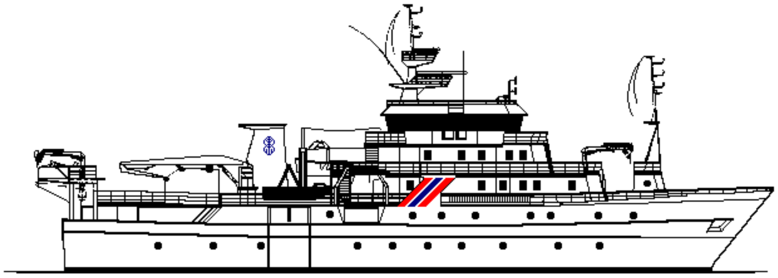

BENEFIT SURVEYS

Preliminary Cruise report No 9/2005

DIURNAL VERTICAL DISTRIBUTION OF DEEPWATER HAKE

27 August – 16 September 2005

by

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1. INTRODUCTION

Objectives

1. Test the assumption that in deep waters (deeper than 450 m) hake do not perform diurnal vertical migrations.

This survey with R/V *Dr. Fridtjof Nansen* is the sixth experiment within the BENEFIT project "Effects of Environmental Factors on Availability and Catching Efficiency of the Demersal Sampling Trawl" where the main objective is to investigate factors that affect the catchability of hake. During the experiments conducted in 2000 and 2001 the herding effects of the bridles were investigated. The results showed that large hake seem to be herded into the net, although the extent of such herding differed from one area to another. The experiments conducted in 2002 and 2003 attempted to establish whether hake escape under the fishing line of the demersal sampling trawl and to investigate any species and length dependent escapement. The 2002 and 2003 experiments showed clear differences in escapement between the two hake species, with 15-50% escapement of *M. paradoxus* and less than 10% escapement for *M. capensis*. The 2004 survey and the current survey will address the effects of diurnal vertical migration on the availability of hake to bottom trawling.

Swept area surveys conducted in South Africa and Namibia provide input data to the hake stock assessment models used in both countries. The hake abundance indices and length distribution estimates from the surveys are used in the models, in addition to fishery dependent data, to calculate the age structure and abundance of the hake stocks. The abundance estimates from the bottom trawl surveys are used as relative indices of the hake biomass, while the length frequencies estimated are assumed to reflect the underlying population characteristic. These assumptions are invalid if fishing is done at times when the availability of hake to the bottom trawl is reduced for some or all size groups

Prior studies have shown hake to perform vertical migrations away from the seabed predominantly at night (Payne 1989, Huse *et al*. 1991, Iilende *et al*. 1991). Based on several years of survey data, Iilende *et al*. (2001) estimated that on average 10% of the hake biomass is pelagic at noon, compared to around 20% in the morning and afternoon and 60% around midnight. Estimation of the pelagic biomass was based on acoustic recordings made during the surveys, but due to few pelagic trawl stations taken, the identification of acoustic targets in the pelagic zone is uncertain. The authors stress the need for more systematic observations on the diel variation in the vertical migration of hake. Huse *et al*. (1991) found a diel pattern in daytime catch rates of hake with highest catches at noon. Observed variation was, however, large. During the Namibian hake bottom trawl surveys, trawling is for this reason limited to daytime hours in order not to introduce severe bias into the survey data. However, in deep waters (deeper than 450 m) hake is not assumed to perform extensive diurnal vertical migrations, hence trawling is also carried out during nighttime.

During the survey in September/October 2004, the validity of the latter assumption was tested. Bottom and pelagic trawl hauls in combination with hydro acoustic observations were done throughout the 24 h diel cycle to establish the diel variation in bottom trawl catch rates. The experiments were confined to an area with a water depth of 540-560 m. The results showed that more than 50% of the hake biomass in the survey area was not accessible to the bottom trawl, i.e. distributed more than 5 m above the bottom. No clear diel pattern was seen, neither in the bottom trawl catch rates nor in the calculation based on acoustic observations.

Participation
The scientific staff consisted of the following:

From Namibia:
Johnny Gamathan , John Kathena, Nelda Katjivena, Toini Mweenda, Peter Schneider (Team leader), Malakia Shimhanda,

From Norway:
Ólafur Ingólfsson , Terje Jørgensen (Cruise leader), Thor Egil Johansson, Tore Mørk, Ronald Pedersen

Narrative

27 August – 3 September	Awaiting exemption from discard ban
3 September	Departure Walvis Bay
16 September	Arrival Cape Town

2. MATERIAL & METHODS

2.1 Trawling experiments

Initially, the objective was to choose one deep (550 m) and one shallower (350 m) experimental area. However, fish abundance in deep waters (500-600 m) was found to be very low, despite several exploratory hauls along the shelf between Walvis Bay and Lüderitz. The highest recorded fish abundance was made at 450 m at position 25º 25' S and 13º 38' E and this area was therefore chosen. Trawling took place day and night with both a bottom and a pelagic trawl. For logistic reasons the cruise period was more than one week shorter than initially planned. There was therefore not sufficient time to perform experiments in the shallower area.

