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An Evaluation of Recent Changes in the Population Dynamics of Southern Gulf Herring

by

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INTRODUCTION

Landings from this stock complex decreased from peak levels of 300,000 m tons in 1970 to a low of 37,200 m tons in 1974. Research studies (Winters and Hodder 1975) have revealed that the precipitous decline in abundance during the 1970's was due to a combination of moderate growth overfishing and successively poor recruitment to both spawning components (spring and fall) following two very large but apparently anomalous year-classes produced in the late 1950's. More recent studies (Winters et al. 1977, Winters 1978) have indicated divergent recruitment patterns in the two spawning components during the last decade, resulting in a shift in predominance towards spring-spawners. Winters (1976) attributed the relatively poorer recruitment in fall-spawners to a greater predation of fall-spawned larvae by an increasing mackerel biomass in the late 1960's but a similar diminution in the recruitment of fall-spawners in a much wider area including Western (Moores and Winters 1977) and Eastern (Winters and Moores 1977) Newfoundland suggests perhaps a more cosmopolitan environmental change. This document presents new information derived from research studies conducted in 1978.

I. Fishery removals in 1978

a. Catch Statistics: Considerable difficulty was experienced in obtaining reliable catch statistics broken down into appropriate gear types according to monthly total landings. Purse-seiner landings presented the greatest difficulty and Tables 1 and 2 present purse-seiner catches as provided by the Maritimes Economics Branch and from purse-seiner log records respectively. If one accepts that individual log records present more detailed catch information, both in terms of temporal and spatial units, than conglomerate statistics collected by field personnel (with considerable time lag for processing), then it is evident from a cursory comparison of Tables 1 and 2 that landing statistics (at least in the preliminary form) do not accurately reflect the actual seasonal and areal fishing patterns. With the exception of unit area 4Vl (the "Edge") for which landing statistics (Nfld. and Maritimes combined)

adequately reflect the log record information, purse-seiner catches in the Southern Gulf in 1978 have been broken down into unit areas and months (Table 3) according to the area/month catch key given in Table 2. These statistics are shown in Table 4 together with inshore catches (unit areas only were provided for Quebec inshore statistics and these were broken down by month according to the pattern in 1977). Total landings increased from slightly less than 43,000 m tons in 1977 to nearly 52,500 m tons in 1978, representing the greatest removals since 1973. Total purse-seine landings increased from 34,500 m tons in 1977 to nearly 40,000 m tons in 1978; the "Edge" spring fishery declined from 13,600 tons in 1977 to just under 5,200 m tons in 1978 whereas the Southern Gulf fall purse-seine fishery increased to over 29,000 m tons in 1978, including a revival of the fall fishery off eastern P.E.I. (Unit area 432). Inshore catches remained approximately the same as 1977 levels in the Magdalens whereas in the remainder of the Southern Gulf an increase from 6,300 m tons in 1977 to 11,700 m tons in 1978 was observed. This increase in inshore landings was most predominant in the spring fishery.

b. 1978 Age Compositions: Commercial sampling data distributed over gear, season and area were used to decompose the total catches into age-specific numbers for each spawning group. Considerable difficulty was encountered in trying to assign the younger age-groups (4 and younger) to the two general spawning groups (spring and fall) particularly in the Southern Gulf fall fishery where the maturity stages recorded by the biological samples were difficult to reconcile both with the otolith nuclei and the fish-length/gonad weight relationship (eg. a gonad weight of less than 2 gms was assigned to a variety of stages from immature (stage 2) to spent (stage 8) and to incipient development (stage 3). In general, the age-readers tended to use both criteria (otolith nuclei and maturity stage) for mature fish and nuclei type only for the immatures. Thus the younger age-groups, particularly those completely immature may be incorrectly assigned to a particular year-class in some instances.

In the purse-seine fisheries along the "Edge" (Fig. 2) younger fish were much more evident in the catches in 1978 compared to 1977. Amongst spring-spawners, fish of the 1968 year-class and older contributed less than 45% of the catches of that spawning component in 1978 compared to about 75% in 1977; the younger age-groups tended to be dominated by the 1974 year-class. Amongst fall-spawners old fish (11+) continued to contribute significantly to the catches (30-35%) whereas in the younger age-groups the 1973 year-class began to emerge as a dominant one.

In the traditional fall fisheries by purse-seiners in the Southern Gulf i.e. excluding eastern P.E.I. (Unit area 432) the year-class composition of the catches of spring-spawners in 1978 was very similar to that observed in 1977 with the 1974 year-class heavily ($\geq$ 65%) predominating in the landings. Amongst fall-spawners a shift in age-composition from a prodominance of the 1970 year-class in 1977 to a predominance of the 1974 year-class in 1978 was observed and in general the younger age-groups ($\leq$ 5) tended to assume the major contribution to the landings. The revived purse-seine fishery which developed off eastern P.E.I. in the fall

of 1978 was mainly based on young immature fish (Fig. 3) particularly the 1975 year-class of fall-spawners and the 1976 year-class of spring-spawners. Overall the purse-seine fisheries in 1978 were based on much younger age-groups than was the case in 1977 and this is at least partially due to the increased strengths of most recent year-classes.

Inshore fisheries in the Southern Gulf and the Magdalens in 1978 showed similar trends in age-composition data (Fig. 4). A shift towards younger age-groups was evident in the Magdalens where the 1974 and 1975 year-classes of spring-spawners predominated in 1978; in 1977 the 1972 year-class was dominant. The spring-spawning component in the inshore fisheries in the Southern Gulf in 1978 was heavily influenced by the 1974 and 1975 year-classes (approximately 85%) whereas the 1973 and 1974 year-classes predominated in the fall-spawning component (about 50%).

II. Abundance Indices in 1978

a. Commercial CPUE: Detailed catch-per-unit-effort information have been available for the purse-seine fleet operating in the Southern Gulf fisheries since the early 1970's and from Southwest Newfoundland during the late 1960's and early 1970's. In 1978 these log records accounted for nearly 80% of the reported catch for that fleet component, thereby maintaining their excellent reporting record since the late 1960's. An analysis of catch-per-operating day in relation to catch-per-set by Winters (1978) has shown that both indices are consistent in their representation of abundance changes over the period considered. Table 5 illustrates the historical catch-per-set data for the spring "Edge" fishery. The 1978 CPUE index continued the decline observed in the "Edge" fishery in recent years although it may be biased downwards by an anomalous migration pattern in 1978; many purse-seiner skippers felt that a large proportion of the fish had immigrated into the Southern Gulf by late April and this is somewhat confirmed by the very low representation of spring-spawners in both April and May of 1978 (Table 6) implying an earlier than usual departure of spring-spawners to their respective spawning areas.

In the Southern Gulf fall purse-seine fishery in 1978 (excluding unit area 432) the CPUE index (Table 7) increased by about 10% over the 1977 level and continues the trend of increasing abundance observed in recent years. The CPUE index for Unit area 432 (Eastern P.E.I.) was very similar to that for the Chaleur Bay-Gaspé area (Unit area 436-438). If these concentrations of fish off eastern P.E.I. in September-October, 1978 represent an anomalous extension of the normal distribution of herring in 4T during the fall period, then the commercial CPUE may be underestimated in 1978.

b. Research Vessel Abundance Indices: Incidental catches of herring in the fall groundfish surveys in the Southern Gulf have been analyzed by Dr. W. Stobo who has kindly supplied them to the authors. The catch of each set has been log transformed, summed and averaged, and then retransformed. The resulting indices are shown in Table 8 along with a summary of the various commercial CPUE indices. All indices indicate a similar trend in abundance and correlation analyses between the research vessel data and the Southern Gulf

fall purse-seine CPUE index ($r = 0.97$) supports the validity of the commercial indices. The decline observed in the research vessel index in 1978 may or may not be real, given the incidental nature of the catch and the possibility of anomalous distribution of young fish in 1978 as pointed out above.

III. Calculation of Assessment Parameters

a. Selectivity Factors: The Southern Gulf fall purse-seine fishery has historically exploited a wide spectrum of age-groups and has traditionally been fairly representative of the population age-structure (Winters and Hodder 1975). Therefore, the ratio of the relative abundance of an age-group in the total catch to the purse-seine catch is an estimate of the selectivity factor of the fishery as a whole. Table 9 illustrates this comparison for the 1978 catch data. The analyses suggest that there was some concentration on the youngest age-groups in 1978 and that most age-groups older than 3 years old were essentially fully recruited. These selectivity factors along with an arbitrary value for age-group 2 were used for initial runs of cohort analysis.

b. Average Weights-at-age: The weights-at-age averaged for the first and second quarter are shown below in relation to those used in the 1978 assessment of this stock.

Spawning Group	Year	Weight-at-age (Kg)									
		2	3	4	5	6	7	8	9	10	11+
Spring	1978	.095	.150	.200	.245	.295	.305	.325	.340	.345	.375
	1977	.050	.120	.170	.220	.250	.280	.300	.320	.330	.360
Fall	1978	-	.130	.190	.230	.260	.290	.315	.315	.320	.365
	1977	.050	.120	.170	.220	.250	.280	.300	.320	.330	.360

Increases in growth are evident in both spring- and fall-spawners and are probably temperature related (Moores and Winters 1978).

c. Terminal Fishing Mortality (F_T): Using the selectivity factors given in Table 9, trial values of F_T were used to obtain estimates of fishing mortality (spring and fall combined and weighted by population size) for ages 3 and older for the period 1969-77. These were then regressed against fishing effort in an iterative manner until the historical relationship between fishing mortality and fishing effort produced a predicted level of fishing mortality in 1978 equal to the input F_T. The results (Table 10 and Fig. 5) suggest a terminal fishing mortality of $F_T = 0.11$ for 1978.

