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Variation in the Pattern of Fish Aggregation

Daily vertical migration patterns of Baltic 0-group cod

by

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ABSTRACT

From 1993 to 1997 investigations were carried out in the Bornholm Sea concerning the occurrence and the daily vertical migration patterns of pelagic and settled 0-group cod. These investigations were a part of the EU project CORE. On 8 cruises with R/V „Solea" trawls were carried out in the time interval from September to November in areas where it was expected that juvenile cod settled. The water depth at the investigated stations varied between 20 to 70 meters. At the stations the different layers of the water column were exploited with midwater and bottom trawls both at daylight and nighttime The main emphasis of this paper lies in the representation and discussion of those catches which used a Isaacs-Kidd-Midwater-Trawl (IKMT).

The catches with this trawl shown a clear change in the daily migration pattern of the growing juvenile cod. The migration is related closely to the settling process of the cod which starts with a total length of about 4 cm and is completed at about 7 cm. The small pelagic stages (2 - 4 cm) were observed predominantly at daytime in the upper water layers and by night in the deeper layers or close to the bottom. Hauls in different depth layers from the surface down to about 65 meter proved that the pelagic cod sank as deep as 60 meter at night. These cods entered at this migration the cold deep water layer below the termocline region in 30 to 40 meter depth.

Individuals with a total length of more than 5 cm (settled stages) rarely were observed in the upper water region at daytime and by night. At night the catches of this length group increased clearly in hauls within the depth zone of 3 to 6 meter above the bottom. This pattern of the settled stages can be explained by a life very close to the bottom at daytime and a partial upward migration of these individuals at night. Possible reasons of these migration patterns (survival strategy) as well as the importance of these results for the 0-group cod surveys will be discussed.

Key words: juvenile cod, Baltic Sea, IKMT, vertical migration

1. Introduction

Within a project funded by the EU investigations were carried out about the recruitment mechanism of the Baltic cod between 1994 and 1997. Starting point for this multi national project was the dramatic decrease of the eastern Baltic cod stock during the '80s, which reached a historical low in 1992.

The recruitment of a fish stock is decisively influenced by the development success of the early life stages. On one hand these stages are very sensitive in opposite to unfavourable hydrographical conditions, on the other hand these stages are essentially influenced by predators because the escape reaction of these small individuals is low.

About the number of eggs and larvae of the eastern Baltic cod extensive investigations (Wieland 1995) were carried out. From these investigations and analyses of the spawning time it can be concluded, that the main spawning activities as well as the egg and larvae development of the eastern cod stock can be observed between May and September.

Only a few investigations about the following development phases of the cod from the post larvae to the juvenile fish were carried out until today. Field investigations of these development stages are difficult. Only after the transition to the demersal oriented life the juvenile cods can be observed again regular in bottom trawls. It seems, that the pelagic stages are spread widely with relative low densities in the eastern Baltic Sea. Small plankton nets (Bongo, Multinet) do not catch these individuals. Additionally the swimming velocity of these cods make successful escape reactions possible. The use of larger pelagic trawls with large mesh sizes in the pre-net and small meshes within the cod end is not suited for successful observations as found in preliminary examinations.

The trawls have a high catchability concerning medusae, which occur in high densities, and the pelagic fish species like herring and sprat. Within catches of such larges dimensions often the small cods are not found. Out of that there are indices, that these juvenile individuals escape from the wide-meshed pints in the front.

This paper deals with results obtained of six research cruises in the Baltic Sea during the years 1993 - 1997. With different pelagic trawls and with bottom trawls catches were carried out at special selected positions at day and night. These analyses were concentrated on the results of the Isaacs-Kid-Midwater-Trawl (type IKMT 1150/12-04a). This trawl was planned specifically for the catch of small individuals.

The principal aim of the present study was the investigation of the vertical distribution and vertical migration patterns of 0-cod during the pelagic phase and during the time of the transition to the demersal habitat.

The knowledge of these migration patterns is a condition for the design and interpretation of surveys investigating these pelagic stages.

Although only a relatively small number of cod was caught, it is possible to derive statements about the vertical and diurnal migration patterns from these investigations.

2. Material and Methods

Time and area of investigations

The investigations were carried out between 1993 and 1996 using the r/v „Solea". In each year one cruise started between the end of October and the beginning of November. Additionally cruises were carried out in September of 1994 and 1995. The essential information about those cruises are summarised in Table 1. The focus area on all cruises was the Bornholm Sea. This area is one of the main spawning areas of the eastern Baltic cod stock. If it was timewise possible, stations were investigated also within the more western Arkona Sea. Figure 1 shows the area and the stations of investigation.

The used trawl

For the described experiments the Isaacs-Kid-Midwater-Trawl (IKMT 1150/12-04a) was used. The IKMT is a small trawl, which is easy to handle. Only one dragline is required for the tow of the IKMT. The set out and the heaving of the gear is little time consuming. The spreading of the 6 m² net mouth was caused by a beam in combination with a depressor for the lower direction.

Figure 2 shows the used form of the IKMT with the essential parameters. The mesh size of the trawl was chosen for the catch of fish with a total length of more than 2.5 cm. The tow speed of the ship was 4 kn.

Methods of sampling and analyses

The IKMT hauls were a part of a special design program. In the frame of the program it was fished on stations at several positions with the IKMT and additionally with a pelagic and a bottom trawl. For the sequence of the hauls a constant temporal design was used. The hauls between 11 and 16 o'clock (UTC) were repeated at the same position in darkness between 18 and 23 o'clock (UTC). From the total 8 hauls with the IKMT 4 hauls were chosen within the layer close to the surface (10 - 20 m depth). The other 4 hauls were used to observe the depth range close to the bottom (3 - 8 m above the bottom).

