CRUISE REPORT >DR. FRIDTJOF NANSEN=

SURVEY OF THE FISH RESOURCES OF NAMIBIA

Cruise Report No 2/98

Part I

Hake survey methodology

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by

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CHAPTER 1 INTRODUCTION

1.1 Objectives

The cruise had the following overall objective:

- To work towards a catchability coefficient (**q**) for hake for the "Nansen" bottom trawl

Specific objectives were:

- To quantify escapement of hake under the bottom trawl
- To quantify hake area density from echograms
- To relate area density to trawl catches in order to establish **q**
- To Study fish escapement and gear performance in the trawl mouth
- To quantify day-time variation in hake catchability

The first specific objective was to be met by doing alternating hauls using identical trawls, but with and without bobbins ground gear.

The second specific objective was to be addressed by surevying the trawl path during the night at slow speed generating high resolution echograms where individual fish traces could be counted in order to establish fish area densities. During the day a submersible transducer was to be lowered into the mesopelagic fish concentration close to bottom in order to resolve single hake traces.

The third specific objective was to be addressed by comparing the area densities generated from echogram counts to the trawl catches.

The fourth specific objective was to be achieved by using the RS 400 video obsrvation system mounted in the trawl mouth.

The fifth specific objective was to be addressed by comparing day-time catches with light intensities from the submersible light meter on the CTD probe with trawl catches and time of day.

1.2 Participation

The scientific staff consisted of:

From Angola:
Paulo BRINCO, Agostinho DUARTE

From Namibia:
Gerhard OECHSLIN, Peter SCHNEIDER, Malakia SHIMANDA, Shaun WELLS
Guest: Hans Lothar KÜCHENMEISTER

From South Africa:
Sharon du Plessis, Ralton MAREE, Chris SMITH

From Norway:
Bjørn Axelsen, Yngve FJELLSTAD, Ingvar HUSE, Ronald PEDERSEN, Ingvald SVELLINGEN

1.3 Narrative

The working areas are shown in Figure 1.

Two days were spent in Walvis Bay installing and testing the Focus 400. The vessel left Walvis Bay with a limited scientific staff and two representatives from McArtney on the afternoon of 13 April and steamed west to carry out the sea acceptance test of the Focus. En route an attempt to observe a trawl haul with the Focus and video camera was made at 50 m depth. The acceptance tests were carried out at around 300 m depth west of Walvis Bay, after which the ship returned to port to pick up the rest of the scientific staff. Reports from the fishing fleet indicated low catches of hake in all areas, and the course was set for an area at around 300 m depth North West of Walvis Bay at S 21°40" and E 12°43" (Figure 1, Work Area I). The first haul here was promising, but later hauls showed quite small concentrations of hake, and the course was set south along the shelf on 20 April. At S 24°25" E 13°40" good concentrations of both species of hake were found, and most of the work under objective 2

Figure 1. The work areas.

was carried out here. Most of the photographic Focus work was abandoned after the results from the northern area, as very little fish was seen on the photographs, and visibility in the sea was limited to less than 4 m at all depths, normally not more than 2m. As a methodical substitute it was decided to carry out vertical trawl sampling to try to identify the diurnal dynamic aspects of the different biological components present, mainly both species of hake, mesopelagic fish, krill and cephalopods. On 26 April the ship called at Walvis Bay to set ashore Boyer and Strømme, and went out again the same afternoon to commence the work. Another unsuccessful attempt at trawl observation was made, and also some attempts at density measurements of horse mackerel schools (Figure 1, Work Area III). 29 and 30 April were spent doing comparative fishing with AWelwitchia@ and some experimental swept area studies. The ship returned to Walvis Bay to end this part of the cruise on 1 May.

CHAPTER 2 HYDROGRAPHY

A hydrographical transect of the shelf at the latitude of Walvis Bay taken at the beginning of the cruise is presented in Figure 2. It shows a moderate upwelling situation with the lowest surface temperatures and highest salinities inshore. Bottom oxygen values are also below 0.5 ml/l all the way down to 300 m, with values of around 0.25 ml/l down to 150 m.

Figure 2. Hydrographic section Walvis Bay - West; temperature, salinity and oxygen.