IV. Results of Assessment

a. Trends in Population Size and Recruitment: The 2+ biomass of the Southern Gulf of St. Lawrence stock complex decreased from approximately 1800 KT in 1969 (Table 11) to a low of 400 KT in 1975, increased to nearly 525 KT in 1978 and is predicted to decline to 480 KT in 1979 under assumptions of the strength of the 1976 and 1977 year-classes being equal to the geometric mean of the 1968-75 year-classes. The spring-spawning biomass which declined from 440 KT in 1969 to 150 KT in 1975 had increased substantially to 270 KT by 1978 whereas the fall-spawning biomass had increased only marginally in 1978 from a low of 230 KT in 1976. Amongst spring-spawners the 1974 year-class is estimated to be the largest observed in this component since the very large 1959 year-class (Fig. 6) and is about twice the strength of the 1968 year-class. The strength of the 1975 year-class is estimated to be fairly weak although some uncertainty must be expressed in recognition of the problem noted previously with regard to classification of spawning groups. The high abundance of the 1976 and 1977 year-classes observed in the purse-seine fishery off eastern P.E.I. suggests that these year-classes are perhaps better than average.

Amongst fall-spawners the 1973 year-class is about one-half the strength of the 1970 year-class which has been the strongest in the fall-spawning component since the early 1960's (Fig. 6). The 1974 year-class is estimated to be about 80% as strong as the 1970 year-class whereas the 1975 year-class appears to be below average, despite its predominance in the purse-seine fishery off P.E.I.

Recognizing that estimates of the strength of most recent year-classes (1972-75) are very sensitive to the input parameters in 1978, an alternative method of year-class strength estimation was developed based on catch-per-unit-effort indices of these year-classes at ages 3 and 4, adjusted for annual changes in partial recruitment, defined as the ratio F_t/F_{5+}. The basic calculations are shown in Tables 12 and 13 and the relationships between population size at age from cohort analyses and the corresponding age-specific CPUE are shown in Fig. 7. The correlation coefficients are statistically significant in each case and a summary of the estimates of year-class strengths adjusted to age-group 2 is shown in Table 14. In general, the estimates of year-class strength derived from cohort analyses appear to be reasonably reliable although there may be some under-estimation of the spring-spawning year-class. In a previous assessment of this stock Winters (1978) estimated the 1974 and 1975 year-classes to be 1.6 billion and 0.57 billion, respectively, which is also somewhat higher than the values derived from cohort analyses in this assessment. This may indicate that these year-classes were not fully recruited to the fall purse-seine fishery in 1978, an assumption which is inherent in the calculation of partial recruitment factors for the 1978 fishery as a whole (see Table 9). The 1972 year-class of spring-spawners is perhaps more reliably estimated by cohort analysis, given the extent of convergence expected from a 4-year time series of catches. In addition, the estimate of that year-class derived from the CPUE index is somewhat greater than the strength of the 1968 year-class and such does not appear to be the case from age-composition data of commercial catches during the past several years.

b. Survey Abundance Indices and Cohort Analyses: Research vessel abundance estimates (in numbers) have been indexed to the initial year (1968) and are compared with mean annual population estimates of 2+ fish from cohort analyses in Fig. 8. The high correlation coefficient obtained provides some confidence in the estimates of population size derived from sequential computation analyses given the input parameters used in this assessment.

c. Relationship between Inshore Catches and Biomass Estimates: Inshore fisheries conducted principally by gillnets and traps tend to be much more passive exploiters of a fish population since increases in fishing effort result mainly from additional units of gear rather than increased effort by the same gears. Thus inshore catches tend to reflect dynamic changes in stock abundance much more than such active gears as purse-seines. This appears to have been the case in the Southern Gulf where inshore catches are very highly correlated with 3+ biomass estimates (gillnets and traps have a very low selectivity factor for age-group 2 fish) (Fig. 9). The average annual exploitation rate (calculated as the ratio $C_{t/B_{3+}}$) since the mid-1960's has been 2.5% and if one assumes that inshore fisheries exerted a similar exploitation rate during the period 1935-55 this implies (from an annual average catch of about 30,000 m tons) an average biomass of 1200 KT during that period. Since this is more than twice the size of the current biomass of herring in the Southern Gulf further increases in the inshore catch will result mainly from increases in fishing effort, unless recruitment prospects considerably improve.

V. Catch Prognosis

a. Calculation of $F_{0.1}$: Winters et al. (1977) calculated $F_{0.1}$ = 0.52 based on partial recruitment rates estimated for the period 1969-74 from cohort analyses. Recent patterns of fishing, particularly those by the purse-seine fleet in 1978 suggest a greater exploitation rate of the younger age-groups due not only to the greater abundance of younger fish in the fall fishery but also to the recent demise of the "Edge" fishery which traditionally exploits the older age-groups. In order to reflect these new events in the fishery the partial recruitment rates for 1977 (Winters 1978) and 1978 (Table 9) have been averaged (spring- and fall-spawners combined) and smoothed to devise the general approximation described below, and compared with the previous values used by Winters et al. (1977).

Age/PR	2	3	4	5	6	7	8	9	10	11
New	.25	.35	.45	.55	.75	.90	.95	.98	1.00	1.00
Old	.06	.15	.27	.39	.50	.60	.75	.87	.94	1.00

The revised yield-per-recruit curve (Fig. 10) indicates an $F_{0.1}$ = 0.38.

b. Catch Projection for 1979: A catch projection for 1979 has been carried out at $F_{0.1}$ = 0.38 assuming that the 1976 and 1977 year-classes of both spring- and fall-spawners are equal to the geometric mean of the 1968-75 year-classes (0.2 billion fish at age 2). The results (Tables 15a, 15b) indicate an optimal yield of 104,000 m tons in 1979 which will result in a 1980 population (2+) biomass of about 392,000 m tons, assuming that the 1978 year-class is also 0.2 billion fish at age 2. This is a significant decrease from the 480,000 m tons predicted at the beginning of 1979 and continued fishing at $F_{0.1}$ levels in the future would result in a long-term average yield of about 42,000 m tons at an average biomass level of 220,000 m tons. If future recruitment is equal to the average level estimated for the 1970-75 year-classes (0.30 billion fish at age 2 for each spawning component) then present biomass levels could be maintained under an average annual yield of about 60,000 m tons.

DISCUSSION

The appearance of several relatively abundant year-classes in the Southern Gulf of St. Lawrence herring stock complex during the mid-1970's is to a certain degree consistent with several analyses of the recruitment mechanisms of this stock by both Winters (1976) and Lett and Kohler (1976). Winters (1976) concluded that the Southern Gulf herring biomass had exerted logistic control of its recruitment enabling the production of several very large year-classes in the late 1950's when spawning stock levels were very low but severely restricting the population to a succession of relatively weak year-classes during the 1960's when biomass levels were very high. During the late 1960's competition and predation by an expanding mackerel population prevented a resurgence of herring production as would have been expected from the rapid attrition in the herring biomass during that period. Lett and Kohler (1976) arrived at a similar conclusion regarding the homeostatic effect of the pelagic (herring and mackerel) biomass on herring recruitment but with added logistic control exerted by density-dependent ℓ_1 growth. More recently, however, the hypotheses of density-dependent growth in Southern Gulf herring has been seriously challenged by Moores and Winters (1978) who, through correlation analyses, have indicated the growth (both ℓ_1 and subsequent growth) is largely controlled by the environmental signal, temperature. Nevertheless, the precipitous decline in both mackerel biomass and recruitment (Winters 1978) during the mid-1970's (the 1975, 1976, 1977 year-classes are all very poor) has evidently reduced this added constraint on the recruitment of Southern Gulf herring, allowing the production of several relatively good year-classes. Furthermore, and accepting the general parallelism in year-class strengths observed in a variety of herring stocks in the Atlantic area, it is interesting to note that, for example, the 1974 year-class has not been nearly as strong in spring-spawning stocks around the Newfoundland area - these stocks for the most part were at very high levels of abundance during the period 1973-75.

The maximum growth potential of Southern Gulf herring is generally reached during the fifth year of its life cycle. The observed age-specific catch in 1978 and that predicted for 1979 includes large numbers of fish younger than age-group 5 implying some loss in yield-per-recruit. Since the "Edge" fishery has traditionally exploited mainly the older age-groups a partitioning of the Southern Gulf TAC to include a significant allocation to the spring "Edge" fishery therefore remains a desirable biological

objective if undue exploitation of juvenile herring in the Western Gulf fall purse-seine fishery is to be ameliorated.

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Table 1. Purse-seiner catches of herring in 4T in 1978 as reported by the Maritimes Economics Branch.*

Month/Area	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL
4T-	125	-	-	720	1863	-	-	8	6311	11347	6838	2061	29273
432	115	-	-	-	-	-	-	-	233	544	-	-	892
433	-	-	-	-	-	-	-	-	-	-	-	-	-
434	-	-	-	-	-	-	-	-	-	-	-	-	-
435	-	-	-	-	446	-	-	-	-	-	-	-	446
436	-	-	-	-	-	-	12	-	190	360	-	-	562
437	-	-	-	-	-	-	-	-	-	-	-	-	-
438	-	-	-	-	2219	-	-	8	2021	894	-	-	5142
TOTAL	240	-	-	720	4528	-	12	16	8755	13145	6838	2061	36315
Nfld. (431)				1121	1278								

* (From Leo Brander - Halifax)

Table 2 . Purse-seiner catches in Area 4T in 1978 as derived from log book records.

