Effects of Changing Fishing Mortality on Atlantic Salmon (*Salmo salar* L.) Egg Deposition in Gander River

by

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Abstract

Assessments of the Gander River salmon populations indicated that from 1989-1991 the Gander River only received about 35% of its required egg deposition. An evaluation of the effects of changing the fishing mortality in the commercial and recreational fisheries indicated the egg deposition would be: 1) 40% of requirements if only the recreational fishery is closed; 2) 60% of requirements if only the commercial fishery in Gander Bay is closed; 3) 72% of requirements if the commercial fishery in Gander Bay and the recreational fishery are closed; 4) 87% of requirements if all commercial fisheries are closed; and 5) 100% of requirements if all the commercial and recreational fisheries are closed. These evaluations assume that the total population size would be similar to the average size observed for 1989-91.

Résumé

Une évaluation des populations de saumon de la rivière Gander a révélé qu'entre 1989 et 1991, la ponte n'a représenté que 35 p. 100 des besoins. On a établi qu'en modifiant la mortalité due à la pêche commerciale et sportive, la ponte s'établirait comme suit : 1) 40 p. 100 des besoins si on fermait seulement la pêche sportive; 2) 60 p. 100 des besoins si on fermait la pêche commerciale dans la baie de Gander seulement; 3) 72 p. 100 des besoins si on fermait la pêche commerciale dans la baie de Gander et la pêche sportive; 4) 87 p. 100 des besoins si on fermait toute pêche sportive et 5) 100 p. 100 des besoins si on fermait toute pêche commerciale et toute pêche sportive. Ces chiffres sont fondés sur l'hypothèse d'un population comparable à la moyenne de 1989 à 1991.

Introduction

The Atlantic salmon (Salmo salar) population entering the Gander River has declined during the 1980's, and from 1989 to 1991, only 33-36% of the egg deposition requirement (46.211×10^6) has been achieved (O'Connell and Ash 1992). O'Connell and Ash (1992) also concluded that the commercial fishery in Gander Bay contributed to this decline.

This paper evaluates the possible benefits that changing the fishing mortality may have on increasing egg deposition in the Gander River. Five scenarios for reducing fishing mortality are considered, namely:

1. Closing the recreational fishery in the Gander River.

2. Closing the commercial fishery in Gander Bay, with the recreational fishery left open.

3. Closing the commercial fishery in Gander Bay and the recreational fishery in Gander River.

4. Closing all commercial fisheries exploiting salmon of Gander River-origin, with the recreational fishery left open.

5. Closing all commercial fisheries exploiting salmon of Gander River-origin and also closing the recreational fishery on Gander River.

Methods

Data

Commercial catch statistics for five communities in Gander Bay (Fig 1), 1974-91, were available from the Fisheries Statistics and Systems Branch of the Department of Fisheries and Oceans. Recreational catch statistics for the Gander River are presented in Table 1. The number of salmon entering the river and estimates of numbers of spawners and egg deposition are from O'Connell and Ash (1992).

Biological characteristics for Atlantic salmon in the Gander River are from O'Connell and Ash (1992). Biological characteristics of salmon caught in the commercial fishery in Gander Bay are from samples taken in the commercial fishery at Fredericton in 1989 (Table 2). Small salmon refers to salmon < 63 cm for salmon in the river and salmon < 2.68 kg in the commercial fishery. Large salmon refers to salmon ≥ 63 cm for salmon in the river, and ≥ 2.68 kg in the commercial fishery.

Egg deposition from reducing fishing mortality

The effect that each of the five scenarios, referenced above, would have on increasing egg deposition in the Gander River was evaluated by applying the

closure in scenarios 1, 2, and 3 to landings during the period 1974-91 and the closures in scenarios 4 and 5 to landings during the period 1989-91.

