Not to be cited without permission of the authors[1]

Ne pas citer sans autorisation des auteurs[1]

Canadian Atlantic Fisheries Scientific Advisory Committee

Comité scientifique consultatif des pêches canadiennes dans l'Atlantique

CAFSAC Research Document 84/86

CSCPCA Document de recherche 84/86

Relationships between egg deposition, survival and the production of 0^+ Atlantic salmon parr in Maritime rivers

by

B.M. Jessop
Fisheries Research Branch
Dept. of Fisheries and Oceans
P.O. Box 550
Halifax, N.S.
B3J 2S7

[1]This series documents the scientific basis for fisheries management advice in Atlantic Canada. As such, it addresses the issues of the day in the time frames required and the Research 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 by the author.

[1]Cette série documente les bases scientifiques des conseils de gestion des pêches sur la côte atlantique du Canada. Comme telle, elle couvre les problèmes actuels selon les échéanciers voulus et les Documents de recherche qu'elle contient ne doivent pas être considérés comme des énoncés finals 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 par les auteurs dans le manuscrit envoyé au secrétariat.

Abstract

The relationship between the estimated deposition of Atlantic salmon eggs and the subsequent abundance of 0^+ parr was examined. Data from four Maritime rivers (Nashwaak, Tobique, Big Salmon and LaHave) were combined because a sufficient range of egg depositions does not exist for any single river.

The density of 0^+ parr varied with egg density in a skewed, dome-shaped curve. Maximum production of 0^+ parr was achieved at about 4.0 eggs.m^{-2}. A deposition of 2.4 eggs.m^{-2} is currently accepted as minimum for optimal smolt production and is used to determine spawner requirements. It is suggested that a deposition of 2.4 eggs.m^{-2} is less than optimal.

Résumé

Nous avous examiné le rapport entre la densité estimative de la ponte chez le saumon de l'Atlantique, et l'abondance subséquente de tacons d'age 0+. Pour ce faire il a été nécéssaire de combiner les données de quatre rivières des provinces Maritimes (Nashwaak, Tobique, Big Salmon et LaHave), la gamme des densités de ponte n'étant pas suffisament large dans une seule rivière.

La courbe de la densité des tacons d'age 0+ en foncton de la densité des oeufs pondus auparavant, prend la forme d'une dôme biais. La production maximale de tacons 0+ correspond à une ponte d'environ 4,0 oeufs.m^{-2}. Une ponte de 2,4 oeufs.m^{-2} est actuellement considérée comme le minimum pour une production optimale de saumoneaux; c'est cette valeur qu'on emploie pour calculer les besoins en reproducteurs. Nous pensons qu'une ponte de moins de 2,4 oeufs.m^{-2} est inférieure à l'optimale.

Introduction

The relationship between spawning stock size and future recruitment is central to the effective management of Atlantic salmon stocks. A series of linkages exists between spawning stock size and the abundance of spawning progeny. Aspects of this relationship have previously been studied, e.g., survival of egg-to-emergent-fry (Shearer 1961), egg-to-parr survival (Meister 1962; Elson 1975), egg-to-smolt survival (Elson 1962, 1975; Paloheimo and Elson 1974; Chadwick 1982; Buck and Hay 1984), fry density and smolt year-class size (Elson 1962, 1975), egg deposition to adult recruitment (Watt and Penney 1980). This paper will consider the relationship between potential egg deposition and the abundance of 0^+ parr.

Methods

A fence on the Big Salmon River, New Brunswick, was used annually between 1964 and 1973 to count and obtain biological data on adult Atlantic salmon (Jessop 1984). Annual potential egg deposition was calculated using the length distribution of female fish in the escapement and the revised fecundity-length relationship ($Y = 177.77e^{0.05X}$, where Y = fecundity and X = fork length (cm) provided by Glebe et al. (1979) and Glebe (pers. comm., 1983). Electrofishing surveys of juvenile abundance were conducted annually in late August and September of the years 1968 and 1970-1973. Sampling sites were distributed throughout the river system and were chosen to be representative of the region where they were located. This analysis used from 9 to 13 of the sites fished annually. Sites (1 or 2) normally inaccessible to spawning salmon, where hatchery-reared fry had been released in 1971 and 1972, were excluded. At each site, an area of 100 m^2 to 400 m^2 was enclosed by barrier nets and fished by catch-removal procedures using up to five sweeps. All salmon parr were counted, with 0^+ parr categorized by their size.

