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

by

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Abstract

Target spawning requirements in terms of fluvial and lacustrine habitats were derived for various rivers in Notre Dame, St. Mary's, and Placentia bays, Newfoundland. Spawning requirements were calculated from smolt production estimates using an egg-to-smolt survival rate of 1.25% for fluvial habitat and a rate of 1.9% for lacustrine habitat. Smolt production estimates were derived assuming the production of 3 smolts per unit from fluvial parr rearing habitat and 7 smolts per hectare from lacustrine habitat.

Résumé

On a établi les besoins-cibles de reproducteurs des habitats fluviaux et lacustres en se fondant sur diverses rivières des baies de Notre Dame, de St. Mary et de Placentia, à Terre-Neuve. Ces besoins ont été calculés d'après la production estimée de saumoneaux fondée sur des taux de survie oeufs-saumoneaux de 1,25 % et 1,9 % respectivement pour les habitats fluviaux et lacustres. Les estimations de production de saumoneaux reposent sur une hypothèse de production de 3 saumoneaux par unité dans les habitats fluviaux d'élevage de tacons et de 7 saumoneaux par hectare dans les habitats lacustres.

Introduction

In 1990, management measures affecting the commercial fishery for Atlantic salmon in the Newfoundland Region were implemented on a zonal or Salmon Fishing Area (SFA) basis for the first time. In an attempt to increase river escapements, quotas were set in the commercial fishery in each SFA while previous management measures were maintained. Ideally, levels of harvest allocated to user groups should centre around meeting river specific target (preferably optimum) spawning requirements in each SFA. The 1990 commercial quotas were implemented without consideration of spawning requirement information.

Before the status of a particular stock can be determined, the spawning requirement has to be defined. In insular Newfoundland, in addition to utilizing 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). In this paper, spawning requirements are calculated in terms of both fluvial and lacustrine habitat for various rivers in Notre Dame Bay (SFA 4), St. Mary's Bay (SFA 9), and Placentia Bay (SFA 10). The location of each SFA is shown in Fig. 1.

Methods

Biological characteristic data

Biological characteristic information used to convert target spawning requirements in terms of eggs to requirements in terms of number of adults was obtained by sampling recreational catches. Where possible, data for specific rivers (all years combined) were used. Mean values for all rivers combined in a given SFA were used as defaults for rivers where no biological characteristic data were available.

Fecundity was determined from ovaries collected from salmon caught 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. Fecundity for each river was expressed as relative fecundity (mean no. of eggs/kg). Where river-specific information on fecundity was not available, all data for a given SFA were used in default.

Accessible habitat determinations

The total surface area of accessible lacustrine habitat available for each river was determined using an Altek graphic digitizer with AC40 controller from 1:50,000 topographic maps (Surveys and Mapping Branch, Department of Energy, Mines and Resources, Ottawa). In the case of Gander River, the surface area of Gander Lake was omitted from the total. The amount of classical fluvial parr rearing habitat (Elson 1957) for each system was taken from river survey files. These surveys were conducted from helicopter and on foot.

Target spawning requirements

Smolt production was determined by multiplying the amount of fluvial and lacustrine habitat by production parameter values derived for each SFA by O'Connell et al. (1991). These values were 3 smolts/unit of fluvial habitat (a unit = 100 m^2) and 7 smolts/ha of lacustrine habitat.

Target egg deposition requirements were calculated from smolt production estimates using egg-to-smolt survival rates. For fluvial habitat, a rate of 1.25% was used. This value was derived by dividing 3 smolts per unit by 240 eggs per unit, the egg deposition of Elson (1975) that is currently recommended in eastern Canada. For lacustrine habitat, a value of 1.9% derived for Western Arm Brook (SFA 14) by O'Connell et al. (1991) was used. In Western Arm Brook, an estimated 67% of total smolt production was reported to have come from lacustrine habitat (Chadwick and Green (1985).

Target spawning requirements in terms of adults were calculated only for specimens < 63 cm in length. The calculation was as follows:

$$\text{No. of grilse} = \frac{\text{Target no. of eggs}}{\text{Relative fecundity X Mean weight X \% female}}$$

Most of these fish were virgin grilse with some repeat spawning grilse. Egg deposition from large salmon ($\geq$ 63 cm) was considered as a buffer to estimates of spawning requirements. These fish generally constitute approximately 10% of total runs to the rivers in the SFAs in question, and are predominantly repeat spawning grilse.

