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Trends in Abundance of Short-finned Squid (*Illex illecebrosus*) and Environmental Conditions in the Northwest Atlantic

by

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ABSTRACT

Trends in abundance and distribution of short-finned squid (Illex illecebrosus) were examined in relation to environmental variation during 1970-96. Squid abundance was relatively stable in the southern-most fishery area, on the eastern USA Continental Shelf, and did not appear to be related to environmental variation. Highly variable abundance in northern fishery areas, the Nova Scotian Shelf and Newfoundland was correlated with latitudinal displacement of the Gulf Stream Front and the Shelf-Slope Front. Displacement of the Gulf Stream Front was correlated with area of ice coverage and bottom temperature in the Newfoundland Region. Adaptive mechanisms whereby the environment may affect squid distribution and abundance are discussed.

RÉSUMÉ

On a étudié les tendances d'abondance et de distribution de l'encornet nordique (*Illex illecebrosus*) en rapport avec la variation environnementale entre 1970 et 1996. On a constaté que l'abondance de l'encornet était relativement stable dans la zone de pêche la plus méridionale - le plateau continental de l'est des États-Unis - et qu'elle ne semblait pas liée à des variations environnementales. Une abondance extrêmement variable dans les zones de pêche du nord, la plate-forme néo-écossaise et Terre-Neuve, a été corrélée avec un déplacement latitudinal du front du Gulf Stream et du front du talus continental. Le déplacement du front du Gulf Stream a été corrélé avec la superficie de la couverture de glace et les températures de fond dans la région de Terre-Neuve. Il est aussi question de mécanismes d'adaptation par lesquels l'environnement peut influer sur l'abondance et la distribution de l'encornet nordique.

Introduction

The northern short-finned squid (Illex illecebrosus) is distributed from central Florida to Newfoundland and Labrador (Squires 1957, Dawe and Warren 1993). It supports summer-fall fisheries on the eastern USA Shelf, the Nova Scotia Shelf, and in Newfoundland coastal waters (Fig. 1).

This species spawns south of Cape Hatters as far south as central Florida, presumably in close proximity to the Gulf Stream (Trites 1983). Spawning occurs throughout most of the year, with several seasonal peaks, the major peak being in winter (Lange and Sissenwine 1983). Young stages are advected northeastward by the Gulf Stream (Trites 1983). Larvae, and probably egg masses, are transported within the fast-flowing landward portion of the Gulf Stream (Fig. 2), (Rowell and Trites 1985, Hatanaka et al. 1985) whereas small juveniles of about 1-3 cm mantle length (ML) are concentrated in the Gulf Stream Front (Fedulov and Froerman 1980, Dawe et al. 1982, Dawe and Beck 1985a, 1985b, Rowell and Trites 1985, Rowell et al. 1985, Hatanaka et al. 1985). Larger juveniles are concentrated at the Shelf-Slope Front in spring (Fig. 3). Squid catches from directed squid surveys in May-June on the southwest slope of the Grand Bank were generally associated with incursion of the Shelf-Slope Front and bottom temperatures of 5^{o}C or greater. Similarly, squid occurrence in Newfoundland coastal waters is associated with local water temperature, at less than 30 m depth, exceeding 5^{o}C (Beck et al. 1994).

It may be expected that yearclass strength would be greatly affected by environmental variation for an annual species which is so closely related to oceanographic features. This may be especially true at Newfoundland, the approximate northern limit of the species range of distribution (Dawe and Warren 1993, Mann and Drinkwater 1994, Coelho et al. 1994).

In this paper we review trends in squid catch and abundance for all three Northwest Atlantic fishery areas. We attempt to relate annual variation in catch by area to indices of broad-scale variation within the Gulf Stream System. We also examine the relationship of squid abundance at Newfoundland to local environmental conditions.

Methods

We use commercial catch by fishery area as an index of abundance of the single yearclass squid population. Before about 1970 commercial catch at Newfoundland was greatly affected by markets and fishing technology (Dawe 1981). However since 1970, when international trawl fisheries were established on the Scotian Shelf and the USA Shelf, catches approximately reflect squid abundance.

Indices of annual variation within the Gulf Stream System include latitudinal displacement of both the Gulf Stream Front and the Shelf-Slope Front. Mean annual values of North-South displacement (km) of these fronts from their mean position in the region between 50°W and 75°W were estimated from satellite imagery and presented by Drinkwater et al. (1994) for 1979-92 and updated to 1994 by Drinkwater et al. (1996). Unfortunately this time series could not be updated for 1995 and 1996 because of unavailability of processed imagery data.

Indices of environmental variation used for correlation with squid abundance at Newfoundland during 1970-96 (Fig. 4) include mean annual values for the North Atlantic Oscillation (NAO index, anomaly in mb), Newfoundland Shelf ice area (10^3 km^2), Station 27 bottom temperature (BT), and Station 27 vertically integrated (0-176 m) temperature (VT). We include these two ocean temperature indices because the short-finned squid is a diel migrator, being near bottom during daylight and dispersed in the water column at night. For all comparisons Spearman correlation coefficients were calculated (Table 1).

Results and Discussion

Trends in Squid Catch and Abundance

Annual variability in squid catch was lowest for the USA Shelf (Fig. 5), closest to the spawning area, where recruitment occurs from all seasonal spawning groups (Lange and Sissenwine 1983, Coelho et al. 1994). Variability is much greater in the Canadian fishery areas and synchronous between inshore Newfoundland and the Scotian Shelf, where fisheries are dependent on recruitment from the winter spawning peak (Coelho et al. 1994).