Egg deposition and 0^+ parr abundance data for the Tobique and Nashwaak rivers were obtained from T.L. Marshall (pers. comm.) and for the LaHave River from R.E. Cutting (pers. comm.). Electrofishing and parr abundance estimation techniques for these locations are believed to be similar to those for the Big Salmon River.

Results

Egg-to-0^+ parr survival was significantly negatively related ($P < 0.001$) to the density of egg deposition when data from several rivers were combined (Table 1; Fig. 1) The relationship was described by the equation $Y^{-1} = 0.0373 + 0.0372X$, where Y = % egg to 0^+ parr survival and X = egg deposition.m^{-2} of rearing area ($n=21$, $r^2 = 0.88$). The density of 0^+ parr varied with egg density in a skewed, dome-shaped manner (Fig. 2). The logarithmically- transformed parr and egg densities.100 m^{-2} (Fig. 3) were fitted using a polynominal equation of the form $Y = -0.902 + 1.005X - 0.201X^2 - 0.679X^3$ where Y = log number of 0^+ parr.100 m^{-2} and X = log egg deposition.m^{-2} ($n=20$, $r^2=0.73$, $s^2_{y.x} = 0.0214$). The circled points in Figures 1 and 2 were omitted from the fitted curves for reasons given in the discussion.

The turning point of the curve in Figure 1 occurs at about 4.2 eggs $.\ m^{-2}$ of rearing area whereas the peak of the curve in Figure 3 occurs at 3.8 eggs$.m^{-2}$ (note: the G.M. estimate of the point at the peak has been converted to the A.M. estimate (Ricker 1975)). This relationship implies that, although decreasing egg deposition below about $4.0.m^{-2}$ results in higher survival to 0^{+} parr, the density of 0^{+} parr decreases and vice versa. A deposition of 4.0 eggs$.m^{-2}$ should produce about 29 0^{+} parr$.100m^{-2}$ of accessible rearing area, with parr production declining at egg levels greater than $4.0.m^{-2}$.

Discussion

A relationship between egg deposition and smolt production implies a more direct relationship between egg density and abundance of 0^{+} parr, linked by the positive relationship Elson (1962, 1975) found between fry densities and smolt production. The influence of egg density on smolt production also varies with the smolt age composition (Symons 1979).

Egg deposition and survival to the 0^{+} parr stage were found to be negatively curvilinearly related when a sufficiently wide range of egg densities was considered. Data from the Big Salmon River and three other Maritime rivers were combined because the necessary quantity of, and contrast in, data was unavailable for any single river. The use of data from several river systems may be objected to on the grounds that environmental factors influencing survival and growth obviously differ between rivers, not to say within rivers. It is also true that, within geographic regions, similar environmental factors (climatic, edaphic, geomorphologic) result in similar fish yields (Binns and Eiserman 1979; Schlesinger and Regier 1982) and that relationships derived from pooled data may usefully predict yields for individual rivers. According to Smith (1966), the four rivers considered here have low productivity and broadly similar climate and geomorphology.

The 1980 Tobique River spawning was omitted from calculations because of its unusually high egg-to-parr survival, which may have been related to the abnormally high water levels (37% higher than the 10-year mean and 7% higher than any other year) throughout the winter of 1980-81. Chadwick (1982) attributed poor survival rates to low winter temperatures and discharges, and the converse is probable. Tobique River survival rates (n=11) were related to discharge levels at the 90 percent, but not at the 95 percent, probability level.

The curve in Figure 1 implies that egg-to-0^{+} parr survival declines substantially with increasing egg deposition in the 1 to 4 eggs$.m^{-2}$ range. It should be recognized, however, that there is considerable variability in the data within this range. The rate of decline in egg-to-parr survival is clearly inadequate to overcome the increasing abundance of parr derived from increasing egg deposition until the critical level is reached at about 4.0 eggs$.m^{-2}$. Smoothing the data by using group means creates a curve having a flat or slightly descending slope up to egg depositions of about 4 eggs$.m^{-2}$, after which it declines sharply. Such a curve might be interpreted as indicating that egg-to-parr survival is constant or declines slowly until a critical egg density is reached. However, smoothing can eliminate important effects and indications of shape in smoothed data must be viewed cautiously (Mosteller and Tukey 1977). The theoretical implications of each interpretation are intriguing, but it is fair to say that more data are required before a firm choice of interpretation can be made.

