Northwest Atlantic Fisheries Organization

Serial No. N721

NAFO SCR Doc. 83/VI/61

SCIENTIFIC COUNCIL MEETING - JUNE 1983

Distribution of Some Squid Species in the Northwest Atlantic in Relation to Physical Oceanographic Features

by

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ABSTRACT

Spatial distribution of common squid species in relation to the dynamic and hydrographic structure of waters off the Nova Scotia Shelf in spring season 1983 is described. The functional role of various water type structures for squid distribution over the area under investigation is discussed.

INTRODUCTION

The aim of this paper is to reveal some regularities in spatial distribution of several off-shore squid species inhabiting Northwest Atlantic in relation to the peculiarities of the dynamic and hydrological water structures in this area.

Many papers have been published recently on *Illex illecebrosus* which is so thoroughly studied because of its commercial importance. As to other common for this area but non-commercial squid species, no attempts have been made up to the present time to describe their distribution and summerize the information although the data necessary for such a summary have been collected regularly since 1979.

The present paper is the first attempt of this kind and should be looked at as a preliminary one since it is based only on the data obtained during the BMPT Gizhiga cruise in March-April 1983 according to NAFO program on short-finned squid.

Study of this type will allow in future to determine the functional role of various abiotic components in the pelagic ecosystem for squid from the Northwest Atlantic (the Gulf Stream, meanders, WCE's) and to get more knowledge on the habitats and life histories of these molluscs.

MATERIAL AND METHODS

Data collected during the BMPT Gizhiga cruise from March 10 to April 28 conducted in accordance with NAFO program (trawling and plankton survey of the young short-finned squid *Illex illecebrosus*) are used in the present paper. A total of 175 trawl sets (at 119 stations) of depths from 25 down to 500 m (Table 1) were made during the cruise. Large mid-water trawl with a small-meshed liner (#10 mm) was used. It was assumed that this gear catches squid only with its small-meshed liner. The mouth opening of the liner had almost a circular shape with a radius of 7.5 m and a square of the mouth was 176 m^2. 61 towings lasted for 30 min. while all the rest had a duration of 15 minutes. For the purpose of the analysis a total number of squid caught by each 30-min. set was divided by 2.

At each station the hydrographic operations consisted of 1 out of 3 following: 1) an XBT cast down to 450 m, 2) Nansen bottle samplings for salinity and dissolved oxygen determinations with temperature readings at standard depths down to 1000 m, or 3) temperature and oxygen content were determined using a TO_2 D-zond casted down to 1000 m.

Based on the hydrographic parameters, type of hydrographic or dynamic water structure was determined for each set. Stations were generally occupied along the transects (Fig. 1) and the distribution pattern of the hydrographic parameters along those transects was also taken into account when referring a trawl set to this or that type of water structure (named "water type" everywhere below).

It should be noted that the identification of water types was made for the spring season and within a limited area and, hence, in other seasons and within a larger area to hydrographic parameters of the water types distinguished may have other values.

8 species of nektonic squid among the cephalopods caught by trawl were selected for the present analysis. These squid species were most common in the trawl catches; they inhabited epipelagic and upper mesopelagic waters and were relatively easy to identify. Those were the animals from tropical and sub-tropical waters: *Lamadioteuthis megaleia, Selenoteuthis scintillans (Lycoteuthidae fam.), Pyroteuthis margaritifera, Pterygioteuthis gemmata, Abraliopsis hoylei (Enoploteuthidae fam.), Onychoteuthis banksii (Onychoteuthidae fam.), Ornithoteuthis antillarum (Ommastrephidae fam.)* and a local species *Gonatus fabricii*. Species were identified using a key complied by Nesis (1982).

When sorting the catches aboard the ship a total number of each species was counted and their mean weight were calculated. No biological analysis was done at sea.

Basing on the numbers of squid in the trawl catches, mean number of a particular squid species per set was calculated for each water type by two depth intervals: 25-150 m and 200-500 m.

Mean weight of a single squid specimen was calculated for each water type for the same depth intervals. Later in the paper a layer of 25-150 m will be referred to as an epipelagic layer and a layer of 200 - 500 m as a mesopelagic one.

For the purpose of characteristics of squid occurence within different water types a percentage of sets where a particular squid species was found from a total number of sets within a particular water type was calculated.

RESULTS AND DISCUSSION

Water types

7 types of hydrological or dynamic water structures were distinguished in the area of investigation (Fig. 2).

1. Sargasso Sea (SS) is almost a homogeneous water mass directly adjacent to the Gulf Stream from the south. It is characterized by maximum salinity for the area ranging within narrow limits (36.50-36.60°/₀₀) and high temperatures (18-21°C) in a layer from the surface down to 200-300 m.

