DFO Atlantic Fisheries Research Document 94/13

MPO Pêches de l'Atlantique Document de recherche 94/13

Population Sizes of Juvenile Atlantic Salmon (*Salmo salar* L.) in Lakes of the Experimental Ponds Areas as a Measure of Stock Recovery in the Gander River, Newfoundland

P.M. Ryan[1], R. Knoechel[2], and M.F. O'Connell[1]

[1]Science Branch
Department of Fisheries and Oceans
P.O. Box 5667
St. John's, Newfoundland A1C 5x1

[2]Biology Department
Memorial University of Newfoundland
St. John's, Newfoundland A1B 3X9

[1]This series documents the scientific basis for the evaluation of fisheries resources in Atlantic Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the secretariat.

[1]La présente série documente les bases scientifiques des évaluations des ressources halieutiques sur la côte atlantique du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

Les Documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au secrétariat.

Abstract

This report is an examination of the population sizes of juvenile Atlantic salmon in two lakes at the headwaters of the Gander River system from 1979-93 as a measure of stock recovery in the entire river. The lakes are a part of the Experimental Ponds Area and a short history of studies in the Area is given for the convenience of the reader. Spring population sizes of juvenile salmon in two lakes of the Experimental Ponds Area from 1979 to 1984 were positively related to the abundance of returning adults as measured by angler success one year later. During this period, the commercial gillnet catch in Gander Bay increased. After that time, the relationship between juvenile abundance and subsequent river escapement disappeared, concurrent with a precipitous decline in the commercial gillnet catch in Gander Bay. These events suggested that dramatic changes in the marine mortality of adults had occurred. It appears likely that comparable indices of stock size will not be generated by recreational and commercial fisheries for future assessments and that stock recovery in the Gander River will be manifested in an increased abundance of young in the lakes of the Experimental Ponds Area. A stock-recruit curve for the Gander River developed from Experimental Ponds Area data has potential to serve as a means of evaluating angling management strategy and the attainment of maximum spawner capacity.

Resume

Le présent rapport porte sur l'étude de la grosseur des populations de saumons de l'Atlantique juvéniles dans deux lacs de la partie supérieure du réseau hydrographique de la rivière Gander de 1979 à 1993, étude visant à mesurer la reconstitution du stock dans l'ensemble de la rivière. Les lacs en question font partie d'une zone expérimentale ayant fait l'objet de diverses études, dont le lecteur trouvera un bref aperçu. Il a été établi que la grosseur des populations printanières de saumons juvéniles dans deux lacs de la zone expérimentale de 1979 à 1984 était directement proportionnelle à l'abondance des remontées de saumon, mesurée d'après les prises des pêcheurs à la ligne l'année suivante. Au cours de la période considérée, les prises commerciales au filet maillant dans la baie de Gander ont augmenté. Par la suite, la relation entre l'abondance des juvéniles et les échappées subséquentes dans la rivière a disparu, en même temps que les prises commerciales au filet maillant dans la baie de Gander ont subitement reculé. Ces phénomènes sembleraient dénoter des changements profonds dans la mortalité des adultes. Il est probable qu'on n'établira pas d'indices comparables de la grosseur du stock dans la pêche récréative et dans la pêche commerciale pour les évaluations futures, et que le rétablissement du stock se manifestera par une abondance accrue de juvéniles dans les lacs de la zone expérimentale. Une courbe stock-recrutement dans la rivière Gander établie à partir de données portant sur la zone expérimentale pourrait servir à évaluer la stratégie de gestion de la pêche à la ligne et à déterminer si l'on a atteint la capacité maximale de reproducteurs.

Introduction

This report is an examination of the population sizes of juvenile Atlantic salmon in two lakes at the headwaters of the Gander River system as a measure of stock recovery in the entire river.

Atlantic salmon returning as adults to spawn in the Gander River system of insular Newfoundland have been in low abundance at least since 1989-91; resulting in an egg deposition of only about 35 % of that required for the river (Porter and O'Connell 1992, O'Connell and Ash 1993). Changes in the fishery for adult salmon have included, in 1992, a closure of the commercial salmon fishery on the island and a quota in the recreational fishery (with subsequent catch and release fishing) (O'Connell and Ash 1993).

As a result of the changing salmon fishery and resultant changes in applicable fishing effort statistics, alternate methods to assess stock recovery in the Gander River system are being explored. One of these is the assessment of variations in juvenile abundance with the assumption that large increases in the abundance of juveniles are, unless shown otherwise, indicative of increases in the size of the spawning stock. Previously, it has been shown that the spring population size of juvenile salmon in the Experimental Ponds Area prior to 1985 was a strong (r=0.813) positive correlate of the subsequent year's angler success (fish/rod/week) (Ryan 1986a). Thus, there was strong evidence that juvenile abundance in the headwaters of the river system was an index of the health of the stock. Additionally, it was expected that a stock-recruit relationship could be developed from a measure of adult escapement to the river and the known abundance of juveniles at the headwaters.

