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Ratio of Adults to Experimental Ponds Area Juveniles in a Stock Assessment of Atlantic Salmon (Salmo salar L.) in the Gander River, Newfoundland with a Projection of Adult Returns in 1997

by

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ABSTRACT

Spring population sizes of juvenile Atlantic salmon were determined by Schnabel multiple, mark-recapture methods in two Experimental Ponds Area (EPA) lakes at the headwaters of the Gander River from 1979-96. Juvenile abundance in 1995 and 1996 was considerably higher than expected as indicated by a previously derived stock-recruit relationship between juvenile abundance and adults returning to the Salmon Brook fishway on a lower river tributary four years earlier.

Total river adult (small salmon <63 cm) returns were obtained over the period 1989-96 at the counting fence near the mouth of the river and the fish angled downstream of the fence. Changes in the ratios of returning small salmon to the juvenile abundance one year earlier were indicative of a more than four-fold (4.5 X) increase in the average marine survival of Gander River salmon following closure of the commercial fishery in 1992. However, our results suggest that marine survival of the 1995 migrants was decreased relative to the other years during the closure of the commercial fishery. Total river adult returns in 1997 were projected from 1996 juvenile abundance and the post-commercial fishery ratio of returning small salmon to the juvenile abundance one year earlier. Projections indicate that 50,103 small salmon should return to the Gander River to spawn in 1997 and exceed the current conservation spawning requirement.

RÉSUMÉ

Les effectifs printaniers de saumons atlantiques juvéniles ont été déterminés de 1979 à 1996 par des méthodes de recaptures après marquage multiples de Schnabel dans deux lacs de la zone expérimentale EPA situés dans le secteur supérieur de la rivière Gander. En 1995 et 1996, les juvéniles étaient beaucoup plus nombreux que ne le laissaient prévoir une relation stock-recrues déjà dérive du nombre de juvéniles et d'adultes compté quatre ans auparavant à la passe migratoire du ruisseau Salmon, tributaire situé en aval.

Le nombre total de saumons adultes (de longueur inférieure à 63 centimètres) qui ont remonté la rivière de 1989 à 1996 a été déterminé à la barrière de dénombrement située près de l'embouchure et lors de relevés des prises des pêcheurs sportifs effectuées en aval de la barrière. Les changements dans le ratio du nombre de petits adultes et du nombre de juvéniles ayant remonté la rivière un an auparavant révélaient une augmentation de plus du quadruple (4,5 X) du taux moyen de survie en milieu marin des saumons de la rivière Gander après la fermeture de la pêche commerciale en 1992. Toutefois, nos résultats semblent indiquer que le taux de survie en milieu marin des migrants de 1995 a diminué par rapport aux autres années pendant les périodes où la pêche commerciale était fermée. Nous avons réalisé une projection du nombre total d'adultes qui remonteront la rivière en 1997 à partir de l'effectif de juvéniles de 1996 et du ratio du nombre de petits adultes et du nombre de juvéniles ayant remonté la rivière après la période de pêche commerciale un an auparavant. Cette projection indique que 50 103 petits saumons devraient

Introduction

The Gander River (Fig. 1) has insular Newfoundland's largest river basin area that is naturally accessible to sea-run Atlantic salmon (Murray and Harmon 1969). The minimum or conservation spawning requirement for the Gander River has been estimated as 21,828 small salmon (O'Connell and Dempson 1991). However, the decreased abundance of adults returning to spawn in the river has, particularly during 1989-91, resulted in an egg deposition of only about 35 % of that requirement (Porter and O'Connell 1992, O'Connell and Ash 1993).

Changes in the fisheries for adult salmon have included, starting in 1992, a closure of the commercial salmon fishery on the island and imposition of a quota in the recreational fishery (with subsequent catch and release fishing) (O'Connell and Ash 1993).

A recently developed method of salmon stock assessment in the Gander River system has been the evaluation of relationships between the abundance of juveniles in two headwater lakes in the Experimental Ponds Area (EPA) (Fig. 2) and the abundance of adults returning to the river to spawn. These juvenile-adult relationships have provided indications of changes in both freshwater and marine mortality (Ryan 1986a, 1986b, Ryan et al. 1994, 1995, 1996).

In this paper we examine two adult-juvenile relationships with data available up to 1996 for the purpose of assessing stock recovery in the Gander River system. Following the methods of Ryan et al. (1995, 1996), we update the numerical relationship between adult small salmon (<63 cm) returning to the Salmon Brook fishway (as spawners) and the juveniles in two EPA lakes at the headwaters of the Gander River system (as recruits) four years later. Subsequently, we assess that stock-recruit relationship for current applicability.

