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DIURNAL CHANGES IN BOTTOM TRAWL CATCHES AND VERTICAL FISH DISTRIBUTION

by

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ABSTRACT

Bottom sampling trawl catches and acoustic abundance estimates of North-East Arctic cod and haddock in the Barents Sea were collected and examined according to time of day. The trawl catches were at average larger by day than by night, and there was a larger proportion of small fish (<40 cm) in the night catches. The acoustic recordings showed a considerable diurnal vertical migration of cod and haddock. The fish seemed to stay close to bottom by night and lift off from bottom by day. Aggregations of haddock were observed up to about 150 m above bottom at daytime. Fish density in the bottom layer as estimated from trawl catches agreed closely to echo abundance by night. At daytime no correlation was found.

INTRODUCTION

Stock assessments of North-East Arctic cod and haddock are mainly based on annual bottom trawl surveys and acoustic surveys in the Barents Sea (Anon. 1988). Predictions of fish abundance are thus dependent on the efficiency of the trawl and on the reliability of acoustic estimates. Knowledge of the vertical and horizontal distribution of different fish species is of great importance for interpreting acoustic data for stock assessment purposes.

Trawl catches are known to vary throughout the day, usually with the highest catches of gadoid fishes during daytime (Woodhead 1964, Jacobsen 1986, Shepherd and Forrester 1987). Likewise, the catch ratio between different species varies with time of day. The integrator values during acoustic surveys are also reported to show diurnal changes in total amount and vertical distribution (Engås and Godø 1986).

Gadoid fishes are usually reported to migrate from bottom during nighttime and stay close to bottom during day, although exceptions from the general pattern are reported (Beamish 1966)

The aim of this study is to evaluate changes in diurnal migration patterns of cod and haddock in the Barents Sea in the late winter season, and its possible effect on catch composition.

MATERIALS AND METHODS

The experiments were carried out off the coast of Finnmark 17.-21. February 1988, while R/V "G.O. Sars" and "M. Sars" were carrying out comparative trawl experiments with the commercial trawler "T.O. Senior" (Engås, Jacobsen and Soldal 1988). All vessels used the standard Norwegian bottom sampling trawl. The vessels were towing parallel about 2 cables apart with a speed of 3 knots for 30 minutes. A total of 25 hauls were accomplished; no. 1 to 16 at an average depth of about 350 m (Area 1) and 18 to 25 at about 250 m (Area 2). Station 17 was a single haul in a separate area and is thus excluded from further analysis.

The acoustic equipment used on both vessels was the same as on standard surveys for cod and haddock in the Barents Sea (Hylen, Nakken and Sunnanå 1986). Standard instrument settings were kept with one exception: Six bottom channels (0-2, 2-4, 4-6, 6-10, 10-14 and 14-22 m) were used to get a better resolution of vertical changes in integrator values near the bottom.

Deadzone estimates were added to the integrator value of the lowest bottom channnel according to Dickson (1988). At stations where the bottom channel values seemed to contain bottom echoes, a value derived from the correlation between the integrator value of the channel 2-4 m above bottom and the lowest bottom channel as described by Dickson (op. cit.) was used. Integrator values were split up between the most abundant species according to standard judging procedure, based on species composition of trawl catches and identification of fish traces on echo recordings (Dalen and Nakken 1983).

Trawl catches and acoustic data were grouped by time of day according to light level at medium haul time. Hauls between 05.45 and 14.45 GMT were classified as day-hauls, while hauls between 15.45 and 04.45 were taken as night-hauls. As a result two stations between 14.45 and 15.45 had to be excluded from the day-night analysis.

To get two independent estimates of area density of cod and haddock, we chose to convert the trawl catches to equivalent acoustic values and compare them to the measured integrator values (M). Usually catches and acoustic abundance are compared by converting both values to numbers of fish per nm^2. However, length freqencies measured from the catches have to be used in the estimation of numbers of fish from the integrator values. There will thus be a dependence between the two estimates. On the other hand, trawl catches can be converted to equivalent acoustic values without using information from the echo abundance, and are then independent of the acoustic output.