CHAPTER 3 HAKE SURVEY METHODOLOGY

3.1 Introduction

In Namibian hake bottom trawl surveys all catches are sampled for composition of weights and numbers by species. The bottom trawl has a headline of 31 m (float line), a footrope of 47 m, headline height of 5-6 m and a distance between the wings during towing of about 22 m. All trawl hauls are monitored by SCANMAR trawl sensors (headline height and distance between the doors). This technology allows the determination of the correct trawl bottom time. For conversion of catch rates to fish densities the area between the wings is assumed to be equal to the effective fishing area and the retention factor q is equal to 1. With the new vessel, starting from January 1994, a new trawl gear was introduced with smaller bobbins. For the hake species the new gear is assumed to have no difference in performance. The trawl doors are Thybor□en 7.9 m2, and the trawl is a simple two panel Gisund Super. The length of a haul over bottom, recorded as distance trawled, is normally measured by log pulses from the GPS, and checked against the lengths of the traces of the hauls on the GPS plot on the MacSea system. Catch data are given in Annex I.

The swept area of a trawl haul is a crucial parameter in swept area survey methodology, particularly if the survey is supposed to estimate total biomass rather than just give a yearly index. Swept distance is easy to measure, while the sweeping width is the difficult parameter. In Namibian hake surveys a swept width of 18.5 m is used. If the assumption for hake is that wing spread is the correct sweeping width, we are in other words overestimating the hake population slightly as the true wing spread is 22 m. Some attempts have been made to find the correct sweeping width for hake, but this is a general problem in swept area assessment methodology all over the world, and the methodological aspects are very complicated, as it is almost impossible to isolate sweeping width as the only parameter involved. The problem consists of assessing how much fish of different species and size groups are herded towards the trawl opening by doors, sand clouds stirred up by the doors, and the bridles which attach the net to the doors, and which are about 50 m long. In addition there is also potential escapement over and under the trawl. No one has yet succeeded in assessing the true efficiency of a trawl gear except in very shallow waters. Still the swept area metodology seems to give the most consistent results for assessing groundfish. Hake definitely seems to be less herded than e.g. cod in the experiments carried out so far, and perhaps the use of a slightly reduced (18.5 m) swept width in the assessment as opposed to the measured 22 m wing spread compensates adequately for escapement over and under the trawl. Still this problem needs to be further addressed, and in the present cruise a new methodology (on/off bottom, paragraph 3.1.5) was attempted to find the hearding efficiency of doors, sand clouds and bridles.

The problem of mid-water occurrence of hake and its effect on the swept area assessments has been discussed in earlier cruise reports. Mesopelagic fish quite often cover the pelagic zone close to the bottom in the daytime, making it impossible to correct for pelagic hake. Consequently the hake biomass may be underestimated if no correction is made for situations where the pelagic hake distribution is unknown due to shading by mesopelagic fish and plankton. Probably this problem is most pronounced in the north where the acoustic correction to the trawl index constitutes an average of about 10 % addition to the demersal biomass in the day hauls where the conditions allow it to be assessed. In a limited number of night hauls in the January/February survey this year the average corrections were, however, 56, 33 and 43 %. This indicates that the overall corrections would be somewhat higher if daytime acoustic corrections were not made impossible by the presence of mesopelagic fish.

Initially we set out on this cruise to try to define the retention factor or catchability constant q by comparing fish distribution and density from pictures taken by the Focus 400 with trawl catches. But as visibility, and probably fish avoidance of the Focus did not permit us to pursue this methodology, the emphasis was shifted to the behavioural ecology of the hakes and their cohabitants. The objectives then became to describe and if possible explain the diurnal vertical dynamics of the ecosystem, and to assess the problem of acoustic shading of hake by dense layers of mesopelagic fish and plankton. In addition we would test alternative methods to elucidate hake catchability with the sampling trawl.

3.2 Methods

The Focus 400 (Figure 3) is a towed manoeuvrable vehicle with electrical supply for instruments, and fiberoptic transmission of data to and from the ship. It can go down to 400 m and can go out to about 80 m on each side from the course line. It has surface or bottom lock autopilot modes. On this cruise it carried a SIT video camera, a Simrad/Mesotech FS-3300 sonar, a photomultiplier based light meter and a Nikon F4s photographic camera with a 250 frame automatic backplane in an underwater housing. Kodak Ectachrome 200 film was used and processed on board in an automatic processing machine.

Figure 3. The Focus towed vehicle system.

In the first part of the cruise (Figure 1, Work Area I) the work in each 6 hour watch consisted of one bottom trawl haul, one acoustic coverage and one Focus run 5 m from the bottom, all along the same lane.

In the second area (Figure 1, Work Area II) one bottom trawl haul, one acoustic coverage, and at least one pelagic haul was made along the same lane every 6-hour watch around the clock. The pelagic community was quite distinctly layered both day and night (Figure 2, a and b), and the different layers were sampled with pelagic trawl in an attempt to identify the composition.

The bioluminescense of the pelagic layers could be monitored with the light meter, and could also be readily observed with the SIT video camera. It was possible to follow each layer during the vertical migration on the 38KHz EK500 sounder used. Normal fish samples were taken from all hauls, and stomach content of hake was also observed in many of the hauls.