Egg deposition and the subsequent abundance of 0^+ parr were related in a dome-shaped curve. Elson's (1975) conclusion that underyearling density was linearly dependent on density of egg deposition, over the range of egg depositions he considered (< 2.5 eggs.m^{-2}) is consistent with these results. In Figure 2, a linear relationship is evident up to egg depositions of about 4.0 eggs.m^{-2}; non-linearity becomes evident at higher egg densities. A linear egg-0^+ parr relationship was reported by Buck and Hay (1984) for egg densities between 2-12 eggs.m^{-2} in a small Scottish stream. Continuation of the linear trend at egg densities greater than 4 eggs.m^{-2} is consistent with the density-dependent effects observed by them between parr year-classes and the fact that many Scottish parr emmigrated from the stream at ages 1-1.5 years younger than typical in Maritime streams. Data on the 1967 Big Salmon River egg deposition were omitted from calculation of the relationship on the grounds that the high (3 times larger than the next largest egg deposition) deposition was unrepresentative of the relationship existing at lower egg densities. Despite a very low egg-to-parr survival rate, the large egg deposition resulted in moderate parr abundance, possibly via a process of density-dependent mortality. Ricker (1954) has shown for Pacific salmon that maximum recruitment occurs not from maximum but from intermediate levels of spawning. Elson (1975), Symons (1979) and Buck and Hay (1984) have reported results suggestive of density-dependent mortality influencing the production of Atlantic salmon younger parr and smolts.

If optimal spawning requirement is defined as the lowest egg deposition which maximizes 0^+ parr production, then 4.0 eggs.m^{-2} is optimal. Chadwick (1982) cautioned that the potential deposition of 2.4 eggs.m^{-2} recommended by Elson (1957, 1975) for optimal smolt production could be an underestimate. This study supports that caution, given the positive relationship between 0^+ parr abundance and smolt production (Elson 1962). Buck and Hay (1984) recommend 3.4 eggs.m^{-2} as appropriate for the production of migrant parr in a small Scottish stream.

Greatly increased escapements will be needed to achieve the proposed optimum egg depositions in most Maritime rivers; such escapements will be difficult to attain given the present failure to achieve depositions of even 2.4 eggs.m^{-2} in most rivers.

Acknowledgements

The author would like to thank R.E. Cutting and P.G. Amiro for their constructive review of this manuscript.

References

Binns, N.A. and F.M. Eiserman. 1979. Quantification of fluvial trout habitat in Wyoming. Trans. Amer. Fish. Soc. 108:215-228.

Buck, R.J.G. and D.W. Hay. 1984. The relation between stock size and progeny of Atlantic salmon, Salmo salar L., in a Scottish stream. J. Fish Biol. 23:1-11.

Chadwick, E.M.P. 1982. Stock-recruitment relationship for Atlantic salmon (Salmo salar) in Newfoundland rivers. Can. J. Fish. Aquat. Sci. 39:1496-1501.

Elson, P.F. 1957. Number of salmon needed to maintain stocks. Can. Fish. Cult. 21:19-23.

Elson, P.F. 1962. Predator-prey relationships between fish-eating birds and Atlantic salmon. Bull. Fish. Res. Bd. Canada 133:87 p.

Elson, P.F. 1975. Atlantic salmon rivers, smolt production and optimal spawning: an overview of natural productions. Int. Atl. Salmon Found. Spec. Publ. Ser. 6:96-119.

Glebe, B.D., T.D. Appy and R.L. Saunders. 1979. Variation in Atlantic salmon (Salmo salar) reproductive traits and their implications in breeding programs. I.C.E.S./C.M. 1979/M:23. 11 p.

Jessop, B.M. 1984. Analysis of the run of Atlantic salmon (Salmo salar) to the Big Salmon River, New Brunswick. Can. Man. Rept. Fish. Aquat. Sci. In press.

Meister, A.L. 1962. Atlantic salmon production in Cove brook, Maine. Trans. Am. Fish. Soc. 91:208-212.

Mosteller, F., and J.W. Tukey. 1977. Data analysis and regression. Addison-Wesley Publishing Co., 588 p.

Paloheimo, J.E. and P.F. Elson. 1974. Reduction of Atlantic salmon (Salmo salar) catches in Canada attributed to the Greenland fishery. J. Fish. Res. Board Can. 31:1467-1480.

Ricker, W.E. 1954. Stock and recruitment. J. Fish. Res. Board Can. 11:559-623.

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

Schlesinger, D.A. and H.A. Regier. 1982. Climatic and morphoedaphic indices of fish yields from natural lakes. Trans. Amer. Fish. Soc. 111:141-150.