The numbers of fish in the trawl catches were converted to numbers per nm^2 using the swept area method. The sweep width of the trawl was set to 25 m, which previously has been used in swept area estimates of cod and haddock abundance (Hylen, Nakken and Sunnanå 1985). Fish densities per nm^2 were then converted by equation (1) to (3) to equivalent acoustic values (M), i.e. the integrator value the same ammount of fish would have given if recorded by our acoustic equipment.

(1) $$M(l) = N(l)/CF(l)$$

(2) $$CF(l) = \frac{10^{-(TS(l)/10)}}{4\pi}$$

(3) $$TS(l) = 21.8 \log(l) - 74.96$$

l = mean length of length group
M = integrator value
N = number of fish
CF = conversion factor
TS = target strength

RESULTS

Table 1 shows the average catches in numbers and weight of cod and haddock grouped by time of the day and by area. The catches of cod and haddock were higher by day than by night except for cod in the two day hauls in the shallow area (area 1).

The length frequency distribution of cod and haddock in both areas are shown in Figure 1. A significantly higher proportion of small cod and haddock (<40 cm) was found in the night catches in both areas (chi-square test).

There was no significant difference in the integrator values for each channel from the two vessels ($p>0.05$), except for the lowest bottom channel (QM-value, 0-2 m). The transducer of R/V "G.O. Sars" forms a narrower beam (5°) than that of "M. Sars" (8°), and in addition it is gyro stabilized. The acoustic equipment of "G.O. Sars" is therefore likely to give a somewhat better resolution close to bottom. In the further analyses the QM value from R/V "G.O. Sars" and the mean values from both vessels for the other channels are used.

The vertical distribution of cod and haddock differed by time of day. Figure 2 shows examples of the overall distribution of cod and haddock by day and night, while Figure 3 shows an expansion of the near bottom layer (0-22 m). At daytime cod and haddock were distributed through the watercolumn from bottom up to about 150 m (deep area) and 100 m (shallow area). At night fish stayed more close to the bottom, with integrator values for the bottom channel (0-2 m) of about 4 times that of the day. The difference in the diurnal vertical distribution of fish was most pronounced in the shallow area (Table 3).

The area density of fish calculated from trawl catches did not differ significantly between night and day (Table 4), while the integrator values from the bottom channels up to the headline hight of the trawl (4 m) recorded by the echointegrator were by far larger by night.

At daytime the correlation between integrator values calculated from catch and the echo abundance at individual hauls were low (r^2 = 0.03). At nighttime the correlation was much higher (r^2 = 0.87). This indicates that factors other than observed fish density in the bottom layers influence the the size of the trawl catches at daytime.

DISCUSSION

Trawl catches are known to vary considerably throughout the day, usually with the highest catches of gadoids during daytime (Woodhead 1964, Jacobsen 1986, Shepherd and Forrester 1987). Our results show the same tendency, except for cod in the shallow area (area 2). In most of the litterature the differences between day and night are larger than found in this study.

The higher proportion of small cod and haddock (<40 cm) in the night catches could be a result of the difference in vertical migration pattern and/or difference in catchability between small and larger fish.

It is generally accepted that cod and haddock stay closer to bottom by day than by night. Our results show an opposite pattern. The midwater trawl catches in the acoustic survey for cod and haddock in the same area during February (Anon. 1988) show that the observed integrator values off the bottom during daytime mainly consisted of haddock feeding on small beacked redfish (Sebastes mentella). The echo traces from our study also show dense columns typical of haddock ascending in the sea by day. This indicates that haddock has a far greater vertical diurnal migration than cod. Beamish (1966) also reported patches of haddock high in the water colum by day.

The vertical range of the diurnal migration is broader in the deep area than in the shallow area. Limitations imposed by a closed swimbladder on the extent of diurnal vertical migrations in different depth regimes, could be an possible explanation for the observed results (Harden-Jones 1977).