The swept width methodology studies were aiming at finding a way to minimize the effect of doors, sand clouds and bridles. A promising method tested was to lift the doors about 6 m off bottom. In order to be able to do this without loosing bottom contact with the gear, weights had to be attached to the gear at the wing ends. A few comparisons were made in alternative hauls with the doors on and off bottom. Weights were used in both situations.

3.3 Results and discussion

Technical performance of the Focus 400

All technical acceptance tests with the Focus 400 vehicle were satisfactory apart from a cable winch spooling problem. Operational specifications were met or exceeded, and all interfaces with deployed equipment worked. It was comparatively easy to operate, and the bottom lock auto pilot mode was stable enough on flat bottom to keep a distance of 1.5-2 m at 3 knots. The ROS SIT zoom camera used had a lower light sensitivity than expected, and was significantly less sensitive than an Osprey 1323 with which it was compared. The FS-3300 sonar functioned as expected, but video sync out did not work, so no recordings could be made. The photographic camera worked satisfactory and could be operated both in pre set auto mode and in user real time release mode. The flash gun housing window broke due to a faulty glass, and one flash gun was destroyed, but with a replacement flash gun and glass it worked well. The light meter produced sensible readings down to 10^{-5} lux which corresponds to around 400 m depth in the day-time in the surveyed area at this time of year. It also picked up significant amounts of bioluminescence.

Photography

Altogether nine photographic Focus dives with at least 60 frames shot in each dive were made. After some initial problems the method worked well. Due to the low visibility we were, however, forced to keep a shorter distance to the bottom (3 m) than planned (6 m). This led to a smaller bottom area observed in each shot, and also increased the risk of scaring away large groundfish like hake. And accordingly, in all the hundreds of pictures taken only one hake was observed. This is far below expectancy considering the covered volume and trawl catches in the same area, and strongly indicates an avoidance reaction by the hake. Small bottom dwelling fishes were observed in most pictures, as well as a number of sessile species. The conclusion is that photography from the Focus can not be used as a method to estimate true densities of hake along the bottom in Namibian waters. It can, however, be used to assess sessile organisms and slow moving fish and crustaceans, but as it still will have to keep a close distance to the bottom the area covered in each shot will be small (<10 m^2).

We also tried to run the Focus close to the bottom with the video camera and lights on. We did see fish and could observe typical flight reactions in burrowing fish. The images were not analysed in detail, but they were asumed to be monk by size, form and behaviour. It could be of value to try a systematic observation to investigate the basis for a monk/sole true density assessment using this technique. If this could be achieved one would also have a method to assess the retention factor for these species in the sampling trawl.

Acoustics

The main working area (Figure 1, Work Area II) was characterised by good concentrations of both hake species and a substantial pelegic component consisting of mesopelagic fish, euphausids and squid. The pelagic component underwent extensive diurnal vertical migration which is examplified in the echograms in Figures 4 (day) and 5 (night). At least 4 layers (5 with the obscured hake layer) were identified during the day and could be followed through diurnal vertical migration where at night the deepest mesopelagic layer split to form 2 sublayers (Figure 5), giving a total of 6 fairly easily discernable and stable layers at night. These were from the surface and down: -one diurnally stable surface layer (L1), 4 vertically migrating mesopelagic layers (L2-L5), and a hake layer (L6) below 300 m. Mean hourly values of total acoustic back-scattering is given in Figure 6. The figure was made from post processed acoustic data, and all acoustic information received during the four diurnal cycles the experiment lasted was combined into one diagram. The six layers can be readily discerned from the combined four day data, illustrating the day-to-day stability of the dynamics. It should also be noted that the light conditions these days were quite stable (Figure 7).

The species composition in the layers was identified from trawl catches (see below). The surface layer (L1) consisted mainly of large medusae and other plankton, and was covered at night by the top mesopelagic layer (L2). The mesopelagic layers (L2-L5) dominated the acoustic backscattering energy in the system, and probably also the biomass. Strangely enough there was no clear cut species separation in the mesopelagic layers despite the distinct separation of the layering. The myctophid fish *Symbolophorus boops* was found in all mesopelagic layers during night-time, totally dominating L2 and L3, still being prominent in

Figure 4. Echogram of acoustic scattering layers in Work Area II in the day-time. 1) Plankton including large medusae; 2) Diving seal; 3) Mesopelagic layer L2; 4) Mesopelagic layers L3 and L4; 5) Hake (L6) within Mesopelagic layer L5; 6) Bottom expansion (10 m)

Figure 5. Echogram of acoustic scattering layers in Work Area II during night-time. 1) Plankton layer L1 and mesopelagic layer L2; 3) Mesopelagic layer L3; 4) Mesopelagic layer L5; 5) Hake (L6); 6) Bottom expansion (10 m) showing hake and other ground fish, mainly *Helicolenus dactylopterus*

Figure 6. Isoplethe diagram of total acoustic concentrations (S_A values) by depth and time of day. Values are hourly averages of four 24h periods in Work Area II.

