Northwest Atlantic Fisheries Organization

Serial No. N304

NAFO SCR Doc. 81/VI/25

SCIENTIFIC COUNCIL MEETING - JUNE 1981

An examination of the influence of squid (*Illex illecebrosus*) on recruitment in several finfish stocks off eastern Newfoundland and Labrador

by

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Abstract

The impact of predation by squid on year-class strength of cod, capelin and herring in the coastal waters of eastern Newfoundland and Labrador was examined by correlation analysis. The only significant negative correlation was between squid abundance and 2+3K capelin, assuming squid prey on age-group 0 and 1 capelin. The many sources of error in existing data and the lack of information on many other aspects of the interaction precluded definitive evaluation of the effect of squid predation.

Introduction

The short-finned squid (*Illex illecebrosus*) is an annual migrant to inshore Newfoundland waters. During July to November it supports an inshore fishery which has resulted in catches of up to 83,000 t in 1979. While quantitative estimates are not available, inshore squid abundance is subject to severe non-cyclic yearly fluctuations (Squires 1957).

Short-finned squid have historically been first observed each year during May or June on the Grand Bank when catch rates from bottom-trawl surveys have provided an indication of later inshore abundance (Squires 1957; Hurley MS 1980). They move inshore, usually in July, and leave again by late November. By November a high proportion of males reach advanced stages of maturity, whereas females remain immature (Squires 1957). Late-season departure from inshore

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areas is believed to be associated with spawning offshore, probably during January or February (Squires 1967). Recently, young squid have been captured during late February-April in the vicinity of the Gulf Stream (Fedulov and Froerman MS 1980). The short-finned squid is a short-lived species, probably living only one year and dying after spawning (Hurley and Beck 1979). Thus, yearly fluctuations in year-class strength would be expected.

Squid on the continental shelf in spring feed almost exclusively on crustaceans, whereas squid examined inshore contain crustaceans and a higher proportion of fish remains (Squires 1957, Ennis and Collins 1979). Identification of fish remains in squid stomachs is difficult since food is macerated during consumption. Squires (1957) used hard structures found in stomachs to identify fish prey as capelin, redfish and gadoids. Incidence of fish remains in squid stomachs varies with inshore area and season. There is a pronounced late-season increase in cannibalism which Ennis and Collins (1979) suggested may be due to a decrease in availability of fish prey.

Concern has been expressed regarding the possible effect of inshore predation by squid on abundance of commercially important fish species (NAFO 1980). This paper presents a preliminary examination of this potential interaction on the east coast of Newfoundland (NAFO Div. 2J, 3K, 3L). Species which may be susceptible to squid predation in this area would include cod (Gadus morhua), capelin (Mallotus villosus), and herring (Clupea harengus). The young of these species have a coastal distribution (Lear et al. MS 1980, Reddin and Carscadden MS 1981; Moores 1980). Young of cod and capelin are also found offshore. It is assumed that squid may affect abundance of cod, capelin and herring by preying on 0-group and 1-group juveniles, thereby affecting year-class strength.

Methods

Estimates of yearly inshore abundance of short-finned squid, 1958-1980 (Table 1), were taken from Dawe and Hurley (this meeting). These estimates are qualitative, based on such subjective information as annual reports of the Department of Fisheries and Oceans Research and Resource Services, newspaper comments, weekly reports of field officers of the Inspection Branch, weekly reports of district offices of the Conservation and Protection Branch, and opinions of staff of Research and Resource Services (Squires 1957; Dawe and

Hurley, this meeting). Annual inshore catches were provided by the Economics and Intelligence Branch.

Population estimates were available from cohort analysis (Pope 1972) with constant rates of natural mortality for 2J+3KL cod (Wells and Bishop MS 1980), four herring stocks (White Bay-Notre Dame Bay, Bonavista Bay, Trinity Bay and Conception Bay) (Wheeler and Winters, MS 1980), 2+3K capelin (Carscadden and Miller, MS 1981) and 3L capelin (Carscadden et al., MS 1981). Year-class strengths at the youngest age-group given in the population matrices was used as an index of abundance for all age-groups younger than those presented in the cohort analyses (Table 1). For convenience year-class strength of capelin and herring was expressed as a percentage of the size of the largest year-class present in each time series for comparison with inshore squid abundance. A second index of year-class strength for cod was the average number caught at age-groups 2 and 3 per hour trawling during Soviet research surveys (1959-1975) in Divisions 3K and 3L (Konstantinov and Noskov, MS 1980). Catch rates in 3K and 3L were summed for comparison with squid abundance.