The correlation between the area density of fish recorded by acoustics and the area density estimated from trawl catches varied conciderably between night and day. While the correlation was good at night, no correlation was found by day. Strømme et al. (1982) obtained a linear function between trawl catches and integrator abundance estimates of cod and haddock in the Barents Sea.

The acoustic abundance of fish close to bottom was much larger by night than by day. The difference between trawl catches night and day was much less, and in the deepest area the catches were larger by day. The narrow beam width of the transducer and the smooth bottom of the investigated area makes it ulikely that large ammounts of fish are lost to the system in a bottom deadzone and thus makes the catches unpredictable. If we accept that fishes in the bottom layer are recorded by the echo sounder with the same efficiency day and night, the observed lack of correlation between cathes and acoustic abundance must be due to diurnal changes in fish behaviour and reactions towards the fishing gear.

The efficiency of the trawl must be larger by day than by night. Engås and Godø (1986) also report lack of correlation between trawl catches and acoustic abundance, and conclude that this may be due to variation in catchability during the day. Probably the herding effect of the trawl are larger by day because of better visibility of sweeps and wings.

The differences between the day and night observations may also be due to avoidance reactions of fish to the vessel. We observed large densities of fish high up in the watercolumn by day, and lower concentrations close to bottom. As the vessel propeller passes, fish are earlier observed to aviod noise by diving reactions (Ona 1988, Ona & Chruikshank 1986). This may lead to increasing fish densities close to bottom and thus make more fish available to the trawl. At night the fish are more closely associated to bottom and the diving effect may be less.

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Table 1a. Average trawl catches (± s.d.) of cod

Time	No. of tows	Depth (m)	Catch (no. of fish) G.O.Sars		Catch (no. of fish) M.Sars/T.O.S.		Catch (weight kg) G.O.Sars		Catch (weight kg) M.Sars/T.O.S.	
Day	6	350	136	± 97	193	±125	144	±110	171	±103
Night	9	350	86	± 56	134	± 86	81	± 57	119	± 72
Day	2	250	98		80		100		66	
Night	5	250	116	± 64	192	±102	94	± 44	179	±104

Table 1b. Average trawl catches (± s.d.) of haddock

Time	No. of tows	Depth (m)	Catch (no. of fish) G.O.Sars		Catch (no. of fish) M.Sars/T.O.S.		Catch (weight kg) G.O.Sars		Catch (weight kg) M.Sars/T.O.S.	
Day	6	350	656	±500	1067	±975	433	±331	728	±646
Night	9	350	550	±524	987	±1241	328	±307	587	±749
Day	2	250	278		337		185		224	
Night	5	250	226	± 89	314	±105	129	± 60	193	± 73

Table 2. Mean difference in integratorvalues between R/V "M.Sars" and R/V "G.O.Sars" for each integratorchannel from the surface to the bottom. Number of observations 22. (t-test).

Int. channel	Mean difference	S.D.	P	
Pel. 6	0	0	0	
Pel. 5	0	0	0	
Pel. 4	2.4	9.2	0.243	
Pel. 3	-0.4	16.9	0.911	
Pel. 2	-0.5	33.8	0.949	
Pel. 1	10.8	62.4	0.425	
14-22 m	4.9	12.1	0.070	
10-14 m	3.2	7.9	0.068	
6-10 m	2.1	7.3	0.192	
4- 6 m	0.6	3.9	0.487	
2- 4 m	0.2	2.8	0.727	
QMch 0- 2 m	41.1	57.9	0.003	*

Table 3. Comparison of integrator values for cod an haddock from day and night observations in the near bottom layer, from 0 to 22 m above bottom. (Analysis of variance).

a) Deep area.