Effects of Variability in the Gulf Stream System

There was no apparent relationship between USA catch and position of either the Gulf Stream Front or the Shelf-Slope Front (Fig. 6, Table 1). However, for both the Scotian Shelf and Newfoundland, high squid abundance during 1979-82 was associated with southward displacement of these fronts whereas low abundance during 1983-94 was associated with northward displacement. Correlations were stronger with the Shelf-Slope Front than with the Gulf Stream Front (Table 1). Southward displacement of the Gulf Stream front is associated with an increase in the speed of the Stream (Drinkwater and Myers 1993). Northward displacement, then, is associated with a slow and extensively-meandering Gulf Stream. This effectively increases the length of the Gulf Stream Front and the speed of advection. Also, Warm Core Eddies (WCE's) are frequently formed by 'pinching-off' of Gulf Stream meanders (Trites 1983, Myers and Drinkwater 1989). Large quantities of larvae and juveniles are entrained in the periphery of WCE's (Dawe et al. 1982, Dawe and Beck 1985b). Thus, anticyclonic WCE's represent 'concentrated packages' of young squid, which may move to the southwest in Slope Water as far 'upstream' as Cape Hatteras before they dissipate or are resorbed by the Gulf Stream (Trites 1983). It appears generally that northward displacement of the Gulf Stream may negatively impact recruitment to Canadian fishery areas, perhaps through inefficient passive advection of young stages. Southward displacement of the Gulf Stream is directly related to zooplankton production in the NE Atlantic (Taylor and Stephens 1980, Taylor et al. 1992) and recruitment of eels (Anguilla sp.), which spawn in the Sargasso Sea and rely upon the Gulf Stream for advection of young stages (Castonguay et al. 1994).

Effects of Local Environmental Conditions at Newfoundland

Latitudinal displacements of both the Gulf Stream Front and Shelf-Slope Front were strongly correlated with annual area of ice coverage and Station 27 bottom temperature (Table 1). Similarly, squid catch at Newfoundland was most closely correlated with the same local environmental indices (Table 1, Fig. 7-8). High squid catch during 1975-82 was associated, as indicated by high bottom temperature and small ice area, with a locally warm period whereas extended low abundance during 1983-95 was associated with a generally cold period. Although squid abundance remained low during the relatively warm period of 1986-89 it increased in 1996 in association with local warming.

General Life History Strategy

These environmental relationships are supportive of a general life history strategy proposed for short-finned squid by Coelho et al. (1994). A relatively stable resource exists in the southern-most fishery area. Total population size or yearclass strength is affected predominantly by the winter spawning group, the progeny of which are advected to northern waters in synchrony with the spring productivity peak. This strategy is highly adaptive in that environmental conditions which promote strong yearclasses also favour population expansion through expedient advection of young stages and a suitable oceanographic regime in the northern-most area to assure sufficiently rapid growth and maturation to support the long spawning migration and so complete the life cycle.

We recognize that our analysis is based on a rather limited data set. However, we feel that relationships of population abundance and distribution with environmental variation, presented here, represent logical working hypotheses for future re-examination.

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Table 1. Spearman correlation coefficients and probability values for all squid abundance (catch) and environmental indices. Values in bold are significant at the conventional 0.05 probability level.

	USA Catch	NS Catch	Nfld. catch	GS Front	Sh.-Sl. Front	VIT	BT	NAO
NS catch	**0.58824**							
	0.0165							
Nfld. catch	**0.51765**	**0.84706**						
	0.0400	**0.0001**						
GS Front	0.07358	-0.21634	-0.39294					
	0.7865	0.4210	0.1322					
Sh.-Sl. Front	-0.35294	**-0.62059**	**-0.65588**	**0.54452**				
	0.1800	**0.0103**	**0.0058**	**0.0292**				
VIT	-0.12509	0.13245	0.01030	-0.29013	-0.18985			
	0.6444	0.6248	0.9698	0.2757	0.4813			
BT	0.04566	0.42268	0.45950	**-0.84230**	**-0.69367**	0.45247		
	0.8667	0.1029	0.0734	**0.0001**	**0.0029**	0.0784		
NAO	0.07353	0.20000	0.01471	0.17071	0.15588	0.00000	-0.27099	
	0.7867	0.4577	0.9569	0.5273	0.5643	1.0000	0.3100	
ICE	-0.09272	-0.40618	-0.41943	**0.80118**	**0.70787**	**-0.51105**	**-0.95652**	0.31199
	0.7327	0.1185	0.1058	**0.0002**	**0.0022**	**0.0431**	**0.0001**	0.2394

