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LENGTH AND SPECIES DEPENDENT DIURNAL VARIATION IN CATCH RATES IN THE NORWEGIAN BARENTS SEA BOTTOM TRAWL SURVEYS

by

Knut Korsbrekke and Odd Nakken
Institute of Marine Research
P.O. Box 1870 Nordnes
N-5024 BERGEN, NORWAY

ABSTRACT

Diurnal variation in capture efficiency may add to the variability in swept area estimates (or indices) from bottom trawl surveys. In the present study the relationship between the day/night ratio of swept area estimates and fish length was examined for 5 species observed in the Barents Sea bottom trawl survey in winter in the years 1989-1996. Generally, most species showed increased catch rates during day light at all sizes as compared with darkness. For cod and haddock a substantial reduction in the day/night ratio with fish length was observed. Some possible behavioural explanations for these findings are discussed for cod. In addition is there a tendency that increased stock size increases the difference in catch rates for both cod and haddock.

The implications of the findings for the conduct of the surveys and the reliability of swept area estimates/indices are considered.

INTRODUCTION

The reliability of indices of abundance from bottom trawl surveys depends on a range of factors. Usually one can use the coefficient of variation as an indicator of the precision in the estimates. In the Norwegian bottom trawl survey in the Barents Sea in winter the coefficient of variation of the abundance indices for cod by 5 cm length groups seems to have a tendency to peak between 25 and 40 cm, with some changes between years. This is not so for haddock where the coefficient of variation seems to increase from the most abundant lower length groups up to larger sizes. As this bottom trawl survey yields one of the most important tuning series in the annual stock assessment work all knowledge on uncertainties related to the results is useful.

Catch rates in bottom trawl are known to vary with the time of day (Shepherd and Forrester 1987, Walsh 1988, Atkinson 1989, Engås *et al.* 1988, Ehrich and Gröger 1989, Engås and Soldal 1992, Michalsen *et al.* 1995). The catch composition by size groups is also known to vary.

The questions initiating this work were: Can the special pattern in the coefficients of variation of abundance indices for cod be explained by size dependent changes in catch rates throughout the day? Are these changes in catch rates related to fish density?

THE BARENTS SEA BOTTOM TRAWL SURVEY

A combined acoustic and bottom trawl survey for demersal fish in the Barents Sea is conducted annually in January - March by The Institute of Marine Research, Bergen (IMR). The main aim of the survey is to map the spatial distribution and obtain indices of abundance of the most important commercially exploited demersal fish species in the Barents Sea. The target species are cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), golden redfish (*Sebastes marinus*), beaked redfish (*S. mentella*) and Greenland halibut (*Reinhardtius hippoglossoides*). A description of the survey can be found in Jakobsen *et al.* 1997.

Data and results are used in the stock assessments in ICES and in several projects at IMR, especially multispecies research and development of new methods.

Data from the bottom trawl survey in the years 1986 to 1996 is studied in this work. The survey area was increased through this period and only data from the central regions (A, B, C and D) with a good coverage in all survey years is used (see Figure 1 below).

