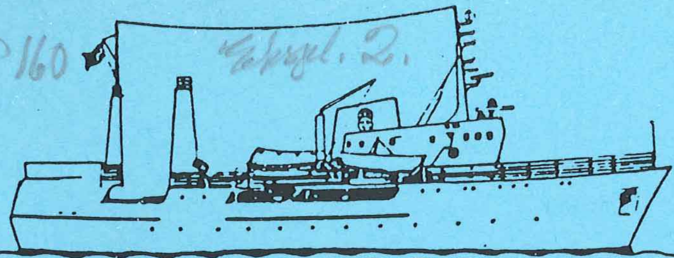

Reports on Surveys with the

R/V Dr. Fridtjof Nansen

NORAD/FAO/UNDP. PROJECT GLO/82/001

Survey of Mesopelagic Fish Resources in the Gulf of Oman

February 1983

Gjøsæter, Jakob and Snorre Tilseth

Institute of Marine Research, Bergen
University of Bergen, Department of Fisheries Biology

Reports on Surveys with the R/V "Dr. Fridtjof Nansen".

SURVEY OF MESOPELAGIC FISH RESOURCES IN THE GULF OF OMAN

February 1983

By

Jakob Gjøsæter* and Snorre Tilseth**

* University of Bergen, Department of Fisheries Biology.

** Institute of Marine Research, Bergen.

May 1983

NORAD/FAO/UNDP. PROJECT GLO/82/001

INTRODUCTION

During the surveys of the pelagic fish resources of the North-western Arabian Sea carried out with R/V "Dr. Fridtjof Nansen" 1975-1977, and the subsequent surveys for mesopelagic fish in 1979 and 1981 a very large biomass of the lantern-fish Benthosema pterotum was observed in the Gulf of Oman (Gjøsæter, 1981a, 1981b, Aglen et al. 1982). Estimates based on acoustical surveys ranged between 8 and 20 mill. tonnes.

Based on this information on biomass size, and on biological parameters derived from these cruises, preliminary estimates suggest that the stock can give a yield of up to about 10 mill. tonnes per year (Svåsand, 1983). It has also been shown that large catch rates occasionally can be taken with small pelagic trawls (Aglen et al. 1982), but catching the fish at a commercial scale was not tried.

It was decided to undertake more research in the Gulf of Oman, and a cruise with R/V "Dr. Fridtjof Nansen" was conducted in February 1983.

The primary objective of the February 1983 cruise reported here was to do experimental trawling with gears specially designed for this purpose. In addition to this the aim was to get new estimates of the abundance of lanternfish, and to collect data for further studies of their ecology, behaviour and life history. A special report has been prepared on the fishing gear trials (Schärfe, 1983) and only a brief summary has been included here.

MATERIAL AND METHODS

The cruise tracks in the Gulf of Oman from 4 February to 3 March 1983 are shown in Fig. 1-3.

The vessel is a 150 foot stern trawler with a main engine of 1500 Hp. A description of the vessel is given by Anon (1978).

The participating scientific and technical staff is listed in Annex 1.

The acoustical equipment consisted of three scientific sounders (120, 50 and 38 kHz) and two echo integrators, each with two channels. The vessel is also equipped with a sonar (24 kHz) and a net sonde (50 kHz). In addition to the hull mounted transducers, there is one towed body with two transducers. The vessel also has a 21 kHz sonar.

The 38 kHz sounder used for integration, is coupled to a ceramic transducer and a 2 KW external transmitter was applied. A 120 kHz echo sounder was used to get better resolution in the upper 100 m.

Details about the acoustical equipment and the settings used are given by Aglen et al. (1982, Annex 2).

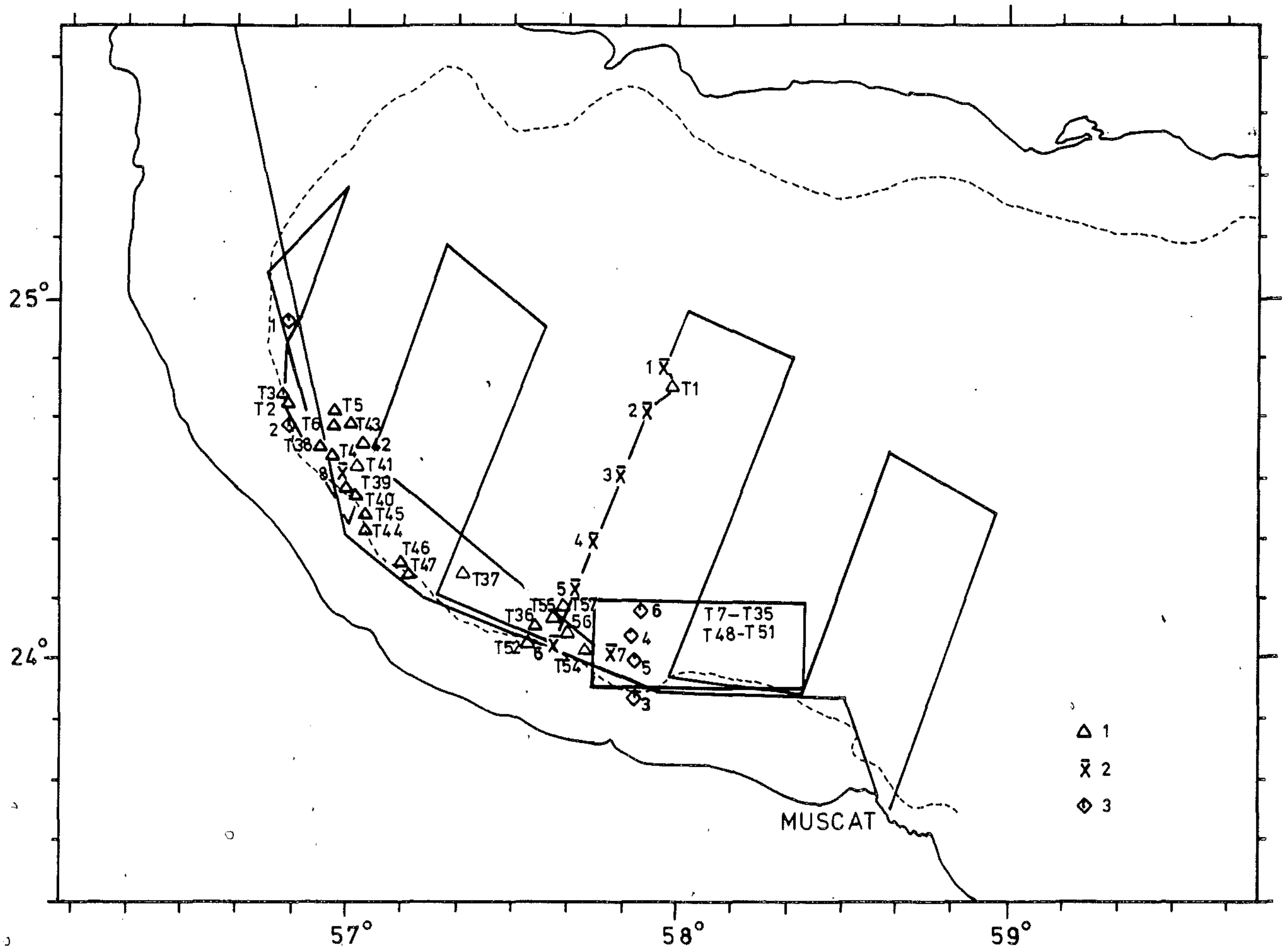

Fig. 1. Cruise tracks in the Gulf of Oman, Main survey I. February 1983. The tracks within the square shown at the map were too dense to be shown. 1, Pelagic trawl; 2, Hydrographical station; 3, Plankton station.

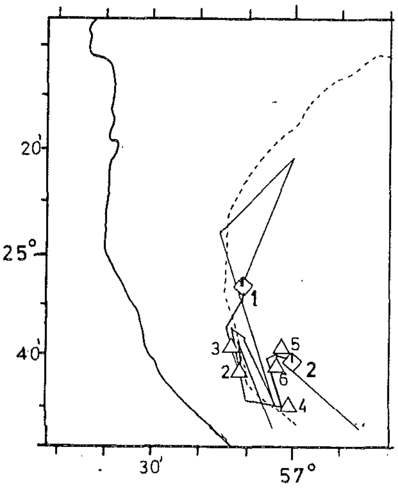

Fig. 2. Cruise tracks in the Gulf of Oman, Detail surveys. 15 and 23-24 Feb. Legend as Fig. 1.

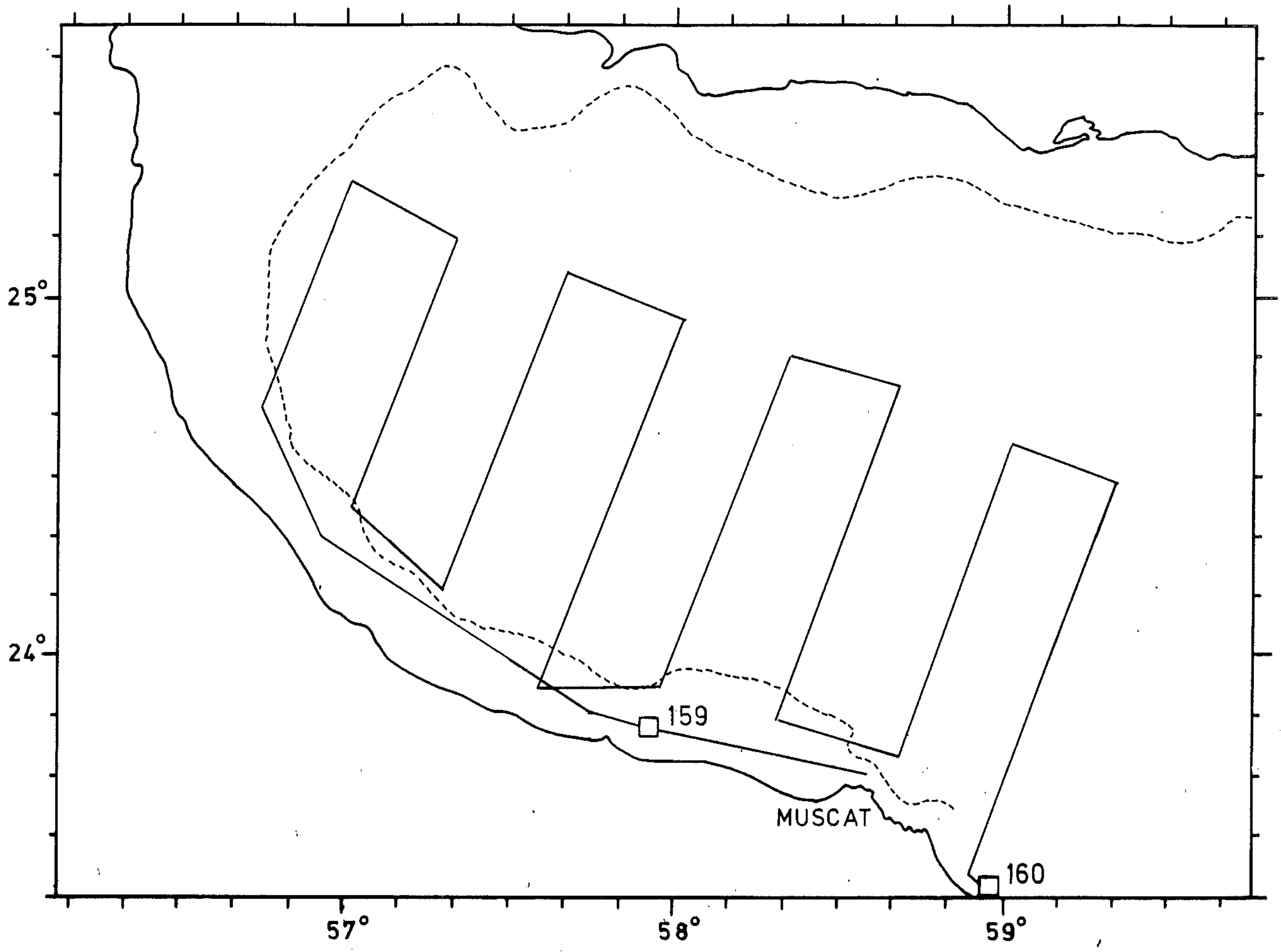

Fig. 3. Cruise tracks in the Gulf of Oman. Detail survey II. 1-4 March 1983. Legend as Fig. 1.

