Northwest Atlantic Fisheries Organization

Serial No. N3045

NAFO SCR Doc. 98/54
Corrigendum

SCIENTIFIC COUNCIL MEETING - JUNE 1998

Environmental Effects on Short-finned Squid Recruitment to Canadian Fishing Areas

by

E. G. Dawe[1], E. B. Colbourne[1] and K. F. Drinkwater[2]

[1]Science Branch, Department of Fisheries and Oceans
P. O. Box 5667, St. John's NF A1C 5X1

[2]Bedford Institute of Oceanography
P. O. Box 1006, Dartmouth NS B2Y 4A2

FOLLOWING IS THE CORRECTED **TABLE 2** FOR SCR 98/54, SERIAL NO. N3045

Table 2. Correlations of catch indices with environmental indices. Each cell includes Spearman's correlation coefficient, probability value, and number of years. P. values in bold are significant at the 0.05 probability level.

Index	NAO	ICE	CIL	BT	VT	GSF	SSF
SA 3 catch index	-0.2943 **0.0115** 73	-0.3475 0.0647 29	-0.3427 **0.0148** 50	0.3919 **0.0059** 48	0.3216 **0.0258** 48	-0.4561 **0.0219** 25	-0.6506 **0.0004** 25
SA 4 catch index	-0.2257 **0.0469** 78	-0.3377 0.0732 29	-0.3819 **0.0062** 50	0.4067 **0.0041** 48	0.3007 **0.0378** 48	-0.2455 0.2378 25	-0.5965 **0.0016** 25

Northwest Atlantic Fisheries Organization

Serial No. N3045 NAFO SCR Doc. 98/54

SCIENTIFIC COUNCIL MEETING - JUNE 1998

Environmental Effects on Short-finned Squid Recruitment to Canadian Fishing Areas

by

E. G. Dawe[1], E. B. Colbourne[1] and K. F. Drinkwater[2]

[1]Science Branch, Department of Fisheries and Oceans
P. O. Box 5667, St. John's NF A1C 5X1

[2]Bedford Institute of Oceanography
P. O. Box 1006, Dartmouth NS B2Y 4A2

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.

This species spawns south of Cape Hatters 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. 1), (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. 2). 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°C or greater (Dawe and Warren 1993). Similarly, squid occurrence in Newfoundland coastal waters is associated with local water temperature, at less than 30 m depth, exceeding 5°C (Beck et al. 1994). Squid distribution on the Nova Scotian Shelf is associated with bottom temperatures greater than 6°C (Rowell et al. 1985).

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 in both Canadian Atlantic squid fishery areas, Nova Scotia (NAFO Subarea 4) and Newfoundland (NAFO Subarea 3). We attempt to relate annual variation in catch by fishing 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 indices.

Methods

We use commercial catch by fishery area as an index of abundance of the single yearclass squid population. Estimates of yearly catch date back to 1920 for Subarea 4 and to 1911 for Subarea 3 (Mercer 1973, Dawe 1981).

However, catches have been greatly affected by market-related changes in fishing effort (Fig. 3). We approximately adjusted for periodic changes in fishing effort by expressing catch as a proportion of the maximum within each of three relatively distinct time periods, 1925-52, 1953-69, and 1970-97 (Fig. 4). Market conditions were relatively constant and catch fluctuations similar within each time period at Newfoundland (Fig. 3). The earliest period was extended back to 1920 for Subarea 4. A subjective ranking of Newfoundland inshore abundance generally agrees with trends in catch. The catch indices were significantly positively correlated between Subareas 3 and 4 ($r_s = 0.6914$, $p = 0.0001$) and each was negatively serially correlated ($p = 0.001$-0.002).

Indices of environmental variation used for correlation with squid abundance indices (Table 1) included the North Atlantic Oscillation (NAO) and the Newfoundland Shelf ice area (ICE). Other indices included Station 27 bottom temperature (BT), and Station 27 vertically integrated 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. Another continental shelf index used was thickness of the Cold Intermediate Layer (CIL). Oceanic indices which reflect variability within the Gulf Stream System were latitudinal displacement of the Gulf Stream Front (GSF) and the Shelf Water-Slope Water Front (SSF). For all comparisons Spearman correlation coefficients were calculated.

Results and Discussion

Synchrony between inshore Newfoundland and Nova Scotian catch indices reflects squid fisheries dependent on recruitment from the winter peak spawning in both areas (Coelho et al. 1994). In both fishery areas the occurrence and duration of periods of low abundance increased throughout the time series.

The environmental indices were significantly correlated, with few exceptions (Table 1). The BT, VT, CIL and SSF were also all significantly serially correlated, whereas NAO, ICE and GSF were not. The strong correlations between the North Atlantic Oscillation and the continental shelf indices (ICE, CIL, BT, and VT) reflect the effects of strong northwesterly winds associated with high NAO anomalies. These winter-spring strong northwesterlies bring cold Arctic air into the Newfoundland area which promotes ice coverage and reduces melting (Colbourne et al. 1994). These winds also promote downward mixing of cold water (Mann and Drinkwater). A high NAO and strong cyclonic circulation is also related to a northward displacement of the Gulf Stream Front. Taylor et al. (1992) noted that shifts in the Front are related to changing weather patterns over the North Atlantic. However, the mechanism is unclear because anomaly winds oppose the displacements. Taylor (1996) noted that northward displacement is associated with reduced cyclone frequency and that meandering may not be simply related to any single atmospheric variable.

The squid abundance index for both Subareas was significantly correlated with most of the environmental indices. The strong correlations with the NAO (Fig. 5), the Gulf Stream Front, and the Shelf-Slope Front (Fig. 6), particularly for Subarea 3 (Table 2) suggest that winter-spring conditions during the early oceanic phase of the life cycle are important in regulating recruitment.

High squid abundance was related to a weak NAO and southward displacement of both oceanic fronts, but correlations were stronger with the Shelf-Slope Front than with the Gulf Stream Front (Table 1, Fig. 6). 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).