Additionally, we update the numerical relationship between the juveniles in the EPA at the headwaters and the adults returning to the entire river system one year later (as determined from a counting fence and angler survey on the main stem of the river since 1989). We then project total river adult small salmon returns in 1997 from the juvenile abundance in 1996 and the post-commercial fishery ratio of total returning adults to the juvenile abundance one year earlier.

Juvenile Study Areas

Headwater and Spruce ponds are shallow (mean depth 1.1 and 1.0 m respectively), dilute (mean conductance 35 $uS \cdot cm^{-1}$), brown-water lakes within the Department of Fisheries and Oceans' Experimental Ponds Area (EPA) at the headwaters (48°19'N; 55°28'W) of the Gander River system (Fig. 2). The physical and chemical characteristics of the EPA have been detailed by Ryan and Wakeham (1984). The history of ecological assessment in the EPA has been reviewed by Ryan et al. (1994). Reviews of the population dynamics of salmon in the EPA are available in Ryan (1993a, b) and references therein.

The closest known 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).

Adult Counting Sites

Detailed maps, analyses, and history of the Gander River fisheries and adult counting facilities (Fig. 1) are available in O'Connell and Ash (1992, 1993, 1994), Porter and O'Connell (1992), Ryan et al. (1996), and references therein. Salmon Brook, a tributary with a fishway in place, is downstream of Gander Lake on the main stem of the Gander River. Additionally, an adult counting fence has been operated on the main stem of the Gander River since 1989 (Fig. 1). Total adult small salmon returns to the Gander River system have been calculated as the sum of the number passing through the fence and the number angled downstream of the fence (O'Connell and Ash 1994).

Methods

Juvenile Salmon Abundance

Population structures of juvenile salmon were determined in the spring and fall from 1978-96 in Spruce Pond and from 1979-96 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.

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). Additionally, 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 (Table 1) as a readily obtainable index of the smolt migration up to 1996.

Adult (Small Salmon) Abundance

Small salmon (<63 cm) counts at the Salmon Brook fishway in 1974 and from 1978 to 1996 have been documented by O'Connell et al. (1997). Complete fishway counts were not obtained in 1979 but we have used all available data including the partial count (Table 1).

Total adult small salmon returns to the Gander River system have been calculated as the number of adults passing through the counting fence on the mainstem of the lower river plus the number angled downstream of the fence (O'Connell and Ash 1994). We have used all return counts since installation of the fence in 1989 as updated to 1996 by O'Connell et al. (1997).

Juvenile-Adult Relationships

In order to examine adults as a predictor of subsequent juvenile abundance (stock-recruit), we followed the methods of Ryan et al. (1995, 1996) and compared counts of salmon at the Salmon Brook fishway with juvenile salmon abundance four years later. This reflects the emergence of young the following year plus the dominance of age-group three EPA juveniles in the spring (Ryan 1986b). Successful application of this method requires a proportionality between counts of salmon at the Salmon Brook fishway and adult returns to the total river system (described by Ryan et al. 1996) but permits a forecast of juvenile abundance four years in advance (Ryan et al. 1995). We then assessed the stock-recruit relationship for its current applicability by a simple examination of deviations from prior trends.

In order to examine juveniles as a predictor of adult abundance, juvenile abundance was compared to data on adult returns in the following year to reflect the predominant (94%) one year residence of adults at sea (see O'Connell and Ash 1994). We updated the previously described (Ryan et al. 1995, 1996) numerical relationship between the juveniles in the EPA at the headwaters and the adults returning to the entire river system one year later (as determined from the counting fence and angler survey on the main stem of the river since 1989). We then projected total river adult small salmon returns in 1997 from the mean post-commercial fishery ratio of total returning adults to the juvenile abundance one year earlier.

Results

Experimental Ponds Area Juveniles

The expected recapture rates during the last three day's fishing in Spruce Pond averaged 19.58% while the observed recapture rates on those days averaged 20.45%. Similarly, in Headwater Pond, the expected recapture rates during the last three day's fishing averaged 5.87% while the observed recapture rates on those days averaged 6.39%. The differences between expected and observed recapture rates in the ponds were less than the average difference of 3% observed during the censuses of juvenile salmon in the study lakes over the long term (Ryan 1990). The small differences between expected and observed recapture rates are consistent with a close approximation of ideal census requirements during Schnabel multiple, mark-recapture censusing.

