Atlantic Salmon (Salmo salar L.) Smolt Production Parameter Values for Fluvial and Lacustrine Habitats in Insular Newfoundland

by

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Abstract

Interim smolt production parameter values for use in the calculation of spawning requirements were determined for insular Newfoundland (Newfoundland Region) in terms of fluvial and lacustrine habitats. For fluvial parr rearing habitat, a value of 3 smolts/100 m^2 was recommended for all Salmon Fishing Areas (SFAs). For lacustrine habitat, a value of 7 smolts/ha was recommended for all SFAs except the Great Northern Peninsula portion of SFA 3 where 2 smolts/ha was adopted.

Résumé

On a établi les paramètres provisoires de production de saumoneaux à utiliser dans le calcul des besoins de reproducteurs pour les habitats fluviaux et lacustres de l'île de Terre-Neuve (région de Terre-Neuve). Pour ce qui est des habitats fluviaux d'élevage des tacons, on recommande un ratio de 3 saumoneaux par 100 m^2 dans toutes les zones de pêche du saumon (ZPS). Dans le cas des habitats lacustres, on recommande un ratio de 7 saumoneaux par hectare dans toutes les ZPS, sauf dans la péninsule Great Northern (ZPS 3), où ce ratio est réduit à 2 saumoneaux par hectare.

INTRODUCTION

In 1990, the commercial fishery for Atlantic salmon in the Newfoundland Region was managed on a zonal or Salmon Fishing Area (SFA) (Fig. 1) basis for the first time. In an attempt to increase river escapements, commercial quotas were introduced in each SFA while previous management measures were also maintained. Along with the implementation of such a management regime comes the need to determine the status of stock for each river in a given SFA in relation to a target spawning requirement. In insular Newfoundland, in addition to using fluvial habitat for rearing, juvenile Atlantic salmon make extensive use of lacustrine habitat (Pepper 1976; O'Connell and Reddin 1983; Chadwick and Green 1985; Pepper et al. 1985; O'Connell 1986; Ryan 1986; O'Connell and Ash 1989; O'Connell et al. 1990; O'Connell and Dempson 1990). Spawning requirements therefore have to be determined in terms of both fluvial and lacustrine habitats.

There is published and unpublished information available on smolt production from fluvial and lacustrine habitats for several river systems spread throughout insular Newfoundland. In this paper, we use this information to derive interim smolt production values appropriate for general application to calculate target spawning requirements in terms of each habitat type.

RIVER SPECIFIC SMOLT PRODUCTION

FLUVIAL

O'Connell (1986) and O'Connell and Ash (1989) found that North Harbour River in SFA 9 and Bay du Nord River in SFA 11 (Fig. 2) are capable of producing 3 smolts/unit (a unit = 100 m^2) of classical parr rearing habitat (Elson 1957). This value was based on complete counts of smolts obtained with counting fences. The portions of these river systems accessible to anadromous Atlantic salmon are characterized almost exclusively by fluvial habitat.

LACUSTRINE

Gander River (SFA 4)

Ryan (1986) calculated the net number of juvenile salmon leaving two ponds located in the headwaters of the Gander River, central Newfoundland (Fig. 2), as the difference between spring and fall population estimates. The Schnabel multiple mark-recapture method was used to estimate population size. A significant positive relationship was obtained between the number of emigrants in one year and adult abundance (as catch per unit effort in the recreational fishery) in the following year. Emigrants were therefore used as an index of smolt production. The number of spring to fall (in the same year) emigrants from the two lakes combined for the period 1979-83 averaged 13.4 fish/ha.

However, if one looks at the change in population estimates from fall (year i) to spring (year i+1), there is an increase in population levels. This is indicative of a movement of juveniles into these ponds from stream habitat for overwintering. O'Connell et al. (1990) showed that parr can become resident in standing water as early as the underyearling stage. Fall

population estimates in Ryan (1986) can be regarded as being indicative of parr that have spent probably a large part of their lives in ponds. Smolt age in the Gander River ranges from 3+ to 6+ years (O'Connell and Ash 1991). Multiplying the fall population estimates of Ryan (1986) by the proportion of parr age 2+ and older gives the number eligible to become smolts the following spring. These parr numbers can be converted to smolts by multiplying by the parr-smolt survival (0.40) of Elson (1975). Estimated smolt production ranged from 4.3 to 7.8 smolts/ha (Table 1).

