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A Re-examination of the Catch Matrix Utilized for the Assessment of the Newfoundland West Coast Herring Stock

by

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Abstract

Although recent tagging studies have shown the west coast of Newfoundland to be a discrete herring stock area, studies conducted in the early 1970's showed an overlap between the west coast stock and southern Gulf of St. Lawrence herring stock. These studies indicated that the overlap was probably most extensive during the spring in the area of the St. George's Bay. In formulating the initial catch matrix for analysis of the west coast stock this fact was accounted for by partitioning the St. George's Bay catch between the two stock areas with all catches prior to 1975 being assigned to the southern Gulf and all catches from 1975 onward to the west coast.

Recent analyses of the status of the west coast herring stock have shown anomalies between the catch matrix and the results of cohort analysis, most notably for the period prior to 1975. Potential errors in the catch matrix were investigated using three sources of data: (1) age and spawning type frequencies from sampling data, (2) magnitude and distribution of purse seiner activity in St. George's Bay from interviews and (3) catch data from southwest Newfoundland.

These data support the view that the main area of overlap was St. George's Bay and that the fisheries along southwest Newfoundland and north of the Bay of Islands exploited different stocks. It was also shown that the southern Gulf stock had ceased to be a significant contributer to the St. Goerge's Bay fishery by 1973. A detailed partitioning of the St. George's Bay catches from 1966 to 1973 was conducted. The data also indicated that the gillnet fishery in the St. George's Bay area has always exploited fish of the west coast stock.

Based on these findings a new catch matrix was generated. Using the new matrix and the previously utilized matrix cohort runs were performed and the results compared.

Résumé

Bien que des expériences de marquage récentes aient montré que la côte ouest de Terre-Neuve possède un stock distinctif de harengs, des études effectuées au début des années 1970 indiquaient un chevauchement entre le stock de la côte ouest et celui du sud du golfe du Saint-Laurent. D'après ces études, le chevauchement était propablement maximal au printemps dans la région de la baie Saint-Georges. Lors de l'établissement initial de la matrice des prises commerciales pour l'analyse du stock, on a tenu compte de ce fait en répartissant les prises effectuées dans la baie Saint-Georges entre les stocks des deux régions, toutes les prises antérieures à 1975 étant attribuées au sud du golfe et toutes les prises effectuées à partir de 1975, à la côte ouest.

Des analyses récentes de l'état du stock de harengs de la côte ouest révèlent des anomalies entre la matrice des prises et les résultats de l'analyse des cohortes, en particulier pour la période antérieure à 1975. On a cherché à déterminer les erreurs possibles dans la matrice des prises à l'aide de données émanant de trois sources: 1) fréquences des âges et des types de reproducteurs établies à partir d'échantillons commerciaux 2) ampleur et répartition de la pêche à la senne coulissante dans la baie Saint-Georges, d'après des renseignements recueillis lors d'interviews et 3) données sur les prises au sud-ouest de Terre-Neuve.

Ces données confirment que la baie Saint-Georges est l'endroit où le chevauchement des stocks est le plus important et que les prises effectuées au sud-ouest de Terre-Neuve et au nord de la baie des Iles proviennent de stocks différents. On constate aussi que la part émanant du stock du sud du golfe dans les prises effectuées dans la baie Saint-Georges a cessé d'être importante dès 1973. On a également procédé à un démembrement détaillé des prises effectuées dans la baie Saint-Georges de 1966 à 1973. Il apparaît que les prises effectuées avec des filets maillants sont toujours provenues du stock de la côte ouest.

Compte tenu de ces constatations, on a établi une nouvelle matrice des prises commerciales. A l'aide de la nouvelle matrice et de l'ancienne, on a procédé à des analyses de cohortes, dont on a ensuite comparé les résultats.

Introduction

The first analytical assessment of the west coast herring stock was performed in 1977 (Moores and Winters 1977). The definition of the management unit to encompass this stock was based primarily on external tagging studies, conducted since 1975, which indicate that the west coast of Newfoundland was discrete from adjacent stock areas. However, earlier tagging studies (Winters and Parsons 1972, Winters and Hodder 1975) conducted in the early 1970's indicated that some portion of the overwintering southern Gulf of St. Lawrence herring stock was being exploited along the west coast of Newfoundland particularly during the spring in the St. George's Bay area. The absence of southern Gulf fish in St. George's Bay since 1975 reflects a change in the overwintering distribution and range of this stock due to the reduction of its numbers.

The overlap of these two stocks presents problems in accurately assigning the catch to the appropriate stock particularly for St. George's Bay. In constructing the first catch matrix for this stock Moores and Winters (1977) examined the pattern of fishing effort in St. George's Bay as shown by log records and compared the spawning-type composition of herring sampled in the St. George's Bay spring fishery and that occurring along the "edge". These analyses indicated that there was a marked change in both sets of data from the period prior to 1975 and since 1975. On this basis all catches from St. George's Bay (Area K) (Fig. 1) prior to 1975 were assigned to the southern Gulf of St. Lawrence stock complex while all catches from 1975 onward were attributed to the west coast stock complex.

In recent years it has been noted that there are inconsistencies between the population composition produced by cohort analysis and other pieces of available data. For example, the cohort analysis indicates that from 1966 to 1972 the autumn-spawning component represented 3/4 of the total stock yet with the exception of one year represented less than half the catch. Also the fall purse-seine fishery which is expected to be most representative of the stock composition indicates a lower percentage of autumn-spawners in the stock than does cohort analysis (with M and F the same for both components). The problems are most noticeable for the early years of the analysis (Moores et al. 1982).

Possible explanations for these inconsistencies included a different level of natural mortality acting on the two spawning components or removals from the stock which were not accounted for by the catch matrix. Before any detailed analysis of mortality rates can be attempted the catch matrix should be re-examined. Previous analyses of F and effort, CPUE and biomass indicate a marked difference between the historical period (1966-73) and the recent period (1975-81). This change coincides with the decline of the southwest coast fishery and the development of the St. George's Bay fishery on pre-spawning concentrations of spring-spawning herring. The main emphasis of the following analyses was therefore directed at trying to perform a more precise assignment of the pre-1975 St. George's Bay catches between the two Gulf stocks.

Data Sources

Data from three sources were utilized to examine the question of how the St. George's Bay catch should be partitioned. These were: 1) the commercial sampling data from which age and spawning type frequencies were available, 2) interview records of seiner captains and plant personnel for the years 1966-73 which provided information on the size and location of purse-seine catches made in St. George's Bay and 3) detailed catch statistics for southwest Newfoundland.