The abundance of juvenile salmon in the Experimental Ponds Area has fluctuated during the period 1979 to 1996 (Fig. 3) with a record high population of 6,558 salmon in Spruce and Headwater ponds in the spring of 1996 (Table 1). The pattern of seasonal change continued to be one of comparatively high spring abundance followed by a lower fall abundance after smoltification and the seaward migration.

Current Applicability of the Stock-Recruit Curve

The spring 1996 population size of Experimental Ponds Area juveniles, as did the 1995 spring population size, deviated markedly from the previously described (Ryan et al. 1995) stock-recruit relationship between juveniles and adult small salmon returns monitored at the Salmon Brook fishway four years earlier (Fig. 4).

The previously described (Ryan et al. 1995) relationship (with all data prior to 1995 included) between juvenile abundance (Y) and adult returns four years earlier (X) was statistically significant:

Equation 1: $Y = 2167.370 + 0.909X$; $r = 0.619$; $N=12$; $p < 0.05$.

However, the spring juvenile year 1985 had been deleted from that regression for predictive purposes as a result of an hypothesized much lower than expected number of juveniles in the ponds in 1985 due to extreme regional flooding in January of 1983 (Environment Canada 1983) and the fact that the data point (corresponding to the 1981 fishway count) was well outside the range of data used in projections. With the juvenile year 1985 deleted from that regression (Equation 1), seventy-four percent of the variation in juvenile abundance (Y) was accounted for by adult returns four years earlier (X):

Equation 2: $Y = 1468.360 + 1.776X$; $r = 0.859$; $N=11$; $p < 0.01$.

The inclusion of the 1995 or 1996 juvenile census results in the analysis with all data included did not result in a relationship of statistical significance ($p > 0.05$). Furthermore, the inclusion of the 1995 and 1996 juvenile census data in the analysis with the juvenile year 1985 deleted did not result in a relationship of statistical significance ($p > 0.05$). As a result of the dramatic departure of the spring juveniles in 1995 and 1996 from the previously recognized trend, we did not employ the stock-recruit curve in our projections.

Possible reasons for the radical departure of the spring 1995 and 1996 juvenile population from the previously recognized stock-recruit curve, were explored by a comparison of Gander River total small salmon returns to the adult count at the Salmon Brook fishway (Fig. 5). A strong relationship between the variates was apparent ($r = 0.899$; $p < 0.01$). Accordingly, the departure of the spring juveniles in 1995 and 1996 from the previously recognized trend could not be attributed to the absence of a proportionality between counts of salmon at the Salmon Brook fishway and adult returns to the total river system.

Gander River Adults Related to Juveniles One Year Earlier

The relationship between the spring estimate of abundance of Experimental Ponds Area juveniles and the total adult small salmon returns to the Gander River system in the subsequent year revealed a distinct separation of data points corresponding to the periods before and after the closure of the commercial fishery (Fig. 6). The mean survival ratio index (ratio of adult returns to EPA juveniles in the previous year) of 1.71 for the two years prior to the closure of the commercial fishery in 1992 increased to a mean of 7.64 for the five years after ($t = 4.26$; $p < 0.02$) (Table 2). This difference was consistent with previously described increases in salmon survival after the closure of the commercial fishery (Ryan et al. 1995, 1996) and was indicative of a more than four-fold increase in marine survival rates.

Projected Adult Abundance in 1997

Juvenile abundance in 1996 multiplied by the mean post-commercial fishery ratio of adults to juveniles in the previous year provided a projection of Gander River small salmon returns to 1997 (Table 1, Figure 7). Calculations indicate a high level of adult returns to the Gander River in 1997 with returns in that year calculated as 50,103 small (<63 cm) salmon, an amount in excess of the spawner requirement.

Discussion

Validity of Juvenile Census Data

Juvenile census results of the type employed here have been previously verified by comparisons of calculated frequencies of marked fish in the lakes with observed frequencies in catches and by the relationships between catch per unit effort and census results (Ryan 1990). Accuracy of census results has been further improved through empirical analysis and design optimization (Knoechel and Ryan 1994). Additionally, the small differences between expected and observed recapture rates during the spring 1996 juvenile census are consistent with a close approximation of ideal census requirements.