2. The Gulf Stream (GS) is a zone of maximum horizontal stream velocities, 10-20 miles wide. It is characterized by high horizontal temperature and salinity gradients and is usually inclined towards the Slope water (Fig. 2). A decrease in salinity (from 36.50 to 36.10°/₀₀) and temperature (from 18 to 14°C in a layer of 0-200 m and from 17 to 10°C at depths of 400-500 m) in the Gulf Stream was observed in the direction from Sargasso Sea water towards the Slope water.

3. Transitional Zone (TZ) stretches from the northern edge of the Gulf Stream to the Slope water and has a width of 10-15 miles. Its main feature is a neglectedly low - as compared to the Gulf Stream - velocity though this zone is directly adjacent to the northern edge of the Gulf Stream. The salinity ranges approximately from 35.80 to 36.40°/₀₀ and temperature - from 13 to 17°C.

As to the hydrographic parameters, the Transitional Zone could be referred to the Slope water. This zone was distinguished for the purpose of comparison of squid abundance transported by the Gulf Stream to that observed in the waters immediately adjacent to the northern edge of the Gulf Stream but excluded from the Gulf Stream transportation.

4. Warm Eddy Core (EC) is a homogenous warm water cell within the anti-cyclonic eddy. It is formed mainly of the Sargasso Sea water. Horizontal velocities are low. Temperature and salinity in the Eddy Core are almost constant for the particular core, but their values may range for different edies from 35.80 to 36.50°/₀₀ and from 15 to 18°C, respectively.

5. Eddy Periphery (EP) - the eddy itself - is a narrow band around the Eddy Core with flow velocities similar to those recorded in the Gulf Stream. High horizontal temperature and salinity gradients are observed within the Eddy Periphery; their values depend on those parameters values for the core and the surrounding water.

6. Slope Water (SlW) occupies the area between the Transitional Zone and Shelf water. Salinity and temperature range from 35.10 to 35.90°/₀₀ and from 10 to 15°C, respectively.

6. Shelf Water (ShW) lies over the shelf and stretches into the open sea as far as 100-150 miles being, on the average, 100 m thick. It is underlaid by Slope water. Its salinity is much lower than 35.0°/₀₀ and temperature - lower than 10°C.

Two more water types can be distinguised in the area under investigation (Fig. 2): North Atlantic Central water and poorly defined slope Labrador water (Gatien, 1976) but no trawl sets were made in these water types.

Distribution of squid in relation to water type

Different water types and depths were towed with different intensities (Table 1). The largest number of tows was made in the Slope water, the smallest one - in the Eddy Core.

A total catch of each squid species greatly varied from one water type to another. *Abraliopsis hoylei* was caught in greatest numbers, while squid from *Lychoteuthidae fam.* were the least abundant in the catches (Table 2). The majority of squid species were caught in greater numbers at night. Only three species - *S. scintillans, A. hoylei,* and *G. fabricii* - were caught almost in equal numbers at night and in the daytime (Table 3). These differences in catches of different squid species (in terms of numbers) at night and in the daytime can probably be attributed to the differences in the distances of vertical migrations characteristic for these animals.

All squid species except *G. fabricii* were found in all the water types with the exception of Shelf water. Only *G. fabricii* was caught in the Shelf water. Species occurencies in different water types varied greatly (Table 4).

Based on the data on the species abundance in different water types, an attempt was made to distinguish main regularities in spatial distribution characteristic for each species in spring for the area off Nova Scotia Shelf.

Lamadioteuthis megaleia

This species was the least abundant in the catches as compared to other squid species taken for the analysis (Table 2). It was often caught from the epipelagic layers of the Gulf Stream, Transitional Zone and Eddy Core (Table 4). This squid was relatively often found in the catches from epipelagic layers of the Eddy Periphery. In the Eddy Core it was caught in the epipelagic and mesopelagic layers in equal numbers. From mesopelagic Sargasso Sea, Gulf Stream and Transitional Zone layers larger specimens were captured (Fig. 2a).

It is probable that during the survey period *L. megaleia* was transported by the Gulf Stream from more southern areas and aggregated in the Transitional Zone. At first sight it seems strange that this species was practically absent from Sargasso Sea water but was found relatively often in the Eddy Core formed mainly of the Sargasso Sea water (Fig. 2a). Taking into account small abundance of this species observed, we can't exclude a possibility that this result is accidental. But it is probable, however, that this phenomenon is attributed to the dynamics of the anti-cyclonic eddies.

This squid is transported into the Slope water from a Transitional Zone and Eddy Periphery in small numbers. *L. megaleia* was caught at night in much greater numbers than in the daytime. Main reason for this may be a vertical migration of these animals in the daytime within the Eddy core into deeper layers of the homgenious water. This can serve as an explanation of almost equal catches of the species from epi- and mesopelagic layers of the core. In the Gulf Stream and Transitional Zone waters, in contrast to the Eddy Core, the hydrographic conditions in meso- and epipelagic layers are different and this may be the reason why small squid do not migrate into the mesopelagic layers.