Scenario 1: Closure of the Recreational Fishery

The potential effect that closing the recreational fishery 1974-91 would have had on the egg deposition was calculated by using the following formula:

$$1)\quad E_r = [(A_g * W_g * S_g) + (A_l * W_l * S_l)] * R_f$$

where: E_r = Potential egg deposition from closure of the recreational fishery
A_g = Angling catch, in numbers, of small salmon
W_g = Mean weight of small salmon
S_g = Percent female of small salmon
A_l = Angling catch, in numbers, of large salmon
W_l = Mean weight of large salmon
S_l = Percent female of large salmon
R_f = Relative fecundity (eggs/kg)

The relative fecundity for all sizes of salmon was assumed to be 1,665 eggs/kg (O'Connell and Ash, 1992)

Scenario 2: Closure of the commercial fishery in Gander Bay and the recreational fishery in Gander River left open

The potential effect that closing the commercial fishery in Gander Bay, 1974-91, would have had on the egg deposition was calculated by using the following formula:

$$2)\quad E_b = [\{(C_g * P * S_{cg})\ (1-U_g)\} + \{(C_l * P * S_{cl})\ (1-U_l)\}] * R_f$$

where: E_b = Potential egg deposition from salmon which would have been released from the commercial fishery in Gander Bay
C_g = Commercial catch in kg of small salmon in Gander Bay
P^g = Proportion of salmon that are Gander River-origin
S_{cg} = Percent females of small salmon in commercial fishery
S^{cg} = Percent females of large salmon in commercial fishery
U_g^{cl} = Exploitation rate on small salmon in the recreational fishery in Gander River
U_l = Exploitation rate on large salmon in the recreational fishery in Gander River
C_l = Commercial catch in kg of large salmon in Gander Bay

Three calculations were performed, assuming that the proportion of Gander River-origin salmon in the catches in Gander Bay was either 1.0, 0.75, or 0.50.

The exploitation rates on small salmon in the recreational fishery were 0.153, 0.149, and 0.175 in 1989, 1990, and 1991 respectively, as calculated from data provided in O'Connell and Ash (1992). It was assumed that there was no angling mortality on large salmon, 1984-91. The mean exploitation rate

(0.159) for 1989-91 was assumed for all previous years for small salmon and for years prior to 1984 for large salmon.

Scenario 3: Closure of the commercial fishery in Gander Bay and the recreational fishery in Gander River

The potential effect of these closures when applied to 1974-91 can be derived making U_g and $U_l = 0$ (equation 2) and summing E_r from equation (1) and E_b from equation (2).

Scenario 4: Closure of all commercial fisheries exploiting Gander River-origin salmon and the recreational fishery in Gander River left open

The potential effect that closing all commercial fisheries harvesting salmon of Gander River-origin would have had on the egg deposition was calculated for 1989, 1990, and 1991. These were years in which total escapements to the Gander River are known. The following formula was used:

$$3)\quad E_c = [(ES_g * (1-U_g) * W_{cg} * S_{cg}) + (ES_l * W_{cl} * S_{cl})] * R_f$$

where: Ec = Potential egg deposition from salmon which would have been released from commercial fisheries
ES_g = Additional escapement of small salmon
ES_l^g = Additional escapement of large salmon
W_{cg} = Mean weight of small salmon released from commercial fisheries
W_{cl} = Mean weight of large salmon released from commercial fisheries

The terms ES_g and ES_l are further defined:

$$4)\quad ES_g = (RE_g * 1/U_{cg}) - RE_g$$

$$5)\quad ES_l = (RE_l * 1/U_{cl}) - RE_l$$

where: RE_g and RE_l = River escapement of small and large salmon respectively
U_{cg} and U_{cl} = Commercial exploitation rate of small and large salmon respectively

The commercial exploitation rates were assumed to be 0.50 on small salmon (U_{cg}) and 0.75 on large salmon (U_{cl}). The biological characteristics of the additional fish released from the commercial fisheries were assumed to be the same as those derived from salmon sampled at Fredericton in 1989 (Table 2).

Scenario 5: Closure of all commercial and recreational fisheries exploiting salmon of Gander River-origin

The potential effect that closing all commercial and recreational fisheries harvesting salmon of Gander River-origin would have had on the egg deposition was also calculated for 1989, 1990, and 1991. The effects (E_c) of closing all commercial fisheries was calculated using Equation (3) and setting U_g at 0.0. The effect (E_r) of closing the recreational fisheries was

calculated from Equation (1). The total potential egg deposition which could have occurred in 1989, 1990, and 1991 was determined by summing E_c, E_r, and the estimate of the egg deposition estimated by O'Connell and Ash (1992).

Results

There was a substantive increase in the commercial landings of small salmon in Gander Bay, beginning in 1981 (Table 1). The average landings increased from about 4.5 t, 1974-83, to about 12.6 t, 1984-91. The landings of large salmon tended to remain relatively constant over years. The landings of small salmon in the recreational fisheries declined from about 3,000 fish, 1974-83 to about 2,000 fish, 1984-91.