At the seven cruises between 1993 and 1997 this program was repeated 54 times. The positions and depths of the used stations are given in Table 2 and Figure 1. The trawl duration was 30 minutes normally. All catches were analysed concerning the species and size composition. The results of the hauls were converted in catch per hour for a better comparability.

The following time table gives a description the daily program at each station.

11:00 - 12:30 UTC	both, one IKMT haul within the pelagic layer (10 - 20 m), as well as in the layer close to the bottom, hydrographical measurements
12:30 - 14:15 UTC	one haul with the pelagic trawl within the surface layer (10 - 20 m) as well as with a bottom trawl
14:15 - 16:00 UTC	both, one IKMT haul within the pelagic layer (10 - 20 m), as well as in the layer close to the bottom
18:20 - 19:30 UTC	both, one IKMT haul within the pelagic layer (10 - 20 m), as well as in the layer close to the bottom, hydrographical measurements
19:30 - 21:15 UTC	one haul with the pelagic trawl within the surface layer (10 - 20 m) as well as with a bottom trawl
21:15 - 23:00 UTC	both, one IKMT haul within the pelagic layer (10 - 20 m), as well as in the layer close to the bottom

The positions for these experiments were chosen within areas with water depth between 20 and 80 meters. The results of the analyses are summarised and presented for areas with different water depths. The following strata were chosen: 20 - 30 m, 31 - 60 m and 61 - 80 m. The separation of the depth areas with more than 60 m is chosen with look on the settling process of the growing juvenile cod. It is common knowledge, that the preferred settling area is located at water depth of less than 60 m (Kändler 1949). Therefore it is assumed, that the

vertical excurions are limited predominantly on the area above 60 m. In this case the inclusion of deeper stations must falsify the results.
Also the stations with less than 30 metres water depth were separated because the differences between the upper and the lower layer of the IKMT hauls were only about 12 m. In these cases depth depending differences of the fish densities can probably not be detected clearly. At the used sampling strategy we hoped to find in the depth area 30 - 60 m the clearest references for the vertical migration behaviour.

Statistical analyses

Statistical analyses of the repeated IKMT hauls were carried out in order to detect the vertical migration patterns of the juvenile cods. The aim of these investigations was to find the best time of the day and the best depth layer for a survey of the horizontal distribution of pelagic 0-group cod.
For the statistical analyses only the results from those positions with a water depth between 31 and 60 metres were chosen.
A main problem of this investigation were the very high number of stations with zero catches on all four positions (absences of juvenile cod). Only at some stations in all years and areas juvenile cod could caught with the IKMT. One cause for this can be the not optimal time of the surveys.
An other problem for the statistical analyses was that not on all stations hauls could be carried out for all of the four features / factors. Furthermore stations with high densities of juvenile pelagic cod could not be found for the observation of the migration pattern on a long run station in all surveys
Because the hauls were carried out at the same stations paired samples could be formed. It was assumed, that the density of the juvenile cods did not change between the first anf last hauls of the station.

For the same stations the paired difference of the hauls was calculated for each length interval.

D(j,d) = O(j,d) - B(j,d)

j	index of the station
d	index for day trawls
n	index for night trawls
O	index for surface layer
B	index for near bottom layer

This paired differences can be used to examine the hypotheses
Ho: E(D(j,d)) = 0

If the paired data detect a significant difference of the mean from zero it can be concluded that the densities for the observed features were significantly different.
To exclude the influence of stations which were outside of the distribution area of juvenile cod only those station were used in the analyses at which juvenile cod could be observed in at least one of the hauls. Because the number of such stations were very low within one cruise the data of all years and areas were combined.

The sequential fishery in different depth layers using the IKMT

For the experiments, which were described so far, the essential criterion was the proximity of the juvenile cods to the surface or to the bottom. In order to analyse the vertical migration patterns with a higher vertical resolution an additional sampling program was realised.

These experiments were carried out on the 396th „Solea" cruise in October 1996. In all 24 IKMT hauls were performed in four series between noon and midnight on positions in the central Bornhom basin. In each series 1 haul was carried out within the depth layers of 5, 10, 20, 30, 40, 50, and 60 metres.
The information about the depth refers to the position of the net sonar below the water surface. The net sonar was mounted at the upper beam of the IKMT. The duration of each haul was constantly 15 minutes.
The used positions of these experiments were chosen depending on results of simultaneous investigations about the horizontal distribution of the pelagic 0-group cod on this cruise. The bottom depth of this station amounted 90m.

Sampling of hydrographical data

In combination with each day/night station a hydrological vertical profile was taken using a ME-OTS memory probe. This probe stored pressure, temperature and salinity for depth intervals of 1m. In addition the oxygen content was observed every 10 m.
The memory probe was calibrated before each cruise. During the cruise a comparison with a second independent measurement unit was carried out daily.

3. Results

Within the total 325 hauls of the day/night stations of all cruises 295 0-group cods of the length group 2 - 9 cm were caught. In some cases also adult cods with total lengths up to 76 cm were found. The large individuals could be observed exclusively in night catches (see Figure 3).
Table 3 summarises the results of all hauls sorted according to the 0-cod catch rates. A very high portion (about 75%) of the IKMT hauls of the day/night stations did not contain any 0-group cod. Catches with more than 6 individuals per hour were very seldom. Beside other cruise informations the mean catches per hour (CPUE) of the cruises are presented in Table 1 summarising all cruises.
On the two September cruises the lowest catches of 0-group cod were observed. The highest catch rates were found on the October cruises in 1993 and 1997. Figure 4 shows the changed number of caught 0-group cod within the two layers (surface and close to the bottom) during the day time.
The numbers of 0-group cod caught directly below the surface and close to the bottom showed clear reversal tendencies. While CPUE decreases within the surface layer from day to night, the CPUE increases within the layer close to the bottom at the same time.

