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Estimation of Biomass and Yield of the St. Mary's-Placentia Herring Stock Complex

by

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INTRODUCTION

Historical catch statistics for St. Mary's and Placentia Bays (Fig. 1) herring fisheries indicate peak average landings of about 15,000 m tons during the period 1945-50, principally by inshore gears in Placentia Bay. During the 1950's and early 1960's landings dropped substantially to 1000-2000 m tons but began to increase again during the late 1960's due to the expansion of the large purse-seine fleet into these areas. Landings peaked at 6,700 m tons in 1974 and 1975 (mainly from Placentia Bay) and have since declined to about 3,500 m tons since 1977.

Previously reported tagging studies (Moores and Winters 1977) have shown that a portion of St. Mary's Bay herring overwinter in Placentia Bay. A summary of more recent returns (Table 1) confirms this conclusion although it is evident that St. Mary's Bay herring also intermingle in varying degrees with the adjacent southern Avalon (Area F) and Conception Bay (Area E) areas. Since these latter two areas tend to mix more extensively with themselves rather than St. Mary's Bay (Winters and Moores 1979) the Placentia-St. Mary's Bay herring have been maintained as a unit stock for management purposes in this document.

A. 1979 Catch and age-composition data:

Landings increased slightly from 3,529 m tons in 1978 to 3,613 m tons in 1979 (provisional statistics) from a TAC of 3,400 m tons (Table 2). St. Mary's Bay continues to dominate the landings, accounting for about 60% of the total catch; prior to 1977 Placentia Bay accounted for the bulk of the catch and the reversal since then has been mainly due to the reduction in the large purse-seine fleet's allocation in Placentia Bay and the more effective catching power of the St. Mary's Bay small purse-seine (ring-net) fleet. Inshore catches have remained relatively stable between 800-900 m tons in recent years.

Age-composition data (Fig. 2) of commercial catches in 1979 were very similar to age-specific catches in 1978 and continues to reflect the predominance of younger fish of the 1974 year-class in Placentia Bay whereas old fish primarily of the 1968 year-class predominated in the catches in St. Mary's Bay, traditionally and pre-spawning and spawning fish operation. These data indicate that both the 1975 and 1976 year-classes are relatively weak and suggest that the 1977 year-class is probably not large.

A comparison of predicted and observed age-specific catches in 1979 (Table 3) indicates more older and less younger fish in the observed catches than predicted by Winters and Moores (1979). While this may be due to a bias in the estimation of population numbers-at-age it is more likely a reflection of the partial recruitment factors used by Winters and Moores (1978) in predicting the 1979 age-specific catch. These partial recruitment rates were calculated from the ratio of age-specific fishing mortalities from cohort analyses for the period 1972-75 when Placentia Bay, which traditionally exploits a greater representation of younger fish, dominated the total catches.

B. Catch and effort statistics:

Since the early 1970's the participation of the large mobile fleet in the Placentia Bay winter fishery has steadily declined to the extent that since 1977 only one vessel has operated in that fishery. Catch rate statistics for this vessel ("Canada 100") are shown in Table 4 for the period 1974-78 (log records are not available for the 1979 fishery). These show a steady decline in catch-per-operating day although the 1978 catch rate is somewhat suspect since the bulk of the catch was taken outside the normal area and time of the traditional winter fishery and when the St. Mary's Bay fish would have undoubtedly emigrated to St. Mary's Bay preparatory to spawning there in mid-May. Table 5 presents a summary of catch rate data for the large purse-seine fleet as a whole and suggests that the abundance of this stock complex has been declining steadily at least up to and perhaps including 1978.

Catch rate data for the small purse-seine (ring-net) fleet which has developed in Placentia and St. Mary's Bays during the late 1970's are shown in Table 6. These are grouped into categories according to degree of experience and participation in the fishery in a manner similar to that described by Winters and Moores (1979) for East Newfoundland herring stocks. In the St. Mary's Bay fishery, for example, a large learning factor is evident from 1976-77 but this appears to be much less significant for these same boats from 1977 to 1978. Similarly comparing the 1978 and 1979 catch rates for the 3 categories of vessels indicates a substantial learning factor for new vessels in 1978 compared with those which entered the fishery in 1976. Assuming that in category (A) learning was complete by 1978 suggests a substantial decline in abundance of St. Mary's Bay herring from 1978 to 1979.