Figure 7. Surface illumination (mE) during the experimental period.

L4, but also being found frequently in L5. On the other hand, the mesopelagic fish *Photichtys argentus* was mainly found in L5 at night, but was also partly and sparingly present in L3 in the early evening. Krill was at night found in layers L3 to L6, but was most abundant in L4. A small (mean weight around 10 g) squid species of the genus *Lycoteuthis* was found in quantities in the order of magnitude of 5% of the total mesopelagic biomass. It migrated from around 230 m in the daytime to L2 and L1 at night. A larger (mean weight of adults >1 kg) squid species of the genus *Todarodes* was less abundant, and stayed generally deeper than the small species in the day-time, but small specimens migrated as high as to L3 in the early evening. Why this mixing of the same species into many layers occur is unclear. It could reflect the feeding motivation or predator avoidance level in the individual fish. Possibly it could also at times reflect by-catch from other layers than the one sampled, particularly in the deeper hauls.

The hake layer (L6, Figure 8) consisted of both species of hake. Acoustic day values were adjusted by trawl catch data and acoustic night values as the hake layer was covered by the other layers during the day. The acoustic observations indicated a certain rise from the bottom at dawn and dusk, and also a most pronounced pelagic distribution in the early evening. It should, however, be noted that this may more reflect the scrutinizing of the echograms than the true distribution. This will be discussed along with the trawl data below.

Figure 8. Isoplethe diagram of acoustic concentrations of hake by depth and time of day. Values are hourly averages of four 24h periods in Work Area II

Figure 9 is a presentation of mean hourly acoustic backscattering values over the whole water column. It is dominated by mesopelagic fish, krill and squid. It shows low night values, very low morning- and evening values, and very high daytime values. Figure 10 shows the same relationship for several years of survey activity for herring in Norway (from Huse and Korneliussen, 1995). The picture there is the same as in the present study. The

Figure 9. Mean hourly acoustic backscattering for all species (Namibian shelf) for the experimental period.

Figure 10. Mean hourly acoustic backscattering for herring during six acoustic assessment surveys in Norway.

major difference originates from the fact that the day length is shorter in Northern Norway during winter. Rheinesson et al.(1994) have shown the same characteristics for *Sebastes mentella* in the Irminger Sea between Iceland and Greenland. Generally the curve can be looked upon as a representation of the diurnal variation in acoustic target strength (TS) of the species involved. This is generally modulated by e.g. the tilt angle of the fish (Nakken and Olsen, 1977). The low values at dusk and dawn can therefore be interpreted as being tilt angle induced related to vertical migration. The generally low night values are for herring also caused by tilt angle variations related to an energy saving behaviour pattern (Huse and Ona, 1996). What the cause might be in the present situation is not known, but it may possibly have to do with a more or less constant vertical migration, and a consequent angular articulation of the different components of the biomass measured. It is also noteworthy that in the day-time when the backscattering is strongest the scattering organisms are at their deepest, and consequently, gas filled swimbladders will be most compressed, a situation which should rather minimize reflection. This shows the importance of behaviour in general and tilt angle distribution in particular on acoustic reflection and abundance estimation. The interesting assessment aspect of it all is that if this is a general situation with pelagic fish, the present practice using an average constant TS can give very wrong estimates depending on at what time of day large fish aggregations are encountered. The solution to the problem could be to use dynamic TS functions where the diurnal variation in TS is included. Such functions would, however, have to be modified for different stocks and times of year.

In an acoustic survey situation the best resolution of the hakes will be at night. One way of resolving the issue of hake shading by mesopelagic layers will therefore be to backtrack the survey lane at night when hake surveying is often discontinued anyway due to lower hake catchability in bottom trawl. See also the last part of the next section.