Shearer, W.M. 1961. Survival rate of young salmonids in streams stocked with "green" ova. I.C.E.S./C.M. No. 98:3 p.

Smith, M.W. 1966. The Atlantic Provinces of Canada. In: Limnology in North America (ed. D.G. Grey). Univ. Wisconsin Press, Madison. p. 521-534.

Symons, P.E.K. 1979. Estimated escapement of Atlantic salmon (*Salmo salar*) for maximum smolt production in rivers of different productivity. *J. Fish. Res. Board Can.* 36:132-140.

Watt, W.D. and G.H. Penney. 1980. Juvenile salmon survival in the Saint John River system. Can. Tech. Rept. Fish. Aquat. Sci. No. 939. 13 p.

Table 1. Potential egg deposition, 0^+ parr abundance and percent egg-to-parr survival for Atlantic salmon from four Maritime rivers.

River	Year-class	Eggs.m^{-2}	0^+ parr.m^{-2}	% survival egg - 0^+ parr
Tobique	1970	0.44	0.069	15.8
	1971	0.61	0.079	13.0
	1972	0.71	0.066	9.3
	1973	1.31	0.152	11.6
	1974	0.87	0.072	8.3
	1975	2.69	0.347	12.9
	1976	3.68	0.314	8.5
	1977	2.45	0.287	11.7
	1978	3.09	0.428	13.9
	1979	1.93	0.247	12.8
	1980	3.62	0.712	19.7
	1981	1.19	0.208	17.5
	1982	1.40	0.103	7.4
Nashwaak	1972	1.20	0.220	18.3
	1973	3.04	0.340	11.2
Big Salmon	1967	30.60	0.307	1.0
	1968[1]	18.10	-	-
	1969	11.50	0.161	1.4
	1970	9.80	0.203	2.1
	1971	6.70	0.140	2.1
	1972	6.20	0.173	2.8
LaHave	1979	2.93	0.231	7.9
	1980	6.37	0.338	5.3

[1]Electrofishing not done in 1969.