Gillnet Catches

There are two main gear components in the St. George's Bay herring fishery: gillnets and purse-seiners. The gillnet fishery is a traditional near-shore fishery which occurs primarily in the spring of the year. Samples from this component are almost exclusively spring-spawners. The timing and spawning-type composition of these catches indicate that the gillnet fishery exploits a locally spawning population of spring-spawners. Therefore, all gillnet catches should be included with the west coast stock complex rather than the southern Gulf stock.

Purse Seine Catches

The only catches requiring detailed examination therefore are those of the purse-seine fleet which operated along both the west and southwest coasts of Newfoundland. All three data sources are utilized to examine this gear component.

(1) Age and Spawning Type Composition

Sampling data were available since 1966 for the west coast and southwest coast herring fisheries. These purse-seine fisheries can be broken down into three components: 1) the winter-spring southwest coast fishery, 2) the fall- winter fishery north of Bay of Islands and 3) the spring fishery in St. George's Bay. If one assumes that the southwest coast samples are representative of the overwintering population of the southern Gulf stock, and that the samples from the winter fishery north of the Bay of Islands are representative of the west coast population, then by comparing these frequencies to those of the St. George's Bay fishery, it would be possible to assign the St. George's Bay catches to the appropriate stock. The age distributions, adjusted to correspond to a fall fishery, and the spawning type composition for each of the three fisheries for the period 1965-75 are shown in Fig. 2 and 3.

Looking first at the autumn-spawning component it is apparent that in all cases, except for the 1973-74 data, there is a lower proportion of autumn-spawners in the fishery north of the Bay of Islands than for the southwest coast. In the northern fishery the 10+ age-group is dominant in all years indicating that year-classes older than 1955 are important in

this area. Along the southwest coast the 1958 year-class was dominant and is probably the major contributor to the + group in subsequent years. The 1958 year-class does not appear to be a significant contributor in the northern Gulf.

The percentage of autumn-spawners in St. George's Bay is highly variable. In 1967-68 it is identical to southwest Newfoundland and in 1970-71, 1972-73, and 1973-74 it is higher than the southwest coast and lower in the remaining years. The percentage of autumn-spawners is however generally higher than in the northern fishery. The presence of the 1958 year-class in the early years suggests a relation to southwest Newfoundland while from 1970-71 to 1972-73 it is difficult to detect differences between all three areas due to the dominance of the + group. By 1973-74 however the St. George's Bay samples are most similar to the west coast northern samples.

For the spring-spawner component the data support the findings seen for autumn-spawners. Springs form a larger portion of the west coast catch than southwest Newfoundland with St. George's Bay tending to be intermediate. The 1959 year-class is dominant in both fisheries, however, it represents a lower part of the catch in the northern area. Prior to 1971-72 the small sample size in St. George's Bay does not allow for a definitive comparison with the other fisheries. In the northern fishery the 1968 year-class becomes a significant contributor in 1971-72 but does not appear in the other areas until 1972-73. The age compositions since 1973-74 appear to be most closely related between the northern and St. George's Bay fisheries.

It should also be noted that between 1971-72 and 1972-73 the southwest Newfoundland fishery switches from predominantly autumn-spawners to predominantly springs. This may indicate a reduction in the size of the migratory southern Gulf stock present in the area which is supported by the reduction in catch.

Some caution, however, should be exercised in interpreting these data as regards the St. George's Bay samples. First, it should be remembered that the St. George's Bay and southwest Newfoundland fisheries were exploited at the same time and by the same fleet with mixed catches from both areas being landed at the same plant. Some samples assigned to St. George's Bay therefore may be from southwest Newfoundland. Second sample composition may be influenced by the location in the bay the fish were caught. It would be expected that samples from Cape Anguille would more probably be related to the southwest coast than would catches from the Cape George or Sandy Point area.

Additionally, the spawning type composition from St. George's Bay may be influenced by two factors other than sample location. Firstly, the period of the fishery (spring) occurs during the period when maturity assignment is most difficult (Cleary et al. 1982) and also the proportion of each component in the fishable population is affected by the timing of the spring-spawners separating from mixed schools to go to the spawning grounds. Under these conditions the purse seine fishery could show a bias

towards autumn-spawners and overestimate the abundance of this component in St. George's Bay.

Bearing these considerations in mind, the data do suggest that the northern and southwest Newfoundland fisheries exploited different stocks and that the St. George's Bay fishery has exploited primarily west coast fish probably as early as 1973.

(2) Fleet Activities

Data on the location and magnitude of purse-seine catches from 1966 to 1973 were available from interviews with purse-seine captains and plant personnel. On the basis of these interviews catches can be assigned to one of the six subdivisions which constitute the St. George's Bay area (Area K) (Fig. 1). The information from these interviews is summarized in Table 1. From 1966 to 1968 the purse-seine fishery occurred in the southern portion of Area K around Cape Anguille. Moores and Winters (1977) suggested that Cape Anguille was a reasonable division line between the west coast and southwest coast stocks. These catches therefore are most probably from the southern Gulf stock.

From 1969 and 1970 the catches from St. George's Bay occur in the north of the bay and early in the year when the southern Gulf fish most probably occur along southwest Newfoundland, thereby, implying that these are west coast fish.

From 1971 to 1973 the areas fished are much more diversified but occur primarily further in the bay than in the 1966-68 period and also along the northern side of the bay. This would indicate a higher proportion of west coast fish should be in the catch. This would be particularly true for catches in K 41-1 which corresponds to the Sandy Point spawning grounds.

These records are more comprehensive than the data obtained from log records utilized previously (Moores and Winters 1977) and which were not available prior to 1972. The log records however do not show as extensive an area of fishing activity and show a higher concentration in area K 40-1 and K 40-2 than do the interviews for 1972 and 1973. While these ambiguities may temper ones faith in either data set the more extensive coverage of the interviews and the degree of personal contact involved would tip the scales in favor of the interview records.

(3) Catch Records for the Southwest Coast

The fishery along southwest Newfoundland exploited migratory southern Gulf fish and to some degree local populations (Winters and Hodder 1975). The fleet followed the migrating fish as they moved along the southwest coast. Tagging studies (Winters and Beckett 1978) showed that the fleet followed the schools westward as they migrated back along the southwest coast to cross the Cabot Strait to the spawning grounds in 4T. An examination of the catch from each of the two subareas along southwest

Newfoundland (Fig. 1) should give some indication of the presence of the extent of overwintering southern Gulf fish along southwest Newfoundland.

Catch records (Table 2) show Area J catches increasing from 1964 to 1969 and decreasing thereafter. By 1973 catch levels were only 2% of peak and from 1974 onward catches were back to historical inshore levels. Catches in J_1 were initially largest peaking in 1968 with J_2 not peaking until 1970. J_2 represents the more western area and should therefore support a fishery as long as southern Gulf fish are migrating to southwest Newfoundland. George's Bay fishery. This fishery ended in 1972 suggesting that since 1973 the St. George's Bay fishery has primarily been supported by west coast fish.