Results and Discussion

Estimated smolt production in terms of fluvial and lacustrine habitats and total smolt production for the major rivers in Notre Dame Bay, St. Mary's Bay, and Placentia Bay are presented in Tables 1-3 respectively. Also shown for each river is the ratio of the amount of lacustrine to fluvial habitat and the percentage of total smolt production coming from lacustrine habitat. Corresponding spawning requirements in terms of eggs and adults are shown in Tables 4-6. Pertinent biological characteristic data are also shown.

The use of fixed parameters such as 3 smolts/unit of fluvial habitat and 7 smolts/ha of lacustrine habitat to calculate smolt production for all rivers in SFAs 4, 9, and 10 has limitations in that there could be inter-river as well as inter-annual variation in such parameters. The same is true for the value of 240 eggs per unit used to calculate the egg-to-smolt survival of 1.25% for fluvial habitat. The egg-to-smolt survival value of 1.9% chosen for lacustrine habitat was calculated for Western Arm Brook (O'Connell et al. (1991) which has a modal smolt age of 4+ years (Chadwick et al. 1978). The dominant smolt age for the rivers in the present analysis is 3+ years. With one less year spent in freshwater, egg-to-smolt survival could be higher in these rivers than in Western Arm Brook and hence spawning requirements in terms of lacustrine habitat could be overestimated. The value of 1.25% for

fluvial habitat is similar to one used by Symons (1979) for 3+ smolts with 'medium' survival. Should this value be too high for Newfoundland rivers, then spawning requirements could be underestimated.

Chadwick and Green (1985) reported conductivity and hardness values for Western Arm Brook that were quite higher than those observed for rivers in SFAs 4, 9, and 10 (O'Connell and Andrews 1987; Porter et al. 1974a, b, c). Compared to rivers in these SFAs, any advantage in productive capacity accruing to Western Arm Brook as a result of water chemistry could be offset by its shorter growing season as evidenced indirectly by its older smolts.

Ideally, stream production should be defined in terms of different types of fluvial habitat. In the present analysis, smolt production (based on complete counts) was defined in terms of the amount of classical parr rearing habitat available, the relative proportion of which could be quite variable among rivers, thus confounding estimates. Expressing lacustrine production in terms of total lake surface area as opposed to production from different lentic habitats poses similar problems and as well, variability in morphometric parameters affecting production are important considerations (O'Connell and Ash 1989; O'Connell et al. 1990; O'Connell and Dempson 1990).

The phenomenon of atresia has been reported to occur in Atlantic salmon in the Soviet Union (Melnikova 1964) and in France (Prouzet et al. 1984). Recently there is evidence to show that it can occur to varying degrees in insular Newfoundland (O'Connell and Dempson, unpublished data). Fecundity values therefore have to be regarded as potential values. Since target spawning requirement calculations were based on eggs in early stages of development, the occurrence of atresia in a given year on a particular river would increase the number of spawners required.

The calculations of target spawning requirements assume that the locations of spawning substrate and nursery areas are such that under natural mechanisms of distribution, juveniles will have access to all the specified fluvial and lacustrine habitat. This condition will likely be met to varying degrees on different rivers.

Landlocked salmon populations are known to occur in certain rivers in all three SFAs. These parr may interact with anadromous parr and reduce anadromous smolt production per unit area.

Until the parameter values used in the present analysis can be updated, target spawning requirements calculated from them serve as reasonable standards against which to evaluate stock status.

References

Chadwick, E.M.P., and J. M. Green. 1985. Atlantic salmon (Salmo salar L.) production in a largely lacustrine Newfoundland watershed. Verh. Internat. Verein. Limnol. 22: 2509-2515.

Chadwick, E.M.P., T. R. Porter, and P. Downton. 1978. Analysis of growth of Atlantic salmon (Salmo salar) in a small Newfoundland river. J. Fish. Res. Board Can. 35: 60-68.

Elson, P. F. 1957. Using hatchery reared Atlantic salmon to best advantage. Can. Fish. Cult. 21: 7-17.

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

Melnikova, M. N. 1964. The fecundity of Atlantic salmon (Salmo salar L.) from the Varguza River. Vopr. Ikhtiol. 4: 469-476.