Figure 5 presents the length distributions of the 0-cods on stations within the three different areas of water depth. In addition separations were done according to day and night as well as for the observed depth layers (surface, close to the bottom).

From these observations the following suggestions are possible:

Within the surface layer the CPUE values of 0-group cod clearly decrease from day to night in all areas. The individuals with a total length from 2 to 5 cm are dominant in all three depth strata.
Only single larger 0-group cod with a total length between 6 and 9 cm could be observed within the surface layer in the areas with a water depth between 31 and 60 m as well as between 61 and 80 m.

Within the layer close to the bottom the catches of the length range between 3 to 9 cm increased significantly from day to night in the areas with water depth between 31 and 60 m. Such differences could not be observed in the same layer (close to the bottom) in the regions with water depths lower than 31 m. In areas with a water depth of more than 60 m 0-group cod could not be caught close to the bottom at night, but small catches were observed at daytime.

Table 4 presents the results of the statistical analyses. The first tests showed clear differences within the migration patterns of the smaller and larger 0-group cod. Therefore the analyses were performed for the length intervals from 2 to 4.9 cm and from 5 to 9 cm separately. The juvenile cods, which were larger than 9 cm, could be observed only with low densities in the different pelagic layers. Therefore theses individuals were not included in the analyses, either. Within the parts of Table 4 the number of used stations (n), the mean differences (mean) of the catches, the standard deviation of these differences (std), the extreme values, the t-value of the t-test and the quantiles of the Student's distribution for $\alpha = 0.05$ and n-1 degrees of freedom are shown.
For the juvenile cods with a total length between 2.0 and 4.9 cm the density is significantly higher ($P<0.05$) at the surface during daytime. At night no significant differences in the catches were found. Furthermore the catches at the surface were significantly higher during the day than in the night ($p<0.05$).

The distribution patterns of the juvenile cods with a total length between 5.0 and 9.9 cm are different compared to the smaller individuals. At daytime the density of these cods is higher in the surface layer and decreases at night. During the darkness the catches close to the bottom are significantly higher ($p<0.05$) than at day time. The catches of the night close to the bottom were also higher than in the surface layer at the same time.

Figure 6 shows the results of the IKMT hauls, which were carried out in seven depth layers of stations within the central Bornholm Basin. During the 24 hauls xxx 0-group cods were caught. The total lengths of theses individuals ranged from 22 to 55 mm. The cods were found predominantly at daytime within the layer between the surface and the depth of 30 m. During the night they were found down to a depth of 65 m.

The hydrographical situation of these stations is shown in Figure 7. The data describes a typical situation within the Bornholm Basin in autumn. The termocline developed in the summer is still received. It is observed near 40m. The surface layer with a temperature of 11.8 °C and a salinity of 7.1 ppt is separated by this termocline. The water body below this termocline is marked by an increasing salinity down to the bottom. The temperature of the deeper water was very variable. The layers with the warmer water are clearly indications several inflow events from the west preceding Arkona Sea within the summer. Caused by the high salinity this water replaces the cooler winter water in the Bornholm Sea.

4. Discussion

Density, vertical distribution and migration of the juvenile cods

It follows from the results of the described experiments, that the pelagic 0-group cods are distributed with very low densities in the investigated areas. In opposite to that catches with many juvenile cods (500 - 1000 individuals/hour) of the same length range could be observed within the western Baltic Sea (Mecklenburger Bucht) using the same IKMT trawl (Mieske, cruise report, RV „Solea“ 409/1997). Beside juvenile cod sprat and stickleback were caught

regularly with the IKMT in the Arkona and Bornholm Basin. These results remove all doubt, that the low numbers of caught cods within the Bornholm Sea were caused by a bad catchability of the used trawl. The observations suggest, that for the length range from 2 to 9 cm of the 0-group cod a patchiness of these individuals did not occur within the areas and the periods of investigation.
As supposed before, it was not possible to find clear results about the vertical migration patterns within areas with water a depth between 20 m and 30 m as well as between 61 m and 80 m. The very low catches below 60 m water depth confirm the experiences, that the areas with more than 60 m of water depth have a minor importance for the settling process of the pelagic juvenile cods.
A possible reason for the avoidance of water depths with more than 61 m may be the bad oxygen conditions in many cases. The occurence of areas with a oxygen deficit increased temporal and spatially in the past years in the Bornholm Basin.

From the results within areas with water depth between 31 m and 60 m clear detectable vertical migration patterns were found. Differences were observed between day and night catches for two length intervals (2 to 4.9 cm and 5 to 9 cm) of the juvenile cods.
A nightly downwards directed migration of the juvenile pelagic cods (2 to 4.9 cm) could be clearly detected from the decreased number of these individuals within the surface layer in combination with an increase of these cods in the layer close to the bottom.
The model of the migration patterns of pelagic 0-group cods was supported by the results of the hauls in different depth layers during the 381th „Solea" cruise (see Figure 6). The increasing number of these cods within the depth layer between 40 m and 60 m can not be caused by upwards migrating individuals from the bottom.

A termocline in depths between 30 m and 45m normally was observed during the hydrographical investigations at all cruises. As described before the pelagic 0-group cods (2 to 4.9 cm) migrated from the warm surface layer down to the cooler water below this termocline. From this observation it follows, that the termocline is not a barrier for the vertical migration of these juvenile cods.

The drift (direction and speed) of the two water layers separated by the termocline can be different. Therefore the vertical migration of the pelagic juvenile cods influences their drift and the time period until these cods arrive the shallow areas around the Bornholm Basin where the settling process is possible.