Catch rates for the ring-net fleet in Placentia Bay are highly variable and more difficult to interpret. Even those vessels with 3 years experience (Category (B)) underwent a doubling of catch rates in 1979 and, considering the age-composition data in Fig. 2, this must reflect a large increase in the catchability coefficient in 1979.

C. Estimation of stock status:

The lack of continuity of catch rate data from either component of the mobile fleet precludes the use of conventional methodology for evaluation of current stock status. Since the 1974 year-class is very critical to prognosis of biomass and yield levels for 1980 two approaches to its estimation have been used, involving both the large and small purse-seine catch rate information.

Method I:

The catch rate data in series (a) (Table 5) have been used to calculate the CPUE-at-age of the 1968-73 year-classes at age-groups 3 and 4 (Table 7). These have been adjusted for annual changes in partial recruitment from comparison of age-specific fishing mortalities from cohort analyses (F_T = 0.40 in 1979). The selectivity factor for the 1974 year-class at age-group 3 was obtained empirically from a comparison of purse-seine catch-at-age in Placentia Bay with the age-composition of the total catch in 1977. The CPUE of each year-class so adjusted for partial recruitment was then averaged for age-groups 3 and 4 and regressed against the mean population size of that year-class as determined from cohort analyses. Regression analyses were performed both including and excluding the 1968 year-class with the following results:

(1968 included) $Y = 1.02X - 1.37$ ($r^2 = .999$) Predicted 1974 YC = $32 \times 10^{+6}$

(1968 excluded) $Y = 0.85X - 0.12$ ($r^2 = .995$) Predicted 1974 YC = $37 \times 10^{+6}$

The two estimates of the strength of the 1974 year-class at age-group 3 were then averaged and projected ahead to 1979. Assuming that the purse-seine age-composition for Placentia Bay was representative of the 5+ population age-structure in 1979, population size-at-age for age-groups 6+ in 1979 were determined from relative comparison with the estimated strength of the 1974 year-class at age-group 5 in 1979. An arbitrary value of 5 million recruits at age-group 2 was chosen for the 1977 year-class whereas the 1975 and 1976 year-classes were calculated from the Baranov catch equation using partial recruitment values determined from the ratio of age-specific F to F_{5+} for the period 1972-77. The results of cohort analyses, initiated with the above age-specific population sizes, are shown in Table 8.

Method II:

Since the St. Mary's Bay fishery is based mainly on mature fish in the age range 6-11+ (Fig. 2), it is assumed that the reduction in abundance of these age-groups from 1978 to 1979 is representative of their decline in the total population and that furthermore the small purse-seine CPUE in St. Mary's Bay (Table 6 - Category (A)) adequately reflects this decline from 1978 to 1979. Table 9 illustrates the results of the calculation of total mortality (Z) based on these catch rates. The fishing mortality rate thereby derived ($F = 0.46$) was then used to calculate the 6+ population size in 1979. This was decomposed into age-groups according to the purse-seine age-composition for the winter fishery in Placentia Bay in 1979. The results are shown below and indicate an excellent agreement with the estimates obtained by Method I.

	Age-group						
	5	6	7	8	9	10	11+
N_t	21450	690	4050	990	473	1035	10770

The estimates of population size obtained by Method I (Table 8) was therefore used as a basis for stock and yield prognoses for 1980.

Biomass levels (2+) increased from 35,500 tons in 1969 to 70,600 tons in 1972 (Table 8) and has declined continuously since then to slightly more than 14,000 tons in 1979. The adult biomass (5+) increased substantially to 55,700 tons in 1973 with the recruitment of the very strong 1968 year-class but declined to 10,000 tons in 1978 before increasing slightly to 12,400 tons in 1979, reflecting the entry of the 1974 year-class. The 1974 year-class is the strongest of the most recent year-classes, although relative to the 1968 year-class it cannot be considered to be strong. The 1975 and 1976 year-classes appear to be very weak and therefore the short-term prognosis implies a continued decline of the adult biomass.