Selenoteuthis scintillans

This squid is also not abundant and is captured mainly from the epipelagic layers of the Sargasso Sea water (Fig. 2b). It is recorded in relatively large numbers in the epipelagic Eddy Core where it is certain to be entrained together with Sargasso Sea water in the process of eddy formation. Very few squid of this species were captured in the Gulf Stream, Transitional Zone, Eddy Periphery and Slope waters.

Mean weight of these squid from different water types were approximately equal.

It is probable that *S. scintillans* is typical for warm water of the Sargasso Sea and it does not immigrate into the zones of high temperature gradient in large numbers. The zones of the Gulf Stream, Transitional Zone and Slope water seem to be the areas of this squid expatriation.

Pyroteuthis margaritifera

Squid of this species were found in all catches taken from Sargasso Sea and Eddy Core waters while in other water types they were captured a little more seldom (Table 4).

P. margaritifera was caught almost in equal numbers in epipelagic and mesopelagic layers of all the water types (Fig. 2c). Larger mature specimens were found in the Sargasso Sea water and in the mesopelagic layer of the Gulf Stream; smaller ones were caught in the epipelagic layers of the Gulf Stream as well as in the Transitional Zone, Eddy Periphery and Eddy Core.

The Gulf Stream seems to be a transportation way for the young of this squid which while growing leaves it for the Sargasso Sea water and the Transitional Zone. Together with the Gulf Stream water they may get into the Eddy Periphery and later - into its core. This scheme of transportation is supported by the facts that only smaller specimens were found in the Eddy Core (of the same size as in the Gulf Stream) and the larger ones from the Sargasso Sea were practically not caught in the Eddy Core.

Slope water seems to be a zone of this species expatriation as it was observed for the species described above.

Pterygioteuthis gemmata

This species is abundant in the catches from the epipelagic layers of the Gulf Stream, Transitional Zone and Eddy Periphery (Fig. 2d). High frequency of occurence of this squid in the Eddy Core (Table 4) resulted from presence of only 1 specimen in each catch from this water type.

From a total catch of 123 specimens of *P. gemmata* from the Sargasso Sea 93 animals were found in a single trawl catch. Though this station is referred to the Sargasso Sea, as to its hydrographic parameters, it was occupied, in fact, on the southern edge of the Gulf Stream and can't be looked at as a typical one for the Sargasso Sea water. This catch being excluded from the calculations, the abundance of *P. gemmata* in the Sargasso Sea is not high (dashed line in Fig. 2d), which is in good agreement with a relatively low abundance of this squid in the Eddy Core.

It seems probable that *P. gemmata* during the period of observations was transported by the Gulf Stream and aggregated within the zones of mixing of the warm Gulf Stream and cold Slope waters, which is supported by high abundance of *P. gemmata* in the Transitional Zone and Eddy Periphery. While growing this squid seems to migrate into the Slope water which is evidenced by the increase in this animal weights from the Gulf Stream towards Slope water (Fig. 2d). It is interesting to note that *Illex illecebrosus* is characterized by the same pattern of migration. The larger specimens of *P. gemmata* are caught in limited numbers in the Eddy Core.

Abraliopsis hoylei

This squid is the most abundant among the squid species chosen for the analysis. It is characterized by very high occurence for all water types except Slope water and Shelf water (Table 4). It is caught almost exclusively in the epipelagic layers; in the mesopelagic ones it is found only in the Transitional Zone in small numbers (Fig. 2e)

Maximum abundance of this squid was recorded in the Sargasso Sea water and in the Eddy Core.

It is possible that *A. hoylei* is transported in large numbers by the Gulf Stream from southern areas and migrates into the Sargasso Sea and into the northern edge of the Gulf Stream and Slope water, but in smaller quantities. It can get into the Eddy Core by two ways: being entrained by the Sargasso Sea water and migrating from the Eddy Periphery.

Mean weights of animals from all water types were approximately equal except for the Eddy Core where *A. hoylei* mean weights were a little larger. Such an increase in the mean weight of animals for the Eddy Core resulted from a catch taken at one station where 317 specimens captured (from a total of 395 animals taken in the same water type; Table 2) with mean weight of 3.3. grams. If this catch data are excluded from the calculations, mean weight of an animal will be the same as recorded for other water types.

Onychoteuthis banksii

The occurence and mean number of specimens per set of *O. banksii* for all water types, except Slope and Shelf waters, are practically equal and rather high (Fig. 2f). Catches from epipelagic and mesopelagic layers stand close by their values, but the weight of the animals from mesopelagic layers are 2 or 2.5 times as large as those for epipelagic ones.

It seems probable that during the survey period these animals were transported by the Gulf Stream and migrated from it both into the Sargasso Sea and into the Transitional Zone and Slope waters.

