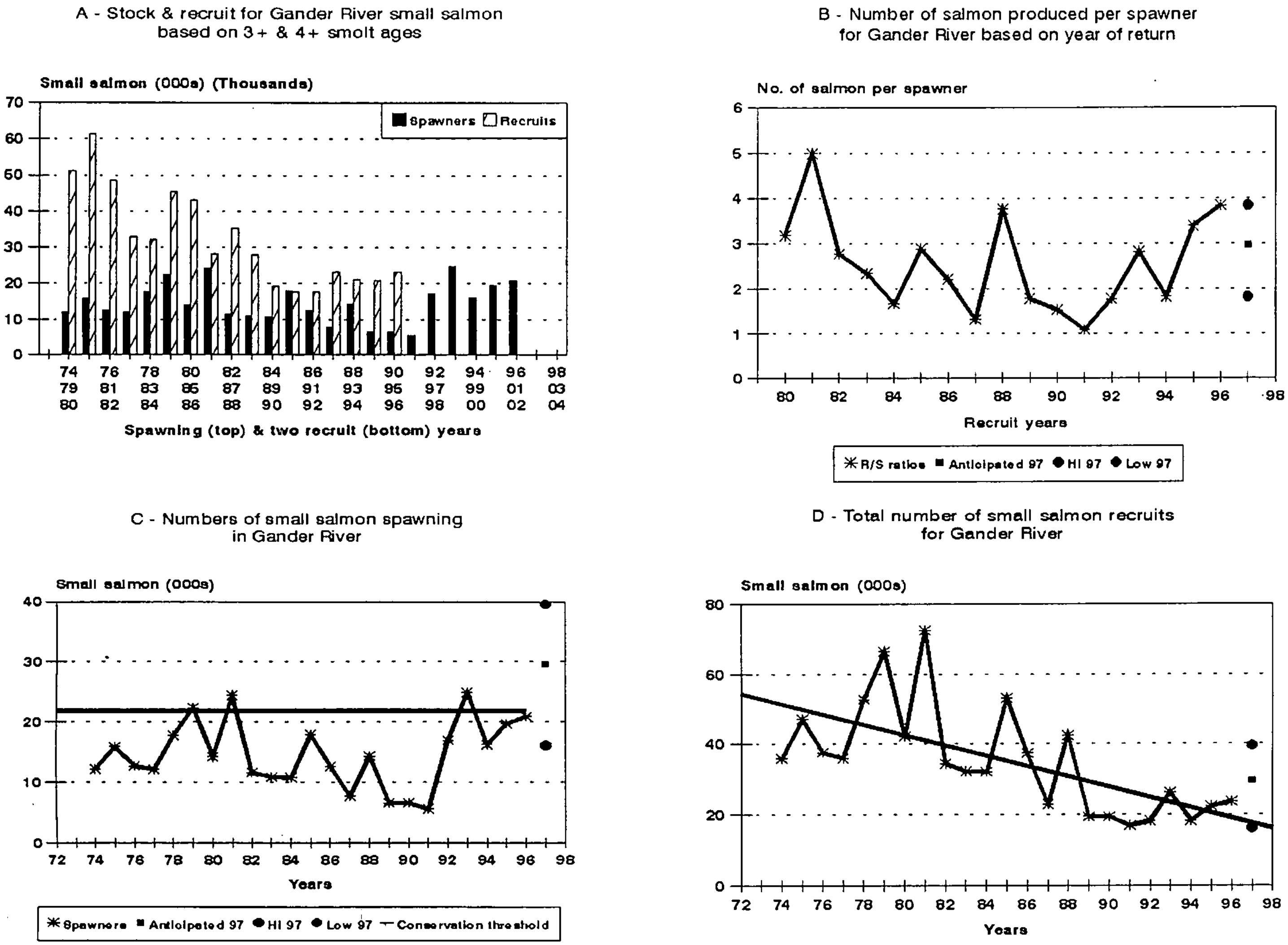

Fig. 5. Number of small salmon spawners and recruits, lagged and totalled according to smolt age (A), number of small salmon produced (years i+5,6) per spawner (year i) (B), number of small salmon spawners, 1975-96, and anticipated returns in 1997 in relation to conservation spawner requirement (C), and the total number of small salmon produced (recruits), 1975-96, and anticipated returns for 1997 (D) for Gander River.