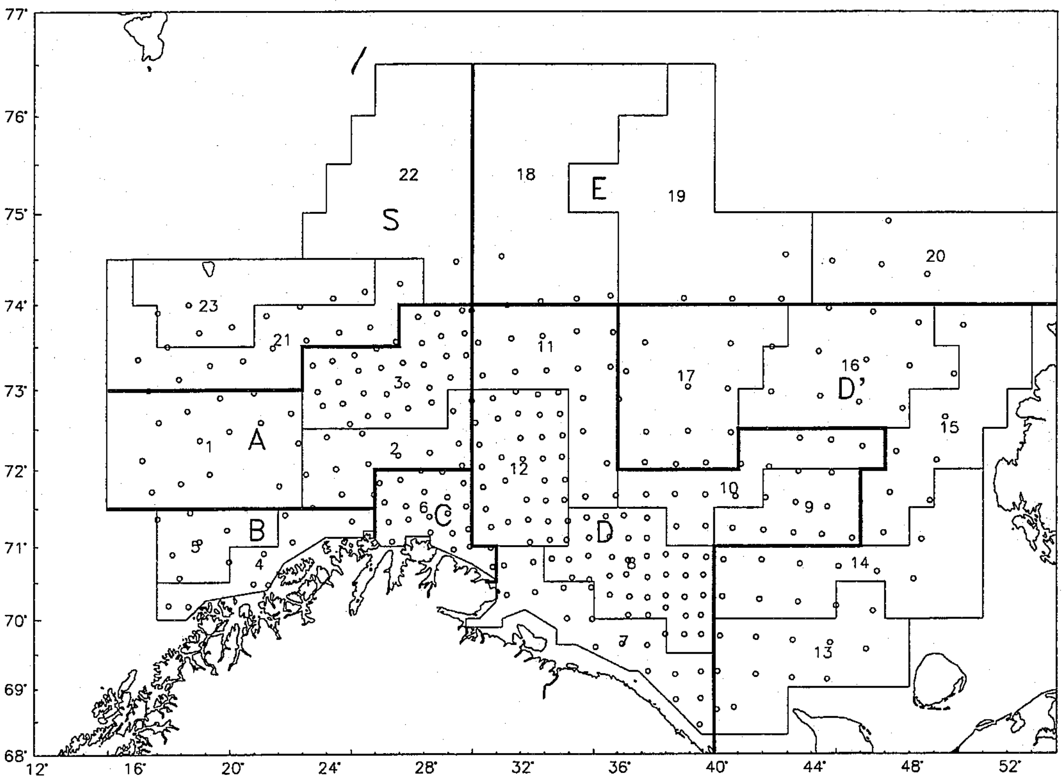

Figure 1 Strata system and the main regions (A, B, C, D, D', E and S) used in the bottom trawl survey. Trawl stations winter 1996 is shown.

The effort and equipment used in these years have changed. The biggest change was the reduction of mesh size in the codend from 40 to 22 mm in 1994. This change introduced a drastic increase in abundance indices of small fish. However, it is assumed that this change had little effect on the day/night ratio between catch rates of the smallest size groups.

ESTIMATION OF INDICES

A description of the estimation of abundance indices by length can be found in Jakobsen et al. 1997. In the present study only length based indices of abundance are used. The size of the traditional 5 cm lengthgroups has been changed into the following set of intervals:

Table 1 Length intervals used in the estimation of abundance indices. The size of each interval represents proportional increases.

12 - 15 cm	16 - 22 cm	23 - 31 cm	32 - 44 cm	45 - 63 cm	64 - 89 cm

The estimated coefficients of variation for each year are shown for both cod and haddock (see Figure 2 and Figure 3).

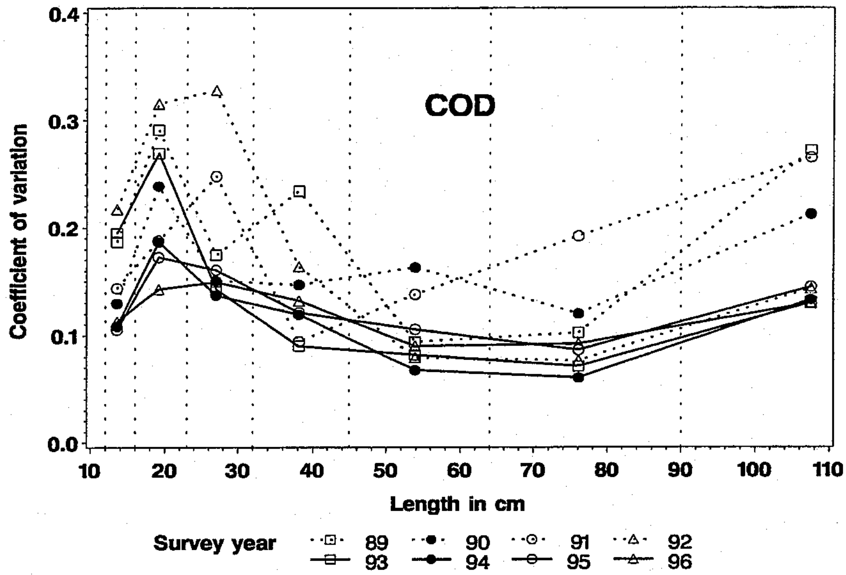

Figure 2 Coefficient of variation for each year and lengthgroup for cod.