The mean length of the cod, which start with the settling process, is about 4.5 cm. At a length of 7 cm this process is finished in general (Böttcher & Oeberst 1996, Hüssy et al. 1995). The observed results support the assumption, that a change of the behaviour of the pelagic cod starts at a length of 5 cm. A correlation between this change in the migration pattern and the settling process is very probable.

From the results the following generally description of the migration patterns can be concluded.

<u>Juvenile cods with a total length of less than 4 cm</u> prefer the upper part of the pelagic water at day time. In the night they migrate into the deeper water layers. A migration down to 60 m was detected in the investigations. Also juvenile cods with a total length, which are larger than 4 cm take part in this migration process. If these individuals arrive at the bottom, it is possible, that longer stays at the bottom replace the daily migration.

Juvenile cods with a total length of more than 5 cm are oriented to the demersal life at the bottom after the transition and have a close relationship to the ground.They could not be caught with the IKMT during daytime. In the night these individuals dissolve direct bottom contact. But they migrate not very high and stay in the layer some metres above the bottom.

This migration pattern explains the increased portion of the larger individuals (6 cm to 9 cm) in the layer close to the bottom at night, which could not be caught at daytime whether in the surface layer nor close to the bottom.

The results of the hauls with different bottom trawls on the day/night stations support this hypothesis of the upwards directed migration of the larger juveniles. The catches with bottom gears as the beam trawl (GSN 1200/16-19, vertical net opening of 0.5 m), which works very close to the bottom, show only a small increase in the number of the larger juvenile cods from day to night. If the catches from the HG20/25 (vertical net opening of 4m) are compared between day and night, a clear increase of the caught larger juvenile cods was observed in the night. This gear does not work so close to the bottom.

For the interpretation of the differences between day and night catches the different reaction of the fishes regarding to the approaching net must be considered beside the migration pattern. The adult cod prefers the bottom layers the whole day. With the small IKMT however they were only caught in the night (Figure 3). Reasons may be the reduced optical perception or an occasionally sleepness of the fishes in the night. Therefore a successful escape is reduced.

The results, described by Bromley & Kell (1995) and found in investigations of pelagic 0-group gadidae in the North Sea, show partially an upward migration of these fishes at daytime. These results are not always unambiguous. The authors concluded, that the „vertical migration is a widespread but somewhat variable phenomena. Patterns varied between years, between species and even from day to night at the same site.“

Robb (1980) observed during investigations within the midwater (10 m to 30 m and 30 m to 50 m) in the North Sea an increase of 0-group catches at night. Between the two depth layers no differences could be detected. Furthermore the low number of catches at the bottom did not chang between daytime and night. It must be pointed out, that the water depth was 132 m within these observations, clearly deeper than within the Bornholm Basin. Furthermore the sampling frequency was relatively low.

The results of other authors, which studied the catchability of pelagic and bottom gears, indicated, that demersal juvenile gadidae have markedly migration pattern, moving away from the bottom at night and returning by day (Colton 1965, Scott 1984, Potter et al. 1989). Also the observations by Lough et al. (1989), using video technique, support these statements. They observed, that the juvenile cods with a total length between 5 cm and 13 cm stay immediately above the bottom at daytime. After the sunset a part of these individuals removes the ground and migrates in the layer between 3m to 5 m above the bottom. If the headlights were turned on, the fishes immediately returned to the ground.

Does the migration pattern influence the survival rate of the juvenile cods?

The habitat choice of species presumably a trade-off between foraging needs and predation risks (Gillian & Farser 1987, Rudstam et al. 1989)
Hüssy et al. (1997) found, that juvenile Baltic cods of a length less than 5.0 cm prey exclusively on pelagic food items such as copepods and cladocerans. Beginning at a total length of 4.0 cm a few juvenile cods began to prey on benthic organisms such as mysidis and

amphipods. Between 6.0 cm and 9.0 cm the importance of the benthic prey increased greatly. They found only very rare cods, which had pelagic as well as benthic prey types in the stomach. The transition between those two prey types occurred in the majority of the juvenile cods at a size of 4.5 to 5.5 cm. From this result an abrupt transition of the habitants follows. According to our analyses the change of the migration patterns takes place also within this length range. Juvenile cods with a total length of more than 6 cm were not caught in the midwater. According to this, it seems to be, that the nightly downward migration of the pelagic stages is not connected with the intake of the benthic prey. The transition to other prey types occurs first while longer remaining in the bottom region.

According to Jones (1978) cod is mainly optical-oriented predator. An effective predation success is therefore depending on sufficient light conditions. The mouth proportions allow its early crossing to large prey organisms (Robb & Hislopp 1979). The early transition in the direction of larger prey types reduces the energetic effort for the feeding success and produces a benefit in the growth. Such higher growth rates reduce the period in which the juvenile cods are prey for the older cod (cannibalism) or for other predator species. Therefore the following suggestion is possible, that an early transition to the demersal prey can decrease the mortality of these individuals.

At the look-up and exploration of suitable settling areas the juvenile cods penetrate the distribution area of the adult cods. These large individuals are the main predator in the Baltic Sea. For the settling process the juveniles need therefore areas in which beside prey also sufficient oxygen concentrations as well as hiding places as protection areas if predators occur are given (Gotceitas & Brown 1993).

The downward migrations of the pelagic stages are therefore also positively to see in relation to the searching of suitable settling areas. The penetration of areas with higher predator densities in the darkness influences the survival positively. According to Walsh & Hickey (1993) the activities of the adult cods is reduced to the night. Furthermore the very narrow contact of the juvenile cods with the bottom makes the optical contact by the predators at daytime difficult.

The nightly upward migration of the demersal juveniles agrees with the behaviour of other small species (gobiidae). Perhaps a relation exists to the migration pattern of the mysidacea. These species are a main component of the prey of the small demersal fishes. According to Rudstam et al. (1989) Mysis mixta leaves the bottom at night. Also the loss of the optical contact to the bottom can be the reason for the not so narrow bottom contact. The return of the juvenile demersal cods to the bottom at sudden light as observed by Lough et al. (1989) points out the essential importance of the factor light for the behaviour of the juvenile cods.