Northeast Brook, Trepassey (SFA 9)

Population estimates of parr (using the Schnabel multiple mark-recapture method) have been carried out in a pond located in Northeast Brook (Trepassey) (Fig. 2) since 1984. Numbers of parr (> 10 cm in length) in late summer can be converted to smolts as above using the parr-smolt survival of 0.40 and production expressed as the number of smolts/ha. Production ranged from 27.0 to 105.1 smolts/ha (Table 1).

Northeast River, Placentia (SFA 10)

O'Connell (1986) and O'Connell and Ash (1989) determined smolt production in terms of lacustrine habitat for Northeast River (Placentia) and the Beaver River tributary of Southeast River (Placentia). The location of each river is shown in Fig. 2. These systems are dominated to a large extent by lacustrine habitat. The total number of smolts leaving each system in 1977 was counted using fyke nets. Smolt production in terms of lacustrine habitat was determined by subtracting the number of smolts attributable to fluvial habitat. Smolt production in fluvial habitat was estimated by applying the value of 3 smolts/100 m^2 of classical parr habitat presented above. Production in terms of lacustrine habitat for Northeast River was 10.1 smolts/ha and for Beaver River it was 10.9 smolts/ha.

Conne River (SFA 11)

Annual stock assessments have been ongoing for Conne River (Fig. 2) since 1986 (Dempson 1990). As part of the overall assessment each year, total smolt output is determined by mark-recapture using partial counting fences (Dempson and Stansbury 1991). For a description of the techniques used to estimate smolt production see Dempson (1990). Estimated smolt production in terms of lacustrine habitat can be determined as above for Northeast River and Beaver River (i.e., by subtracting fluvial production based on 3 smolts/100 m^2). Estimated smolt production from lacustrine habitat for the period 1987-90 ranged from 4.6 to 8.0 smolts/ha (Table 1).

Western Arm Brook (SFA 14)

Western Arm Brook (Fig. 2) is the only river system in insular Newfoundland for which a stock-recruitment relationship in terms of smolts has been demonstrated (Chadwick 1982, 1985a). In this system, an estimated 67% of smolt production comes from lacustrine habitat (Chadwick and Green 1985).

An average egg-to-smolt survival rate of 0.017 has been calculated for Western Arm Brook (Chadwick 1982, 1985a). This value however represents

survival for fluvial and lacustrine habitats combined. Currently in Atlantic Canada, the recommended seeding rate for fluvial habitat is 240 eggs/100 m^2 (Elson 1975). Dividing the fluvial smolt production value of 3 smolts/100 m^2 by 240 eggs/100 m^2 results in an assumed egg-to-smolt survival rate of 0.0125 for fluvial habitat. By fixing egg-to-smolt survival for fluvial habitat in Western Arm Brook at 0.0125, survival attributable to lacustrine habitat can be determined according to the following equation:

$$(1) \qquad ES_l = \frac{0.017 - PF\ (ES_f)}{PL}$$

where

ES_l = estimated egg-to-smolt survival for lacustrine habitat
ES_f = estimated egg-to-smolt survival for fluvial habitat
PF = proportion of smolt production from fluvial habitat
PL = proportion of smolt production from lacustrine habitat

or,

$$ES_l = \frac{0.017 - 0.33\ (0.0125)}{0.67} = 0.019$$

The optimal spawning requirement for Western Arm Brook has been estimated to be 370 spawners and 500 spawners was considered to be somewhat high (Chadwick 1985b, 1987). The spawner requirement for Western Arm Brook can be apportioned in terms of the relative contribution of fluvial and lacustrine habitats as follows:

$$(2) \qquad SR = \frac{(SP_f \cdot A_f \cdot 1/ES_f) + (SP_l \cdot A_l \cdot 1/ES_l)}{EN}$$

where

SR = spawner requirement
SP_f = smolt production per unit area of fluvial habitat
SP_l = smolt production per unit area of lacustrine habitat
A_f = area of fluvial habitat
A_l = area of lacustrine habitat
ES_f = egg-to-smolt survival in fluvial habitat
ES_l = egg-to-smolt survival in lacustrine habitat
EN = number of eggs per fish