During daytime the echo recordings were divided into three groups:

Plankton	(Usually upper 100 m)
Upper mesopelagic (D I)	(Usually 100-200 m)
Deep mesopelagic (D II)	(Usually below 200 m)

During night usually two groups could be recognized:

Upper mixed layer (N I, plankton)	(Upper 100 m)
Deep mesopelagic (N II)	(Below 200 m)

To estimate the amount of mesopelagic fish in the upper mixed layer, the recordings of plankton during daytime in the same or in a near by area were subtracted. The recordings of plankton were, however, usually very low during the survey in 1983.

The integrated echo was converted to estimates of fish biomass using the formula:

$$B = \int \overline{M}CdA = MCA$$

where B is biomass of the scattering organisms, M is integrated echo intensity (mm/n.miles). A is the corresponding area. The conversion factor depends on the size of the fish:

$$C = C'L$$

where L is fish length and C' is a constant depending on the performance of the acoustical equipment and the fish species in question. As no reliable estimation of C' for myctophids are available, a C' estimated for other small pelagic fishes was used:

$$C = 0.6\ L$$

where L is fish length in cm. This corresponds to an average target strength of -10 log L -22 dB ref. 1 kg/m^2, and should therefore be comparable to the conversion factor used on the previous surveys on R/V "Dr. Fridtjof Nansen" and on R/V "Lemuru" working in the same area in 1977-1978 with compensation for the difference in the performance of the equipment.

Fishing experiments were carried out using a small mesh Krill trawl extended with a front part of 800 mm mesh size stretched and alternatively with 1600 mm mesh size. SUBERKRUB 8 m^2 other boards were used during the trials. More details about the gears and its use are given by Schärfe (1983) who was responsbile for the fishing experiments.

Eggs and the early larval stages were identified by stripping eggs from mature female fish and artificially fertilizing these eggs with sperm from mature male fish. This was done on board the R/V Dr. Fridtjof Nansen" with fish from trawl samples.

Fertilized eggs were incubated at constant temperature (21 ^{o}C) in a thermostate. This method was developed for B. pterotum during the R/V Dr. Fridtjof Nansen" survey to Gulf of Oman in 1981, and was successfully repeated during the present survey.

The neutral buoyancy of newly fertilized eggs was measured in a density-gradient column according to the method described by Coombs (1981).

The vertical distribution of B. pterotum eggs and larvae in the Gulf of Oman was studied by samples from a series of vertical broken Juday net (80 cm in diameter, 350 μm mesh size) hauls from 300-200 m, 200-100 m, and 50-5 m depth intervals.

Eggs in the most early cleavage stage sampled by the Juday net were incubated on board at 21 ^{o}C, the incubation period (time to hatching) was observed and compared to that of artificially fertilized eggs. Larvae hatched from these eggs were also compared to larvae from artificially fertilized eggs for identification purposes. These comparisons gave the necessary key to the identification of B. pterotum eggs and larvae in Juday net samples.

Standard hydrographic stations were worked out along one transect and at two separate stations (Fig. 1).

In each station Nansen bottles were used in standard depths down to the bottom or to 500 m depth. Temperature and salinity were observed at all standard depths; 0-10-20-30-50-75-100-125-150-300-400-500 m. Oxygen was observed at the same depths except 0 m. The salinity and oxygen samples were analysed on board.

BEHAVIOUR AND SPECIES COMPOSITION

Behaviour

Mesopelagic fish were found off the continental shelf where the water was deeper than about 150 m. During morning and afternoon two sound scattering layers were usually observed. In addition a weak plankton layer in the surface was sometimes observed. The upper layer (D I) was usually found at about 150 m depth and had a vertical extention of 20-40 m (Table 1, Fig. 4). It consisted of small schools and dense concentrations. At deeper

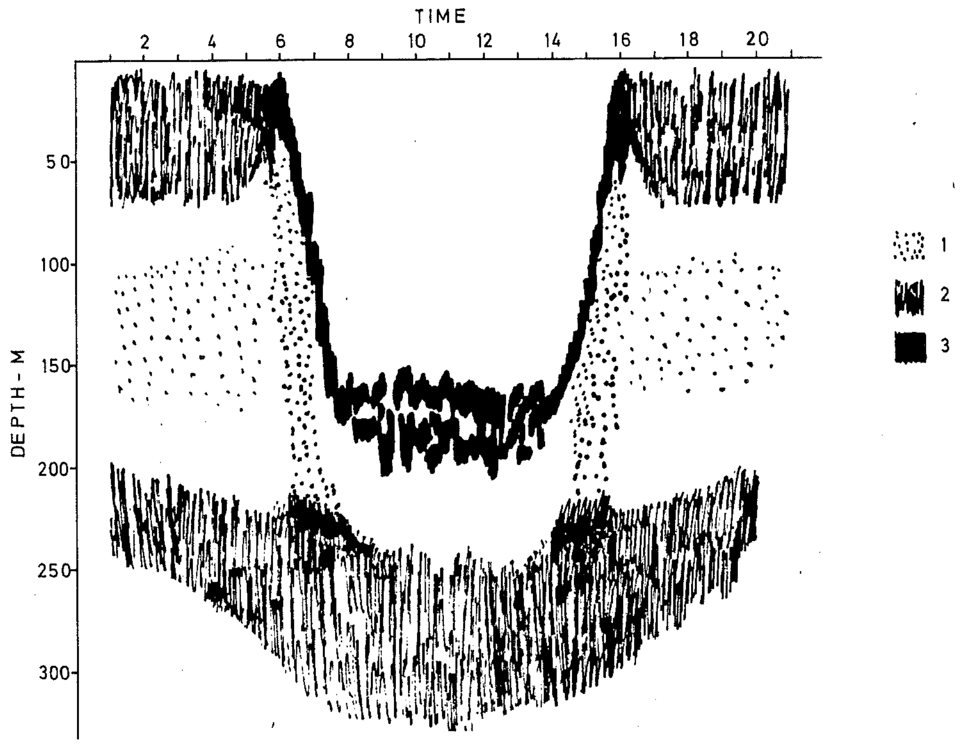

Fig. 4. Schematic drawing of the layers of B. pterotum. For explanation, see text. 1, very scattered; 2, dense; 3, very dense echo recordings.

Table 1. Typical depth distribution of the mesopelagic fish layers in the Gulf of Oman.

Layer	Depth	Vertical extention
D 1	150 (140-200)	40
D 2	250	80
N 1	20	70
N 2	220	70

water, usually centered at about 250 m depth another scattering layer (D II) appeared. This usually had a vertical extention of 70-100 m. Although it sometimes gave very high echo recordings, it had a more "smoky" appearance on the echograms than D I. A few hours after sunrise the D I layer often migrated downwards and mixed with the D II layer (Fig. 5). Usually it appeared again about 2-3 hours before sunset. About one hour before sunset the layers started to migrate slowly upwards. About half an hour before sunset D I usually reached about 100 m.

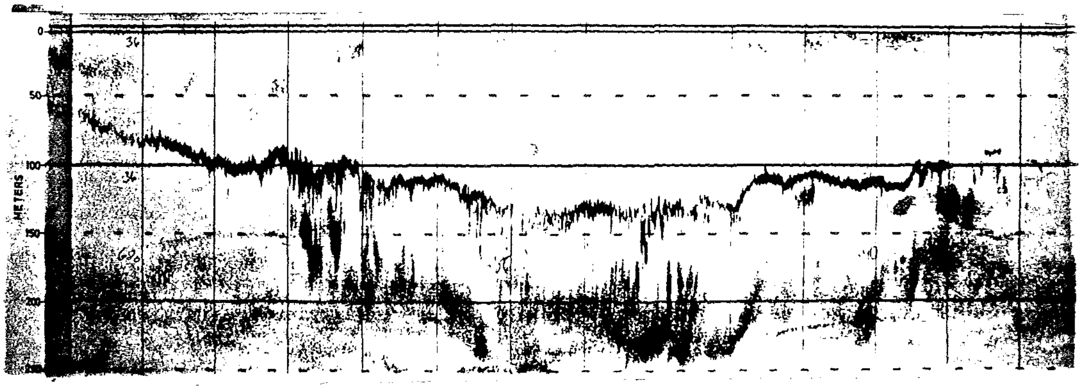

Fig. 5. Echo recording showing a descending D I layer mixing with the D II layer and disappearing. Distance between vertical marks one n.mile.

At this time both this layer and parts of the lower layer moved rapidly towards the surface where they mixed with the plankton layer if present. The highest speed during upward migration was usually recorded between about 100 and 10 m, were an average of 1,7 m/min corresponding to 0,8 fish length/sec was often observed (Table 2). The downward migration was usually faster than the upward migration, (3 m/min or 1.4 fish length/sec between 10 and 100 m depth) usually NI concentrate near the surface before starting the migration (Fig. 6). Parts of the deep day layer stayed in deeper waters also during night time. The night layers were usually less concentrated than the day layers, and often scattered recordings were found at a very wide depth range.

Table 2. Migration speed of D I.

	Depth range	No. of observ.	Speed m/min. mean	Speed m/min. range
Downward	10 - 100	10	3.0	0.9 - 4.0
	100 - 150	2	1.1	0.5 - 1.7
	150 - 200	2	1.9	1.3 - 2.5
Upward	100 - 10	4	1.7	1.3 - 1.8
	150 - 100	1	0.8	-

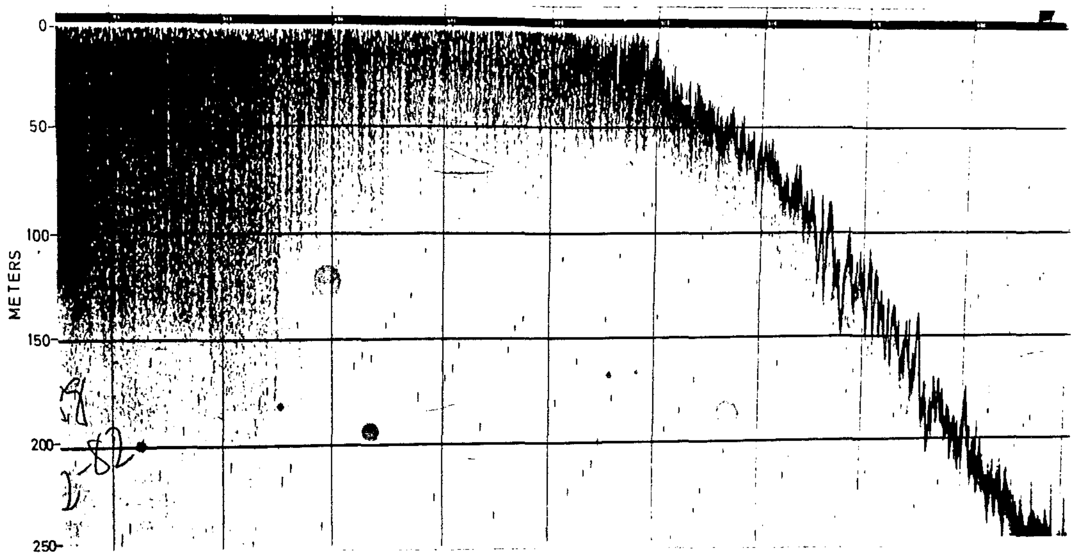

Fig. 6. Echo recording showing N I layer concentrating near the surface before starting the downward migration.

