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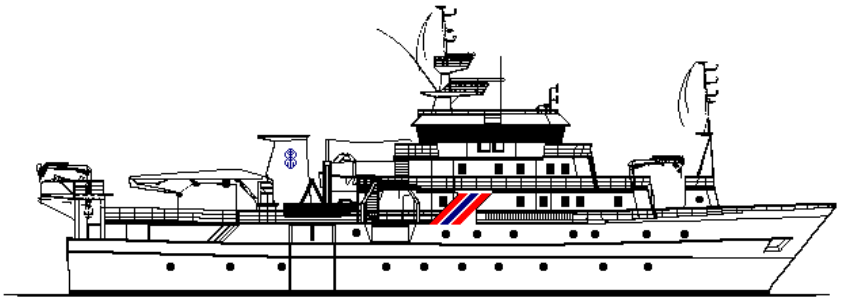
CRUISE REPORTS "DR. FRIDTJOF NANSEN"



BENEFIT SURVEYS

Cruise Report No 5/2001

Multifrequency acoustic target identification

8 – 15 September 2001

Marine and Coastal Management
Cape Town
South-Africa

Ministry of Fisheries & Marine Resources
Swakopmund
Namibia

Institute of Marine Research
Bergen
Norway

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Multifrequency acoustic target identification

8 – 15 September 2001

by

Bjørn Erik Axelsen[1], Ralton Maree[2], Johan Rademan[2], Bronwen Currie[3], Deon Durholtz[2], Vicky Herbert[3], Susan Jones[2], Jens-Otto Krakstad[3], Envor Malan[2], Janine van der Poel[2] and Charlene Rogers[2]

1. Institute of Marine Research, P. O. Box 1870 Nordnes, N-5817 Bergen, Norway

2. Marine and Coastal management, P.Bag X2, Rogge Bay, Cape Town, South Africa

3. National Information and Marine Research Centre, P.O. Box 912, Swakopmund, Namibia

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CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

Off the west and south coasts of South Africa, and the Coast of Namibia, four pelagic fish species co-occur in varying degrees at different times of the year. These include anchovy (*Engraulis capensis*), sardine (*Sardinops sagax*), round herring (*Etrumeus whiteheadi*) and horse mackerel (*Trachurus trachurus capensis*). Acoustic assessments of the biomass of both anchovy and sardine in the Benguela current region have been done since the mid 1980's.

The accuracy of hydroacoustic stock assessment has traditionally been limited by the ability of differentiating taxonomic groups of sound-scatterers. Identification methods most commonly used include trawl sampling from the population of acoustic targets and visual interpretation of the echograms based on previous knowledge of a species' shoaling patterns. These techniques may, however, be biased for co-occurring species. Catchabilities of different species may vary and the trawl neither spatial nor temporal sampling intensities comparable with that of sonars. Additionally, identifying species based on echogram characteristics is subjective and may hence be subject to bias.

The scattering of sound by marine organisms depends on ther size, shape, orientation and physiological properties, but also on the carrier frequency of the echosounder. Differences in backscattering intensity for the same organism at different frequencies may theredore be used as a means of distinguishing between insonified taxii. Targeting discrete layers and schools using *Multisampler* enables ground-truthing of observations. Ultimately, developing multifrequency target identification methods that enable objective species identification may reduce the errors in the acoustic biomass estimates in the region.

1.2 OBJECTIVES OF THE SURVEY

The overall survey objective was to continue the investigations in 1999 and 2000 aimed at improving multifrequency acoustic species identification techniques, specifically to:

- Carry out continous acoustic measurements of horse mackerel (*Trachurus trachurus capensis*) and associated pelagic and epi-demersal species at 18, 38, 120 and 200 kHz during 24 hour cycles to elaborate potential acoustical characteristics at different times of day and night.

- Species identification of recorded layers or schools using pelagic sampling trawl with multiple codends (*Multisampler*) enabling discrete samples from various depths. Sampling of fish close to and onto the bottom using demersal trawl.

- Depth-discrete sampling of zooplankton layers using the Hydrobios multinet and Bongo nets.

- CTD casts and ADCP recordings for mapping of environmental factors

1.3 PARTICIPATION

The scientific staff consisted of:

From South Africa:
Ralton MAREE (*Team leader*), Deon DURHOLTZ, Susan JONES, Envor MALAN, Janine van der POEL, Johan RADEMAN and Charlene ROGERS

From Namibia:
Bronwen CURRIE, Vicky HERBERT and Jens-Otto KRAKSTAD

From Norway:
Bjørn Erik AXELSEN (*Cruise leader*), Tore MØRK, Roar SKEIDE and Jan-Frode WILHELMSEN.