The potential annual effect that the various closures could have had on the egg deposition if applied during the period 1974-91, for scenarios 1, 2, and 3, and 1989-91 for scenarios 4 and 5, are shown in Tables 3-7. These results are summarized below. For scenarios 2 and 3, the percent egg requirements are based on calculations using 0.75 as the proportion of the salmon in the commercial fishery in Gander Bay which were of Gander River-origin.

	% of egg requirements released from fisheries				
Years	Scen 1 Close Rec	Scen 2 Close GB	Scen 3 Close GB+Rec	Scen 4 Close Com	Scen 5 Close Com+Rec
1974-83	16	15	33	-	-
1983-91	9	30	45	-	-
1989-91	5	25	36	52	65

The above percentages are in addition to the egg deposition which actually occurred.

During the period 1989-91, the Gander River potentially could have achieved 87% of its egg deposition requirements if there was no commercial fishing mortality and the recreational fishing exploitation rate was 0.159 (Table 6). If both the commercial and recreational fisheries had been closed, about 100% of the egg deposition requirements could have been met (Table 7).

Discussion

The decline in recreational fishery landings coincides with an increase in landings of small salmon in the Gander Bay commercial fishery (Table 1). The high percentage of previous spawners in the commercial fishery in Gander Bay and the similarity of the river ages of salmon sampled in the Gander Bay and Gander River suggests that the salmon in Gander Bay are probably local origin. The proportion of previous spawners, 50% for small salmon and 55% for large

salmon (Table 2) is higher than the 5-10% percent normally observed in the commercial samples taken at Twillingate, also in SFA 4 (Reddin pers. comm.). The river age of salmon sampled in Gander Bay ranged from 2 to 5 years with a mean river age of 3.5 years (9% river age 2) which is similar to the mean river age of 3.7 years for salmon sampled in the Gander River (O'Connell and Ash, 1992). Since there are no other salmon rivers in Gander Bay, it is reasonable to assume that about 75% of the salmon caught in the commercial fishery in Gander Bay are of Gander River-origin.

The differences in mean weight of large salmon in the commercial fishery (3.05 kg) and in the river (3.41 kg) (Table 2) is probably related to the small sample sizes. Whereas, the larger mean weight of small salmon in the commercial fishery is believed to be related to selectivity of the commercial fishery for larger fish (Table 2).

The increased fishing mortality in Gander Bay in the 1980's could have resulted in an average additional reduction of 15% (potential egg loss in 1974-83 minus loss in 1984-91) of the Atlantic salmon egg deposition requirements of the Gander River (Table 4).

O'Connell and Ash (1992) indicated that from 1979 to 1988 the Gander River received 60-65% of its egg deposition requirements. If the commercial fishery in Gander Bay had been closed, 1979-1988, 81-86% of the egg deposition requirements could have been met (Table 4). A closure of both the commercial fishery in Gander Bay and the recreational fishery would have increased this percentage to about 100% of requirements (Table 5).

In recent years, 1989, 1990, 1991, salmon egg depositions have only been 35%, 36%, and 33% respectively, of requirements (O'Connell and Ash, 1992). A closure of the commercial fishery in Gander Bay and the recreational fishery in the Gander River (scenario 3) could have increased the egg deposition to 88%, 65%, and 58% of egg deposition requirements for 1989, 1990, and 1991 respectively (Table 5). If all commercial fisheries were closed but not the recreational fishery (scenario 4), 1989-91, 86-89% of the egg deposition requirements could have been met (Table 6). A closure of all commercial and recreational fisheries (scenario 5), 1989-91, could have resulted in 97-102% of the egg deposition being met (Table 7).

The above exercises calculating potential additional returns to the Gander River should be considered to represent just one of many possible results. There is uncertainty in most of the parameter values used in the calculations, and a simulation approach may have yielded a somewhat different distribution of expected results. The final outcome, however, would probably be consistent; that is, major changes to current fishing strategies on the Gander River origin salmon population would be required in order to increase egg deposition levels necessary for rehabilitation of the stock

Management Considerations for Restoring the Gander River Salmon Populations

Consideration needs to be given to whether the management objective is to restore the salmon population to the estimated productive capacity of the Gander River in one or two life cycles (5 or 10 years). It is recommended that if the objective is to restore the population in two life cycles, then the

management target should be to attain at least 75% of egg deposition requirements for each of the next 5 years and 100% of the target in years 6-10. If it is assumed that the population size during the first five year period will be similar to the size observed 1989-91, then it will be necessary to: 1) close the commercial fishery in Gander Bay and the recreational fishery in Gander River; or 2) close all commercial fisheries exploiting Gander River-origin salmon, but not the recreational fisheries. Option 2 would be successful only if strict controls were placed on the recreational fishery and the illegal fishery, so that any benefits obtained from the commercial closure would not be lost.