On previous cruises a migration from the D I to the D II layer was occasionally observed. A consistant pattern with migration from D I to D II in the morning and back to D I in the afternoon has, however, not been recorded (Gjøsæter 1981a, Aglen et al. 1982). There is no difference between hydrographical condition this year and during previous years that can explain this change in behaviour. Neither is there any obvious change in feeding conditions or maturity stages (Dalpadado, 1983). An explanation therefore, remains to be found.

The migration pattern observed this year will seriously reduce the possibility of getting good catch rates, as compared to conditions previously observed. Further research should be carried out to see if this pattern is more common than previously believed. Correlatious of this pattern with seasonal or environmental factors should also be tried to see if it can be predicted.

Species composition

B. pterotum was the dominant species in all layers except in the sets from the deep night layer (N II) where jellyfish made up 75% of the catches. Probably these jellyfishes were mainly caught in the surface layer during setting and hauling of the net. When the trawl was hauled in the D I, D II and the N I layer the fish was so abundant that jellyfish made up a small proportion of the catch although they were equally abundant measured in average kg/h.

The only fish group except B. pterotum which was of any importance was Paralepidiae which made up about 5% of the catches from the D II layer. In a few night hauls taken close to the shelf Decapterus was caught, but not in quantities of commercial interest.

Table 3. Composition (percentage of weight) of trawl catches in the sound scattering layers in the Gulf of Oman. Figures in brackets give the percentage of the catch exclusive of jellyfish. + present, but less than 0.1% of weight.

Species	Day D I	Day D II	Night N I	Night N II
B. pterotum	100	80.6(86.8)	83.1(99.0)	21.0(84.9)
Champsodon		0.1		0.2
Cubiceps		0.2		0.2
Paralepididae		5.3		
Gonostomatidae		+		
Trichiuridae	+	3.0	0.3	1.5
Sphyraena	+	2.4	+	
Decapterus	+		0.6	
Apogonidae		+		
Harpadontidae				1.0
Chauliodus		+		
Jellyfish	+	7.0	16.0	75.3
Squid		0.7		
Shrimps/krill		0.6		0.2
Various				0.8

ACOUSTICAL ABUNDANCE ESTIMATION

The Oman side of the Gulf of Oman was surveyed twice, 13-14 February and 1-4 March 1983 (Fig. 1-3). The northern side was not covered.

The average echo abundances are shown in Table 4 and in Fig. 7 where they are compared to those from 1981.

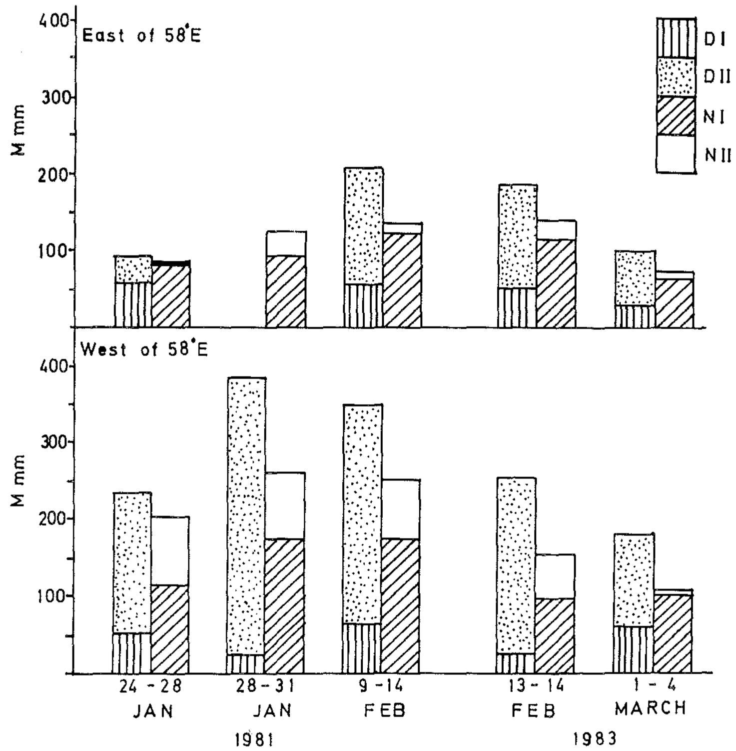

Fig. 7. Echo recordings of B. pterotum from the Gulf of Oman 1981-1983, showing the relative importance of the four types of layers.

Table 4. Echo abundance (mm. integ. deflection) from the two main surveys in the Gulf of Oman in February and March 1983.

Main Survey		Day					Night				
		No five miles	D I		D II		No	N I		N II	
			mean	SD	mean	SD		mean	SD	mean	SD
I	W 58°E	37	25	29	232	145	40	94	73	57	61
	E 58°E	21	50	75	135	151	25	113	91	21	34
II	W 58°E	26	60	49	119	88	31	100	40	9	14
	E 58°E	36	28	39	67	91	25	61	46	9	14

The echo abundance was converted to biomass using the equation

$$B = CL\bar{M}A$$

where B is biomass in tonnes, C is convertion factor taken as 0.6 tonnes/ mm/n.mile x $(\text{n.mile})^2$, L is standard fish length in cm., $\bar{M}$ is average integrator deflection in mm/n.mile and A is area in $(\text{n.miles})^2$.

A fish length of 3.5 cm was used for the transformation. The area of the inner part of the Gulf (W of 58°E) was taken as 7000 n.miles^2 and the outer part (E of 58°E) 15 000 n.miles^2.

The results were as follows:

	Day values	Night values	Average
Survey I	9.6 mill.t.	6.4 mill.t.	8.0 mill.t.
Survey II	5.6 " "	3.8 " "	4.7 " "

Probably the average of these estimates, 6.4 mill. tonnes, gives the best estimate of the total biomass of mesopelagic fish in the Gulf of Oman in February 1983.

In these calculations it is assumed that the cruise tracks provide a representative coverage of the whole Gulf, also the Iran side.

An area in the inner part of the Gulf (Fig. 2) was covered more densely twice, 15 February and 23-24 February. The results of these detail surveys are given in Table 5, and the recordings from the D I layer are compared to six surveys of the same area in 1981 in Fig. 8. In the figure the echo abundance is converted to biomass (gr.) per m^3 supposing that the D I layer has an average depth of 25 m.

An area in the south-eastern part of the Gulf of (marked with a square on Fig. 1) was surveyed in more details during several days in the last part of February. The results of this are given in Table 5.

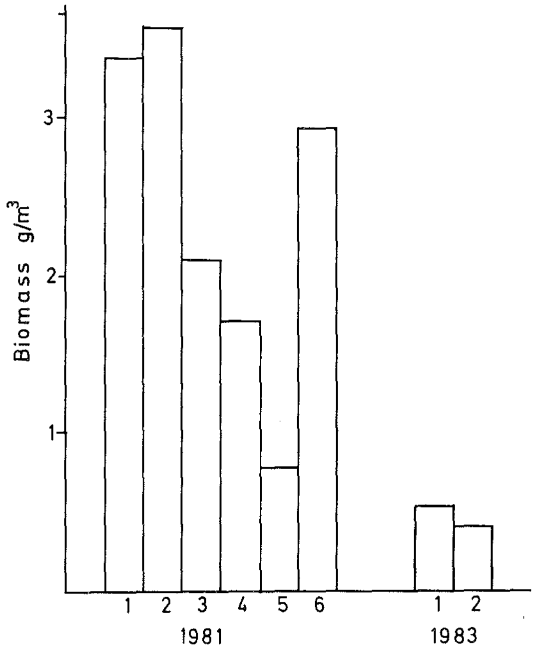

Fig. 8. Estimated density of fish in the D I layer during detail surveys in 1981 and 1983.

Table 5. Echo abundance (mm. integ. deflection) from three detailed surveys in the Gulf of Oman in February 1983.

Survey	Day					Night				
	No five miles	D I		D II		No	N I		N II	
		mean	SD	mean	SD		mean	SD	mean	SD
West 1	15	22	37	125	66	18	117	61	56	34
2	19	17	25	209	49	12	91	36	56	35
South east	19	59	64	250	166	32	88	43	48	39

The abundance of mesopelagic fish was lower in 1983 than on the previous cruises (Fig. 9), but as the variance of the estimates are very high, the difference may not be significant.

From a fisheries point of view the difference in the D I layer may be more important. Especially in the western part of the Gulf the biomass recorded as D I layer was considerably lower than in previous years (See Figs. 7 and 8).

This is partly due to a low average density of the D I layers observed, but also because the D I layer was often absent during large parts of the day (See behaviour).

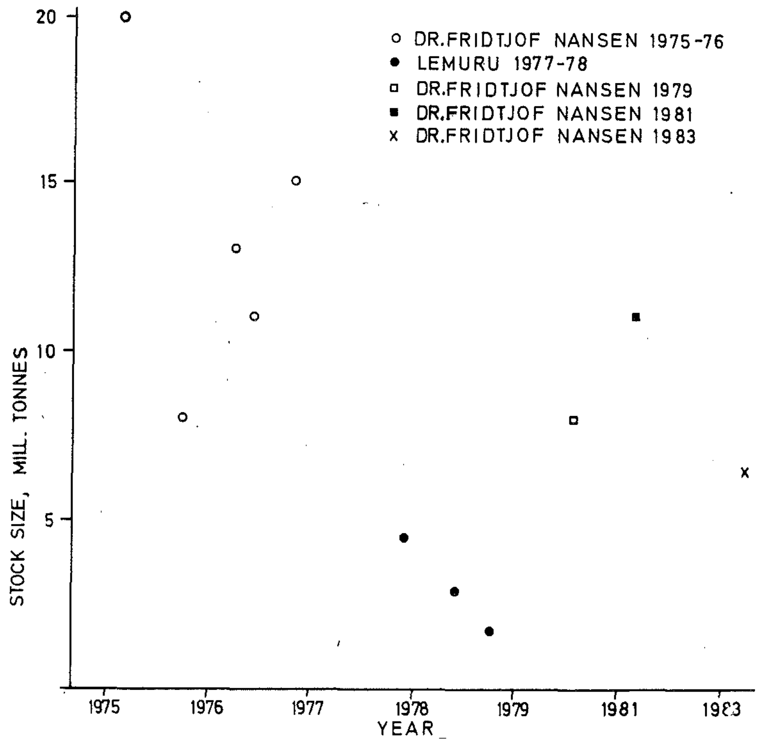

Fig. 9. Estimated abundance of mesopelagic fish in the Gulf of Oman 1975-1983.