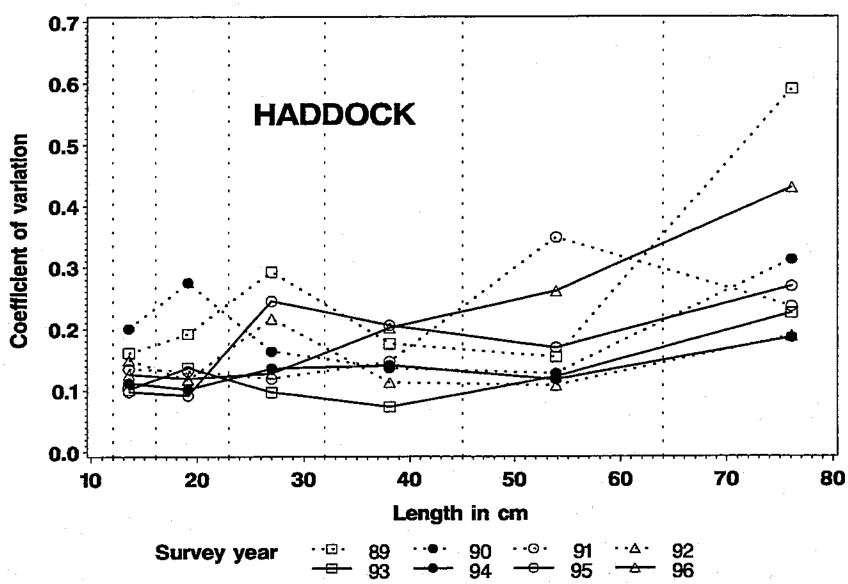

Figure 3 Coefficient of variation for each year and lengthgroup for haddock.

Independent night and day estimates of abundance were produced by defining night hauls as stations taken when the sun was 5° or more below the horizon. Thus stations taken in twilight conditions were included in the day estimates. Since nights are longer than days in winter at high latitudes, this increased the number of day stations and reduced the coefficient of variation in the day estimates.

Some of the strata (especially the northern ones) are in some years sampled poorly during daytime. This poor sampling is mainly in areas with low abundance of all species examined in this study and the possible effect on the total day/night ratio of abundance indices is negligible. Night and day indices were calculated for all years for the following species: Cod, haddock, golden redfish, beaked redfish and long rough dab (*Hippoglossoides platessoides*). Long rough dab is the most abundant flatfish species in the Barents Sea and was included as a reference.

COMPARISON OF DAY AND NIGHT INDICES

Ratios between night and day indices are produced for comparison. Thus each year and lengthgroup ratio represent one observation in the further analysis. The ratios for cod and haddock are shown in Figure 4 and Figure 5 . There is considerable year to year variation, but some patterns appear. The other species show considerable more variation possibly due to the somewhat lower abundance. For comparison purposes are the backcalculated mean log ratio ±2 standard deviations shown in Figure 6, and all species combined without the standard deviations in Figure 7. No bias correction is applied.