The degree of association between year-class success and abundance of squid was assessed by correlation analysis. The hypothesis was that variable predation by squid will result in a negative correlation between year-class strength and squid abundance. The null hypothesis was that the correlation is zero or positive. Associations between year-class strength and the index of inshore squid abundance were tested with the Kendall rank correlation coefficient (Siegel 1956), calculated using the SPSS statistical package (Nie et al., 1975).

Results

A comparison of the qualitative inshore squid abundance index and catch for the years 1958-80 showed a clear correlation (Fig. 1). However, catches for 1965-67 appear to be higher than indicated by the trend, and might be related to increased catching efficiency attending introduction of the Japanese mechanical jigger to the Newfoundland inshore fishery in 1965 (Hurley MS 1980). Also the very high catches since 1976 presumably reflect a marked improvement in market opportunities rather than a dramatic increase in inshore abundance (Hurley, MS 1980). The correlation between the two measures of abundance prior to 1976 suggests that both can be used for evaluation of squid impact. As the catches represent continuous values they are more useful for correlation analysis. However, due to market changes the qualitative index must be used for recent years.

The relationship between inshore squid abundance and 2J+3KL cod was examined using inshore squid catch and year-class strength (at age-group 4) assuming predation by squid on each cod year-class at age-group 0 (Fig. 2) and age-groups 0+1 (Fig. 3). No significant relationship was found. Furthermore, there was no significant relationship between inshore squid catch and average catch of cod at either age-group 2 or age-group 3 in Soviet research surveys, again assuming predation by squid on each cod year-class at age-group 0 and age-groups 0+1.

The relationship between inshore squid abundance and capelin was examined for two capelin stocks (3L and 2+3K) using the index of inshore squid abundance and year-class strength (3L at age-group 3 and 2+3K at age-group 2) assuming predation by squid on each capelin year-class at age-group 0 (Fig. 4) and age-groups 0+1 (Fig. 5). A significant relationship was found only for 2+3K capelin at age-groups 0+1 ($P < 0.01$).

The relationship between inshore squid abundance and herring was examined for four herring stocks (White Bay-Notre Dame Bay, Bonavista Bay, Trinity Bay, and Conception Bay) using the index of inshore squid abundance and year-class strength (at age-group 2), assuming predation by squid on each herring year-class at age-group 0 (Fig. 6) and age-groups 0+1 (Fig. 7). No significant relationship was found.

Discussion

While it is known (Squires 1957, Ennis and Collins 1979) that squid consume various fish species during their annual migration to Newfoundland inshore waters, it remains to be demonstrated that the predation is of sufficient magnitude to generate observable stock effects. In order to assess very crudely the potential impact of squid on commercial finfish, the difference between the largest and smallest year-classes of the fish may be compared with population size and food consumption of squid in Subarea 3. For cod, capelin and herring, population numbers at age 1 were calculated by assuming that prior to the age of recruitment shown in Table 1 there was no fishing mortality and natural mortality was 0.2 (cod, herring) or 0.3 (capelin). The difference between the largest and the smallest year-classes at age-group 1 in the time series of Table 1 is as follows.

	Number	Weight (t)
cod (2J+3KL)	1.4×10^9	0.04×10^6
capelin (2+3K)	294.3×10^9	2.06×10^6
capelin (3L)	42.8×10^9	0.30×10^6
herring (4 stocks)	1.6×10^9	0.10×10^6

These numbers have been converted to biomass by assuming that the average weights of 1-group cod, capelin and herring in late summer are 30, 7 and 60 g respectively (unpublished data).