Ornithoteuthis antillarum

High occurence of this squid species is recorded in the Sargasso Sea, Gulf Stream and Eddy Periphery (Table 4). Maximum abundance of *O. antillarum* is observed in the epipelagic layers of the Sargasso Sea, Gulf Stream and Transitional Zone and it gradually decreases form the Sargasso Sea towards the Transitional Zone. From other water types this squid is caught in extremely insignificant numbers.

In the mesopelagic layers catches of *O. antillarum* increase from the Sargasso Sea towards the Transitional Zone, while in the Transitional Zone its catches are practically equal both from meso- and epipelagic layers.

Young *O. antillarum* were found in the epipelagic layers of the Sargasso Sea and the Gulf Stream while very large specimens (with mantle length up to 25 cm) were caught in the epipelagic and mesopelagic layers of the Sargasso Sea. The Gulf Stream, thus, seems to be a transporter of the young animals of this species from its spawning sites; later these squid migrate into the warm Sargasso Sea waters in large numbers.

Absence of large specimens from the Eddy Core water is not understood. It is possible, that in the process of a new eddy formation, large animals of *O. antillarum* species somehow escape from the entrainment. Insignificant numbers of young squid taken from the Eddy Core may have migrated there from Eddy Periphery and got from the Sargasso Sea in the process of eddy formation.

In contrast to all other species catches of *O. antillarum* were much higher at night than in the daytime. Large specimens of this species seem to escape from the trawl during the daytime.

Gonatus fabricii

Spatial distribution of this squid species greatly differed from those described earlier. *G. fabricii* was abundant in the Shelf water but in the Slope water it was caught in smaller numbers. The specimens from Slope and Core Periphery waters were noticably larger than those from Shelf water. Only large animals were captured in the mesopelagic layers of Slope water.

All catches abundant in *G. fabricii* were taken from the zone of mixing of Shelf and Slope waters.

Thus, it can be seen that the distribution of all squid species chosen for the analysis was closely related to the dynamic structure of the waters in the area of observations. The main reason for this is probably the fact that all squid species, except large active specimens of *O. antillarum* and *G. fabricii*, were of smaller size and were probably semi-planktonic animals.

The Gulf Stream transporting squid of the majority of species plays an important role for their distribution over the habitats.

Some species migrate from the Gulf Stream mainly in the Sargasso Sea, *S. scintillans* and probably *O. antillarum*. Others get only into the Transitional Zone and Slope water, *L. megaleia* and *P. gemmata*. A commercially important species *Illex illecebrosus* should be referred to the same group (Fedulov and Froerman, 1980; Froerman *et al.*, 1981; Dawe *et al.*, 1981, Dawe *et al.*, 1982; and Hatanaka *et al.*, 1982).

The third group migrates into both directions from the Gulf Stream: into the Sargasso Sea and the waters of Transitional Zone and Slope water (*O. banksii, P. margaritifera,* and *A. hoylei*).

Warm Core Eddy formation may significantly effect the population abundance of squid from this area in two ways: by withdrawal of squid from the transportation into the Eddy Periphery by the Gulf Stream and by entrainment of squid inhabiting the Sargasso Sea water into the Eddy Core.

Similar mechanism may exist with cyclonic cold core eddies in the Sargasso Sea as well. Thus, besides 3 specimens of *L. megaleia* captured in the Sargasso Sea, 4 more animals were obtained also on the southern side from the Gulf Stream but in the cold core eddy.

The zone of the Slope water is an area of expatriation for some squid species.

An interesting regularity was observed in all squid species but *G. fabricii*: for each species the ratio of its total catch from the Transitional Zone to its catch from Slope water was approximately the same and was 2.7 on the average (Table 2).

Numbers of sets made in each of these water types are different (Table 1) and for the mean number of specimens per set this ratio value, therefore, increases and is 5.8 on the average (Table 5).

It is unlikely that low variability of this ratio for 7 squid species is accidental; to our opinion it is related to the dynamics of the waters in the area between the Gulf Stream and the continental shelf. Slope water is formed from a mixing of Transitional Zone and the Gulf Stream waters (originated from North Atlantic Central water), from one side, and Shelf and Labrador waters, from the other (McLellan *et al.*, 1953, 1957; Gatien, 1976).

If all squid species are really semi-planktonic, their proportions in these two water types may reflect the intensity of mixing of these waters. Some estimates (McLellan, 1957) indicate the ratio of these waters mixing to be 1:4, which is very close to the ratios for squid species within these water types.

This ratio for *L. megaleia* and *O. antillarum* is noticably lower as compared to other species. The former species is the least abundant one and it could effect the ratio value for TZ/Sl W while adult *O. antillarum* are active nektonic animals.

A significant defficiency of the present paper lies in the limited time duration of the survey which is almost certain not to be compared with time scales of the life spans in the majority of squid species discussed. To obtain a more detailed picture, observations during other seasons are necessary.