The bottom trawl used, the Gisund super (Fig. 1) equipped with 40 m bridles and 7.9 m Thyborøn trawl doors, is the vessel's standard sampling trawl for hake. This is also the same type of trawl as used for the biomass surveys on Namibian hake, different doors are however used during the hake biomass surveys (6.7m^2 Steinshamn doors). The trawl was used with door-spread restriction consisting of a 9 m rope between the warps (130 m in front of the doors) to ensure stable door and wing spreads and to prevent the trawl to be overspread. A similar technique is used during the standard hake surveys in Namibian waters (20m constraining rope, 150m from the doors). The vertical opening of the trawl (4.2 m) and the door spread (52 m) were measured with Scanmar sensors. The duration of a tow was 30 minutes and the towing speed was 1.5 m/s. All trawl hauls were carried out in the same direction and track. A total of 42 bottom trawl hauls were carried out.

Pelagic trawl hauls were carried out with an Åkrahamn pelagic trawl (circ. 198 meshes x 1620 mm, Fig. 2) using the Multisampler. This devise attaches to the extension piece of the pelagic and can take three separate fish samples with washing out intervals (10 minutes used

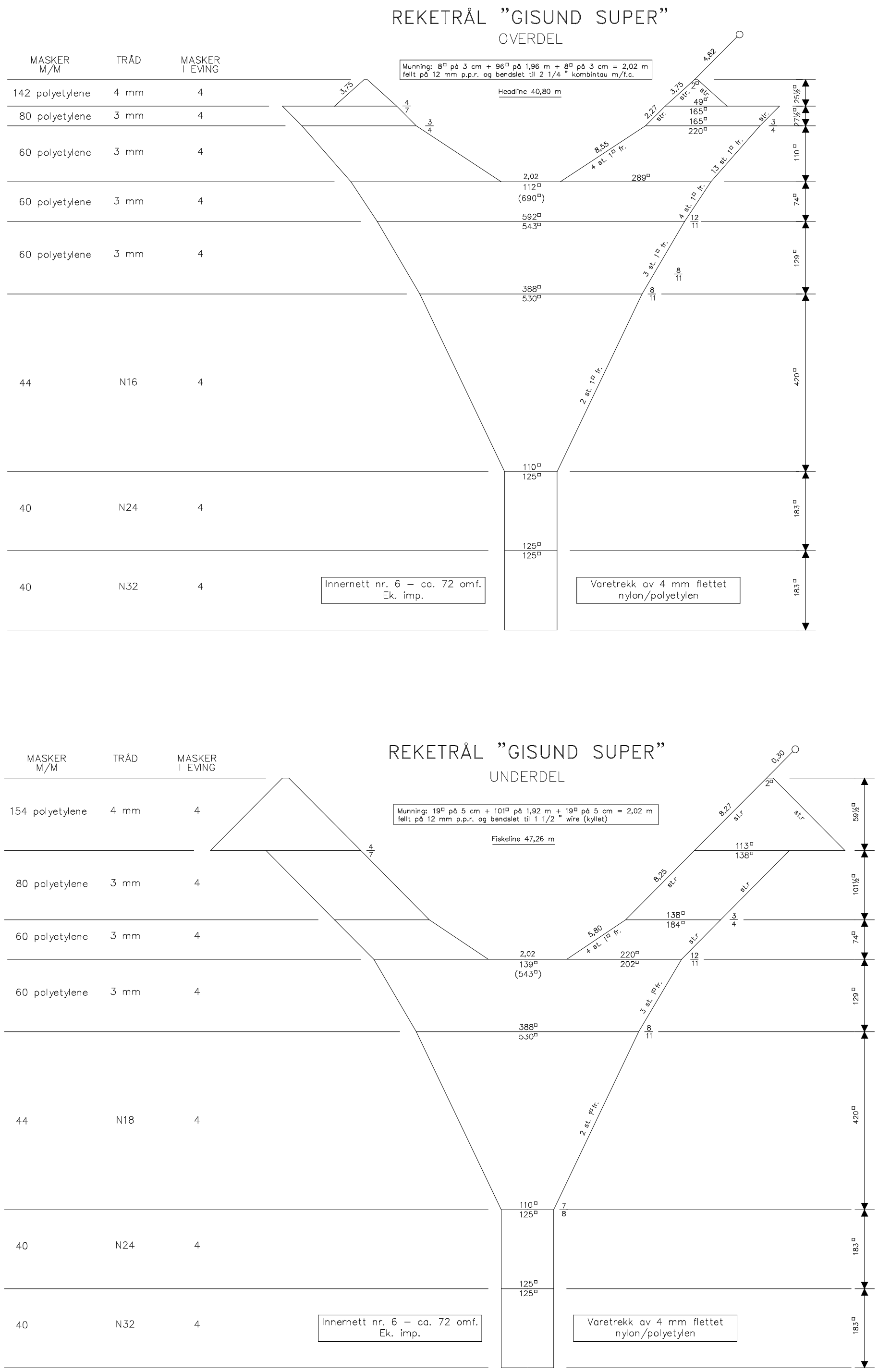

Figure 1. Design of the Gisund bottom trawl.