D. Catch prognoses:

A catch projection for 1980 at $F_{0.1} = 0.30$ (Moores and Winters 1977) is shown in Table 10. The partial recruitment values used reflect the historical pattern when Placentia Bay contributed the larger proportion of the total catch, and a return to this pattern is assumed for 1980. Using the ratio of total catch to catch of spring-spawners (1.14) suggests a level of removals of approximately 2,500 tons in 1980.

E. Discussion and Conclusions:

Since 1977 St. Mary's Bay has accounted for the greater proportion of the total catch of herring from the St. Mary's-Placentia herring stock complex. This is a reversal of the recent historical pattern and is due to recent reductions in the large mobile fleet allocation, which has traditionally been taken in Placentia Bay and a concomitant increase in the small purse-seiner allocations which has mainly been taken in St. Mary's Bay. In addition, the bulk of the inshore catch is also caught in St. Mary's Bay. The analyses presented in this paper indicates a substantial fishing mortality rate on older herring (age-groups 6+) which are mainly exploited in St. Mary's Bay. Furthermore, the moderately good 1974 year-class which predominates in the age-composition of catches in Placentia Bay has not shown up in significant numbers in St. Mary's Bay. It, therefore, appears that the St. Mary's Bay spawning stock has been subjected to a much greater rate of decline than the Placentia Bay adult population. An equalization of exploitation rates would, therefore, be best achieved through partitioning the TAC to include a larger proportion of the total removals from Placentia Bay.

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Table 1. Summary of tag recaptures (excluding year of release) from tagging experiments conducted in St. Mary's and Placentia Bays 1975-78.

Area of Release	Year of Recapture	No. recaptured by area			
		E	F	G	H
St. Mary's Bay	1975	-	4	89	20
	1976	5	-	33	7
	1977	2	11	41	4
	1978	-	-	10	-
TOTAL		7	15	173	31
Placentia Bay	1977	-	-	-	9
	1978		1	15	45
TOTAL		-	1	15	54

Table 2. Herring landings by gear, St. Mary's-Placentia Bay 1976-79.

Year	Area	Gear					Total
		P. Seine	R. Net	B. Seine	Gillnet	Trap	
1976	SMB	-	920	158	352	25	1455
	PB	2056	172	242	177	-	2647
	Total	2056	1092	400	529	25	4102
1977	SMB	-	1132	221	531	29	1913
	PB	740	524	14	78	-	1356
	Total	740	1656	235	609	29	3268
1978	SMB	-	1523	67	489	3	2082
	PB	558	613	30	212	34	1447
	Total	558	2136	97	701	37	3529
1979+	SMB	-	1570	131	330	8	2039
	PB	360	891	17	306	-	1574
	Total	360	2461	148	636	8	3613

+ provisional figures up to June 1979.

Table 3. Comparison of 1979 predicted and observed age-specific catches for Placentia-St. Mary's Bays.

	1979 Catch composition	
Age-group	Predicted ($x10^{-3}$)	Observed* ($x10^{-3}$)
2	1546	95
3	229	725
4	286	305
5	3627	2467
6	100	105
7	432	670
8	42	94
9	64	70
10	206	545
11+	4721	5207

* adjusted to predicted total catch

Table 4. Catch/effort (m tons per operating day) data for the "Canada 100" in Placentia Bay 1974-78.

Year	Month				Average	
	Jan.	Feb.	Mar.	April	Weighted	Unweighted
1974	98.2	-	-	-	98.2	98.2
1975	91.3	-	-	-	91.3	91.3
1976	83.8	88.0	-	-	84.6	85.9
1977	65.5	41.0	-	-	62.5	53.3
1978	0.0	2.0	18.2	85.5	34.0	26.4

Table 5. Summary of catch-per-unit effort (CPUE) and effort for the Placentia-St. Mary's herring stock. (a) includes all purse-seiners in Placentia Bay and (b) represents the "Canada 100" only.

Year	CPUE (m tons/day)		Total Catch	Effort (days)	
	(a)	(b)		(a)	(b)
1972	81.7	-	6178	75.6	-
1973	51.5	-	6224	120.9	-
1974	51.1	98.2	6672	130.6	67.9
1975	43.6	91.3	6715	154.0	73.6
1976	38.3	85.9	4102	107.1	47.8
1977	(23.7)*	53.3	3266	-	61.3
1978	-	26.4	3529	-	133.7
1979	-		3613	-	-

* pro-rated from series (b)

Table 6. Catch/effort (m tons/day) data for Placentia Bay and St. Mary's Bay (Ring net).