Latitudinal displacements of both the Gulf Stream Front and Shelf-Slope Front were strongly correlated with annual area of ice coverage and both Station 27 temperature indices (Table 1). Similarly, squid catch at Newfoundland was most closely correlated with the same local oceanographic indices (Table 1). High squid catch was associated with a warm oceanographic regime on the continental shelf (Fig. 5 and 7-8). Relationships of squid abundance with continental shelf temperature indices did not appear to be linear (Fig. 7-8), as is frequently the case in interactions between physical and biological parameters (Mann and Drinkwater 1994). Squid abundance may be variable when the temperature indices are high, but cold conditions, particularly for extended periods, are related to low squid abundance (Figs. 5 and 7-8).

Relationships described here for northern fishery areas probably reflect effects on the entire single stock population, since abundance trends are significantly positively correlated among all three fishery areas (Dawe and Hendrickson, this meeting).

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 in USA waters. 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. This assures sufficiently rapid growth and maturation to support the long spawning migration and so complete the life cycle.

References

Beck, P. C., E. G. Dawe, and J. Drew. 1994. An update of the fishery for short-finned squid (Illex illecebrosus) in the Newfoundland area during 1989-93 with description of some biological characteristics and temperature trends. NAFO SCR Doc. 94/37, N2405, 14 p.

Castonguay, M., P. V. Hodson, C. Moriarty, K. F. Drinkwater, and B. M. Jessop. 1994. Is there a role of ocean environment in American and European eel decline? Fish. Oceanogr. 3(3): 197-203.

Coelho, M. L., K. A. Stobberup, R. K. O'Dor, and E. G. Dawe. 1994. Life history strategies of the squid, Illex illecebrosus, in the Northwest Atlantic. Aquat. Living Resour. 7: 233-246.

Colbourne, E., S. Narayanan, and S. Prinsenberg. 1994. Climatic changes and environmental conditions in the Northwest Atlantic, 1970-93. ICES Mar. Sci. Symp. 198: 311-322.

Dawe, E. G. 1981. Development of the Newfoundland squid (Illex illecebrosus) fishery and management of the resource. J. Shellfish Res. 1: 137-142.

Dawe, E. G., and P. C. Beck. 1985a. Distribution and size of short-finned squid (Illex illecebrosus) larvae in the Northwest Atlantic from winter surveys in 1969, 1981, and 1982. J. Northw. Atl. Fish. Sci. 6: 43-55.

1985b. Distribution of size of juvenile short-finned squid Illex illecebrosus) (Mollusca-Cephalopoda) south of Newfoundland during winter. Vie et Milieu 35: 139-147.

Dawe, E. G., and L. Hendrickson. 1998. A review of the biology, population dynamics, and exploitation of short-finned squid in the Northwest Atlantic Ocean, in relation to assessment and management of the resource. NAFO Sci. Counc. Studies (this meeting)

Dawe, E. G., and W. G. Warren. 1992. Recruitment of short-finned squid in the Northwest Atlantic Ocean and some environmental relationships. J. Cephal. Biol. 2: 1-21.

Dawe, E. G., Yu. M. Froerman, N. Shevchenko, V. V. Khalyukov, V. A. Bolotov. 1982. Distribution and size composition of juvenile short-finned squid (Illex illecebrosus) in the Northwest Atlantic in relation to mechanisms of transport, February 4-April 30, 1982. NAFO SCR Doc. 82/VI/25, Ser. No. N513, 41 p.

Drinkwater, K. F., E. Colbourne, and D. Gilbert. 1996. Overview of environmental conditions in the Northwest Atlantic in 1994. NAFO Sci. Coun. Studies 25: 25-28.

Drinkwater, K. F., and R. A. Myers. 1993. Investigations of the mean, seasonal and interannual variability in the position of the north wall of the Gulf Stream between 45°W and 75°W. NAFO SCR Doc. 93/49, 6 pp.

Drinkwater, K. F., R. A. Myers, R. G. Pettipas, and T. L. Wright. 1994. Climatic data for the Northwest Atlantic: The position of the shelf/slope front and the northern boundary of the Gulf Stream between 50°W and 75°W, 1973-1992. Can. Data Rep. Hydrogr. Ocean Sci. 125: iv + 103 p.

Fedulov, P. P., and Yu. M. Froerman. 1980. Effect of abiotic factors on distribution of young shortfin squids, Illex illecebrosus (LeSueur, 1821). NAFO SCR Doc. 80/VI/98, Ser. No. N153, 22 p.

Hatanaka, H., A.M.T. Lange, and T. Amaratunga. 1985. Geographical and vertical distribution of larval short-finned squid (Illex illecebrosus) in the Northwest Atlantic. NAFO Sci. Coun. Studies 9: 93-99.

Lange, A.M.T., and M. P. Sissenwine. 1983. Squid resources of the Northwest Atlantic. p. 21-54. In: J. F. Caddy [ed.] Advances in assessment of world cephalopod resources. FAO Fish. Tech. Pap. 31: ix + 452 P.

Mann, K. H., and K. F. Drinkwater. 1994. Environmental influences on fish and shellfish production in the Northwest Atlantic. Environ. Rev. 2: 16-32.

Mercer, M. C. 1973. Nominal catch of squid in Canadian Atlantic waters (Subareas 2-4 1920-68). ICNAF Res. Doc. 73/73, 10 p.

Myers, R. A., and K. Drinkwater. 1989. The influence of Gulf Stream warm core rings on recruitment of fish in the Northwest Atlantic. J. Mar. Res. 47: 635-656.

Rowell, T. W., and R. W. Trites. 1985. Distribution of larval and juvenile Illex (Mollusca: Cephalopoda) in the Blake Plateau region (Northwest Atlantic). Vie et Milieu 35(3/4): 149-161.

Rowell, T. W., R. W. Trites, and E. G. Dawe. 1985. Larval and juvenile distribution of short-finned squid (Illex illecebrosus) in relation to the Gulf Stream frontal zone in the Blake Plateau and Cape Hatteras area. NAFO Sci. Coun. Studies 9: 77-92.