Month / Area	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total (m tons)
431 (F)				1248	2278		24						3550 mt
432 (G)									436	2772			3208 mt
438 (N)						1081		36	7805	4294	3125		16341 mt
436 (L)									1192	3597			4789 mt
437 (M)								7	53	32	1115		1207 mt
433 (H)						30				391			421 mt
434 (J)						18							18 mt
435 (K)						84							84 mt
TOTAL (mt)				1248	2278	1213	24	43	9486	11086	4240		29618 mt

Table 3 . Purse-seine catches in 4T in 1978 broken down by month and area according to log records and reported statistics.

Area/Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.[a]	Oct.[a]	Nov.[a]	Dec.	Total
431	125			1841	3141		24						5131
432	115					184			541	3441			4281
433						65				485			550
434						41							41
435													-
436									1480	4465			5945
437								7	66	40	1335		1448
438						2373		36	9688	5330	3880		21307
Total	240			1841	3141	2663	24	43	11775	13761	5215		38703

a total reported landings, Sept.-Dec., broken down by area and month from log records

Table 4. Catch statistics for 4T herring in 1978 (provisional).

Month	Magdalens - Edge		Eastern P.E.I.		Southern Gulf		Total
	Inshore	P. Seine	Inshore	P. Seine	Inshore	P. Seine	
Jan.		125		115			240
Feb.							-
Mar.							-
Apr.	718	1841	1		47		2607
May	1075	3141	146		6589		10951
June			31	184	737	2479	3431
July		24	4		392		420
Aug.	40		1		2812	43	2896
Sept.	9		10	541	1031	11234	12825
Oct.			10	3441	81	10320	13852
Nov.			5		37	5215	5257
Dec.							
Total	1842	5131	208	4281	11726	29291	52479

Table 5. Monthly catch-per-set data from log records of purse-seiners operating on the "Edge" (Area 4TG).

Year	Catch-per-unit-effort		Mean	
	April	May	Unweighted	Weighted
1969	63.7	58.2	61.0	62.3
1970	62.9	32.5	47.7	55.8
1971	38.9	-	-	-
1972	-	29.7	-	-
1973	21.5	48.8	35.2	43.3
1974	34.8	33.4	34.1	33.6
1975	47.1	61.3	54.2	59.1
1976	44.5	47.1	45.8	45.3
1977	33.3	37.2	35.3	35.3
1978	19.5	35.0	27.3	29.4

Table 6. Percentage of autumn-spawners in samples taken along the "Edge" area of the Southern Gulf of St. Lawrence, 1970-78.

	% Autumn-spawners		
Year	April	May	June
1970	28	-	-
1971	19	-	
1972	-	-	
1973	32	52	56
1974	31	68	
1975	65	81	
1976	51	60	
1977	55	59	
1978	81	94	

Table 7. Monthly CPE data (catch/set) as evaluated from log records of purse-seiners operating in the Southern Gulf 1971-78 (excluding unit area 432).

Year	Catch-per-unit-effort (CPE)						Unweighted Mean Sept.-Nov.
	June	July	Aug.	Sept.	Oct.	Nov.	
1971	17.3	34.9	25.4	47.2	59.4	(54.9)	53.9
1972		37.0	12.9	37.1	53.9	44.3	45.1
1973		26.4	-	49.1	-	-	-
1974		19.4	40.2	28.3	35.4	50.0	37.9
1975			23.6	32.1	37.8	33.5	34.5
1976				27.3	44.5	50.6	40.8
1977				(41.3)	53.1	40.6	45.0
1978	71.4		22.0	45.3	31.7	67.3	48.4
Unweighted mean	45.4	26.4	24.8	38.0	45.1	47.7	

Table 8. CPUE indices for the various fisheries exploiting the Southern Gulf stock complex. Research vessel data are from the autumn groundfish surveys and have been log retransformed (Stobo, pers. comm.).

Year	SW Nfld.	CPE Edge	Magdalens	S. Gulf (P.S.)	S. Gulf (R.V.)
1969	50.3	61.0	-	(110.2)	12.8
1970	41.5	47.7	204	(90.9)	7.6
1971	24.6	-	336	53.9	3.2
1972	13.4	-	112	45.1	3.2
1973	9.2	35.2	91	41.0	2.2
1974	-	34.1	80	37.9	2.1
1975	-	54.2	59	34.5	2.4
1976	-	45.8	46	40.8	2.6
1977	-	35.3	65	45.0	2.7
1978	-	29.4	34*	48.4	1.9

* provisional

( ) see Winters (1978)

Table 9. Comparison of age compositions (3+) of purse-seine catches in the 1978 fall fishery (excluding Unit Area 432) with total age-specific catches for all fisheries in the Southern Gulf.

Age	Spring-spawners			Autumn-spawners		
	%-at-age (PS)	%-at-age (Total)	Selectivity Factor	%-at-age (PS)	%-at-age (Total)	Selectivity Factor
3	9.0	14.5	1.61	11.6	18.7	1.61
4	68.3	65.7	0.96	34.3	27.5	0.80
5	6.5	4.8	0.74	15.6	14.3	0.92
6	9.0	6.9	0.77	4.3	4.0	0.93
7	1.3	1.2	0.92	2.9	3.5	1.21
8	1.5	1.2	0.80	16.0	14.9	0.93
9	<0.2	<0.2	-	1.2	1.6	1.33
10	3.7	3.6	0.99	<0.2	0.9	-
11+	0.5	2.0	4.00	14.0	14.6	1.04

Table 10. Regression analyses of fishing mortality (age-group 3+) on fishing effort for the period 1969-77 at varying levels of F_T in 1978.

Year	Effort	F_T (AS + SS) .08	.11	.125	.14
1969	2549	.214	.225	.229	.233
1970	3263	.320	.333	.341	.355
1971	4365	.343	.384	.400	.408
1972	1951	.187	.207	.218	.237
1973	1422	.107	.120	.127	.140
1974	982	.088	.097	.103	.119
1975	1273	.112	.138	.150	.162
1976	966	.093	.108	.119	.146
1977	956	.055	.076	.085	.091
1978	1090				
	R^2	0.953	0.970	0.968	0.950
	a	0.001	0.011	0.018	0.035
	b	0.000085	0.000090	0.000091	0.000088
	Pred. F_{1978}	0.094	0.109	0.117	0.132

Table 11. Population estimates of spring- and fall-spawning herring in 4T as derived from cohort analyses for the period 1969-79. Recruitment strength at age 2 in 1978 and 1979 is the geometric mean strength of the 1968-75 year-class.

Spawning Group	Age Group	Estimated Population Size ($\times 10^{-5}$)										
		1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
SS	2	902	6239	685	731	1211	3284	1510	12536	1322	(2000)	(2000)
	3	1675	738	5107	532	598	939	2647	1222	10191	1050	1505
	4	2222	1215	528	3584	416	467	689	1924	951	7770	721
	5	1138	1653	627	371	2671	314	352	390	1361	710	5756
	6	1419	815	1239	390	246	1763	241	259	246	1016	536
	7	1358	897	517	927	267	131	1201	45	188	170	766
	8	456	885	439	341	720	178	72	801	34	148	127
	9	1718	296	402	221	236	518	108	37	564	23	110
	10	4403	966	150	194	135	167	368	58	16	402	17
	11+	780	2660	1501	673	583	479	486	585	373	190	331
	N_t ($\times 10^{-5}$)	16701	16365	11195	7965	7082	8241	7671	17856	15245	13477	11869
	W_t (tons)	438590	329290	247020	183070	161310	150270	150070	189200	259480	269430	257760
AS	2	5610	1611	1248	6647	1184	1122	3064	5208	1501	(2000)	(2000)
	3	2794	4571	1299	977	5390	968	876	2508	4263	1227	1620
	4	4037	2090	3361	764	753	4379	747	698	2050	3466	842
	5	4214	3124	1177	1911	484	573	3438	575	554	1613	2598
	6	8548	3274	2284	642	1100	322	415	2584	428	422	1195
	7	4793	6174	2451	1327	333	703	227	276	1868	319	311
	8	2278	2841	3603	1203	821	182	486	156	187	1334	231
	9	2804	1517	1392	1902	741	553	124	353	110	134	963
	10	4181	1838	854	610	1336	514	404	82	251	77	96
	11+	13126	10251	6370	3556	2593	2855	2536	2171	1625	1283	970
	N_t	52384	37292	24040	19539	14734	12172	12317	14608	12837	11873	10826
	W_t	1343036	1000350	653140	372740	319070	280820	245910	230810	247520	244590	221320
SS + AS	N_t	69085	53657	35235	27504	21816	20413	19988	32464	28082	25350	22695
	W_t	1781626	1329640	900160	555810	480380	431090	395980	420010	507000	522780	479080

Table 12. Relationship between catch-per-unit-effort of 3-year-old ($C_{3/E}$) herring and population estimates at age 3 from cohort analyses. Partial recruitment (PR) is defined as the ratio $F_{3/F_{5+}}$ and is used to adjust $C_{3/E}$ based on standarized estimates ($PR/\overline{PR}$).

Year-class	AS				SS			
	$C_{3/E}$	PR	$C^1{}_{3/E}$	N_3	$C_{3/E}$	PR	$C^1{}_{3/E}$	N_3
1966	8.59	.38	9.27	2794	6.75	.35	9.64	1675
1967	12.93	.32	16.57	4571	2.57	.29	4.43	738
1968	7.58	.69	4.50	1299	15.12	.42	18.00	5107
1969	2.67	.22	4.98	977	1.07	.28	1.91	532
1970	2.67	.05	32.36	5390	1.76	.25	3.52	598
1971	5.09	.56	3.73	968	8.96	.68	6.59	939
1972	1.73	.27	2.62	876	21.05	.48	21.92	2647
1973	.30	.01	12.30	(2695)	5.69	.24	11.85	(2180)
1974	2.82	.36*	3.21	(1192)	66.32	.36*	92.11	(16528)
1975	16.51	1.26*	5.37	(1550)	14.13	1.60*	4.42	(852)

* derived empirically from ratio of age-specific purse-seine catches to total catches.