Figure 1. Continued. Schematic drawing of the ground gear used in the experiments.

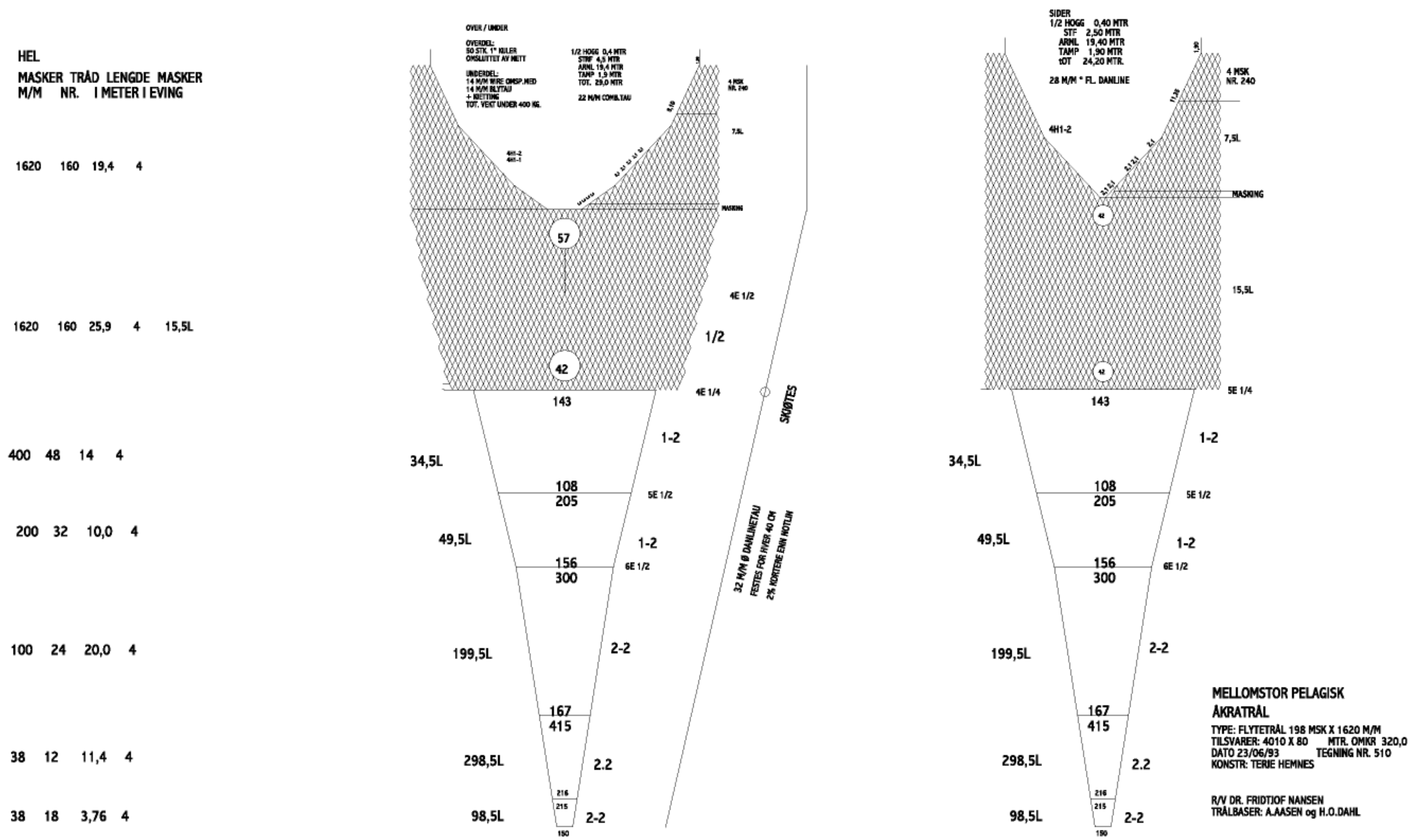

Figure 2. Design drawing of the Åkratrål pelagic trawl.

in this experiment) between each sample, within each trawl haul. The mesh size of the three codends used is similar to the mesh size of the bottom trawl codend, i.e. 24 mm. Three depth intervals were fished with a duration of 30 minutes at a speed of approximately 2 m/s; one sample was always taken in the depth zone between 5-20 above bottom, while the two others were taken in the pelagic zone based on acoustic observations of the distribution of fish/plankton in the water column. Similar to the bottom trawl, the towing direction was constant from haul to haul.