Squires, H. J. 1957. Squid, Illex illecebrosus (LeSueur), in the Newfoundland fishing area. J. Fish. Res. Board Can. 14: 693-728.

Taylor, A. H. 1995. North-south shifts of the Gulf Stream and their climatic connection with the abundance of zooplankton in the UK and its surrounding seas. ICES J. Mar. Sci. 52: 711-721.

Taylor, A. H. 1996. North-south shifts of the Gulf Stream: Ocean-atmospheric interactions in the North Atlantic. Inter. J. Clim. 16: 559-583.

Taylor, A. H., J. M. Colebrook, J. A. Stephens, N. G. Baker. 1992. Latitudinal displacements of the Gulf Stream and the abundance of plankton in the NE Atlantic. J. Mar. Biol. Ass. U.K. 72: 919-921.

Taylor, A. H., and J. A. Stephens. 1980. Latitudinal displacements of the Gulf Stream (1966 to 1977) and their relation to changes in temperature and zooplankton abundance in the NE Atlantic. Ocean. Acta 3: 145-149.

Trites, W. R. 1983. Physical oceanographic features and processes relevant to Illex illecebrosus spawning in the western North Atlantic and subsequent larval distribution. NAFO Sci. Coun. Studies 6: 39-55.

Table 1. Correlation matrix for environmental indices, including Spearman's r_s, probability value and number of years. P values in bold are significant at the 0.05 probability level.

Index	NAO	ICE	CIL	BT	VT	GSF
ICE	0.5238 **0.0035** 29					
CIL	0.3930 **0.0048** 50	0.5397 **0.0025** 29				
BT	-0.5118 **0.0002** 48	-0.8813 **0.0001** 29	-0.4326 **0.0021** 48			
VT	-0.4299 **0.0023** 48	-0.7813 **0.0001** 29	-0.3067 **0.0340** 48	0.7990 **0.0001** 48		
GSF	0.5374 **0.0015** 32	0.7006 **0.0001** 29	0.2355 0.1943 32	-0.60591 **0.0002** 32	-0.5371 **0.0015** 32	
SSF	0.1870 0.3707 25	0.6419 **0.0005** 25	0.3055 0.1374 25	-0.5812 **0.0023** 25	-0.4655 **0.0190** 25	0.5883 **0.0020** 25

NAO - North Atlantic Oscillation annual anomaly (1920-97)
ICE - Newfoundland shelf ice area; km^2 x 10^3 (1969-97)
CIL - Thickness of the Cold Intermediate Layer, m (1948-97)
BT - Station 27 annual mean Bottom Temperature, °C (1950-97)
VT - Station 27 annual mean Vertically Integrated Temperature, 0-176 m (1950-97)
GSF - Latitudinal displacement of the Gulf Stream Front (55°W-75°W), annual anomaly (1973-97)
SSF - Latitudinal displacement of the Shelf Water-Slope Water Front (55°W-75°W), annual anomaly (1973-97)

Table 2. Correlations of catch indices with environmental indices. Each cell includes Spearman's correlation coefficient, probability value, and number of years. P values in bold are significant at the 0.05 probability level.

Index	NAO	ICE	CIL	BT	VT	GSF	SSF
SA 3 catch index	0.2943 **0.0115** 73	0.3475 0.0647 29	0.3427 **0.0148** 50	0.3919 **0.0059** 48	0.3216 **0.0258** 48	0.4561 **0.0219** 25	0.6506 **0.0004** 25
SA 4 catch index	0.2257 **0.0469** 78	0.3377 0.0732 29	0.3819 **0.0062** 50	0.4067 **0.0041** 48	0.3007 **0.0378** 48	0.2455 0.2378 25	0.5965 **0.0016** 25