The use of the results for survey designs

It can be followed from the analyses, that IKMT surveys, which estimate the abundance of the pelagic stages of the juvenile cods in the Bornholm Sea should be carried out in the upper layer of the water column at daytime. Hauls, which observe the depth range between 10m to 30 m stepwise seem to be suitable to balance out small scaled variations of the vertical distribution. The proposed survey should be combined with furthermore observations of the vertical day/night distribution. Useable are IKMT hauls within depth layers of 10 m. These special experiments can be used to investigate possible variabilities and changes in the migration patterns. As described before the experiments only were carried out between midday and midnight. It seems to be necessary to control if the observed migration patterns are the same within the other period of the day. Some special experiments should be carried out to solve this problem.

At discussions concerning the reasons for the very low densities of the early demersal stages of the 0-group cod within the young fish trawl surveys in the Baltic Sea two possible reasons are named.
The used gear HG20/25 with a very limited contact to the bottom does not catch the individuals, which escape to the ground (Dahm et al. 1992)
Furthermore the preferred areas of the 0-group cods are located in parts of the Baltic Sea, which can not be investigated using a bottom trawl which conditional on rough bottom or the risk of the damage of gear is very high. Within the Bornholm Sea many parts with a water depth of less than 60 m have such bottom conditions.
At the young fish surveys in the Baltic Sea the hauls were carried out only at daytime per definition. The results of the IKMT hauls and the observations with the different bottom trawls support the assumption of a very narrow contact of the juveniles cods to the bottom at daytime. But it was also shown, that it is possible to observe these juvenile cods within the layer close to the bottom at night. If suitable trawls are used an investigation of these individuals is possible in areas with bad bottom conditions at night.

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Table 1: Number of IKMT hauls within the Bornholm and Arkona Sea separated for depth layers and daytime as well as the mean catch per hour between 1993 and 1996.

cruise	date	no. of IKMT-hauls				sum	CPUE
		surface near		bottom near			
		day	night	day	night		
Solea 344	22.10.-12.11.93	15	7	10	11	43	2,9
Solea 361	21.10.-04.11.94	17	19	18	20	74	0,6
Solea 377	14.09.-22.09.95	12	13	12	16	53	0,2
Solea 380/1	24.10.-07.11.95	18	16	17	14	65	0,5
Solea396	16.09.-30.09.96	16	16	13	14	59	0,1
Solea398	21.10.-02.11.96	8	7	8	8	31	2,1
sum		86	78	78	83	325	

Table 2: The positions and the water depth of the day/night experiments during the „Solea" cruises between 1993 and 1996.

station	position	bottom depth(m)	cruise number					
			344	361	377	380	396	398
A1	54 50.00N 14 46.00E	42						X
D3	54 55.00N 16 07.00E	60	X					
F3	54 34.00N 14 11.00E	21	X					
F7	54 34.00N 15 44.00E	58	X					
F10	55 41.00N 14 40.00E	57	X					
F11	55 48.00N 14 52.00E	52	X					
2428	54 42.06N 14 07.64E	26	X	X				
2430	54 35.82N 13 52.90E	21	X					
2432	54 44.26N 13 20.67E	37					X	
2438	54 51.50N 14 01.10E	43					X	
2441	54 52.70N 13 13.50E	45			X	X		
2447	55 10.30N 14 17.34E	47		X				
2442	54 56.00N 13 06.50E	42			X			
2552	54 52.60N 16 36.60E	20	X					
2554	54 50.20N 16 31.10E	28		X	X	X	X	X
2555	54 26.14N 15 01.10E	22			X	X		
2560	55 00.45N 17 30.02E	36			X	X		
2561	55 56.55N 15 20.54E	45	X	X		X		
2562	54 26.44N 15 43.00E	44			X	X	X	
2563	54 55.89N 16 13.55E	44		X	X	X	X	
2564	55 50.98N 16 10.60E	57		X			X	X
2566	56 05.70N 17 37.30E	52		X				
2567	55 55.00N 15 36.80E	50				X	X	X
2568	54 37.80N 15 35.80E	65			X	X		
2571	55 41.23N 15 02.82E	66		X				
2572	55 27.50N 16 26.00E	45	X					
2575	55 17.12N 15 04.60E	76	X	X			X	
2579	55 18.26N 17 21.74E	80	X	X		X		
2584	55 56.00N 15 34.00E	50	X					
2586	56 48.00N 16 12.00E	56	X					

Table 3: The distribution of hauls for different numbers of juvenile cod separated for depth layers and the time of the day.

no. of 0-cod	0	2	4	6	8	10	12	14	16	18	20	
	%					%						no. of hauls
surface layer, day	67	13	8	8	1	2				1		86
surface layer, night	78	14	4	1	3							78
bottom layer, day	91	9										79
bottom layer, night	62	19	6	9	2		1	1			1	82
all hauls	74	14	5	5	2	1	0	0		0	0	325

Table 4: Summary of the statistical analyses for the IKMT trawls with water depth between 31 to 60 meters for catch layers and time

day | **night**

surface layer (day/night boundary)

	2 - 4 cm	5 - 9 cm
n	16	6
mean	0,83	0,39
std	1,16	0,77
minimum	-1	-0,5
maximum	3	1,67
t	4,69	3,3
t(0.05;n-1)	2,49	3,16

Day (left):

	2 - 4 cm	5 - 9 cm
n	13	11
mean	1,46	0,68
std	1,03	1,38
minimum	0	-1
maximum	3	3
t	9,3	3,23
t(0.05;n-1)	2,56	2,59