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Table 1. Numbers of sets made within different water types by depth.

	Depth									
Water type	25 m	50 m	100 m	150 m	25-150 m	200 m	300 m	500 m	200-500 m	Total
Sargasso Sea	0	5	6	0	11	0	3	1	4	15
Gulf Stream	0	2	12	0	14	0	1	1	2	16
Eddy's Core	0	2	4	0	6	0	2	0	2	8
Eddy's Periphery	2	5	9	0	16	1	0	0	1	17
Transitional Zone	1	6	15	1	23	1	8	1	10	33
Slope water	0	8	45	8	61	1	9	0	10	71
Shelf water	0	3	5	5	13	2	0	0	2	15

Table 2. Total number of squid caught from each water type by species.

	Water type							
Species	Sargasso Sea	Gulf Stream	Eddy's Core	Eddy's Periphery	Transitional Zone	Slope water	Shelf water	Total
L. megaleia	3	55	16	12	57	25	0	168
S. scintillans	206	15	31	14	24	7	0	297
P. margaritifera	379	363	142	130	452	171	0	1637
Pt. gemmata	123	213	7	396	530	213	0	1482
A. hoylei	1481	281	395	439	659	211	0	3466
O. banksii	134	160	48	79	313	140	0	874
O. antillarum	198	181	3	20	194	65	0	661
G. fabricii	0	0	0	3	0	172	192	367

Table 3. Numbers of sets where a particular squid species was found (upper numeral) and a mean number of specimens per set (lower numeral) at night and in the daytime.

Species	Daytime	Night
L. megaleia	7/1.7	41/4.3
S. scintillans	9/9.0	33/6.9
P. margaritifera	23/8.8	70/21.9
Pt. gemmata	21/3.7	90/16.6
A. hoylei	33/24.3	89/29.8
O. banksii	19/4.0	83/10.4
O. antillarum	18/1.4	77/8.5
G. fabricii	12/9.3	21/13.1

Table 4. Occurence of squid species in different water types (in percent).

Species	Water type						
	Sargasso Sea	Gulf Stream	Eddy's Core	Eddy's Periphery	Transitional Zone	Slope water	Shelf water
L. megaleia	12	40	88	18	52	10	0
S. scintillans	69	33	38	53	33	8	0
P. margaritifera	94	60	100	65	73	34	0
Pt. gemmata	43	80	75	76	82	52	0
A. hoylei	81	80	100	71	94	55	0
O. banksii	56	87	88	71	82	41	0
O. antillarum	75	73	38	71	73	40	0
G. fabricii	0	0	0	18	0	23	53

Table 5. Mean numbers of squid specimens per set taken from Transitional Zone and the ratios for these values.

Species	Water type		
	Transitional Zone	Slope water	TZ/SL W
L. megaleia	1.7	0.35	4.9
S. scintillans	0.7	0.1	7.0
P. margaritifera	13.7	2.4	5.7
Pt. gemmata	16.1	3.0	5.4
A. hoylei	20.0	3.0	6.7
O. banksii	9.5	2.0	4.8
O. antillarum	5.8	0.9	6.4