Gander River Stock-Recruit Curve

The previously described stock-recruit curve for juvenile years up to 1994 (Fig. 4) is consistent with the hypothesis that the abundance of adult salmon returning to the Gander River to spawn has been a major determinant of the subsequent abundance of juveniles. However, the distinct departures (1985, 1995, 1996) from the trend described by the stock-recruit curve suggest that marked variations in year-class survival may be too frequent and too large to allow for accurate long-term prediction based only upon spawner abundance.

As discussed by Ryan et al. (1995), the outlier in the stock-recruit curve (Fig. 4) corresponding to fishway year 1981 may have resulted from a flooding of the river system in January of 1983 which could have reduced the strength of the 1982 year class. Young salmon produced by the 1981 adult run would have been underyearling fish during that flood and susceptible to high mortality.

Similarly, the conspicuous departure of the 1995 and 1996 juvenile populations from the stock-recruit curve was suggestive of atypically high freshwater survival rates of one or more year classes occupying the lakes in the springs of 1995 and 1996.

The close correspondence between Salmon Brook fishway counts and total river adult returns suggests that adult counts at the Salmon Brook fishway will serve as a valid indication of adult escapement to the Gander River. However, since freshwater survival has the potential to be highly variable, juvenile counts are likely to serve as a more accurate predictor of adults than are counts of the preceding generation of adults. Accordingly, censusing of juveniles prior to smoltification can be expected to serve as the more accurate means of evaluating angling management strategy and the attainment of optimal spawner capacity.

Impact of the Fishery Closure

The distinct separation of Figure 6 data points which correspond to the periods before and after the closure of the commercial fishery indicates a dramatic increase in juvenile to adult survival after the fishery closure. These results are indicative of a more than four-fold (4.5 X) increase in the average marine survival of Gander River salmon following closure of the commercial fishery in 1992.

The survival ratio index (Table 2) for adults returning in 1996 was the lowest of those calculated for the years after the closure. Age and length-specific analyses of juvenile population structures (Knoechel et al. 1997) indicated that the low survival ratio index for 1996 adults could not be attributed to an atypical abundance of non-migrating juveniles in the lakes in the spring of 1995. Additional years of observation are required to further characterize the variability of the survival ratio index.

Projected Time of Stock Recovery

The conservation spawning requirement for the Gander River, or the minimum number of spawners required for sustained production, has been estimated as 21,828 small salmon (O'Connell and Dempson 1991).

The survival ratio index projection of 50,103 small (<63 cm) salmon returning to the Gander River in 1997 will exceed the conservation spawning requirement.

Use of the present method (ratio of adults to juveniles) to predict the adult returns to the Gander River one year in advance has previously resulted in a variable level of accuracy. The difference of 3,659 salmon between the observed returns in 1995 and the returns projected from the juvenile 1994 data (Ryan et al. 1995) represented only 16% of the actual 1995 count, indicative of a slightly faster stock recovery than previously anticipated. In marked contrast, the returns projected from the juvenile 1995 data (Ryan et al. 1996) overestimated the observed returns by 13,349 salmon or 56% of the actual 1996 count, indicative of a much slower stock recovery than previously anticipated.

Large fluctuations in the number of adult returns, such as those evident from 1993 to 1996 and to projected 1997 levels, will likely persist due to variations in juvenile year class strength and subsequent marine survival rates. Fluctuations in juvenile year class strength will be evident during future juvenile assessments and permit updating of potential harvest levels as stocks continue to recover. However, substantial departures of marine survival rates from recent levels will result in deviations from projected adult returns. Our results suggest that higher than average freshwater survival rates contributed to a high abundance of juveniles in 1995 and 1996, but that marine survival of the 1995 migrants was decreased relative to the other years during the closure of the commercial fishery.

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References

Knoechel, R., and P. M. Ryan. 1994. Optimization of fish census design: an empirical approach based on long-term Schnabel estimates for brook trout (Salvelinus fontinalis) populations in Newfoundland lakes. Verh. Internat. Verein. Limnol. 25: 2074-2079.

Knoechel, R., P. M. Ryan, and M. F. O'Connell. 1997. Evaluation of age-specific and length-specific estimates of juvenile Atlantic salmon (Salmon salar L.) abundance in the Experimental Ponds Area as predictors of adult returns to the Gander River. DFO Atlantic Fisheries Research Document 97/ (in preparation).

Murray, A. R. and T. J. Harmon. 1969. A preliminary consideration of the factors affecting the productivity of Newfoundland streams. Fish. Res. Board Can. Tech. Rep. 130: vi + 405 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.