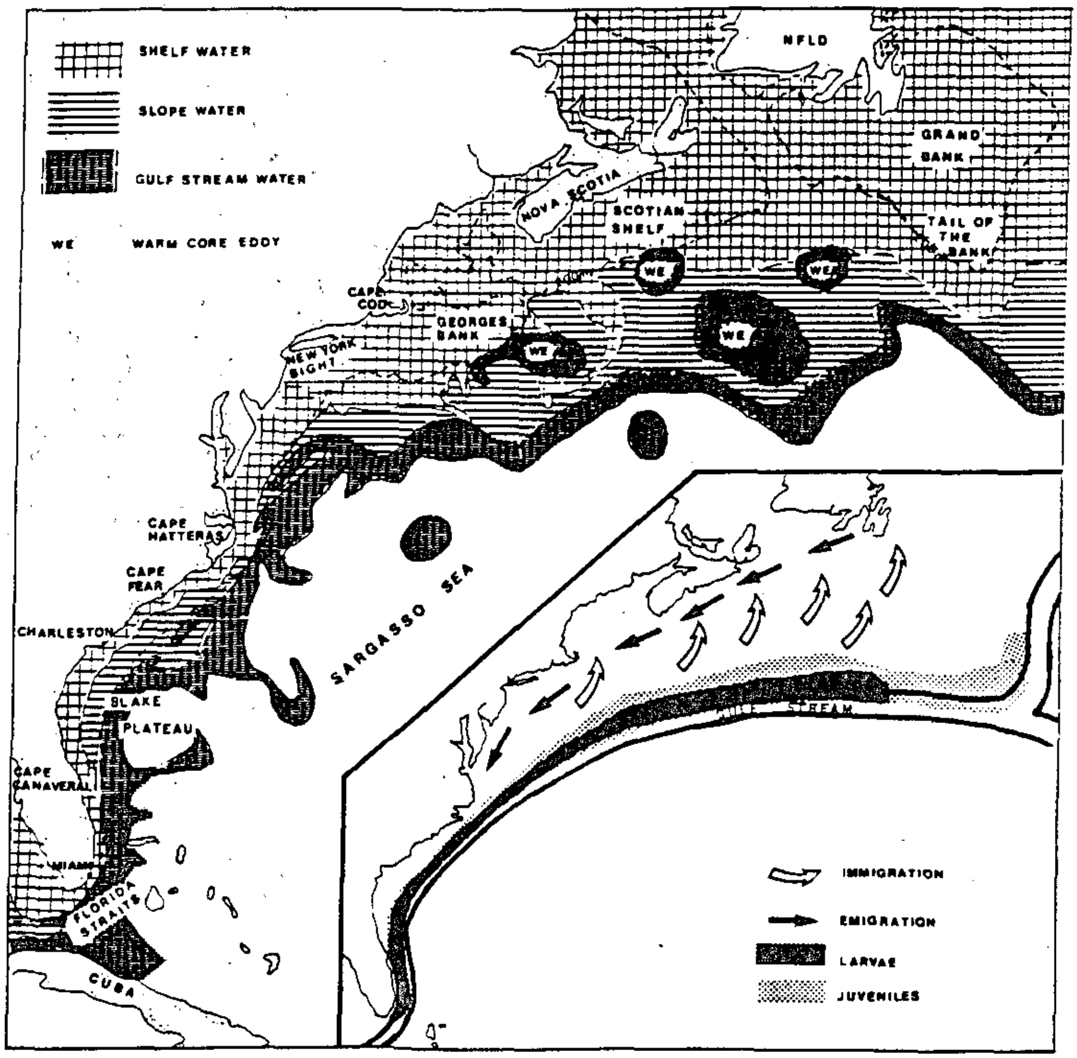

Fig. 1. Schematic representation of the life history of short-finned squid in relation to dynamics of the Gulf Stream System (from Rowell and Trites 1985).

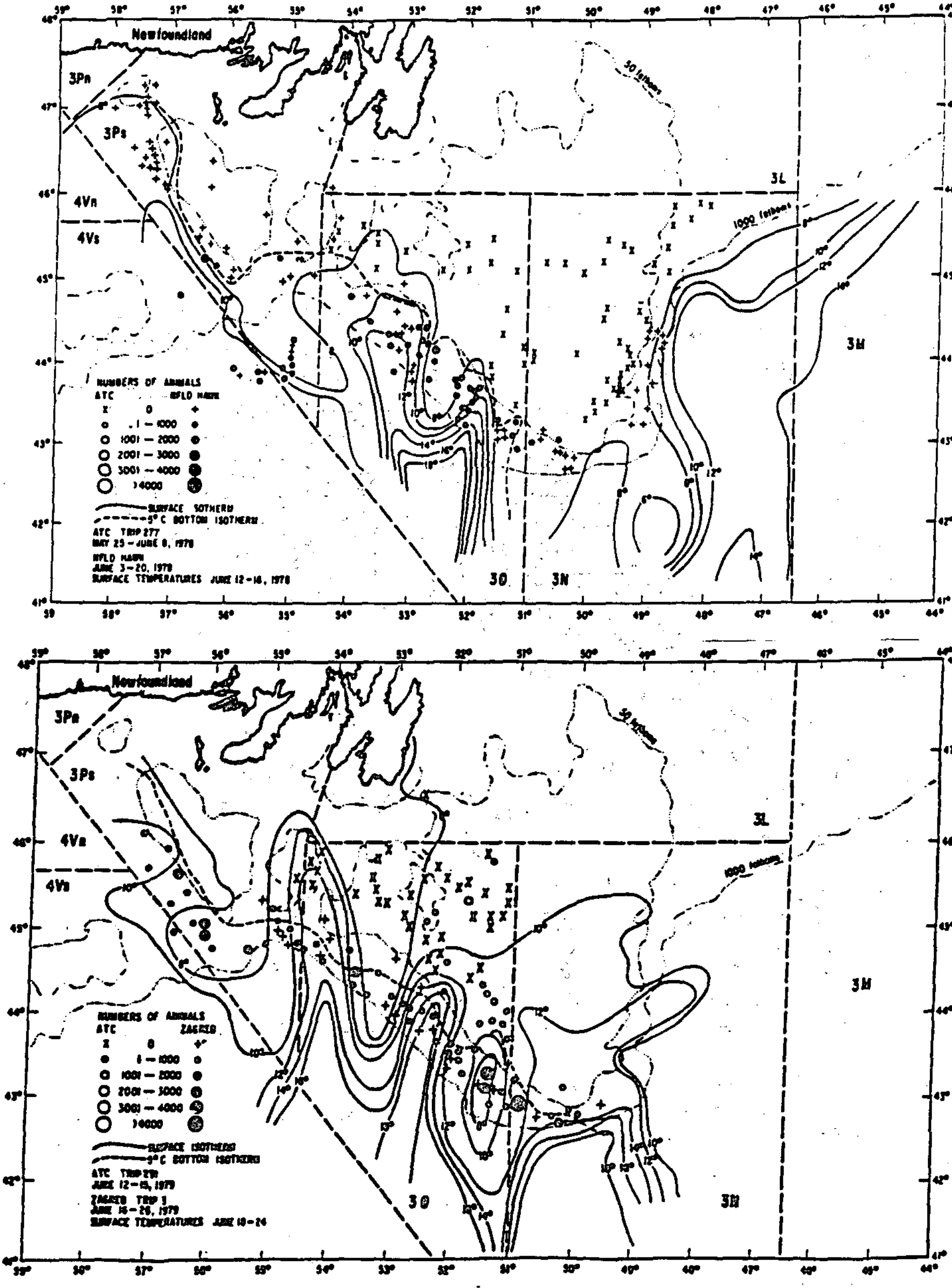

Fig. 2. Squid catches during 1978 and 1979 spring bottom trawl surveys in relation to the surface Shelf-Slope Front (closely spaced isotherms) and the 5°C bottom isotherm.