O'Connell, M. F. 1986. Atlantic salmon (Salmo salar L.) egg deposition potential and annual smolt production for three river systems characterized by lacustrine habitat in insular Newfoundland. CAFSAC Res. Doc. 86/85. 19 p.

O'Connell, M. F., and E.G.M. Ash. 1989. Atlantic salmon (Salmo salar) smolt production in a Newfoundland river system characterized by lacustrine habitat. Int. Revue ges. Hydrobiol. 74: 73-82.

O'Connell, M. F., and C. W. Andrews. 1987. Plankton ecology in relation to flushing rate in four Newfoundland ponds. Int. Revue ges. Hydrobiol. 72: 487-515.

O'Connell, M. F., and J. B. Dempson. 1990. Population and biomass estimates of juvenile Atlantic salmon in lacustrine habitat in insular Newfoundland. CAFSAC Res. Doc. 90/77: 379-391.

O'Connell, M. F., J. B. Dempson, and R. J. Gibson. 1991. Atlantic salmon (Salmo salar L.) smolt production parameter values for fluvial and lacustrine habitats in insular Newfoundland. CAFSAC Res. Doc. 91/19. 11 p.

O'Connell, M. F., J. B. Dempson, and T. R. Porter. 1990. Spatial and temporal distributions of salmonids in Junction Pond, Northeast River, Placentia and Conne Pond, Conne River, Newfoundland. CAFSAC Res. Doc. 90/77: 27-77.

O'Connell, M. F., and D. G. Reddin. 1983. Egg depositions in some Newfoundland rivers. CAFSAC Res. Doc. 83/15. 10 p.

Pepper, V. A. 1976. Lacustrine nursery areas for Atlantic salmon in insular Newfoundland. Fish. Mar. Serv. Tech. Rep. 671. 61 p.

Pepper, V. A., N. P. Oliver, and R. Blundon. 1985. Juvenile anadromous Atlantic salmon of three lakes of Newfoundland. Int. Revue ges. Hydrobiol. 70: 733-753.

Porter, T. R., L. G. Riche, and G. R. Traverse. 1974a. Catalogue of rivers in insular Newfoundland. Volume A. Resource Development Branch, Newfoundland Region, Department of Environment, Fisheries and Marine Service Data Record Series No. NEW/D-74-9. 316 p.

Porter, T. R., L. G. Riche, and G. R. Traverse. 1974b. Catalogue of rivers in insular Newfoundland. Volume B. Resource Development Branch, Newfoundland Region, Department of Environment, Fisheries and Marine Service Data Record Series No. NEW/D-74-9. 287 p.

Porter, T. R., L. G. Riche, and G. R. Traverse. 1974c. Catalogue of rivers in insular Newfoundland. Volume D. Resource Development Branch, Newfoundland Region, Department of Environment, Fisheries and Marine Service Data Record Series No. NEW/D-74-9. 353 p.

Prouzet, P., P. Y. LeBail, and M. Heydorff. 1984. Sex ratio and potential fecundity of Atlantic salmon (Salmo salar L.) caught by anglers on the Elorn River (Northern Brittany, France) during 1979 and 1980. Fish. Mgmt. 15: 123-130.

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

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.

Table 1. Accessible fluvial and lacustrine habitat and estimated smolt production for various rivers in SFA 4, Notre Dame Bay, Newfoundland. Lacustrine (L) habitat is expressed in hectares while fluvial (F) habitat is expressed as the number of classical parr rearing units (a unit = 100 m^2). The ratio L/F is expressed in terms of m^2.

River	Habitat area		Ratio L/F	Estimated smolt production[1]			
	L	F		L	F	Total	% L
West River	2,013	1,620	124.3	14,091	4,860	18,951	74
South Brook	3,616	6,050	59.8	25,312	18,150	43,462	58
Tommy's Arm Brook	1,157	3,377	34.3	8,099	10,131	18,230	44
West Arm Brook	779	1,469	53.0	5,453	4,407	9,860	55
New Bay River	2,293	1,984	115.6	16,051	5,952	22,003	73
Northern Arm Brook	1,009	2,498	40.4	7,063	7,494	14,557	48
Peter's River	442	1,737	25.4	3,094	5,211	8,305	37
Horwood River	4,173	1,685	247.6	29,211	5,055	34,266	85
Gander River	21,488[2]	159,560	13.5	150,416	478,680	629,096	24
Ragged Harbour R.	5,742	3,653	157.2	40,194	10,959	51,153	79

[1]Estimated assuming the production of 3 smolts/unit of classical fluvial parr rearing habitat and 7 smolts/hectare of lacustrine habitat (O'Connell et al. 1991).