Often the best concentrations of mesopelagic fish were observed close to the continental slope (Fig. 10). In such areas echo recordings as high as 4000 mm/n.mile, corresponding to 85 g/m^3 of fish were occasionally observed. These recordings were, however, usually narrow, extending less than one n.mile from the edge of the shelf. Similar observations were made on the previous cruises (Gjøsæter, 1981, Aglen et al. 1982) and also in other areas (Gjøsæter & Blindheim, 1982).

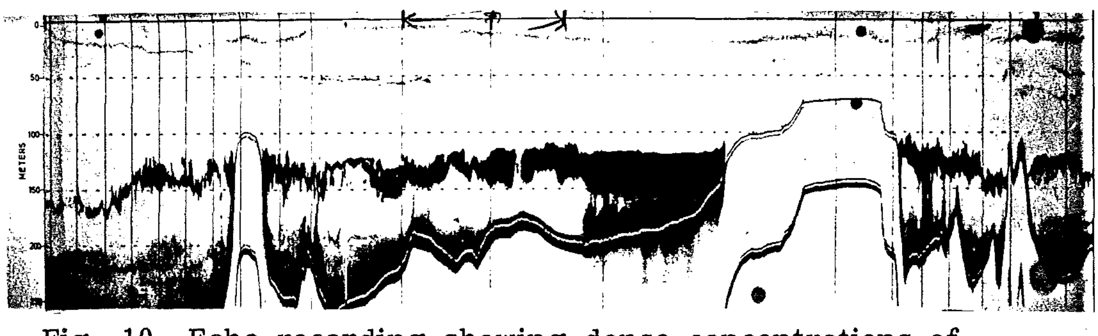

Fig. 10. Echo recording showing dense concentrations of B. pterotum close to the shelf.

During the cruises carried out in 1981 and 1983 the day recordings were consistantly higher than the night recordings (Fig. 7). This is in accordance with the results of Gjøsæter and Myrseth (1980) based on surveys in the Gulf of Oman and the Gulf of Aden during 1979 but opposed to those of Myrseth (in prep.) from Pakistanian waters. Gjøsæter (1980a) found no difference between day and night recordings in the Arabean Sea in 1975-1976. A possible explanation of the lower night values could be that a part of the fish is too close to the surface to be detected.

This could be the case at new moon. Use of a towed transducer looking upwards shows, however, that the fish is not found so close to the surface when the moon is half or larger. Another and probably more likely explanation is the fact that the fish is more scattered during night time, and in parts of the water column it may be too much dispersed to be integrated with the thresholds used.

Resonance in parts of the biomass could also give difference between day and night recordings. Parts of the fish may be within the size range where resonance could be expected at certain depth levels. To study this phenomenon two echo sounders working at 50 and 38 kHz were used. Simultaneously a 21 kHz sonar was used looking downwards. The D I and D II layers were recorded at all three instruments. The sonar gave an additional layer at about 500 m, which could not be observed on the echo sounders. A reasonable explanation could be that D I and D II are non-resonant scattering as they were observed at all frequenzies, while the deep layer observed by 21 kHz could only be caused by resonance. As this layer was not integrated, it is of no importance for the present abundance estimates.

REACTION TO LIGHT

Several experiments were made to study the reaction of B. pterotum to light. Most experiments were carried out using three 1000 W high pressure sodium lamps as a light source. A trial with underwater light was also carried out.

The experiments showed that the fish were repelled by the light (Fig. 11). However, they concentrated at some depth. To get a quantitative idea of

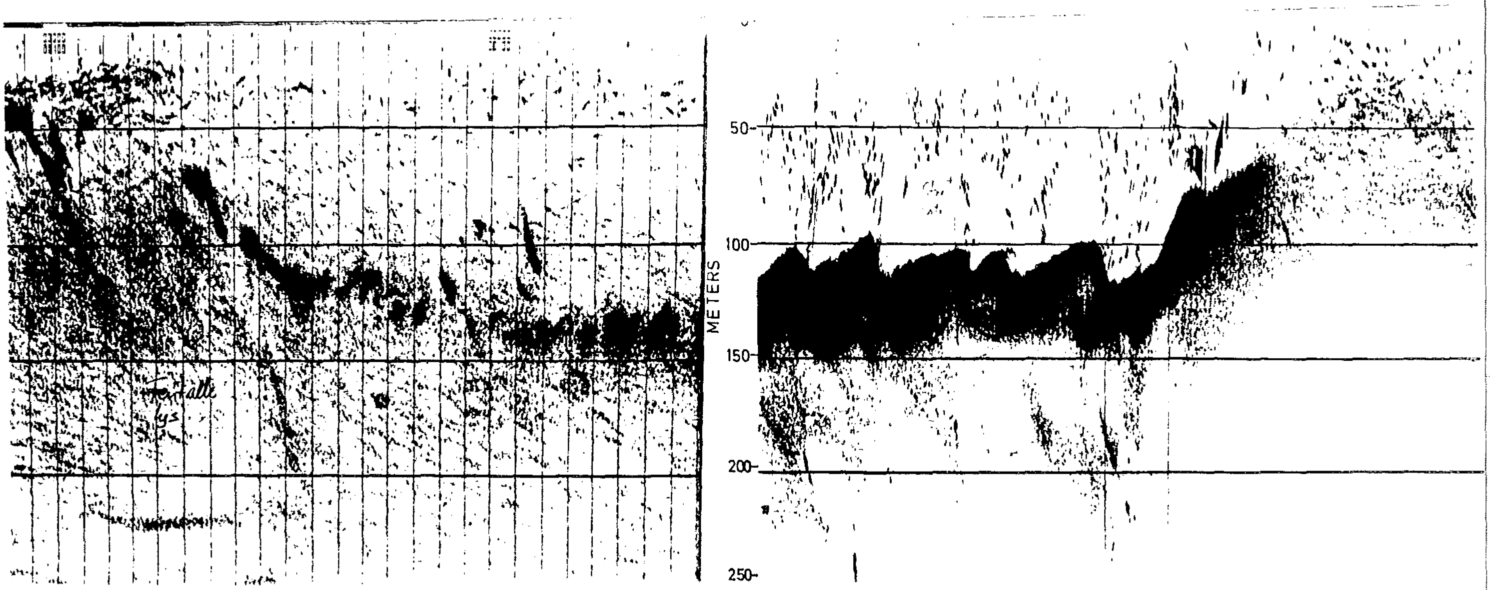

Fig. 11. Echo recordings showing reaction of B. pterotum when light is turned on and when it is turned off. Distance between horizontal lines 20 m.

this concentration, echo integration was carried out. For the purpose of integration a simulated speed of 10 knots was used, although the ship was laying still. The results are shown in Table 6.

Table 6. Results of integration at a simulated speed of 10 kn. Light station 2. (See Fig. 11 right). Gulf of Oman.

Time	Light	N I	N II
1920		16	17
1930	Lights on		
2045		71	43
2325		461	31
2335	Lights off	41	32
2300	Boat at normal speed	46	37

The increase in echo abundance may partly be due to fish too dispersed for integration before the light was turned on concentrated by the light. It could also be due to fish in the blind zone near the surface pressed down to depth where they could be detected. Several other experiments gave similar results. This effect was also used to concentrate fish during trawling.

One 1000 W lamp was placed on each side of the wheelhouse and one on the aft part of the ship. All available deck lights were also used. When trawling at 2 knots, the fish were pressed down to 30 m under the echo transducer, and according to the trawl sonde the densest concentrations were found at 50 m when the trawl reached them.

One experiment was carried out with underwater light. A 200 W bulb was lowered to 27 m in an area where the densest fish layer was found at 15-20 m. When light was turned on, the fish above the lamp moved up and disappeared out to the sides. Fish below the lamp moved down. The light was kept on for about 5 hrs. Then there were very little fish below the boat, but a search light sonar showed that larger concentrations were found in a ring around the boat with radius about 50 m.

Trials using several bulbs to get more light failed because of technical difficulties.

Moonlight gave results similar to those obtained by overwater lights. At new moon the fish are found rather close to the surface, while they stay deeper at full moon (Fig. 12). Use of the towed transducer looking upward, indicated that some fish also stayed above the working level of the bottom mounted transducer during new moon, but not during full moon.

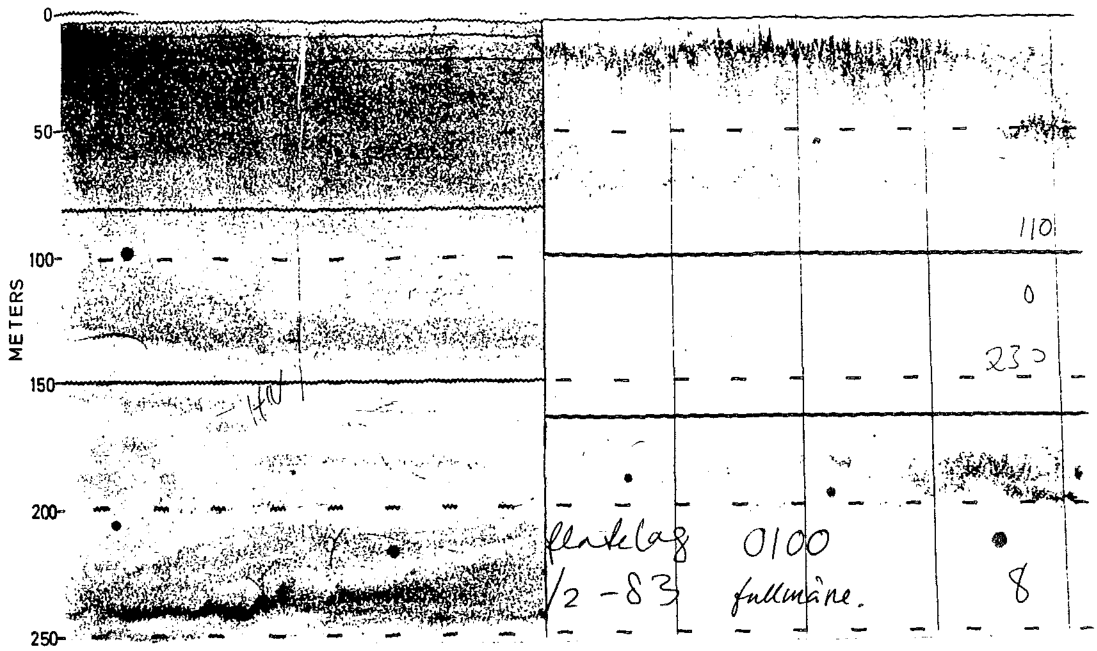

Fig. 12. Echo recordings showing fish standing closer to the surface at new moon (left) than at full moon (right).

FISHING TRIALS

The fishing trials are described by Schärfe (1983) and will only be treated briefly here.

The small mesh Krill trawl used on the previous cruises was extended with a front part of 800 mm mesh size stretched giving it an approximate opening area of about 600-650 m^2. Alternatively a front part with 1600 mm mesh size giving an opening of about 700 m^2 was used. Most of the trawling was carried out within the square shown in Fig. 1. Stations falling outside this area are indicated separately in the figure.