Trawling

Altogether 12 functional bottom hauls and 23 pelagic hauls were carried out during the five days of the special investigation in Work Area II (Figure 1).The time of day and depth of all trawl stations are given in Figure 11. The pelagic hauls were mainly made to elucidate the diurnal hake distribution. Therefore most pelagic hauls were in the hake zone up to 50 m from the bottom, but also the different mesopelagic layers were sampled in order to facilitate adequate scrutinizing of the echograms. The haul which caught hake highest up in the water column was carried out at 20:00 h, and the fishing depth was 265-290 m, 65-90 m from the bottom. The hake catch in this haul consisted of 4 *M. paradoxus* with a mean weight of 0.35

kg. This was the only haul with hake catches above 300 m, but from 300 m and down both species were found in all hauls. Figures 12 and 13 show total weights of both hake species in bottom and pelagic hauls respectively. Figures 14 and 15 show weights and numbers respectively of *M. capensis* and *M. paradoxus* in bottom trawl hauls. Figures 16 and 17 show the same for pelagic hauls. All catches were standardized to a haul of 1.5 nautical mile at the fishing depth. The total hake weights varied substantially both in bottom and pelagic hauls. Still there was a tendency towards higher day-time than night-time catches in the bottom trawl hauls, while the pelagic hauls with hake catches did not give any strong indications, maybe because they were taken at different depths. In the bottom hauls *M. capensis* biomass dominated over *M. paradoxus* in 10 out of 12 hauls. But the number of *M. paradoxus* were higher than the number of *M. capensis* in all bottom hauls, illustrating the size difference of the two species in this area. *M. paradoxus* catches seemed to be higher in the day-time than at night in the bottom hauls, maybe only signifying that the vast majority of the organisms in the system were pressing against the bottom during the day-time, including the *M. paradoxus*. In 9 of the 11 pelagic hauls with hake catches the M. paradoxus biomass was higher than that of *M. capensis*, and of course also the number of *M. paradoxus* was higher than the number of *M. capensis* in all hauls. This may indicate that the small *M. paradoxus* have to maintain a pelagic position when large *M. capensis* occupy the bottom zone, as smaller hake is an important food source for large *M. capensis* (Payne et al. 1987; Punt et al.1992). Alternatively, young *M. paradoxus* feed on prey organisms which stay more pelagic than the prey of large *M. capensis*. This will be discussed further under 3.1.3.5.

The consequece of all of this in a survey situation is that if only a bottom haul is made in a situation where both species are mixed, both the fraction and the numbers of *M. paradoxus* will be underestimated as the mix normally will consist of large bottom dwelling *M. capensis* and smaller more bathypelagic *M. paradoxus*. Accordingly, when there is the likelyhood of a mix, both a bottom and a deep pelagic haul should be made, e.g. by doing the pelagic hauls at night when the survey activities are often discontinued anyhow (see above).

Figure 11. Time and depth of all trawl hauls. Filled squares are hauls with hake catches.

Figure 12. Total weights of both species of hake added together, bottom hauls.

Figure 13. Total weights of both species of hake added together, pelagic hauls.

Figure 14. Weights of both hake species in all bottom hauls.

Figure 15. Numbers of both hake species in all bottom hauls.

Figure 16. Weights of both hake species in all pelagic hauls.

Figure 17. Numbers of both hake species in all pelagic hauls.

Stomach content

Stomach content from both hake species was investigated. The sampling was carried out in order to find if there was a feeding rhythm in hakes, and also to look at prey selection. The samples were collected from 8 bottom hauls and 6 deep pelagic hauls. The 14 *M. capensis* samples contained altogether 281 fish and the13 *M. paradoxus* samples contained 341 fish. Figures 18-22 show % of fishes with stomach content in all samples (Figure 18), bottom M. capensis samples (Figure 19), bottom *M. paradoxus* samples (Figure 20), pelagic *M. capensis* samples (Figure 21) and pelagic *M. paradoxus* samples (Figure 22) respectively. Neither of the data indicate a clear diurnal feeding periodicity, although there might be indications of high early evening values in both species. The data are, however, far from conclusive. This is in good accordance with the findings of Payne et al.(1987), Roel & Macpherson (1988), and Gordoa & Macpherson (1991), suggesting that at least older *M. capensis* do not exhibit marked feeding periodicity. This also seems to be the case for *M. paradoxus* in this investigation.

Figure 18. Percentage non-empty stomachs, all examined fish.

Figure 19. Percentage non-empty stomachs, bottom trawl, *M. capensis*.

Figure 20. Percentage non-empty stomachs, *M. paradoxus*.

Figure 21. Percentage non-empty stomachs, off bottom, *M. capensis*.

Figure 22. Percentage non-empty stomachs, off bottom, *M. paradoxus*.

For *M. capensis* the diet was varied, but contained mainly fish. Small hake and jacobever constituted the main biomass, but krill was also found very frequently. Quite large horse mackerel were also found, as were both small and large squid. *M. paradoxus* proved to be a krill eater. That agrees well with both size and semipelagic distribution. In addition Myctophids were frequently found, and also a few small squid.