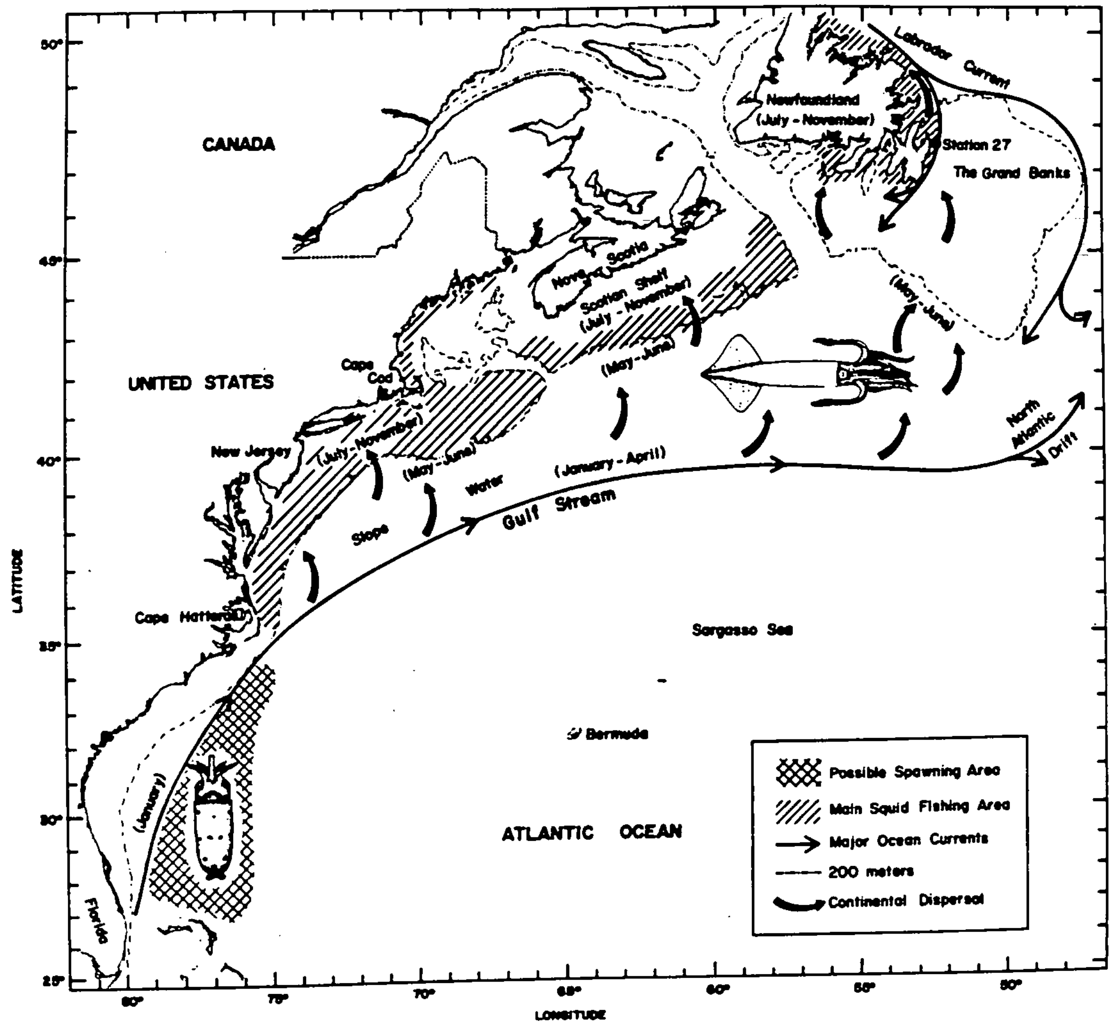


Fig. 1. Schematic representation of the life cycle of short-finned squid in relation to fishery areas and general oceanographic features.