[2]Gander Lake not included.

Table 2. Accessible fluvial and lacustrine habitat and estimated smolt production for various rivers in SFA 9, St. Mary's Bay, Newfoundland. Lacustrine (L) habitat is expressed in hectares while fluvial (F) habitat is expressed as the number of classical parr rearing units (a unit = 100 m^2). The ratio L/F is expressed in terms of m^2.

River	Habitat area		Ratio L/F	Estimated smolt production[1]			
	L	F		L	F	Total	% L
Biscay Bay River	2,685	8,175	32.8	18,795	24,525	43,320	43
Northwest Brook	648	7,460	8.7	4,536	22,380	26,916	17
Peter's River	614	4,105	15.0	4,298	12,315	16,613	26
Salmonier River	912	5,145	17.7	6,384	15,435	21,819	29
Colinet River	1,083	4,228	25.6	7,581	12,684	20,265	37
Rocky River	2,191	7,535	29.1	15,337	22,605	37,942	40
North Harbour River	63	912	6.9	441	2,736	3,177	14
Little Salmonier R.	928	4,488	20.7	6,496	13,464	19,960	33
Big Barachois River	348	1,259	27.6	2,436	3,777	6,213	39
Branch River	150	6,412	2.3	1,050	19,236	20,286	5

[1]Estimated assuming the production of 3 smolts/unit of classical fluvial parr rearing habitat and 7 smolts/hectare of lacustrine habitat (O'Connell et al. 1991).

Table 3. Accessible fluvial and lacustrine habitat and estimated smolt production for various rivers in SFA 10, Placentia Bay, Newfoundland. Lacustrine (L) habitat is expressed in hectares while fluvial (F) habitat is expressed as the number of classical parr rearing units (a unit = 100 m^2). The ratio L/F is expressed in terms of m^2.

River	Habitat area		Ratio L/F	Estimated smolt production[1]			
	L	F		L	F	Total	% L
Great Barasway Brook	88	928	9.5	616	2,784	3,400	18
Southeast River	1,128	2,639	42.7	7,896	7,917	15,813	50
Northeast River	1,072	1,352	79.3	7,504	4,056	11,560	65
Come By Chance River	214	3,093	6.9	1,498	9,279	10,777	14
Black River	1,446	1,375	105.2	10,122	4,125	14,247	1
Pipers Hole River	1,184	11,344	10.4	8,288	34,032	42,320	20
Cape Roger Brook	398	1,284	31.0	2,786	3,852	6,638	42
Bay de L'Eau River	557	3,508	15.9	3,899	10,524	14,423	27

[1]Estimated assuming the production of 3 smolts/unit of classical fluvial parr rearing habitat and 7 smolts/hectare of lacustrine habitat (O'Connell et al. 1991).

Table 4. Target spawning requirements for various rivers in SFA 4, Notre Dame Bay, Newfoundland expressed in terms of lacustrine (L) and fluvial (F) habitats and total requirements. Also included are pertinent biological characteristic data. Numbers of fish are in parentheses.

River	Relative fecundity (eggs/kg)	X ± SD Weight of females (kg)	% females	No. of eggs (x 10^6)			Adults		
				L	F	Total	L	F	Total
West	1,775[1] (580)	1.27 ± 0.23 (105)	73	0.742	0.389	1.131	451	236	687
South	1,775[1] (580)	1.55 ± 0.34[2] (2,669)	77[2]	1.332	1.454	2.784	629	685	1,314
Tommy's Arm	1,775[1] (580)	1.55 ± 0.34[2] (2,669)	77[2]	0.426	0.810	1.236	201	383	584
West Arm	1,775[1] (580)	1.55 ± 0.34[2] (2,669)	77[2]	0.287	0.353	0.640	135	166	301
New Bay	1,775[1] (580)	1.55 ± 0.34[2] (2,669)	77[2]	0.845	0.476	1.321	399	225	624
Northern Arm	1,775[1] (580)	1.55 ± 0.34[2] (2,669)	77[2]	0.372	0.599	0.971	175	283	458
Peter's	1,775[1] (580)	1.55 ± 0.34[2] (2,669)	77[2]	0.163	0.417	0.580	77	197	274
Horwood	1,775[1] (580)	1.55 ± 0.34[2] (2,669)	77[2]	1.537	0.404	1.941	726	191	917
Gander	1,665 (173)	1.63 ± 0.36 (941)	78	7.917	38.294	46.211	3,739	18,089	21,828
Ragged Harbour	1,775[1] (580)	1.45 ± 0.30 (46)	87	2.115	0.877	2.992	945	392	1,337