Initial trials indicated that only the D I layer gave reasonably good catch rates, therefore most of the effort was concentrated on this layer. Unfortunately this layer usually had a lower density and also appeared less regularly than on previous cruises. Still rather high catch rates were obtained. There was one exception to the general rule that only D I gave good catch rates. At the final part of the cruise it was shown that N I layers could give good catches when pressed down by artificial light (See Reaction to light). Table 7 gives a summary of the catch rates of the fishing trials. More details about the trawl stations are given in Appendix 2 and by Schärfe (1983).

Table 7. Catch rates of the fishing trials in the Gulf of Oman 1983.

Layer	Tows	Hours fished	Catch t	Catch t/h
800 mm mesh size frontpart:				
Good D I	10	10.9	41.2	3.8
Other layers	10	10.7	4.5	0.4
Total	20	21.6	45.7	2.1
1600 mm mesh size frontpart:				
Good D I	17	24.9	109.4	5.0
Other layers	4	6.4	8.4	1.3
N I, with light	5	8.0	17.7	2.2
Very dense D I	1	0.5	∿50	∿100
Total	27	39.8	185.5	4.7
Grand total	47	61.4	231.2	3.8

The frequency distribution of catch rates is shown in Table 8.

Table 8. Frequency distribution of catch rates during fishing trials in the Gulf of Oman 1983.

Catch rate t/h	D I	N I with light	Other layers
0 - 0.9	2		7
1 - 1.9	4	3	1
2 - 3.9	11	1	
4 - 5.9	11	1	
6 - 7.9	1		
8 - 9.9	2		
10 - 12	1		
∿ 18	1		
∿100	1		
Total	34	5	8

During all fishing trials the fish abundance in a depth slice corresponding to the vertical trawl opening was estimated using echo integration. The relationship between estimated fish abundance in the trawl track and the abundance of fish caught by the trawl is shown in Fig. 13.

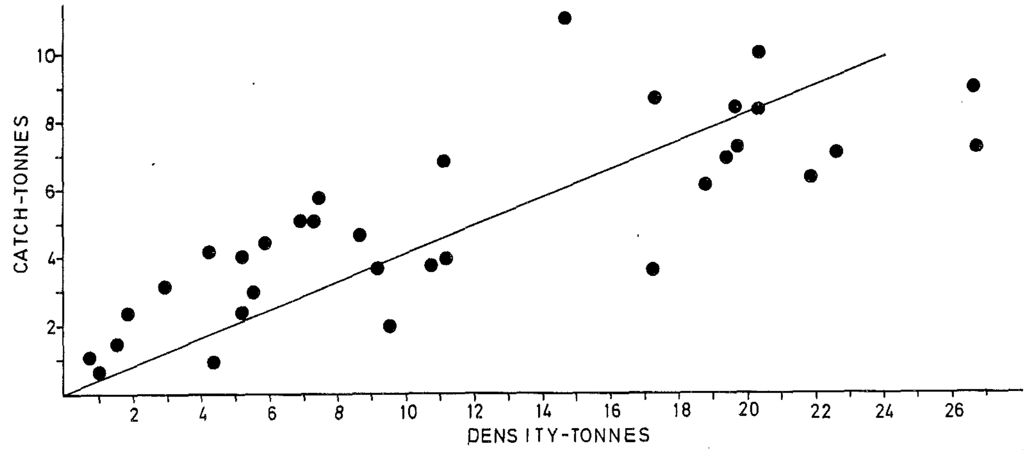

Fig. 13. Relation between fish density in the track of the trawl estimated by echo integration, and catch in the trawl.

A linear functional regression was fitted to the data. The regression goes through the origon and has a slope of 0.4 indicating that an average of 40% of the fish found in the track of the trawl are caught, i.e. that the trawl efficienty is 40%.

EGGS AND EARLY LARVAL STAGES OF B. PTEROTUM

The main objectives of the egg and larval investigations during the present survey were to study the spawning biology of B. pterotum, which have not been described previously.

The size distribution of B. pterotum eggs from Juday net samples is presented in Fig. 14. The diameter varied between 1.00-1.24 mm, which was within the size range found in artificially fertilized eggs (Aglen et al. 1982).

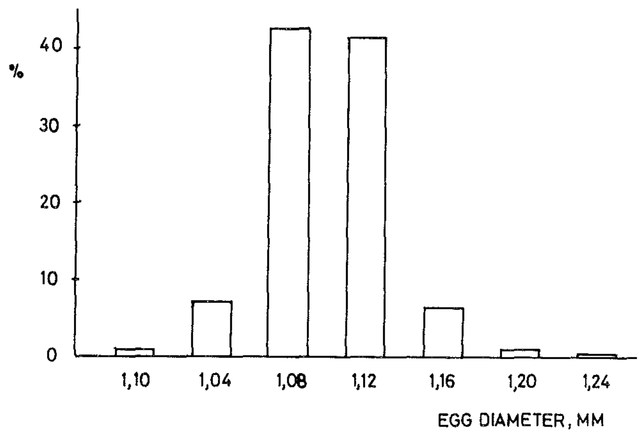

Fig. 14. Size distribution of B. pterotum eggs, sampled by Juday net (80 cm, 350 μm mesh size). Gulf of Oman 15-21 Feb. 1983.

The vertical distribution of B. pterotum and other fish eggs is presented in Table 9. These results show that the main distribution of B. pterotum eggs is between 300-100 m depth. The table also shows that B pterotum eggs outnumber all other pelagic fish eggs, which in contrast were found at the highest concentrations in the upper 100 m of the water column.

Table 9. The vertical distribution of Benthosema pterotum eggs and other fish eggs (unidentified) in numbers per m^3. Sampled by Juday net (80 cm, 350 µm mesh size) in vertical broken hauls, 8 hauls per depth interval. Gulf of Oman 15 Feb. to 21 Feb. 1983.

Depth meters	B. pterotum eggs/m^3	Other fish eggs/m^3
50 - 5	0	4.1
100 - 50	0.6	5.9
200 - 100	22.1	1.9
300 - 200	14.0	0.1

Table 9 indicate that B. pterotum spawn between 300-100 m depth, most probably between 300-200 m. This is demonstrated in Fig. 15, showing the echogram of the distribution of B. pterotum in NI and NII layers, when a series of Juday net hauls were made at 22 hour 17 February. The main distribution of B. pterotum in the NII layer was below 200 m depth.

The result of the buoyancy measurement of newly fertilized eggs gave a mean neutral buoyancy at 33.6 ^{o}/oo salinity. The hydrographic measurements presented in Fig. 18 show that the sea water at depths where B. pterotum eggs were found have a higher salinity than the neutral buoyancy of the eggs. This means that the eggs slowly ascend towards the surface. No eggs were, however, found in the upper 50 meters. This can be explained from the results on the study of incubation period, showing that eggs will hatch within 16 hours at 20 ^{o}C, 10 hours at 25 ^{o}C (Aglen et al. 1982) and 12 hours at 21 ^{o}C. This means that B. pterotum eggs will hatch in the deeper watermasses.

The vertical distribution of B. pterotum larvae and other fish larvae are presented in Table 10. The table shows that B. pterotum was found at about 10 times higher concentrations than all other fish larvae in all depth intervals. The main distribution of B. pterotum larvae were found in the upper 50 meters. However, as shown by Table 9 a substantial concentration of larvae were also found in the deeper intervals.

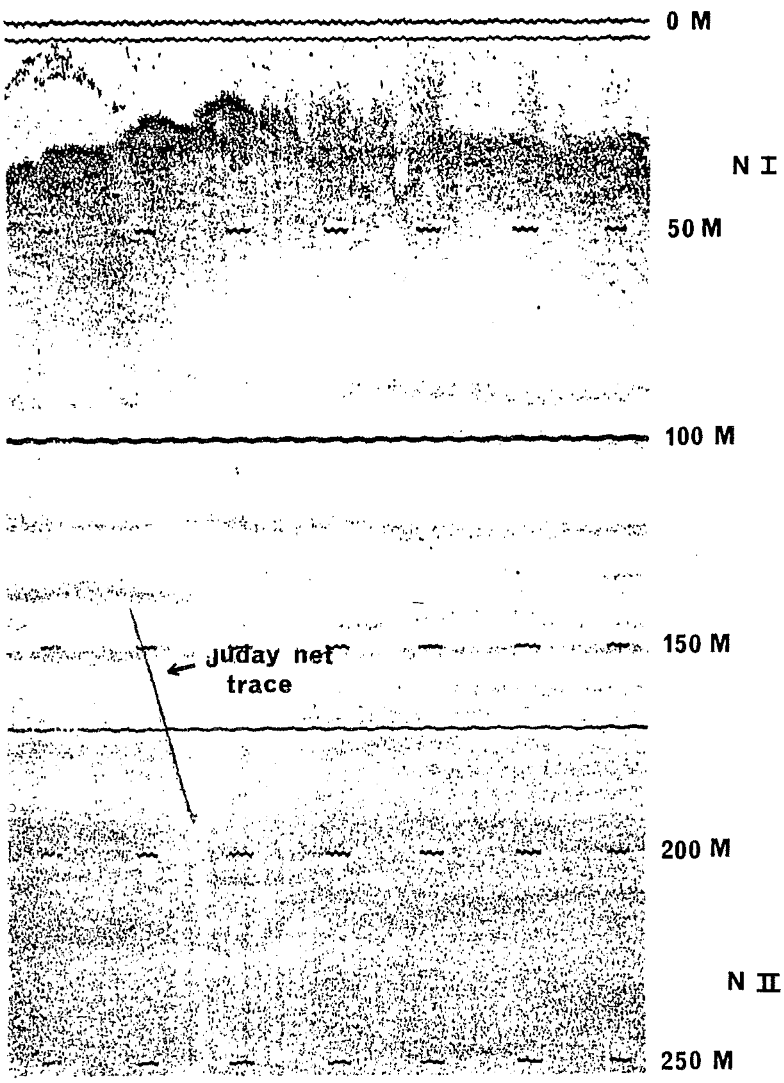

Fig. 15. Echogram showing the distribution of B. pterotum in N I and N II layers, when a series of Juday net samples were made in the Gulf of Oman 17 Feb. at 22 hours.

Table 10. The vertical distribution of Benthosema pterotum larvae and other fish larvae (unidentified) in numbers per m^3. Sampled in broken vertical Juday net (80 cm, 350 µm mesh size) hauls, 8 hauls per depth interval. Gulf of Oman 15 Feb. to 21 Feb. 1983.

Depth meters	B. pterotum larvae/m^3	Other fish larvae/m^3
50 - 5	54.1	5.3
100 - 50	11.1	1.6
200 - 100	6.7	0.7
300 - 200	9.0	0.1

The size distribution of B. pterotum larvae found in the different depth intervals are presented in Fig. 16. This demonstrates that the smallest larvae are found in the deepest layers, showing that the eggs hatch before they reach the surface. The larvae ascends (by positive buoyancy) or migrates towards the surface. No yolksac larvae were, however, found in samples from the upper 50-5 m hauls. Larvae from artificially fertilized eggs still had remains of yolk after 5 days post hatching.