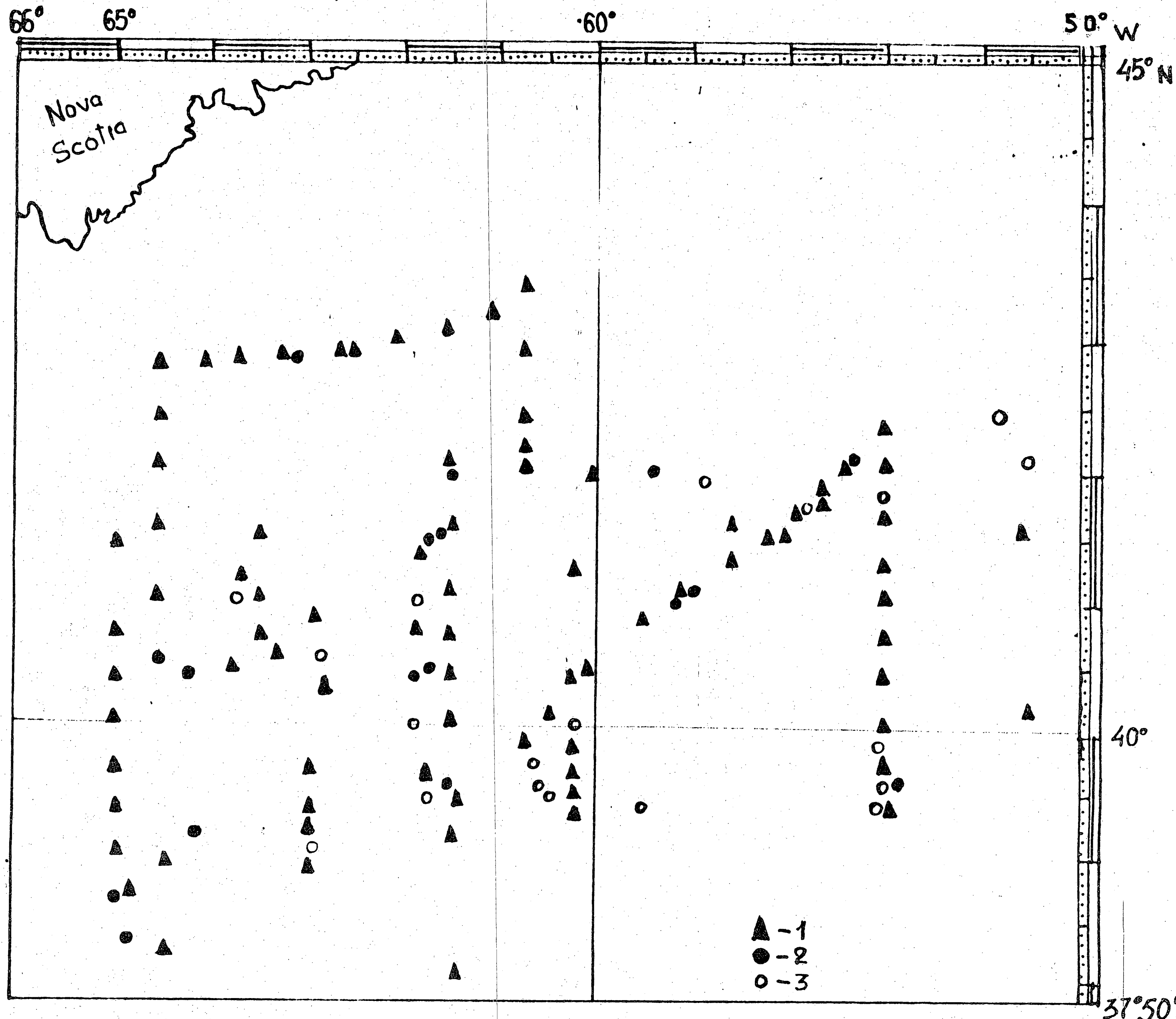

Fig. 1. Location of stations: 1 - hydrographic station; 2 - XBT cast; 3 - TO_2D-zond cast.