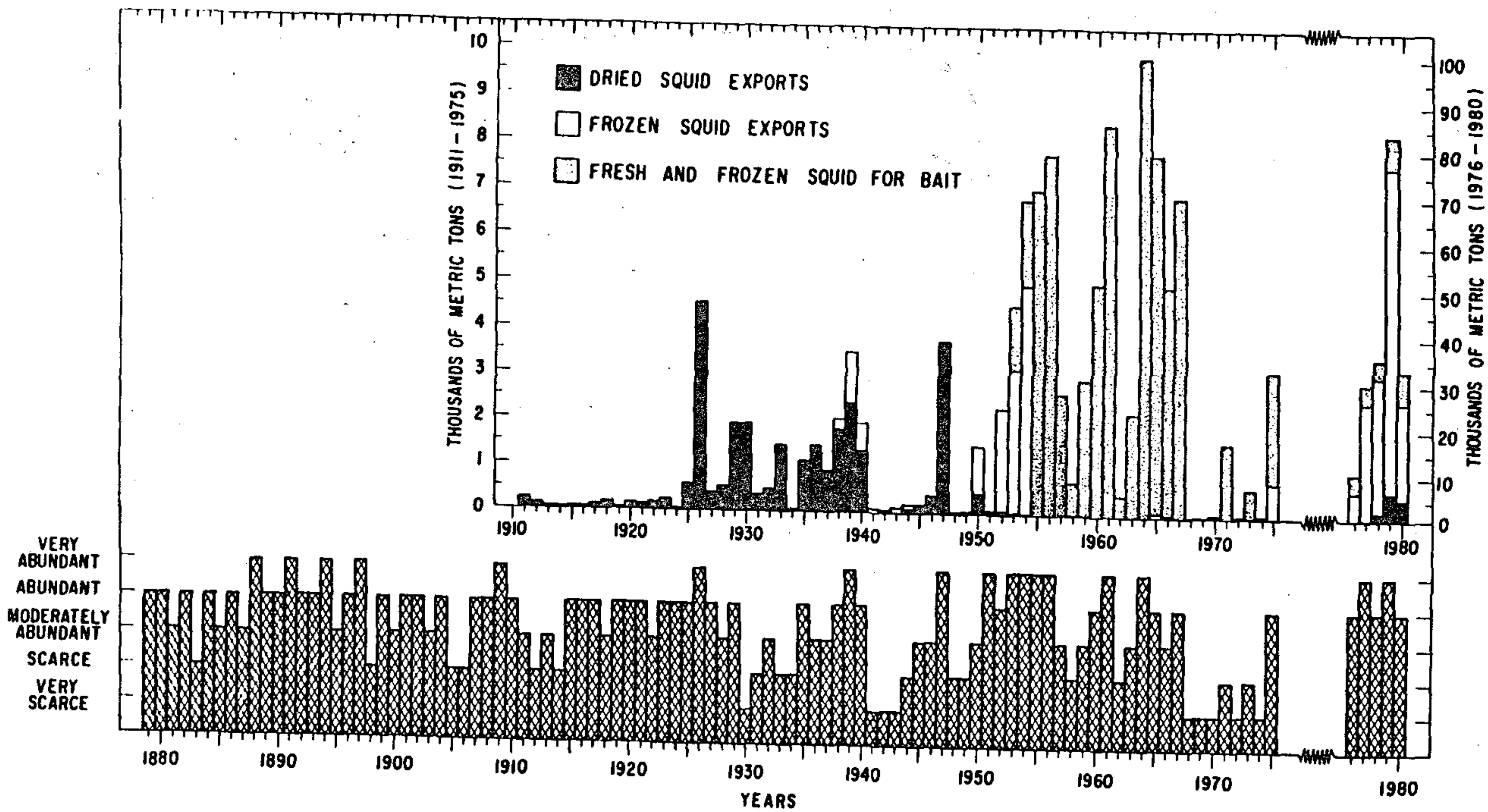

Fig. 3. Breakdown of Subarea 3 catch 1911-1980 by processing category and qualitative estimates of inshore abundance at Newfoundland, 1879-1980 (from Dawe 1981).