O'Connell, M. F. and E. G. M. Ash. 1994. Status of Atlantic salmon (Salmo salar L.) in Gander River, Notre Dame Bay (SFA 4), Newfoundland, 1993. DFO Atlantic Fisheries Research Document 94/50. 17 p.

O'Connell, M. F. and J. B. Dempson. 1991. Atlantic salmon (Salmo salar L.) target spawning requirements for rivers in Notre Dame Bay (SFA 4), St. Mary's Bay (SFA 9), and Placentia Bay (SFA 10), Newfoundland. Canadian Atlantic Fisheries Scientific Advisory Committee Research Document 91/18. 14 p.

O'Connell, M. F., D. G. Reddin, and E. G. M. Ash. 1997. Status of Atlantic salmon (Salmo salar L.) in Gander River, Notre Dame Bay (SFA 4), Newfoundland, 1996. DFO Atlantic Fisheries Research Document 97/ (in preparation).

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.

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., R. Knoechel, and M. F. O'Connell. 1994. Population sizes of juvenile Atlantic salmon (Salmo salar L.) in lakes of the Experimental Ponds Area as a measure of stock recovery in the Gander River, Newfoundland. DFO Atlantic Fisheries Research Document 94/13. 17 p.

Ryan, P. M., R. Knoechel, M. F. O'Connell, E. G. M. Ash, and W. G. Warren. 1995. Atlantic salmon (Salmo salar L.) stock recovery in the Gander River, Newfoundland with projections to 1999. DFO Atlantic Fisheries Research Document 95/95. 16 p.

Ryan, P. M., R. Knoechel, M. F. O'Connell, and E. G. M. Ash. 1996. Ratio of adults to Experimental Ponds Area juveniles in a prediction of Atlantic salmon (Salmo salar L.) returns to the Gander River, Newfoundland in 1996. DFO Atlantic Fisheries Research Document 96/47. 19 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. Spring Atlantic salmon juvenile population sizes in the EPA to 1996, Salmon Brook fishway small salmon (<63 cm) counts to 1996, and Gander River small salmon returns projected to 1997.

Year of Census	Spruce and Headwater ponds total Atlantic salmon juveniles (no.)	Salmon Brook fishway count (no.)(yr N)* (partial count- '79, adjusted count- '90)	Gander River total small salmon returns (yr N)* (no. calculated for 1997 with 95% confidence interval bracketed)
1978		755	
1979	4822	404	
1980	3463	997	
1981	2393	2459	
1982	3077	1425	
1983	1603	978	
1984	3226	1081	
1985	3175	1663	
1986	4474	1064	
1987	3199	493	
1988		1562	
1989	4925	596	7743
1990	3642	345	7740
1991	2362	245	6745
1992	3069	1168	18179
1993	2470	1560	26205
1994	2370	963	18080
1995	4492	1600	22264
1996	6558	946	23665
1997			50103 (21904 - 78303)

* From O'Connell, Reddin, and Ash: DFO Atlantic Fisheries Research Document 97/ (in preparation).

Table 2. Ratios of Gander River small salmon returns to EPA juveniles in the previous year with survival ratio indices before and after the closure of the commercial fishery in 1992.

Year of Census	Spruce and Headwater ponds total Atlantic salmon juveniles (yr N)	Gander River total small salmon returns (yr N+1)	Survival ratio index (adults/juveniles)
1989	4925	7740	1.57
1990	3642	6745	1.85
1991	2362	18179	7.70
1992	3069	26205	8.54
1993	2470	18080	7.32
1994	2370	22264	9.39
1995	4492	23665	5.27
		Mean ratio	5.95
		Mean pre-closure ratio (S. E.)	1.71 (0.198)
		Mean post-closure ratio (S. E.)	7.64 (1.549)

Figure 1. Gander River basin of insular Newfoundland with locations of study sites referred to in the text.