If the objective is to restore the Gander River population in one life cycle, then all commercial and recreational fisheries would need to be closed.

The above approaches to restore the salmon populations assumes that there will be negligible bycatch and there will be no increase in illegal harvest. There are presently no reliable techniques available to estimate the population size of Atlantic salmon prior to returns to the river. Changes in natural mortality could have a substantive effect on variation in the returns to the river with any given egg deposition. In season assessments are required in order to insure management targets are met.

Acknowledgements

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Reference

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), 1989-91. CAFSAC Res. Doc. 92/25. 22p.

Table 1. Landings of Atlantic salmon in the commercial fishery at 5 communities in Gander Bay, SFA 4, 1974-91, and in the recreational fishery in the Gander River. Numbers in the commercial fishery were derived using the mean weights from Table 2.

Year	Commercial				Recreational	
	Weight (kg)		Numbers		Numbers	
	Small	Large	Small	Large	Small	Large
1974	5,090	6,145	2,379	2,015	2,270	19
1975	3,892	5,316	1,819	1,743	2,976	38
1976	1,916	1,560	895	511	2,374	132
1977	3,884	3,099	1,815	1,016	2,269	927
1978	2,621	829	1,225	272	3,332	389
1979	2,107	1,888	985	619	4,199	318
1980	2,717	4,408	1,270	1,445	2,664	268
1981	6,454	3,802	3,016	1,247	4,578	249
1982	7,140	3,433	3,336	1,126	2,176	205
1983	8,978	5,151	4,195	1,689	2,033	239
1984	13,587	3,513	6,349	1,152	2,028	13
1985	14,522	3,552	6,786	1,165	3,358	0
1986	17,710	5,988	8,276	1,963	2,361	0
1987	9,962	4,911	4,655	1,610	1,441	0
1988	12,090	4,084	5,650	1,339	2,686	0
1989	19,803	2,626	9,254	861	1,173	0
1990	9,534	1,528	4,455	501	1,155	0
1991	3,631	5,278	1,697	1,730	1,180	0
Mean (S.D.)						
74-83	4,480 (2,382)	3,563 (1,750)	2,094 (1,113)	1,168 (574)	2,887 (888)	278 (256)
84-91	12,605 (5,067)	3,935 (1,455)	5,890 (2,368)	1,290 (477)	1,992* (868)	0
89-91	10,989 (8,184)	3,144 (1,928)	5,135 (3,824)	1,031 (632)	1,169 (13)	0

* 1987 catch not included in mean

Table 2. Biological characteristics of salmon caught in the commercial fishery at Frederickton, Gander Bay (GB), 1989, and angled in the recreational fishery in Gander River (GR), 1975-87. Numbers in parenthesis is the sample sizes.

	Mean weight (kg)		% female		% Sea age					
					Small[1]			Large[2]		
	Small	Large	Small	Large	1SW	MSW	PS	1SW	MSW	PS
GB	2.14 (94)	3.05 (26)	79 (96)	81 (26)	49	1	50	43	2	55
GR	1.63 (941)	3.41[3] (14)	78 (1217)	88[1] (16)						

[1] Sample size is 144.
[2] Sample size is 44.
[3] Mean for large salmon sampled in the recreational fishery in Gander and Terra Nova rivers.

Table 3. Additional potential egg deposition which would have occurred if the recreational fishery was closed in the Gander River, 1974-91. The percent that this value is of the required egg deposition for the Gander River is also shown. (Scenario 1)

Year	Eggs X 10^6	Additional % of required egg deposition
1974	4.900	11
1975	6.490	14
1976	5.685	12
1977	9.435	20
1978	8.997	20
1979	10.478	23
1980	6.979	15
1981	10.936	24
1982	5.631	12
1983	5.498	12
1984	4.358	9
1985	7.108	15
1986	4.998	11
1987	3.050	7
1988	5.686	12
1989	2.483	5
1990	2.445	5
1991	2.498	5
Mean 1974-83	7.467	16
1984-91	4.217	9
1989-91	2.475	5