Using an iterative approach, the lacustrine smolt production value set in

equation 2 (SP_l)that yields a result close to the optimum of 370 spawners is 2 smolts/ha. Thus, using equation 2 and setting the following values:

SP_f = 3/100 m^2 = 0.03
SP_l = 2/10000 m^2 = 0.0002
A_f = 290000 m^2
A_l = 20170000 m^2
ES_f = 0.0125
ES_l = 0.019
EN = 2304

gives,

$$SR = \frac{(0.03 \times 290000 \times 1/0.0125) + (0.0002 \times 20170000 \times 1/0.019)}{2304}$$

$$= 394$$

This approach yields a lacustrine production value for Western Arm Brook of 2 smolts/ha.

SMOLT PRODUCTION BY SFA

Using the information presented above for specific rivers, an attempt will now be made to derive smolt production values appropriate for use in the calculation of target spawning requirements at the SFA level. For fluvial habitat, it is recommended that the value of 3 smolts/ha found for North Harbour River and Bay du Nord River be used for all SFAs in the Newfoundland Region.

It is evident from Table 1 that there are wide differences among rivers in smolt production from lacustrine habitat. Values for the pond in Northeast Brook (Trepassey) were exceptionally high. It is possible that the high densities of juveniles in this pond could be related to its proximity to spawning areas. The pond is located immediately below the major spawning area in Northeast Brook and some spawning also occurs just below the pond. Pepper et al. (1991) reported an average production of 76.8 smolts/ha from fall fingerlings that were manually stocked into a pond in the Black Brook tributary of Indian River, Newfoundland (SFA 4). By comparison, combined production from the two headwater ponds in Gander River averaged 6.1 smolts/ha. These ponds are not located in the immediate vicinity of spawning areas (Ryan 1986). In contrast to these estimates for individual ponds, values for Northeast River (Placentia), Beaver River, and Conne River were determined on the basis of the entire river (i.e., for all ponds collectively in each river). The values obtained for entire rivers are the net effect of the natural distribution of juveniles into ponds both adjacent to and distant from spawning areas.

In the present exercise, it is necessary to determine lacustrine smolt production in terms of entire rivers. Therefore, estimates for individual ponds in Northeast Brook (Trepassey) and Gander River were not considered appropriate for inclusion with other values. It is recommended that the

overall mean production value for Northeast River (Placentia), Beaver River, and Conne River be adopted for general use for all areas of insular Newfoundland (Newfoundland Region) except the Great Northern Peninsula. Since the values for Northeast River (Placentia) and Beaver River are for the same year and both rivers are located in the same SFA, the mean for these rivers is used along with individual values for Conne River in the calculation of the overall arithmetic mean. The production value thus obtained is 7.4 smolts/ha. The value of 2 smolts/ha derived for Western Arm Brook is recommended for the Great Northern Peninsula.

CONCLUSIONS

There are limitations in using fixed parameters such as 3 smolts/100 m^2 of fluvial habitat and 7 smolts/ha of lacustrine habitat to calculate potential smolt production (and hence target egg deposition) for all rivers in all SFAs, in that there could be inter-river and inter-annual variation in such parameters. The same is true of applying the egg-to-smolt survival value of 1.25% for fluvial habitat to the calculation egg-to-smolt survival in terms of lacustrine habitat for Western Arm Brook. Also, the egg-to-smolt value of 1.25% for fluvial habitat was based on fixed values for egg deposition and smolt production.

The smolt production values recommended for use in this analysis were based on the best information available at the present time. Even though there might be some imprecision when the values are applied on an individual river basis, they should serve reasonably well in the interim. The values will continue to be evaluated as new information becomes available.

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Table 1. Estimates of smolt production (No./ha) in lacustrine habitat for rivers in insular Newfoundland.

River	Year	Estimated smolt production (No./ha)
SFA 4		
Gander River	1979	6.6
	1980	7.2
	1981	7.8
	1982	4.8
	1983	4.3
SFA 9		
Northeast Brook (Trepassey)	1984	105.1
	1985	84.1
	1986	41.1
	1987	27.0
	1988	85.9
	1989	28.8
	1990	44.5
SFA 10		
Northeast River (Placentia)	1977	10.1
Beaver River (Placentia)	1977	10.9
SFA 11		
Conne River	1987	7.6
	1988	6.4
	1989	8.0
	1990	4.6
SFA 14		
Western Arm Brook	*	2.0

*Derived based on a stock-recruitment relationship (see text).