Proposed Revisions to West Coast Catch

Based on the preceding information a series of revisions to the purse-seine catch assigned to the west coast stock can be proposed. All changes relate to St. George's Bay (Table 3). It appears from the southwest coast catch data supported by the spawning composition data that no major migration of southern Gulf fish to southwest Newfoundland has occurred since 1972, therefore all catches from 1973 onward should be attributed to the west coast stock. Based on seiner interviews the 1966-68 catches should be assigned to the southern Gulf stock and the small 1969-70 catches to the west coast stock. The 1971 and 1972 data are more ambiguous. In 1971 the bulk of the catch comes from K 41 and are assigned to the west coast stock but as there was an active fishery in J_1 the catch from K 40-1 was assigned to the southern Gulf stock. In 1972 the St. George's Bay catch occurs throughout the area. The K 41-1 and K 40-3 catches are assigned to the west coast stock due to their proximity to the spawning grounds as are the catches from K 41-3 which is still an important purse-seining location. Although much decreased the fishery in J_1 was still substantial and catches from K 40-1 and K 40-2 were assigned to the southern Gulf of St. Lawrence stock.

The revised catch figures for the Newfoundland west coast stock are shown in Tables 4 and 5 and also include all St. George's Bay gillnet catches.

Revision of the Catch Matrix

Adjustments were made to the previous catch matrix (Table 6, Moores et al. 1982) to account for the changes in catch. The gillnet catches were assumed to be 100% spring-spawners and were broken down using either the gillnet samples from Area K for that year or else using the age frequency for the spring-spawning component present in the purse-seine catches. The purse-seine catch was broken down by the appropriate purse-seine samples. The applicability of some of the earlier samples is suspect however due to small sample size and limited spatial coverage within St. George's Bay. For 1966 and 1970 no samples of either purse-seine or gillnet were available for St. George's Bay. For 1966 the catch frequency and average weight for the west coast area was utilized while for 1970 otter trawl samples for Area K in April were used. The revised catch matrix is given in Table 7.

Comparison of Population Effects

In order to examine the effect of these changes in the catch matrix on the population parameters of the west coast stock, a series of cohort runs were performed. First, the catch matrix was expanded in the fashion explained in previous years such that for the period 1966-81 ages ran from age-groups 2-26. All runs were performed at $F_T = 0.35$ the level of F deemed most appropriate in the previous assessment (Moores et al. 1982). Natural mortality was assumed to be 0.20 for spring-spawners while two options of M (0.20 and 0.10) were utilized for autumn-spawners. The results of these runs in terms of population (2+) biomass and F_{5+} are summarized in Fig. 4 and Table 8, respectively.

As can be seen in Fig. 4 the new matrix produces higher biomass estimates in all cases than the old matrix. There is however no major deviation from the trends of biomass generated by the old matrix.

Table 8 shows the F_{5+} generated for each option. The most significant differences appear in the period 1971-74 when mortalities essentially double using the revised matrix. This would be expected from the additional catch in this period.

The relationships of F and effort and biomass and CPUE were also examined. The correlation coefficients are given in Tables 9 and 10 and illustrative plots are shown in Fig. 5 and 6.

In the comparison of F and effort the most significant difference occurs for spring-spawners with the R^2 value improving from .001 to .570 when using the old and revised catch matrices. In Fig. 5, it can be seen that the relationship still shows a separation between the 1971-73 period and the previous points in spite of the improved relationship. For autumns alone there is no real difference between the results produced using either of the matrices. The combined runs show a higher correlation for the revised matrix as would be expected from the higher correlation of spring-spawners under this option. The relationships are also marginally better for the options utilizing an M of 0.20 for both spawning components.

The relationship of biomass and CPUE is shown in Fig. 6 and Table 10. No major differences were produced using the two matrices. However, the level of biomass (ie. 2+ or 5+) utilized in the analysis produces conflicting results as to which option of M is most appropriate: 2+ biomass indicates an M of 0.10 for autumn-spawners is best while 5+ biomass indicates an M of 0.20 is more appropriate. This conundrum may be resolved if exploitable biomass is used.

Conclusions

This proposed revision to the west coast catch matrix reflects a more detailed analysis of the available data than was previously undertaken. As such it appears to be a more realistic interpretation of the St. George's Bay fishery than was shown by the previous catch matrix. In spite of substantial changes in the catch level the revised matrix has relatively little impact on

the output of cohort analysis. The proposed changes also are insufficient to resolve the inconsistencies previously mentioned. The problem may lie in the actual sampling data available for the early 1970's. As has been previously stated the sample size and spatial and temporal distribution of these samples may introduce biases into the catch matrix which are impossible to quantify. Also the comparisons which have been reported assume that F is the same for both spawning components. Such an assumption is probably unjustified, especially in recent years when the spring fisheries have formed the bulk of the catch and are directed toward spring-spawners. The use of different levels of F_T for each spawning component appropriately fine-tuned would have an impact on the interpretation of the total stock situation.

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Table 1. Distribution of herring landings in St. George's Bay by locality as derived from seiner and weigh master interviews.

Year	Month	K 40				K 41				Total
		1	2	3	Total	1	2	3	Total	
1966	November	297	196	-	493	-	-	-	-	493
1967	April-May	-	674	-	674	-	-	-	-	674
1968	March-April	1795	-	-	1795	-	-	-	-	1795
1969	February	-	-	-	-	-	-	241	241	241
1970	March	-	-	-	-	-	-	29	29	29
1971	April-May	92	-	-	92	-	-	3287	3287	3379
1972	April-May	37	1359	1322	2718	1553	-	1868	3421	6139
1973	April-May	105	350	8174	8629	-	-	-	-	8629

Table 2. Distribution of herring catches (t) along southwest Newfoundland from 1964-76 by Subareas J_1 and J_2 (see Fig. 1).

	J_1		J_2		$J_1 + J_2$		
Year	Mobile	Inshore	Mobile	Inshore	Mobile	Inshore	Total
1964	-	894	-	73	-	967	967
1965	3338	384	473	34	3811	418	4229
1966	15356	170	4063	118	19419	288	19707
1967	57220	266	10430	177	67650	443	68093
1968	83091	229	26505	375	109596	604	110200
1969	42996	375	84195	580	127191	955	128146
1970	30438	1088	88456	1253	118894	2341	121235
1971	26334	5876	65771	1479	92105	7355	99460
1972	6391	1563	18645	1219	25036	2782	27818
1973	2064	308	234	87	2298	395	2693
1974	305	162	-	73	305	235	540
1975	902	55	-	23	902	78	980
1976	109	353	121	14	230	367	597

Table 3. Breakdown of St. George's Bay purse-seine catches by stock.