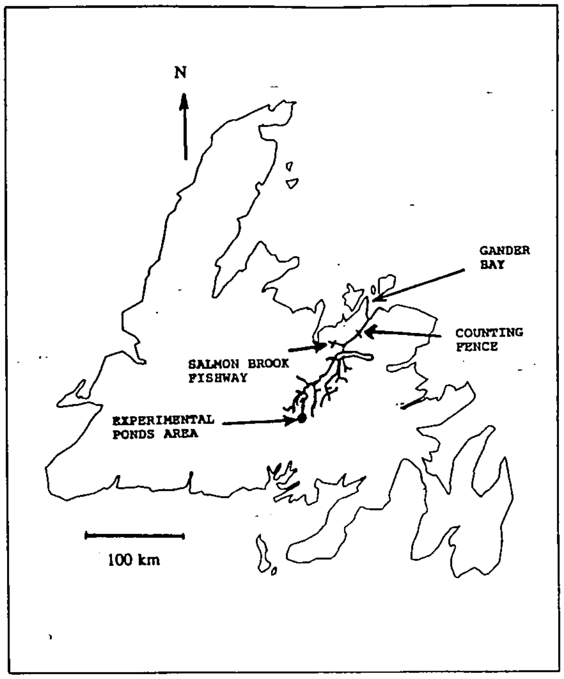


Figure 2. Watershed of the Experimental Ponds Area at the headwaters of the Northwest Gander River, central Newfoundland (inset). The dashed line through the east side of the watershed represents the Bay D' Espoir highway.

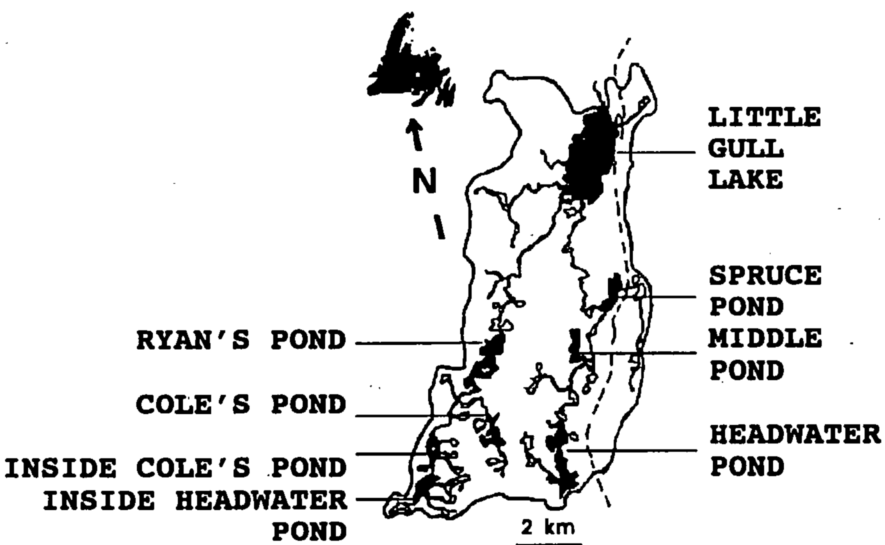
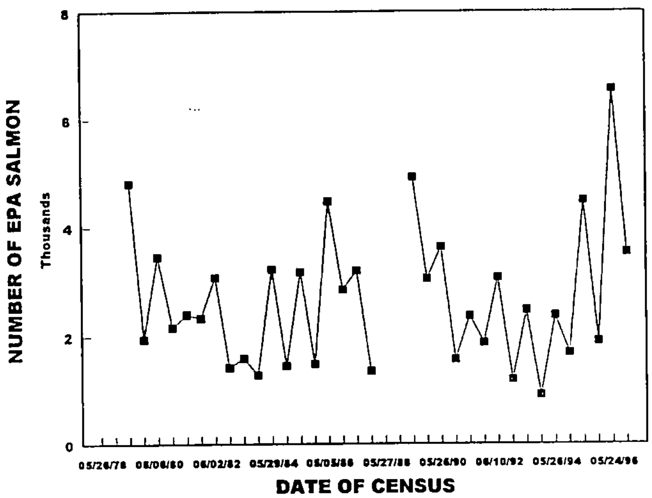


Figure 3. Schnabel population estimates of Experimental Ponds Area (EPA) juvenile salmon (Headwater and Spruce ponds combined) in the spring and fall, 1979-96.