St. Mary's Bay:

	A - Boats common 76-79					B - Boats common 77-79					C - Boats common 78-79				
Year	Feb.	March	April	May	Ave.	Feb.	March	April	May	Ave.	Feb.	March	April	May	Ave.
1976	6.83	6.08	11.61	8.81	9.25	-	-	-	-	-	-	-	-	-	-
1977	-	12.16	21.14	-	19.97	-	-	-	-	-	-	-	-	-	-
1978	-	20.89	10.83	-	15.86	-	9.78	11.42	-	11.13	-	22.10	13.38	-	14.31
1979	-	10.11	6.83	-	8.91	-	9.78	7.23	-	9.23	15.89	24.16	10.41	-	18.99

Placentia Bay:

	A - Boats common 76-79					B - Boats common 77-79					C - Boats common 78-79				
Year	Jan.	Feb.	Mar.	April	Ave.	Jan.	Feb.	March	April	Ave.	Jan.	Feb.	Mar.	April	Ave.
1976	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1977	-	-	-	-	-	6.31	8.83	8.22	11.7	8.32	-	-	-	-	-
1978	-	-	-	-	-	4.26	7.20	4.16	44.7	8.43	7.39	6.80	9.56	-	7.93
1979	-	-	-	-	-	12.89	17.82	21.34	-	16.35	18.58	27.07	-	0.8	20.66

Table 7. CPUE at age of the 1968-74 year-classes, adjusted for partial recruitment (PR = F_t/F_{5+} from cohort analyses; F_T = 0.40) and compared with population number at age (N_t).

Year-class	CPUE		PR		Adj. CPUE		Mean CPUE	$\bar{N}_t$
	Age 3	Age 4	Age 3	Age 4	Age 3	Age 4		
1968	-	270.1	-	1.60	-	168.8	168.8	171.3
1969	1.8	0.6	.08	.04	22.5	15.0	18.8	16.3
1970	2.7	1.8	.95	.91	2.8	2.0	2.4	2.1
1971	2.2	3.1	.75	1.51	2.8	2.1	2.5	2.1
1972	14.6	14.8	.94	1.61	15.5	9.2	12.4	9.5
1973	3.0	1.2	1.79	1.13	1.7	1.1	1.4	1.1
1974	11.9	-	0.38*	-	31.3	-	31.3	

* determined empirically

Table 9. Calculation of $\bar{Z}$ from ring-net CPUE (m tons/day) in St. Mary's Bay 1978-79.

Year	C/Day	Effort (days)	CPUE (5+)	CPUE (6+)	Z
1978	15.86	131	32.32	- }	0.66
1979	8.91	229	-	16.72 }	

Table 8. Results of cohort analyses for St. Mary's-Placentia Bay herring for the period 1969-79.

	Population No. x 10^{-5}										
Age/year	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
2	179	2306	182	39	51	196	24	421	30	64	50
3	1093	146	1883	149	32	41	151	19	342	24	52
4	124	889	119	1537	121	23	31	104	13	267	19
5	90	101	686	96	1073	98	17	21	70	9	203
6	119	73	82	541	70	757	75	12	16	51	7
7	26	94	59	67	399	24	491	47	8	12	37
8	42	20	71	48	48	262	13	275	31	6	9
9	53	34	16	55	35	26	163	9	179	16	4
10	39	42	27	13	40	27	20	102	6	111	10
11+	32	52	85	83	74	80	86	72	112	71	102
2+ Wt ('000 tons)	35.4	61.0	65.9	70.6	59.7	47.4	35.0	27.2	21.5	17.4	14.1
5+ Wt ('000 tons)	13.8	14.4	32.2	30.7	55.7	44.3	31.7	20.3	15.6	9.9	12.3
F_5+	.041	.030	.031	.105	.184	.214	.313	.219	.245	.281	.278

Table 10. Catch projection for 1980 for St. Mary's-Placentia Bay herring.