3.4 Conclusions

The vertical dynamics of the different biological components of the ecosystem studied seemed to be quite stable and was characterised by segregation in distinct layers. The mesopelagic component exhibited an apparent diurnal variation in acoustic back-scattering properties similar to Norwegian herring and Icelandic bathypelagic redfish.

Hake were masked by mesopelagic fish during the day, but were available for acoustic recording at night. Hake generally did not migrate above 60 m from the bottom.

The availability of hake to the bottom trawl was somewhat higher during the day than at night, but there was little difference in pelagic hauls. Bottom or pelagic trawl hauls alone did not reflect the species or size composition of hakes in the area neither night nor day.

No clear diurnal feeding periodicity was demonstrated. Large *M. capensis* fed mainly on fish, while the smaller *M. paradoxus* were krill eaters.

In areas with mixed concentrations of both hake species, bottom hauls as well as pelagic hauls are necessary to find the correct species composition and size distribution. If mesopelagic fish are abundant, pelagic hauls are always necessary, as is night-time acoustic coverage.

3.5 On/off bottom trawling

The study on this cruise was purely methodological, and only 12 tows comprising 6 paired comparisons with the doors on and off bottom respectively were carried out. 125 kg chain weights on each wing end to maintain bottom contact were tried first, but had to be increased to 250 kg to obtain satisfactory results. Possibly even 300 kg or more would add to the robustness of the methodology, as constant bottom contact during the whole tow is an absolute prerequisite for this type of experiment. The results strongly supported this, as off-bottom tows with insufficient bottom contact gave very poor catches. This is probably because the fish are collecting and holding in front of the gear and slip under it as soon as it lifts. Constant attention to door height over the bottom, as well as towing speed is therefore also absolutely necessary to have good results. On the positive side, however, it was quite possible to maintain normal door- and wing spread trawling this way. This means that an experiment can be carried out where there is no sand cloud from door bottom contact to consider as a herding factor. Also, the noise caused by door contact with the bottom will be avoided. Finally, the hearding of the bridles will be negligible, as they will be angling upwards from the wing ends towards the doors, allowing the fish to pass under them. Consequently it may be assumed that the catch difference with the doors on and off bottom should be a representation of herding by doors, sand clouds and bridles. Still it must be remembered that there may be a herding effect by the bridles and doors, so that this catch difference is a minimum representation of the herding.

CHAPTER 4 OTHER EXPERIMENTS

4.1 Trawl observations

Two attempts at trawl observation with video camera in natural illumination were made, as well as one in deep water with artificial light. The objective was to try to observe gear bottom contact, and if possible, fish reactions around the trawl. In all instances the visibility in the water was not good enough to allow video observation. Even at 45-50 m there was too little light for the very sensitive camera used, and the visibility *per se* was also less than 2-2.5 m, and the camera looking down a hole in the net roof it was not possible to at all see the groundgear 4 m below.

In water deeper than 300 m the visibility was somewhat better, but there of course artificial light was necessary. And with considerable amounts of marine snow present the picture was like being in a veritable snow storm. Useful observations of gear details could, however, be made within a range of 1-2 m, but the application of such observations are quite limited.

The conclusion therefore is that if the ANansen@ Focus is to be used for video based gear observations it will have to be in waters outside of Namibia, either in the tropics or in South East Africa. Apart from that, gear geometry can be measured in Namibia with the FS3300 sonar on the Focus, something which can be useful particularly with the pelagic trawls.

4.2 Trawl calibration with AWelwitchia@

AWelwitchia@ is presently being phased in to participate in the hake assessment surveys, and for that purpose a lighter version of the ANansen@ trawl is being considered. It was decided to do an intercalibration exercise between the two ships to evaluate whether the catch efficiencies of the two trawls were comparable.

The intercalibration studies were carried out with both vessels trawling side by side, 0.1-0.2 nautical miles apart day and night for about 24 hours. Seven comparative hauls were made. AWelwitchia@ was using its standard Polyice 1000 kg doors, and it soon became evident that they were not able to spread the gear, as a door spread of about 42 m was maximum as opposed to Nansen=s >50m. The height was also too low, and the trawl dug deeply into the mud, catching more than a ton of substrate in every haul. Twenty additional floats were added to the headrope to lift the trawl. This increased the opening by one meter, but still it was more than one meter lower than that of the ANansen@ trawl. Other minor adjustments were also tried, like lengthening the headrope and lengthening the gear, but no substantial improvements were achieved. The conclusion therefore was to discontinue the intercalibration and suggest that AWelwitchia@ try again with a larger set of doors which were already purchased but unfortunately were not brought for the intercalibration.

4.3 School density

A method for assessing pelagic fish schools by measuring school cross section areas with sonar has been developed within the Nansen programme. However, the fish densities in the schools, and consequently the numbers of fish in a stock is still not known with satisfactory precision. This problem area was therefore preliminarily addressed at this cruise.