All trawl hauls were monitored with Scanmar trawl sensors (door spread (110 m), vertical opening (14 m) and distance between the fishing line and the seabed). During one haul the horizontal opening was measured to 33 m (measured three metres in front of the upper wing). A total of 41 pelagic hauls were carried out.

2.2 Acoustic measurements

The acoustic recordings were recorded using Simrad EK 500 echosounder coupled to a keel-mounted transducer of 38 kHz. Acoustic raw-data were logged on the Sun-Unix based Bergen Echo Integrator (BEI) version 2000. Standard settings of the echosounder was used during the survey. The acoustic data were scrutinized using the post-processing module of the BEI software. The mean 1 n.mile area backscattering coefficient Sa ($m^2/n.\ mile^2$)was allocated to a predefined set of species or species groups. The Sa-values for hake where grouped into 10m depth layers in the pelagic channels and 2 m in the bottom channel. Sa-values for the experiment where plotted by time in different depth layers and a Lowess robust scatter point smoother was (Cleveland, 1979) applied to display possible diel patterns.

The contribution of hake to the Sa-values was estimated by calculating the percentage of hake caught (by weight) to the rest of the catch. When calculating the percentage only species where selected that were assumed to contribute to the Sa –value significantly. For the pelagic hauls this meant that hake was calculated as a percentage to the total catch as all species are believed to contribute to the Sa-values. For the bottom hauls species without swim bladders and those that lie on the bottom were not included in the percentage calculations as they would not contribute to the Sa-values significantly. The main contributors in the bottom hauls where thus the following species besides hake: *Caelorinchus simorhynchus ; Helicolenus dactylopterus; Hoplostethus cadenati; Nezumia micronychodon; Notacanthus sexspinis* and *Selachophidium guentheri.*

2.3 Hydrography and meteorology

CTD stations were carried out morning and evening. Temperature and oxygen were measured. Wind speed and direction, air and sea surface (5 m depth) were logged automatically throughout the cruise using an Aanderaa meteorological station.

In the analysis of the data day was determined as being from 06h00 to 16h00 UTC while night was defined as 18h00 to 04h00 UTC. Dawn was thus defined as from 04h00 to 06h00 UTC and dusk from 16h00 to 18h00 UTC.

2.4 Light measurements

The underwater photo-multiplier-based light meter was connected to the underwater housing of the CTD-probe. The meter has a cosine filter placed on the front of the housing. The light intensity was logged 24 times pr second along with the CTD-data. The light meter produced meaningful readings down to 10^{-4}/ 10^{-5}, corresponding to about 320 m depth during the day, and around 100 m during the night. (Appendix).

In the analysis of the data day was determined as being from 06h00 to 16h00 UTC while night was defined as 18h00 to 04h00 UTC. Dawn was thus defined as from 04h00 to 06h00 UTC and dusk from 16h00 to 18h00 UTC.

Fluctuations were observed in the data recorded and in order to determine whether this had to do with the lower threshold of the equipment or whether this were true fluctuations in the actual readings, a cardboard cover was placed over the light meter. Stable readings where received as light still filtered through this cover. Another layer of cardboard was added and again stable readings where recorded. Layers of thick tape where then added on top of that until the lower threshold was reached. The readings started fluctuating once the readings climbed above 4 volts. This showed that fluctuation in readings that occur at above 4V are due to equipment limitations but that fluctuations below 4V are actual fluctuations in light intensity.

Tests where also conducted to determine the effect the vessel's deck lights had on the light readings during the night. Readings where take with the all deck lights in use during normal operation switched on and then again with all deck lights switched off.

3. RESULTS

3.1 Trawling Experiments

Station and catch composition information are given in the appendix. For most bottom hauls hake was the dominant species by weight, followed by rattails, black slimehead and African sawtail catshark. The catches in the pelagic hauls composed mainly of hake and black slimehead in the deepest hauls (<25 m off bottom). Catch rates of hake decreased with distance above bottom and except for one haul with one fish only, no hake were caught shallower than 100 m above bottom. In the shallower pelagic hauls myctophides and shrimp made up the bulk of the catches. Catch rates of hake showed no clear trend across the experimental period (Fig. 3).

The hake caught were all deepwater hake (*M. paradoxus*). On average, females accounted for 90% of the hake caught. The average length of hake caught in the bottom trawl (pooled data) was higher during night than day. The cumulative length frequency distributions of hake caught during daytime and night-time hauls are presented in Figure 4. A higher proportion of 30-40 cm fish was observed in night-time hauls.

Bottom trawl catch rates of both males and females showed indications of a diel pattern with highest values in the late afternoon (Fig. 5). The same trend was observed for females catches from the deep pelagic layer. No pattern could be seen in the medium pelagic layer (25-100 m above bottom.

