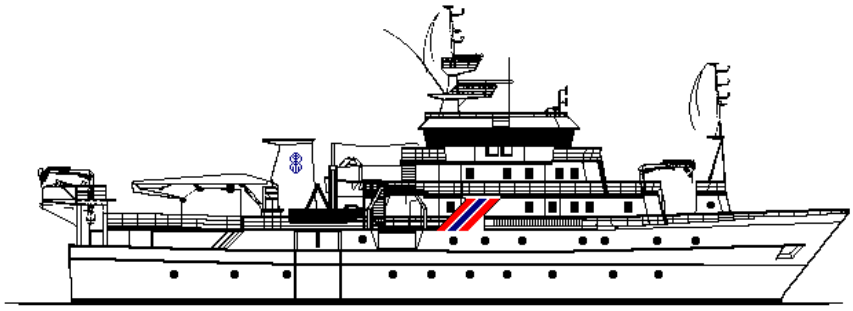

BENEFIT SURVEYS

Acoustic survey, multifrequency target identification, target strength and vertical migration of jellyfish in Namibian waters

20 August - 1 September 2003

University of Western Cape
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Cape Town
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CRUISE REPORTS "DR. FRIDTJOF NANSEN"

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20 August - 1 September 2003

by

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Institute of Marine Research
Bergen, 2004

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CHAPTER 1 INTRODUCTION

1.1 Background

The jellyfish species *Chrysaora hysoscella* (Scyphozoa, Saematosomida, Pelagiidae, colloquially known as "reds") and *Aequorea aequorea* (Hydrozoa, Hydroidomedusae, Leptomedusae, "mags") occur in great abundance in Namibian waters. Evidence suggests that the former of these is less abundant than the latter (REF), and although both are somewhat exclusive in their relative distributions (REFS), as a unit they occur across the shelf to exert a consistently high predation pressure.

There is evidence to suggest that this was not the case prior to the 1970s (*eg* Hart and Currie 1960, Stander and de Decker 1969), and that these jellyfish have become established as a major component of the Benguelan ecosystem over a relatively short period of time (Fearon *et al*. 1992). Rapid increases in jellyfish abundance (blooms) have recently been reported from numerous marine ecosystems worldwide (*e.g*. Mills 1995) to the extent of becoming globally commonplace. Although we are still no clearer to understanding the reasons behind such dramatic increases in population size (in any case, these reasons are likely vary with species and site - REF), the abundant presence of medusae within any ecosystem implies severe changes to the way that ecosystem functions. It may also be, that as rapacious predators (which fail to show satiation), large medusae may not only change the structure of zooplankton assemblages but also suppress the recovery of fish populations. Aside from any impacts that large medusae may have on the ecosystem, however, they also pose practical problems for fisheries and fisheries managers.

The diets of *C. hysoscella* and *A. aequorea* are not well described, but related species are known to prey upon fish eggs and larvae (*e.g*. Purcell 1989). The increase of jellyfish abundance off Namibia appears to have coincided with a period of decline of commercial fish catches of sardine (*Sardinops ocellata*, "pilchard") and anchovy (*Clupea engraulis*) (Shannon *et al*. 1992), and it has been suggested that these phenomena are linked. Introduction of the jellyfish *Mnemiopsis leidyi* in the Black Sea has been related to the crash of fish stocks there (Travis 1993). In addition to their potential predatory impact on fish, jellyfish also hamper fishing activities off Namibia by clogging and subsequently bursting trawl nets. This is a big problem during surveying of the pelagic fish stocks, particularly for pilchard, but also for Cape horse mackerel (*Trachurus trachurus capensis*), due to the fine meshes in the sampling trawls used on research vessels. Jellyfish also cause problems to the diamond extraction industry by

blocking suction devices used to dredge marine alluvial sediments. Constituting an enormous biomass of zooplanktivorous plankton feeding on similar items as larvae, juvenile and adult pelagic fish of commercial importance, knowledge of the distribution and dynamics of the jellyfish is an essential parameters in ecosystem models, which up til now has been lacking.

Despite potential ecological and economic importance of jellyfish in Namibian waters, little of their biology or population dynamics is known (Gibbons *et al*. 1992, Sparks *et al*. 2001). Some information on the distribution and abundance of reds and mags is available from Bongo net surveys (Pagès 1991, Fearon *et al*. 1992), but these nets are small (50 cm mouth opening) and are unlikely to provide unbiased data, partiularly for adult *C. hysoscella* that commonly attain umbrella diameters exceeding 50 cm. Acoustic survey techniques are used commonly for studies of distribution and abundance of fish and zooplankton, and may be useful for studies on jellyfish (Mutlu 1996, Monger *et al*. 1998). Over the two previous BENEFIT jellyfish surveys in September 1999 and September 2001, important knowledge of the acoustic scattering properties of these jellyfish species have been gained (Brierley *et a*l. 2001, 2003).

Acoustic abundance estimation requires knowledge of the acoustical backscattering properties of the ensonified targets in order to identify observed scatterers as a given species. Due to the limited information that can be obtained from the target in conventional single frequency echosounders, some *a priori* knowledge of the acoustical appearence of the target species at the given frequency is prerequisite, although frequent trawl samples confirming the allocation of acoustical density to given species are necessary in any case.

Unless all ensonified targets can be resolved as single echo targets by the echosounder, which hardly ever is the case, knowledge of the dorsal aspect target strength (TS) is required in order to convert the acoustical densities of the targets into an absolute measure of biomass. Target strength is thus an essential parameter in acoustic abundance estimation. Historically, very little work has been conducted on jellyfish, regarding both acoustic target identification or measurements of dorsal aspect target strength. Therefore, acoustic discrimination between several discrete frequencies for target identification purposes and measurements of the dorsal aspect target strengths of mags and reds have been the main foci of the 1999 and 2001 surveys. In the 1999 survey, the acoustic scattering was measured at 18, 38 and 120 kHz, and back calculations from acoustic densities and animal densities obtained with the sample trawl provided average target strength estimates. In 2001, more acoustic density measurements were carried out, including target strength measurements of tethered medusae at 38 kHz under controlled conditions inside Walvis Bay. The addition of a new 200 kHz transducer to the acoustic instrumentation of the ship and a refit of the transducer arrangement that aligned all the frequencies on the same axis (vertical) and maximized the beam overlap, both added

considerable discriminatory power to the multifrequency identification algorithms.

The high abundances of *A. aequora* and *C. hysoscella* along the Namibian coast provide excellent opportunities for studying these animals, as well as a strong motivation for elaborating their acoustic characteristics. Given the basic knowledge of the acoustic back scattering properties of these animals build up over the previous two surveys, the main goal of this year's survey was to carry out a full scale experimental survey over the Namibian shelf in order to produce an acoustic estimate of the jellyfish stocks of reds and mags for the first time. Two diel cycle stations monitoring the acoustical scattering layers of inshore and offshore jellyfish scattering communities were to be carried out for the purposes of obtaining reference multifrequency acoustic measurements of acoustic densities (Sv) and target strength (TS), and to map the diel vertical migrations of the jellyfish and co-occuring zooplankton and pelagic fish.

1.2 Objectives of the survey

- This cruise builds on two previous jellyfish surveys conducted in 1999 (7 days) and 2001 (10 days). The primary objective of the earlier cruises was to develop a multifrequency tool that could be used to assess the abundance, distibution and behaviour of large medusae in the BENEFIT region. Both previous cruises can be viewed as succesful; alltogether 5 scientific papers addressing both TS, distribution, and biology on large medusae has been produced so far.

- The overall objective of the present cruise was to carry out a full scale experimental survey over the Northern Benguela shelf area in order to produce an acoustic estimate of the jellyfish stocks of reds and mags for the first time. Building on this, the following additional sub-goals have been identified:

- To carry out repeated calibrated acoustic recordings of jellyfish backscatter at 18, 38, 120 and 200 kHz in order to verify (or otherwise) and, if possible, refine, previously recorded acoustical characteristics of *A. aequora* and C. *hysoscella* for target identification purposes (Brierley et al. 2001, 2003). Identification of the recorded species was to be conducted using a standard pelagic sampling trawl fitted with a remote operated multiple codend sampling device, the multisampler (Skeide *et al*. 1997), obtaining discrete samples from up to three different depths during one deployment.

- To extract acoustic target strength data from scattered monospecific aggregations of *A. aequora* and *C. hysoscella* at 18, 38, 120 and 200 kHz *in situ* using multifrequency target triangulation and tracking techniques in order to exclude erronous multiple targets and to isolate single specimens, respectively. The TS to size relationships will subsequently be used for conversion from acoustic densities to biomass indicies.

- To complete two diel cycle experiments, inshore and offshore, monitoring the vertical stratification and migrations large medusae, their planktonic prey, and pelagic fish in order to improve the understanding of the vertical dynamics.

- Information on the size structure of *Chrysaora* populations along the coast will be used to support (or otherwise) the contentions of Pages (REF), that benthic polyps of *C. hysoscella* are found in the north, and that the released ephyrae mature and grow southwards, before being swept offshore and returning north to breed again.

- Finally it is hoped to collect specimens of *Chrysaora* for taxonomic description (including

genetic material); there being some concern that we are dealing with not one, but two, species.

1.3 Participation

The scientific staff consisted of:

From Namibia:
Allie GUMBO and Ferdi HAMUKWAYA.

From South Africa:
Mark J. GIBBONS, Ashok BALI, Dylan CLARKE and Conrad A. J. SPARKS,

From Norway:
Bjørn Erik AXELSEN (*Cruise leader*), Thor-Egil JOHANSSON, Leif NØTTESTAD, Roar SKEIDE, Jan-Frode WILHELMSEN and Diana ZAERA.

From Scotland:
Christopher P. LYNAM

1.4 Narrative

The observations made both in September 1999 and in September 2001 showed that mags and reds co-occurred in high densities around 22°00'S. Reds were found in largest concentration inshore, while mags were found further offshore (150-200 m bottom depth). However, the visual observations carried out during several surveys in the northern Benguela (Sparks *et al*. 2001) have shown that both jellyfish species, in particular the reds, are distributed right through to the Namibian–Angolan border, with high density areas in the area south of the Cunene River. In order for this exploratory survey to cover the main distribution area, it was therefore decided to cover the entire Namibian coast, albeit with low sampling intensity, given the time restrictions, using a coarse zig-zag survey design.

After departure from Walvis Bay 20 August at 16h00 local time (UTC +1), course was therefore set northwards to the border at 17°15'S, following the 100 m isobath (presumably in the high-density depth region of the jellyfish distribution) in order to obtain gradient-parallel data whilst steaming northwards. The first of alltogether 22 sections was started inshore at

17°15'S at 20 m detpth at 22 August at about 04.00 local time, heading south-west. The subsequent sections similarly covered the depth range of 20 to 300 m (Fig. 1).

The first trawl trawl Multisampler deployment (PT 1290-1292) was worked inshore at 18°04'S 11°36'E at150, 60 and 25 m headrope depth, fishing a marked scattering layer seen at about 180 m depth. The effective tow time (time elapsed between opening and closing of each codend) was constantly kept at 5 min for each haul for multisampler deployments (n=96) and 10 min for demersal tows (n=2, qualitative hauls checking for demersal fish during the diel cycle stations), due the experience with high densities of jelly causing trawl extension pieces and codend to tear badly both in 1999 and 2001. A mixture of both species occurred in all northern samples, but south of 25°20' only mags were caught .