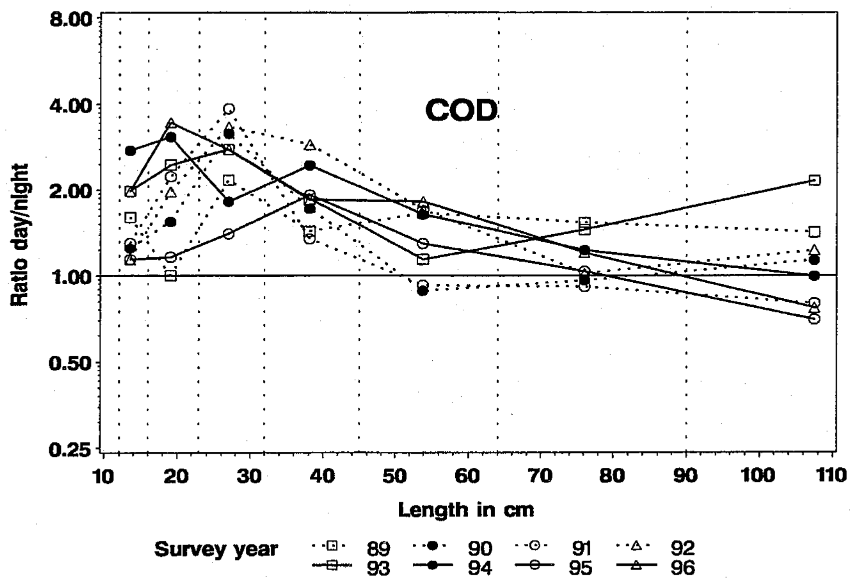

Figure 4 Ratios of day/night estimates by survey year and lengthgroup for cod.

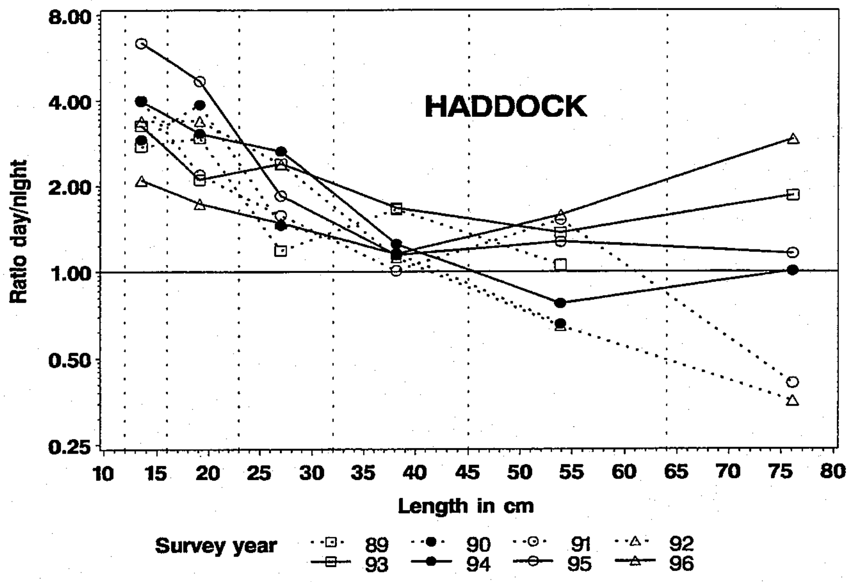

Figure 5 Ratios of day/night estimates by survey year and lengthgroup for haddock.