Gear	Total catch	Nfld. West Coast	Southern Gulf
1966	493	-	493
1967	674	-	674
1968	1,795	-	1,795
1969	241	241	-
1970	28	28	-
1971	3,379	3,287	92
1972	6,139	4,743	1,396
1973	12,112	12,112	-
1974	2,453	2,453	-

Table 4. Revised catches from the Newfoundland west coast herring stock (t) 1966-81.

Year	K	L	M	N	Total catch
1966	216	103	5529	18	5866
1967	216	66	5540	13	5835
1968	156	59	3978	11	4204
1969	277	46	2549	40	2912
1970	79	27	3473	301	3880
1971	3830	2424	1076	1963	9293
1972	4921	862	1544	3628	10955
1973	12537	2862	2067	9222	26688
1974	2611	856	942	2842	7251
1975	3613	113	242	1027	4995
1976	6565	2067	226	1251	10109
1977	5569	2203	156	4358	12286
1978	6808	1984	365	6453	15610
1979	6032	5043	3996	3250	18321
1980	5097	6943	2967	4113	19120
1981	3638	4900	3088	1967	13593

Table 5. Revised herring catches (t) from the west coast Newfoundland area by gear type.

	K		L		M		N		Combined		
Year	Purse Seine	Inshore	Purse Seine	Inshore	Purse Seine	Inshore	Purse Seine	Inshore	Purse Seine	Inshore	Total
1966		216	-	103	5490	39	-	18	5490	376	5866
1967		216	-	66	5464	76	-	13	5464	371	5835
1968		156	-	59	3776	202	-	11	3776	428	4204
1969	241	36	-	46	2344	205	-	40	2585	327	2912
1970	28	51	12	15	2939	534	-	301	2979	901	3880
1971	3287	543	2239	185	725	351	356	1607	6607	2686	9293
1972	4743	178	727	135	1330	214	-	3628	6800	4155	10955
1973	12112	425	2740	122	1763	304	3453	5769	20068	6620	26688
1974	2453	158	756	100	439	503	1071	1771	4719	2532	7251
1975	3495	118	-	113	-	242	-	1027	3495	1500	4995
1976	6067	498	1955	112	-	226	184	1067	8206	1903	10109
1977	5289	280	2008	195	-	156	2167	2191	9464	2822	12286
1978	6252	556	1037	947	-	365	2636	3817	9925	5685	15610
1979	4387	1645	2773	2270	2829	1167	-	3250	9989	8332	18321
1980	3480	1617	3702	3241	2001	966	427	3686	9610	9510	19120
1981	2269	1369	3277	1623	2037	1051	342	1625	7925	5668	13593

Table 6. Removals-at-age ($x10^{-3}$) from the Newfoundland west coast herring stock (SS = spring-spawners; AS = autumn-spawners) from Moores et al. 1982.

Age	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
SS 1	0	0	0	0	0	0	372	0	0	0	0	29	0	0	4	15
2	181	1	103	209	2999	0	375	196	62	96	511	11	0	143	320	51
3	367	8	271	1093	1419	2922	254	96	116	738	997	664	40	30	992	317
4	282	337	187	1502	359	271	6273	712	26	345	982	533	2097	176	85	1832
5	547	60	483	338	557	544	734	15456	206	190	229	516	210	10967	327	97
6	1920	268	131	314	243	257	797	1191	5596	1283	319	287	749	575	14894	318
7	3863	3442	566	173	195	138	861	2557	129	8261	2745	346	287	1039	412	8773
8	2018	2739	1229	439	228	249	182	1156	732	237	15428	4160	2266	456	1304	250
9	1561	1176	2257	975	1008	98	476	1214	457	360	764	16333	8617	2710	258	593
10	287	775	409	372	985	278	118	688	38	140	2851	926	15951	7042	991	215
11+	475	866	433	446	1734	747	1024	3828	1740	671	3134	5547	4380	14466	21735	15134
TOTAL	11501	9672	6069	5861	9727	5504	11466	27094	9102	12321	27960	29352	34597	37604	41322	27595
AS 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	104	0	0	17	0	31	29	0	0	0	0	0	0	0	16	0
3	181	28	226	300	890	0	102	269	12	96	59	3	15	19	215	28
4	639	51	131	540	176	2	113	444	149	174	47	61	53	70	83	337
5	277	529	201	279	136	54	78	669	118	1110	102	113	452	288	143	158
6	274	306	1037	616	243	354	268	648	58	327	338	302	311	2542	253	82
7	277	116	294	519	486	966	352	1054	125	78	470	739	1130	626	1542	191
8	1007	322	223	158	169	2070	463	1118	58	112	108	387	1841	1396	224	717
9	1105	927	288	122	126	1114	960	2383	208	67	158	214	589	2038	691	120
10	926	1128	1208	164	225	723	279	2204	205	63	52	99	379	552	282	98
11+	2781	3155	2568	1259	2140	7664	6589	10029	2237	2229	3969	7159	5681	6824	5027	2716
TOTAL	7571	6562	6176	3974	4591	12978	9233	18818	3170	4256	5303	9077	10451	14355	8476	4447
TOTAL SS + AS	19072	16234	12245	9835	14318	18482	20699	45912	12272	16577	33263	38429	45048	51959	49798	32042

Table 7. Revised removals-at-age ($x10^{-3}$) from the Newfoundland west coast herring stock (SS = spring-spawners; AS = autumn-spawners).

Age	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
SS 1	0	0	0	0	0	0	372	0	0	0	0	29	0	0	4	15
2	189	1	103	240	3011	0	375	4384	137	96	511	11	0	143	320	51
3	390	8	296	1093	1458	3238	254	910	235	738	997	664	40	30	992	317
4	298	337	336	1910	438	271	7843	1177	108	345	982	533	2097	176	85	1832
5	586	70	583	965	660	544	1341	30697	294	190	229	516	210	10967	327	97
6	2052	296	206	314	261	572	1577	2820	10512	1283	319	287	749	575	14894	318
7	4127	3545	616	173	201	453	1879	3139	254	8261	2745	346	287	1039	412	8773
8	2158	3039	1304	439	234	1194	1113	3018	857	237	15428	4160	2266	456	1304	250
9	1670	1429	2282	975	1015	98	1099	1796	689	360	764	16333	8617	2710	258	593
10	303	860	508	372	1012	908	476	1502	195	140	2851	926	15951	7042	991	215
11+	505	969	433	446	1755	1062	4400	6271	2143	671	3134	5547	4380	14466	21735	15134
TOTAL	12278	10554	6667	6927	10045	8340	20729	55714	15424	12321	27960	29352	34597	37604	41322	27595
AS 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	104	0	0	17	0	31	29	0	0	0	0	0	0	0	16	0
3	181	28	226	300	890	0	102	810	16	96	59	3	15	19	215	28
4	639	51	131	642	176	81	113	769	269	174	47	61	53	70	83	337
5	277	529	201	355	142	368	403	1102	388	1110	102	113	452	288	143	158
6	274	306	1037	692	250	590	755	2596	284	327	338	302	311	2542	253	82
7	277	116	294	519	493	2144	1218	2028	288	78	470	739	1130	626	1542	191
8	1007	322	223	158	173	3562	1275	2525	222	112	108	387	1841	1396	224	717
9	1105	927	288	122	128	1899	2097	5196	293	67	158	214	589	2038	691	120
10	926	1128	1208	164	228	1273	1254	8047	336	63	52	99	379	552	282	98
11+	2781	3155	2568	1411	2171	14105	9513	17386	4202	2229	3969	7159	5681	6824	5027	2716
TOTAL	7571	6562	6176	4380	4651	24053	16759	40459	6298	4256	5303	9077	10451	14355	8476	4447
TOTAL SS + AS	19849	17116	12843	11307	14696	32393	37488	96173	21722	16577	33263	38429	45048	51959	49798	32042