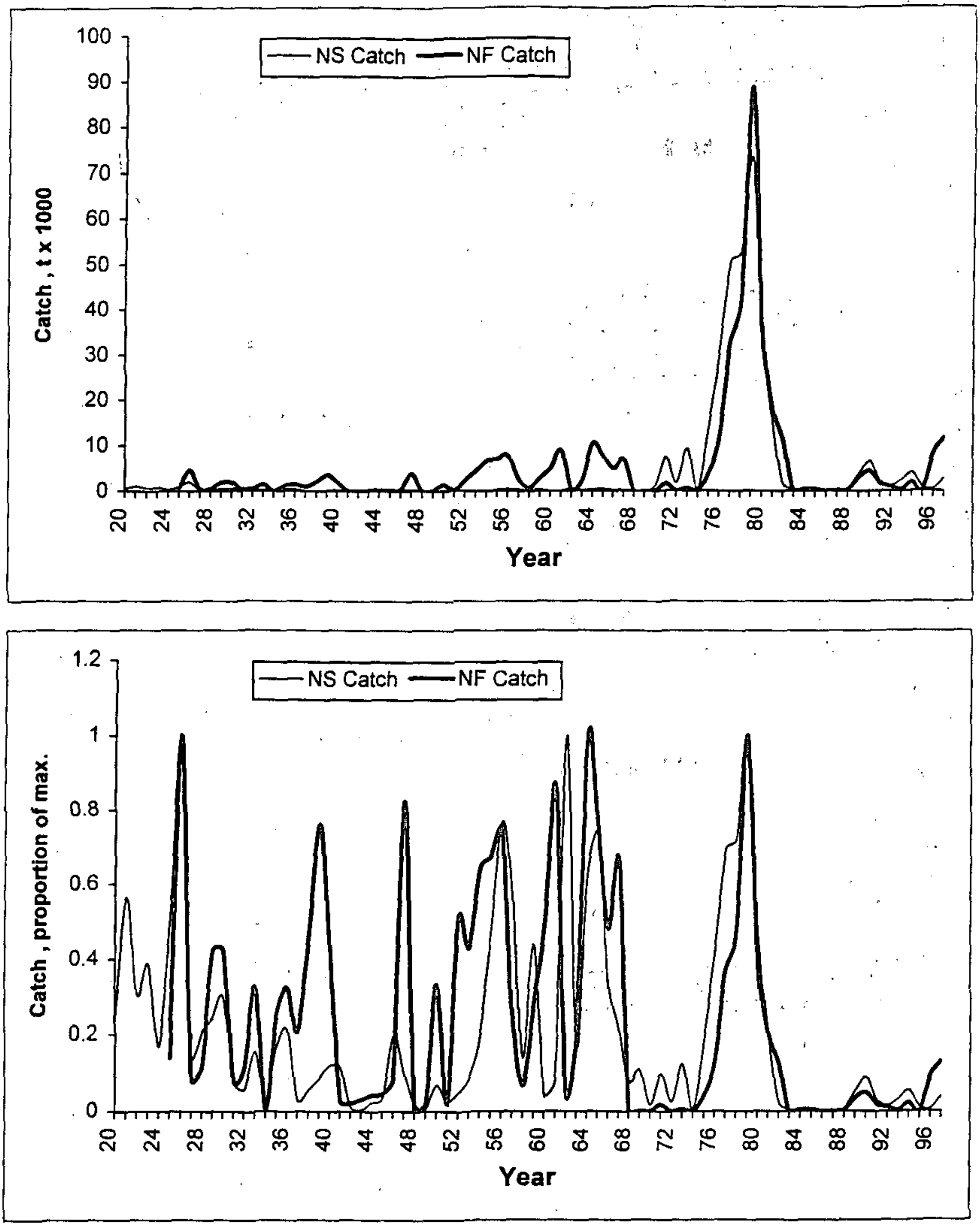

Fig. 4. Annual trends in catch (above) and in catch index; proportion of maximum catch within each of 3 time periods (below), by fishery area.

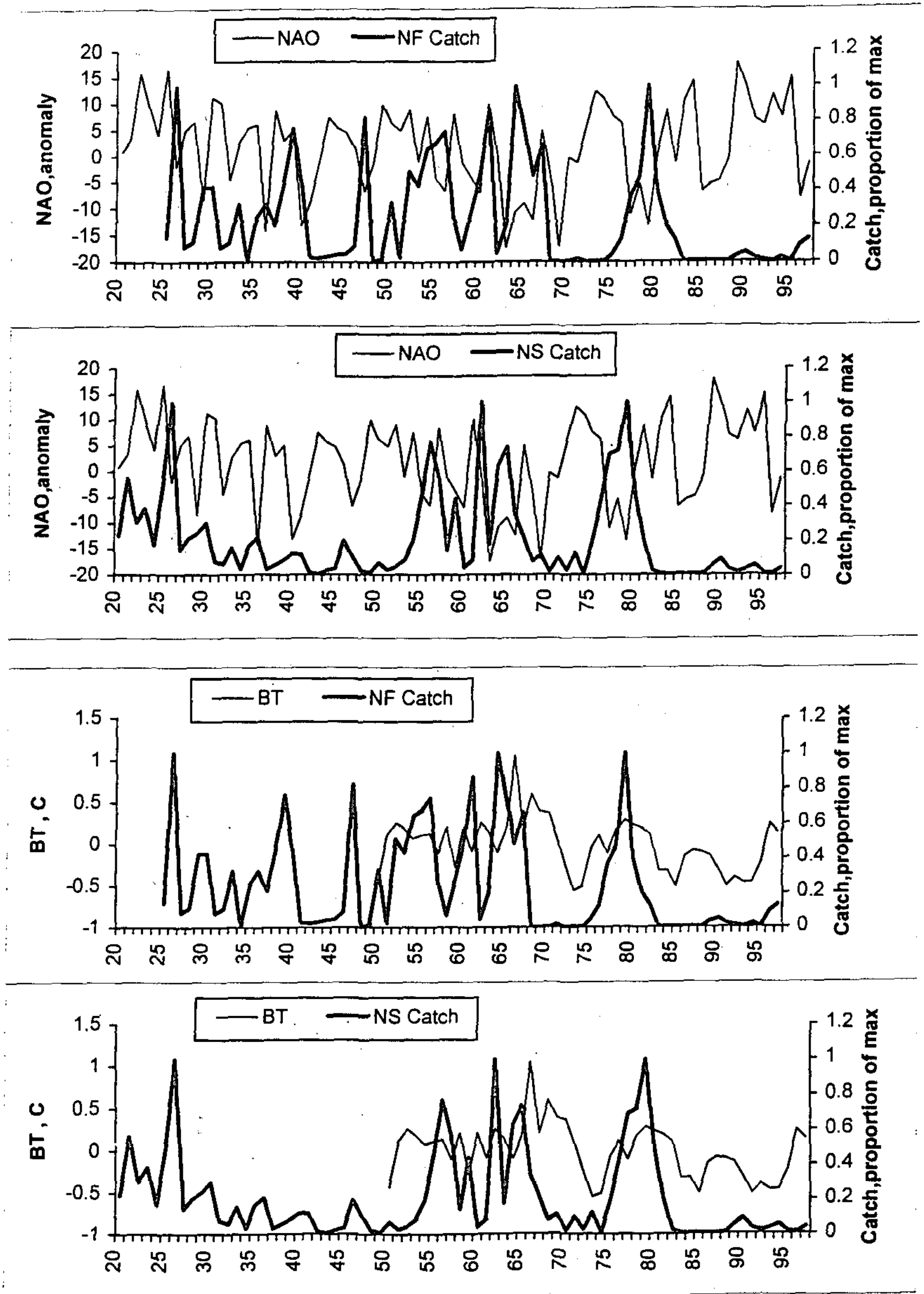

Fig. 5. Yearly trends in catch, by subarea in relation to the North Atlantic Oscillation, NAO (above) and Station 27 annual mean bottom temperature, BT (below).