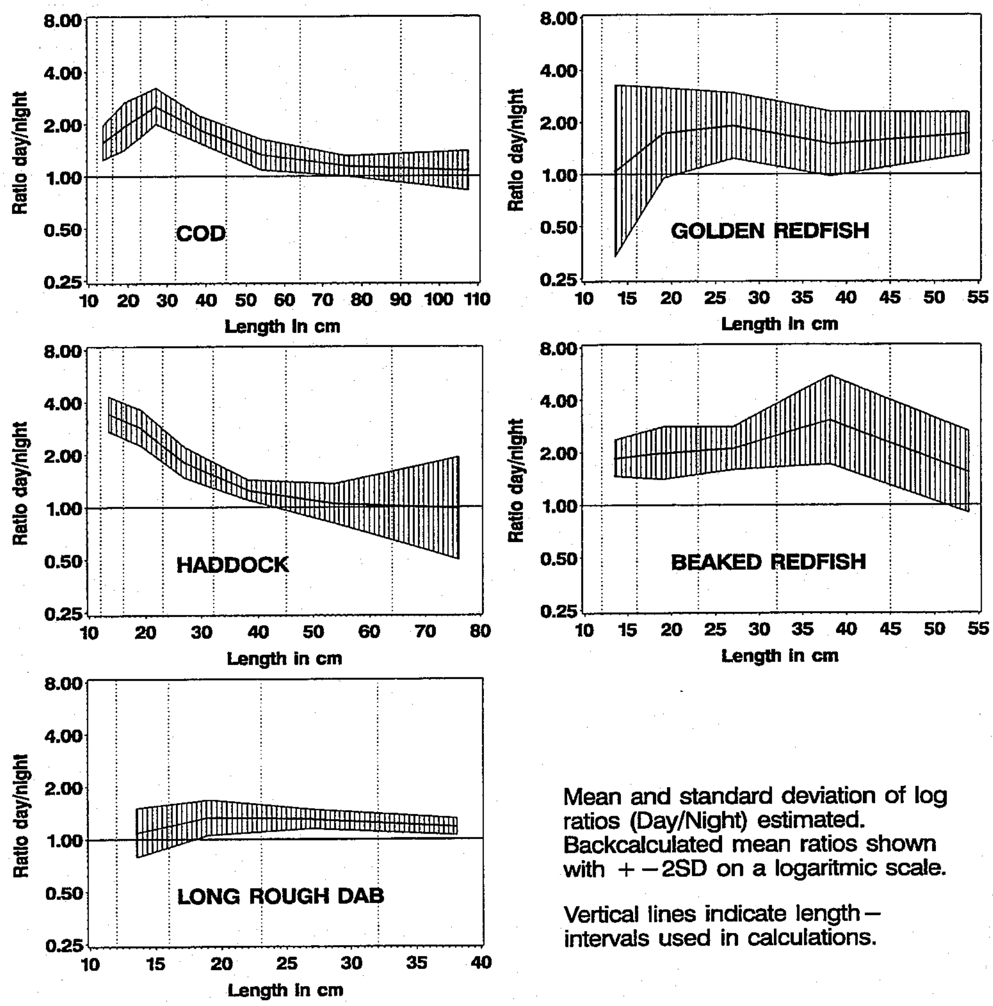

Figure 6 Backcalculated mean log ratios of day over night estimates ± 2 standard deviations for cod, haddock, long rough dab, golden redfish and beaked redfish.

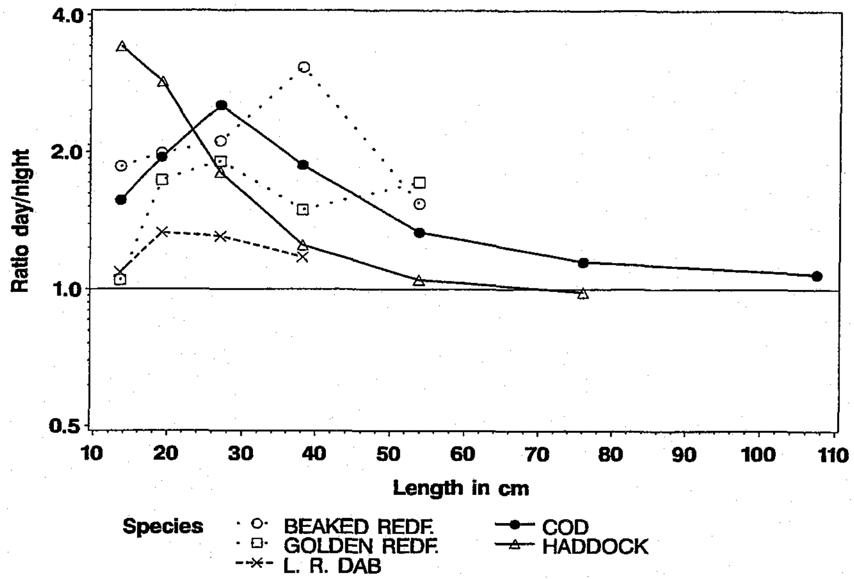

Figure 7 Backcalculated mean log ratios for each of the species (for comparison).