Each sampling cycle throughout the surey was initiated by a multisampler deployment, hence obtaining 3 discrete pelagic trawl samples. Generally if the nets contained jellies, the multisampler was followed by a surface ('balloon') haul and quantitative zooplankton samples using the Hydrobios multinet (x5) plankton sampler (405 micrometer). All sampling cycles were ended with a CTD cast (temperature, salinity and oxygen). Surface (5 m) and bottom (bottom depth – 5 m) water samples were collected on all stations for calibration of the O_2 sensor. The ADCP was only turned on during CTD stations as it interferred with the 120 and 200 transceivers of the echosounder.

Two 24-hour diel cycles were worked on selected stations west of Walvis Bay, near the experimental areas of 1999 and 2001. The first diel cycle was worked at about 60 m water depth at 22°19'S 14°12'E. Here, a scattered aggregation of reds averaging 19.21 cm umbrella diameter was readily identified. At night, the reds mixed with horse mackerel that during the day were seen as schools below the jellies. The second diel cycle was worked south-east, further offshore, at 140 m water depth (22°49'S 13°42'E). In this community, the reds were located immediately below the surface layer during day time, and a bit further down during night. Mags were abundant at all depth, and clean layers were here identified around 80-120 m, immediately above a layer of juvenile hake (15-25 cm) that lifted off the bottom at night.

The "Dr. Fridtjof Nansen" reached the Namibian border at Orangemund 31 August at 12.00, steamed towardsw Cape Town and docked 1 September 2003 at 18.00, according to plan.

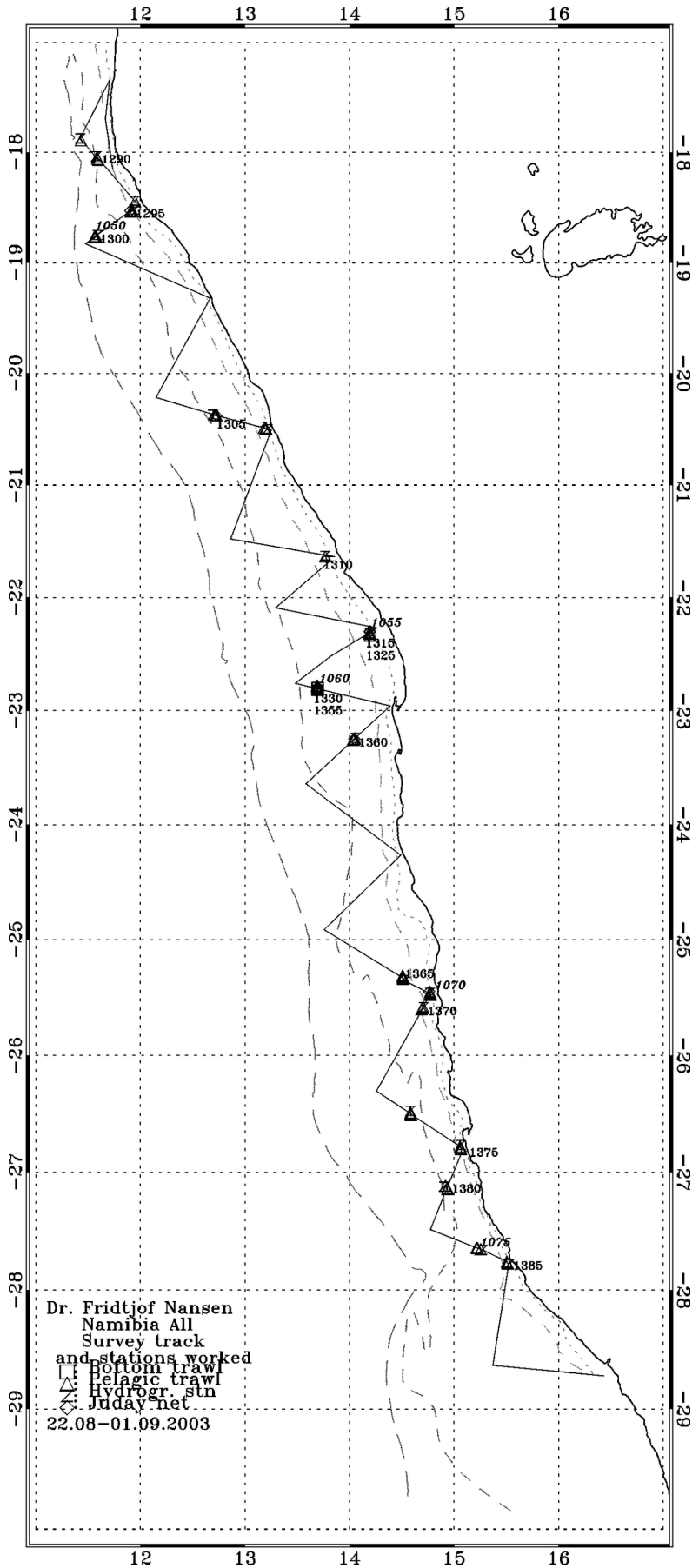


Figure 1. Course track with trawl, zooplankton and hydrographic stations

CHAPTER 2 METHODS

The survey covered the entire Namibian coast, albeit with low sampling intensity, from the Cunene River to the Orange river, using a coarse zig-zag survey design (Fig. 1). Data were also collected along the 100 m isobath during steaming from Walvis Bay to Cunene River. The following sampling activities were carried out during the survey:

- meteorlogical observations
- hydrography
- zooplankton net samples
- jellyfish/ fish trawl samples
- multifrequency acoustic data

Alltogether 98 trawl stations, 20 multinet zooplankton stations, 217 length samples, and 32 CTD stations were worked, and a total of 1794 nautical miles (NM) were surveyed acoustically, disregarding the steaming from Orange River to Cape Town.

2.1 Hydrograhy and Weather data

Meteorological data were obtained throughout the survey using the Aanderaa weather station. Data were logged continously and routinely averaged over 20 sec intervals, and included air and sea surface temperature (SST), wind speed and direction and incident solar intensity. The light intensity was recorded at the roof of the wheelhouse, approximately 14 m above sea level, while the SST was recorded at 5 m depth.

Hydrographic profiles were obtained routinely in conjunction with all trawl samples using a Seabird 911+ CTD probe fitted with temperature, salinity and oxygen sensors. The oxygen sensor was calibrated using water samples obtained at the surface (5 m depth) and near the bottom (5 m above) in order to ensure proper calibration range. The water samples were titrated and the oxygen level measured using the Winkler method.

2.2 Trawl sampling

Fishing gear

Two Åkrehamn pelagic sampling trawls were used for the fish samples. The smallest of these,

with a vertical mouth opening of about 10 m, was fitted with 3 or 4 large floats attached to top panel immdiately behind the headrope for sampling near the surface (down to about 10 m depth).

The largest trawl (12 m opening) was fitted with a codend multisampler that enabled three discrete samples to be obtained in a single deployment (Skeide *et al*. 1997). The system is unique in that the trawl is open before each net is opened, which is facilitated by acoustic trigger from the vessel. A SCANMAR depth sensor fitted on the headline of the trawl provides the captain and multisampler operator with information of the exact depth of the trawl, ensuring that uncontaminated samples can be taken from three selected depths.

The multisampler trawl was operated in midwater, but towards the end of the survey, in the Lüderitz area where the jellyfish densities were low, two floats, normally used for surface tows ('balloon hauls'), were attached during midwater deployments in shallow water in order to provide an extra lift over the bottom (deployment series PT 1366-1368, PT 1369-1371, PT 1375-1377, PT1378-1380, PT 1381-1383; and PT 1384-1386). Although the floats partly collapsed due to the compression they provided enough lift to bring the mouth opening up to 16 m. The last sample was towed at the surface, where the floats recovered full buoyancy.

Splits were cut both in the bottom panel of the extension piece in front of the multisampler and in the front part of each of the codends in order to reduce net tearing. The splits were sewn lightly together using thin twine and each end of the splits greatly enforced, allowing for "controlled" bursts should fill up the codends and threaten to tear the nets as was the case in 1999 and 2001.

In two deployment (diel cycle observations) were a Gisund Suped demersal sampling trawl deployed in order to check for demersal fish during daytime (5 m opening). All trawls were towed using Thyborøen 125" Combi otter boards (7.41 m^2, 2,030 kg). Detailed illustrations of both pelagic and demersal sampling trawls, including the multisampler system, are provided in Annex III.

During the survey, net sampling cycles were initiated when encountering scattering layers that were potential jellyfish targets, or when visual observations of jellyfish at the surface suggested that there jellyfish in the area (reds, in he north). Both the acoustic and the net sampling intensities were rather low due to the large survey area and the limited time available (9 effective survey days from the Cunene to the Orange River).

Each sampling cycle throughout the surey was initiated by a multisampler deployment,

obtaining 3 discrete pelagic trawl samples. Generally, if the nets contained jellies, the multisampler was followed by a surface ('balloon') haul and quantitative zooplankton samples using the Hydrobios multinet (x5) plankton sampler (405 µm mesh). Tow times were standardized at 5 min for both surface and multisampler tows, but problems with the acoustic communication from the ship to multisampler unit sometimes delayed the closing of the nets, causing some samples to be towed for up to 12 minutes. Surface balloon hauls were also towed for the standard 5 minutes, but since this trawl was not fitted with a multisampler unit, jellyfish may have been caught during shooting and hauling, and hence the effective tow time was likely somewhat longer. The surface hauls should therefore not be considered quantitatively in volume density terms.

All sampling cycles were ended with a CTD cast (temperature, salinity and oxygen). Surface (5 m) and bottom (bottom depth – 5 m) water samples were collected on all stations for calibration of the O_2 sensor. The ADCP was only turned on during CTD stations as it interferred with the 120 and 200 kHz transceivers of the echosounder.

For each trawl station, catch size and species composition was determined and punched onto NAN-SIS database following standard procedures. For the jelliyfish, umbrella diameter, and wet weight were measured and punched into EXCEL spreadsheets.