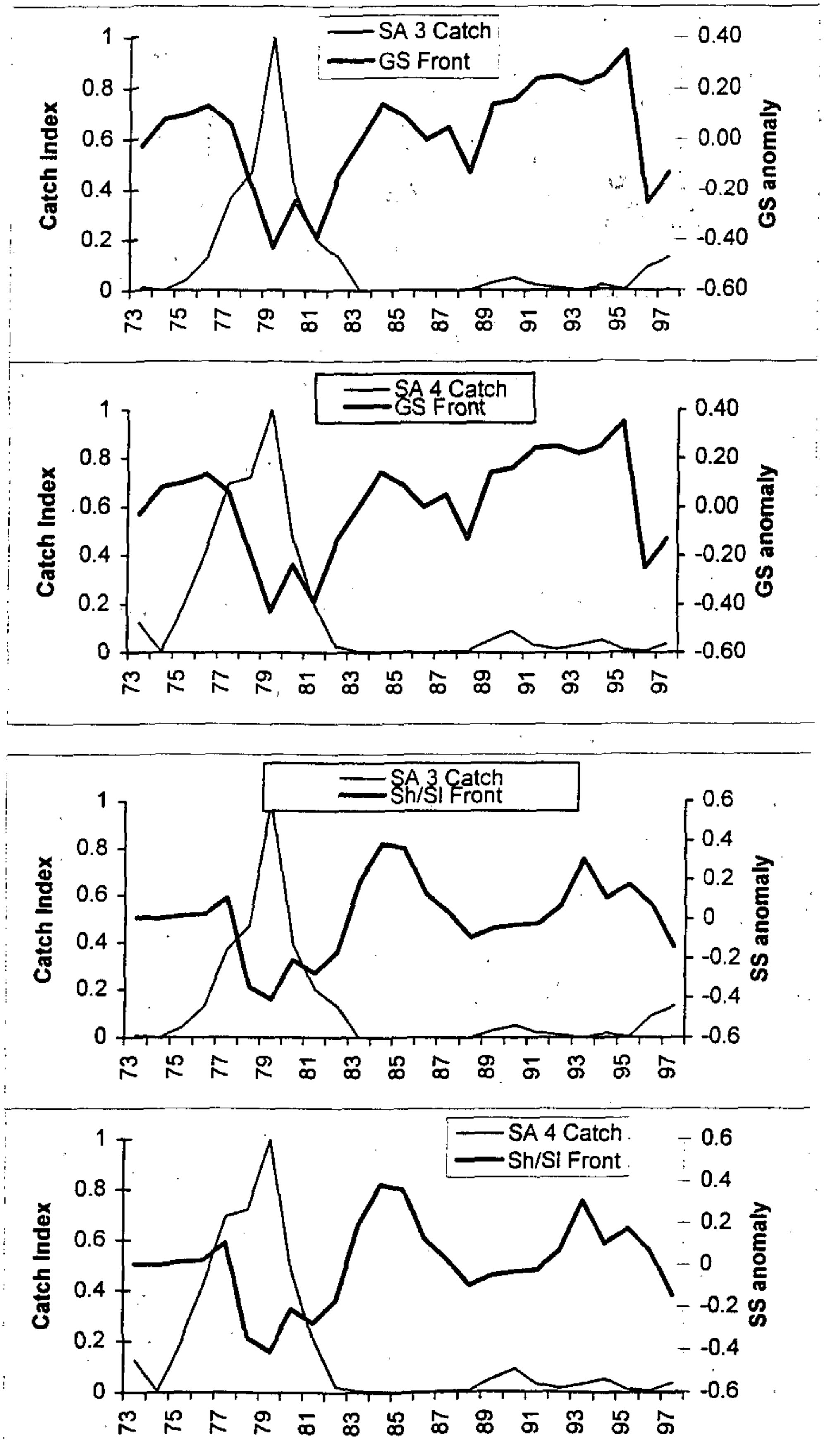

Fig. 6. Relationship between squid abundance and position of the Gulf Stream Front and Shelf-Slope Front by fishery area.