[1]Default: data for Gander River, Exploits River, and Indian River combined.
[2]Default: all available data for Gander River, Exploits River, Indian River, West River, Point Leamington River, Ragged Harbour River, Deadmans Brook, and Windmill Brook combined.

Table 5. Target spawning requirements for various rivers in SFA 9, St. Mary's Bay, Newfoundland expressed in terms of lacustrine (L) and fluvial (F) habitats and total requirements. Also included are pertinent biological characteristic data. Numbers of fish are in parentheses.

River	Relative fecundity (eggs/kg)	X ± SD Weight of females (kg)	% females	No. of eggs (x 10^6)			Adults		
				L	F	Total	L	F	Total
Biscay Bay	2,066 (290)	1.68 ± 0.36 (326)	75	0.989	1.962	2.951	380	754	1,134
Northwest	2,066[1] (290)	1.71 ± 0.38[1] (1,633)	85[2]	0.239	1.790	2.029	79	596	675
Peter's	2,066[1] (290)	1.71 ± 0.38[1] (1,633)	85[2]	0.226	0.985	1.211	75	328	403
Salmonier	2,066[1] (290)	1.05 ± 0.27 (52)	66	0.336	1.235	1.571	235	862	1,097
Colinet	2,066[1] (290)	1.53 ± 0.33 (434)	87	0.399	1.015	1.414	145	369	514
Rocky	2,066[1] (290)	1.71 ± 0.38[2] (1,633)	85[2]	0.807	1.808	2.615	269	602	871
North Harbour	2,066[1] (290)	1.71 ± 0.38[2] (1,633)	85[2]	0.023	0.219	0.242	8	73	81
Little Salmonier	2,066[1] (290)	1.86 ± 0.34 (1,034)	94	0.342	1.077	1.419	95	298	393
Big Barachois	2,066[1] (290)	1.71 ± 0.38[2] (1,633)	85[2]	0.128	0.302	0.430	43	101	144
Branch	2,066[1] (290)	1.69 ± 0.28 (36)	85[2]	0.055	1.539	1.594	19	518	537

[1]Default: data for Biscay Bay River.
[2]Default: data for all rivers combined.

Table 6. Target spawning requirements for various rivers in SFA 10, Placentia Bay, Newfoundland expressed in terms of lacustrine (L) and fluvial (F) habitats and total requirements. Also included are pertinent biological characteristic data. Numbers of fish are in parentheses.

River	Relative fecundity (eggs/kg)	X ± SD Weight of females (kg)	% females	No. of eggs (x 10^6)			Adults		
				L	F	Total	L	F	Total
Great Barasway	2,267[1] (106)	1.56 ± 0.24[2] (390)	91[2]	0.032	0.223	0.255	10	69	79
Southeast	2,267[1] (106)	1.56 ± 0.24[2] (390)	91[2]	0.416	0.633	1.049	129	197	326
Northeast	2,267 (106)	1.56 ± 0.24 (378)	91	0.395	0.324	0.719	123	101	224
Come By Chance	2,267[1] (106)	1.56 ± 0.24[2] (390)	91[2]	0.079	0.742	0.821	24	231	255
Black	2,267[1] (106)	1.56 ± 0.24[2] (390)	91[2]	0.533	0.330	0.863	166	103	268
Pipers Hole	2,267[1] (106)	1.61 ± 0.26 (12)	80	0.436	2.723	3.159	149	932	1,081
Cape Roger	2,267[1] (106)	1.56 ± 0.24[2] (390)	91[2]	0.147	0.308	0.455	46	96	142
Bay de L'Eau	2,267[1] (106)	1.56 ± 0.24[2] (390)	91[2]	0.205	0.842	1.047	64	262	326

[1]Default: data for Northeast River.
[2]Default: data for Northeast River and Piper's Hole River combined.