Table 8. Comparison of the level of fishing mortality (5+) generated using the two catch matrices, F_T = 0.35.

		1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Springs -	old	.062	.065	.041	.027	.046	.015	.030	.057	.018	.027	.077	.110	.177	.194	.325	.348
	new	.060	.064	.039	.027	.039	.028	.077	.104	.030							
Autumns -	old	.016	.018	.016	.010	.013	.058	.051	.131	.027	.039	.060	.136	.185	.399	.404	.226
M = 0.20	new	.016	.017	.013	.009	.011	.089	.080	.257	.053							
Autumns -	old	.043	.045	.037	.021	.026	.108	.090	.222	.043	.058	.082	.173	.223	.456	.437	.226
M = 0.10	new	.039	.038	.029	.017	.019	.151	.128	.413	.084							

Table 9. R^2 values when F_{5+} and effort compared for various options of spawning type and M. Effort related to catch.

		Catch matrix	
		Old	Revised
(1)	Spring-spawners	.001	.570
(2)	Autumn-spawners M = 0.20	.897	.893
(3)	Autumn-spawners M = 0.10	.883	.883
(4)	Combined spring and autumn (M = 0.20)	.915	.972
(5)	Combined (AS = M = 0.10)	.844	.935

Table 10. R^2 values generated from CPUE and biomass relationships at two biomass levels and two levels of M for autumn-spawners for each of the two catch matrices (F_T = 0.35 for both components).

Biomass level	M Spring/autumn spawners	Catch matrix Old	 Revised
2+	.2/.2	.285	.298
	.2/.1	.624	.669
5+	.2/.2	.826	.759
	.2/.1	.098	.030

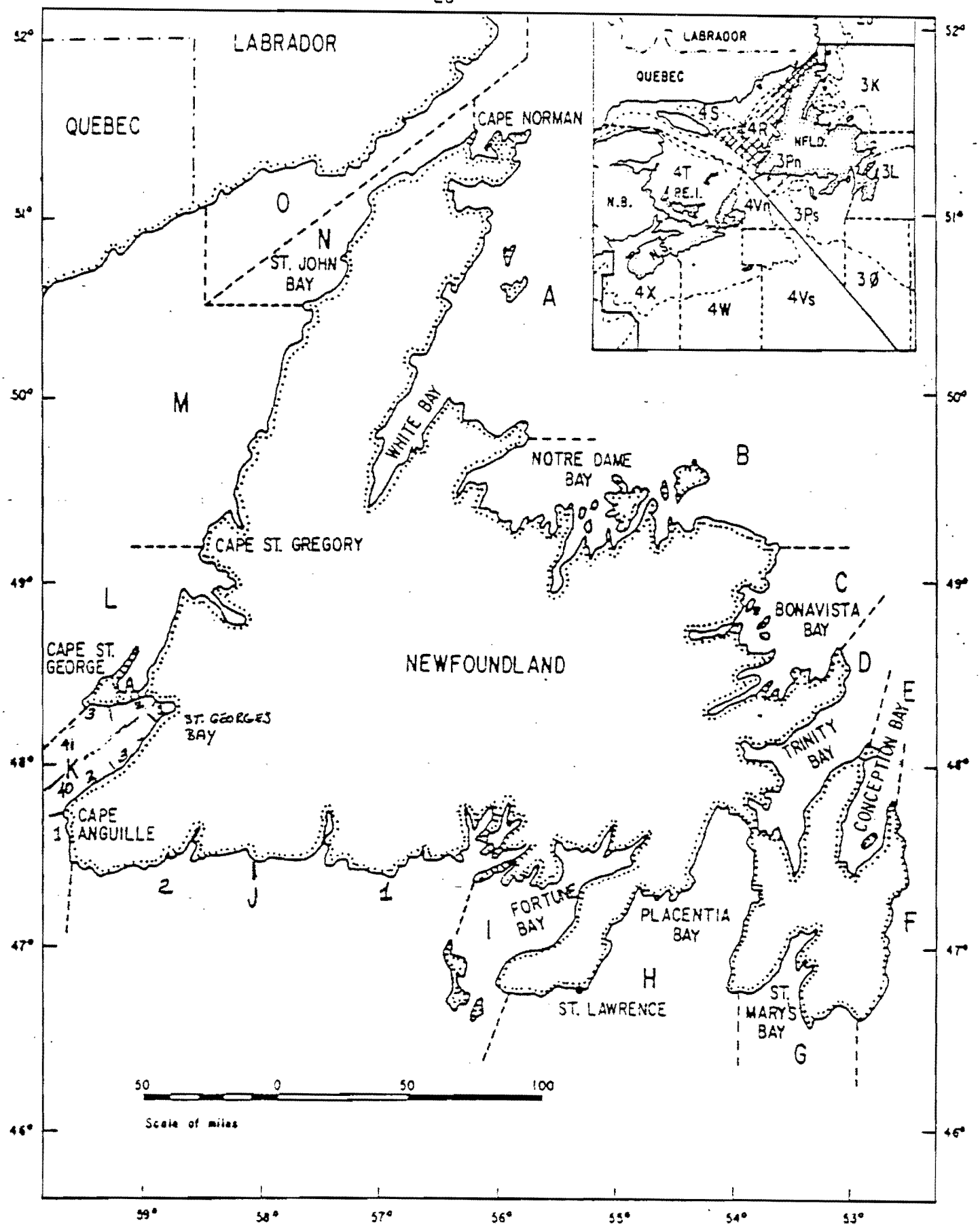

Figure 1. Newfoundland area map.