Table 13. Relationship between catch-per-unit-effort of 4-year-old ($C_{4/E}$) herring and population estimates of age 4 from cohort analyses. Partial recruitment (PR) is defined as the ratio $PR/\bar{PR}$ and is used to adjust $C_{4/E}$ based on standardized estimates.

Year-class	AS				SS			
	$C_{4/E}$	PR	$C^1_{4/E}$	N_4	$C_{4/E}$	PR	$C^1_{4/E}$	N_4
1965	7.84	.24	19.60	4037	7.22	.28	17.79	2222
1966	18.08	1.08	10.04	2090	12.47	1.00	8.60	1215
1967	21.28	.75	17.02	3361	1.56	.40	2.69	528
1968	8.00	.91	5.27	764	14.92	.61	16.88	3584
1969	3.38	.43	4.71	753	2.11	.39	3.73	416
1970	16.60	.40	24.90	4379	3.46	.56	4.26	467
1971	3.22	.60	3.22	747	15.08	1.41	7.38	689
1972	1.97	.25	4.73	(910)	24.53	.67	25.26	(4233)
1973	7.64	.57*	8.04	(1535)	7.95	.58*	9.46	(1468)
1974	24.31	.72*	20.26	(3845)	64.22	.96*	46.16	(7890)

* derived empirically from ratio of age-specific purse-seine catches to total catches.

Table 14. Abundance of the 1972-75 year-classes (at age-group 2) of spring- and fall-spawning herring in 4T as derived by the methods outlined in the text.

Year-class		Estimated strength at age 2 from			Average
		CPE (Age 3)	CPE (Age 4)	Cohort anal.	
SS	1972	-	6720	3284	5002
	1973	2690	2280	1510	2160
	1974	20250	12700	12356	15102
	1975	1090	-	1322	1206
AS	1972	-	1440	1122	1281
	1973	4100	2290	3064	3151
	1974	1455	5760	5208	4141
	1975	1895	-	1501	1698

TABLE 15a

STOCK PROJECTION AREA T SS 1976-

NATURAL MORTALITY# 0.2000 YEAR 1978

AGE	POP. NO. %X10-3<	CATCH NO. %X10-3<	FISHING MORT.	MEAN WT. KG.	POP. WT. %METRIC TONS<	CATCH WT. %METRIC TONS<	RESIDUAL POP. NOS.
2	2000.	157.	0.091	0.090	180.0	14.1	1495.0
3	1050.	154.	0.176	0.150	157.5	23.1	720.9
4	7770.	700.	0.105	0.202	1569.5	141.4	5727.4
5	710.	51.	0.083	0.243	172.5	12.4	535.0
6	1016.	73.	0.083	0.293	297.7	21.4	765.6
7	170.	13.	0.089	0.305	51.8	4.0	127.3
8	148.	12.	0.094	0.323	47.8	3.9	110.3
9	23.	2.	0.101	0.341	7.8	0.7	17.0
10	402.	38.	0.110	0.345	138.7	13.1	294.8
11	9.	1.	0.131	0.373	3.4	0.4	6.5
12	16.	2.	0.131	0.373	6.7	0.7	12.9
13	71.	8.	0.133	0.373	26.5	3.0	50.9
14	27.	3.	0.131	0.373	10.1	1.1	19.4
15	60.	6.	0.117	0.373	22.4	2.2	43.7
16	5.	1.	0.249	0.373	1.9	0.4	3.2
TOTAL	13479.	1221.			2694.3	241.9 x 1/2	9930.0

NATURAL MORTALITY# 0.2000 YEAR 1979

AGE	POP. NO. %X10-3<	CATCH NO. %X10-3<	FISHING MORT.	MEAN WT. KG.	POP. WT. %METRIC TONS<	CATCH WT. %METRIC TONS<	RESIDUAL POP. NOS.
2	2000.	173.	0.100	0.090	180.0	15.6	1481.6
3	1495.	166.	0.130	0.150	224.3	24.8	1074.8
4	721.	102.	0.170	0.202	145.6	20.7	498.0
5	5727.	987.	0.210	0.243	1391.8	239.8	3801.0
6	535.	123.	0.290	0.293	156.8	35.9	327.8
7	766.	201.	0.340	0.305	233.5	61.3	446.1
8	127.	35.	0.360	0.323	41.1	11.3	72.7
9	110.	31.	0.370	0.341	37.6	10.6	62.4
10	17.	5.	0.380	0.345	5.9	1.7	9.5
11	295.	85.	0.380	0.373	110.0	31.7	165.1
12	6.	2.	0.380	0.373	2.4	0.7	3.6
13	13.	4.	0.380	0.373	4.8	1.4	7.2
14	51.	15.	0.380	0.373	19.0	5.5	28.5
15	19.	6.	0.380	0.373	7.2	2.1	10.9
16	44.	13.	0.380	0.373	16.3	4.7	24.5
TOTAL	11927.	1946.			2576.2	467.8 x 1/2	8013.7

Pop Biomass (2+) 1/80 = 222 930 m. tons

TABLE 15 b

STOCK PROJECTION AREA 1 AS 1978=

NATURAL MORTALITY= 0.2000 YEAR 1978

AGE	POP. NO. %X10-3<	CATCH NO. %X10-3<	FISHING MORT.	MEAN WT. KG.	POP. WT. %METRIC TONS<	CATCH WT. %METRIC TONS<	RESIDUAL POP. NOS.
2	2000.	14.	0.008	0.050	100.0	0.7	1624.4
3	1227.	180.	0.177	0.128	157.1	23.0	841.6
4	3466.	265.	0.088	0.191	662.0	50.6	2598.7
5	1613.	138.	0.099	0.231	372.6	31.9	1196.1
6	422.	38.	0.105	0.260	109.7	9.9	311.1
7	319.	33.	0.121	0.288	91.9	9.5	231.4
8	1334.	144.	0.127	0.315	420.2	45.4	961.9
9	134.	15.	0.132	0.313	41.9	4.7	96.1
10	77.	9.	0.138	0.322	24.8	2.9	54.9
11	180.	21.	0.138	0.363	65.3	7.6	128.4
12	43.	5.	0.137	0.363	15.6	1.8	30.7
13	154.	18.	0.138	0.363	55.9	6.5	109.8
14	146.	17.	0.138	0.363	53.0	6.2	104.1
15	700.	75.	0.126	0.363	254.1	27.2	505.3
16	60.	6.	0.117	0.363	21.8	2.2	43.7
TOTAL	11875.	978.			2445.9	230.1 X1.12	8838.3

NATURAL MORTALITY= 0.2000 YEAR 1979

AGE	POP. NO. %X10-3<	CATCH NO. %X10-3<	FISHING MORT.	MEAN WT. KG.	POP. WT. %METRIC TONS<	CATCH WT. %METRIC TONS<	RESIDUAL POP. NOS.
2	2000.	173.	0.100	0.050	100.0	8.6	1481.6
3	1624.	180.	0.130	0.128	207.9	23.0	1167.8
4	842.	120.	0.170	0.191	160.7	22.8	581.3
5	2599.	448.	0.210	0.231	600.3	103.4	1724.6
6	1196.	274.	0.290	0.260	311.0	71.3	732.8
7	311.	82.	0.340	0.288	89.6	23.5	181.3
8	231.	64.	0.360	0.315	72.9	20.1	132.2
9	962.	271.	0.370	0.313	301.1	84.9	544.0
10	96.	28.	0.380	0.322	31.0	8.9	53.8
11	55.	16.	0.380	0.363	19.9	5.7	30.7
12	128.	37.	0.380	0.363	46.6	13.4	71.9
13	31.	9.	0.380	0.363	11.1	3.2	17.2
14	110.	32.	0.380	0.363	39.9	11.5	61.5
15	104.	30.	0.380	0.363	37.8	10.9	58.3
16	505.	146.	0.380	0.363	183.4	52.9	282.9
TOTAL	10795.	1908.			2213.2	464.4 X1.12	7122.0