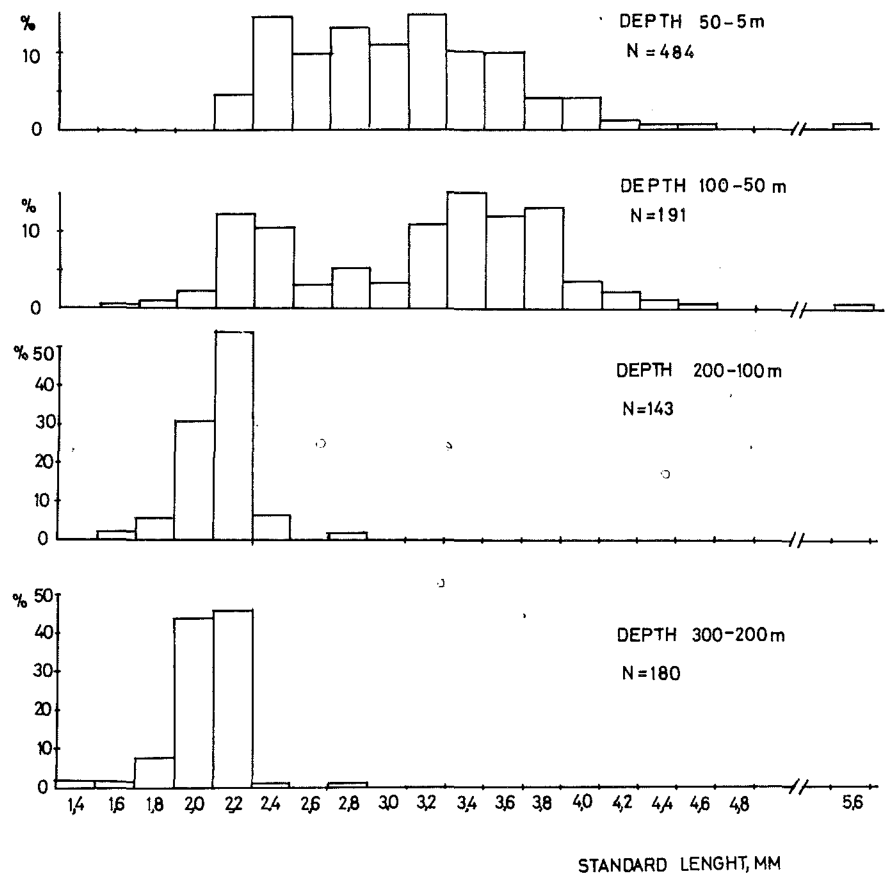

Fig. 16. Size distribution of B. pterotum larvae from different depths, sampled by Juday net (80 cm, 350 μm mesh size). Gulf of Oman 15-21 Feb. 1983.

The youngest larvae will consequently stay in deeper watermasses during the most vulnerable period.

Conclusions

B. pterotum eggs were only found in Juday net hauls made after sunset and in the early morning hours (Aglen et al. 1982). All eggs sampled after sunset was in the very first cleavage stages. When comparing the vertical distribution of B. pterotum eggs (Table 9) and the distribution of B. pterotum from the echograms, it becomes quite clear that B. pterotum spawn in the NII layer and that spawning occurs during the early night hours.

No yolksac larvae were found in the upper 50 meters of the water column. The larval size distribution in samples from different depth intervals shows that the most vulnerable stages stay in the deeper watermasses.

HYDROGRAPHICAL OBSERVATIONS

The hydrographical conditions in the Gulf of Oman during the survey appear from Fig. 17. The stations were worked along a section from the middle of the Gulf towards the continental slope of Oman (see Fig. 1). This section were occupied at the same positions as during the 1981 survey reported by Aglen et al. (1982, see Fig. 23 B).

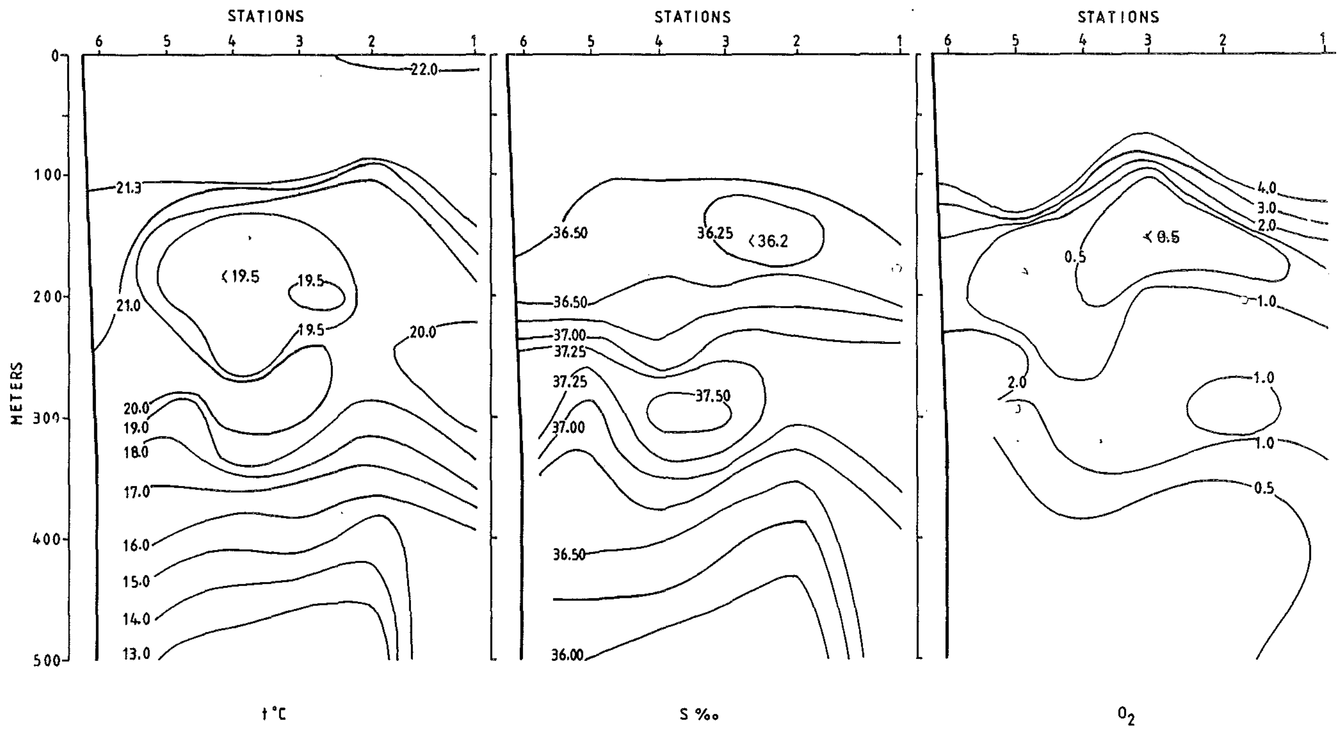

Fig. 17. Hydrographical section in the Gulf of Oman, February 1983.

The hydrographical features in the Gulf of Oman during the present survey was very similar to the conditions observed in winter 1981. The surface layers were well mixed down to about 120 m depth. The temperature was, however, about 1.5 ^{o}C colder in this mixed layer compared to 1981.

Below the thermocline a core of colder less saline water was observed. The origin of this watermass is uncertain. However, below this core the influence of Persian Gulf water was observed in a tongue of water close to the continental slope with higher temperature and salinity than the surrounding watermasses. Both temperature and salinity decreased down to 500 m depth, with temperature and salinity conditions not different from that observed in 1981.

The distribution of the oxygen of the watermasses followed that of the temperature as in 1981. The upper well mixed layers had >5 ml O_2/l, and the highest gradients were found in the thermocline. A core of water with very low oxygen content (<0.5 ml/l) was found just below the thermocline between about 100 - 200 m depth. Similar features were observed in 1981.

The main difference between the hydrographical conditions observed during the present survey and the survey made during the same period in 1981, was that the temperature in the mixed layer was 1.5 ^{o}C colder.

The temperature, salinity and oxygen profiles in the area where the ichthyoplankton investigations (station 7) and the main trawl tows (station 8) were taken, are presented in Fig. 18A and B respectively. Both diagrams show the position of the thermocline between 120-150 m depth with a temperature and oxygen minimum layer at about 200 m depth, and increasing temperature, salinity and oxygen toward 300 m depth. The main distribution of mesopelagic fish in NII layer was found between 200-300 m depth.

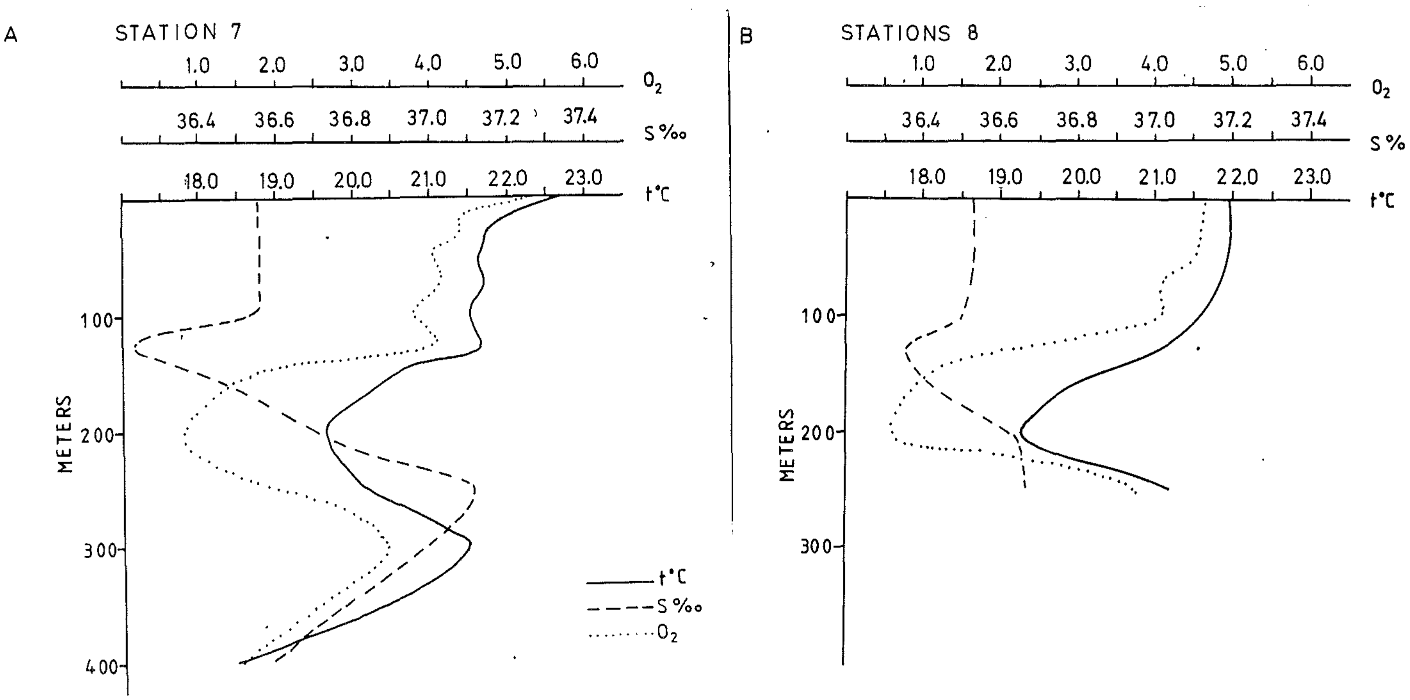

Fig. 18. Hydrographical stations in the Gulf of Oman 1983. See Fig. 1 for locations.