Estimation of trawl sample volume

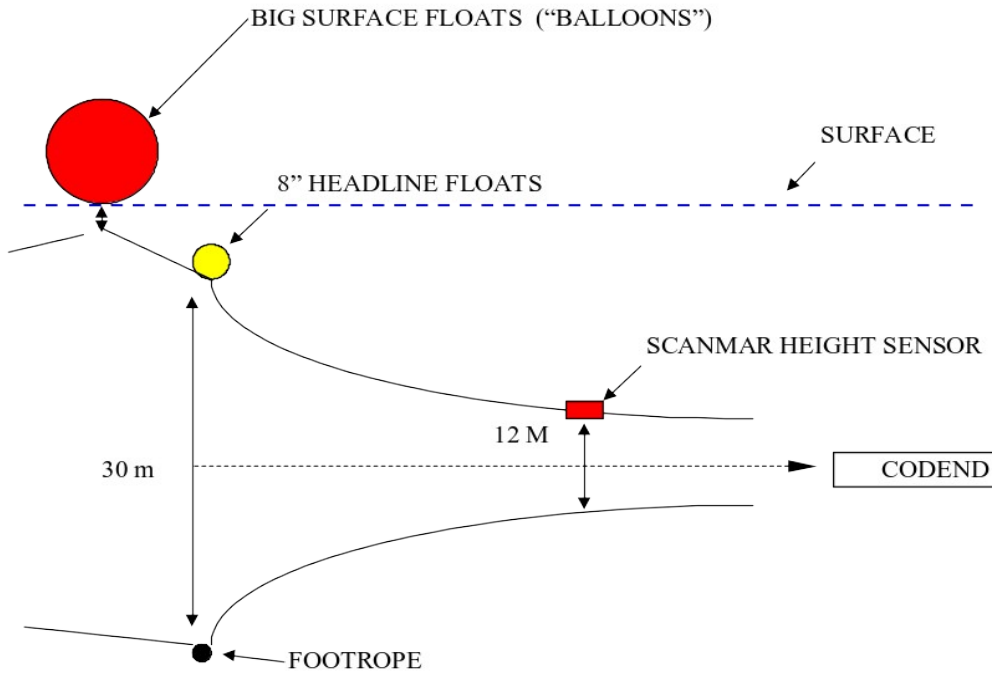
Not actively avoiding nets nor being herded by trawl bridles, jellyfish essentially enter the trawl by passively floating trough the trawl. Jellies will hence be retined if the meshes are small enough. In the present study, sampling volume of the trawl was calculated from the vertical opening (O=12 m) of the trawl mouth of the multisampler trawl:

$$V = \pi(0.5 \cdot O)^2 \cdot td \qquad (m^3) \qquad (1)$$

Where td is the towed distance in m. This assumes circular opening of the trawl, and that all jellyfish that enter the mouth opening are retained in the codend. Some jellyfish may, however, be filtered through the trawl meshes, particularly in the fore large-mesh sections of the trawl. During the 1999 survey the appreciably larger pelagic trawl was utilized. This trawl was identical to the one used in the present study from the belly backwards, but the panels just aft of the mouth had large (3200 mm) meshes. The vertical opening of the former trawl was 30 m. From the extension and backwards, the meshes are the same for all the sampling trawls (400 mm, stretched), and in 1999 it was assumed that the sampling trawl only caught jellyfish effectively from the 400 mm panels and backwards. The opening in this section was measured using a Scanmar height sensor and was found to be 12 m (Fig. 2a). This opening is very close

to the opening of the multisampler trawl used on the present cruise, and it is reasonable to assume that the smaller-meshed fore panels of this trawl (1 620 mm) will retain the jellies, espescially taking into consideration the much steeper aspect angle they will meet the jellies with (Fig. 2b).

a)



b)

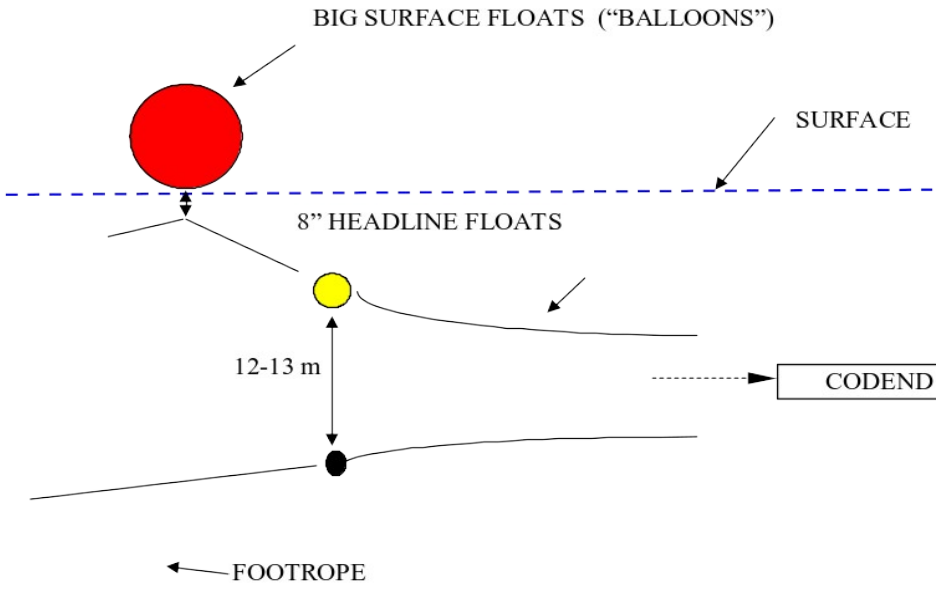


Figure 2 Illustration of the large pelagic sampling trawl used in 1999 (a) and 2003 (b), here rigged with "balloons" for surface trawling. The vertical opening of this trawl was 30 m, and the height at the front of the section believed to catch jellies (400 mm panels) was then measured to 12 m.

Diel cycle studies

Two 24-hour diel cycles were worked on selected stations west of Walvis Bay, near the experimental areas of 1999 and 2001. The first diel cycle was worked at about 60 m water depth at 22°19'S 14°12'E. Here, a scattered aggregation of reds averaging 19.21 cm umbrella diameter was readily identified. The targets were loosely scattered and ideal for extraction of target strength measurements. At night, the reds mixed with horse mackerel that during the day were seen as schools below the jellies. The second diel cycle was worked south-east, further offshore, at 140 m water depth. In this community, the reds were located immediately below the surface layer during day time, and a bit further down during night. Mags were abundant at all depth, and clean layers were here identified around 80-120 m, immediately above a layer of juvenile hake (15-25 cm) that lifted off the bottom at night. In this experiment, the hake layer was sampled twice (daytime in the beginning - the first day – and at the end – the second day – of the experiment). Tow times were 10 minutes for the demersal tows and these samples should, like the surface tows, be considered in qualitative terms.

Each sampling cycle consisting of consecutive deployments of Multisampler trawl hauls (3x remote opening and closing of codend (22 mm) in discrete depth intervals), Multinet plankton hauls (Hydrobios, 5x remote opening/closing of plankton nets, 405 μm) sampling the water column whithin scattering layers and obliquely in adjoining, vertical sample intervals between layers, and CTD casts (temperature, salinity, oxygen). ADCP measurements (Acoustic Doppler Current Profiler), were carried out during the CTD casts.

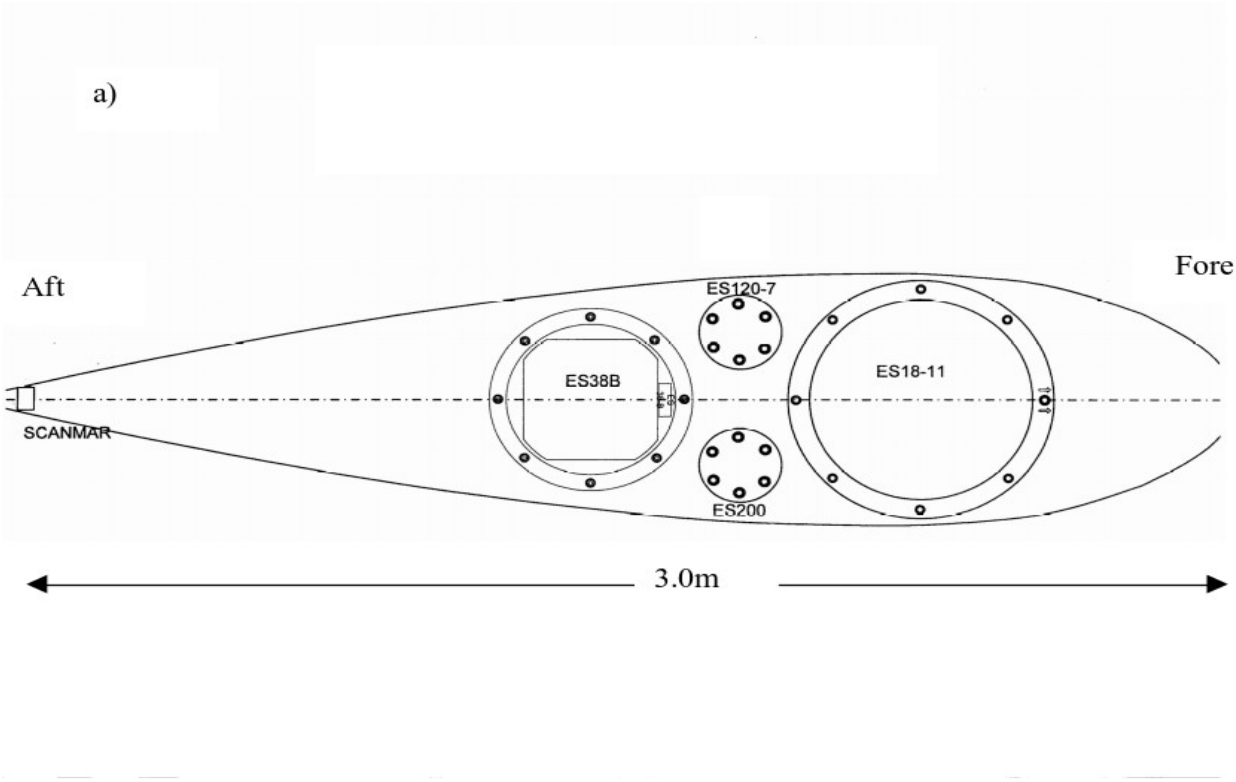
2.3 Acoustic observations

Refit of drop keel in Cape Town, January 2001

Several modifactions have been made to the transducer arrangement during a refit in Cape Town in January 2001, *i.e*. after the September 1999 survey and before the 2001 survey. The ship was dry-docked, and the keel was lifted up through a shaft that runs in the full height of the ship and opens up onto the roof of the wheelhouse. The keel was transported to a workshop where the keel-face was levelled to horizontal at normal ship trim. The off-axis deviation has previously been estimated from acoustic data recorded. The keel was sandblasted, primed and painted. Shells, barnacles and other shrubbery were removed form the keel and inside the shaft. A new, bigger cable gate was fitted to the shaft in order for all cables to run through the same gate. The cables for the 38 and 120 kHz transducers, and the Scanmar hydrophone (HCL) were squeezed, and replaced with new, thinner, cables (50 m).

New holes were bored for 18 kHz (aft), 120 kHz (central, stirbord side) and 200 kHz (central,

port) transducers. The 38 khz transducer was left in its original position. The hole for the 120 kHz was covered. The existing 18 kHz transducer was removed from its initial position on the keel and fitted onto the keel. A new 200 kHz single beam transducer (ES 200-7F) was fitted next to the 120 split beam in the center section of the keel. The modifications of the transducer arrangement have effectively ensured optimal configuration of the transducer; they are now positioned on the same acoustic axis at close to vertical transmission at normal ship trim, and with minimal horizontal spacing of the transducer faces. The new transducer arrangement on the drop keel is illustrated in Figure 3.



b)

c)

Figure 3 Transducer arrangement of the drop keel of R/V "Dr. Fridtjof Nansen" showing schematic illustration of the new orientation of the transducers on the keel (scale 1:10) (a) and photos taken before (b) and after (c) the refit in Cape Town in January, 2001.