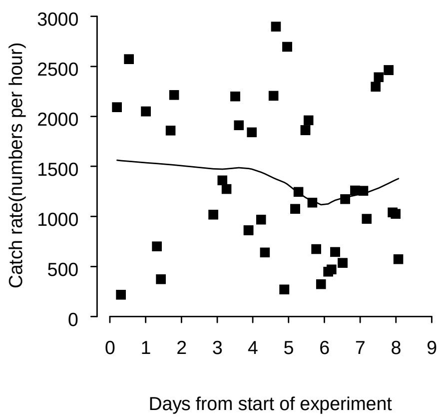

Figure 3. Bottom trawl catch rates of hake across the experimental period.

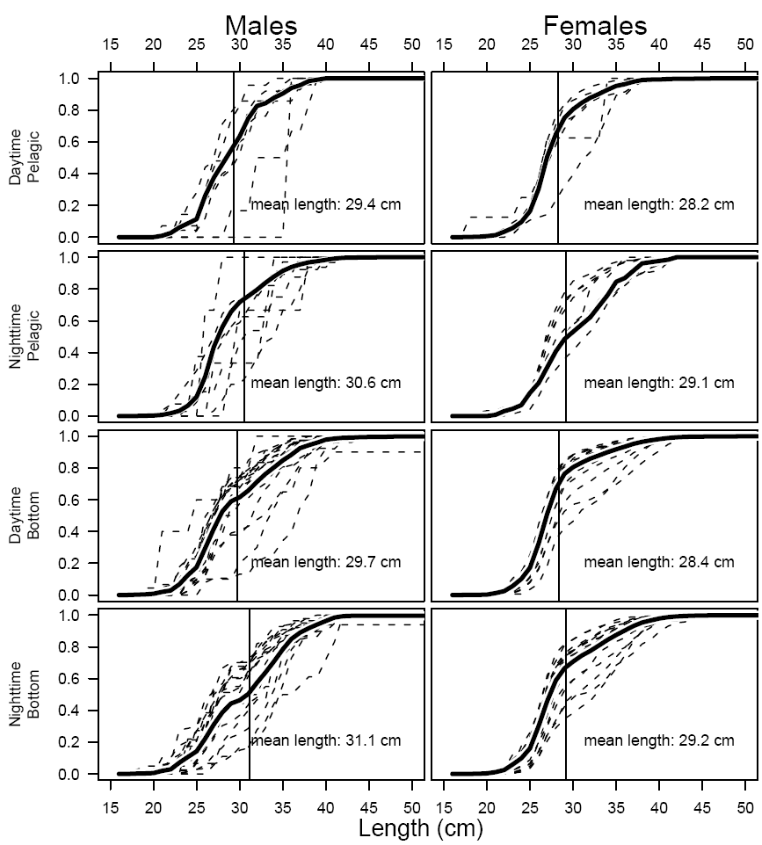

Figure 4. Cumulative length frequency distributions of deepwater hake by individual hauls. Pooled data are shown as bold curves. Vertical lines show mean length.