1st Biomass (2+) 1980 = 168 660 m. Tons

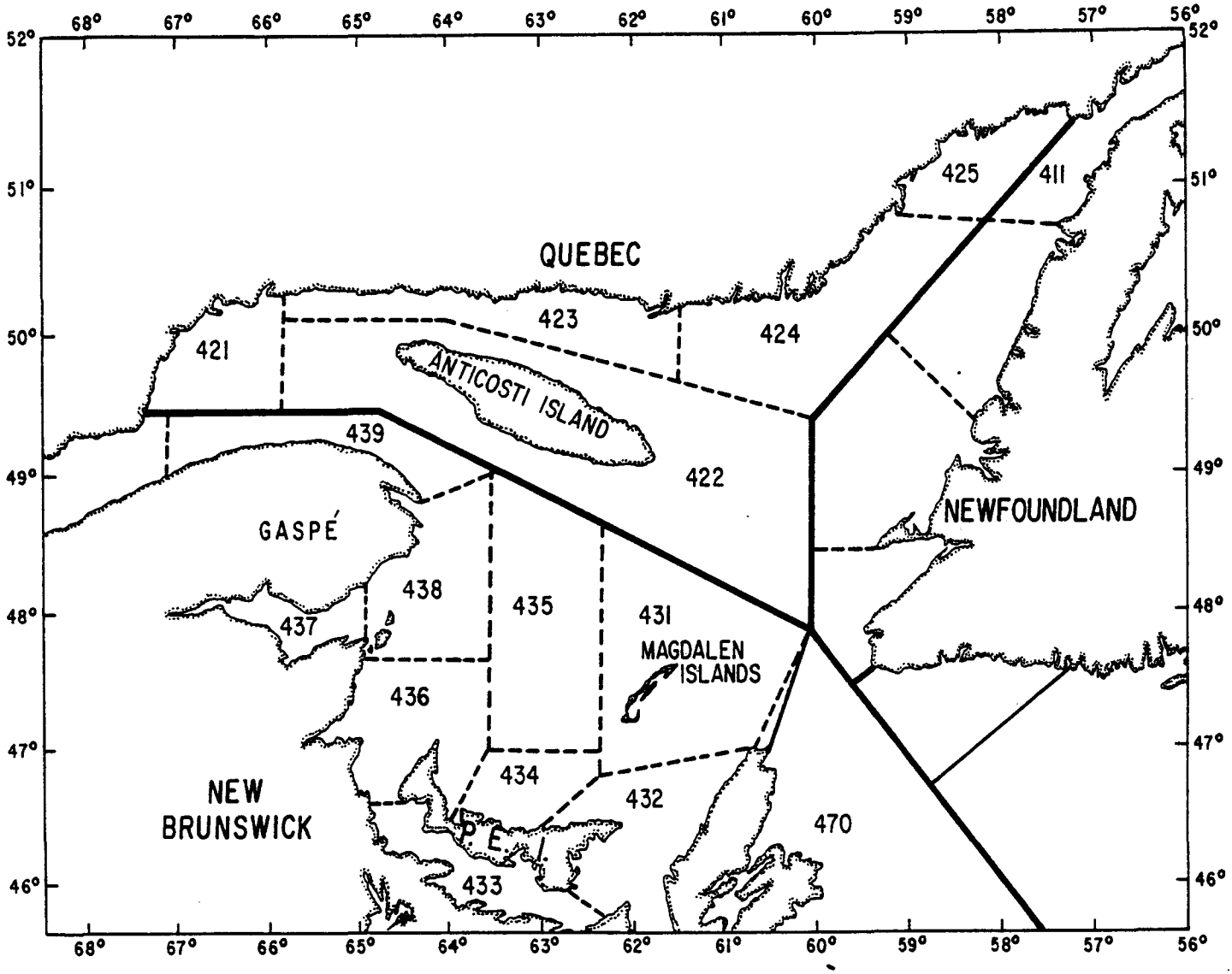

Fig. 1. Map showing statistical unit areas for the Southern Gulf of St. Lawrence.

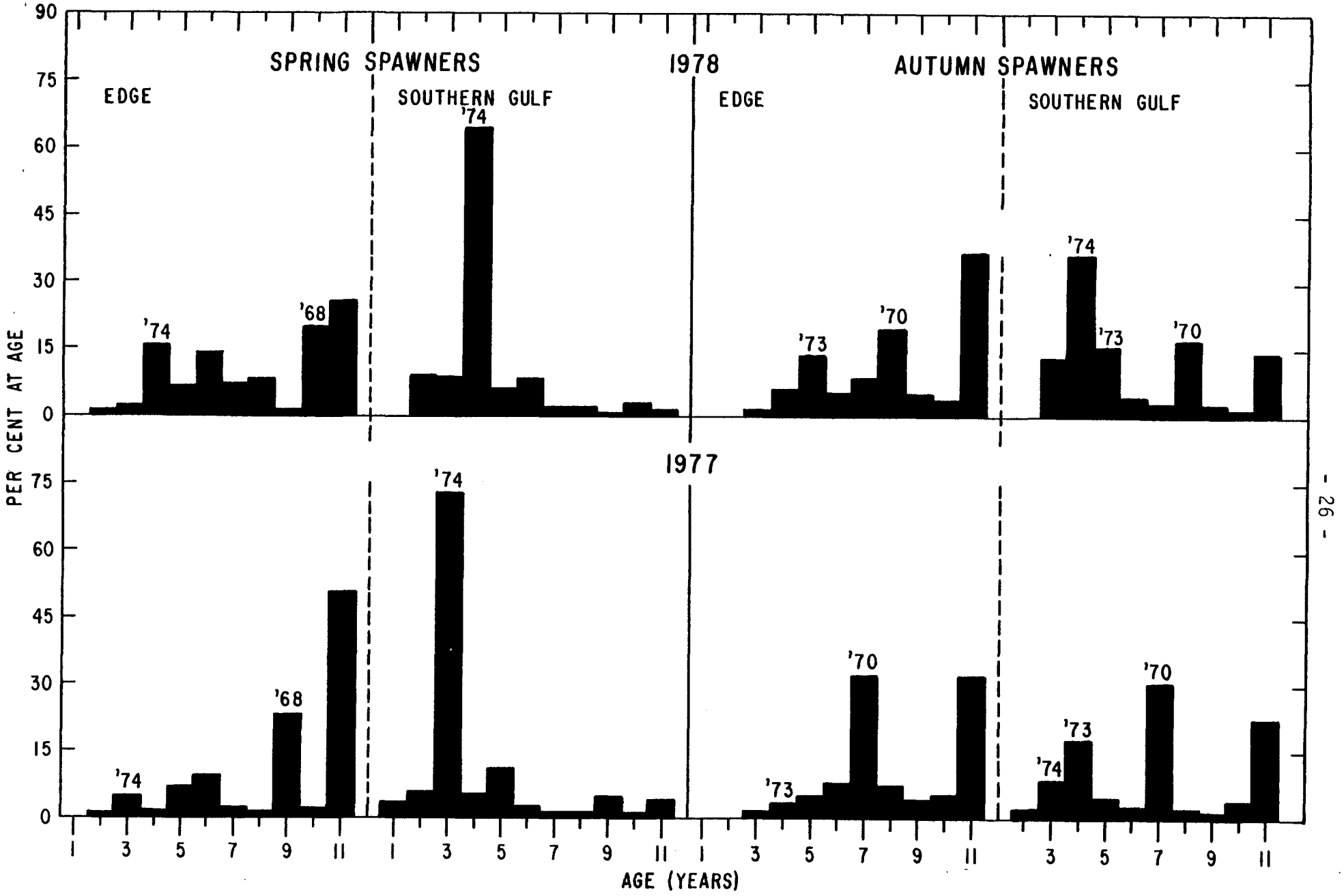

Fig. 2. Age composition data for the purse-seine fisheries operating along the "Edge" and in the Southern Gulf of St. Lawrence (excluding unit area 432) during 1977 and 1978.

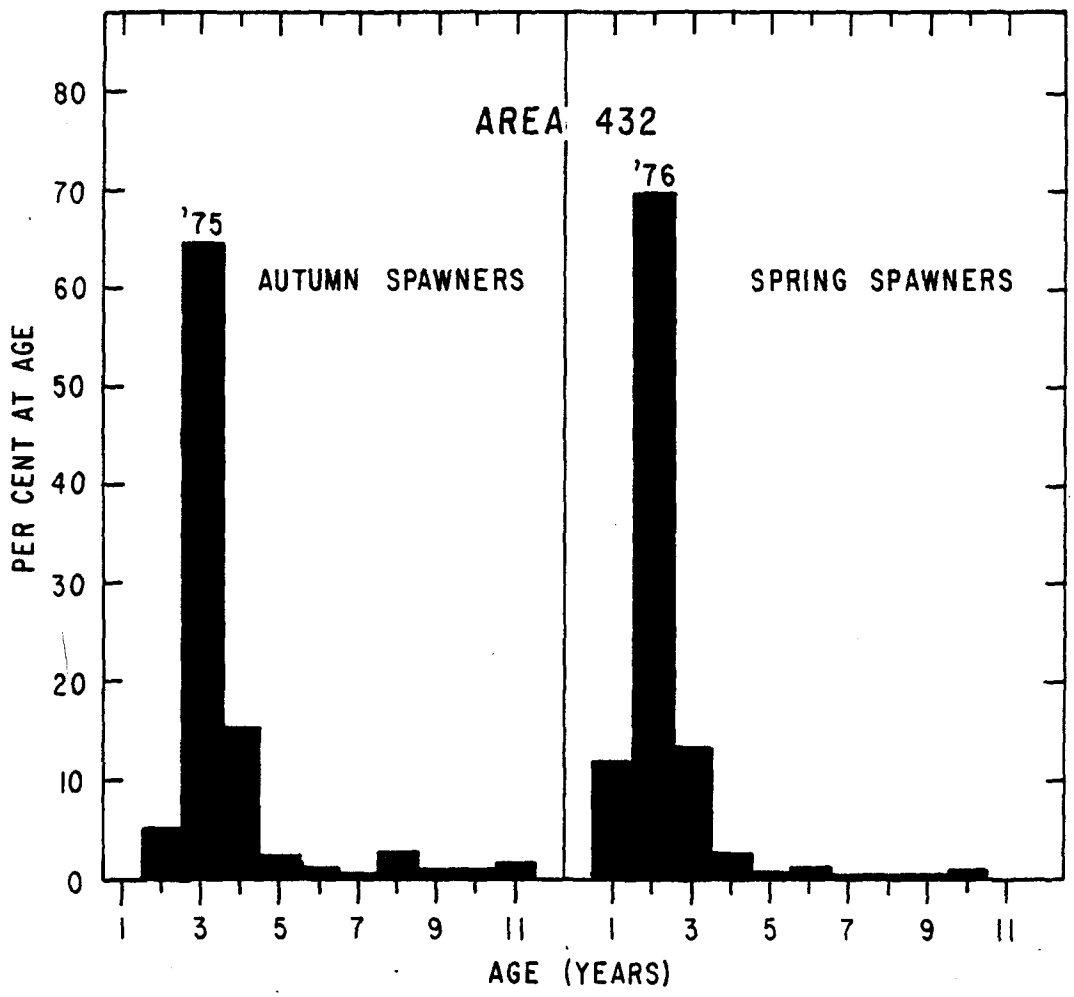

Fig. 3. Age composition data of purse-seiner catches off eastern P.E.I. (Unit area 432) in 1978.