Data collection and calibration

Two SIMRAD EK 500 echo sounders running split-beam transducers operating at nominal frequencies of 18, 38, 120 kHz (EK 1) and a single-beam transducer at 200 kHz (EK 2) were utilized. Data were logged continuously during the diel cycle experiments utilizing SonarData Echolog EK (ver. 2.20.05). The settings used in the EK 500 transceiver menus are presented in Annex I. Note that the pulse length and band width settings were optimised with regard to obtaining similar and high sampling resolution of all frequencies (18 kHz: short/ wide; 38 kHz: medium: wide; 120 kHz: long/narrow; 200 kHz: long/narrow). Post-processing was done using SonarData Echoview (ver 3.00.75.05).

Calibration of all four transceivers were carried out 17 August 2003, at the end of the previous survey (ANG 2 2003). The calibrations were carried out at Langstrand (north of Walvis Bay). The drop-keel was submerged 2.0 m below the hull for the duration of the survey due to relatively rough weather conditions (Fig. 3), giving an effective transducer depth of 7.5 m. The logged draft of all transducers was there-fore 7.5 m before corrections for electronic delay.

2.4 Post-processing of acoustic data

Vertical alignment – electronic transceiver delay

The data underwent a series of correction steps in order to suitably fit into multifrequency analyses. The first step was to align the data vertically, correcting for the electronic delay in the EK500 transceivers, causing a vertical mismatch of the data (Table 1).

Table 1. Electronic delays in the EK500 transceivers (Korneliussen 2003).

EK500 Transceiver	ES 18	ES 38 B	ES 120-7	200-28
Frequency	18 kHz	38 kHz	120 kHz	200 kHz
Vertical offset (m)	0.46	0.30	0.24	0.17

The correction consists of shifting the different frequencies relative to each other in order to minimize the offsets between all 6 frequency-pairs. The bin size in the EK500 telegrams depend on several factors: 1) the number of bins can be set in the EK500 utility menu; 700 is the maximum number of bins, but 500 is usually used on the 'Dr. F. Nansen' as the BEI acoustic post-processing system requires the telegram to have the data in the format of 500 pelagic bins (transducer downwards) and 150 bins for the bottom channel (sounder-detected bottom upwards). The sampled signal is then expressen in terms of bins of the size corresponding to the maximum range (ethernet, printer or display) divided by the number of bins (Table 2).

Table 2. Bin size in the EK500 telegram menus for different combinations of sample range and

number of bins.

r	500 bins	700 bins
100	0.14	0.20
150	0.21	0.30
250	0.36	0.50
500	0.71	1.00
1000	1.43	2.00

In the present study, the post-processing was done using Echoview, and the matching was done by simply adjusting the logged draft setting of the various telegrams before exporting the data according to Table 3. It should be noted that the draft corrections need to be changed according to changing bin sizes (ranges) in the exported telegrams. For 500 m ranges and higher there is no gain in shifting bins, as the bin sizes then exceed the vertical offsets. For the same reason, the degree of overlap in the vertical plane will increase with increasing ranges.

Table 3. Logged draft corrections carried out at the various frequencies and ranges. The number of data bins were 700.

Frequency	18 kHz	38 kHz	120 kHz	200 kHz	r
Vertical offsets	0.46	0.30	0.24	0.17	
Draft corrections	none	0.143	0.143	0.286	100
Draft corrections	none	0.214	0.214	0.214	150
Draft corrections	none	0.357	0.357	0.357	250

Frequency Matching

The next step was to match the EK1 and EK2 datasets. The two EK500 echosounders had to operated with internal clocks due to problem with the EK2 reseting the date to a default value (20 April 2000) if operated on external clock (GPS, serieal). The two clocks of the EK's were therefore synchronised 4 times per day (00.00, 06.00, 12.00 and 18.00 LT) in order to correct for internal drift. The synchronisation was achieved by running both echosounders on external clocks for a brief period. However, although pinging synchronously, corresponding ping returns in the two datasets will have slightly different time stamps (hh:mm:ss.000) due to clock drifting. In practical terms, this was achieved with first resampling all echograms, and then matching the EK2 data (200 kHz) to the EK1 data (38 kHz was chosen, but 18, 38 and 120 have identical time stamps) using the 'match ping times' feature in Echoview.

Noise estimation and removal

The background noise levels will vary between frequencies; the lower frequencies (LF, particularly 18 kHz) will pick up more LF propeller and engine noise, but will generaly be less

dominated by noise than the higher frequencies (120 and 200 kHz) due to the much higher signal to noise ratio (SNR) at short ranges; the signal attenuation being proportional to the carrier frequency. Estimating and subsequent removal of estimated noise from the data has two functions: increasing the SNR at all frequencies, and facilitating comparison of non-biased recordings. In order to correct the data for noise, the background noise (dB @ 1 m) must be estimated at all four frequencies.

This can be achieved in four principally different ways; (1) by recording data in "clean waters" without scattering targets, (2) by recording data without transmitting the signal (i.e. in "passive mode"), (3) by recording the data between the return of the last bottom echo and the first echo from the signal reflected from the surface (*i.e*. the "double bottom"), or (4) by recording data to ranges where the returned signal is dominated by noise and then matching a noise model by iterating the time varied gain (TVG) amplified background noise level to the observed noise levels. The different methods all have their weaknesses. The main obstacle with option (1) is to record data in clean waters; there are virtually always targets such as plankton scatterers that are not considered noise here. While method (2) disregards sound produced transmission-related noise, (3) requires that data are collected at twice the sampling depth, at least for the purpose of the noise estimations. Here, we have fitted noise data as described in (4).

In practical terms, this meant to construct 4 virtual echograms, one for each frequency, where the estimated background noise level at the respective frequency was TVG amplified the same way as the signal (see Annex I for calibration settings). A new virtual echogram was then constructed for each frequency by subtracting the estimated noise from the original echogram.

Beam reduction

The multifrequency analyses aims at comparing the volume backscattering at different frequencies, utilizing the fact that different organisms will have different target strengths at different frequencies, and that these differences will depend on the animal size, shape and density and the acoustic frequency of the signal. Ideally therefore, all signal should be transmitted at equal pulse lengths and the beam geometry should be identical. Unfortunately, this is not possible to achieve with the EK500 system. With the acoustic arrangement of the 'Dr. F. Nansen', the optimal transceiver menu settings range from 0.6 to 1.0 ms pulse lengths and from 6.9 to 11.1 degree opening angles between the four transceivers (Annex I).

In order for the acoustic volume densities to be comparable, all beams were here theoretically reduced to the geometry of 38 kHz beam. This was achieved by estimating the resolvable reverberation volumes of the different beams, and working the ratios between the actual beams and the reduced beams (Table 4).

Table 4. Actual to reduced volume (A/R) ratios and corresponding Sv reductions (re. 38 kHz beam).

Carrier f	18 kHz	38 kHz	120 kHz	200 kHz
A/R - ratio	2.60	(1.00)	1.11	1.04
dB reduction	4.15	(0.00)	0.46	0.19

The volume reductions were achieved in Echoview by simply generating a virtual echogram of fixed Sv values according to Table 4, and subtracting these from the noise-corrected variables. It should be emphasized, however, that the volume ratios are constant (range-independent), and that this procedure therefore will not add any discriminatory power. It will, however, make the volume scattering levels of the various frequences comparable, in the sense that differences between the frequences will reflect differences in scattering levels rather than in beam geometry.

High-pass filtering

The next step concerns the horizontal and vertical offsets. The vertical mis-alignment is partially corrected for in the bin shifting procedure above. There are, however, still imperfect overlaps both in the horizontal and vertical planes that cannot be corrected for. In the horizontal plane, the offsets correspond to the physical horizontal distance between the (midpoint) different beams (Table 5).

Table 5. Horizontal spacing of the four keel-mounted transducers on the' Dr. F. Nansen' in m.

f	38 kHz	120 kHz	200 kHz
18 kHz	0.78	0.46	0.46
38 kHz		0.39	0.39
120 kHz			0.35

There are different ways to improve the comparability of the data recorded at the different frequencies. The most straightforward method would be to average a number of bins in the horizontal and vertical planes, *i.e*. to simply reduce the resolution of the data. The disadvantage of this method is that while the averaging improves the spatial overlap of the compared bins, it significantly reduces the amount of information in the original signal. Another approach, which has been applied here, is to apply a smoothing of each datapoint, acquiring a weighted contribution from the neighbouring cells. This procedure will essentially smooth out the jitter between neighbouring cells with a small loss of information, effectively working as a high-pass filter. We applied a 5x5 convolution matrix fitted weighted according to a Gaussian fit (sd=5) in both horizontal and vertical planes (Table 6).

Table 6. 5x5 Gaussian convolution matrix (weights in %) applied during the high-pass filtering of the acoustic

data (center bin in grey).

0.091	1.738	6.569	1.738	0.091
1.738	3.385	8.216	3.385	1.738
6.569	8.216	13.05	8.216	6.569
1.738	3.385	8.216	3.385	1.738
0.091	1.738	6.569	1.738	0.091

Calculation of linear Sv-ratio distributions

Difference echograms were calculated between all four frequencies using the 5x5 convoluted volume densities (Sv) for all six possible combinations; Sv_{18}-Sv_{38}, Sv_{18}-Sv_{120}, Sv_{18}-Sv_{200}, Sv_{38}-Sv_{120}, Sv_{38}-Sv_{200} and Sv_{120}-Sv_{200}. Since all subtractions were carried out in the log domain, the resulting differences express the linear domain ratios, expressed in dB. The probability distributions of these differences hence represent the 6 available signals, and the hypothesis is that the acoustic signature whithin these signals can be used as a species identificator.

Generally, the reference sample pdf's resemble normal distributions fairly closely, and so a fair description of the expected range of differences can be expressed in terms of a simple 95% confidence interval of the sample data, which is done here.

Reference measurements

Reference acoustic observations of monospecific scattering layers of both species of jellyfish, and for co-occuring fish species such as juvenile Cape horse mackerel (*Trachurus trachurus capensis*) and Cape hake (*Merluccius capensis*), were obtained from the acoustic material in sections where multisampler catches had documented that the layers were monospecific. The Sv matrixes were exported from the 5x5 convoluted data for all frequencies and related to the size structure from the net samples. Region level parameters including min, mean and max Sv, sA, min and max depth and date/time were exported as well. Difference echograms were produced for all six combinations, and associated 95% c.i. computed.

Creating bitmasks

We created bitmasks in order to separate jellyfish from other scatterers. The bitmasks applied here consider one argument that should fall within a specified range and produce the value 1 for bins that confirm with a given argument and the value 0 for bins that do not. Bitmasks were therefore produced for all 6 difference echograms, creating 6 individual jellyfish filters. Filters were then combined to produce separate filters for reds and mags, and for Cape horse mackerel and Cape hake as well. The performance of the two red filters were compared with a

combination of the two, *i.e*. a jellyfish/non-jellyfish filter, and evaluated.

Biomass estimation and target strength estimation

Finally, bitmask filters were overlaid the 5x5 convoluted data to identify bins that conform with the anticiapated difference ranges. Accepted bins were then integrated on the noise filtered, but not volume-reduced, data. Integration was carried out on several frequencies, converted to animal densities using the relationships found in the previous surveys (Brierley *et al*. 2003), and finally compared. Estimates were produced by simple averaging over the identified distribution area, as identified by means of post-stratification.