EFFECTS OF STOCK SIZE

The assumption that day and night estimates are proportional can for each lengthgroup *l* be expressed as:

$$\hat{N}_l^{day} = k_l \cdot \hat{N}_l^{night} \tag{1}$$

Using logarithms:

$$\mathrm{Log}\left(\frac{\hat{N}_l^{day}}{\hat{N}_l^{night}}\right) = \mathrm{Log}(k_l) \tag{2}$$

A (biased) estimator of k_l would be:

$$\hat{k}_l = e^{\frac{1}{n}\sum Log(k_l)} \tag{3}$$

Density dependent effects could be indicated by this relationship not being constant over the range of stock sizes. By replacing Log(k_l) with α_l and adding a term for stock size (2) is rewritten as an analysis of covariance model:

$$\mathrm{Log}\left(\frac{\hat{N}_l^{day}}{\hat{N}_l^{night}}\right) = \alpha_l + \beta \cdot \mathrm{Log}(N_l) \tag{4}$$

Estimates of β being significantly different from 0 would strongly indicate that the ratios between day and night estimates are not only length dependent, but also stock size dependent. If we assumed that the shape of the fish density distributions is similar for both lower and higher stock sizes the ratio could also possibly be dependent on fish density.

N_l was calculated for each of the length groups using VPA estimates as estimators of stock size. VPA numbers at age was used together with age-length keys that used mean length at age as input, and assuming normally distributed lengths within each age group.

The results from the analysis of covariance are given in Table 2 and Table 3 . For cod the year range 1989 to 1996 was used. For haddock the data from 1989 and the data for the lengthgroup 64-89 cm was excluded due to very low abundance.

Table 2 Analysis of covariance output for cod.

	DF	SS	MS	F	P
MODEL	7	16.70283	2.386119	27.85	0.0001
ERROR	41	3.513284	0.08568986		
TOTAL	48	20.21612			
R^2	0.524130	C.V.	56.61310		
COEFF.	EST.	T	P	STD	
LOG(VPA)	0.142626	2.72	0.0095	0.052435	

Table 3 Analysis of covariance output for haddock.

	DF	SS	MS	F	P
MODEL	6	22.45124	3.7418746	43.54	0.0001
ERROR	29	2.492500	0.0859482		
TOTAL	35	24.943747			
R^2	0.768106	C.V.	46.03415		
COEFF.	EST.	T	P	STD	
LOG(VPA)	0.13174718	2.37	0.0247	0.055628	

The results from the analysis of covariance were backcalculated from log ratios and log numbers and are shown in Figure 8 and Figure 9.

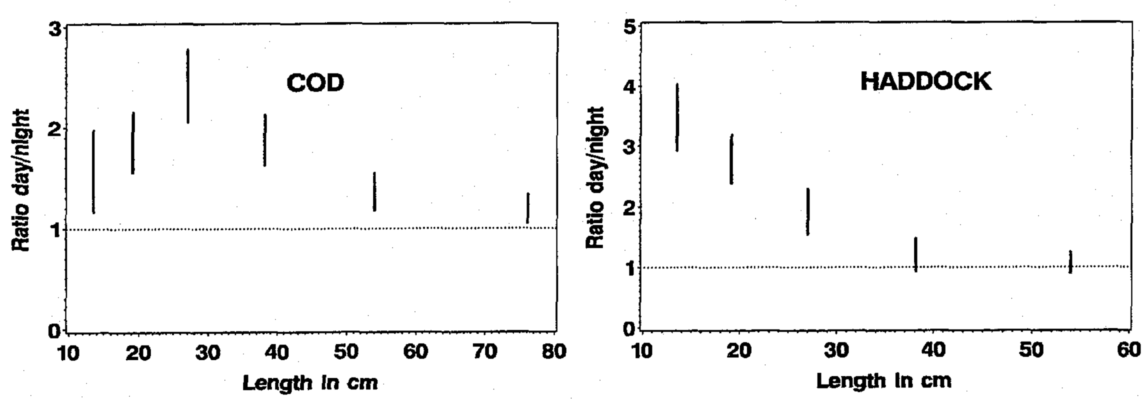

Figure 8 Ratio against length group backcalculated from the analysis of covariance. Lines connect minimum and maximum observed abundance as estimated in the VPA (Anon. 1997).