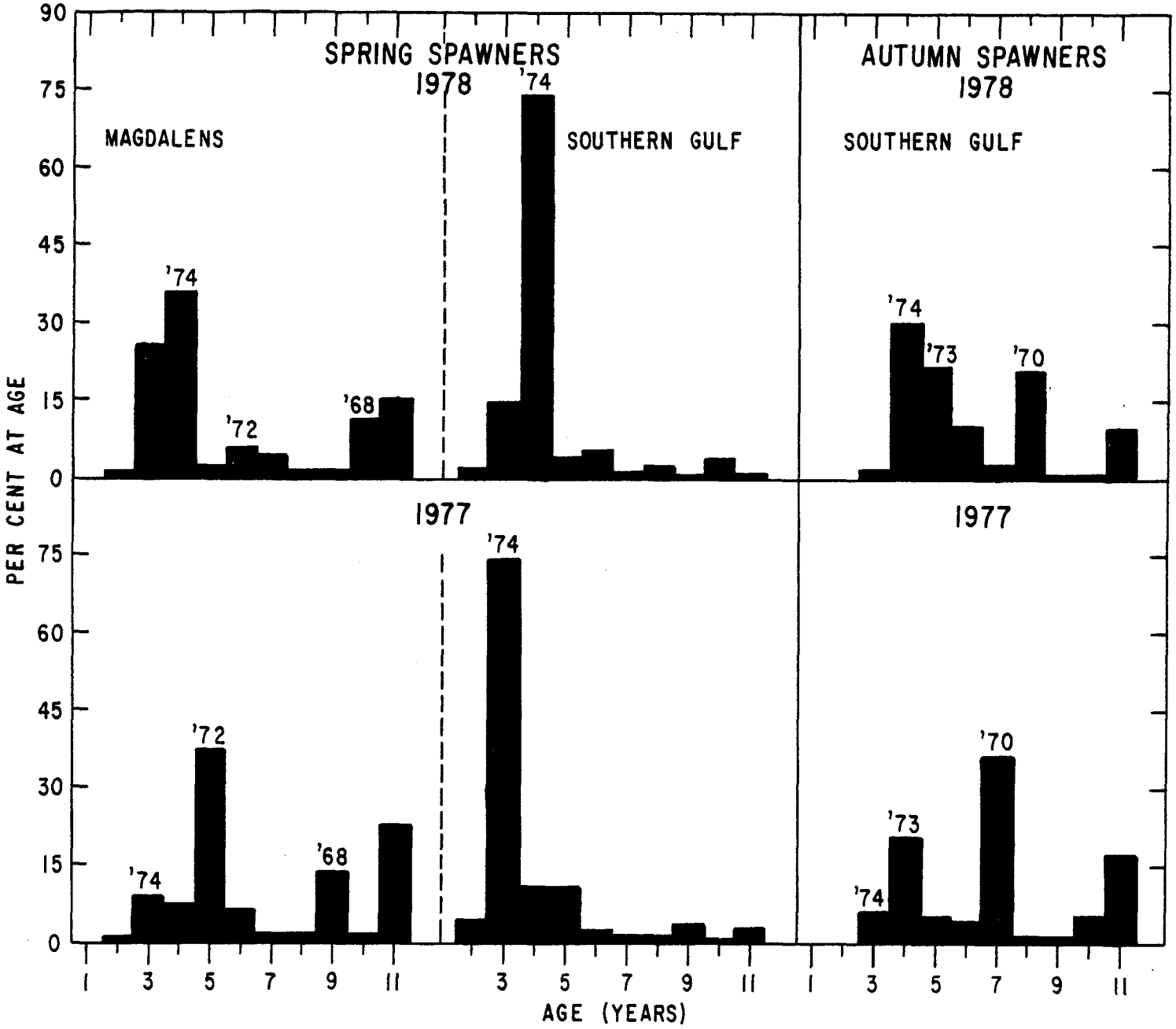

Fig. 4. Age composition data for the various inshore fisheries (all gears combined) in 4T in 1978.

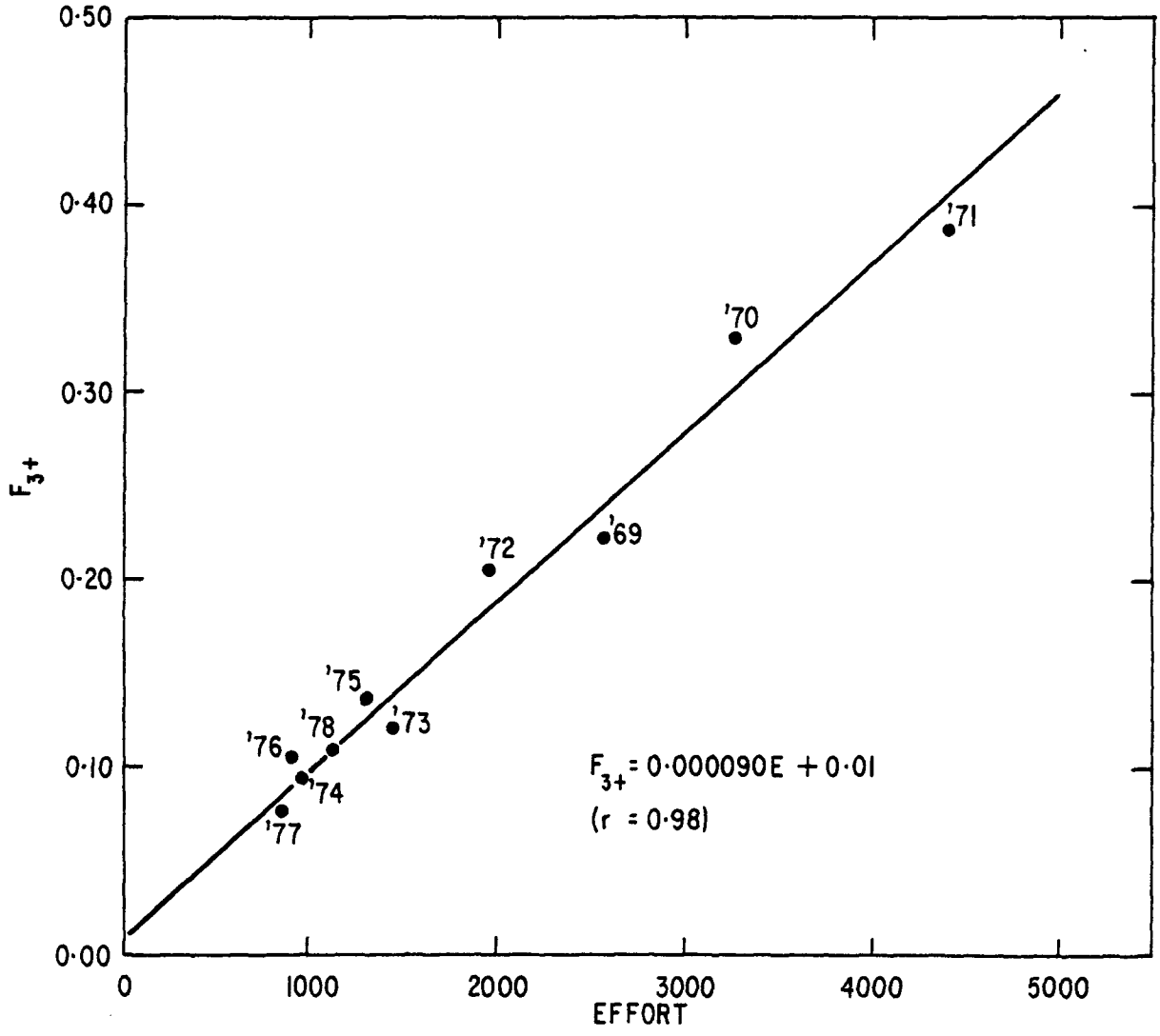

Fig. 5. Relationship between fishing effort and fishing mortality (age-groups 3r) for Southern Gulf herring, 1969-78.