The population of squid in Subarea 3 in 1979, a year of very high abundance, was estimated with a modification of Pope's cohort analysis to decline from 9.6 to 6.1×10^9 individuals between June 1 and September 30 (Dawe and Beck MS 1980). This estimate was considered unreliable and possibly high (NAFO 1980), but it should serve to provide an order-of-magnitude indication of population numbers, since the associated biomass was within the probable range accepted by NAFO (1980). Food consumption by these squid between July 1 and September 30, the approximate period of most predation on fish (Ennis and Collins, 1979), may be crudely estimated as $\bar{N}\Delta W/K$, where $\bar{N}$ is the average number of squid, estimated from Dawe and Beck (MS 1980) to be 7.2×10^9, ΔW is the increase in weight of an individual squid, estimated from Dawe and Beck (MS 1980) to be 0.17 kg, and K is gross growth efficiency, assumed to be 0.3 (O'Dor et al., 1980). Under these assumptions total food consumption could be 4.1×10^6 t.

This estimate of total food consumption by squid is very large and exceeds the difference in biomass between the largest and smallest year-classes of cod, capelin and herring at age-group 1, indicating that squid has the potential to have a significant impact upon recruitment of these species. However, biomass of potential prey cannot be reliably estimated because it is not known for each prey species if the squid prey on larvae, 0-group, 1-group, or older fish. Several cohorts may be preyed upon simultaneously. Furthermore, it is clear that invertebrates and other *I. illecebrosus* are important components of the diet. Thus, annual predation by squid on a single cohort of a single species must be considerably less than the total consumption estimated above. A direct calculation of consumption of each individual prey species was not possible because there are as yet no quantitative studies of the stomach contents of squid in Newfoundland. All studies to date have reported prey in terms of incidence of occurrence, and most fish remains were not identified to species (Squires 1957, Mercer and Paulmier MS 1974, Ennis and Collins 1979).

Indeed, only capelin, redfish, cod, haddock and mailed sculpin have been specifically identified (Squires 1957). Herring has not yet been reported in squid stomachs at Newfoundland, although Amaratunga (MS 1980) stated that squid prey on inshore herring in Nova Scotia.

A further obstacle to assessing the potential impact of squid predation on finfish is the inadequate understanding of the opportunity for predation by squid on various age-groups of potential prey. Since the seasonal and diel variation in the horizontal and vertical distributions of squid and particularly its potential fish prey are not well described on a fine scale, the degree of temporal and spatial overlap of predator and prey is very uncertain. Ennis and Collins (1979) reported that in inshore waters from August to November the incidence of fish in squid stomachs declines and the incidence of squid (cannibalism) increases, indicating a deterioration in feeding conditions.

Although the food consumption by squid in a year of high squid abundance must be very large, the correlaton analyses failed to demonstrate a negative association between abundance of squid and year-class strength of potential fish prey, with the exception of 2+3K capelin (age-groups 0+1). All the analyses may have been confounded by temporal trends, but this problem may be particularly acute with the 2+3K capelin stock, where the time series available is very short (8 years). It is interesting that during the period from 1968 to 1974, when squid abundance was consistently low, neither the cod stock nor the herring stocks experienced consistently good recruitment. However, recruitment in the capelin stocks was generally good through this period.

An examination of predator-prey interactions by correlation analysis, such as has been attempted in this paper, contains many other sources of potential bias which could confound the results. The most obvious source is the use of year-class size at age-groups 2, 3 or 4 as indicators of abundance at age-groups 0 and 1. Ideally, squid abundance should be compared to mortality rates for age-groups 0 and 1, rather than to the number of recruits which are in fact the result of the preceeding mortality. This was impossible due to the lack of population estimates for the younger age-groups. Estimates of mortality are essential if an accurate evaluation of predation is to be made.

It was felt, however, that if predation by squid was the dominant factor in determining year-class size, then even this correlational approach using crude estimates of abundance should have given an indication of the impact.

The influence of squid predation may become more apparent if mortality from other sources such as the physical environment and other species interactions could also be taken into account.

Acknowledgements

We wish to thank D. Stansbury for running the computer analysis and H. Mullett for drafting the figures.

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Table 1. Inshore squid catch (t), index of inshore squid abundance, and year-class strength of potential prey species in eastern Newfoundland and Labrador, 1958-80.