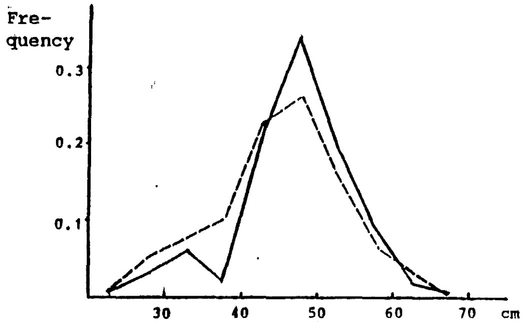
Integrator channel	Day (6 obs.) Mean	S.D.	Night (9 obs.) Mean	S.D.	P
14-22 m	26.6	7.6	21.0	7.5	0.627
10-14 m	12.7	3.8	12.5	3.8	0.968
6-10 m	11.5	2.9	14.2	4.9	0.690
4- 6 m	5.6	1.7	9.7	3.5	0.395
2- 4 m	5.4	1.7	11.4	3.8	0.244
QMch 0- 2 m	19.3	7.0	48.6	18.4	0.235

b) Shallow area.

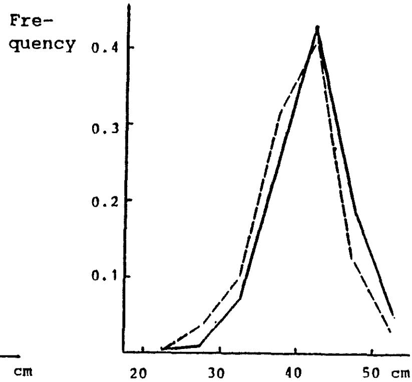
Integrator channel	Day (2 obs.) Mean	S.D.	Night (5 obs.) Mean	S.D.	P	
14-22 m	2.3	0.8	3.8	0.7	0.288	
10-14 m	0.9	0.4	3.3	0.5	0.027	*
6-10 m	1.4	1.1	4.2	0.7	0.090	
4- 6 m	0.9	0.7	3.4	0.6	0.054	
2- 4 m	0.8	0.6	5.2	0.9	0.033	*
QMch 0- 2 m	3.5	3.0	21.6	3.5	0.030	*

Table 4. Integrator values from 0 to 4 m above bottom for cod and haddock compared to area densities calculated from trawl catches.

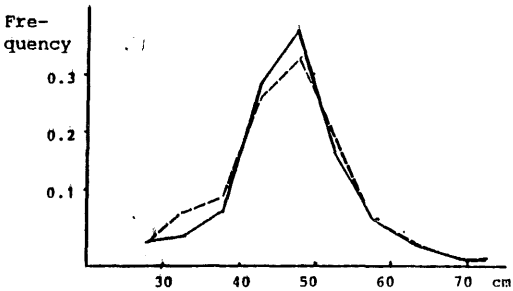
Time of day	Depth (m)	No. of stations	Area density from catch	Integrator value 0-4 m
Day	350	6	91.7	24.5
Night	350	9	75.3	61.0
Day	250	2	31.0	4.9
Night	250	5	36.5	27.2



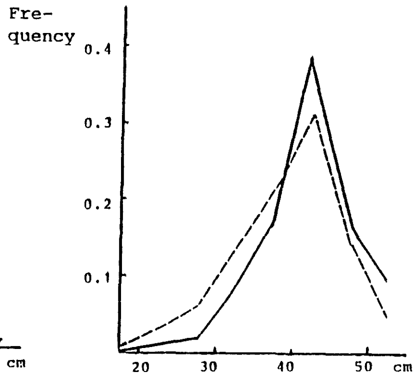
a) Cod, area 1 (depth 350 m)



b) Haddock, area 1 (350 m)



c) Cod, area 2 (depth 250 m)



d) Haddock, area 2 (250 m)

Figure 1. Length frequency distribution of cod and haddock in trawl catches night and day.