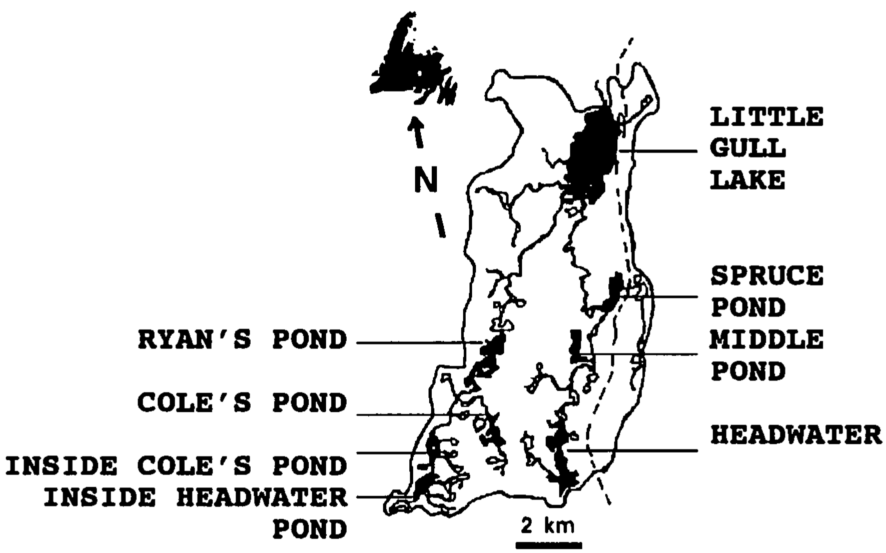
The existence of a trend between juvenile abundance and subsequent adult escapement was indicative of a relatively consistent rate of marine mortality during that period. Additionally, the maintenance of that trend in the future requires a rate of marine mortality comparable to that occurring previously. Thus, deviations from the positive relationship between the abundance of young and the abundance of adults escaping to the river can be considered as an indicator of changing marine mortality. In this paper we examine that relationship with data available up to 1993 with the goal of assessing the applicability of juvenile abundance in the lakes of the Experimental Ponds Area as a measure of stock recovery in the Gander River system. Additionally, we examine available data for the purpose of the development of a stock-recruit curve for the Gander River.

The Experimental Ponds Area

Headwater and Spruce ponds are dilute (mean conductance 35 $\mu S \cdot cm^{-1}$), brown-water lakes within the Department of Fisheries and

Oceans' Experimental Ponds Area (48°19'N; 55°28'W) at the headwaters of the Gander River system (Fig. 1). Their physical and chemical characteristics approximate the average descriptors of water quality in insular Newfoundland (Ryan and Wakeham 1984). Headwater Pond (76.1 ha, maximum depth = 3.3 m, mean depth = 1.1 m) drains 3.5 km to the north into Spruce Pond (36.5 ha, maximum depth = 2.1 m, mean depth = 1.0 m) and the Spruce Pond outlet flows about 155 km northeast to the Atlantic Ocean. The closest major concentration of salmon spawning substrate is about 12 km downstream of Spruce Pond (Ryan and Wakeham 1984). In addition to anadromous Atlantic salmon, other fishes present in these lakes are the brook trout (Salvelinus fontinalis), the American eel (Anguilla rostrata), and the threespine stickleback (Gasterosteus aculeatus).

Figure 1. Watershed of the Experimental Ponds Area at the headwaters of the Northwest Gander River, central Newfoundland (inset). The dashed line through the east side of the watershed is the Bay D' Espoir highway.



History of the Experimental Ponds Area

Limnological data have been collected from the Experimental Ponds Area since 1977 with documentation of chemical, physical, and biological conditions. Original (1977-82) studies by the Department of Fisheries and Oceans (DFO) were primarily intended to determine the long-term effects of forest pesticide use on aquatic systems. However, in 1983 it was concluded that the determination of impacts of the forest pesticide of use (Matacil) at common industrial applications was probably unattainable. With the developing time series on salmonid population structures, DFO decided to continue the monitoring of the salmonids and associated habitat at a reduced level with the goal of contributing to the understanding of factors affecting Atlantic salmon production. In 1987, monitoring studies were expanded when the Area became part of the DFO LRTAP (long-range transport of air pollutants) Biomonitoring Program, along with sites in Ontario, Quebec, and Nova Scotia. The Biomonitoring Program was intended to document aquatic ecosystem changes resulting from anticipated reductions in acidic precipitation. The Experimental Ponds Area was removed from the Biomonitoring Program in 1988, but was reinstated from 1989 to 1992. In the interim, a joint DFO/Memorial University lake fertilization study was conducted from 1991 to 1993 under the LRTAP Program with the aim of determining acidification reduction due to fertilization. Additionally, starting in 1991, the enhancement of salmonid production due to the fertilization has been monitored as part of a Memorial University project funded by the Natural Sciences and Engineering Research Council and DFO. In 1993, salmonid monitoring studies were also carried out by Memorial University as part of the Canada/Newfoundland Cooperation Agreement for Salmonid Enhancement/Conservation (CASEC). This monitoring is intended to document increased juvenile production as a result of the closure of the commercial fisheries.

In addition to DFO and Memorial University, several other agencies have conducted monitoring in the Experimental Ponds Area or vicinity. Forestry Canada has monitored an Acid Rain National Early Warning System (ARNEWS) plot in the watershed since 1984 for the purposes of documenting forest and soil conditions with reference to acidic precipitation. As part of the LRTAP Program, the Conservation and Protection Branch of Environment Canada in Moncton has monitored water quality in the Area since 1987 and, since 1992, the Canadian Wildlife Service has monitored waterfowl (particularly loon - Gavia immer) populations there. The Conservation and Protection Branch in St. John's routinely analyses water samples collected by DFO from the Experimental Ponds Area. Upwind of the Area at Bay D'Espoir, 47 km away on the south coast of the island, Environment Canada operates a Canadian Air and Precipitation Monitoring Network (CAPMON) site and provides available data.

Methods

Data used for this report are compiled in Table 1. Additional data, analyses, maps, history, and interpretation of the Gander River fisheries are available in O'Connell and Ash (1992, 1993), Porter and O'Connell (1992), and references therein. Reviews of the population dynamics of salmon in the Experimental Ponds Area are available in Ryan (1993a,b) and references therein.