1.4 NARRATIVE

The RV *Dr. Fridtjof Nansen* departed from Walvis Bay 8 September 12h00. A location suitable for system calibration of the acoustic tranceivers using a reference sphere was found off Langstrand, north of Walvis Bay. The water depth in the area was 30 m. All four tranceivers running the keel borne transducers at 18, 38, 120 and 200 kHz nominal operating frequencies were successfully calibrated. After completion of the calibration (9 September

04h00), the ship headed northwrds to search for suitable fish aggregations for the acoustic diel cycle experiments.

The ship followed the 200 m isobath until the 18º 15' S latitude line. From this point northwards the ship followed a zig-zag pattern extending between the 150 m and 500 m isobaths, but very little fish were recorded. Four mid-water trawlers were searching in the area between 18º 15' S and the Angolan border (17º 15' S), outside the 200 m isobath (fishing inside the 200 m isobath is forbidden in this area). Contact was made via the VHF radio to a mid-water trawler targeting adult horse mackerel, and the skipper informed us that the vessels had not encountered any fishable aggregations in the area. It was therefore decided to focus the search between the 100 m and 200 m isobaths. A suitable aggregation of juvenile horse mackerel inhabiting a demersal fish community consisting mainly of dentex, round herring and juvenile hake was found at about 130 m bottom depth (17º 38' S 11º 35' E).

A 24 hour diel cycle experiment was initiated 10 September at about 17h00, running sequences (cycles) consisting of bottom trawl, pelagic trawls (3 discrete Multisampler tows), Multinet tows (5 oblique plankton samples – 405 µm mesh), Bongo tow (vertical tow – 200 µm mesh), CTD cast (temperature, oxygen, salinity), and ADCP (Acoustic Doppler Current Profiler) recording. Unfortunately, however, the wind started picking up after approximately 20 hours. Around noon there were southerly winds force strong gail, and trawling had to be stopped. After having awaited improvments in weather conditions for a few hours, the diel cycle was aborted, and the ship resumed the zig-zag search northwards towards the border. The drop keel was submerged. Little fish were found and conditions worsened. Upon reaching the border, the ship turned soutw-west, heading offshore. At around 500 of water depth the ship stopped. It was now blowing a storm (prevailing wind force 35-40 knots) and the swell made any avticity, including fish searching unfeasible. The ship was therefore backing up against the wind for the next 20 hours.

However, conditions did not improve, but rather got slightly worse. At noon 12 September it was clear that it would not be possible to complete another cycle experiment, even if the weather would improve. It was still blowing a prevailing southern storm (40 knots), peaking on full storm (48 knots). We were only able to do about 3 knots speed over ground and therefore had to start steaming towards Walvis Bay in case the weather would not improve. The morning after, 13 September, the wind reduced to strong gail, and our speed was increased to about 7-8 knots. Around mid day the wind further reduced, but the swell was still fairly high. We went inshore to obtain a few bottom sediment samples using the multicorer ("Eagle") between 20 and 21 degrees south. The ship docked in Walvis Bay 14 September at 15h00.

CHAPTER 2 METHODS

2.1 HYDROGRAPHY AND WEATHER DATA

Meteorological information including air and sea surface temperatures, wind speed and direction, and incident solar intensity was logged continously from the ANDREAA weather station. CTD casts were conducted using a Seabird 911+ probe to obtain profiles of temperature, salinity and oxygen. Samples for callibration of the oygen and salinity sensors were collected. The oxygen samples were analysed on board, while salinity samples were analysed at MCM in Cape Town. ADCP (Acoustic Doppler Current Profiler) measurements were carried out during CTD deployments only, as the operation it interferred with the 120 kHz and 200 kHz transducers.

2.2 SURVEY AREA

Heading north from Walvis Bay, the ship followed the 200 m isobath until the 18º 15' S latitude line. From this point northwards a zig-zag pattern extending between the 150 m and 500 m isobaths was followed, but very little fish were recorded. Four mid-water trawlers were searching in the area between 18º 15' S and the Angolan border (17º 15' S), outside the 200 m isobath (fishing inside the 200 m isobath is forbidden in this area). Contact was made via the VHF radio to a mid-water trawler targeting adult horse mackerel, and the skipper informed us that the vessels had not encountered any fishable aggregations in the area. It was therefore decided to focus the search between the 100 m and 200 m isobaths. A suitable aggregation of juvenile horse mackerel inhabiting a demersal fish community consisting of Dentex, juvenile hake and round herring was found at about 130 m bottom depth (17º 38' S 11º 35' E), where two consecutive 24 hour diel cycle experiments were conducted (Figure 1).