Year	Squid Catch	Squid abundance	Cod[1] 2J3KL	Newfoundland East Coast Herring Stocks[2] White-Bay Notre Dame Bay	Bonavista Bay	Trinity Bay	Conception Bay	Capelin 3L[3]	2+3K[4]
1958	718	2	540	-	-	-	-	-	-
1959	2,853	3	579	-	-	-	-	-	-
1960	5,067	4	512	-	-	-	-	-	-
1961	8,971	5	687	-	-	-	-	-	-
1962	482	2	813	-	-	-	-	-	-
1963	2,119	3	926	4286	1832	792	623	-	-
1964	10,408	5	673	1740	146	62	18	17.8	-
1965	7,832	4	579	1117	480	321	128	2.2	-
1966	5,017	3	538	1984	463	115	164	1.0	-
1967	6,917	4	591	493	324	122	38	3.1	-
1968	13	1	480	4512	3958	2840	1573	8.1	-
1969	21	1	214	3632	1110	694	277	12.7	-
1970	111	1	133	1048	81	40	12	9.0	52.2
1971	1,607	2	154	260	24	4	8	8.2	53.0
1972	26	1	313	142	64	21	18	5.1	42.1
1973	600	2	502	57	7	1	2	24.5	224.4
1974	17	1	518	140	84	18	21	9.9	22.2
1975	3,751	4	418	124	39	<1	3	5.1	7.7
1976	11,257	4	-	36	256	3	9	5.0	6.4
1977	29,678	5	-	3	22	4	6	6.0	18.0
1978	34,941	4	-	-	-	-	-	-	-
1979	83,118	5	-	-	-	-	-	-	-
1980	32,466	4	-	-	-	-	-	-	-

[1] N x 10^{-6} at age-group 4 (Wells and Bishop MS 1980, table 10).

[2] N x 10^{-5} at age-group 2 (Wheeler and Winters MS 1980)

[3] N x 10^{-9} at age-group 3 (Carscadden et al. MS 1981, table 10)

[4] N x 10^{-9} at age-group 2 (Carscadden and Miller MS 1981, table 7)