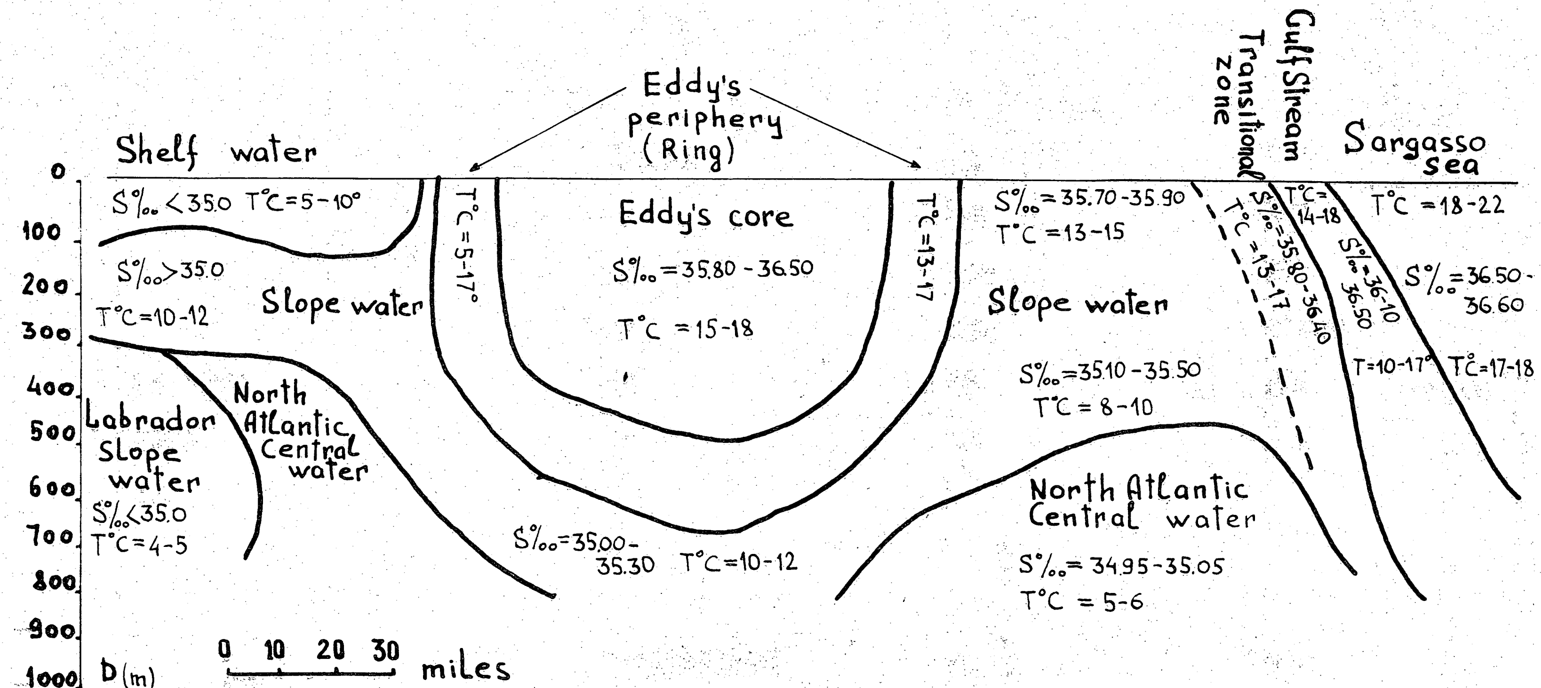

Fig. 2. The distribution of water types along the transect from the Sargasso Sea towards the shelf.

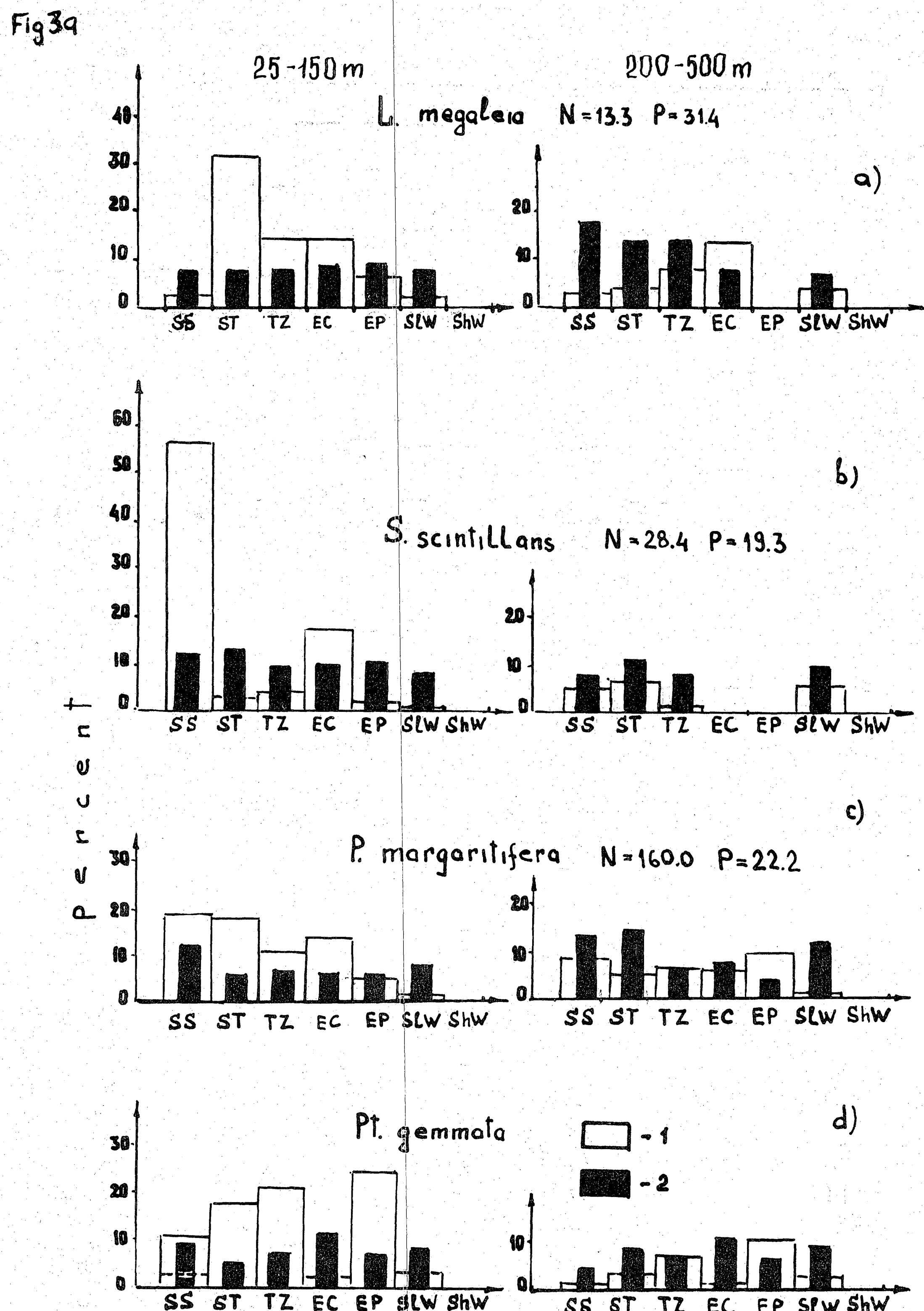

Fig. 3. Mean numbers of squid per set (1) and their mean weights (2) for each water type in the epipelagic (25-150 m) and mesopelagic layers (200-500 m). Mean number of squid per set is calculated as a percentage of a sum of mean numbers per set for all water types (N). Mean weight of squid for a particular water type is calculated as a percentage of a sum of mean weights for all water types (P).