Figure 1. Cruise track and survey details.

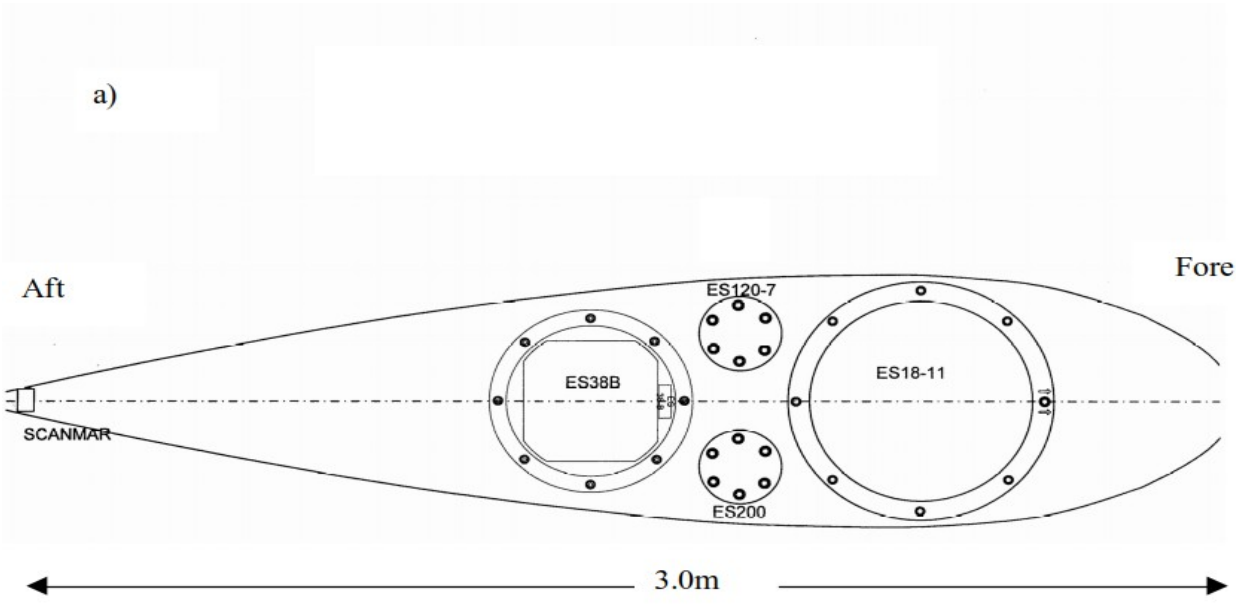
2.3 ACOUSTIC SAMPLING

2.3.1 Refit of drop keel in Cape Town, January 2001

Recently, several modifactions have been made to the transducer arrangement of the drop keel. The modifications were done during a refit in Cape Town in January 2001. 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 according the off-axis deviation angle at normal ship trim, as estimated during acoustic surveys. 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 khx 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 of the keel face. The modifications of the transducer arrangement have effectively ensured optimal configuration of the transducer, as they are now positioned on the same acoustic axis giving ~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 2a, while Figures 2b and 2 are photos of the keelface before and after the refit, respectively.



b) c)

Figure 2 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 photo taken before (b) and after (c) the refit in Cape Town in January 2001.

2.3.2 Collection of acoustic data

Two 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 both Sonardata_Echolog (PC ver. 2.00.21) and Bergen Echo Integrator (BEI) (Sun Unix) logging platforms. 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.

A complete description of the calibration procedures and results are shown in ANNEX II. A minimum integration threshold of –70 dB was used for all four frequencies. Integration limits were set to 5 m below the transducer and 1 m off the bottom. During the first part of the survey, the keel was in flush position (draft: 5.5 m), giving an effective integration limit of about 10 m below the surface. The first diel cycle experiment had to be terminated after 20 hours, as the weather turned a bit rough, with strong gail (35-40 knots prevailing southerly winds). The drop keel was submerged (2.5 m) and a zig-zag transect was worked covering both the inner and outer part of the shelf

2.4 ANALYSIS OF ACOUSTIC DATA

To compare backscattering values at different frequencies resolvable pulse volumes must be comparable. The resolving distance ($c\tau/2$), and hence resolvable volume, depends on the pulse length, which therefore ideally should be identical on all frequencies. However, the EK 500 only facilitates relative standard settings (Short/ Medium/ Wide) which differ between frequencies. Vertical bins were therefore averaged to obtain comparable resolvable pulse volumes between frequencies. The number of scatterers (n) which are ensonified by the beam increases with range (r) according to the equation:

$$n = \rho_v \cdot A_r \cdot \frac{c\tau}{2} \quad (1)$$

where ρ_v ~ the target density (number per unit volume),
A_r ~ insonified area at distance r (m), and
$\frac{c\tau}{2}$ ~ resolving distance (m).