	1979			1980			1981
Age/year	N_t	F_t	C_t	N_t	F_t	C_t	N_t
2	5000	.02	87	5000	.03	135	5000
3	5228	.15	661	4013	.09	313	3973
4	1851	.18	277	3684	.15	466	2875
5	20316	.13	2243	1266	.30	299	2596
6	651	.18	95	14611	.30	3449	768
7	3693	.20	609	448	.30	106	8862
8	937	.11	85	2475	.30	584	271
9	439	.18	64	690	.30	163	1501
10	971	.81	495	301	.30	71	419
11+	10122	.71	4734	4428	.30	1042	2860
W_t ('000 tons)	14.10		3.17	10.40		2.15	8.00

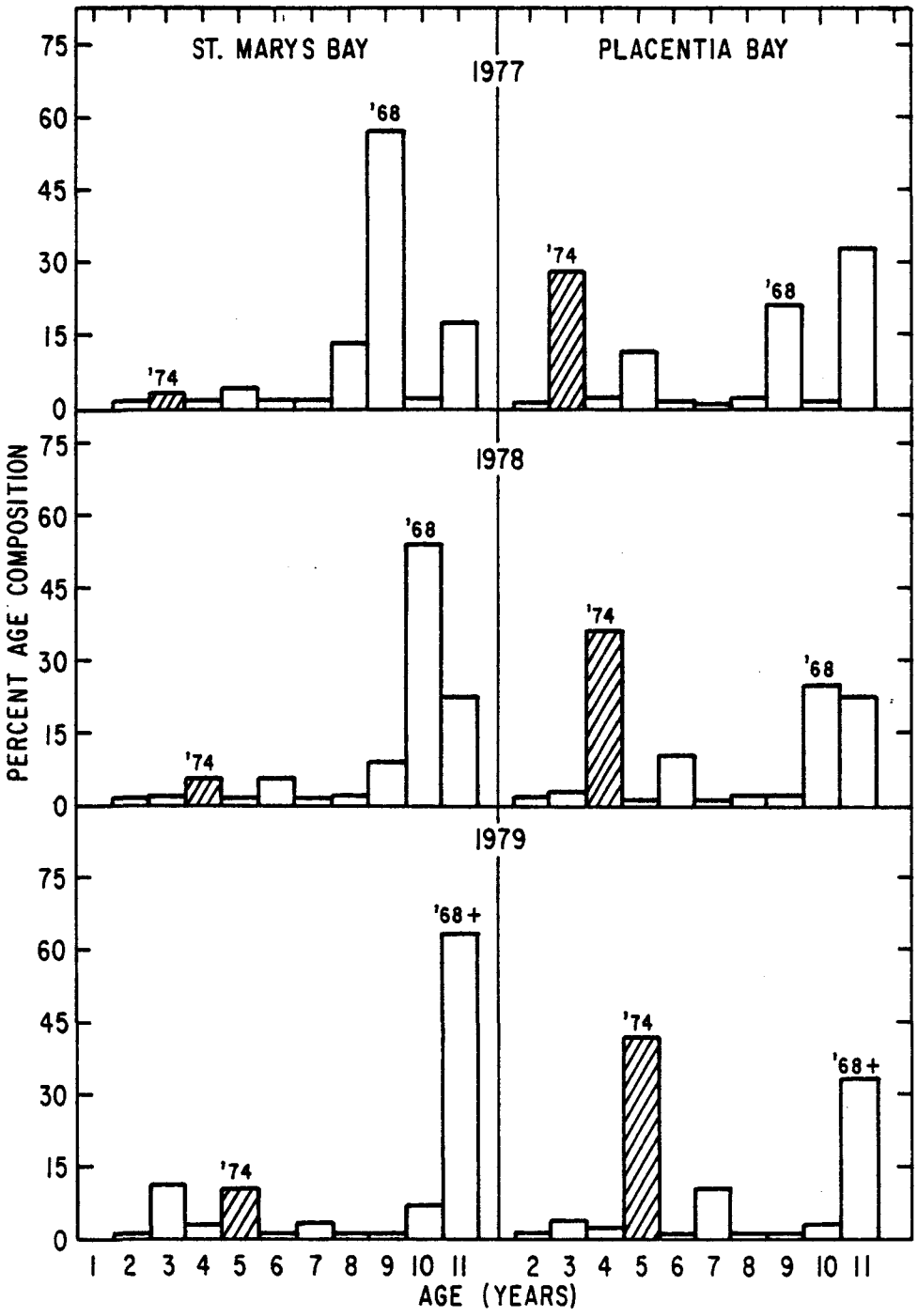

Fig. 2. Age composition data of St. Mary's and Placentia Bay commercial catches in recent years.