Night (right):

	2 - 4 cm	5 - 9 cm
n	10	6
mean	-0,44	-0,57
std	1,59	0,8
minimum	-4,5	-2
maximum	1	0,5
t	-1,82	-4,69
t(0.05;n-1)	2,69	3,16

near bottom layer (day/night boundary)

	2 - 4 cm	5 - 9 cm
n	8	8
mean	0,08	-1,56
std	1,19	1,85
minimum	-1	-5
maximum	2,5	0
t	0,42	-5,53
t(0.05;n-1)	2,84	2,84

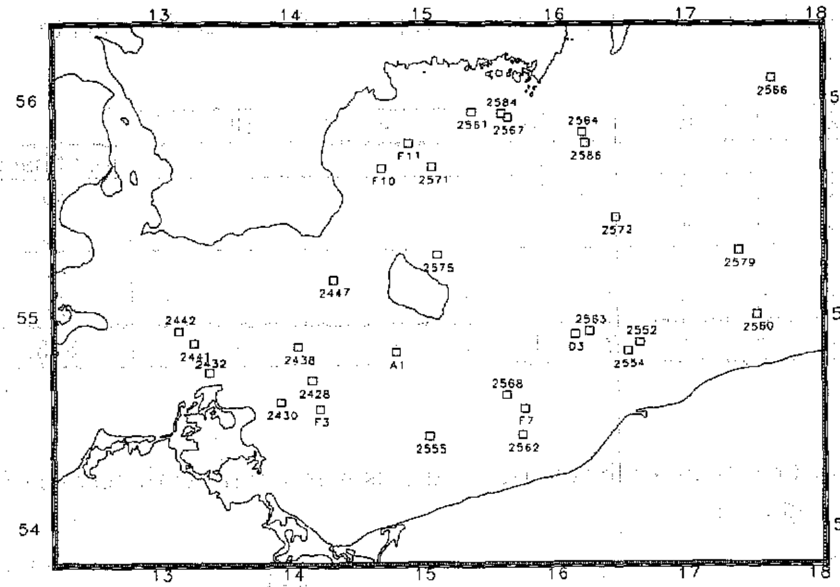

Figure 1: Area of investigations with the stations those were used in the day/night experiments

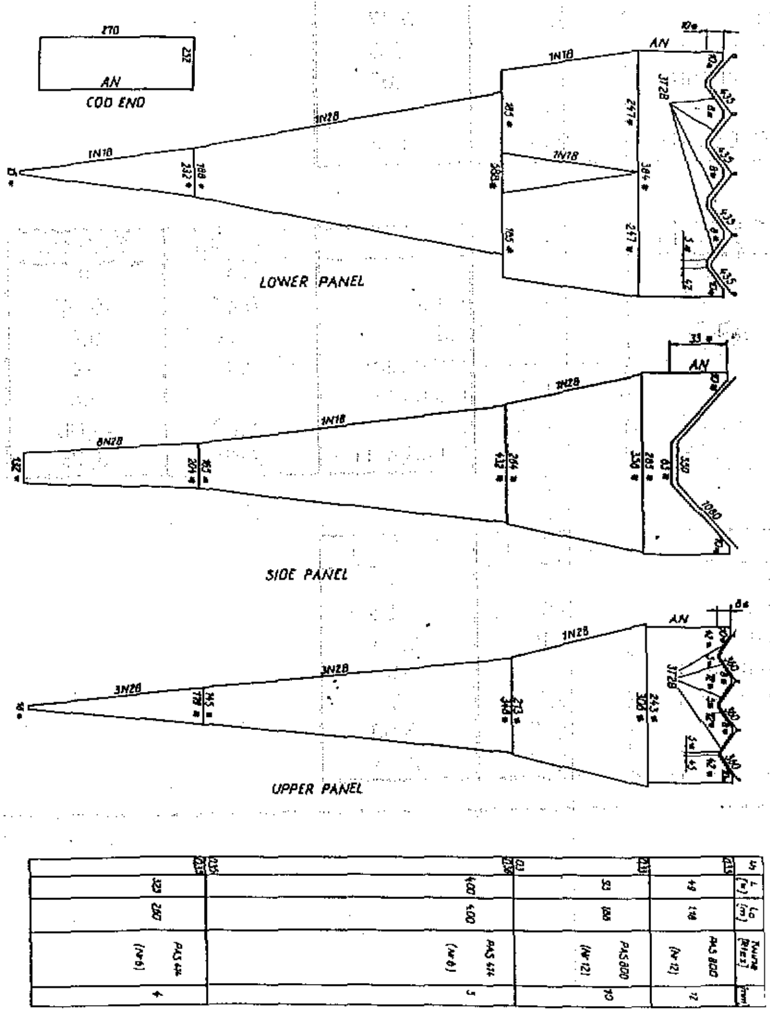

Figure 2: The construction of the used IKMT

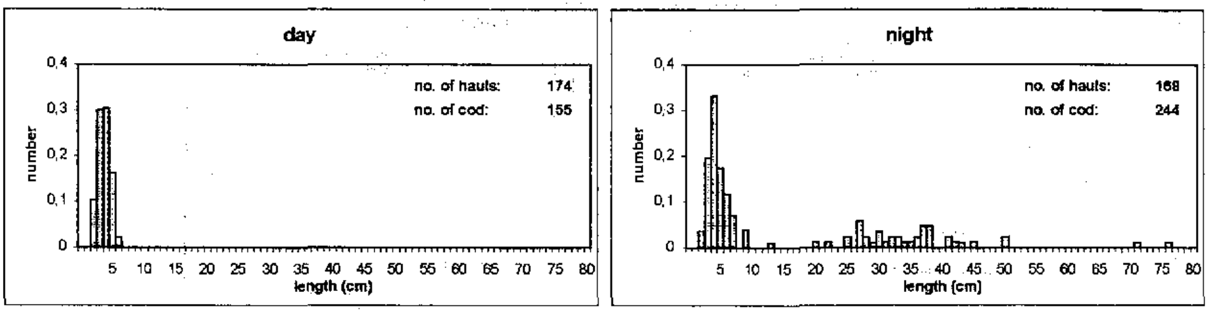

Figure 3: The mean length distribution of cod within the IKMT hauls for daytime and night (all hauls combined).