----- day

______ Night

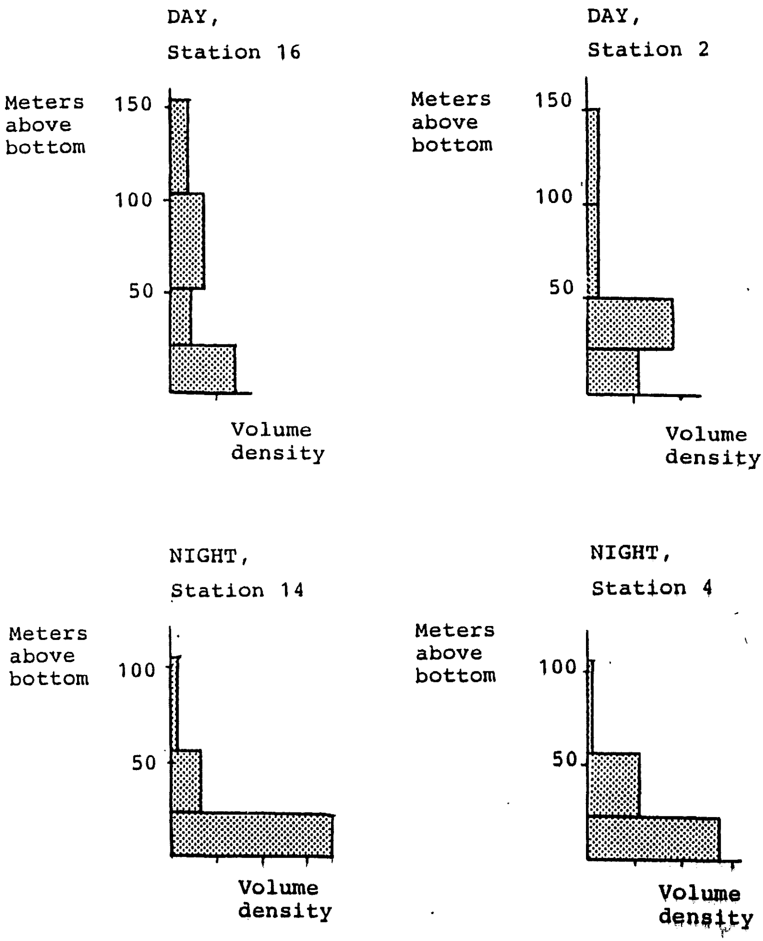


Figure 2a. Examples of vertical distribution of volume density of cod and haddock, day and night, depth 350 m.

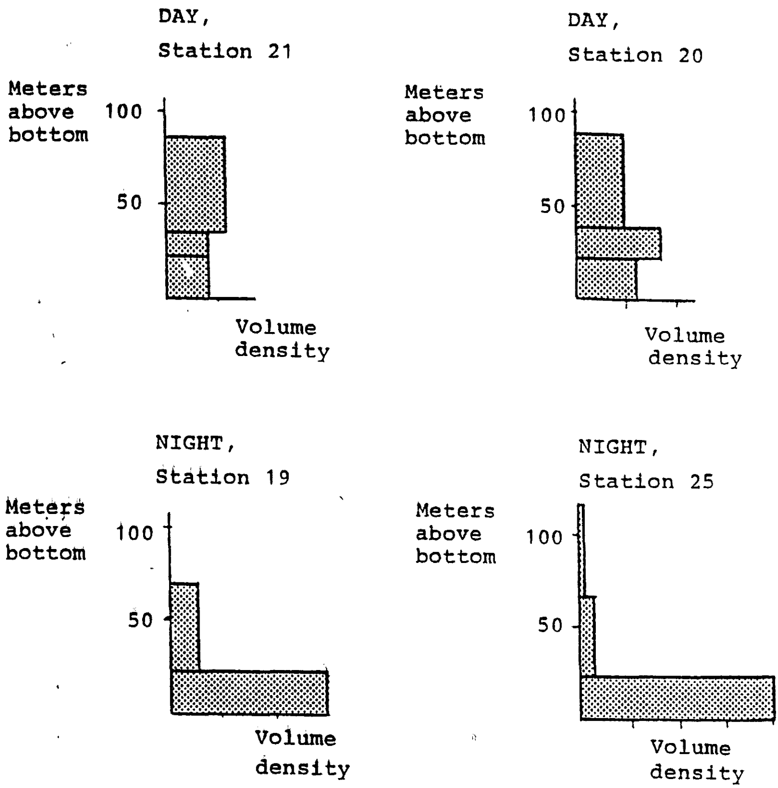


Figure 2b. Examples of vertical distribution of volume density of cod and haddock, day and night, depth 250 m.