DISTRIBUTION OF LARVAL/JUVENILE *ILLEX*

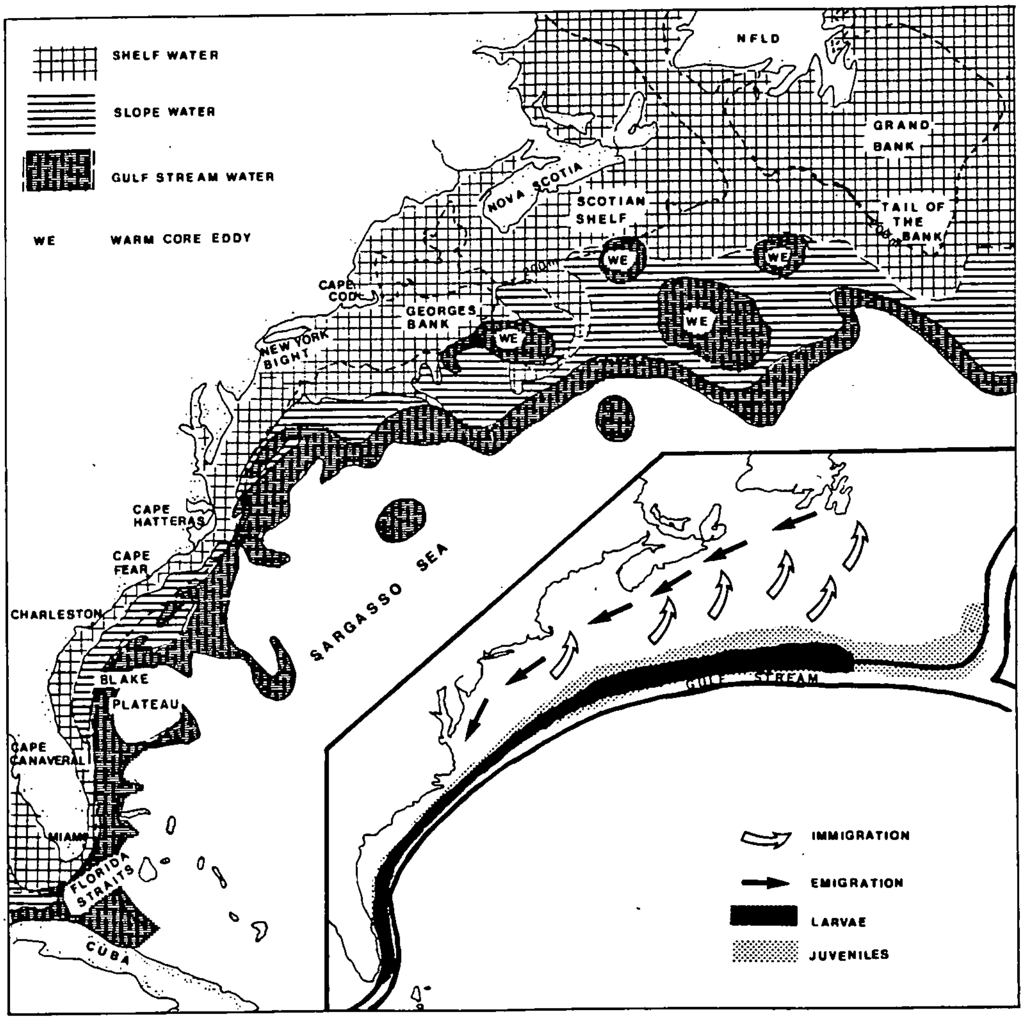


Fig. 2. Schematic representation of the early life history of short-finned squid in relation to dynamics of the Gulf Stream System (from Rowell and Trites 1985).

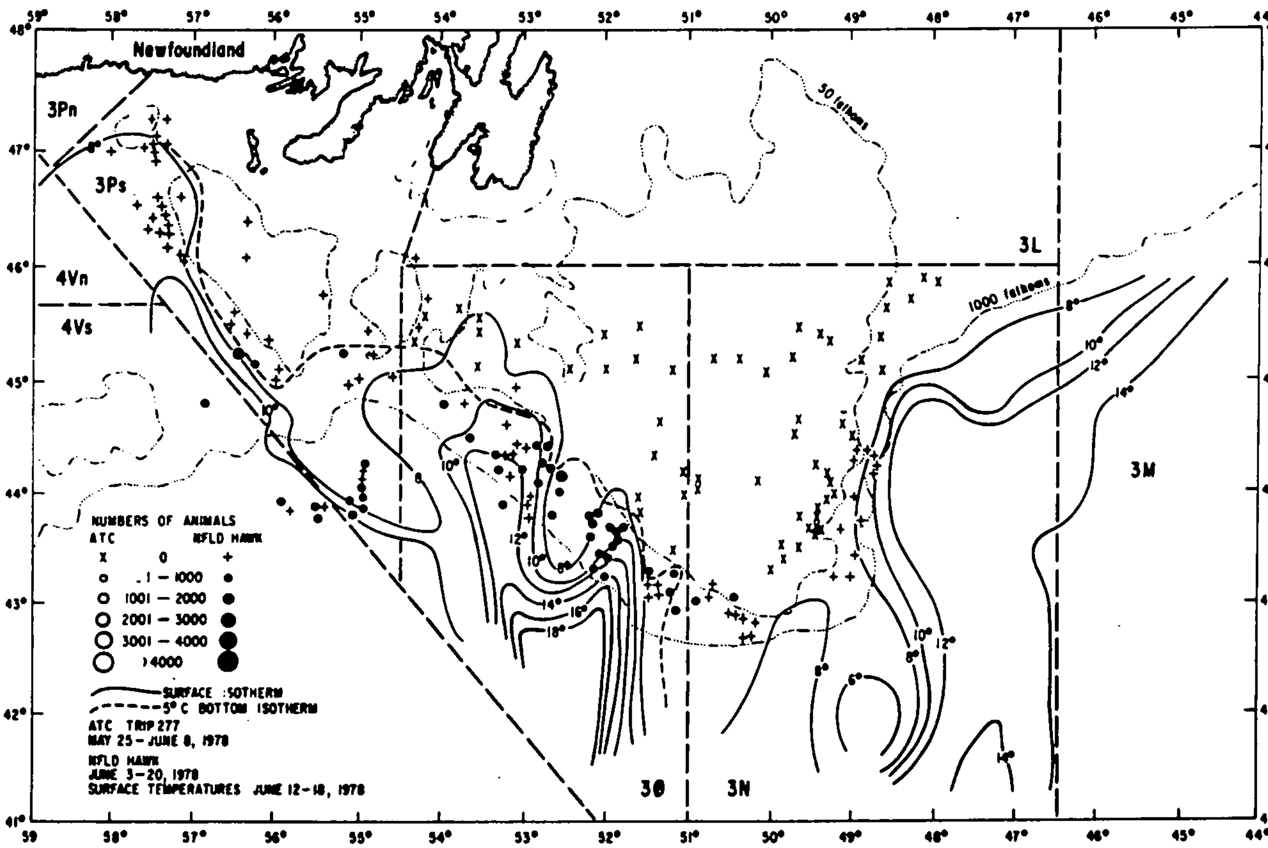


Fig. 3. Squid catches during a 1978 bottom trawl survey in relation to the surface Shelf-Slope Front (closely spaced isotherms) and the 5°C bottom isotherm.