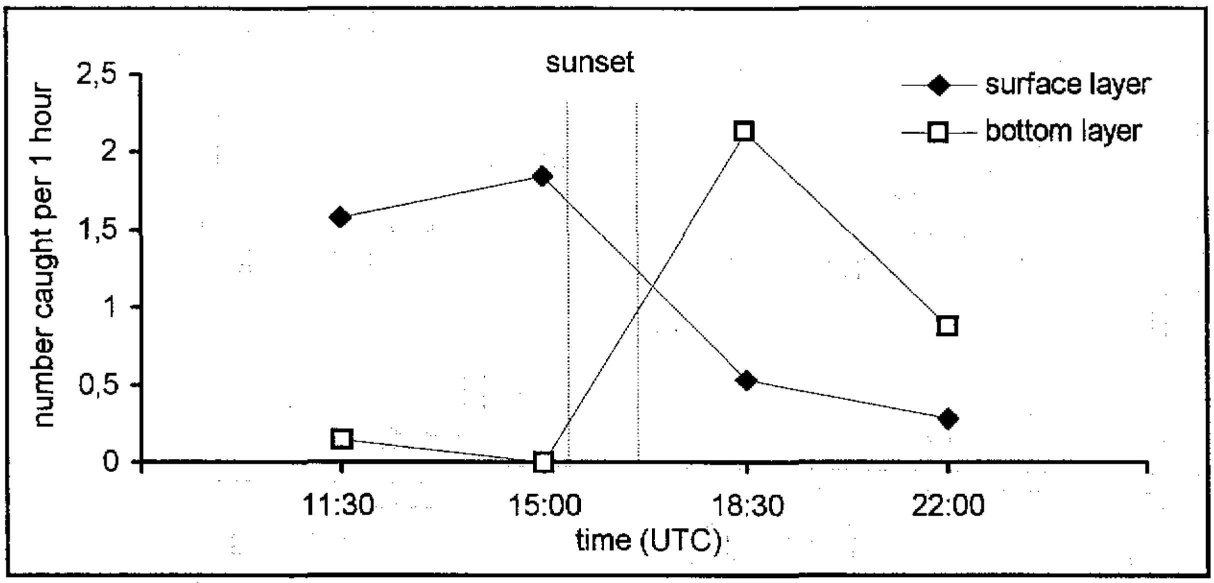

Figure 4: Mean number of juvenile caught cod per hour separated for depth layers in the course of the day (only IKMT hauls within the area with water depth between 31 and 60 m)