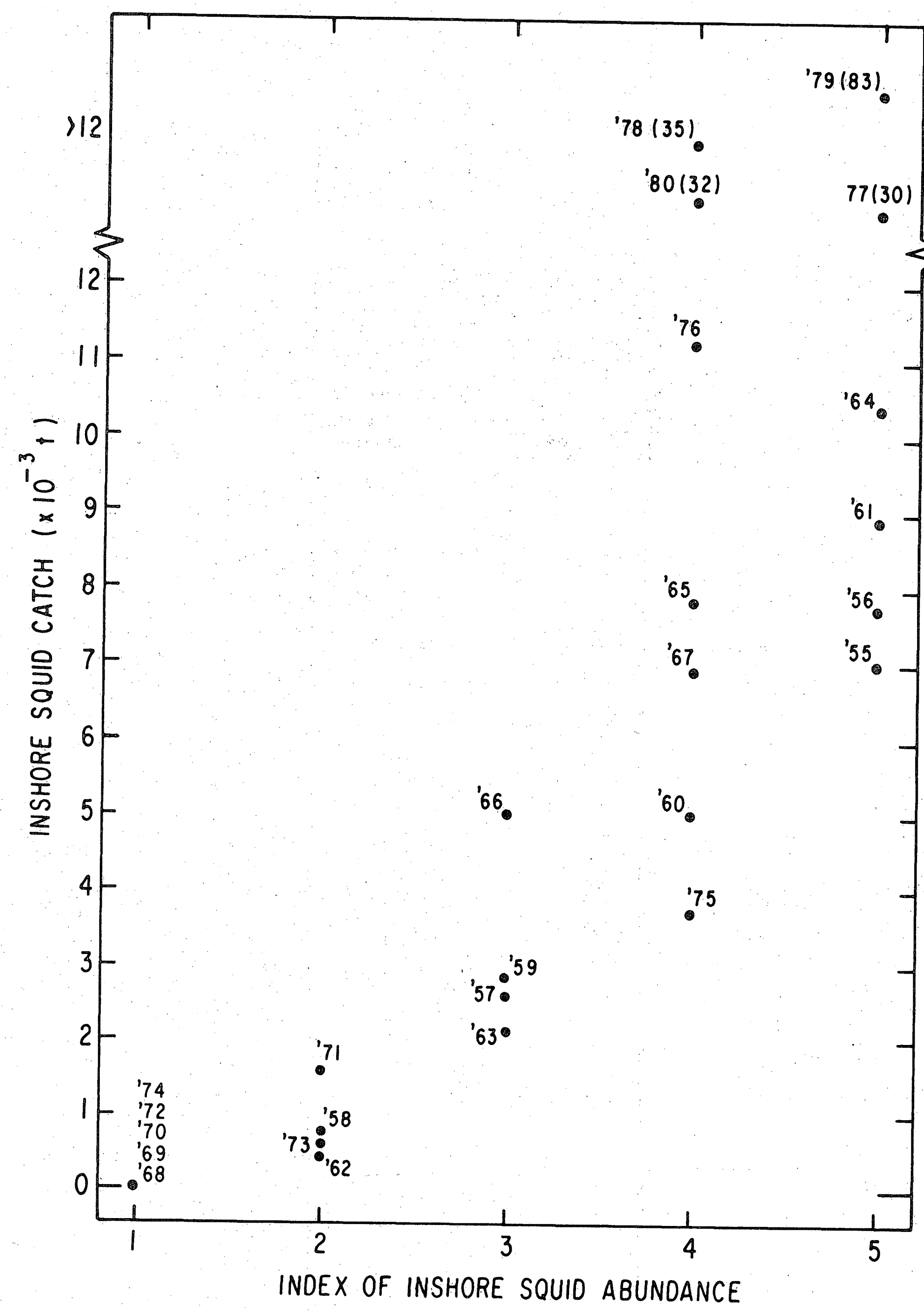

Fig. 1. Relationship between annual index of inshore squid abundance and inshore squid catch 1958-1980 (Catch for 1977-80 in brackets).

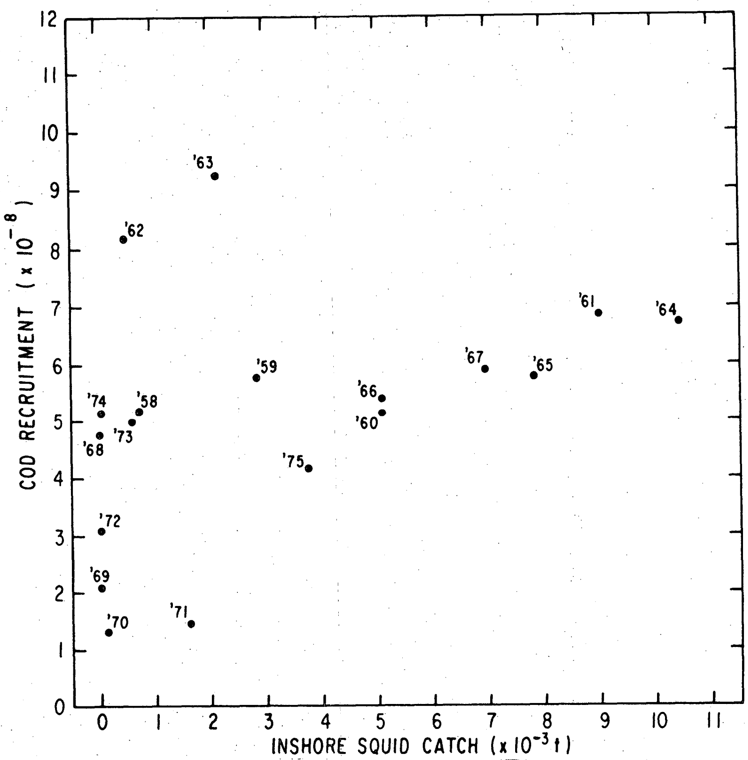

Fig. 2. Relationship between recruitment of 2J+3KL cod at age-group 4 and inshore squid catch during year cod were spawned ($r = 0.395$, $N = 18$, $P > 0.05$).