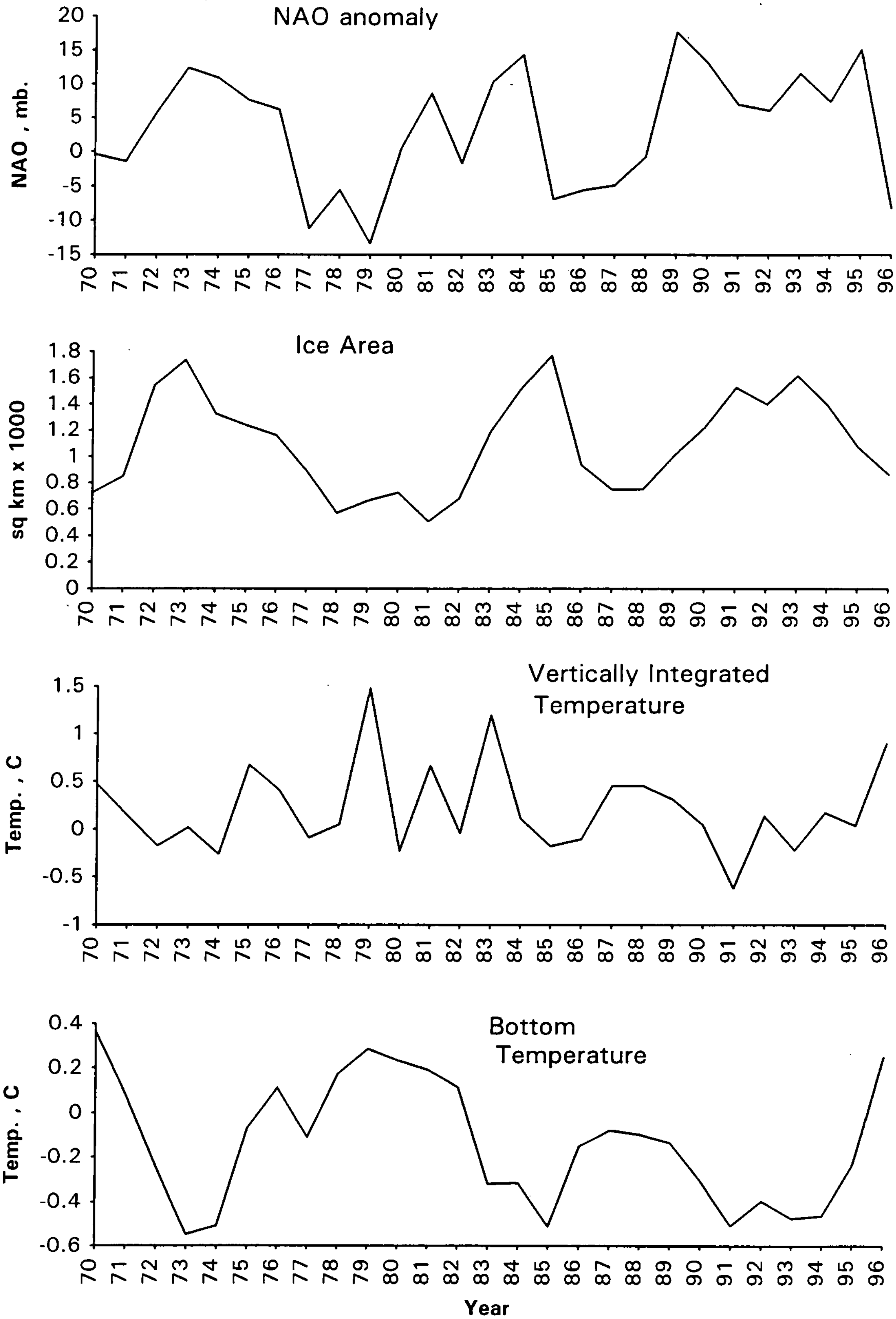


Fig. 4. Trends in local environmental indices in the Newfoundland Region.