Juvenile Salmon Abundance

Salmon were censused, concurrently with brook trout, in the spring and fall from 1978-93 in Spruce Pond and from 1979-93 in Headwater Pond using fyke nets and Schnabel multiple mark-recapture techniques as detailed by Ryan (1990). The study was terminated by management in 1988, but subsequently reinstated in 1989. Fish were captured in fyke nets, measured for length, marked with fin holes or clips, released, and recaptured for the computation of population size. Weights and scale samples have been routinely collected as documented by Ryan (1986b).

The age composition of the population during each census up to 1983 has been calculated from the ages and lengths of subsampled fish, the lengths of released fish, the computed population size, and their relative proportions using age-length keys (Ricker 1975). Age-specific migrations to and from the lakes were calculated as the differences, by age-group, between censuses. Thus, the number of salmon smolts migrating out of the lakes each year up to 1983 has been calculated as the loss in numbers of salmon from each of the age-groups over the spring-to-fall period (Ryan 1986b). The calculated number of smolts in those years has been related to the number of salmon present in the lakes in the spring of the year ($r=0.987$) by least-squares regression (Ryan 1986a). Accordingly, we have used spring juvenile abundance here as a readily obtainable measure of the smolt migration up to 1993.

Adult (Grilse) Abundance

Commercial grilse (1-sea-winter salmon <63 cm) catch data from 5 communities in the Gander Bay gillnet fishery from 1974 to 1991 have been tabulated by Porter and O'Connell (1992). These data represent only the catch, rather than a measure of stock abundance, as no reliable indicator of fishing effort is available. The Gander River flows to the Atlantic Ocean in Gander Bay and it is probable that the majority of the grilse taken in the Gander Bay fishery were returning adults destined for the Gander River system.

Recreational grilse catch data throughout the Gander River system from 1953 to 1992 have been tabulated by O'Connell and Ash (1993). Additionally, a corresponding measure of fishing effort (Ricker 1975) as the number of angler-days fishing was included. Here we have calculated a measure of grilse abundance during the recreational fishery as the average number of fish taken by each angler each week (number/rod/week).

Grilse counts at the Salmon Brook fishway from 1974 to 1992 have been tabulated by O'Connell and Ash (1993). Salmon Brook, a tributary, is downstream of Gander Lake on the main stem of the Gander River. Grilse counted there represented 3.8-9.1% of the grilse counted at the Gander River counting fence on the mainstem from 1989 to 1992. Complete fishway counts were not obtained in some years and here we have used available data from 1980 (corresponding to the year after the first census of both Spruce and Headwater ponds) to 1992.

Comparisons among commercial grilse catch, recreational grilse catch per unit effort, fishway counts, and the number of juvenile salmon in the study lakes in spring were made with simple linear graphs and linear regression analyses. In order to examine juveniles as a predictor of adult abundance, juvenile abundance was compared to data on adults in the following year to reflect the usual one year residence of adults at sea. In order to examine adults as a predictor of subsequent juvenile abundance (stock-recruit), we compared fishway counts with juvenile abundance four years later to reflect a typical smolt age of three years.

Results

The abundance of juvenile salmon in the spring in the Experimental Ponds Area has fluctuated from 1979 to 1993 (Fig. 2) with a maximum spring population of 4,925 salmon in Spruce and Headwater ponds in 1989 (Table 1).

Spring population sizes of juvenile salmon for the entire period were not significantly related to the abundance of returning adults, as measured by angler success one year later (upper panel Fig. 3). As documented previously (Ryan 1986a), Experimental Ponds Area salmon population sizes prior to 1985 were positively related to the abundance of returning adults (middle panel Fig. 3). After that time, the apparent trend was negative (although not statistically significant at the $p<0.05$ level); suggesting that dramatic changes in the marine mortality of adults had occurred (lower panel Fig. 3).

Examination of data from the recreational and commercial fisheries (Fig. 4) indicates that adult returns to the Gander River (as measured by angler catch per unit effort) declined slightly over the period 1980-92 while the commercial gillnet catch in Gander Bay increased dramatically from 1980-86 and then declined precipitously from 1989-91.

Angler catch per unit effort appeared to be a valid measure of adult escapement to the river over the entire period as indicated by a significant ($p<0.05$) positive relationship between angler success and grilse counts at the Salmon Brook fishway on the downstream portion of the Gander River system (Fig. 5).

Marine mortality appeared to have had influenced river escapement from 1979 to 1991. Although there was no clear relationship between the commercial catch and the Salmon Brook fishway count (Fig. 6), an inverse relationship between the two variates was suggested if the data points corresponding to the lowest commercial catches were omitted. Similarly, angler success was inversely related to the commercial catch at a level of statistical significance between 5 and 10% probability (Fig. 7).

The spring population size of Experimental Ponds Area juveniles demonstrated a strong stock-recruit relationship with adult salmon returns monitored at the Salmon Brook fishway four years earlier, except for two notable outliers (fishway years 1981 and 1988) (Fig. 8). The outliers may have resulted from factors such as unusual environmental variation during the four year interval between adult return and the subsequent assessment of juveniles or variations in year-class strength. Analyses are being conducted to increase the predictive power of the stock-recruit curve by taking those variables into account.

Discussion

Census data from the present study do not provide point estimates and associated variances may be imprecise due to the fact that census requirements were approximated (Ryan 1990). However, the validity of census results has been verified by comparisons of marked fish in the lakes on penultimate sampling days with frequencies in the final census samples and by the relationships between catch per unit effort and census results (Ryan 1990 and references therein). Accordingly, census results have provided a practical way of monitoring the stock. Similarly, a measure of uncertainty and absence of variance estimates are associated with angler catch and effort data which are, on occasion, estimated rather than observed when river wardens are absent (see Ash and Tucker 1984). However, as a result of the internal consistencies in the results herein (ie. correspondence of angler success to fishway counts, commercial catch, and juvenile densities) valuable inferences can be drawn concerning the status of the Gander River salmon.