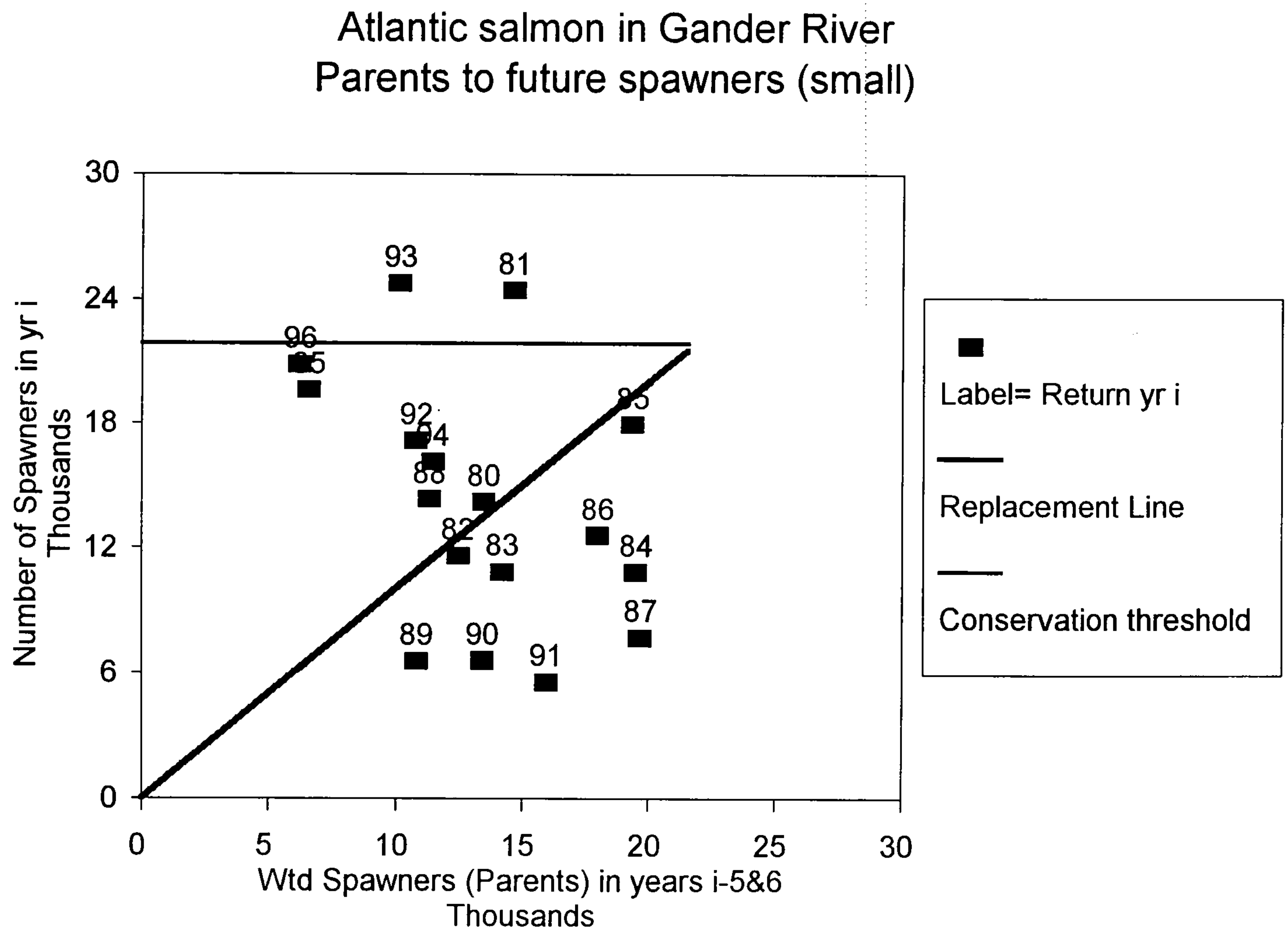

Fig. 6. The relationship between parents and spawners (after exploitation), the replacement (diagonal) line, and conservation spawner requirement (horizontal) line for small salmon for Gander River.