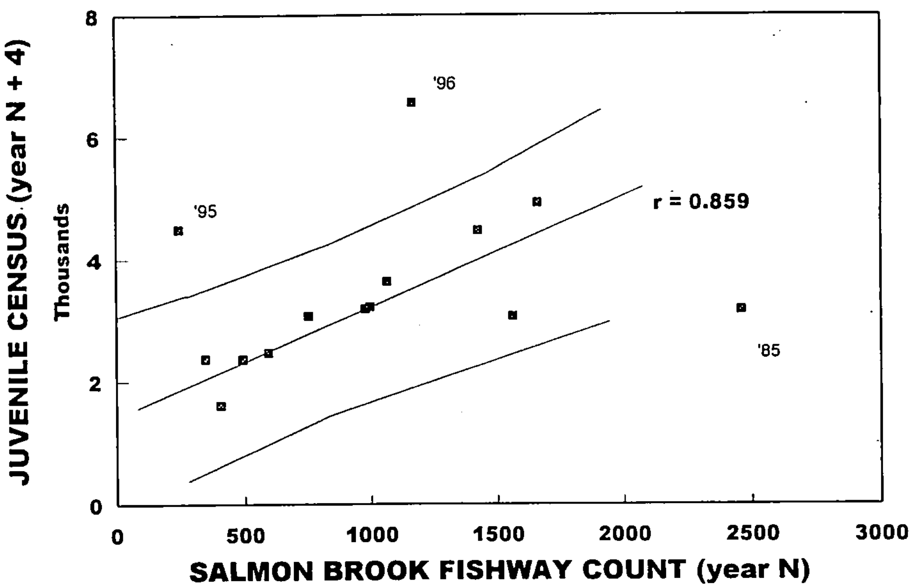


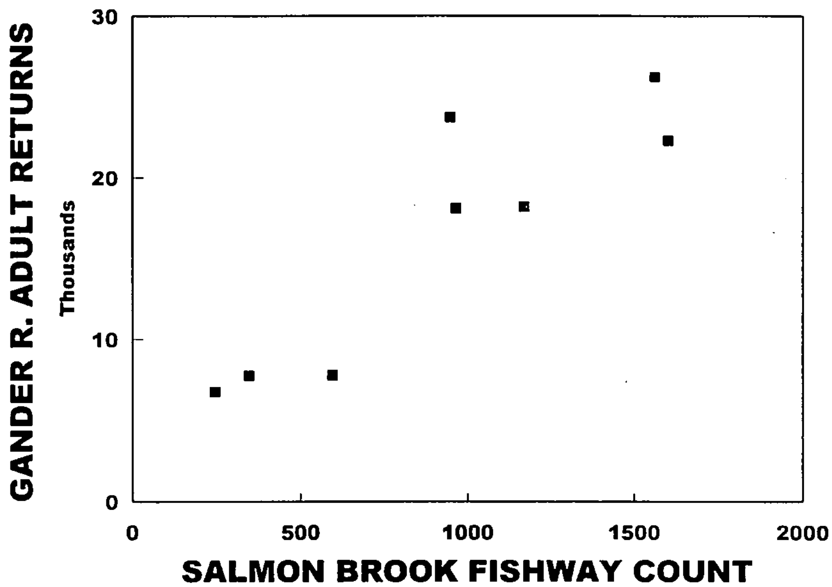
Figure 4. Stock-recruit relationship for the Gander River system based upon counts of small salmon (<63 cm) at the Salmon Brook fishway and the spring census of juveniles in the Experimental Ponds Area four years later. The obvious outliers are juvenile years 1985, 1995, and 1996. The regression equation with those outliers removed is:

Equation 2: $Y = 1468.360 + 1.776X$; $r = 0.859$; $N=11$; $p < 0.01$

The 95% confidence belt about the regression is shown.

Figure 5. Proportionality between small salmon returns to the Gander River in its entirety (Y) and counts of small salmon at the Salmon Brook fishway (X), 1989-96. The trend between the variates can be described by:

Equation 3: $Y = 3491.548 + 13.834X$; $r = 0.899$; $N=8$; $p < 0.01$



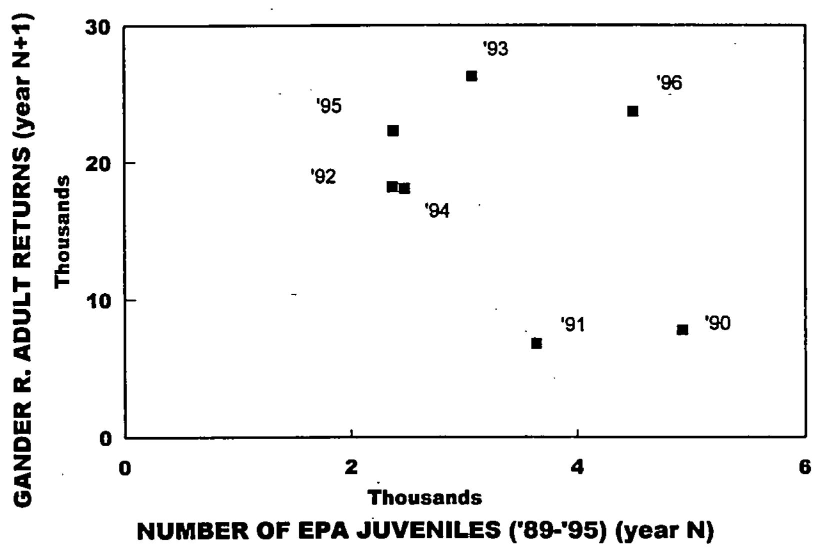


Figure 6. Decreased marine mortality of Gander River Atlantic salmon associated with the closure of the commercial salmon fishery in 1992 as indicated by total Gander River small salmon returns and the spring census of juveniles in the Experimental Ponds Area (EPA) one year earlier. Adult return years are indicated. The two data points at the lower right represent adult data prior to the closure while the upper five points correspond to the period of no commercial fishery.

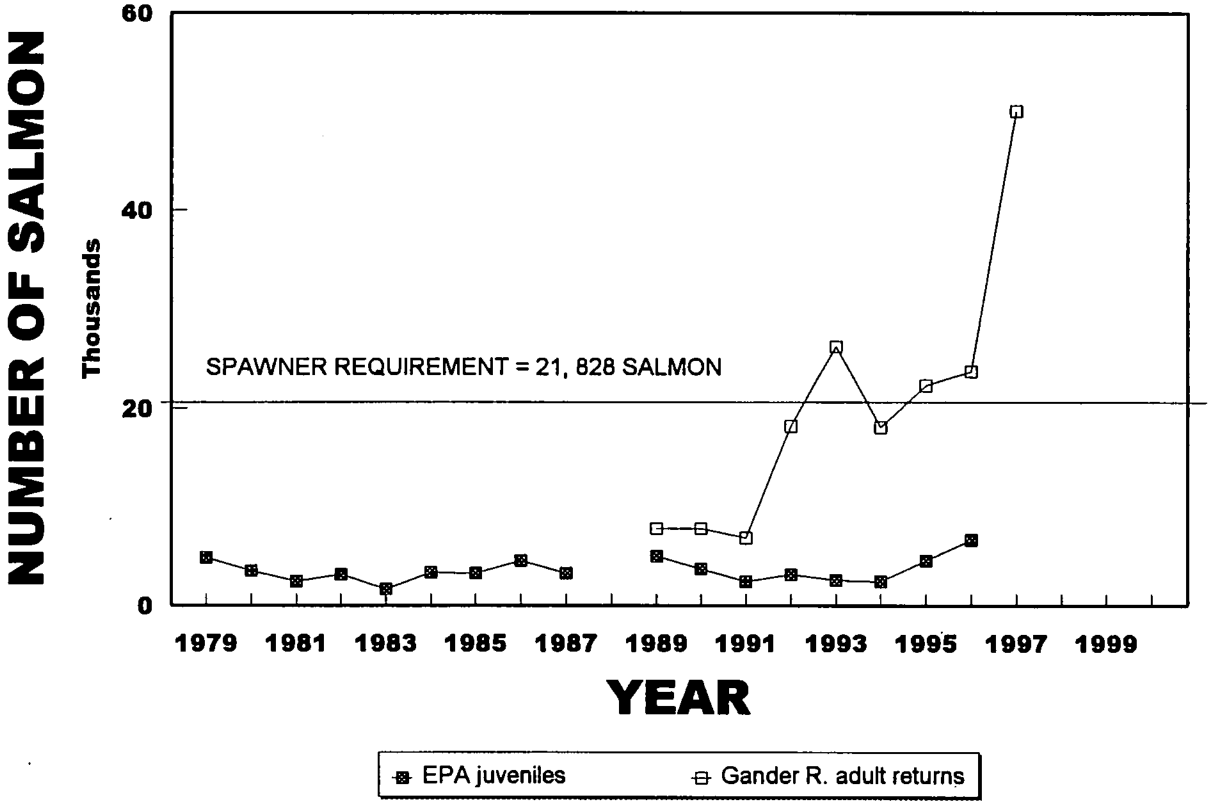


Figure 7. Experimental Ponds Area (EPA) spring juvenile salmon abundance to 1996 and Gander River small salmon returns to 1997. Juvenile numbers to 1996 are from census data. Adult returns to 1996 are actual values while returns for 1997 were calculated from the juvenile numbers in 1996 and the mean ratio of adults to juveniles in the previous year after the closure of the commercial fishery. Projected returns for 1997 (with 95% confidence interval) are 50,103 small salmon (21,904-78,303). Presented for comparison is the estimated conservation spawning requirement for the Gander River (horizontal line).