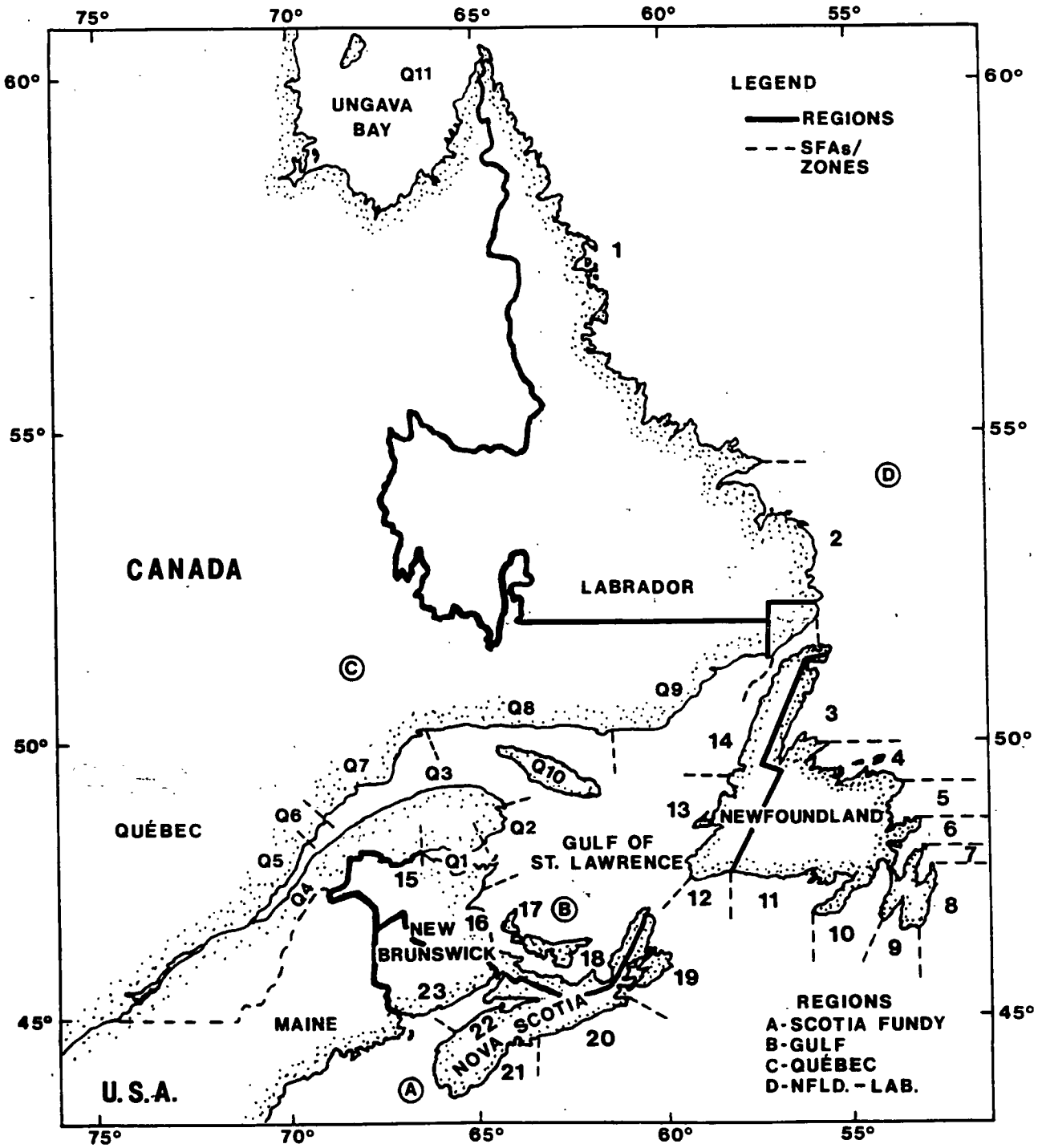

Fig. 1. Map of Atlantic Provinces of Canada showing Salmon Fishing Areas (SFAs) 1-23, Salmon Management Zones of Quebec (Qs) 1-11, and regional boundaries. The Newfoundland Region is comprised of SFAs 1-11.