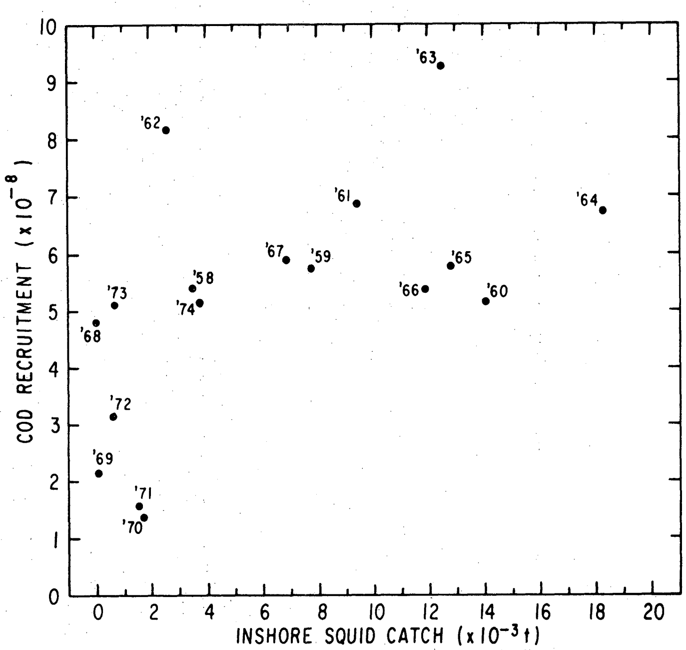

Fig. 3. Relationship between recruitment of 2J+3KL cod at age-group 4 and sum of inshore squid catches during year cod were spawned and subsequent year ($r = 0.562$, $N = 17$, $P > 0.05$ for one-tailed test when negative correlation expected).

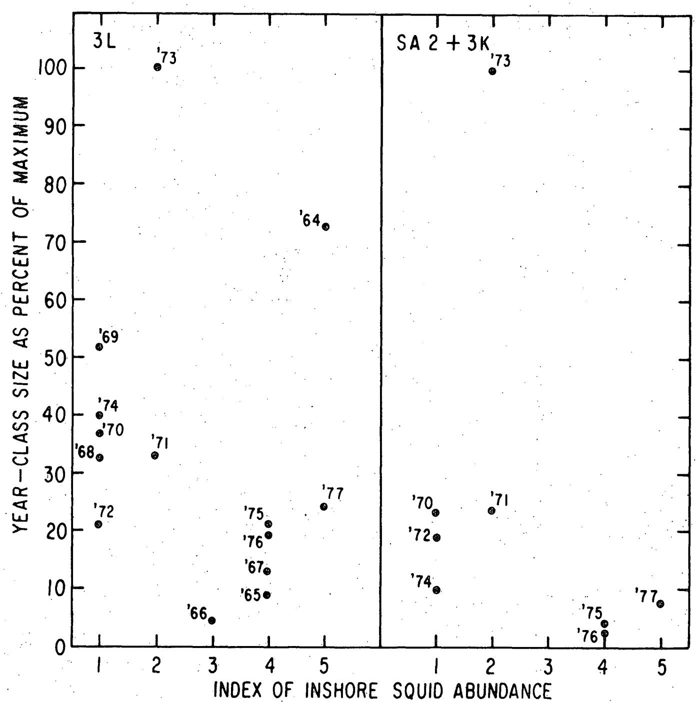

Fig. 4. Relationship between capelin recruitment (in 3L (age-group 3) and 2+3K (age-group 2)) and inshore squid abundance during year capelin were spawned (3L: τ = -0.184, N = 14, P > 0.05; 2+3K: τ = -0.276, N = 8, P > 0.05).