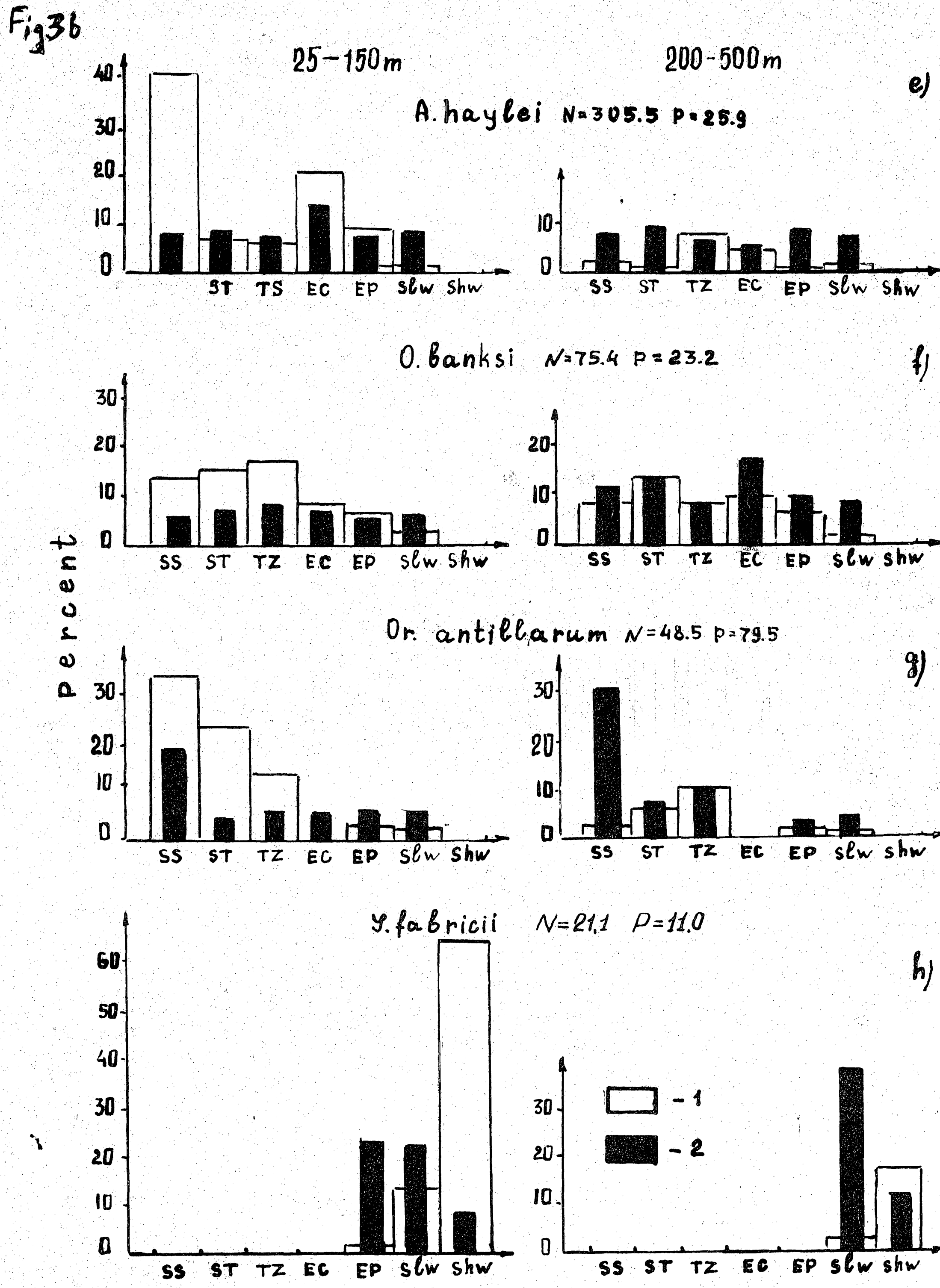
Fig3b
25–150m
200-500m
e)
A. haylei N=305.5 P=25.9
f)
O. banksi N=75.4 P=23.2
g)
Or. antillarum N=48.5 P=79.5
h)
S. fabricii N=21,1 P=11,0
percent
SS ST TS TZ EC EP Slw Shw
– 1
– 2