Table 4. Additional potential egg deposition which would have occurred in the Gander River if the commercial fishery in Gander Bay had been closed, 1974-91, and assuming that the proportion of the fish which are of Gander River-origin was either 1.0, 0.75, or 0.50. Recreational fishery open. (Scenario 2)

Year	p = 1.0		p = 0.75		p = 0.50	
	pot. eggs $\times 10^6$	% req. eggs	pot. eggs $\times 10^6$	% of req eggs	pot. eggs $\times 10^6$	% of req eggs
1974	12.514	27	9.386	20	6.257	14
1975	10.260	22	7.695	17	5.130	11
1976	3.867	8	2.900	6	1.934	4
1977	7.768	17	5.826	13	3.884	8
1978	3.828	8	2.871	6	1.914	4
1979	4.446	10	3.335	7	2.223	5
1980	7.943	17	5.957	13	3.972	9
1981	11.399	25	8.549	19	5.700	12
1982	11.744	25	8.808	19	5.872	13
1983	15.702	34	11.777	26	7.851	17
1984	19.949	43	14.962	32	9.975	22
1985	21.038	46	15.779	34	10.519	23
1986	27.976	61	20.982	45	13.988	30
1987	17.897	39	13.423	29	8.949	19
1988	19.093	41	14.320	31	9.547	21
1989	25.583	55	19.187	42	12.792	28
1990	12.686	28	9.515	21	6.343	14
1991	11.407	25	8.555	19	5.704	12
Mean (S.D.) 74-83	8.947	19	6.710	15	4.474	10
84-91	18.352	40	13.764	30	9.176	20
89-91	15.678	34	11.759	25	7.839	17

Table 5. Additional potential egg deposition which would have occurred in the Gander River if the commercial fishery in Gander Bay and recreational fishery had been closed, 1974-91, and assuming that the proportion of the fish which are of Gander River-origin was either 1.0, 0.75, or 0.50. (Scenario 3)

Year	p = 1.0		p = 0.75		p = 0.50	
	pot. eggs $X 10^6$	% req. eggs	pot. eggs $X 10^6$	% of req eggs	pot. eggs $X 10^6$	% of req eggs
1974	19.780	43	16.060	35	12.340	27
1975	18.690	40	15.640	34	12.590	27
1976	10.283	22	9.134	20	7.984	17
1977	18.572	40	16.263	35	13.954	30
1978	13.549	29	12.401	27	11.273	24
1979	15.764	34	14.443	31	13.121	28
1980	16.424	36	14.063	30	11.702	25
1981	24.490	53	21.102	46	17.713	38
1982	19.595	42	16.104	35	12.613	27
1983	24.168	52	19.501	42	14.833	32
1984	26.909	58	21.271	46	15.634	34
1985	30.941	67	24.983	54	19.025	41
1986	36.269	79	28.451	62	20.634	45
1987	22.695	49	17.784	39	12.873	28
1988	27.028	59	21.693	47	16.353	35
1989	32.029	69	24.643	53	17.256	37
1990	17.021	37	13.376	29	9.733	21
1991	14.304	31	11.353	25	8.401	18
Mean (S.D.) 74-83	18.106	39	15.446	33	12.467	28
84-91	26.038	56	20.583	45	15.128	33
89-91	21.117	46	16.457	36	9.321	26

Table 6. Estimated additional potential number of spawners and egg deposition which would have occurred if the commercial fishery had been closed 1989-91. Estimated actual egg deposition (O'Connell and Ash, 1992) and percent of egg requirements are also shown. Recreational fishery open. (Scenario 4)

Year	(1) Additional Spawners				(2)	(1) + (2)	
	Small	Large	Eggs $\times 10^6$	% of Eggs req	Actual Eggs $\times 10^6$	Total Eggs $\times 10^6$	% of Eggs req
1989	6,512	1,353	23.887	52	16.272	40.159	87
1990	6,578	1,524	24.591	53	16.478	41.069	89
1991	5,565	2,010	23.931	52	15.128	39.059	85
Mean	6,218	1,629	24.136	52	16.177	40.096	87

Table 7. Estimated additional number of spawners and egg deposition which would have occurred if the commercial and recreational fishery had been closed 1989-91. Estimated actual egg deposition (O'Connell and Ash 1992) and percent of egg requirements are also shown. (Scenario 5)