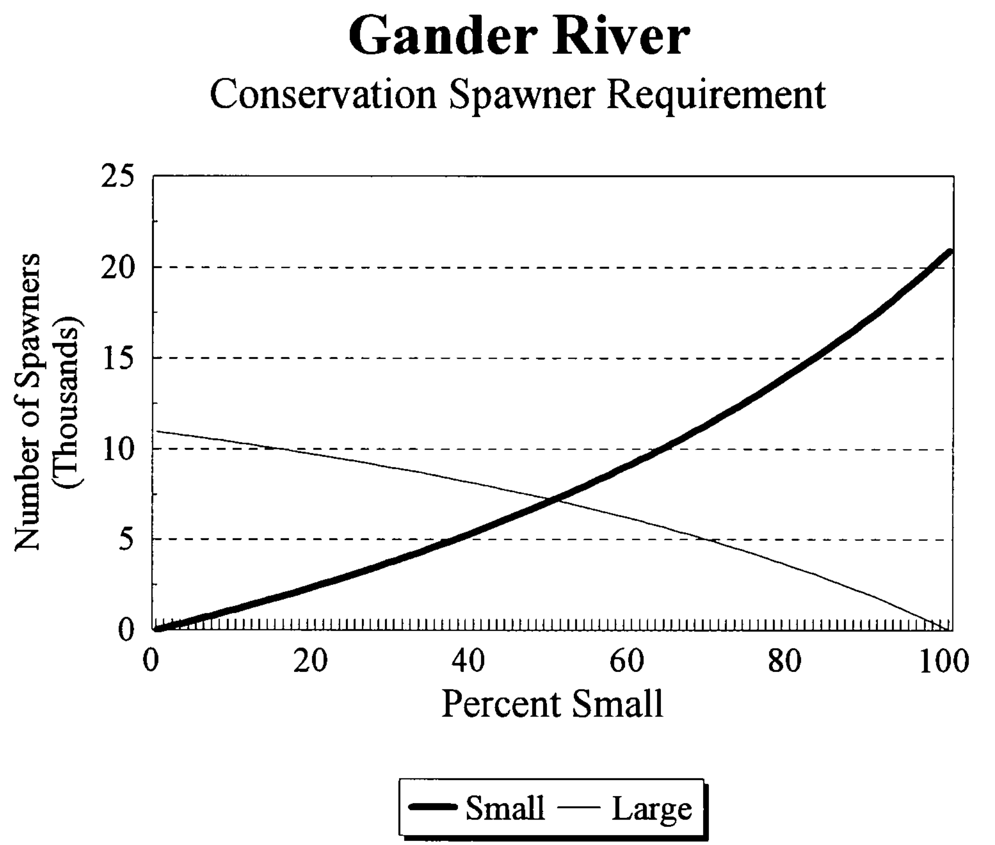

Fig. 7. Graphic representation showing the impact of selecting a particular percentage of conservation egg requirement to come from small salmon on the number of large salmon required to make up the remainder of the egg requirement, for Gander River. See text for further explanation.

Appendix 1. Atlantic salmon recreational fishery catch and effort data for Gander River, Notre Dame Bay (SFA 4), 1974-96. Ret. = retained fish; Rel. = released fish.

	Effort	Small (<63 cm)			Large (>=63 cm)			Total (Small + Large)			
Year	Rod Days	Ret.	Rel.	Tot.	Ret.	Rel.	Tot.	Ret.	Rel.	Tot.	CPUE
1974	5153	2270	.	2270	19	.	19	2289	.	2289	0.44
1975	6670	2976	.	2976	38	.	38	3014	.	3014	0.45
1976	6633	2374	.	2374	132	.	132	2506	.	2506	0.38
1977	6939	2269	.	2269	927	.	927	3196	.	3196	0.46
1978	8322	3332	.	3332	389	.	389	3721	.	3721	0.45
1979	7217	4199	.	4199	318	.	318	4517	.	4517	0.63
1980	6384	2664	.	2664	268	.	268	2932	.	2932	0.46
1981	10643	4578	.	4578	249	.	249	4827	.	4827	0.45
1982	8026	2176	.	2176	205	.	205	2381	.	2381	0.30
1983	6934	2033	.	2033	239	.	239	2272	.	2272	0.33
1984	7590	2028	.	2028	13	.	13	2041	.	2041	0.27
1985	10207	3358	.	3358	*	.	0	3358	.	3358	0.33
1986	9740	2361	.	2361	*	.	0	2361	.	2361	0.24
1987	6384	1444	.	1444	*	.	0	1444	.	1444	0.23
1988	7943	2686	.	2686	*	.	0	2686	.	2686	0.34
1989	6290	1173	.	1173	*	.	0	1173	.	1173	0.19
1990	7118	1155	.	1155	*	.	0	1155	.	1155	0.16
1991	5853	1180	.	1180	*	.	0	1180	.	1180	0.20
1992	6273	1268	525	1793	*	3	3	1268	528	1796	0.29
1993	9073	1271	1950	3221	*	92	92	1271	2042	3313	0.37
1994	11287	2122	448	2570	*	39	39	2122	487	2609	0.23
1995	12215	2598	612	3210	*	74	74	2598	686	3284	0.27
1996	12347	2974	1153	4127	*	73	73	2974	1226	4200	0.34
84-89 $\bar{X}$	8354.0	2321.2	.	2321.2	.	.	.	2323.8	.	2323.8	0.28
95% CL	1998.7	1003.6	.	1003.6	.	.	.	1002.1	.	1002.1	0.07
N	5	5	0	5	0	0	0	5	0	5	5
86-91 $\bar{X}$	7388.8	1711.0	.	1711.0	.	.	.	1711.0	.	1711.0	0.23
95% CL	1910.7	931.9	.	931.9	.	.	.	931.9	.	931.9	0.09
N	5	5	0	5	0	0	0	5	0	5	5
92-95 $\bar{X}$	9712.0	1814.8	883.8	2698.5	.	52.0	52.0	1814.8	935.8	2750.5	0.28
95% CL	4207.5	1048.3	1135.9	1075.6	.	62.7	62.7	1048.3	1181.3	1137.0	0.09
N	4	4	4	4	0	4	4	4	4	4	4

1987 DATA NOT INCLUDED IN MEAN.

IN THE ABOVE TABLE A PERIOD INDICATES NO DATA FOR THAT YEAR.

CPUE IS BASED ON RETAINED + RELEASED FISH FOR 1992-96 AND ON RETAINED FISH ONLY PRIOR TO 1992.

* NOT ALLOWED TO RETAIN LARGE SALMON IN INSULAR NEWFOUNDLAND.