There are two major indications of substantial change in the marine mortality of Gander River salmon over the period of study. The disappearance of a positive relationship between the abundance of young at the headwaters and the subsequent abundance of adults escaping to the river (Fig. 3) is consistent with the dramatic increase in the commercial catch in Gander Bay (Fig. 4).

The commercial catch data can not be considered as true measures of stock abundance as no reliable effort data are available for the correction of variable effort in that fishery. However, the inverse relationship between commercial catch and angler success (CPUE) (Fig. 7) is indicative of an interceptory marine fishery affecting escapement to the river. The disappearance of the expected trend between young and adults (Fig. 3), concurrent with the large increase in commercial catch, suggests that the commercial fishery was taking an increasingly larger portion of the stock.

It is apparent that a need exists for the continued monitoring of the abundance of juvenile salmon in the Experimental Ponds Area. With the closure of the commercial salmon fishery on the island and ongoing changes to the recreational fishery, comparable indices of stock size may not be generated by those fisheries for future assessments. It appears that adult counts at the Salmon Brook fishway will serve as an indication of adult escapement but, since that fishway is located on a tributary well downstream on the river system, it may not provide an indication of recovery of the Gander stock in its entirety. The Salmon Brook tributary could be adequately seeded in the future while the remainder of the Gander River system remained below carrying capacity. If the Salmon Brook fishway counts are a representative measure of adult escapement, the stock-recruit curve being developed from Experimental Ponds Area data will serve as a means of evaluating angling management strategy and the attainment of maximum spawner capacity.

It is reasonable to believe that stock recovery in the Gander River will be manifested in an increased abundance of young at the headwaters, particularly since egg deposition has been estimated as only about 35 % of that required for the river (Porter and O'Connell 1992, O'Connell and Ash 1993) and the developing stock-recruit relationship shows no asymptote. In this regard, staff of the Salmonid and Habitat Sciences Division have recommended the continued monitoring of juvenile salmon in the Experimental Ponds Area as an aid to the understanding of the salmon population dynamics of the Gander River as well as Newfoundland river systems in general (Ryan et al. 1993).

Acknowledgements

A large number of Fisheries and Oceans staff and Memorial University students have assisted with data collections in the Experimental Ponds Area over the years. We especially appreciate the assistance of C. E. Campbell, K. Clarke, L. J. Cole, D. P. Riche, and D. Wakeham. Graduate students of Memorial University assist with current data collections. J. B. Dempson provided a manuscript review.

References

Ash, E. G. M. and R. J. Tucker. 1984. Angled catch and effort data for Atlantic salmon in Newfoundland and Labrador, and for other fishes in Labrador, 1982. Can. Data Rep. Fish. Aquat. Sci. 465: xv + 96 p.

O'Connell, M. F. and E. G. M. Ash. 1992. Status of Atlantic salmon (Salmo salar L.) in Gander River, Notre Dame Bay (SFA 4), Newfoundland, 1989-1991. Canadian Atlantic Fisheries Scientific Advisory Committee Research Document 92/25. 22 p.

O'Connell, M. F. and E. G. M. Ash. 1993. Status of Atlantic salmon (Salmo salar L.) in Gander River, Notre Dame Bay (SFA 4), Newfoundland, 1992. DFO Atlantic Fisheries Research Document 93/30. 15 p.

Porter, T. R. and M. F. O'Connell. 1992. Effects of changing fishing mortality on Atlantic salmon (Salmo salar L.) egg deposition in Gander River. Canadian Atlantic Fisheries Scientific Advisory Committee Research Document 92/32. 16 p.

Ricker, W.E., 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191, 382 p.

Ryan, P. M. 1986a. Prediction of angler success in an Atlantic salmon, Salmo salar, fishery two fishing seasons in advance. Can. J. Fish. Aquat. Sci. 43: 2531-2534.

Ryan, P. M. 1986b. Lake use by wild anadromous Atlantic salmon, Salmo salar, as an index of subsequent adult abundance. Can. J. Fish. Aquat. Sci. 43: 2-11.

Ryan, P. M. 1990. Sizes, structures, and movements of brook trout and Atlantic salmon populations inferred from Schnabel mark-recapture studies in two Newfoundland lakes. Amer. Fish. Soc. Symp. 7: 725-735.

Ryan, P. M. 1993a. An extrapolation of the potential emigration of Atlantic salmon (Salmo salar) smolts from Newfoundland lakes in the absence of brook trout (Salvelinus fontinalis). p.203-207. In R. J. Gibson and R. E. Cutting (eds.) The production of juvenile Atlantic salmon in natural waters. Can. Spec. Publ. Fish. Aquat. Sci. 118: 262 p.

Ryan, P. M. 1993b. Natural lake use by juveniles: a review of the population dynamics of Atlantic salmon in Newfoundland lakes. p.3-14. In Ryan, P. M., M. F. O'Connell, and V. A. Pepper. 1993. Report from the workshop on lake use by Atlantic salmon in Newfoundland, Canada. Can. MS Rep. Fish. Aquat. Sci. 2222: iv + 54 p.

Ryan, P. M., M. F. O'Connell, and V. A. Pepper. 1993. Report from the workshop on lake use by Atlantic salmon in Newfoundland, Canada. Can. MS Rep. Fish. Aquat. Sci. 2222: iv + 54 p.

Ryan, P. M., and D. Wakeham. 1984. An overview of the physical and chemical limnology of the Experimental Ponds Area, central Newfoundland, 1977-82. Can. Tech. Rep. Fish. Aquat. Sci. 1320: v + 54 p.