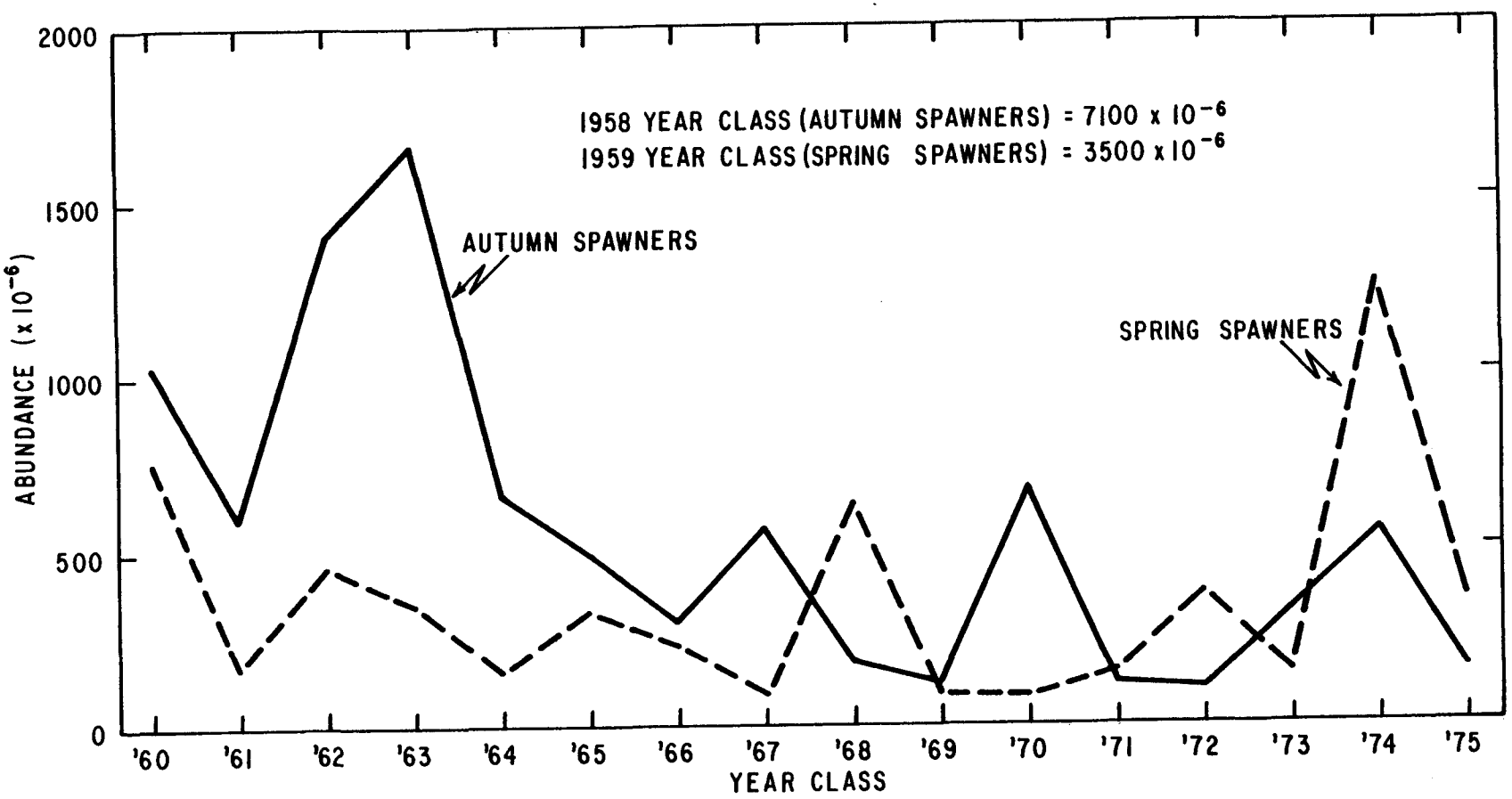

Fig. 6. Trends in year-class size of spring- and fall-spawning herring in the Southern Gulf of St. Lawrence herring stock complex, 1960-75.

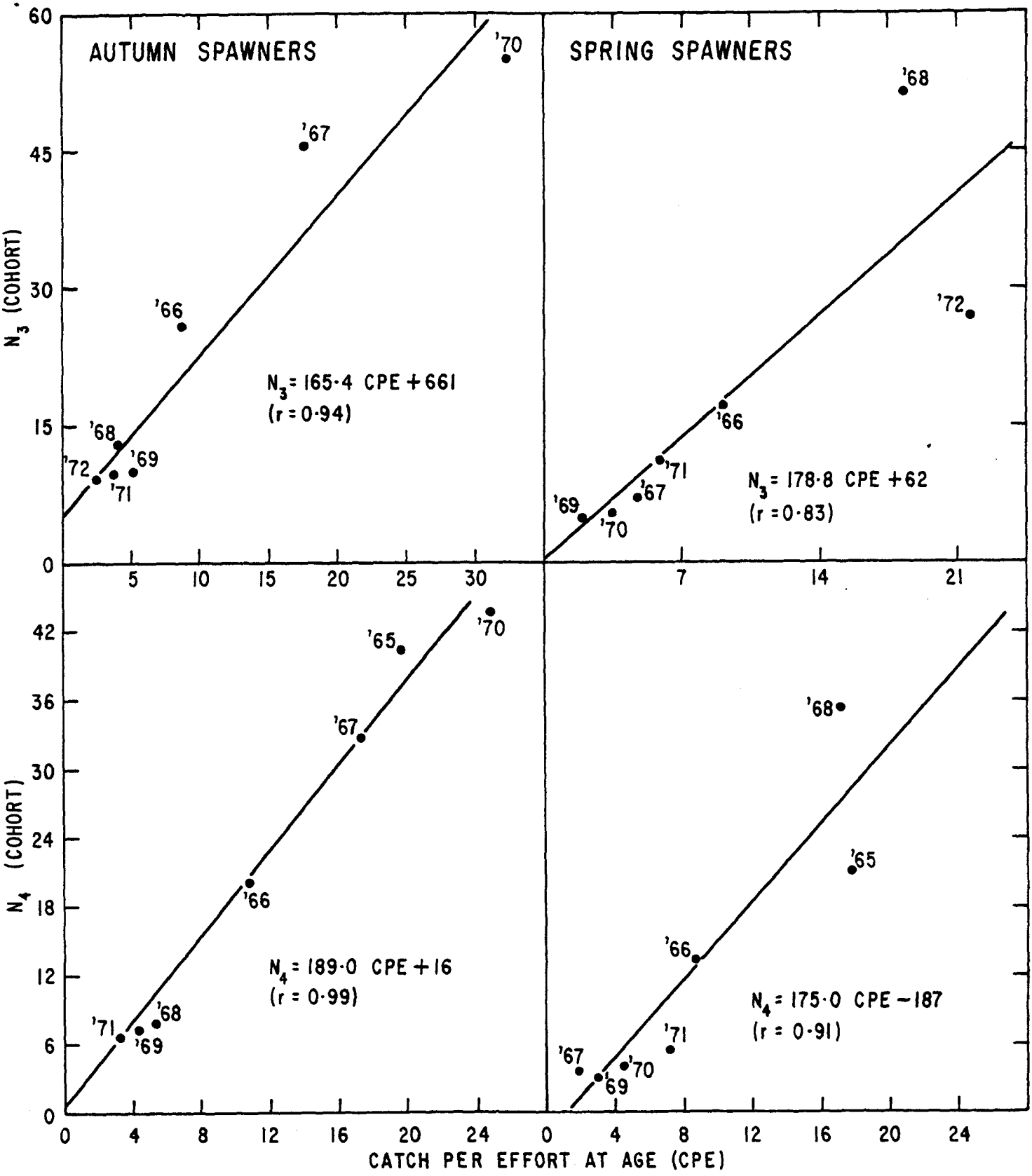

Fig. 7. Relationship between population size at age from cohort analyses and catch-per-unit-effort indices of abundance at age-groups 3 and 4. See text for explanation.