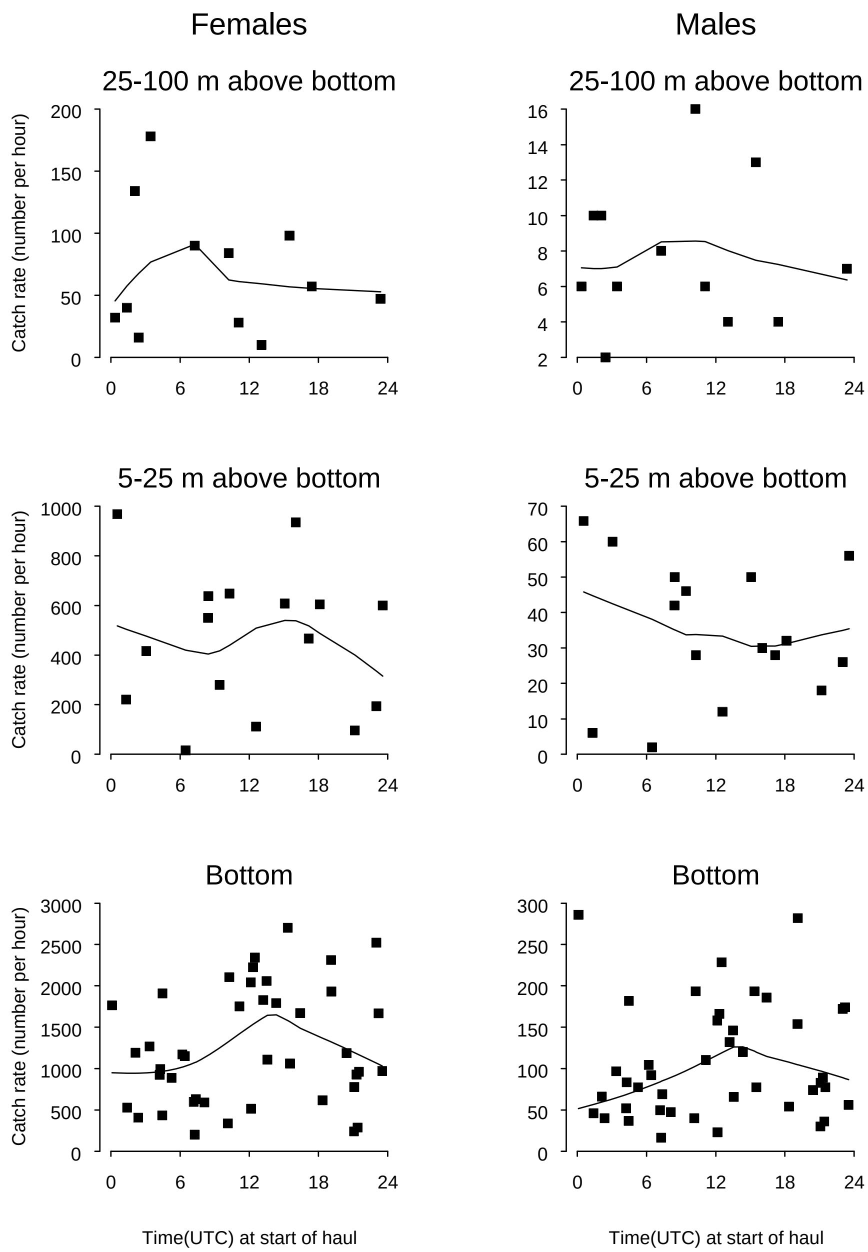

Figure 5. Catch rates by hour for females (left panel) and males (right panel) in the bottom layer (bottom trawl) and in the deep and medium pelagic layers (pelagic trawl).

3.2 Acoustic estimates

The diel variation in estimated Sa values for the various depth layers are shown in Fig. 6. No clear pattern was seen for any of the layers. The highest Sa values were observed in the 20-100 layer (mean=153), followed by the 4-20 m layer (33) and the 0-4 m layer (21). Based on these values approximately 10% of the hake was available to the bottom trawl (0-4 m layer above bottom). No hake Sa was allocated to the layers more than approximately 100 m above bottom.