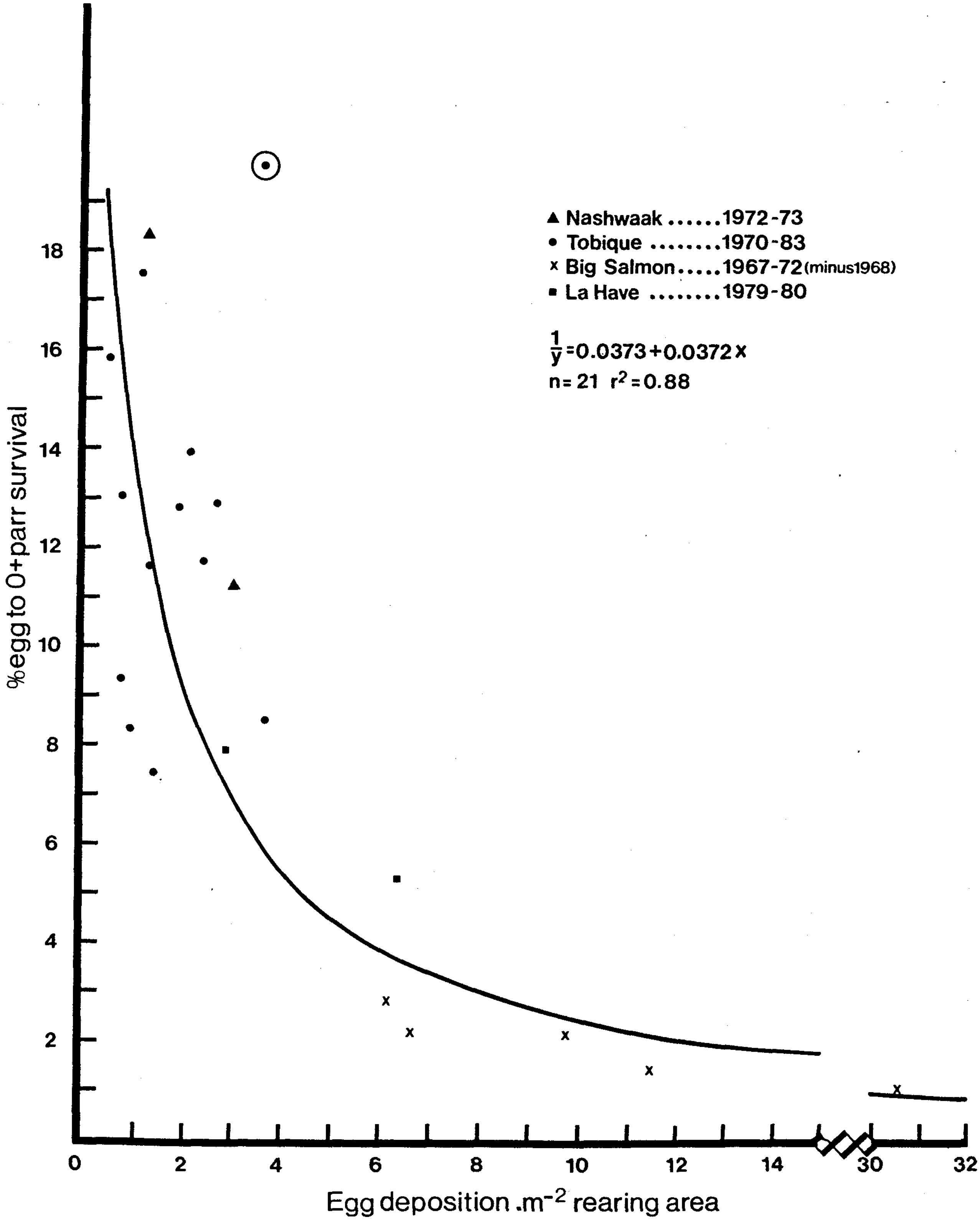

Figure 1. Relationship between density of egg deposition and survival to 0+ parr for Atlantic salmon. Data pooled from four Maritime rivers.

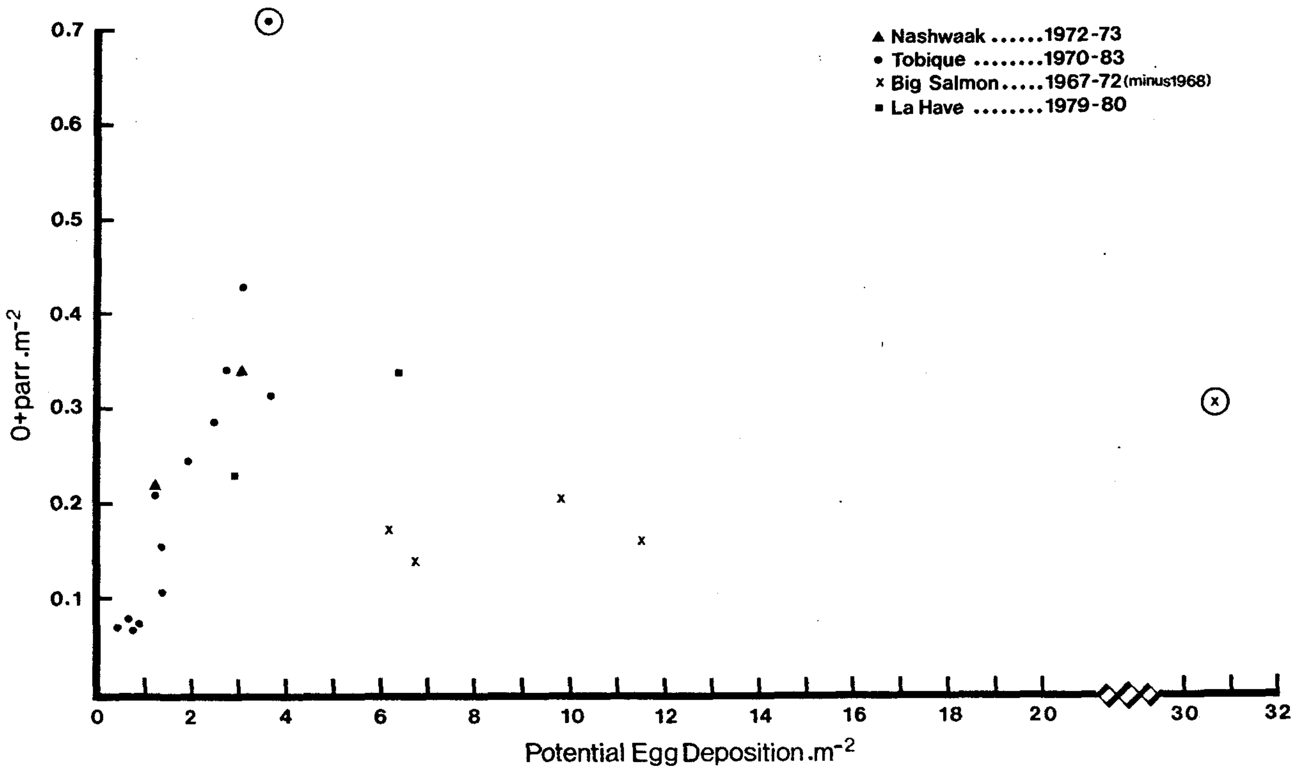

Figure 2. Relationship between potential Atlantic salmon egg deposition $.m^{-2}$ and subsequent density of 0+ parr $.m^{-2}$ based upon the pooled data from four Maritime rivers.