BIOLOGICAL OBSERVATIONS

Size and growth

The length distribution of B. pterotum is shown in Fig. 19. The largest mode, comprising fish between about 30 and 45 mm (SL) with a median of about 35 mm, is similar to the size distribution found in 1981 (Aglen et al. 1982). The smallest fish (10-25 mm) which were caught mainly in the N I layer, were not represented in 1981, but were much more abundant in

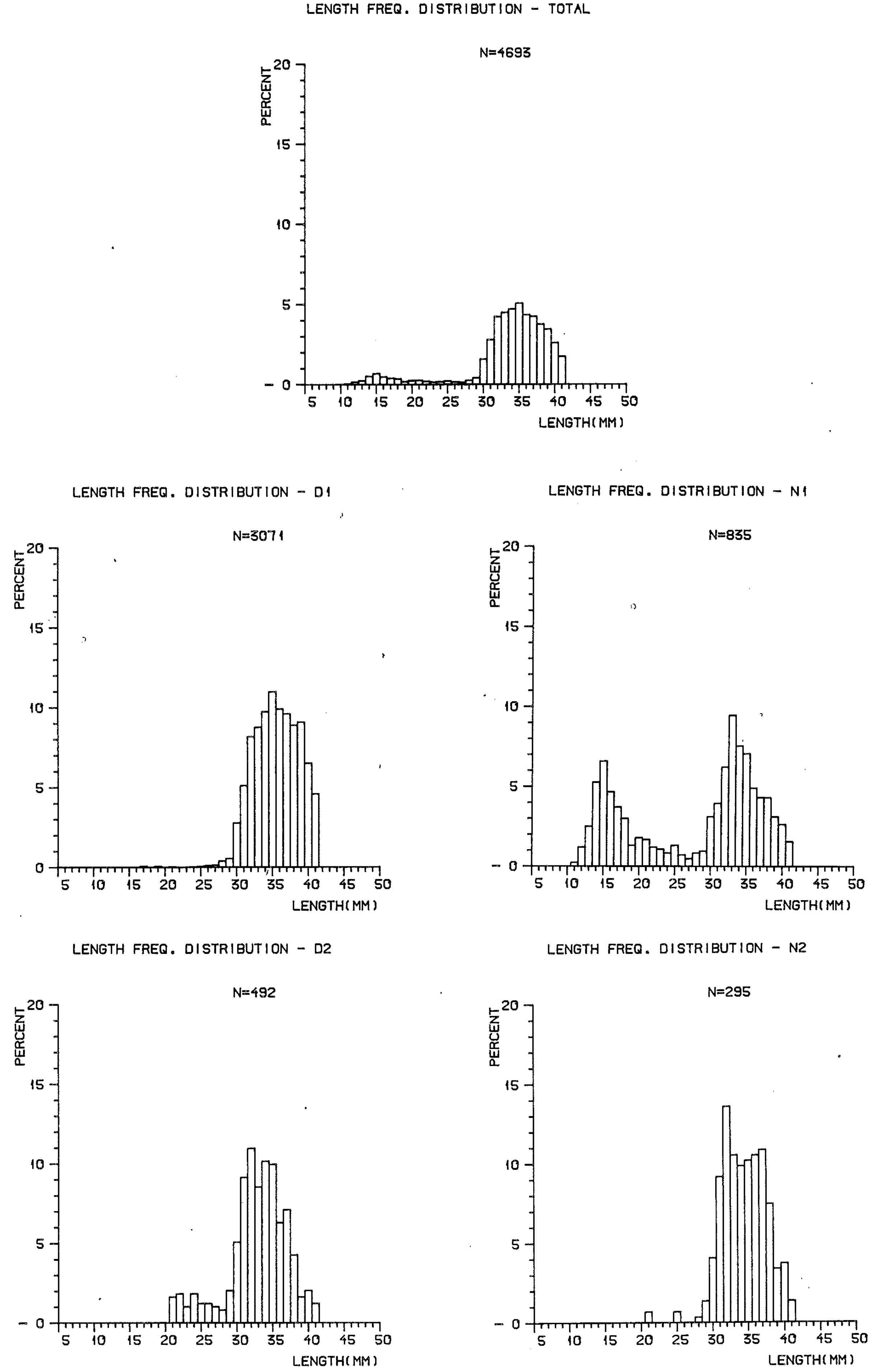

Fig. 19. Length distribution of B. pterotum from the Gulf of Oman, February 1963. A. Total material. B-E. Fish caught in layers D I, D II, N I and N II respectively.

1979. The average size in the samples from February 1983 was 34.0 mm. The corresponding values for 1979 and 1981 were 30.5 and 36.7 mm respectively.

Age was determined, using daily growth rings in otoliths of a few samples with a total of 80 fish (Fig. 20). Based on this a von Bertalanffy's growth equation was fitted.

$$l_t = 67.6\text{mm}\ (1 - e^{-1.56(t\ -\ 0.01)})$$

This indicates a somewhat higher growth rate than that found by H. Gjøsæter (1981) and Gjøsæter (1981a).

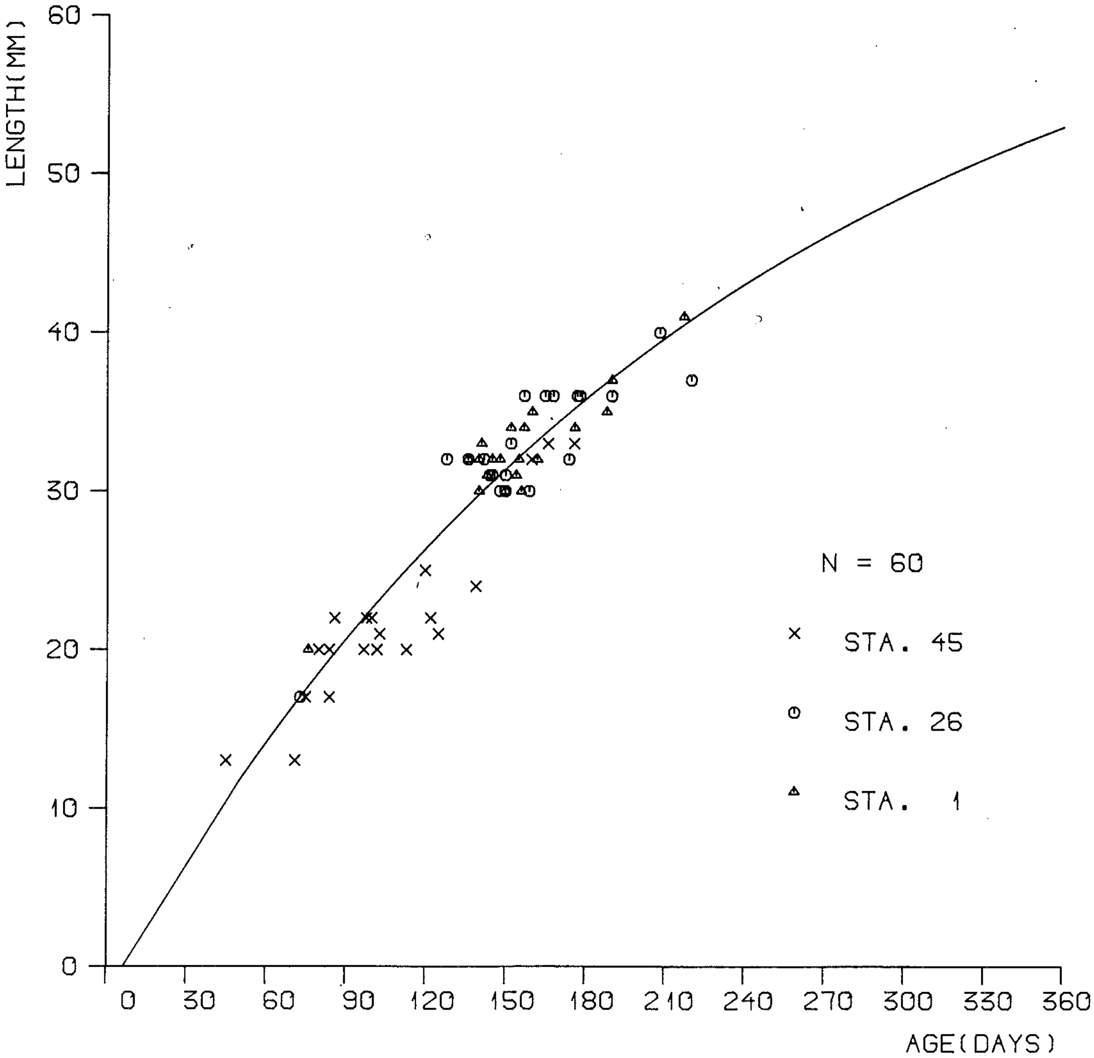

Fig. 20. Age of B. pterotum as estimated from counting primary growth rings. The curve shows the von Bartalanffy equation fitted to the data.

Stomach contents

About 350 stomachs were opened to study the composition of their content. Copepods were the main food items, both in numbers and volume, with Larvaceans ranking next (Table 11).

Table 11. Stomach contents of B. pterotum from the Gulf of Oman, February 1983.

Food item	Occurrence of fish with that food item No.	%
Copepods	255	94
Euphausiids	16	6
Ostracods	1	-
Crustacean larvae	36	13
Amphipods	6	2
Bivalv larvae	16	6
Gastropods	18	7
Squid larvae	1	-
Chaetognats	7	3
Larvaceans	89	33
Fish	4	1
Polychaets	2	-
No. with identifiable contents	272	

Dalpadado (1983) studied the material in more details. She concludes, based on size distribution of the copepods eaten, that they are mainly herbivorous as are the larvaceans. It seems, therefore, that B. pterotum mainly prey on the second trophic level.

Feeding chronology generally followed the pattern described by Gjøsæter (1981a) (Dalpadado 1983).

Sex and maturity

About 540 fish were sexed, of these 55% were females and 45% males. Of 28 trawl stations analysed, 7 gave significantly more females than males, 3 significantly more males and 18 showed no significant difference.

The distribution of maturity stages is shown in Table 12. For a description of the stages, see Dalpadado (1983).

A total of three fishes were observed, which could be previous spawners, but the results are not conclusive.

Table 12. Distribution of maturity stages of B. pterotum from the Gulf of Oman, February 1983 (% in each stage).

	Females	Males
Immature	5	6
Developing	17	23
Mature	32	49
Ripe	35	22
Spawning	10	

Although the studies of egg distribution show that the fish spawn in the N II layer, no difference in maturity stages could be found between the different layers.

A more detailed study of the sex and maturity is presented by Dalpadado (1983).

REFERENCES

Aglen, S., J. Gjøsæter, B. Myrseth and S. Tilseth, 1982. Surveys of mesopelagic fish resources in the Gulf of Oman and the Gulf of Aden Jul-Aug 1979 and Jan-Feb 1981. Rept. Surv. R/V "Dr. Fridtjof Nansen". Bergen 1982. 70 pp.