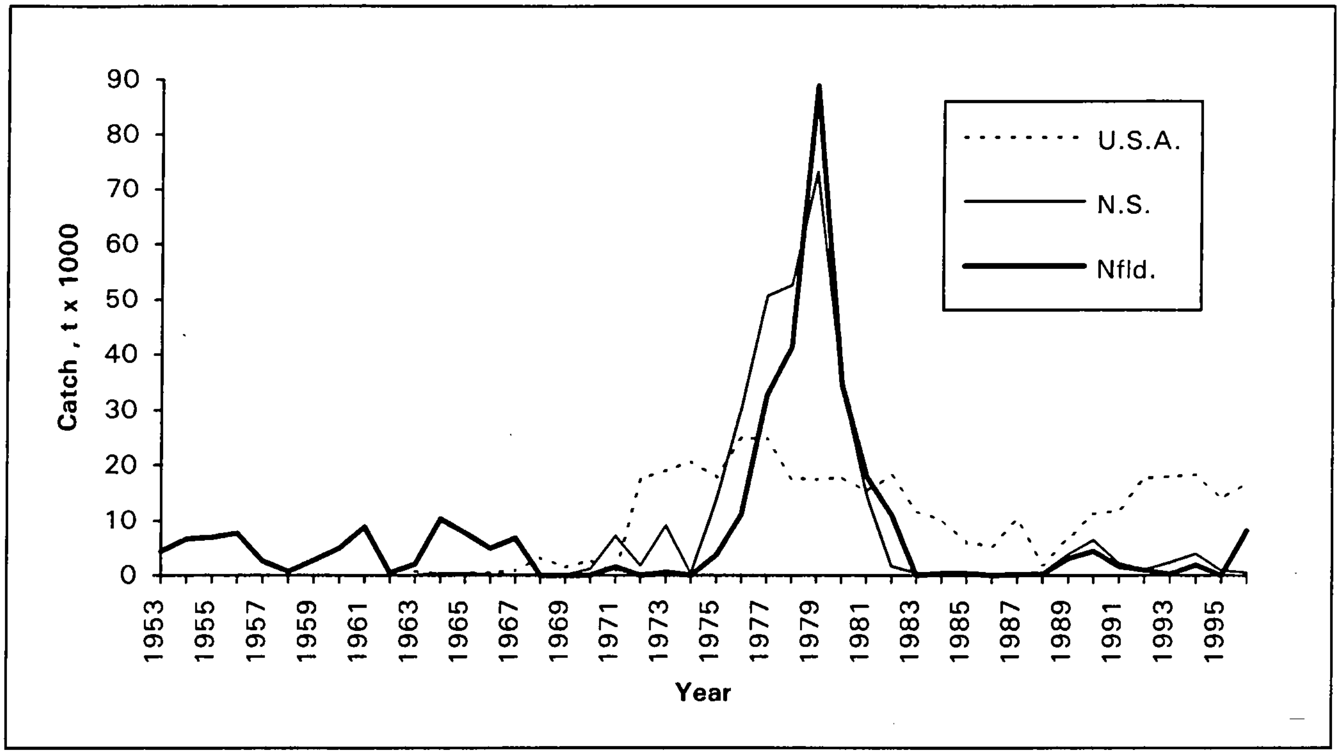
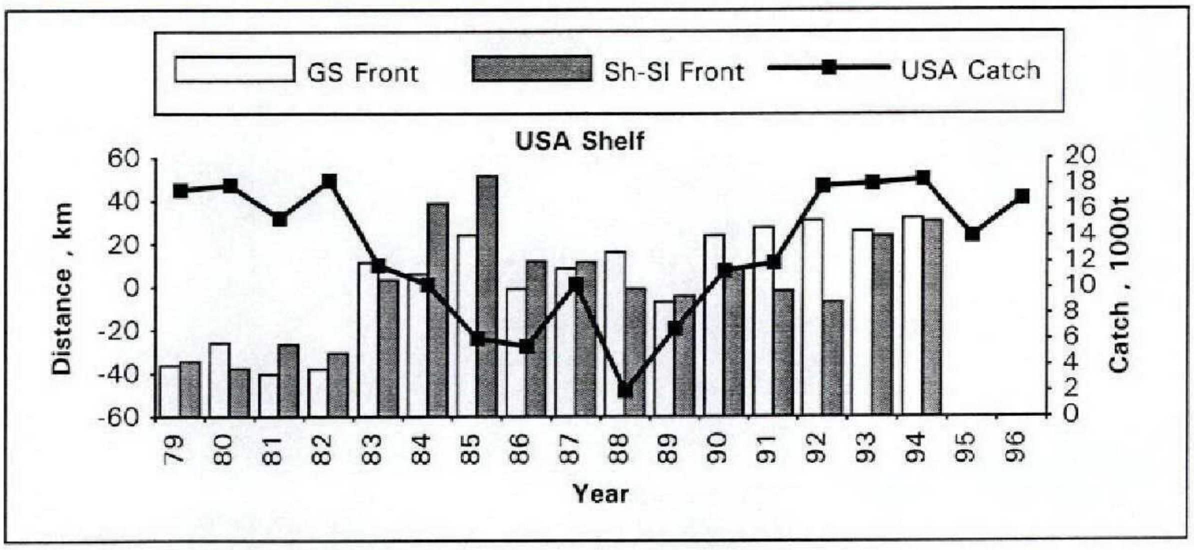
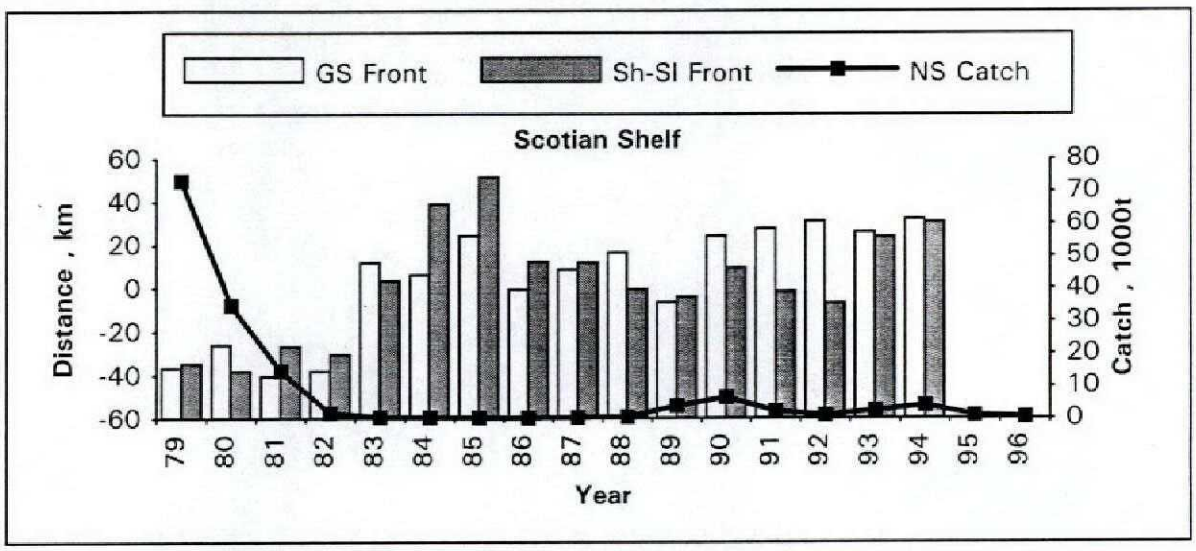


Fig. 5. Trends in annual catch of short-finned squid by fishery area.