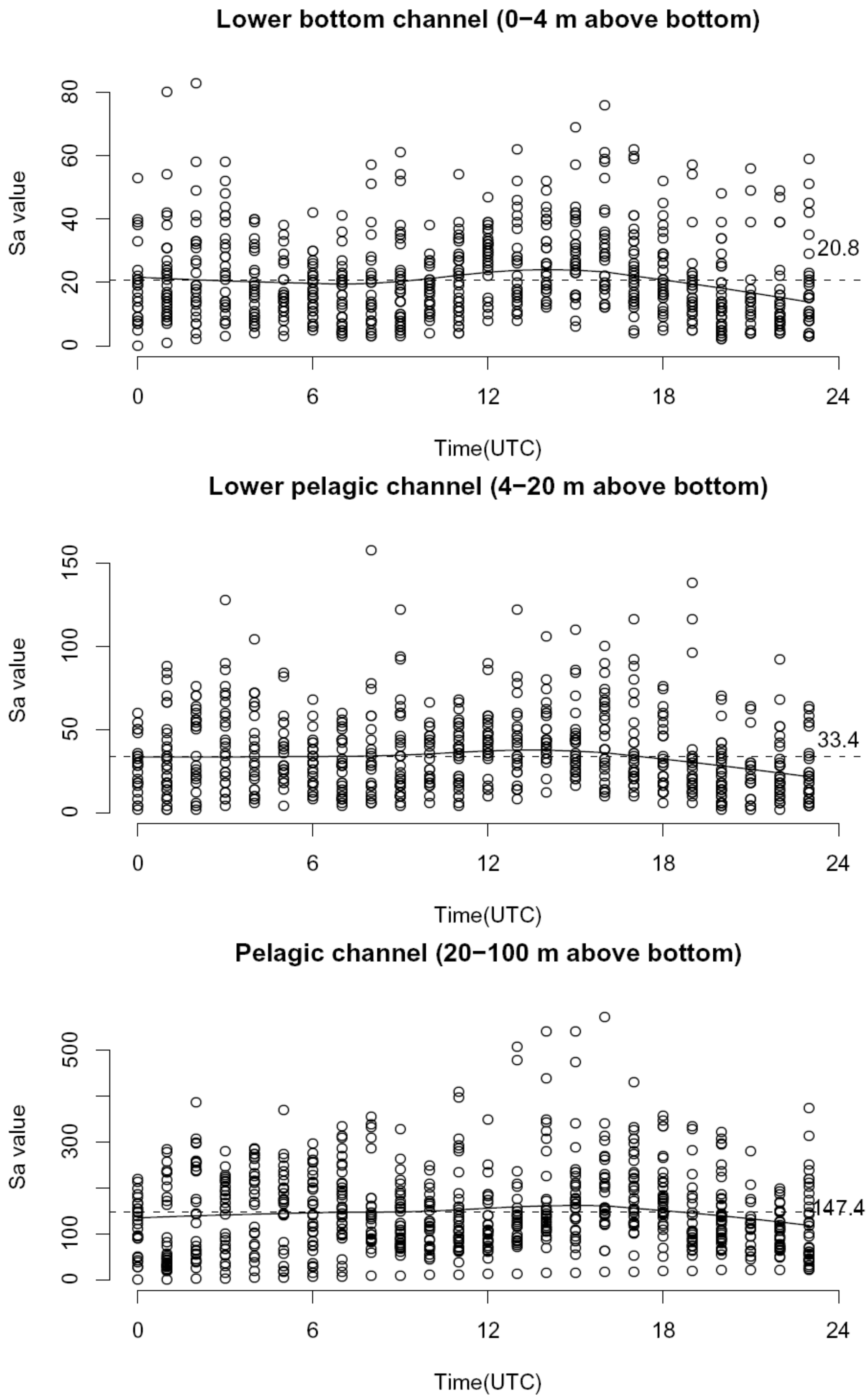

Figure 6. Estimated Sa values for the bottom layer (0-4 m) and the 4-20m and 20-100 m above bottom pelagic layers. Fitted curves are Lowess smoothers. Mean values for each layer is shown to the right of the plot.

3.3 Light measurements

Light measurements were analysed on an individual station basis but little variation was observed when comparing all daytime measurements. The same was also found to be true for the nighttime measurements. The data was thus pooled and plots of the overall average of the measurements are presented in Fig. 7 for both daytime and nighttime results. The nighttime results are further divided into two curves one representing readings with the vessels deck lights switched on and one for readings with the vessels deck lights switched off.

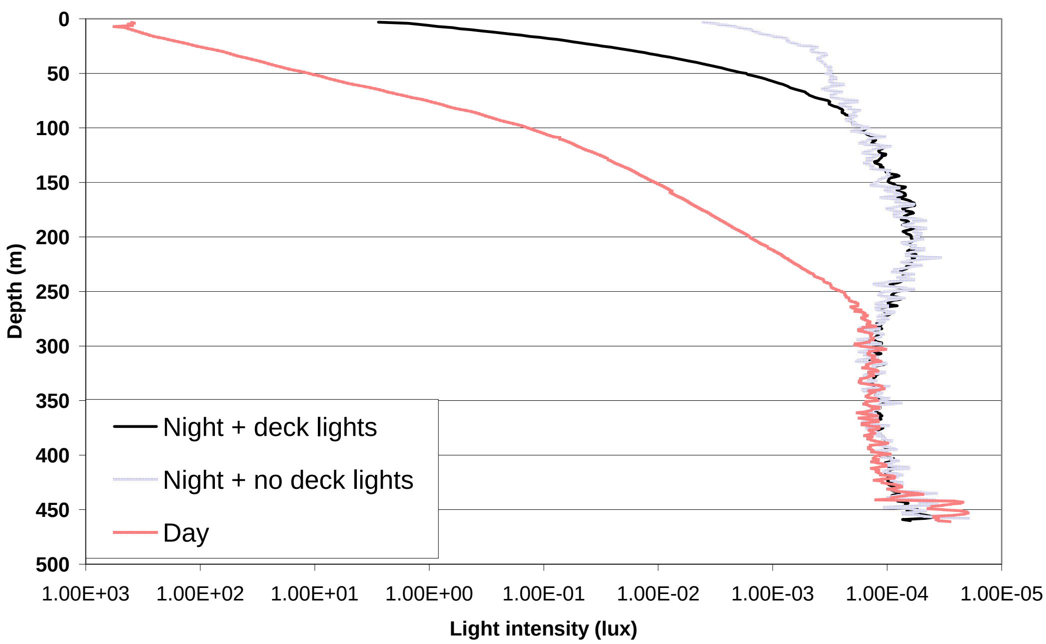

Figure 7. Light intensity measurements summarized for daytime, nighttime with deck lights and nighttime without deck lights

The results show that light from the surface has a measurable influence down to about 250 m in the daytime and down to about 80 m at night with the vessels deck lights switched on. If the deck lights are switched off this decreases to about 30 m. The effect the deck lights had on the light measurements was determined as discussed in section 2.4.

It was observed that light measurements started fluctuation substantially when light readings went below approximately 3.0E-04 lux. This corresponds to about 2.5 V and is thus within the equipment limitations (See section 2.4). These fluctuations are thus actual fluctuations in the light intensity readings and not due to equipment limitations. It is assumed that these fluctuations are caused by bioluminescence.

3.4 Oxygen, temperature and salinity

Little variation was observed for oxygen, temperature and salinity readings between individual stations. The data was thus pooled and average curves are presented (Fig. 8).