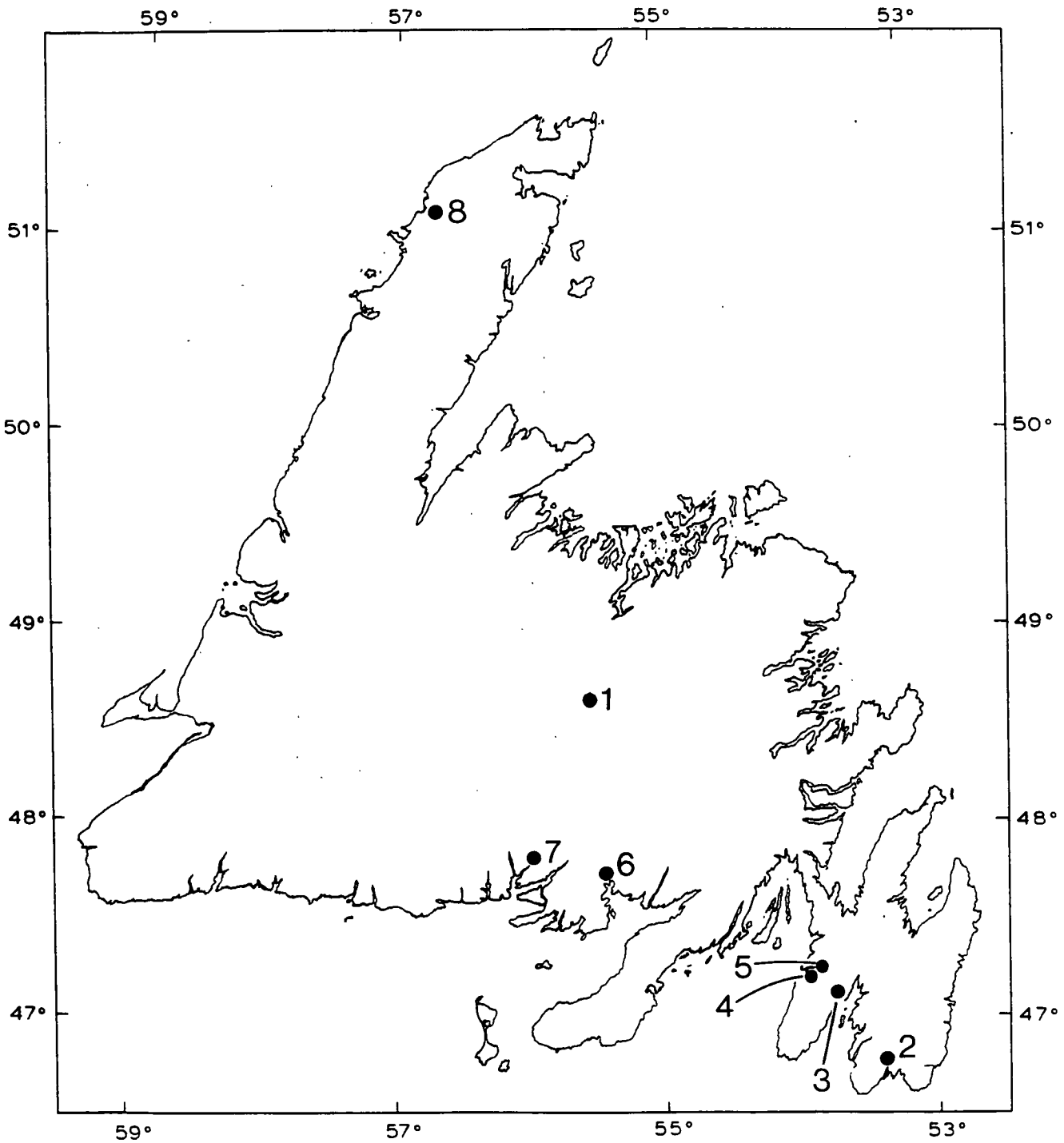

Fig. 2. Map showing specific rivers for which smolt production parameters were available. 1= Gander River; 2= Northeast Brook,Trepassey; 3= North Harbour River; 4= Beaver River (Southeast River),Placentia; 5= Northeast River, Placentia; 6= Bay Du Nord River; 7= Conne River; 8= Western Arm Brook.