Unless all ensonified targets can be resolved as single echo targets by the echosounder, which is hardly ever the case, knowledge of the dorsal aspect target strength (TS) is required in order to convert the acoustical densities of the targets into numbers of individuals and hence into an absolute measure of biomass. In this years' survey, TS detections were extracted from the EK500 underway data (*in situ* method) and TS was estimated from backcalculation of average densities (Sv, dB), integrator values (s_A, m^2 NM^{-2}), depth range (m) animal densities (m^{-3}) and sizes (total umbrella diameter, cm) (the comparison method) as in 1999 and 2001 (Brierley *et al*. 2001, 2003). Target strength data were essentially extracted from the reference samples, at all four frequencies. The ***in-situ*** data were first filtered using the split-beam triangulation technique to remove erroneous multiple target detections, and then traced in order to isolate returns from single specimens and express the data in terms of mean-trace values. This work will be completed after the survey, and the data presented here therefore are meant as examples. Due to time restrictions, no experiments with tethered animals (Brierley *et al*. 2003) were carried out this year.

CHAPTER 3 RESULTS (from here 1999/2001)

3.1 Weather conditions

Weather conditions were fairly good with moderate wind strengths ranging from 0 to 25 m/s (Figure 4). It was generally cloudy, but no rain throughout the cruise. The Solar intensity levels measured on top of the wheelhouse are given in Figure 5. The temperature at the sea surface ranged from 10.4 to 12.0˚C.

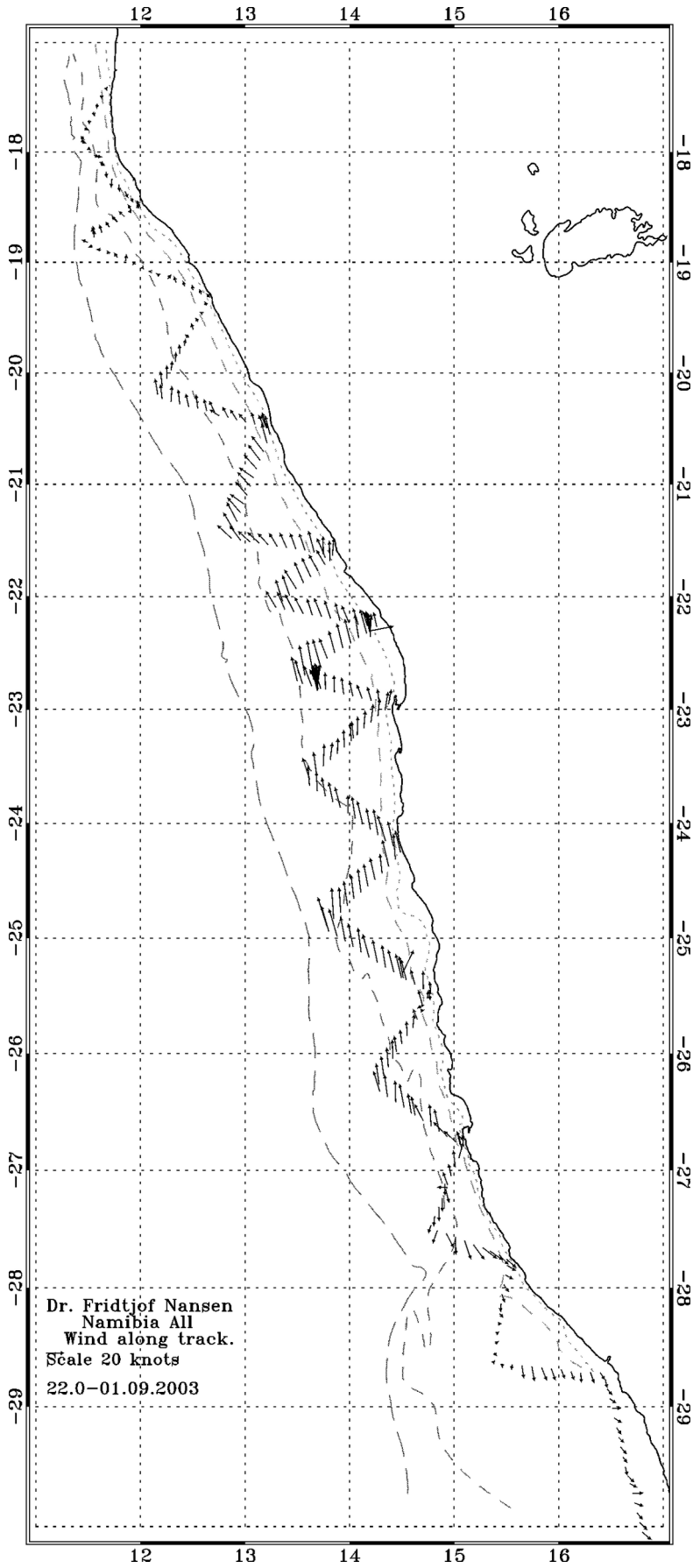


Figure 4.a. Wind conditon in the surveyed area.

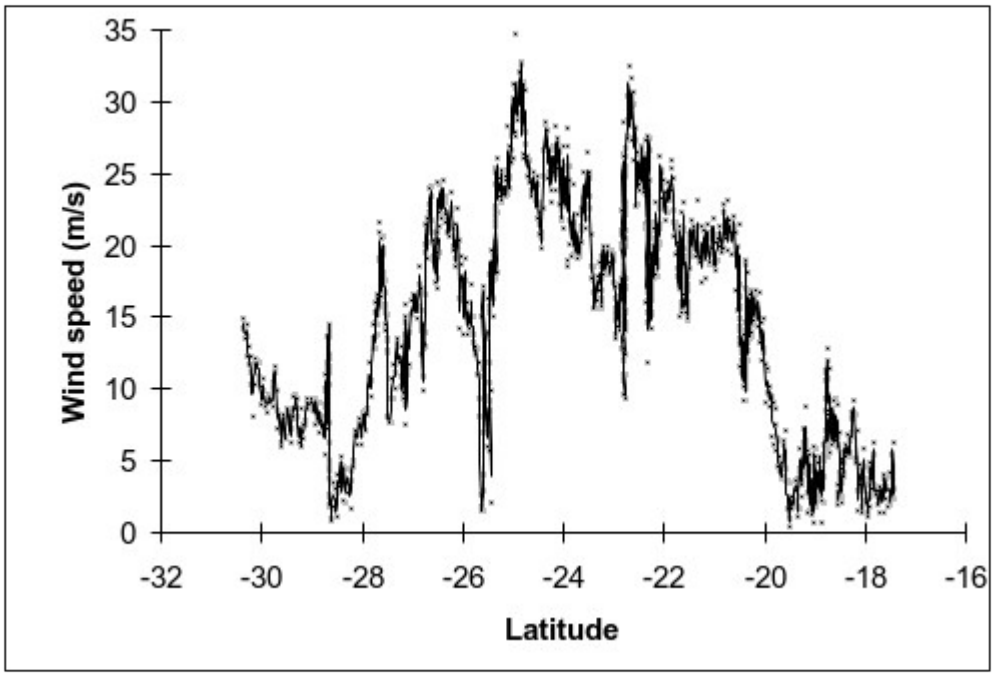


Figure 4.b. Wind speed recorded every 10 min (•) with the Aanderaa weather station throughout the cruise.

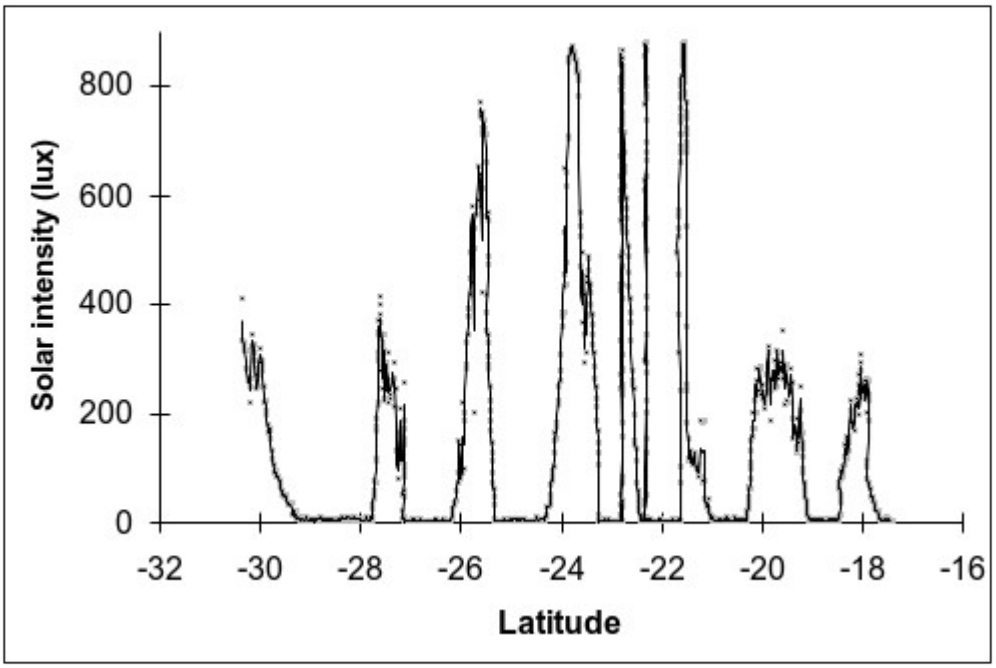


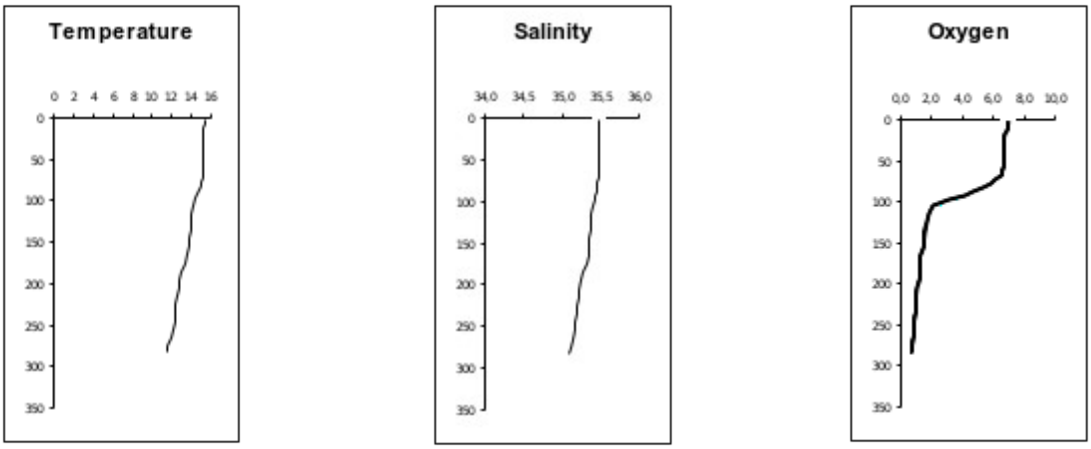
Figure 5 Surface solar intensity (lux) recorded every 10 min (•) with the Aandreaa weather station throughout the cruise.