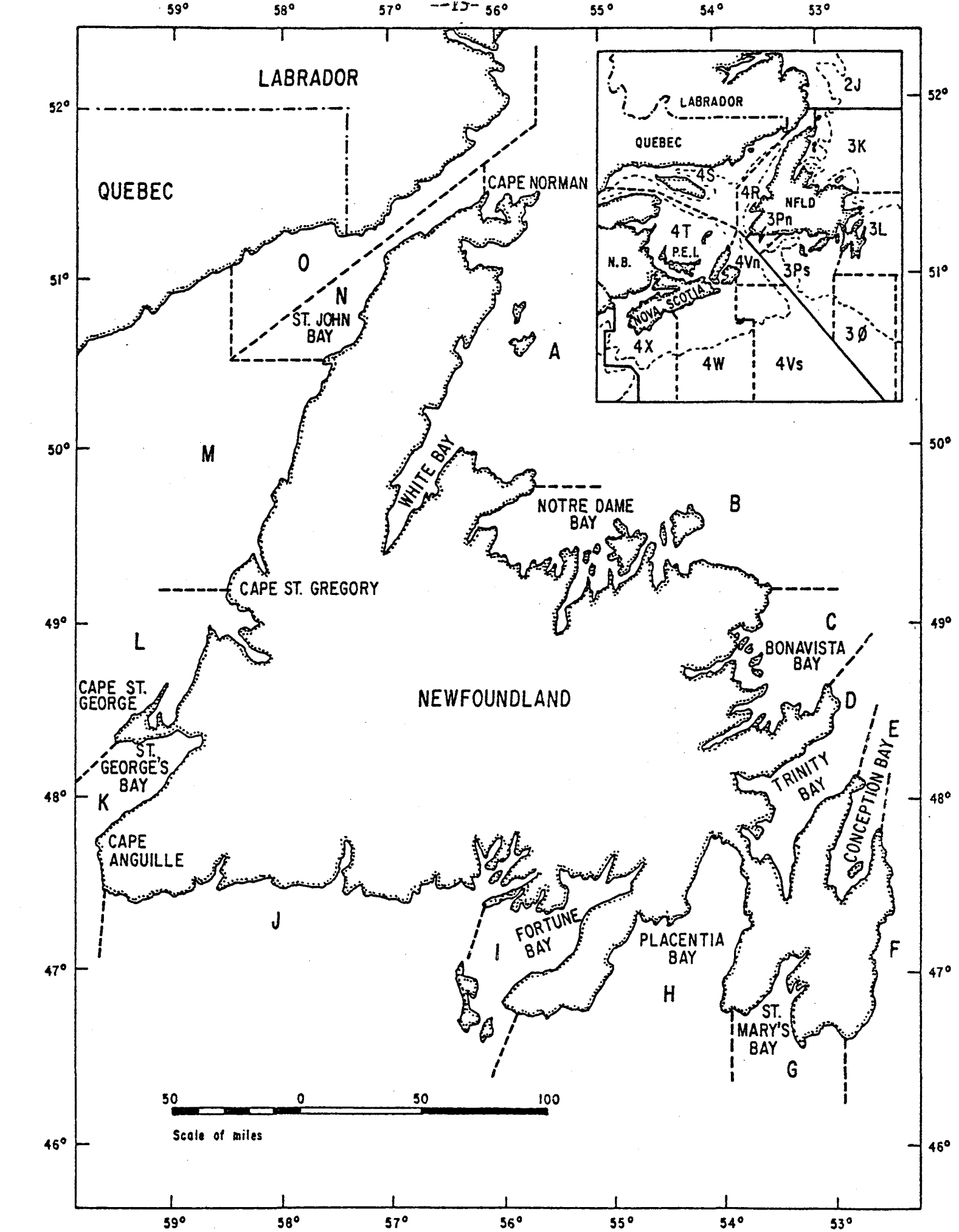

Fig. 1. Area map of Newfoundland.