School density of pelagic fish was to be addressed by count calibration of single targets on images obtained by the FS 3300 sonar on the Focus. By integration/school area measurement and counting the numbers of fish per unit of volume the number of fish in a school can be estimated, as can the acoustic target strength of the fish. The idea was to find schools of horse mackerel with the SA950 sonar and to subsequently run the Focus close to the schools in order to resolve single targets as deep into the schools as possible with the 2.6°x2.6° transducer of the FS 3300.

We did find suitable schools and launched the Focus to do sonar observations. But very soon it became clear that the fish were avoiding the Focus. Whether it be on the starboard or port side the fish kept a distance of about 40 m to the vehicle (Figure 23). As the FS3300 sonar would not be able to resolve single targets further away than about 30 m at the densities expected in such schools (>1 fish/m^3) the experiments were abandoned. Probably the avoidance was caused by sound waves emitted by the tow cable going through the sea. This could be heard and felt at the tow block. The phenomenon is known, and the remedy is to Afeather@ the cable with plastic strips. Probably this has to be done in order to reduce avoidance, particularly of pelagic fish which generally tend to be more easily influenced than groundfish.

Figure 23. Scanning sonar picture of a vertical plane perpendicular to the ship=s course. The bottom is horizontal. The bent band is a layer of horse mackerel avoiding the FOCUS 400 carrying the sonar, located in the centre of the picture.

4.4 Light measurements and bioluminescence

A surface light meter measured illumination during the whole cruise. The results for the observation period in Work Area II was presented above in Figure 7. It shows that all days were clear and sunny with peak readings of 17-1800 mE corresponding to around 90,000 lux. The underwater readings showed substantial extinction, reducing the illumination level to about 1 lux at 100m (Figure 24).

Figure 24. Light measurements. (A) Day-time underwater extinction curve with bioluminescence jitter below 230 m. (B) Night-time underwater curve showing bioluminescence jitter at all measured depths. (C) Surface recording to show that the jittering represents true readings.

Bioluminescence is a well known phenomenon and is believed to be used as antipredator and signalling mechanisms among mesopelagic fish and invertebrates. The very sensitive light meter used on the Focus (10^{-6} lux) was easily able to measure it as it ranged between 10^{-2} and 10^{-4} lux. It appeared to oscillate between these values, tending to jitter the light extinction curves substantially (Figure 24 a and b). That the jitter was caused by the bioluminescence and not by the light meter is shown by the dark curve in Figure 24 c. The bioluminescence range of illumination is well within the visual scope of many fishes, and it may be argued that illumination from bioluminescence could provide predators with opportunity of feeding. It is, however, uncertain whether such intermittent illumination can at all be utilised in this context, and it may also be that the Focus going through the layers of bioluminescent organisms may itself have induced at least part of the measured bioluminescence by triggering antipredator behaviour. Alternatively it is also quite likely that herding of fish by trawl gear may very well be a function of bioluminescence induced by the gear with doors and bridles going through the water. This may partly explain why herding is often seen to be similar day and night in many trawl fishing situations (Engås and Ona 1991, Huse *et al*. 1994).

CHAPTER 5 ECOPHYSIOLOGY OF CAPE HAKE

by Peter Woodhead

5.1 Introduction

The Cape hake is a dominant demersal predator on the Namibian shelf, where bottom waters are persistently depleted of oxygen. The hake are highly successful in these waters, although there are significant constraints for active predation in a hypoxic environment. Energy expenditures occur during swimming in pursuit and capture of prey. Anaerobic white muscles are used during burst swimming. Lactic acid produced accumulates and must subsequently be metabolised aerobicly. Further, digestion of prey is an oxidative process during which metabolic rates may double, or more. So, there are large aerobic costs incurred in the active pursuit, capture and digestion of prey. These oxygen debts must be replaced before further activities may take place. Availability of oxygen is critical to recovery. Therefore in hypoxic environments, recovery of oxygen debts from predation will be slow.

During a cruise in August 1995 measurements of gas taken from swimbladders of freshly caught Cape hake showed an average gas content of 89 % oxygen. It is possible that the swimbladder gas might provide an enriched source of oxygen which could be used to supplement respiratory requirements, through release of oxygen into the bloodstream when hake live in conditions of hypoxia. Such an adaptation might enable hake to recover more rapidly from energy expenditures and the oxygen debt acquired when pursuing and feeding on active prey. Such possibilities were investigated by making measurements of hake swimbladder gases during the present cruise.