Year	(1) Additional Spawners				(2)	(1) + (2)	
	Small	Large	Eggs $\times 10^6$	% of Eggs req	Actual Eggs $\times 10^6$	Total Eggs $\times 10^6$	% of Eggs req
1989	8,858	1,353	29.680	64	16.272	45.952	99
1990	8,888	1,524	30.481	66	16.478	46.959	102
1991	7,925	2,010	29.752	64	15.128	44.880	97
Mean	8,557	1,629	29.971	65	16.177	45.930	99

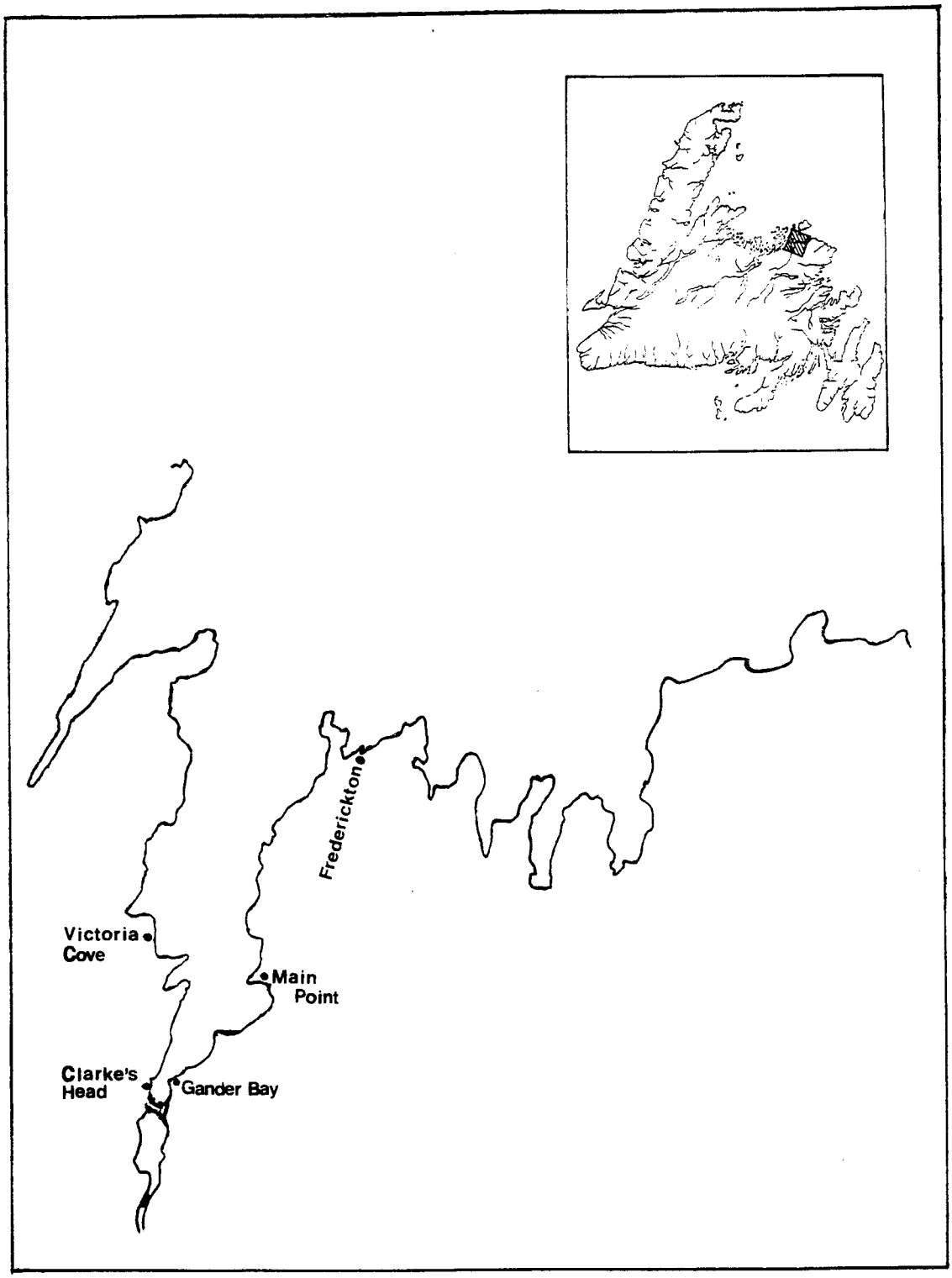

Fig. 1. Location of 5 communities in Gander Bay for which commercial catch statistics are available.