3.2 Hydrography and vertical distribution

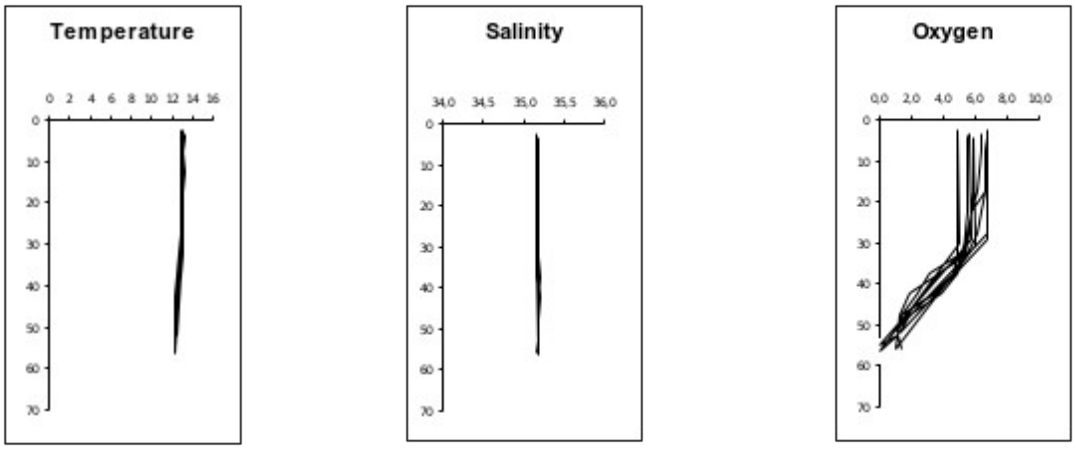
Sea surface temperatures for the northernmost station (Figure 6.a) was 15°C and 16°C and for the southernmost station (Figure 6.c), 11°C. Two 24 hour stations were sampled at 22°19.12'S 14°11.71'E (first 24 hour station) and 22°48.70'S 13°41.91'E (second 24 hours station) respectively. The sea surface temperatures for both 24 hours stations (Fig 6.b and d) was 13°C. The thermocline at the northernmost station was stronger than the southernmost station and was situated at 100 m. This also indicates that the water column was more stratified than the southernmost station. The vertical structure of the water column for both 24 hour stations were similar, with the first 24 hour station located inshore and the second offshore.

The salinity for both 24 hour and southernmost stations indicated poor vertical stratification (salinity ranged from 34.8 to 35.2 psu); whereas the northernmost station showed a much stronger pycnocline at 100 m. Salinity at the sea surface was highest at the northernmost station (35.4 - 35.6 psu) and lowest at the southernmost station (34.8 psu).

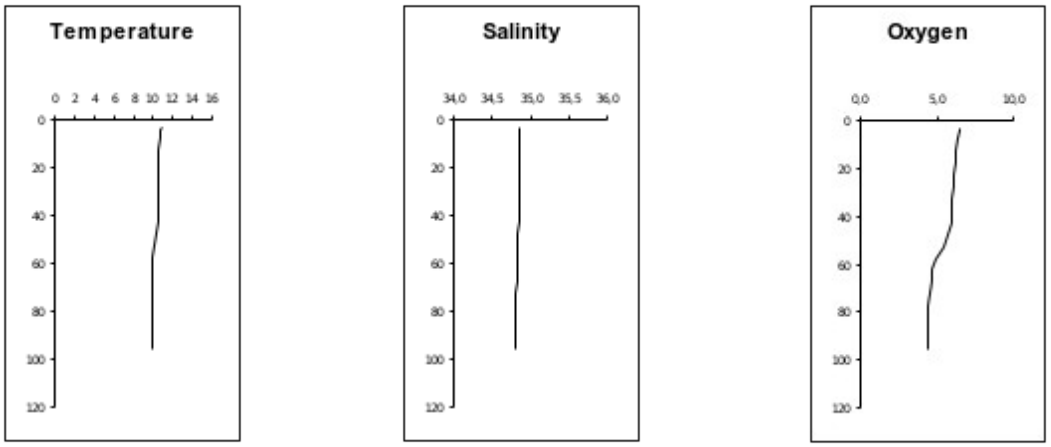
The oxygen gradient was strongest in the northernmost station (Fig 6.a), but the highest oxygen concentration value at sea surface, was observed in the offshore 24 hour station (Fig 6.d).



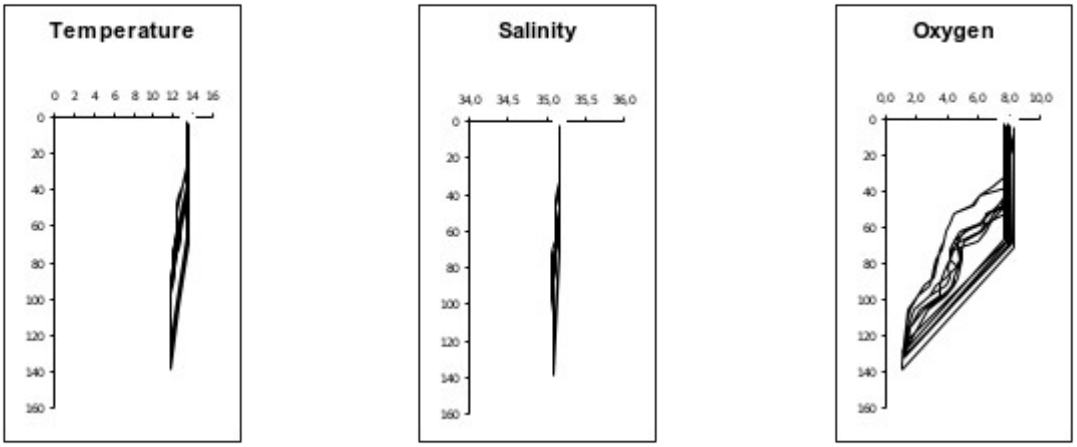
a)



b)



c)



d)

Figure 6. CTD profiles at: a) northernmost station, b) first 24 hours station, c)southernmost station, and d) second 24 hours station.

3. 3 Acoustic reference measurements

Reference measurements

In order to identify the jellyfish, bitmask filters were constructed to separate the relatively weak jellyfish echoes from other scatterers such as zooplankton and fish. The probability distributions of the differences between the four different frequencies were determined by subtracting matched and filtered frequency pairs as described in Chapter 2. Reference observations were obtained in cases where the multisampler trawl catches indicated at least 98% of the target species in weight and the total catch was at least 1.3 ton = 7.8 t/h (mags), or 791 kg = 4.7 t/h (reds). Separate filters were made for the two jellyfish species, juvenile hake and horse mackerel.

Fig. X shows example reference probability distributions for the paired frequency differences obtained for mags (left panel) and reds (right). The shape of the different pdf\s are generally nicely uniform, resembling normal distributions, although there are examples were some of the curves are somewhat irregular (reds, example 2), or where there are tendencies of an additional mode being presented. This noise may well be contribution from other scatterers like zooplankton present in the sampled volume. On the overall, however, there are overwhelmingly clear differences between the four frequencies for both jellyfish species.

Interstingly, while the degree of frequency separation is similar for the two jellyfish species, the actual differences are virtually opposite. The mags are at least X dB stronger on the 38 kHz than on the 120 and 200 kHz, while the reds are at least .

3.4 Trawl Sampling

A total of 31 stations were sampled (representing 17 distinct locations – Figure 7), and 98 trawls were made. The catches of large medusae per station are shown in Table 6 (as kg.1000 m^{-3}), whilst the catches per haul (kg.hr^{-1}) are shown in Annex II

Table 6. Biomass (kg 1000 m^{-3}) of large medusae (by species) collected at each station (see Figure 7) in the northern Benguela.

24 hr St.	St. Code	DATE	LAT	LONG	End Time	Cycle	Bottom Depth	TOTAL *C hysoscella*	TOTAL Other *Chrysaora*	TOTAL *A aequorea*
	1	22-Aug-03	18.07	11.60	10:52:33	Day	171	0.06		18.65
	1A	22-Aug-03	18.45	11.95	15:54:24	Day	52	44.81	19.20	
	2	22-Aug-03	18.53	11.92	18:04:31	Day	110	116.88		66.17
	3	22-Aug-03	18.77	11.55	23:36:54	Night	256	0.48		0.51
	4	23-Aug-03	20.38	12.73	18:51:49	Dusk	150	3.90	0.06	16.11
	5	24-Aug-03	20.48	13.18	0:14:12	Night	64	104.41	0.46	0.35
	6	24-Aug-03	21.63	13.77	15:29:52	Day	65	266.01		
A	7	25-Aug-03	22.32	14.20	5:53:18	Dawn	60	33.74		149.38
A	8	25-Aug-03	22.32	14.20	9:05:43	Day	61	23.53	0.57	119.93
A	9	25-Aug-03	22.32	14.20	12:40:34	Day	61	81.42	0.94	266.57
A	10	25-Aug-03	22.33	14.20	18:45:33	Dusk	60	4.21		14.67
A	11	25-Aug-03	22.32	14.20	22:47:33	Night	60	16.76	1.59	0.73
A	12	25-Aug-03	22.33	14.20	1:44:09	Night	63	1.45	0.14	0.47
B	13	26-Aug-03	22.82	13.70	14:06:04	Day	140	5.69		59.70
B	14	26-Aug-03	22.80	13.70	17:08:23	Day	140	6.81		8.58
B	15	26-Aug-03	22.82	13.70	19:08:18	Dusk	139	3.24		232.81
B	16	26-Aug-03	22.82	13.70	23:17:10	Night	140	6.23		164.42
B	17	27-Aug-03	22.82	13.70	4:53:45	Night	140	1.02		95.83
B	18	27-Aug-03	22.82	13.70	8:14:01	Day	139	3.21		44.83
B	19	27-Aug-03	22.80	13.70	10:22:20	Day	140	12.75		2.28
B	20	27-Aug-03	22.82	13.70	14:12:49	Day	141	22.22		210.31
B	21	27-Aug-03	22.82	13.70	19:07:30	Dusk	139	68.53		241.25
	22	28-Aug-03	23.25	14.05	3:42:36	Night	141	7.40		352.07
	23	29-Aug-03	25.33	14.52	3:10:01	Night	130			37.75
	24	29-Aug-03	25.48	14.77	8:03:38	Day	60			
	25	29-Aug-03	25.60	14.68	11:04:15	Day	101			0.31
	26	29-Aug-03	26.52	14.58	20:25:59	Night	248			5.04
	27	30-Aug-03	26.80	15.07	1:43:46	Night	77			0.51
	28	30-Aug-03	26.15	14.93	6:36:38	Day	172			
	29	30-Aug-03	27.65	15.25	13:37:33	Day	127			0.50
	30	30-Aug-03	27.77	15.50	16:10:44	Day	60			0.02

3.5 Biomass estimate from the catch data

The biomass of the two dominant species (*Chrysaora hysoscella* and *Aequorea aequorea*) across the sampling area is shown graphically in Figure 8. Of the two species, *A. aequorea* tended to be caught more frequently than *C. hysoscella* (Table 6), although in the northern area, the biomass of *C. hysoscella* tended to exceed that of *A. aequorea* (Table 6). The biomass of *C. hysoscella* was highest in the waters off Walvis Bay, and it decreased to both the northern and southern extremes of the sampling grid (Figure 8, Table 6). Although, this species was regularly caught in the waters close to the Cunene River mouth, it was largely absent south 25ºS. The biomass of *C. hysoscella* tended to be higher inshore than offshore (as

Sparks ***et al***., 2001). The absence of *C. hysoscella* in the vicinity of Lüderitz, and between Lüderitz and the Orange River mouth, is in agreement with the results of Fearon ***et al***. (1992), and it implies the absence of benthic scyphistomae in these regions. In the area just north of Lüderitz, it is likely that medusae are continuously swept offshore and northward in the extensive and vigorous upwelling plume there, so that southward penetration inshore is prevented. Sparks and Gibbons (in press) have recently suggested that the very low diversity of hydromedusae in the area of the Orange River Delta reflects the sedimentary nature of the benthic environment there, and the lack of suitable substrata for polyp settlement. Such would preclude a penetration of ephyrae and medusae from the south, of the area between Lüderitz and the Orange River mouth.