5.2 Results

1. The average gas content in swimbladders was 89% oxygen for Cape hake which had empty stomachs.

2. Cape hake which were digesting food and had full stomachs (usually containing fish) had significantly lower oxygen content in swimbladder gas. There was a wide range of oxygen contents measured for feeding hake; more than 40% of the measurements fell below the minimum oxygen contents for non-feeding hake swimbladders (Figure 25).

3. Measurements for possible diel changes in swimbladder oxygen content (associated with vertical migration) did not show significant differences between day and night for Cape hakes inhabiting the shelf-slope at 370m, where environmental dissolved oxygen concentrations were above 2ml O_2/litre.

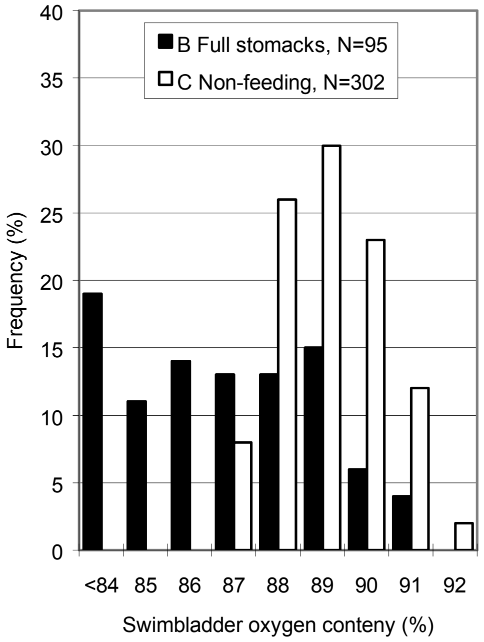

Figure 25 Oxygen contents (% O2) measured for swimbladder gas in Feeding and non-feeding Cape hake.

Collections of blood were made from freshly-caught hake. Both *Merluccius capensis* and *M. paradoxus* were sampled. Series of blood samples were taken from individual fish, and pooled samples were also collected. These materials will be used in investigations of the respiratory characteristics of hake. In particular, assessment of the oxygen-carrying capacity of the blood will be made, and the efficiency of hake haemoglobins to combine with oxygen in severely hypoxic environments will be measured through construction of haemoglobin-oxygen dissociation curves.

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Figure legends:

Figure 1. The work areas

Figure 2. Hydrographic section Walwis Bay - West; temperature, salinity and oxygen

Figure 3. The Focus towed vehicle system

Figure 4. Echogram of acoustic scattering layers in Work Area II in the day-time. 1) Plankton including large medusae; 2) Diving seal; 3) Mesopelagic layer L2; 4) Mesopelagic layers L3 and L4; 5) Hake (L6) within Mesopelagic layer L5; 6) Bottom expansion (10m)

Figure 5. Echogram of acoustic scattering layers in Work Area II during night-time. 1) Plankton layer L1 and mesopelagic layer L2; 3) Mesopelagic layer L3; 4) Mesopelagic layer L5; 5) Hake (L6); 6) Bottom expansion (10m) showing hake and other ground fish, mainly *Halicolenus dactylopterus*

Figure 6. Isoplethe diagram of total acoustic concentrations (S_A values) by depth and time of day. Values are hourly averages of four 24h periods in Work Area II

Figure 7. Surface illumination (mE) during the experimental period

Figure 8. Isoplethe diagram of acoustic concentrations of hake by depth and time of day. Values are hourly averages of four 24h periods in Work Area II

Figure 9. Mean hourly acoustic backscattering for all species (Namibian shelf) for the experimental period.

Figure 10. Mean hourly acoustic backscattering for herring during six acoustic assessment surveys in Norway.

Figure 11. Time and depth of all trawl hauls. Filled squares are hauls with hake catches.

Figure 12. Total weights of both species of hake added together, bottom hauls.

Figure 13. Total weights of both species of hake added together, pelagic hauls.

Figure 14. Weights of both hake species in all bottom hauls.

Figure 15. Numbers of both hake species in all bottom hauls.

Figure 16. Weights of both hake species in all pelagic hauls.

Figure 17. Numbers of both hake species in all pelagic hauls.

Figure 18. % fishes with stomach content: all examined fishes.

Figure 19. % fishes with stomach content: bottom trawl, *M. capensis*.

Figure 20. % fishes with stomach content: bottom trawl, *M. paradoxus*.

Figure 21. % fishes with stomach content: off bottom, *M. capensis*.

Figure 22. % fishes with stomach content: off bottom, *M. paradoxus*.

Figure 23. Scanning sonar picture of a vertical plane perpendicular to the ship=s course. The bottom is horisontal. The bent band is a layer of horse mackerel avoiding the FOCUS 400 carrying the sonar, located in the centre of the picture.

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