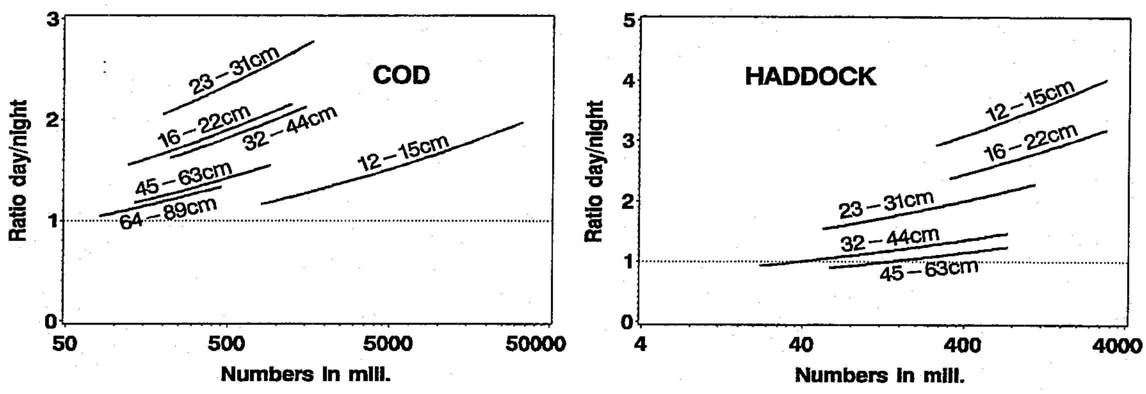

Figure 9 Ratio against stock size (by lengthgroups) backcalculated from the analysis of covariance. Lines connect minimum and maximum observed abundance as estimated in the VPA (Anon. 1997).

DISCUSSION

There was a distinct difference in day and night estimates for all species in this analysis (see Figure 6 and Figure 7) with the day estimates higher than night. The largest differences were found for the two redfish species. Smallest difference was found for log rough dab. Neither of these species showed any obvious pattern between lengthgroups while such a pattern was obvious for both cod and haddock. The main cause for the large day/night ratio between estimates for the redfish should be diurnal vertical migration and this is also supported by acoustic observations. Although long rough dab has been observed in pelagic trawl hauls the small difference observed should be caused mainly by the changes in the visual effects of otterboards and sweeplines. One should however not rule out the possible additional effects of other species being more abundant close to the bottom and in the trawl opening and also showing reactions to the vessel and the fishing gear during daytime.

Cod and haddock showed a different pattern between lengthgroups. The day/night ratio increased from the smallest lengthgroups of cod until a peak for the lengthgroup 23-31cm (some 2 year olds, but mainly 3 year olds). The ratio then decreased with increasing length. The largest ratio was observed for the smallest lengthgroup of haddock. The ratio decreased to approximately 1 for the largest lengthgroup. The increase in ratio between day and night estimates from the smallest length groups could possibly be caused by either:

a) Reduced vertical migration as compared to larger size groups.
b) Less visual effect of otterboards and sweeplines (catch mostly depending on the size of the trawl opening, bottom contact etc.)

or a combination of both. The further decrease in ratio with increasing size could possibly be caused by larger fish being able to react to vessel noise and noise from the otterboards and ground gear and dive to the bottom thus increasing catch rates during night time (Aglen 1996). A similar description may be used as a possible explanation for the decrease in ratio with increasing size for haddock.

The results of the analysis of covariance clearly indicate that the day/night ratio in abundance increases with increasing stock numbers both for cod and haddock; the more fish the larger are the day catches as compared with the night catches (at least for some size groups). The model used (4) assumes changes in ratio proportional to the log stock size and this assumption may not hold (especially for the larger size groups).

This increase in ratio with increasing stock size could be related to:

a) Vertical migration being density dependent. The more fish the higher proportion migration upwards during night-time.

b) Catching efficiency of the trawl being density dependent. The visual effect of other fish reacting to noise and possible schooling like effects.

The values of β (given in tables 2 and 3) generate approximately a 10 percent increase in the day/night ratio of estimates when stock numbers are doubled. Hence, for ranges in year class strength of 2-3 decades as experienced for cod and haddock in the Barents Sea, the effects on the estimates might be substantial.

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