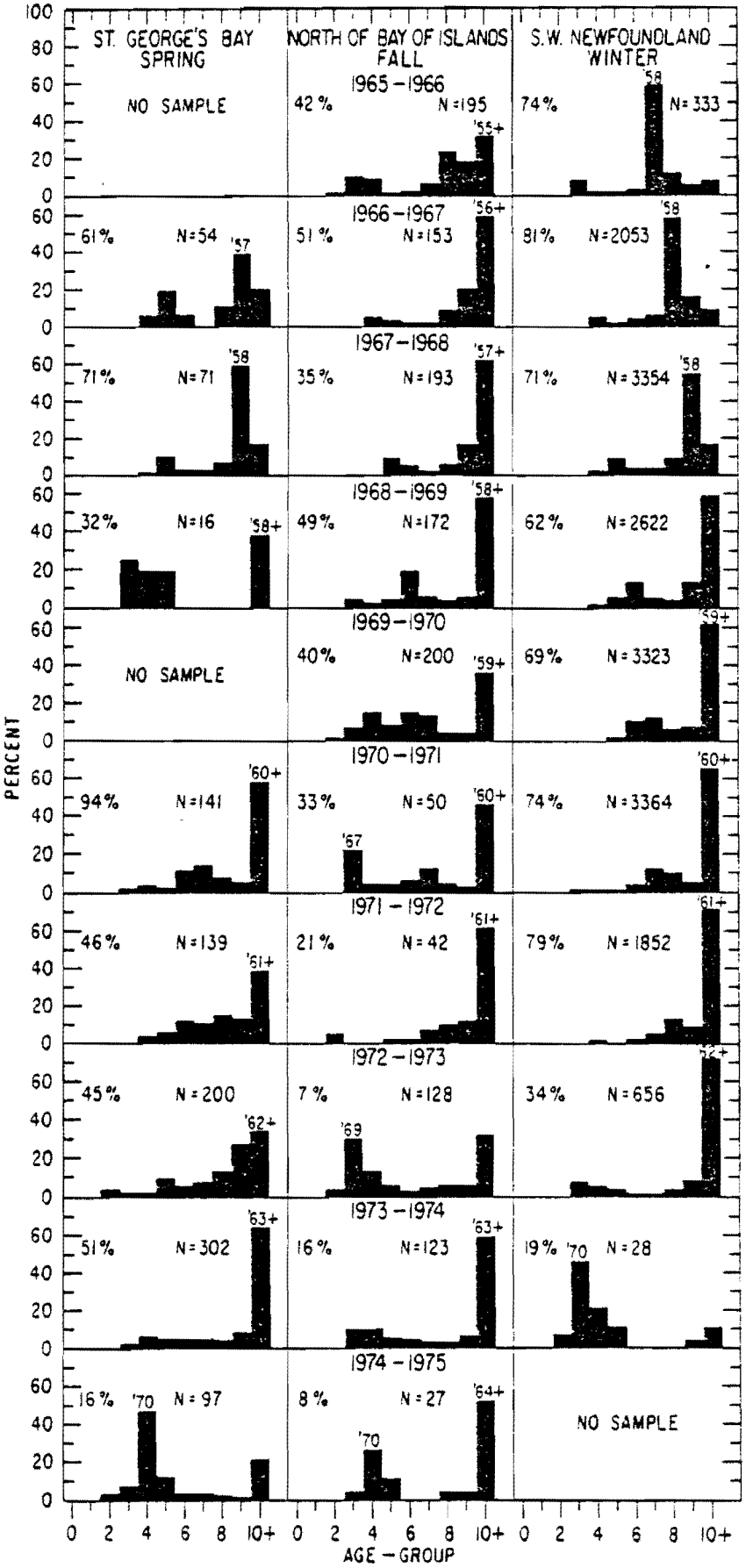

Fig. 2. Age-group and spawning type composition of autumn-spawners from purse-seine samples taken along the west and southwest coasts of Newfoundland.