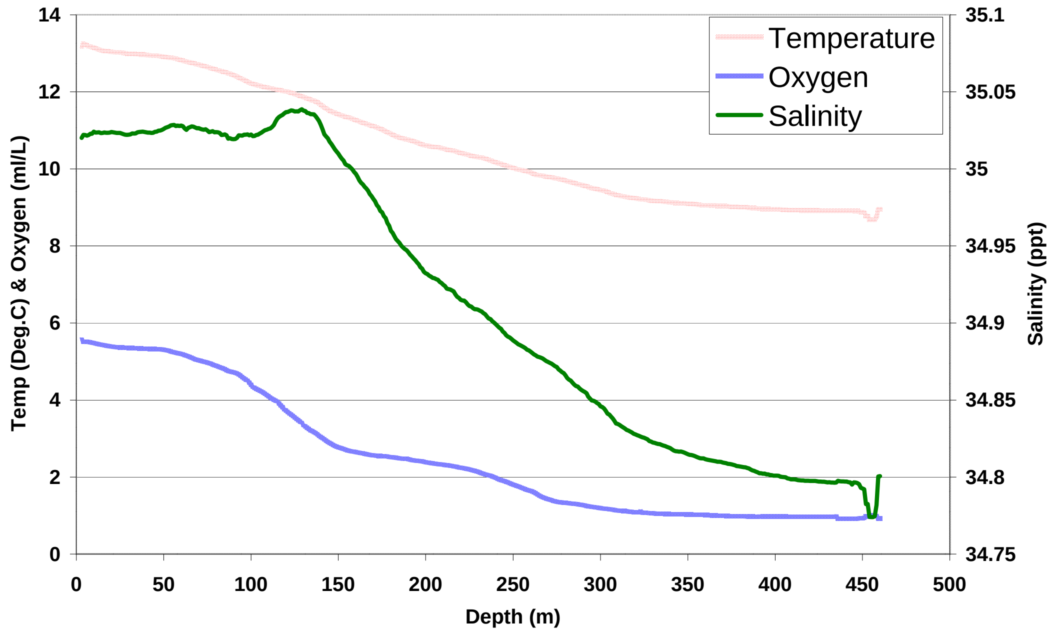

Figure 8 Summarization of temperature, dissolved oxygen and salinity measurements take throughout the cruise

The temperature was recorded to be around 13°C at the surface and gradually decrease to about 9 °C at the bottom. The salinity remained relatively constant at 35 ppt down to about 150 m and then a slight gradual decrease in salinity was observed with bottom readings of around 34.8 ppt. Oxygen measurements also showed a gradual decrease with increase in depth. At the surface oxygen readings were at around 5.5ml L^{-1} and then decreased to about 2 ml·L^{-1} down at 250 m. For depths greater than 250 m the oxygen content stayed stable at around 1 ml·L^{-1}.

4. DISCUSSION AND CONCLUSIONS

The present study was done to test the assumption that hake in deep waters do not perform extensive diurnal vertical migrations, and that during bottom trawl surveys trawling can therefore be carried out throughout both day and night. Intensive trawling by both bottom and pelagic was carried out at the same location for a total of eight days. Acoustic recording were made continuously during the experimental periods. Detailed recording were also made of key environmental variables.

The analysis of the bottom trawl catches of deepwater hake showed a diurnal pattern with a peak in the afternoon. Peak catches were approximately 1.5 times nighttime catches. This differs from the results observed at 550 m depth in 2004, but conforms to other studies where daytime maximum has been observed (Payne 1989, Huse et. al., 2001; Iilende et al. 2001). The diurnal pattern was less clear in the pelagic hauls, especially shallower than 25 m above bottom. No marked difference in mean length between day and night hauls was observed, neither in the bottom nor in the pelagic hauls. Only small fish were caught and therefore no inference could be made about possible length dependent differences in diurnal migration.

Based on the hydro-acoustic data, only 10% of the hake was available to the bottom trawl. This estimate seems very low compared to other studies, e.g. Iilende et al. (2001) who found more than 50% of the hake to be available to the trawl. The absolute Sa value for the bottom layer (0-4 m) corresponds well to the survey results obtained in 2004 (at 550 m depth), but the pelagic Sa values (especially the 20-100m layer above bottom) are considerably higher.

The allocation of recorded Sa values to the various species was based on their relative contribution to the trawl catches. Moreover, the frequency response pattern (based on the target strength with the three frequencies 18, 38 and 120 kHz) was used to aid in the judging. However, little is known of the relative target strengths of the fishes found in the pelagic layers. Moreover, the catch efficiency of the pelagic trawl for small pelagic species is unknown and the composition of the catch may therefore deviate from the relative abundance of the species in the sea. The latter may lead to a serious bias in the acoustic estimation of hake abundance. Increasing the sampling effort in the pelagic layer will not resolve the question whether pelagic hauls are representative of actual species composition. In our opinion, a subjective allocation of hake Sa to obtain "reasonable" estimates is not justified.

The underwater light measurement profiles recorded during the present study indicate no diel variation in light level below 300-350 m. It is therefore unlikely that the light level trigger the vertical migrations directly. There was nevertheless a noticeable difference between this years (at 450m) and the last years (at 550m) surveys.

5. REFERENCES

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