Although *A. aequorea* also reached peak biomass in the waters off, and just south of, Walvis Bay, it was present across the region and persisted in nearshore waters south of Lüderitz (albeit at low biomass). There was no clear inshore-offshore gradient in the biomass of *A. aequorea*, as has been reported previously (Sparks ***et al***., 2001), perhaps because the sampling grid did not extend to depths greater than 200 m. That this species is present in the area between Lüderitz and the Orange River mouth, suggests that benthic polyps are likely to be present in the area, though as biomass was low it could be argued that populations might have penetrated from the north (given the high "southerly" biomass of this species) following some sort of breakdown in the upwelling system at Lüderitz.

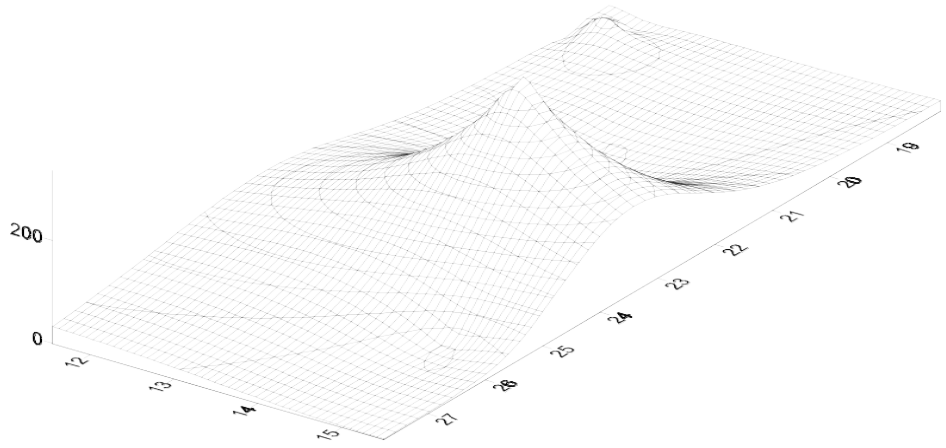
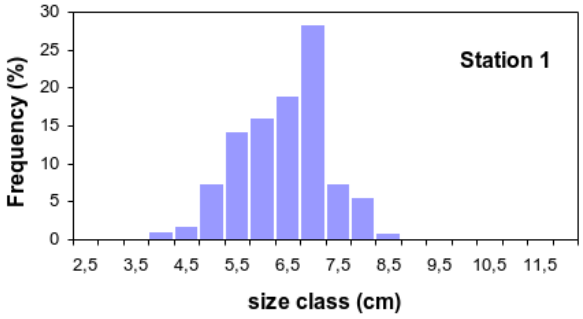


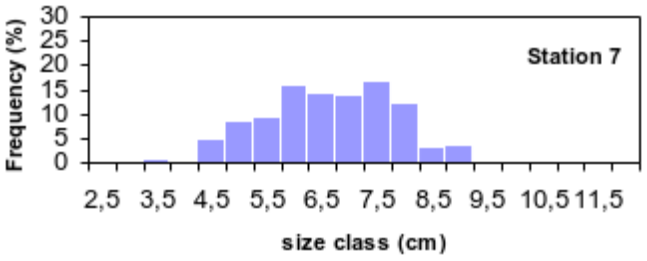
Figure 8. 3-D plots showing the distribution of *C. hysoscella* (i) and *A. aequorea* (ii) across the survey grid

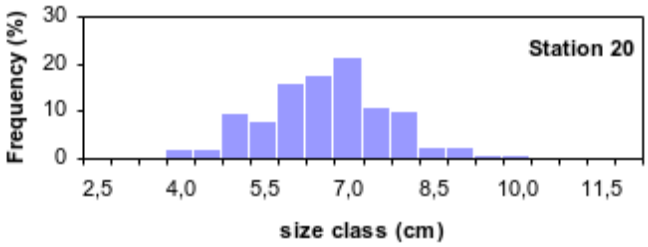
3.6. Size Structure

The population size structure of *C. hysoscella* and *A. aequorea* across the region is shown in Figures 9 and 10: only stations where greater than 100 individuals were measured are shown and discussed. In the case of *A. aequorea* there was no apparent change in the size structure with latitude (Figure 10) or distance offshore (data not shown), which implies that benthic polyps of this species occur throughout the region. By contrast, there was a clear increase in the size of individual *C. hysoscella* from the northern to the central region of the sampling grid (Figure 9), and there was a slight increase in the size of animals offshoreward (compare station 9 and station 21; Figure 9). Although these results are in partial agreement with the [crude] observations of Fearon *et al*. (1992), they do not support their conclusions[1], as small individuals were found throughout the region[2]. This implies that scyphistomae of *C. hysoscella* are also likely to be found throughout the region. Evidence for seasonality in the release of either ephyrae (*C. hysoscella*) or medusae (*A. aequorea*) is unclear, as distinctive

[1] Fearon *et al*. (1992) suggested that the scyphistomae of *C. hysoscella* are concentrated in the northern waters of the northern Benguela, and that the ephyrae released drift southwards at depth on the inshore counter-current; growing and maturing as they do so. Spawning was then postulated to occur in offshore waters of southern populations, and the fertilised eggs were suggested to drift northwards on the wind-driven surface currents.
[2] It should be noted in this regard, however, that examination of Fig 2b (in Fearon *et al*., 1992) suggests that with the exception of one southern station (~25º 30' S), small specimens of *C. hysoscella* were found across the region!


Station 1
Frequency (%)
30
25
20
15
10
5
0
2,5
3,5
4,5
5,5
6,5
7,5
8,5
9,5
10,5
11,5
size class (cm)


Station 7
Frequency (%)
30
25
20
15
10
5
0
2,5
3,5
4,5
5,5
6,5
7,5
8,5
9,5
10,5
11,5
size class (cm)


Station 20
Frequency (%)
30
20
10
0
2,5
4,0
5,5
7,0
8,5
10,0
11,5
size class (cm)

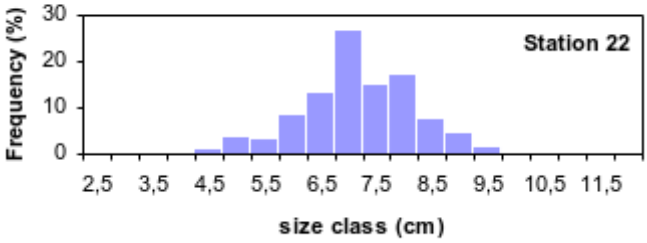
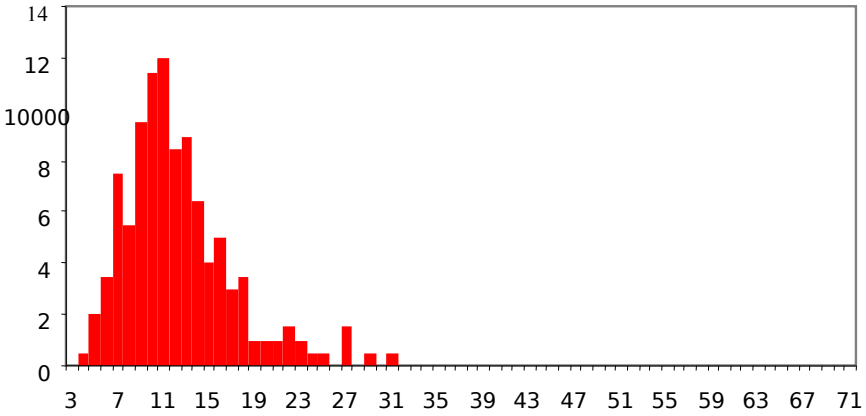
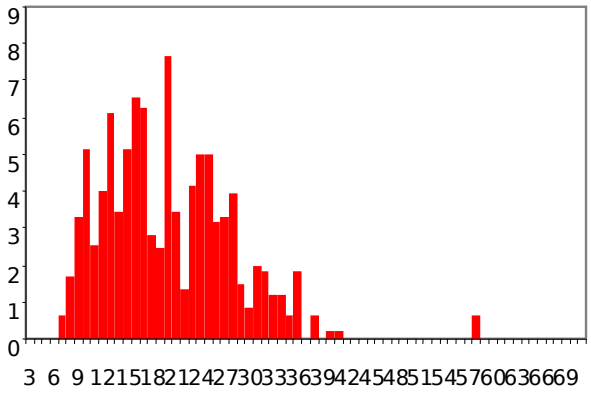

Station 22
Frequency (%)
30
20
10
0
2,5
3,5
4,5
5,5
6,5
7,5
8,5
9,5
10,5
11,5
size class (cm)

Figure 9. Diameter frequency histogrammes of sampled *A. aequorea* populations from selected (N>100) stations across the survey area. See Figure A for position of stations.





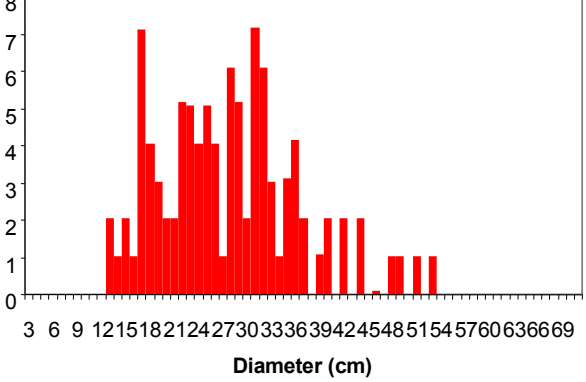


Figure 10. Diameter frequency histogrammes of sampled *C. hysoscella* populations from selected (N>100) stations across the survey area. See Figure A for position of stations.

cohorts of either species cannot be identified. Given the diverse size range of *C. hysoscella* collected here, however, it is assumed that ephyrae are released by this species on a continuous, aseasonal basis, though the same cannot be made for *A. aequorea.*

Interestingly, populations of *C. hysoscella* collected from surface waters (at both nearshore and offshore stations) included less big individuals, than those collected from deeper water (Fig.11). This result is novel. However, if it is assumed that medusae behave like other species of zooplankton the result is not surprising, because an increase in size is associated with an increase in individual mobility, and consequently with a greater control of vertical position. On the one hand, smaller zooplankton, or rather – the juvenile stages of coastal (but not necessarily oceanic) zooplankton, tend to be found closer to the surface, where abundant food resources are concentrated. Normally (but not in this instance), the near-surface distribution of juvenile stages makes them more susceptible to surface-water flow, and it is usual to find such stages concentrated further offshore. It would be wrong to suggest that juvenile *C. hysoscella* may possess some mechanism to limit offshore advection, given that some small individuals were found across the shelf at all depths. It is possible, however, that the large adults might spawn in deep water – fertilised eggs drifting onshore in the compensation currents to ensure that the settlement of planulae occurs in an appropriate, shallow environment. Having said that, however, there is no hard support for a shallow distribution of scyphistomae (none have ever been collected in the region), although it may be assumed that such a distribution allows individuals to better place ephyrae in order to take advantage of the various cross-shelf and along-shore current regimes in the region.