Table 1. Experimental Ponds Area, Gander River, and Gander Bay data used in analysis of stock-recruit relationships.

Year of Census	Spruce and Headwater ponds Total Atlantic salmon spring (Spring no.) (yr n)	Gander Bay * Grilse netting (yr n) Catch (no.)	Gander River ** Grilse angling (yr n) Catch (no.)	Rod days	CPUE (no./rod/wk) x 1000	Salmon Brook fishway ** Count (no.)(yr n) partial counts- 79,87,90	Grilse netting and angling Catch (no.)(yr n)
1974		2379.00	2270.00	5153.00	3083.64		4649.00
1975		1819.00	2976.00	6670.00	3123.24		4795.00
1976		895.00	2374.00	6633.00	2505.35		3269.00
1977		1815.00	2269.00	6939.00	2288.95		4084.00
1978		1225.00	3332.00	8322.00	2802.69		4557.00
1979	4820.00	985.00	4199.00	7217.00	4072.74		5184.00
1980	3463.00	1270.00	2664.00	6384.00	2921.05	997.00	3934.00
1981	2393.00	3016.00	4578.00	10643.00	3010.99	2459.00	7594.00
1982	3077.00	3336.00	2176.00	8026.00	1897.83	1425.00	5512.00
1983	1603.00	4195.00	2033.00	6934.00	2052.35	978.00	6228.00
1984	3226.00	6349.00	2028.00	7590.00	1870.36	1081.00	8377.00
1985	3175.00	6786.00	3358.00	10207.00	2302.93	1663.00	10144.00
1986	4474.00	8276.00	2361.00	9740.00	1696.82	1064.00	10637.00
1987	3199.00	4655.00	1444.00	6384.00	1583.33		6099.00
1988		5650.00	2686.00	7943.00	2367.12	1562.00	8336.00
1989	4925.00	9254.00	1173.00	6290.00	1305.41	596.00	10427.00
1990	3642.00	4455.00	1155.00	7118.00	1135.85		5610.00
1991	2362.00	1697.00	1180.00	5853.00	1411.24	245.00	2877.00
1992	3069.00		1268.00	4123.00	2152.80	1168.00	
1993	2470.00						

* From Porter and O'Connell (1992; CAFSAC Res. Doc. 92/32, 16 p.).