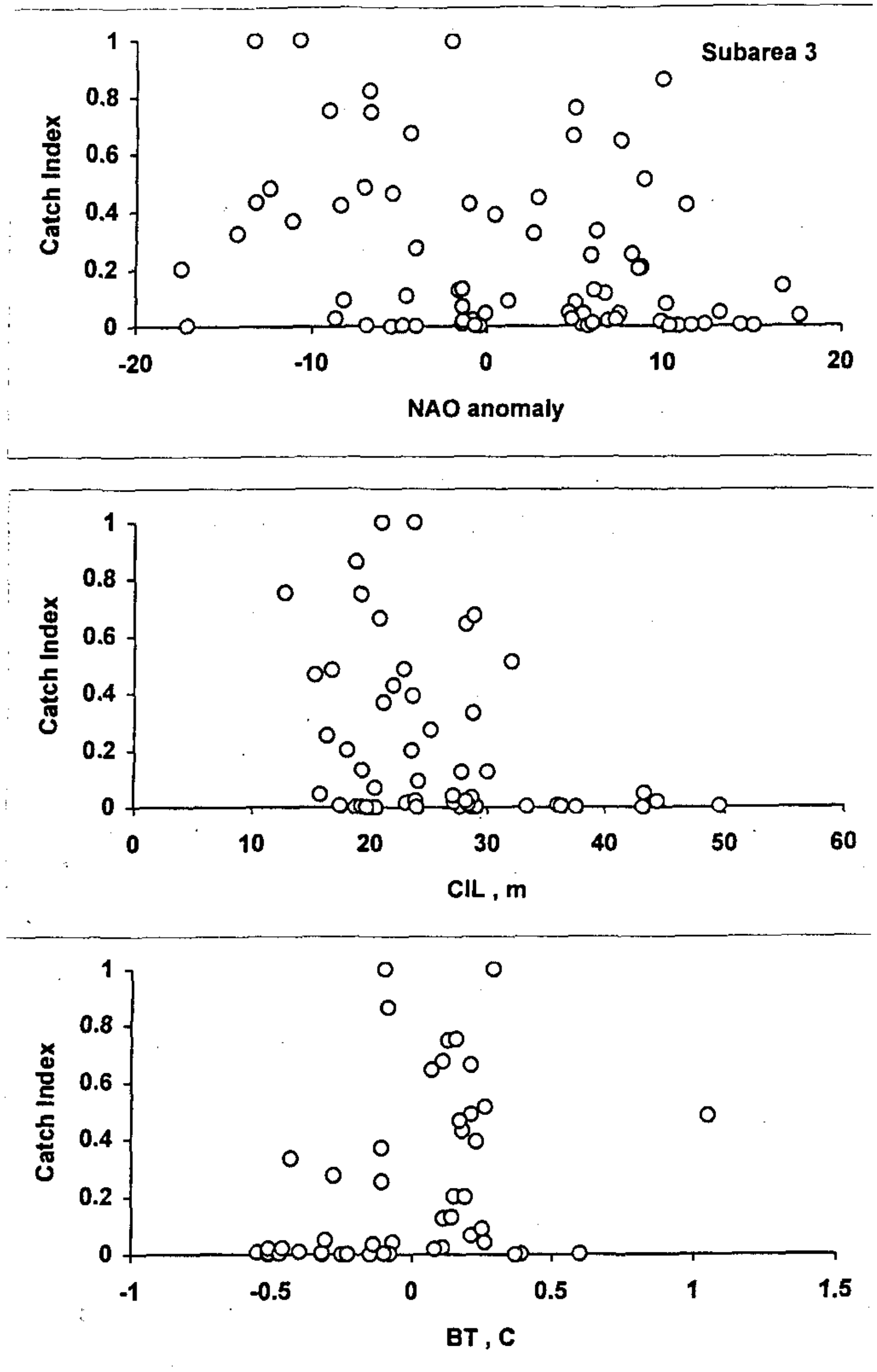

Fig. 7. Scatterplot of Subarea 3 catch index versus North Atlantic Oscillation, NAO (top) thickness of the Cold Intermediate Layer, CIL (middle), and Station 27 annual mean bottom temperature, BT (bottom).

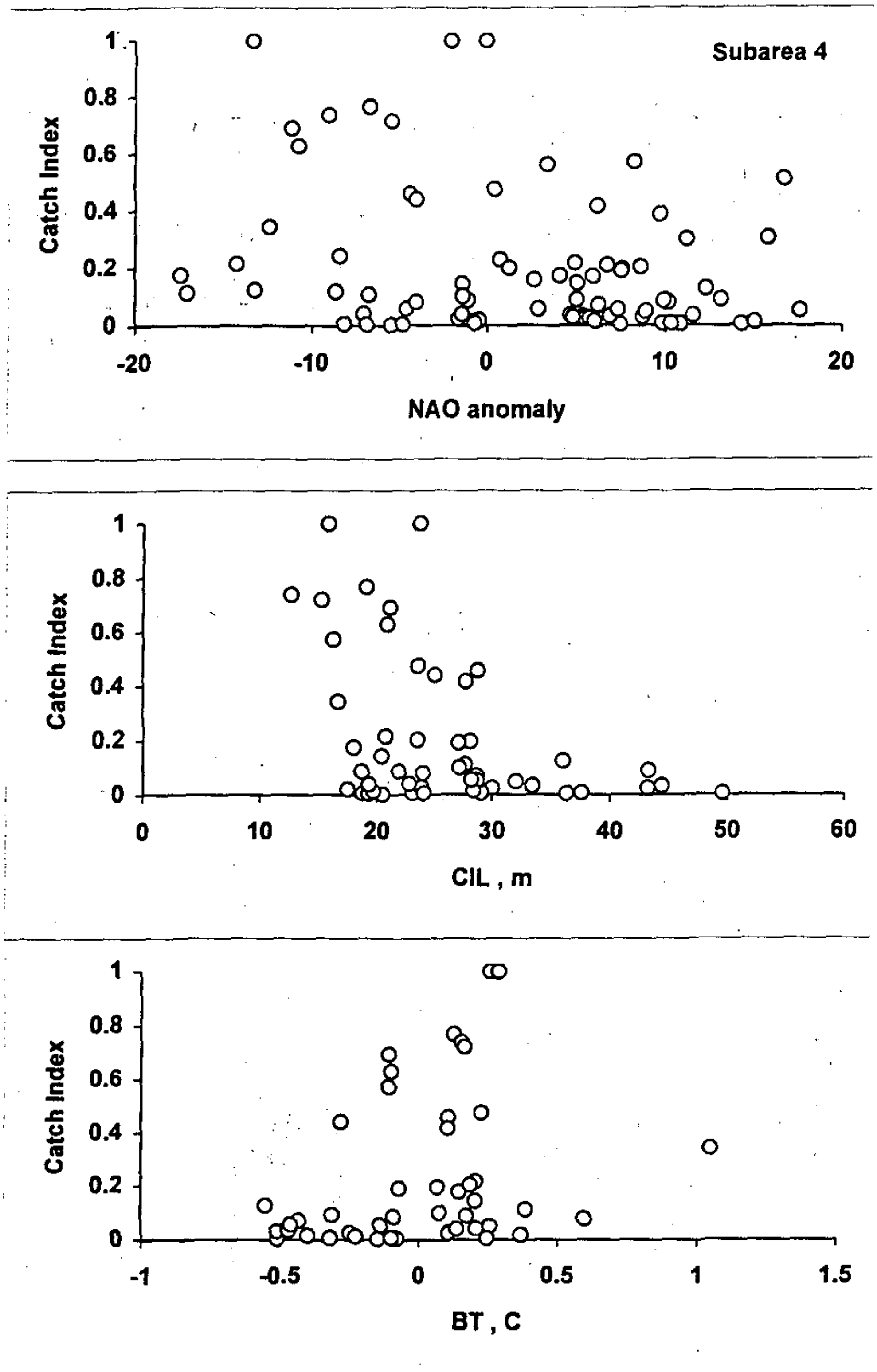

Fig. 8. Scatterplot of Subarea 4 catch index versus North Atlantic Oscillation, NAO (top) thickness of the Cold Intermediate Layer, CIL (middle), and Station 27 annual mean bottom temperature, BT (bottom).