Dalpadado, P. 1983. Aspects of the biology of Benthosema pterotum from the Indian Ocean. M.Sc. thesis. University of Bergen.

Coombs, S.M. 1981. A density-gradient column for determining the specific gravity of fish eggs, with particular reference to eggs of the mackerel, Scomber scombrus. Mar. Biol., 63: 101-106.

Gjøsæter, H. 1981. Dagsonelesning som metode i aldersstudier på fisk. Cand.real. thesis. University of Bergen. 172 pp.

Gjøsæter, J. 1981a. Abundance and production of lanternfish (Myctophidae) in the western and northern Arabean Sea. Fisk. Dir. Skr. Ser. HavUnders., 17: 215-257.

Gjøsæter, J. 1981b. Review of the mesopelagic fish resources of the Arabian Sea. FAO/GCP/INT/368(NOR): 1-32.

Gjøsæter, J. and Myrseth, B. 1980. Mengdemåling og fangst av mesopelagiske fisk. Rept. to NORAD. University of Bergen. 52 pp.

Myrseth, B. in prep. Mesopelagic fishes from the coast of Pakistan.

Schärfe, J. 1983. Report on midwater trawling trials for lanternfish with R/V Dr. Fridtjof Nansen in the Gulf of Oman 9 Feb. to 1 March 1983. Rept. to FAO. In prep.

Svåsand, T. 1983. Populasjonsmodell for fish med kort livssyklus med anvendelse på en tropisk myctophidae. Cand.Scient. thesis, University of Bergen. 64 pp.

ANNEX 1

Scientific and technical staff:

H. Abrahamsen
B. Bakken
J. Gjøsæter
S. Tilseth
H. Ullebust

ANNEX 2

Records of fishing operations.

DATE	TIME START	STN No.	GEAR TYPE	DEPTH (M) BOTTOM	GEAR	POSITION NORTH	EAST	CATCH (KG) TOTAL	PR HR	DOMINANT SPECIES	WEIGTH (KG) PR HR	%
14.02	1245	1	PT	>500	320	24°45'	057°58'	35,0	26,2	Benthosema pterotum	18,00	68,7
										Krill	5,25	20,0
										C E P H A L O P O D A	1,50	5,7
										Champsodon sp.	,52	1,9
15.02	1358	2	PT	220	140	24°42'	056°49'	750,0	500,0	Benthosema pterotum	500,00	100,0
15.02	1715	3	PT	150	150	24°42'	056°48'	2010,0	3015,0	Benthosema pterotum	3000,00	99,5
16.02	1052	4	PT	287	167	24°32'	056°57'	105,0	94,5	Benthosema pterotum	67,50	71,4
										Trichiurus sp.	13,50	14,2
										JELLYFISH	13,50	14,2
16.02	1418	5	PT	354	170	24°40'	056°58'	1500,0	1500,0	Benthosema pterotum	1500,00	100,0
16.02	1735	6	PT	305	220	24°38'	056°56'	200,0	400,0	Benthosema pterotum	260,00	65,0
										JELLYFISH	130,00	32,5
										Miscellaneous	10,00	2,5
17.02	0717	7	PT	293	120	23°56'	057°54'	4200,0	4116,0	Benthosema pterotum	4116,00	100,0
17.02	1023	8	PT	265	168	23°55'	057°52'	1080,0	756,0	Benthosema pterotum	756,00	100,0
17.02	1423	9	PT	266	150	23°58'	057°45'	2400,0	2400,0	Benthosema pterotum	2400,00	100,0
17.02	1640	10	PT	329	137	24°00'	057°44'	10,0	6,1	Benthosema pterotum	6,10	100,0
18.02	0738	11	PT	>500	126	24°02'	058°02'	230,0	213,9	Benthosema pterotum	153,45	71,7
										JELLYFISH	60,45	28,2
18.02	0955	12	PT	425	250	23°56'	057°56'	356,0	356,0	Benthosema pterotum	300,00	84,2
										PARALEPIDIDAE	25,00	7,0
										C E P H A L O P O D A	4,00	1,1
										Trichiurus sp.	5,00	1,4
18.02	1431	13	PT	467	140	24°00'	057°50'	1530,0	1040,4	Benthosema pterotum	1040,40	100,0
18.02	1710	14	PT	446	125	23°59'	057°48'	2000,0	1600,0	Benthosema pterotum	1600,00	100,0
18.02	1927	15	PT	480	200	24°02'	057°49'	65,0	86,4	Benthosema pterotum	73,15	84,6
										Harpodon sp.	5,32	6,1
										Trichiurus sp.	5,32	6,1
										JELLYFISH	2,66	3,0
19.02	0705	16	PT	320	90	23°58'	057°47'	7000,0	4410,0	Benthosema pterotum	4410,00	100,0
19.02	1016	17	PT	421	126	24°03'	057°43'	300,0	189,0	Benthosema pterotum	132,30	70,0
										JELLYFISH	56,70	30,0
19.02	1305	18	PT	320	150	23°57'	057°45'	3010,0	3010,0	Benthosema pterotum	3010,00	100,0
19.02	1504	19	PT	310	110	57°45'	023°59'	5700,0	5700,0	Benthosema pterotum	5700,00	100,0
19.02	1655	20	PT	303	80	23°59'	057°42'	9000,0	18000,0	Benthosema pterotum	18000,00	100,0
19.02	1915	21	PT	297	10	23°58'	057°56'	105,0	210,0	Benthosema pterotum	100,00	47,6
										JELLYFISH	100,00	47,6
										CARANGIDAE	10,00	4,7
20.02	0905	22	PT	315	105	23°57'	057°51'	4400,0	5588,0	Benthosema pterotum	5588,00	100,0
20.02	1121	23	PT	311	124	23°57'	057°50'	6900,0	3933,0	Benthosema pterotum	3933,00	100,0
20.02	1418	24	PT	255	100	23°55'	057°53'	4600,0	4600,0	Benthosema pterotum	4600,00	100,0
20.02	1345	25	PT	300	105	23°59'	057°45'	10000,0	8200,0	Benthosema pterotum	8200,00	100,0
20.02	1945	26	PT	350	10	23°57'	027°49'	217,5	435,0	Benthosema pterotum	20,00	4,5
										Decapterus sp.	14,00	3,2
										JELLYFISH	400,00	91,9
21.02	0733	27	PT	264	110	23°57'	057°55'	5100,0	2448,0	Benthosema pterotum	2448,00	100,0
21.02	1125	28	PT	>500	120	23°55'	058°00'	3700,0	8880,0	Benthosema pterotum	8880,00	100,0
21.02	1431	29	PT	413	90	24°01'	057°51'	3900,0	2496,0	Benthosema pterotum	2496,00	100,0
21.02	1653	30	PT	300	80	23°57'	057°48'	7300,0	5840,0	Benthosema pterotum	5840,00	100,0

DATE	TIME START	STN No.	GEAR TYPE	DEPTH (M) BOTTOM	GEAR	POSITION NORTH	EAST	CATCH (KG) TOTAL	PR HR	DOMINANT SPECIES	WEIGTH (KG) PR HR	%
21.02	2055	31	PT	430	10	23°59'	057°51'	47,0	94,0	Benthosema pterotum	10,00	10,6
										JELLYFISH	80,00	85,1
										Decapterus sp.	4,00	4,2
22.02	0746	32	PT	310	110	23°58'	057°45'	3100,0	1023,0	Benthosema pterotum	1023,00	100,0
22.02	1316	33	PT	238	110	23°55'	057°50'	11000,0	4510,0	Benthosema pterotum	4510,00	100,0
22.02	1655	34	PT	244	100	23°55'	057°55'	8700,0	10005,0	Benthosema pterotum	10005,00	100,0
22.02	1905	35	PT	316	1	23°55'	057°51'	30,0	60,0	Benthosema pterotum	60,00	100,0
22.02	2250	36	PT	370	200	24°05'	057°35'	320,0	320,0	Benthosema pterotum	18,00	5,6
										JELLYFISH	300,00	93,7
23.02	0705	37	PT	340	100	24°14'	057°12'	5100,0	4335,0	Benthosema pterotum	4335,00	100,0
23.02	1548	38	PT	279	140	24°36'	056°56'	3600,0	2376,0	Benthosema pterotum	2376,00	100,0
23.02	1900	39	PT	300	10	24°32'	056°58'	35,0	70,0	Benthosema pterotum	10,00	14,2
										JELLYFISH	60,00	85,7
23.02	2015	40	PT	300	215	24°33'	056°57'	38,0	76,0	Benthosema pterotum	10,00	13,1
										JELLYFISH	60,00	78,9
										SCIAENIDAE	4,00	5,2
										Trichiurus sp.	2,00	2,6
24.02	0726	41	PT	323	110	24°32'	057°01'	1100,0	1221,0	Benthosema pterotum	1221,00	100,0
24.02	1016	42	PT	436	135	24°34'	057°04'	600,0	570,0	Benthosema pterotum	570,00	100,0
24.02	1248	43	PT	>500	300	24°38'	057°03'	35,0	70,0	Benthosema pterotum	4,50	6,4
										JELLYFISH	60,00	85,7
24.02	1600	44	PT	305	130	24°21'	057°04'	6100,0	6100,0	Benthosema pterotum	6100,00	100,0
24.02	1850	45	PT	302	10	24°23'	057°01'	141,0	282,0	Benthosema pterotum	200,00	70,9
										JELLYFISH	80,00	28,3
24.02	2140	46	PT	340	10	24°15'	057°10'	41,0	82,0	Benthosema pterotum	60,00	73,1
										JELLYFISH	20,00	24,3
										TRICHIURIDAE	2,00	2,4
25.02	0458	47	PT	336	40	24°01'	057°41'	5600,0	5600,0	Benthosema pterotum	5600,00	100,0
25.02	0652	48	PT	330	40	23°59'	057°44'	6900,0	3174,0	Benthosema pterotum	3174,00	100,0
25.02	1011	49	PT	329	110	24°02'	057°37'	6300,0	1953,0	Benthosema pterotum	1953,00	100,0
25.02	1408	50	PT	349	80	23°59'	057°44'	3800,0	2432,0	Benthosema pterotum	2432,00	100,0
25.02	1706	51	PT	>500	70	24°01'	057°40'	7230,0	5784,0	Benthosema pterotum	5760,00	99,5
25.02	1953	52	PT	335	28	23°59'	057°43'	3500,0	1750,0	Benthosema pterotum	1750,00	100,0
25.02	2353	53	PT	333	43	24°04'	057°35'	2060,0	2060,0	Benthosema pterotum	2000,00	97,0
										JELLYFISH	50,00	2,4
26.02	0139	54	PT	340	30	24°00'	057°43'	4620,0	2310,0	Benthosema pterotum	2310,00	100,0
26.02	0427	55	PT	345	30	24°03'	057°37'	1900,0	1900,0	Benthosema pterotum	1900,00	100,0
26.02	0622	56	PT	343	35	24°02'	057°39'	8400,0	4704,0	Benthosema pterotum	4704,00	100,0
26.02	0905	57	PT	352	120	24°04'	057°34'	200,0	400,0	Benthosema pterotum	360,00	90,0
										Lestidium sp.	20,00	5,0
										Trichiurus sp.	20,00	5,0
26.02	1400	58	PT	200	130	23 55	058 04	50000,0	99999,9	Benthosema pterotum	100000,0	100,0