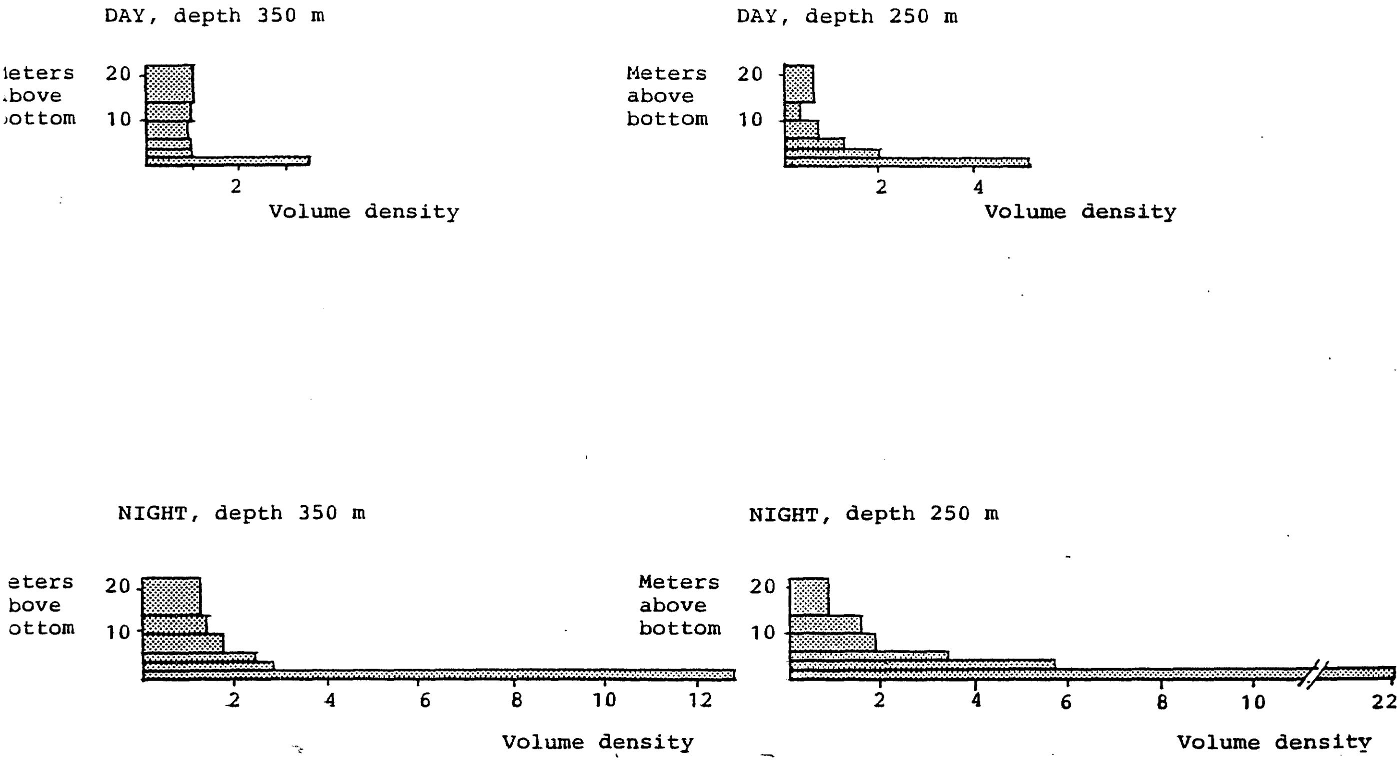


Figure 3. Average vertical distribution of volume density of cod and haddock from 0 to 22 m above bottom.