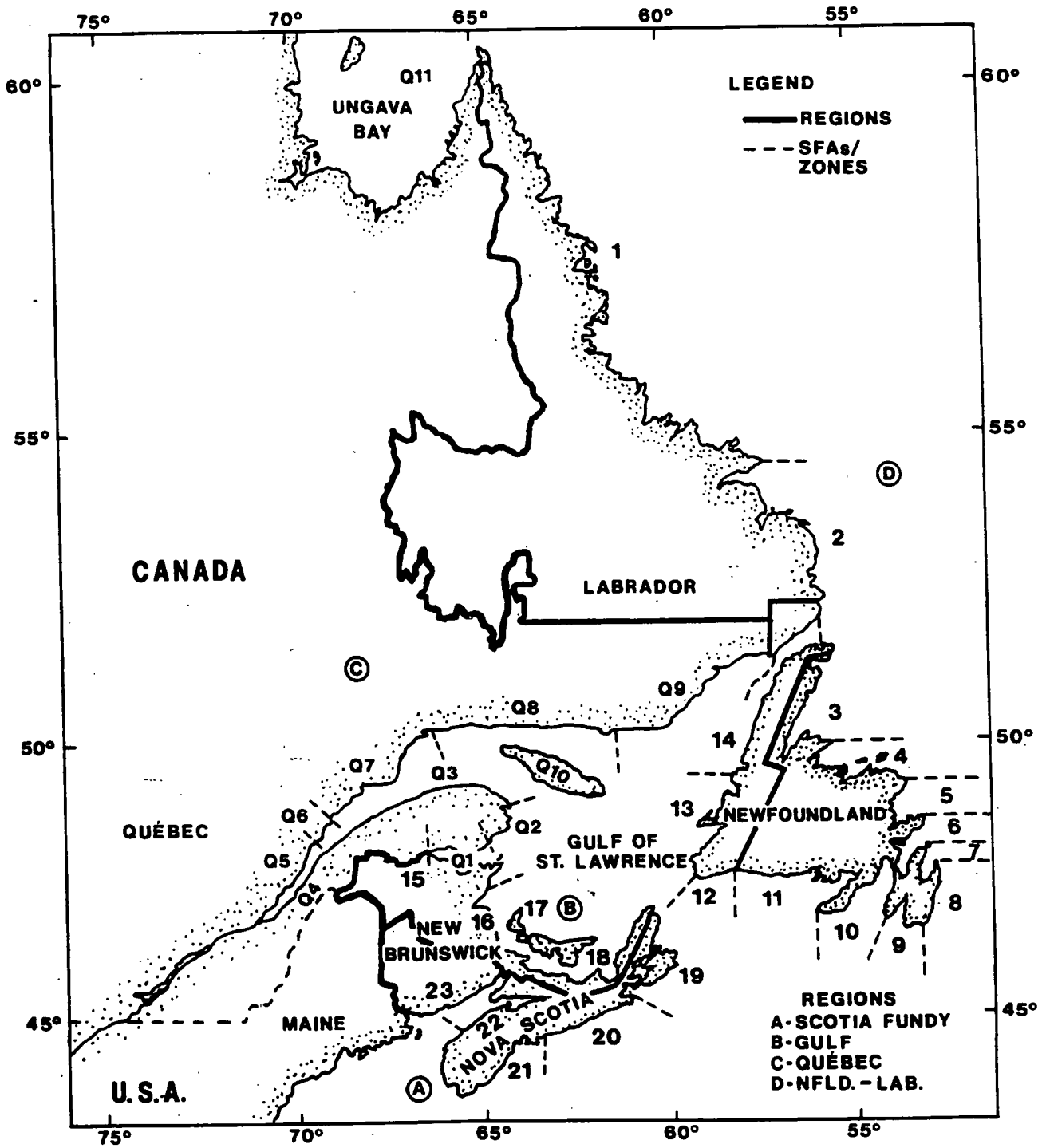

Fig. 1. Map of Atlantic Provinces of Canada showing Salmon Fishing Areas (SFAs) 1-23, Salmon Management Zones of Quebec (Qs) 1-11, and regional boundaries. The Newfoundland Region is comprised of SFAs 1-11.