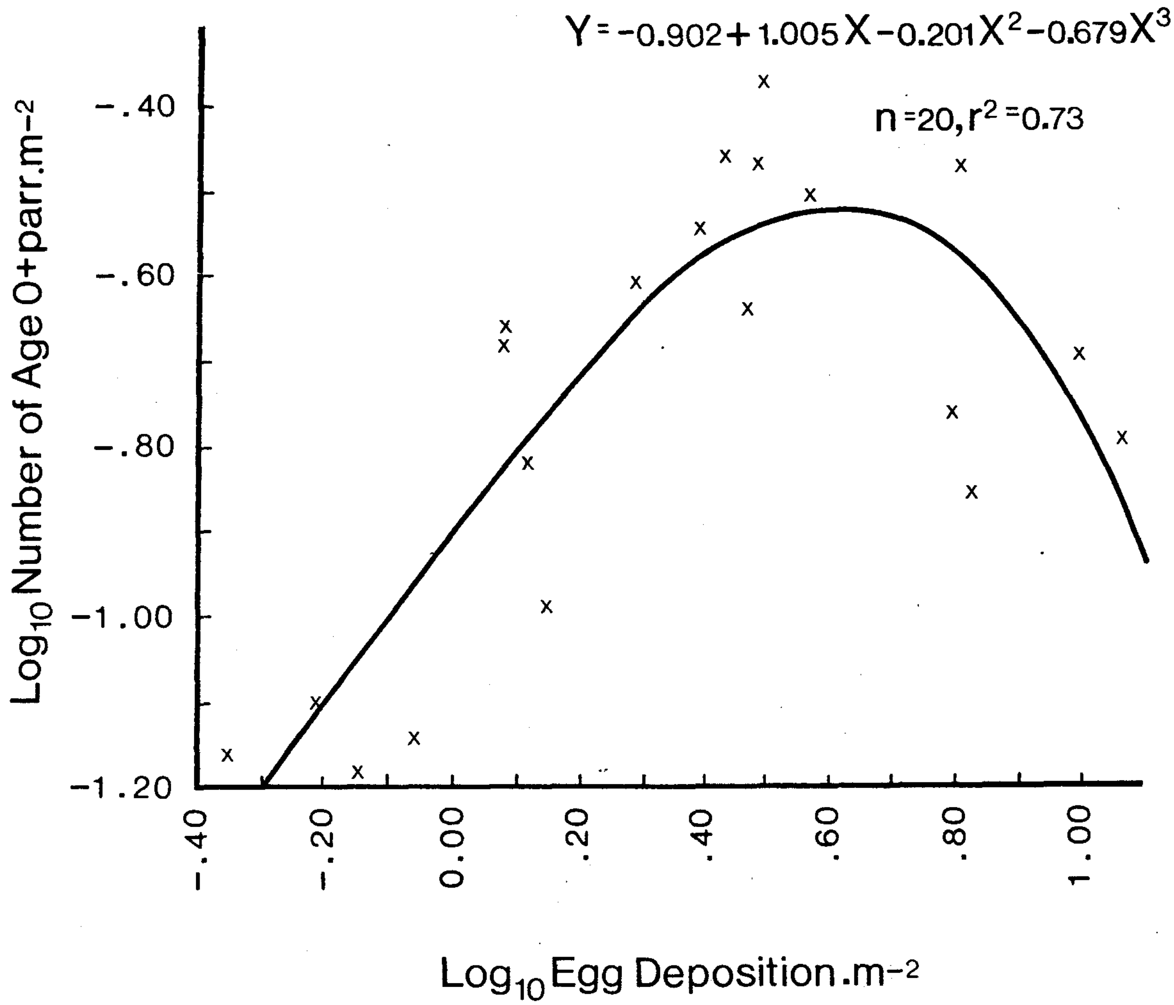

Figure 3. Relationship ($\log_{10}$ transformed) between density of egg deposition and abundance of 0+ parr for Atlantic salmon. Data pooled from four Maritime rivers.