** From O'Connell and Ash (1993; DFO Atlantic Fisheries Res. Doc. 93/30, 15 p.).

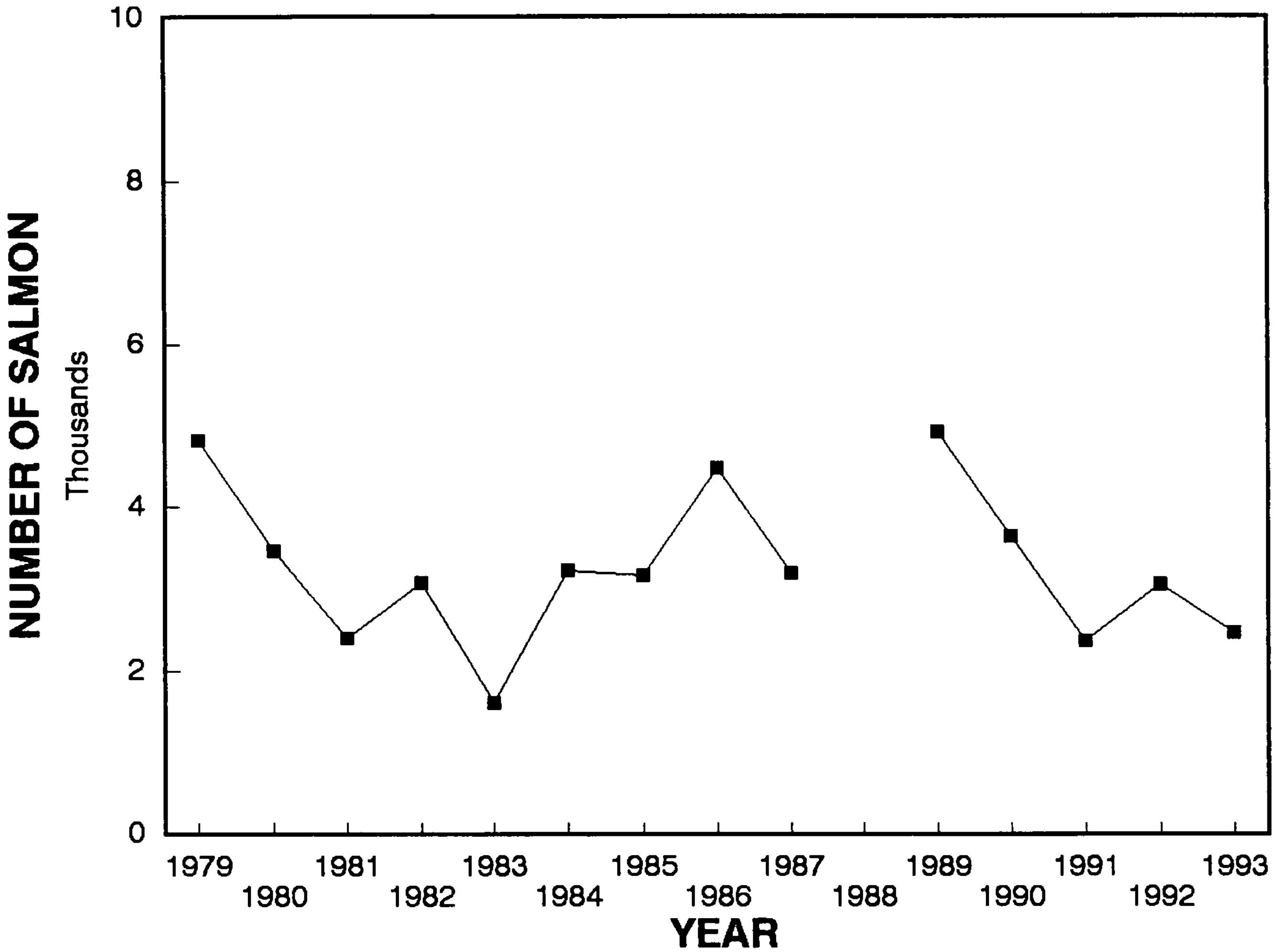
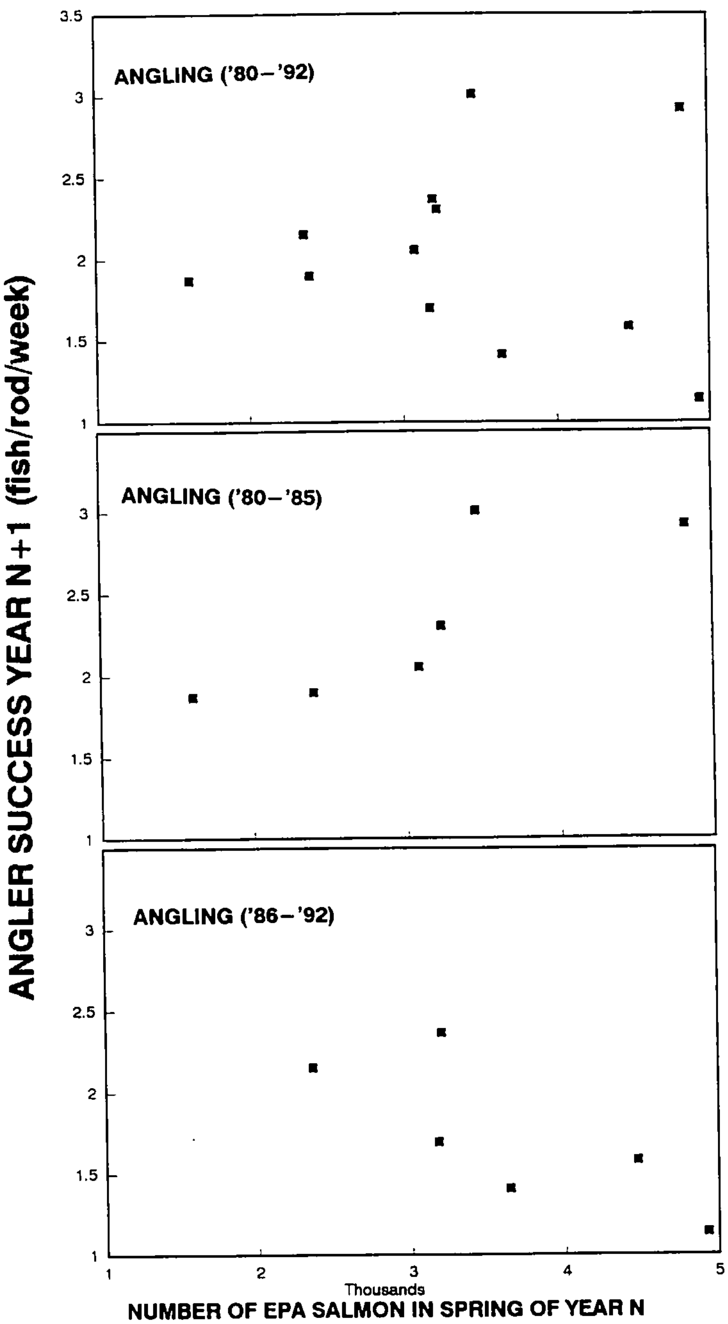


Figure 2. Schnabel population estimates of Experimental Ponds Area salmon (Headwater and Spruce ponds) in the spring, 1979-93.

Figure 3. Number of Experimental Ponds Area salmon in the spring compared to angler success in the Gander River grilse fishery in the following year with the data of all years combined (upper panel), EPA data from 1979-84 (middle panel), and EPA data from 1985-91 (lower panel). The data in the middle panel represent a statistically significant linear relationship ($Y = 1.145 + 0.0004X$; $r = 0.824$; $p<0.05$). The data in the other two do not ($p>0.05$).