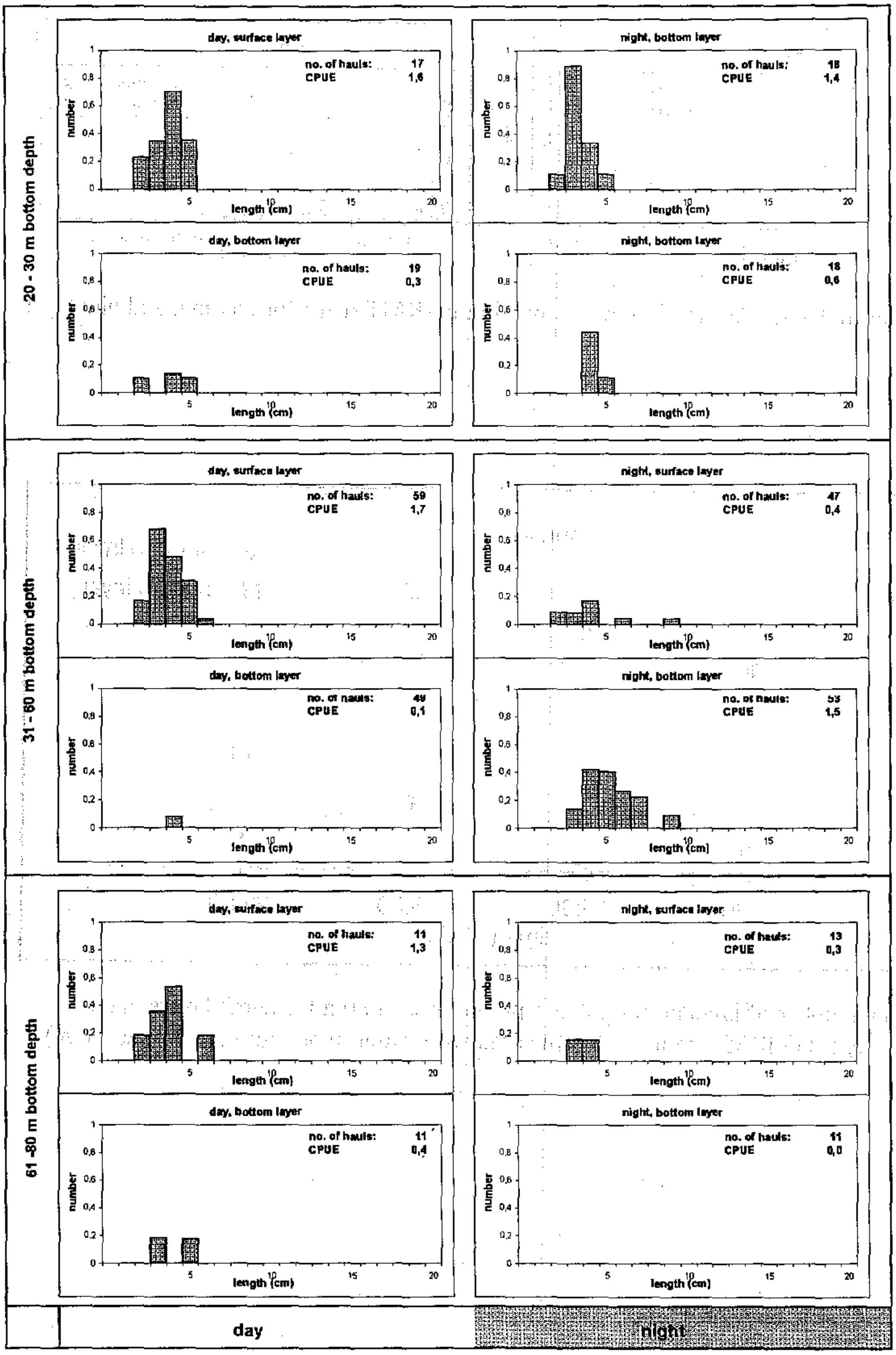

Figure5: Mean length distributions of 0-group cod within the IKMT hauls separated for depth layers and the time of day (summary of all stations).

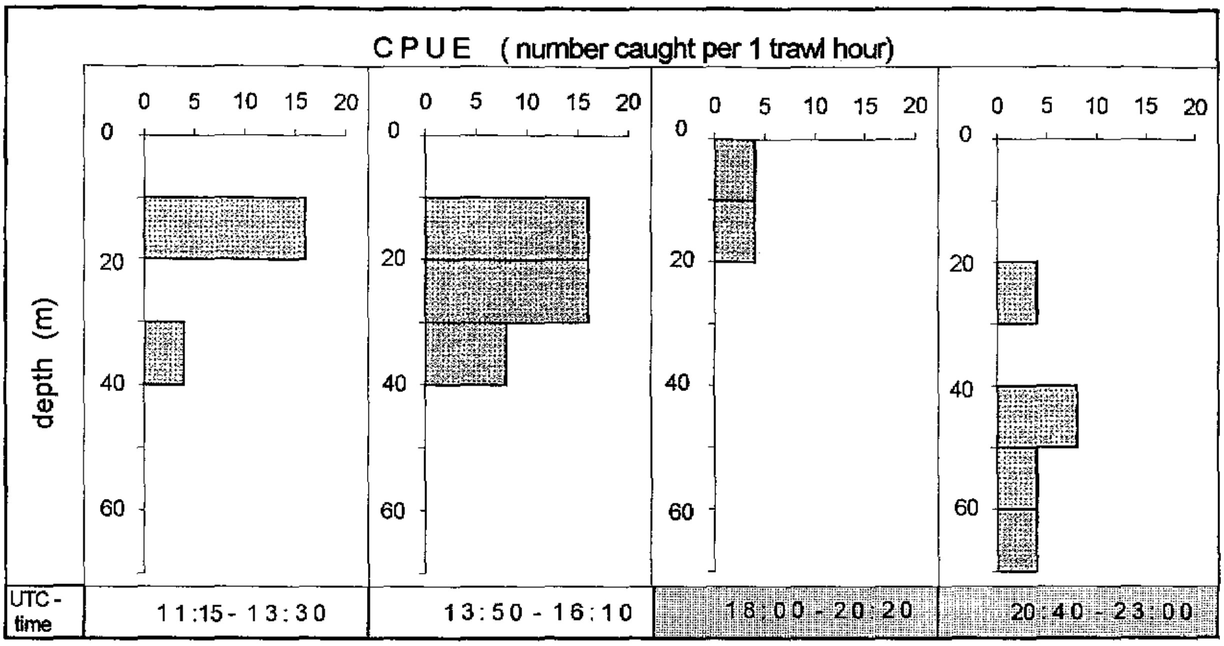

Figure 6: Mean catch of pelagic 0-group cod within the series of IKMT hauls in the different depth layers (398th Solea cruise, station 14, 28 October 1996).

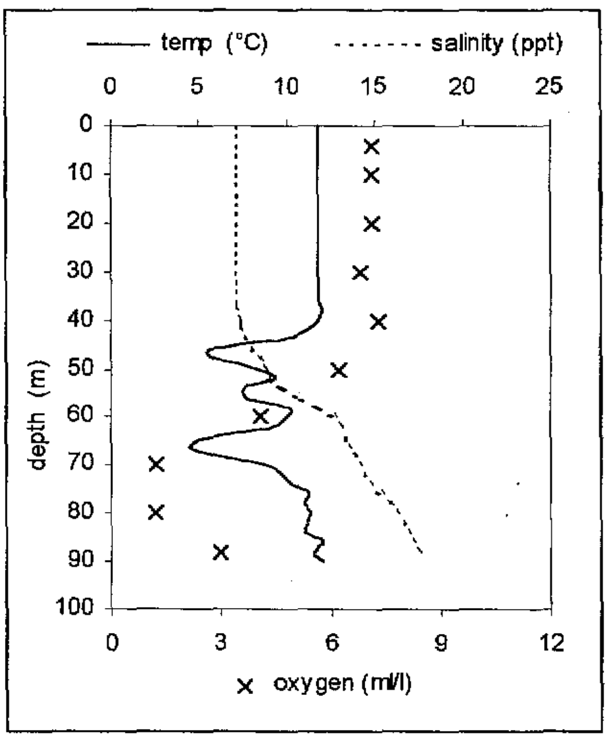

Figure 7: Vertical profile of temperature, salinity and oxygen (398th Solea cruise, station 14, 28 October 1996).