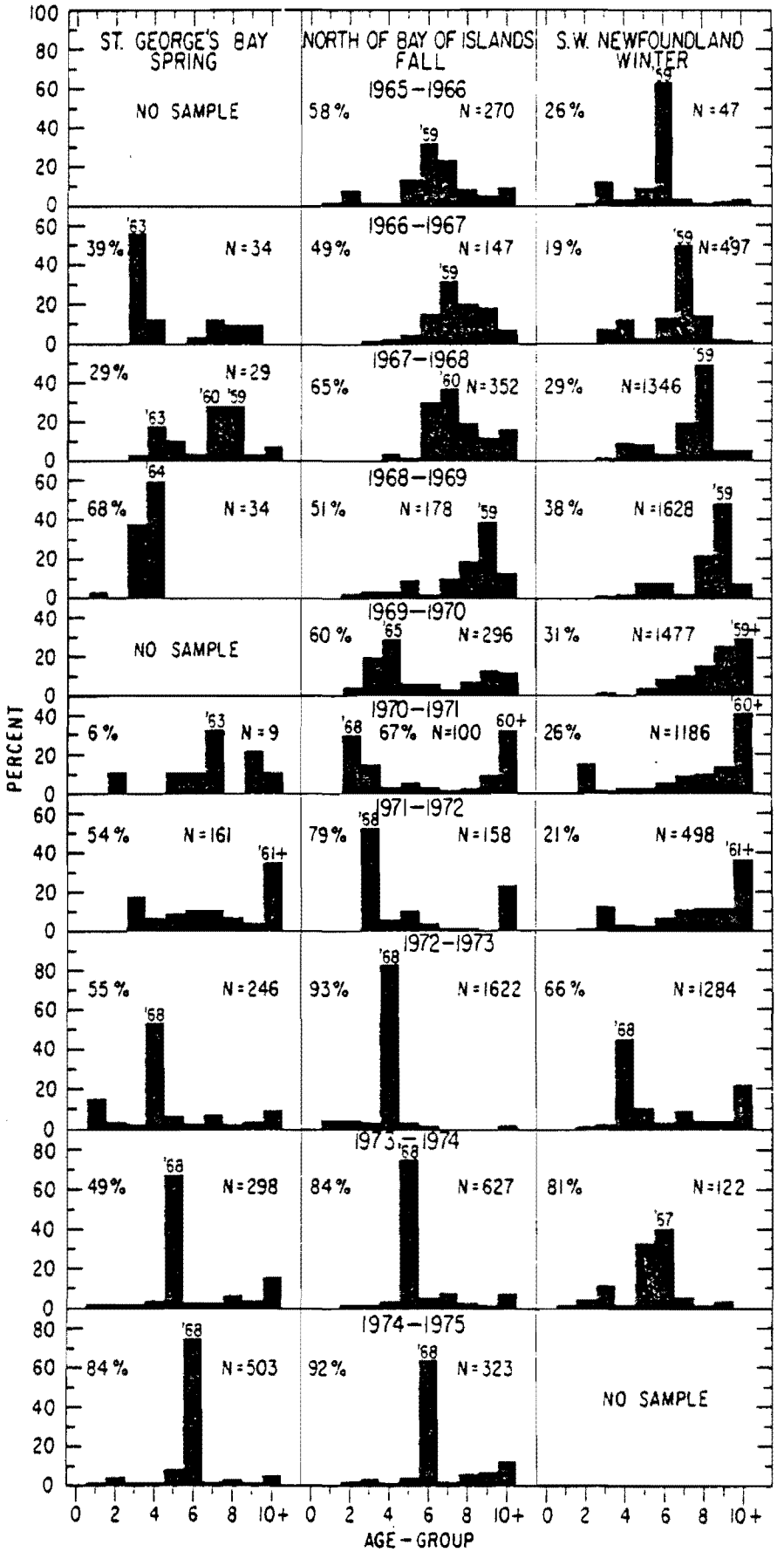

Fig. 3. Age-group and spawning type composition of spring-spawners from purse-seine samples taken along the west and southwest coasts of Newfoundland.

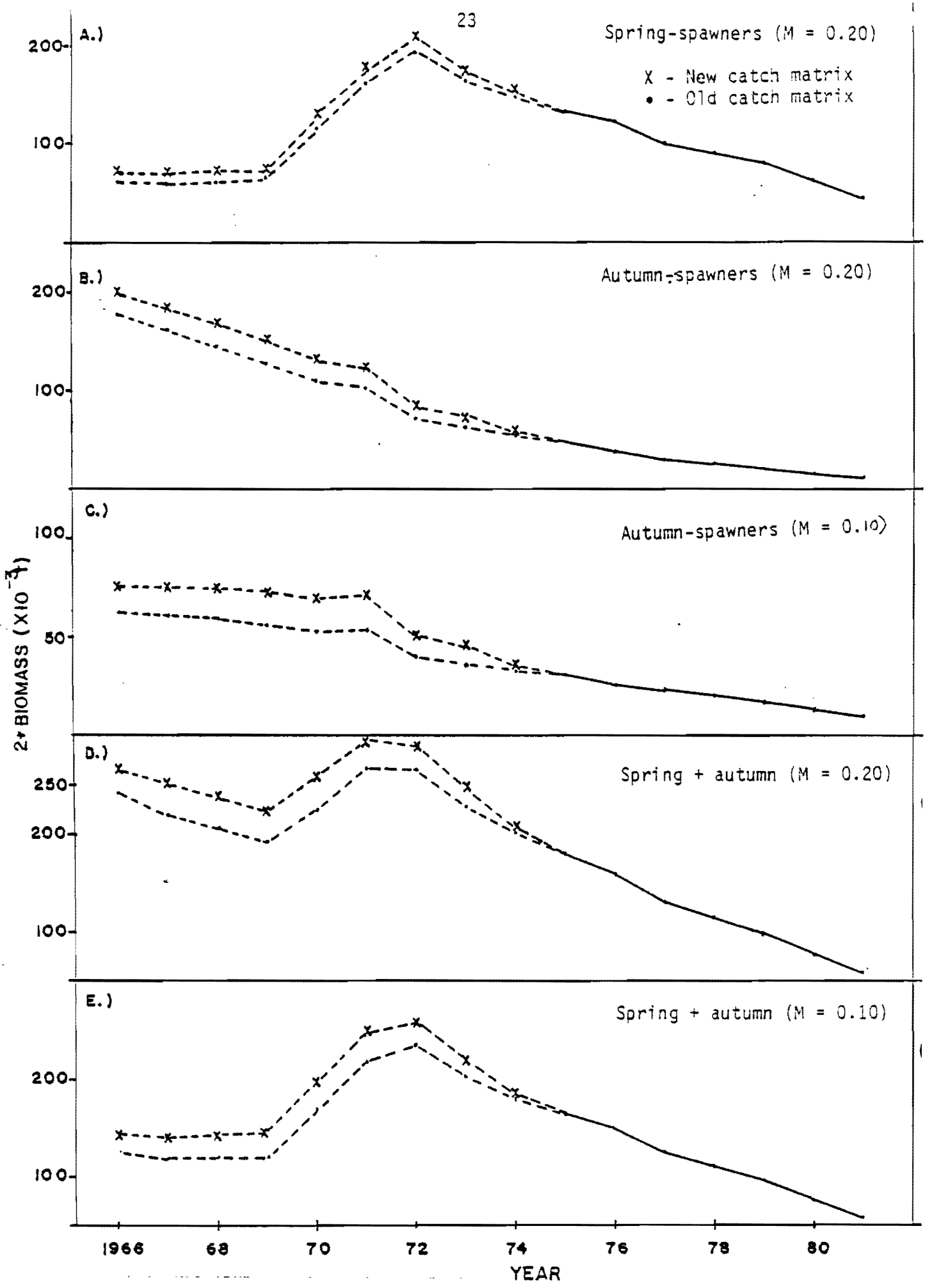

Fig. 4. A comparison of the population (2+) biomass estimates derived from cohort analysis (F_T = 0.35) for 2 options of catch and M.