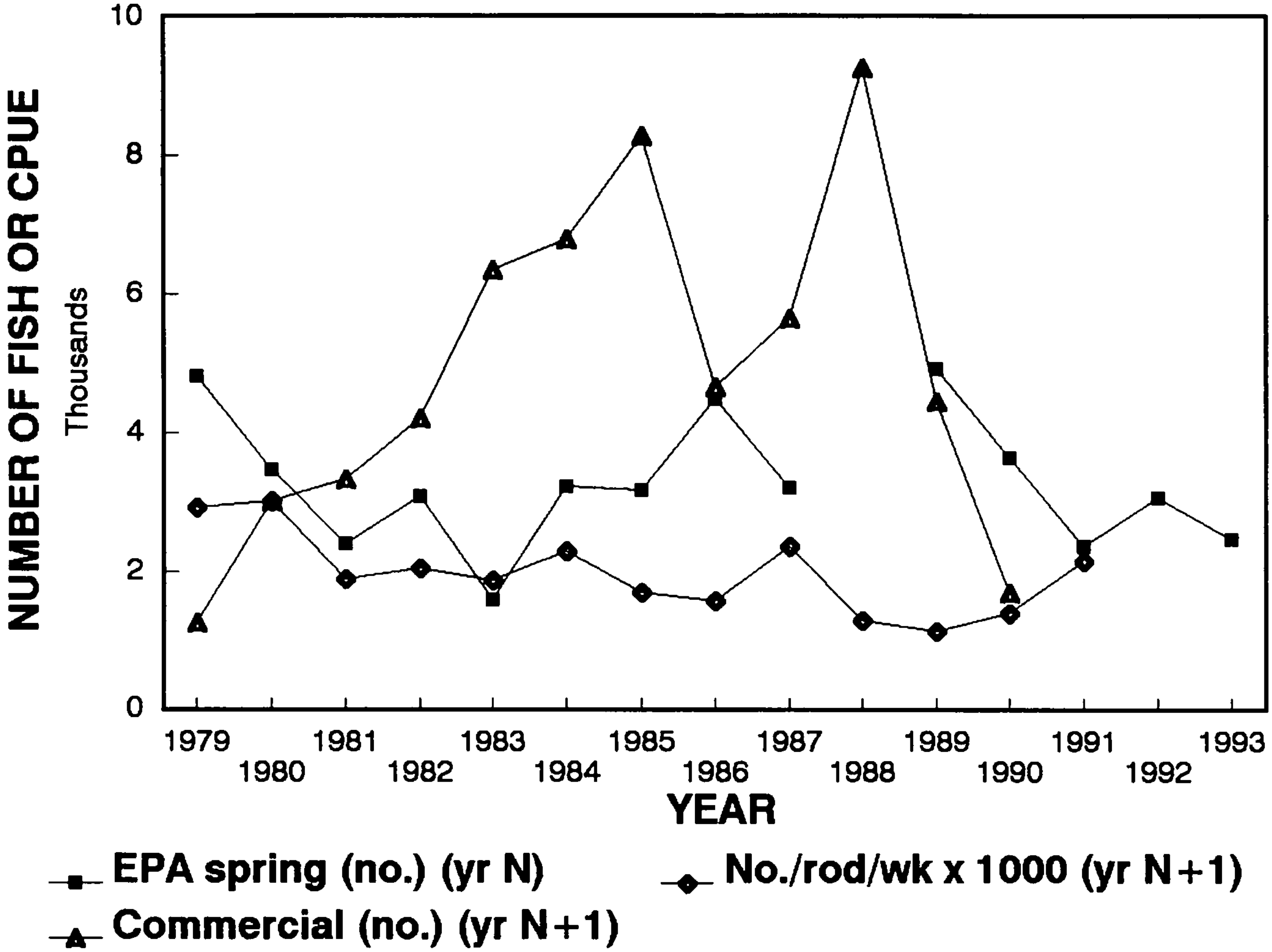


Figure 4. Changes over time of Experimental Ponds Area salmon numbers in the spring and in the following year, angler success in the Gander River and commercial catch in Gander Bay.

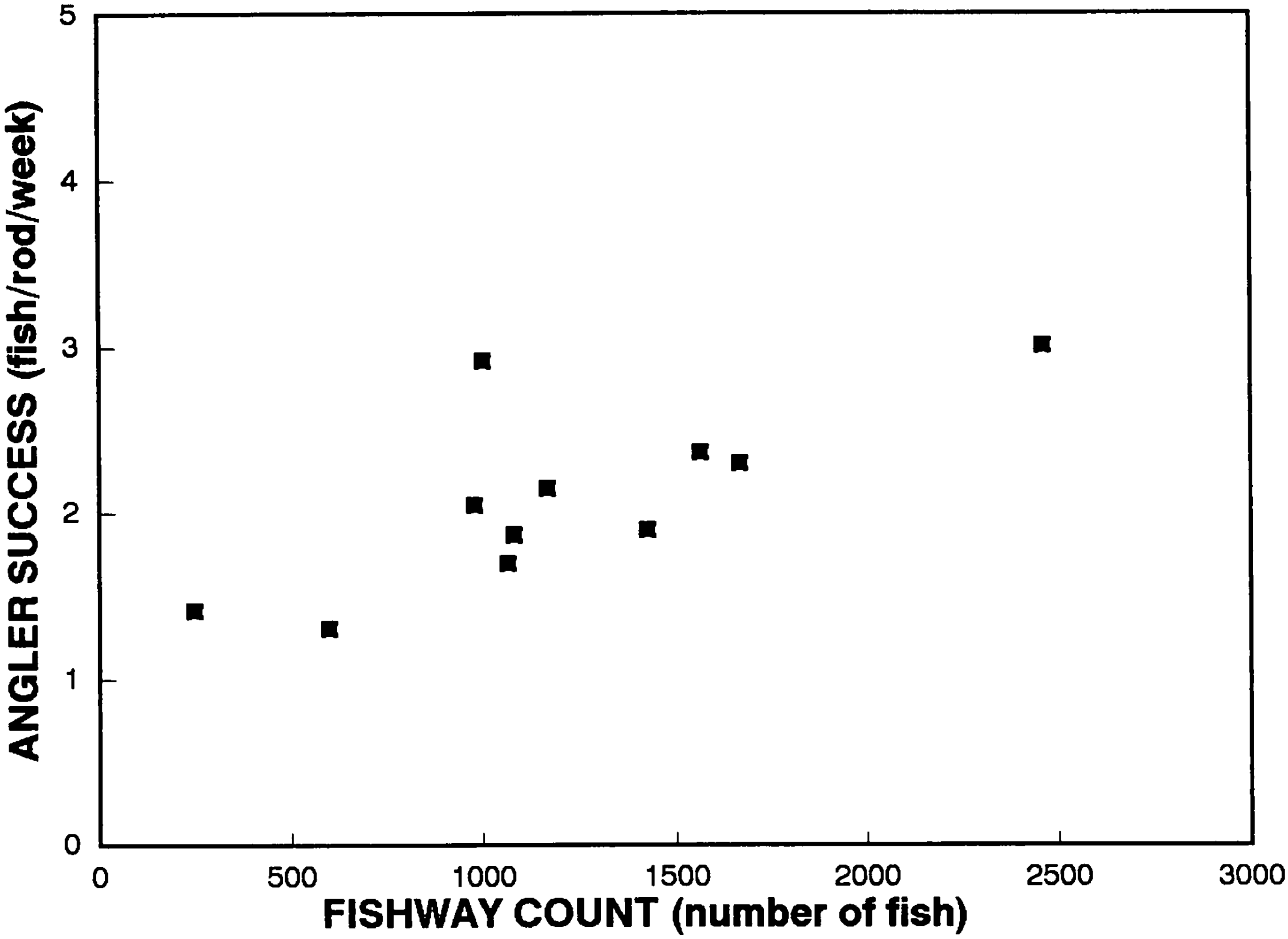
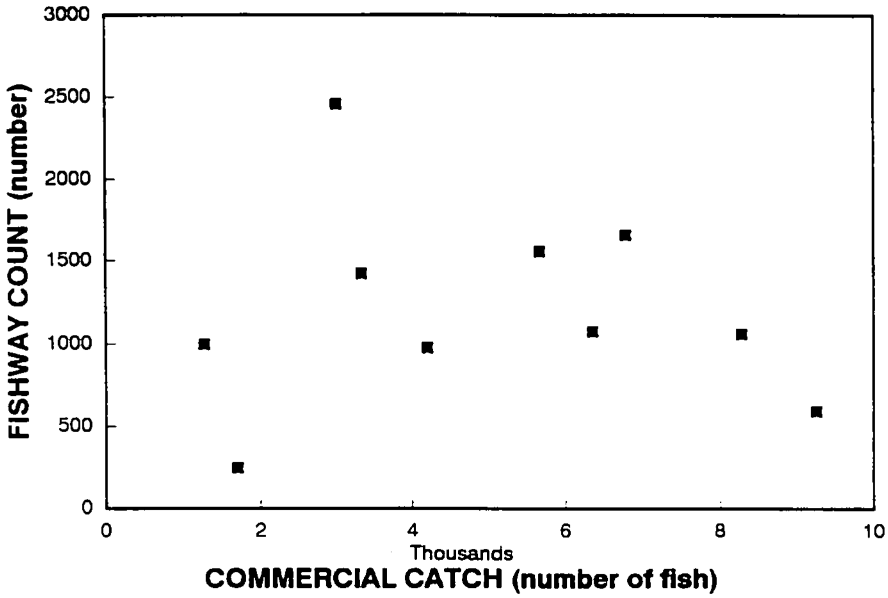