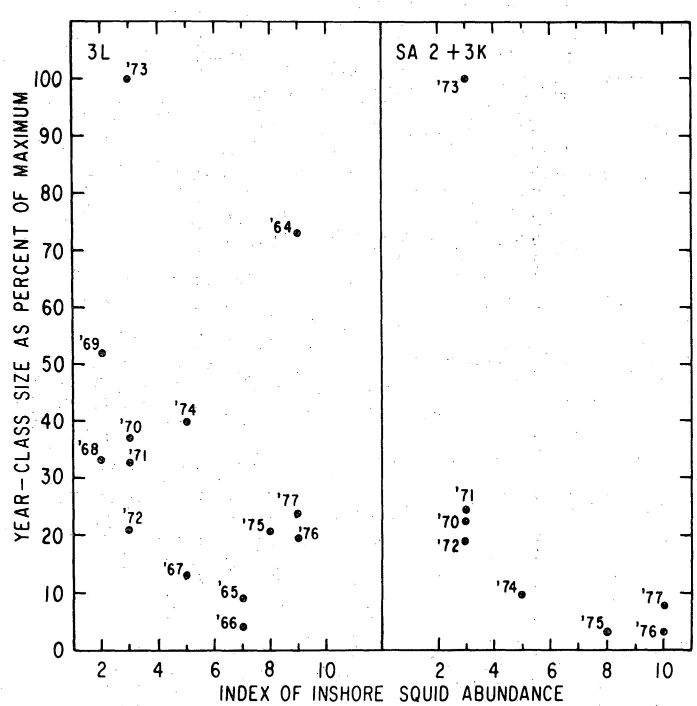

Fig. 5. Relationship between capelin recruitment (in 3L (age-group 3) and 2+3K (age-group 2)) and sum of inshore squid abundances during year capelin were spawned and subsequent year (3L: τ = -0.224, N = 14, P > 0.05; 2+3K: τ = -0.784, N = 8, P < 0.01).

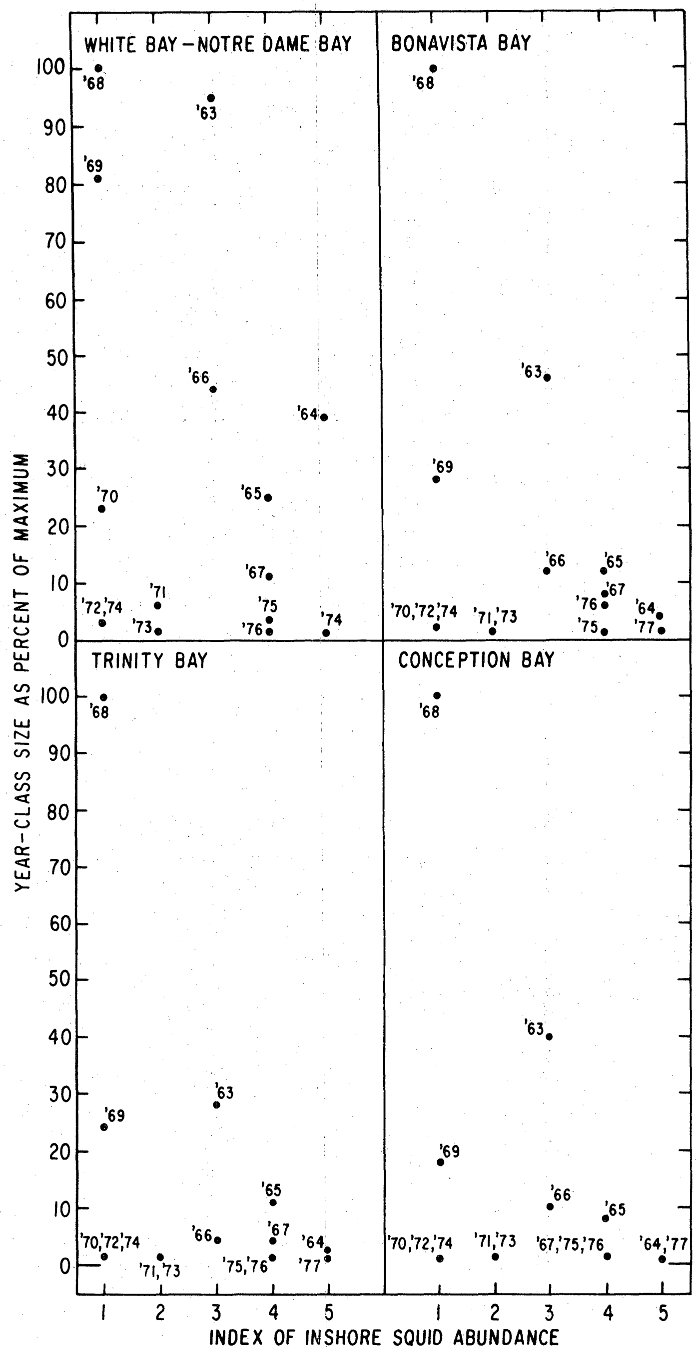

Fig. 6. Relationships between herring recruitment at age-group 2 in four east coast stocks and inshore squid abundance during year herring were spawned (White Bay-Notre Dame Bay: τ = -0.232, N = 15, P > 0.05; Bonavista Bay: τ = -0.147, N = 15, P > 0.05; Trinity Bay: τ = -0.170, N = 15, P > 0.05; Conception Bay: τ = -0.243, N = 15, P > 0.05).