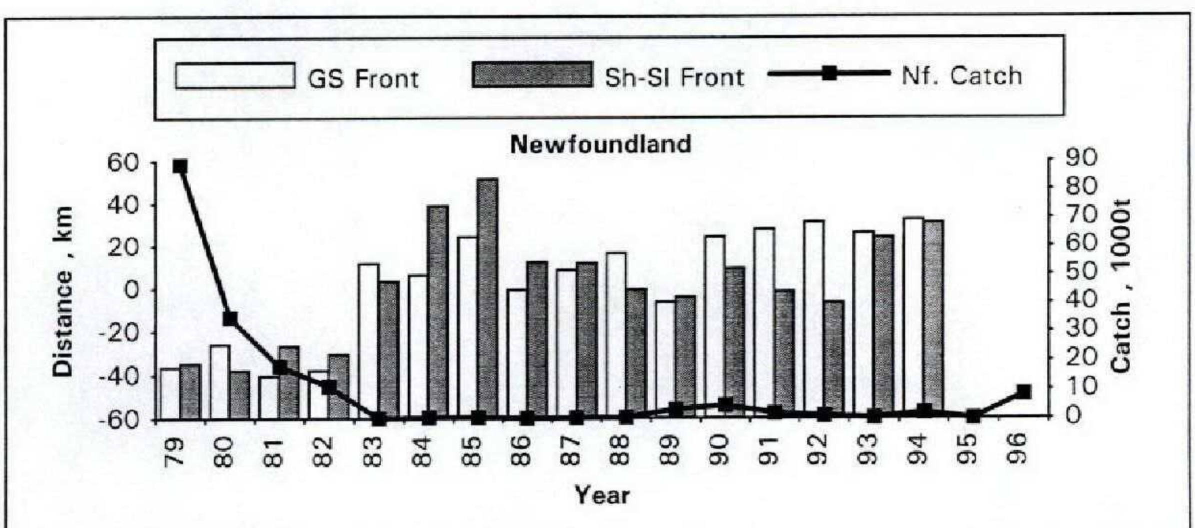
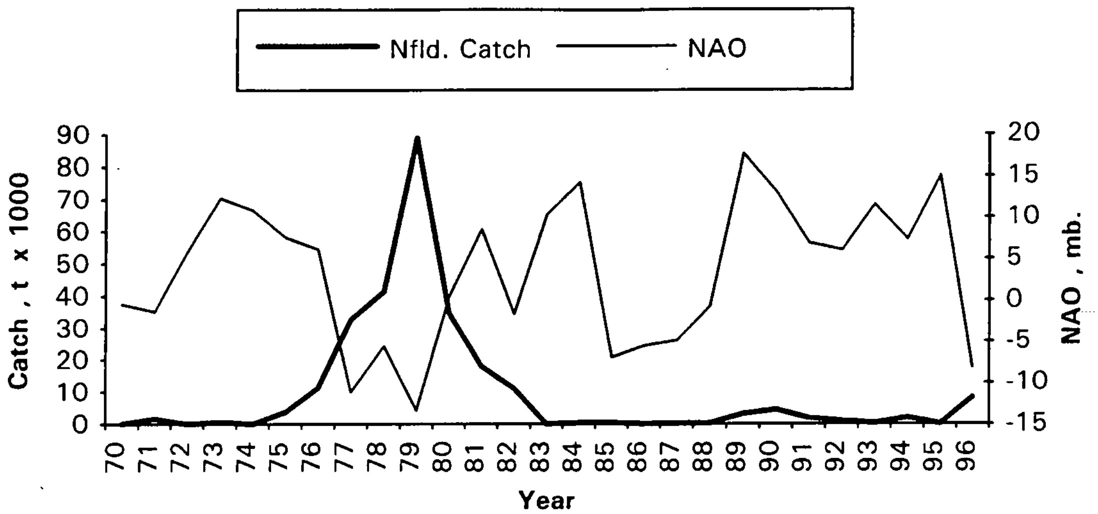


Fig. 6. Relationship between squid catch and position of the Gulf Stream Front and Shelf-Slope Front by fishery area.