Figure 5. Comparison between grilse counts at Salmon Brook fishway and angler success in the Gander River recreational grilse fishery from 1980-92. Partial fishway counts from 1987 and 1990 are excluded. The data represent a statistically significant linear relationship ($Y = 1.252 + 0.0007X$; $r = 0.741$; $p<0.01$).

Figure 6. Comparison between grilse counts at Salmon Brook fishway and grilse catches in the Gander Bay commercial gillnet fishery from 1980-91. Partial fishway counts from 1987 and 1990 are excluded. There is no significant relationship ($p>0.05$) between the two variates.



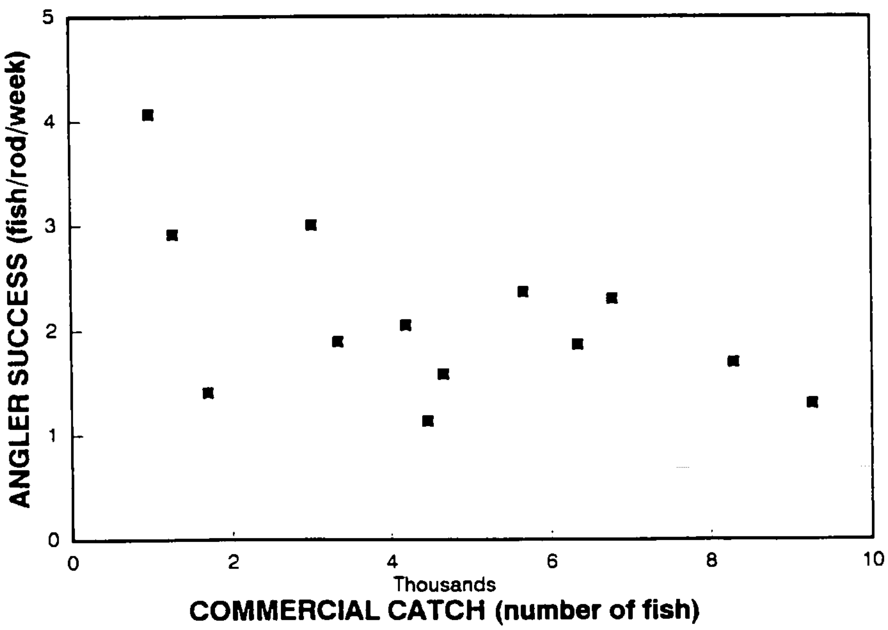


Figure 7. Comparison between angler success in the Gander River recreational grilse fishery and grilse catches in the Gander Bay commercial gillnet fishery from 1979-91. A relationship between the two variates ($Y = 2.91 - 0.00017X$) is just below the level of statistical significance ($0.05<p<0.10$). Omission of the 1990 and 1991 outliers results in a significant relationship as documented by O'Connell and Ash (1992).

Figure 8. Stock-recruit curve for the Gander River system based upon fishway counts at the Salmon Brook tributary and the spring census of juveniles in the Experimental Ponds Area four years later. Years of fishway counts are indicated. The regression equation with the 1981 and 1988 fishway data removed is $Y = 1136.4 + 2.281X$; $r = 0.986$; $p<0.01$).