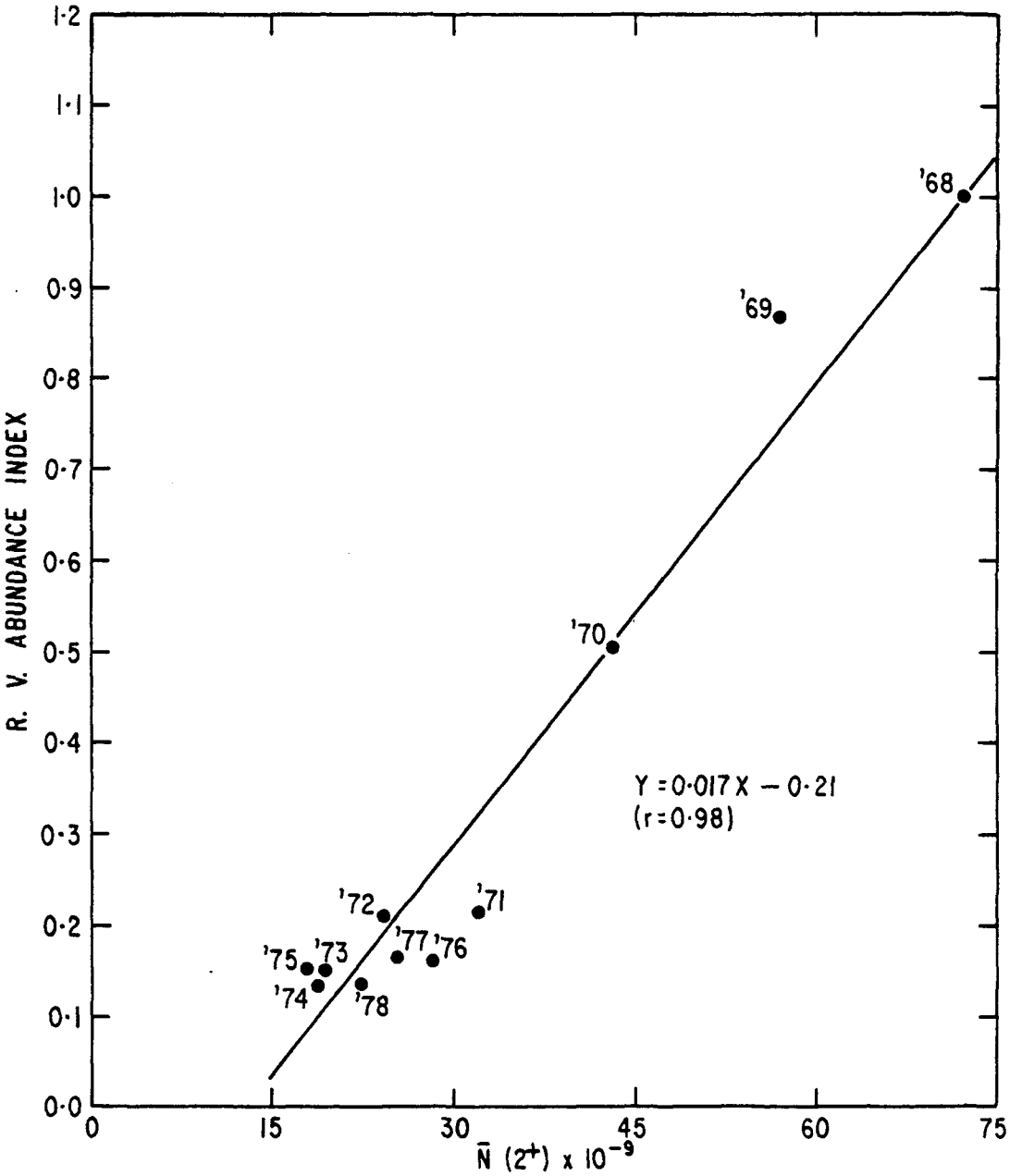

Fig. 8. Relationship between research vessel survey indices of abundance and mid-year ($\bar{N}$) population estimates (age-groups 2+) from cohort analyses.

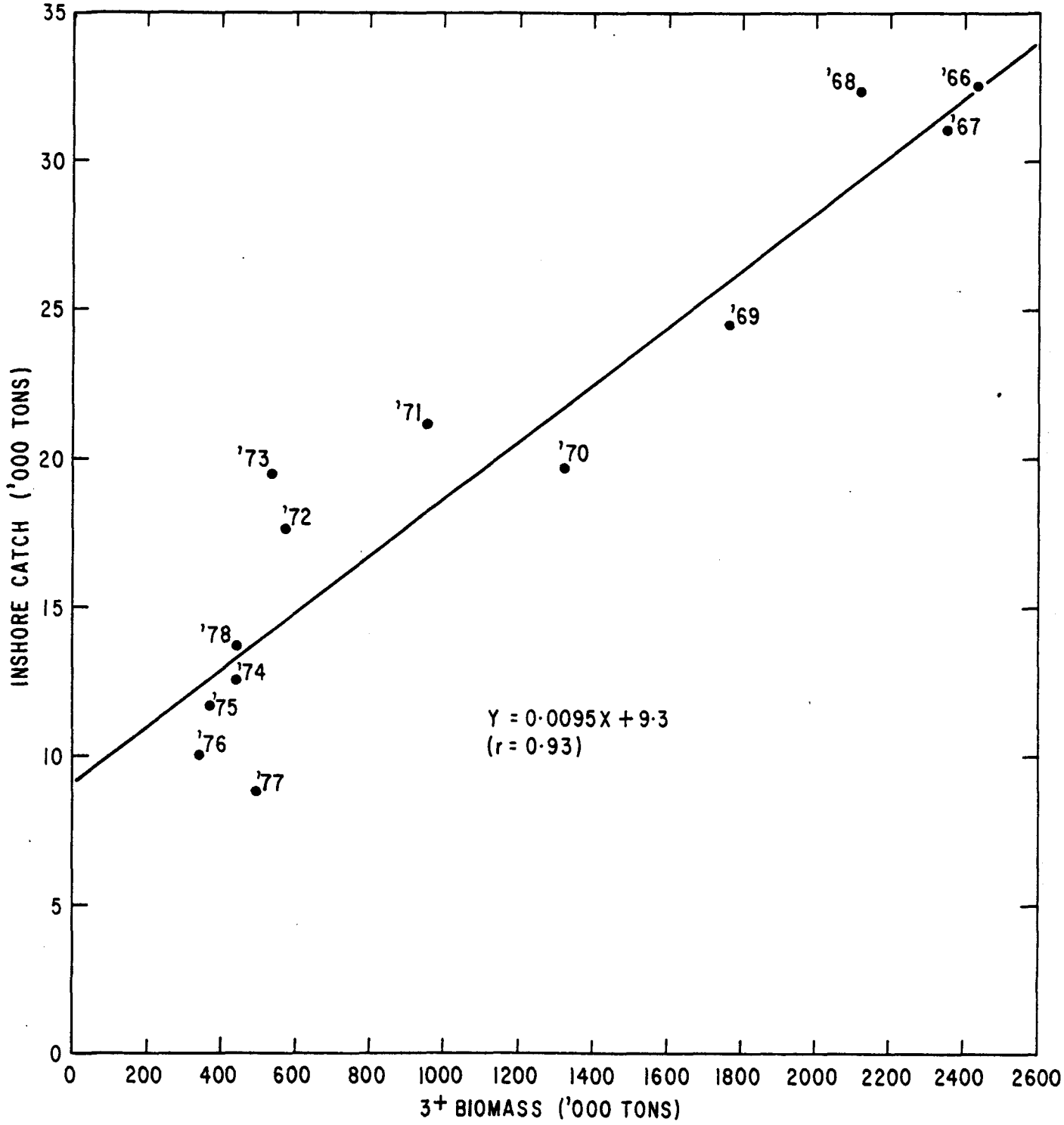

Fig. 9. Relationship between inshore catches in the Southern Gulf of St. Lawrence and 3+ biomass estimates from cohort analyses.

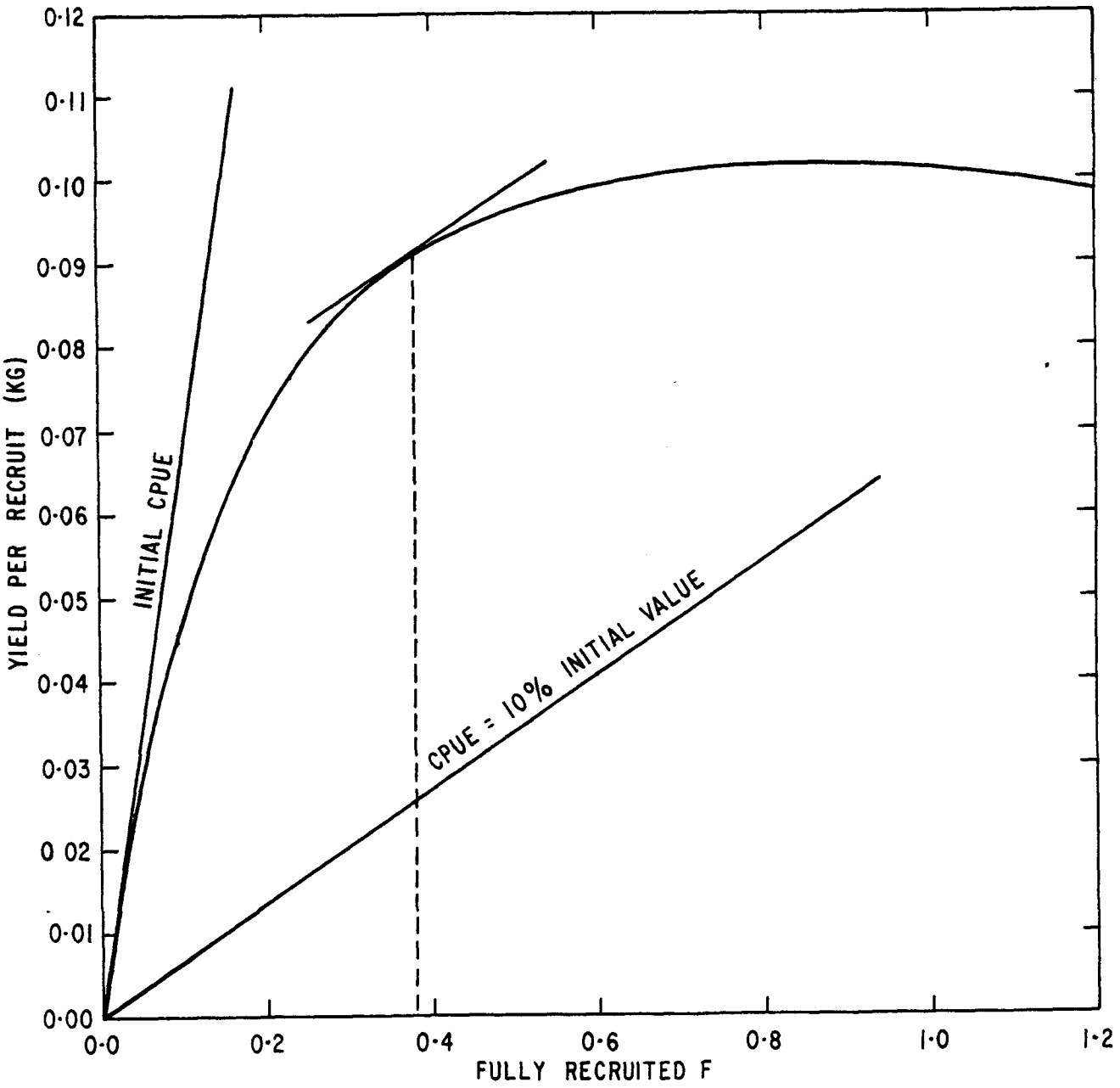

Fig. 10. Yield-per-recruit curve for the Southern Gulf stock complex of herring (spring-spawners and fall-spawners combined) based on the average partial recruitment pattern calculated for 1977-78.