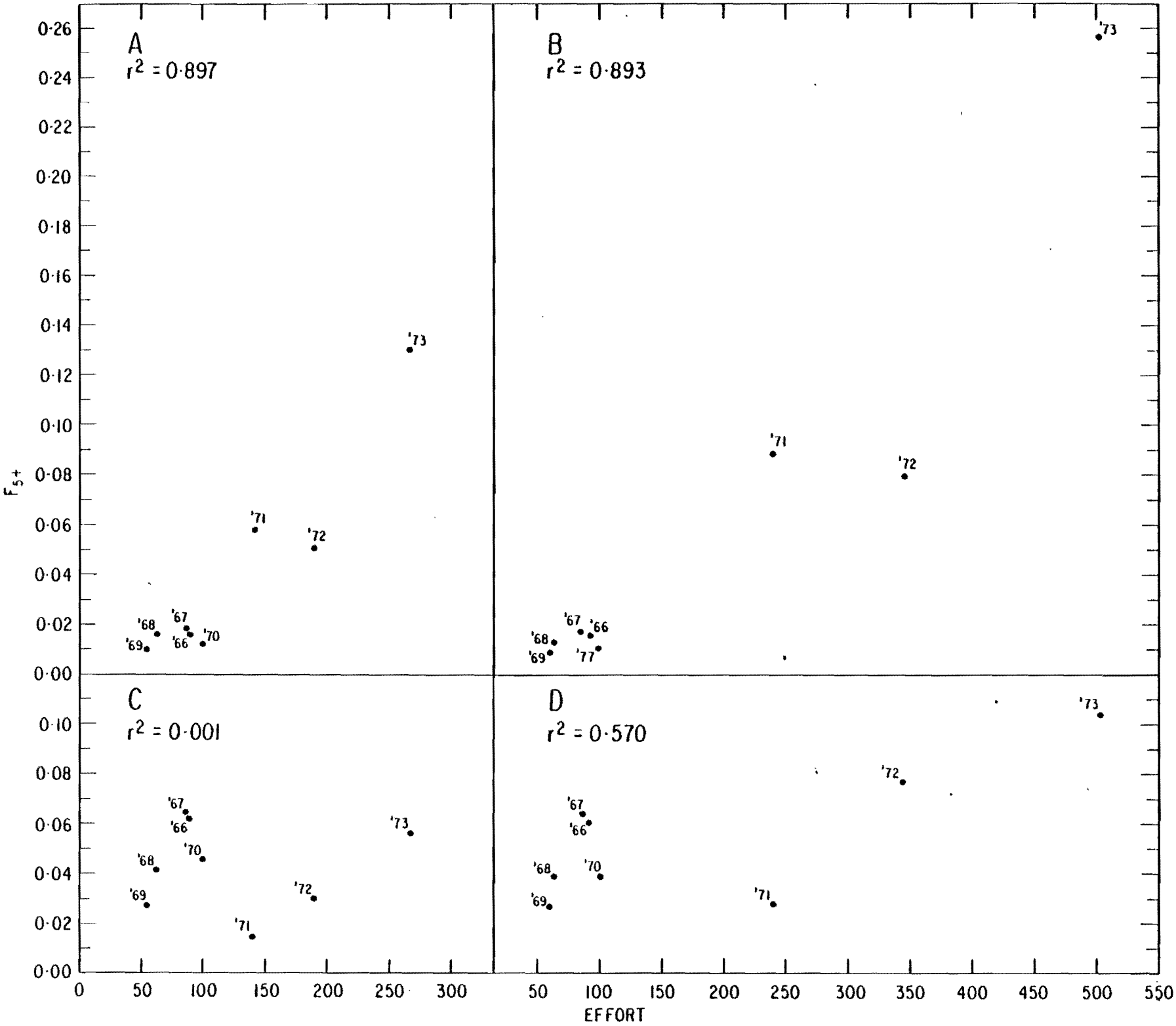

Fig. 5. Relationship of F_{5+} and effort (M = 0.20, F_T = 0.35)
A) Old matrix - AS
B) New matrix - AS
C) Old matrix - SS
D) New matrix - SS

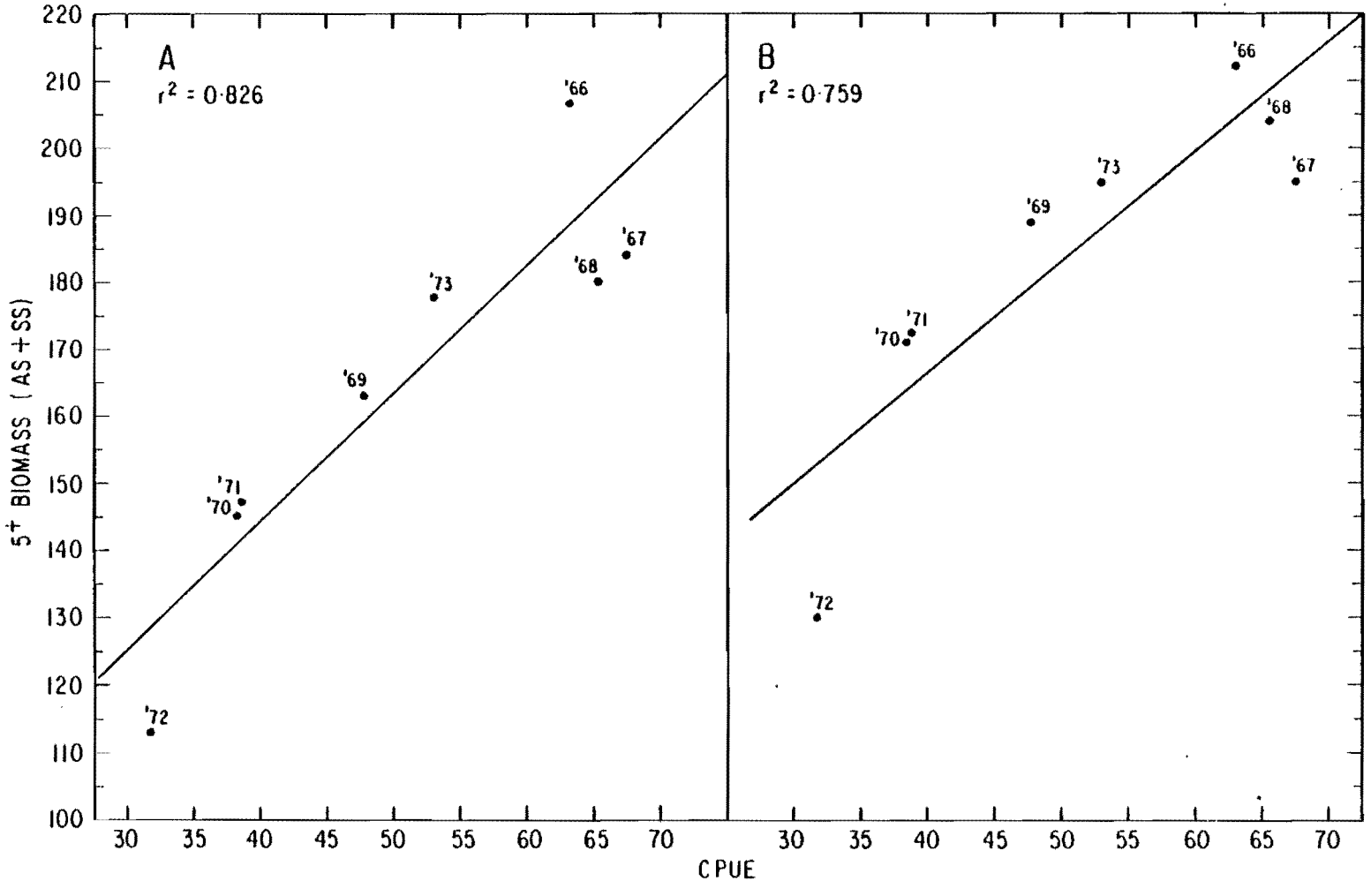

Fig. 6. A comparison of the relationship of biomass and CPUE produced using two options of catch for autumn- and spring-spawners combined with M = 0.20.