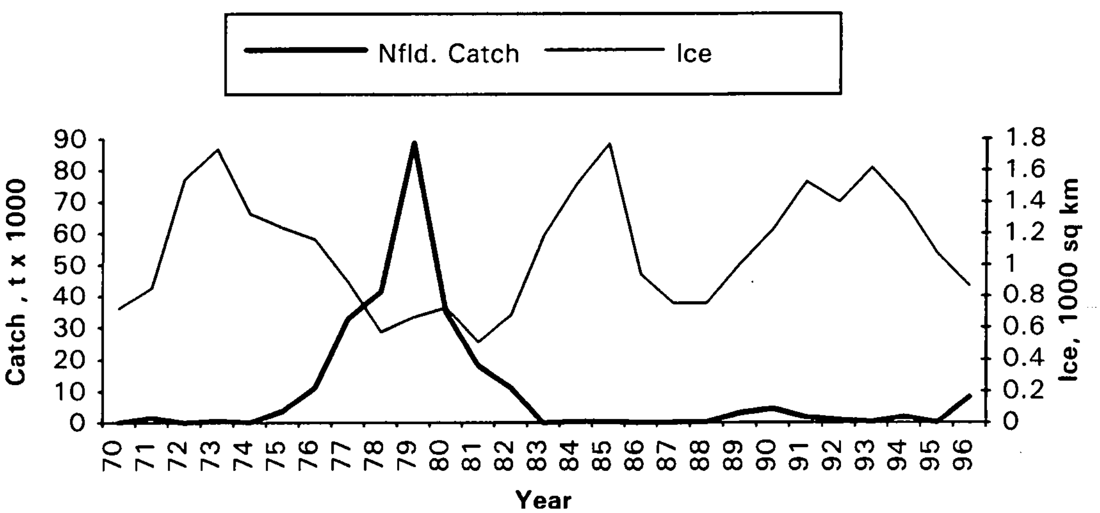


Fig. 7. Relationships of Newfoundland squid catch with North Atlantic Oscillation (NAO) anomaly (above) and mean annual area of ice coverage (below).

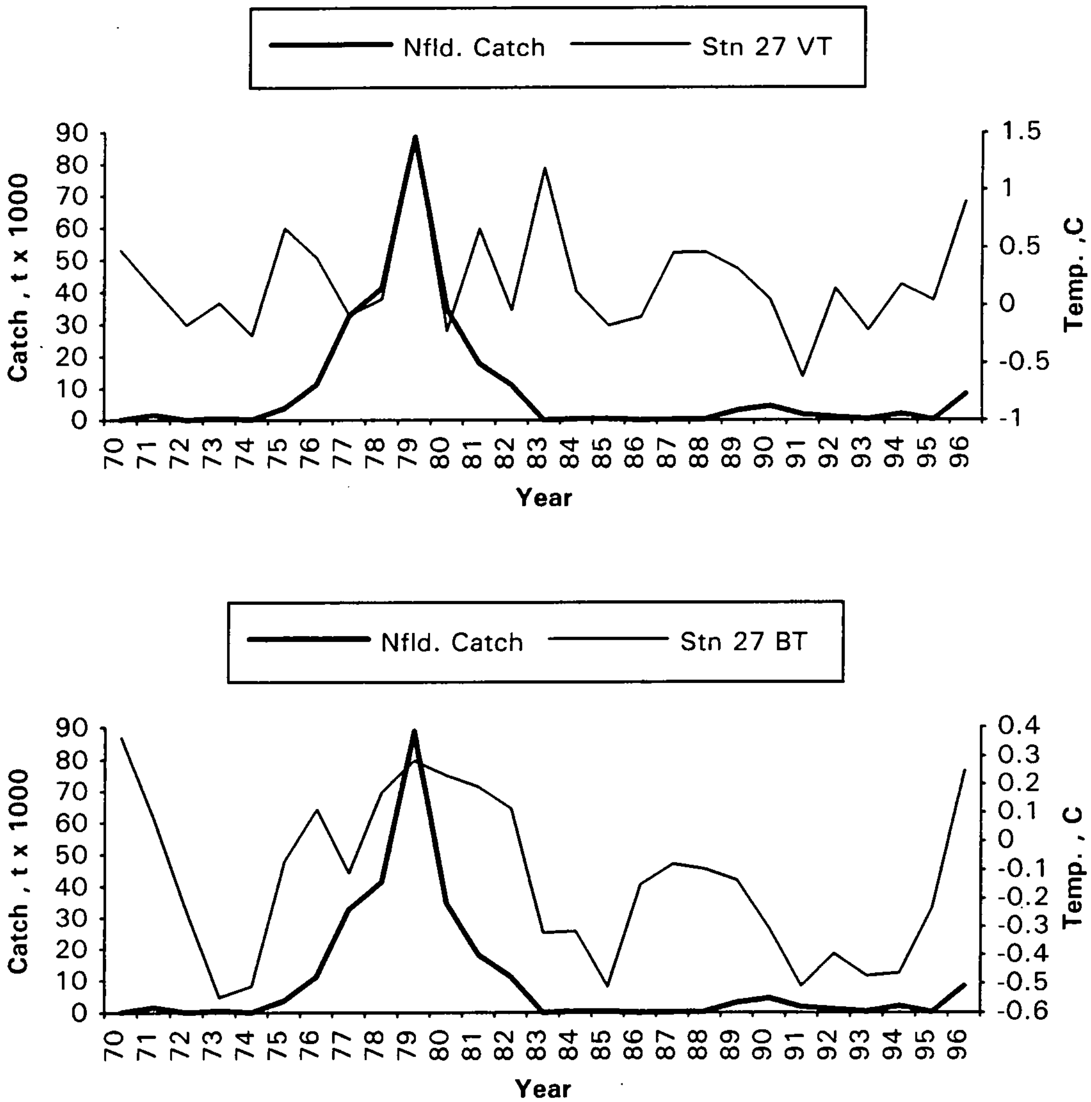


Fig. 8. Relationship of Newfoundland squid catch with vertically integrated temperature (above) and bottom temperature (below) at Station 27.