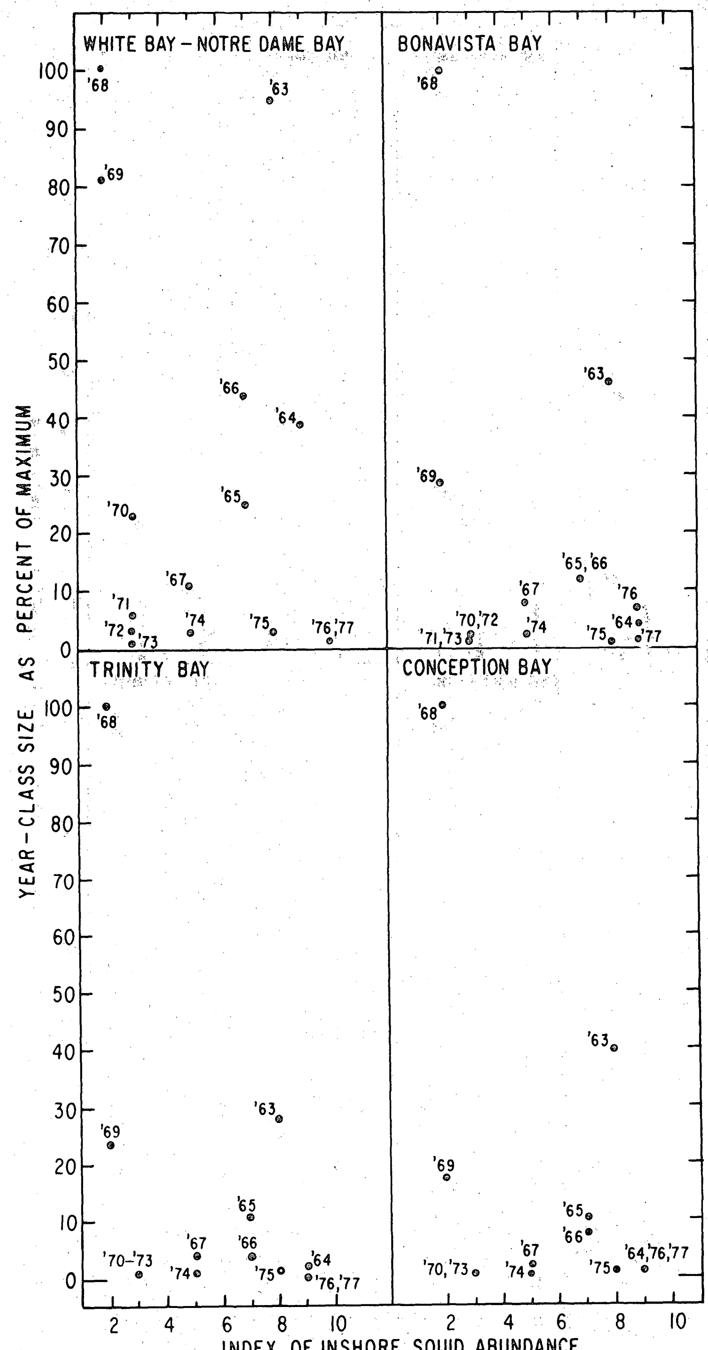

Fig. 7. Relationship between herring recruitment at age-group 2 in four east coast stocks and sum of inshore squid abundances during year herring were spawned and subsequent year (White Bay-Notre Dame Bay: $r = -0.244$, $N = 15$, $P > 0.05$; Bonavista Bay: $r = -0.041$, $N = 15$, $P > 0.05$; Trinity Bay: $r = -0.185$, $N = 15$, $P > 0.05$; Conception Bay: $r = -0.133$, $N = 15$, $P > 0.05$).