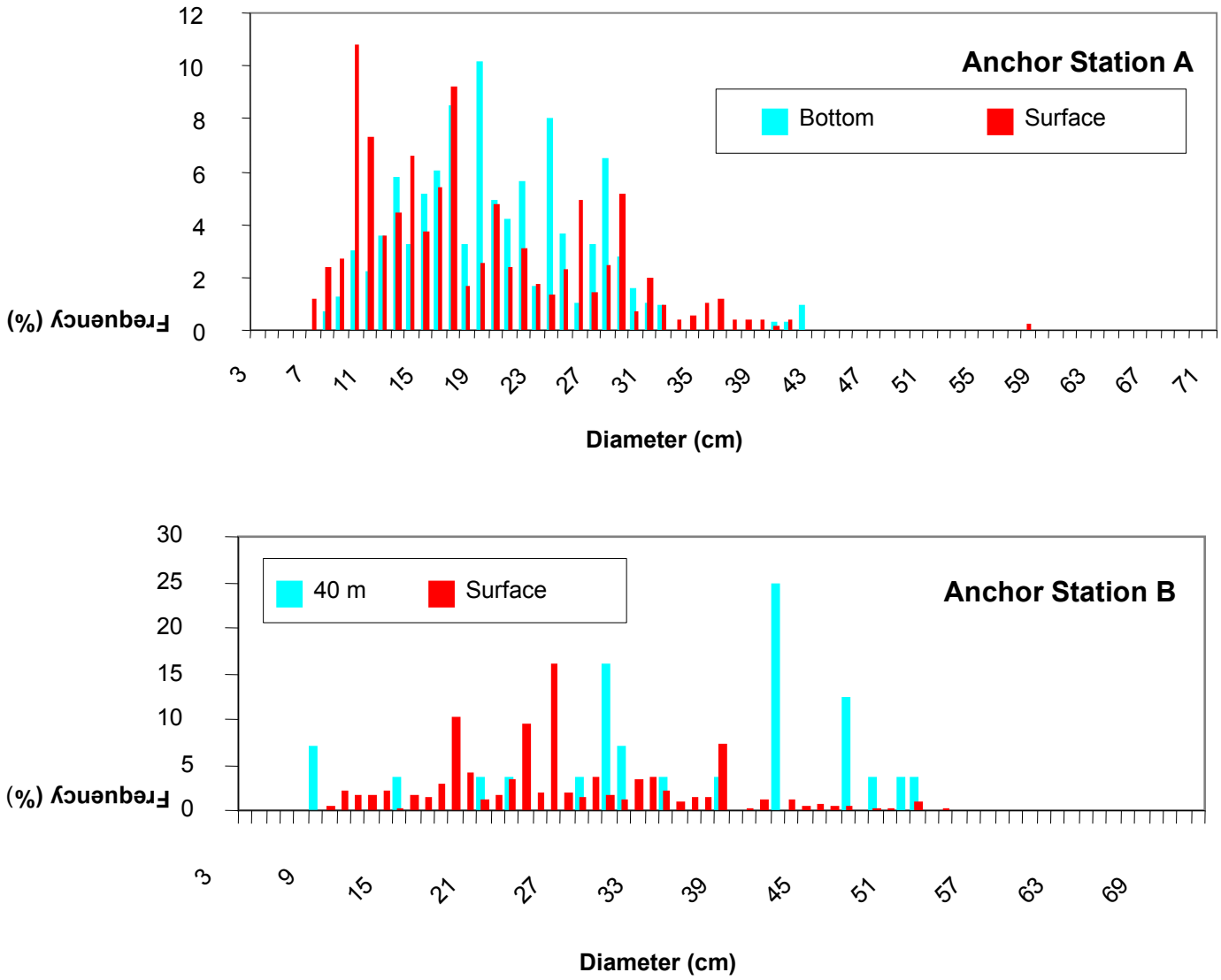


Figure 11. Diameter frequency histogrammes of sampled *C. hysoscella* populations from surface and deep-water hauls at the two anchor stations.

3.7 Vertical migration

For the purposes of this report, our analysis and discussion of diel vertical migration (DVM) are confined to the two 24-hr anchor stations only. Although information about DVM can be gleaned from the balance of the stations sampled, these need to be analysed with care, given variations in the thermal and chemical structure of the water column, along and across the shelf. We should also be careful how we interpret the results, given that our net samples are from discrete layers, and that we lack as a consequence ANY trawl information on abundances

between layers. This makes it difficult to explain, in advance of analyses of the acoustic data, anything but the most obvious patterns.

In the case of *C. hysoscella* at Anchor Station A (Figure 12), it is clear that individuals are present throughout the water column at night, and during the dawn, but that the population is concentrated near the surface during the day. At Anchor Station B, by contrast, *C. hysoscella* was found throughout the water column throughout the day, and there was no clear pattern of DVM (Figure 13). These different findings make it difficult to gereralise about DVM in *C. hysoscella*, but they suggest that it is an individual, rather than a population, behaviour.

A. *aequorea* was found throughout the water column, throughout the day, at both anchor stations (Figures 14 and 15). Although there is evidence at Anchor Station B (Figure 15) to suggest that *A. aequorea* might occur in deeper water during the day than night, this pattern is disrupted at 15h00; and is opposite to any pattern observable at Anchor Station A (Figure 14).

It is clear that these data need to be analysed in more detail, and that they need to be interpreted together with the results of the hydro-acoustic work.

3.8 Taxonomy

A number of specimens of *Chrysaora* were collected from across the sampling area, and there were preserved in 5% formalin for detailed examination in the laboratory. The specimens included a range of size classes. Cursory examination of the material reveals that two species are definitely present in the region. The first of these (*C. hysoscella*) is characterised by 8 marginal tentacles, and a massive bell of rose-pink and brown colouration. This species generally lacks obvious patterns on the bell, though faint markings can be observed on occassion. The other species, which was far less common and was generally recovered from the northern areas only, is smaller and more gracile. It has up to 40 tentacles and the bell is clearly patterned, having a colourless base and pronounced purple stripes (in various combinations and patterns – see Figure 16).
A number of samples from both species were collected for genetic analysis by colleagues in the USA.

Legends to Figures

Figure A – Map of the survey grid showing the station locations and numbers

Figure B - 3-D plots showing the distribution of *C. hysoscella* (i) and *A. aequorea* (ii) across the survey grid.

Figure C – Diameter frequency histogrammes of sampled *A. aequorea* populations from selected (N>100) stations across the survey area. See Figure A for position of stations.

Figure D – Diameter frequency histogrammes of sampled *C. hysoscella* populations from selected (N>100) stations across the survey area. See Figure A for position of stations.

Figure E – Diameter frequency histogrammes of sampled *C. hysoscella* populations from surface and deep-water hauls at the two anchor stations.

Figure F – Diel changes in the proportional distribution of *C. hysoscella* (%) through the water column at Anchor Station A.

Figure G – Diel changes in the proportional distribution of *C. hysoscella* (%) through the water column at Anchor Station B.

Figure H – Diel changes in the proportional distribution of *A. aequorea* (%) through the water column at Anchor Station A.

Figure I – Diel changes in the proportional distribution of *A. aequorea* (%) through the water column at Anchor Station B.

Figure J – Photographs of specimens of the two species of *Chrysaora* collected during Cruise Ben5 2003. (i) *C. hysoscella*, (ii-v) *Chrysaora* sp. All pictures courtesy of C. Sparks.

CHAPTER 4 DISCUSSION

4.1 TRAWL SAMPLING

All pelagic sampling trawls on R/V "Dr. Fridtjof Nansen" are identical from the extension and backwards, with fine meshes (XY mm, Annex III). The two pelagic trawls applied were the biggest one (30 m vertical opening) and the intermediate one (15 m opening, *Multisampler*). Only the biggest trawl could be used at the surface due to problems with tearing of the smaller one. The problems of tearing may be related to the fact that the largest trawl inevitably will select out jellyfish more selectively due to the larger meshes from the extension and forewards. The tearing may however also have been caused by the fact that the rigedly mounted metal frame behind the extension reduced the flexibility of the trawl. Furthermore, the extension in the smaller trawl consists of square meshes, in order to keep the side-, top- and bottom panels straight to avoid bulbs around the metal framework of the multisampler, and these have considerably lower tearing strength than diamond meshes have. If, however, as previously assumed effective catching of jellyfish primarily takes place were the meshes are small enough to retain the jellyfish (e.g. no herding or "inflow" effect), the effective sampling volume will be the same for the two trawls. There will nevertheless be bias both from haul to haul with the same trawl and between the two pelagic trawls. A poistive bias may caused by jellyfish being lead in to the trawl by the current created by the trawl, and a negative bias is the "bucket-effect", or reduced inflow of water into the trawl, which also sometimes cause tearing of the nets.

4.2 ACOUSTIC OBSERVATIONS

Jellyfish appeared as weak acoustic scatters. In some instances, jellyfish echoes may have been disguised by the massive backscattering plankton layers, but even in cases where extreme densities were recognised from the trawl samples at the surface (above the plankton layer), only wek integrator values were recorded. It therefore seems unlikely that they can be surveyed acoustically at the frequencies and with the technical configuration applied in the current investigation, at least with the high concentrations of plankton prevailing in the Benguela.

However, careful post-processing of acoustic and net haul data however revealed a linear and statistically significant relationship between catch size and integrated echo energy for reds, and multi-beam filtering techniques may be of help to extract jellyfish echoes from plankton. Further processing may hopefully reveal a similar relationship for mags, although our

impression at this stage is that mags are much less detectable acoustic targets than reds. Reds and mags being extremely weak sound scatterers was supported by measurements indicating that both species had densities indistinguishable from water (~1.0) (see also Mutlu 1996).

4.3 CONCLUDING REMARKS

- The distribution of both jellyfish species appeared to be confined to the upper 150 m of the water column, and reds were typically found shallower than mags within this range. Both species seemed to undertake some diel vertical migration: the proportion of mags in the upper 50 m multisampler net (from sample depths 150, 100 and 50 m) increased with the onset of darkness, whereas reds were caught in larger numbers in surface trawls at night than in the day. Higher densities of reds at the surface at night was supported by visual observations of the jellyfish.

- Reds and mags appeared to have different cross shelf distribution patterns. Catches containing reds only were made exclusively inshore (<100 m bottom depth), while mixed catches were made on the mid-shelf (100-250 m), and clean catches of mags were only made offshore (>250 m).

- There seems, at least to some extent, to be mechanisms separating the two species in terms of depth and cross shelf location.

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