The ensonified area A_r relates to the solid angle (Ω) from the half beam angle (θ_{rad}) according to:

$$\Omega = 2\pi(1-\cos\theta) \quad (2)$$

where $\theta_{rad} = \left(\frac{\frac{\theta}{360} \cdot 2\pi}{2} \right)$ (rad.), and θ is the beamwidth in º.

The ensonified area A_r (m^2) at distance r (m) hence corresponds to:

$$A_r = r^2 \Omega \quad (3)$$

Substituting for (A_r) in (1), the increase in number of scatterers within the resolved volume as a function of range is calculated:

$$n = \rho_v \cdot r^2 \cdot \Omega \cdot \frac{c\tau}{2} \quad (4)$$

The ratio of the increase in the number of scatterers within the resolved volume is then

calculated between transducers. For the purposes of this study, the solid angle of the 18 kHz transducer was theoretically reduced to that of the 38 kHz transducer and the ratio of n (reduced, 38kHz Ω) to n (wide 18 kHz Ω) was calculated to be 0.417. In effect this necessatates a reduction in Sv value at 18 kHz of approximately 3.8 dB. Figure 3 shows the comparison of pulse volume vs range for the three different transducers before any standardization. Figure 4 shows the volume differential between transducers, after applying corrections for changes in sampling volume with range and pulse duration.

Table 1 Pulse lengths and resolvable sampling distances of the EK 500 tranceivers.

Carrier frequency	**18 kHz**	**38 kHz**	**120 kHz**	**200 kHz**
Pulse length τ (ms)	0.7	1.0	1.0	0.6
Simrad annotation	short	medium	long	long
resolving distance (cτ/2) (m)	0.53	0.75	0.75	0.45
# of bins averaged	6	4	4	7
Comparable resolvable distance (m)	3.15	3	3	3.15

These corrections were then applied to the raw sv data exported by echoview and frequency distributions of density for different species at 18, 38 and 120 kHz were computed.

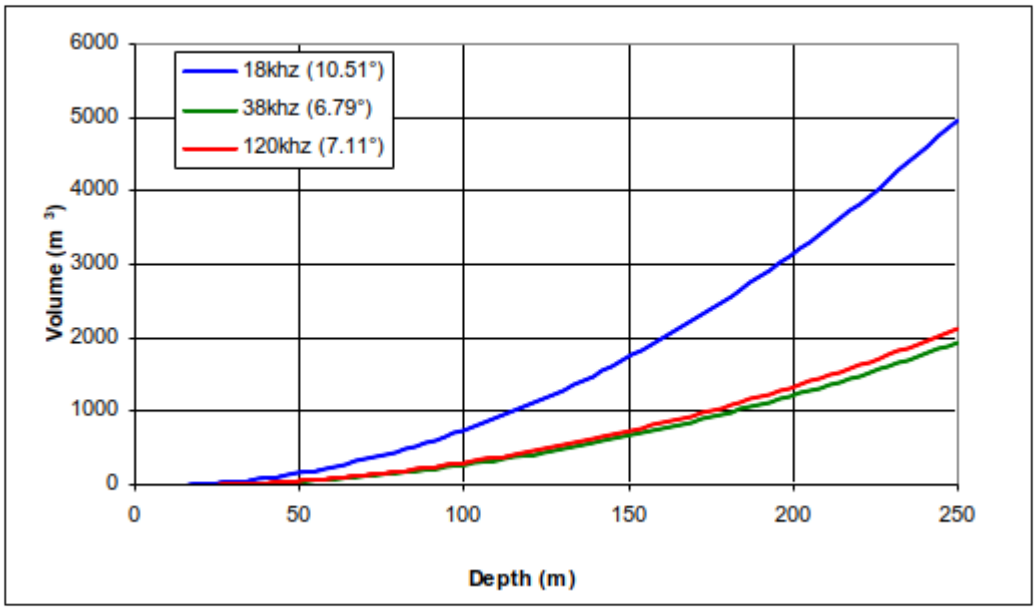


Figure 3. Pulse volume vs. range of the 18, 38 and 120 kHz transducers on *Dr. Fridtjof Nansen*.

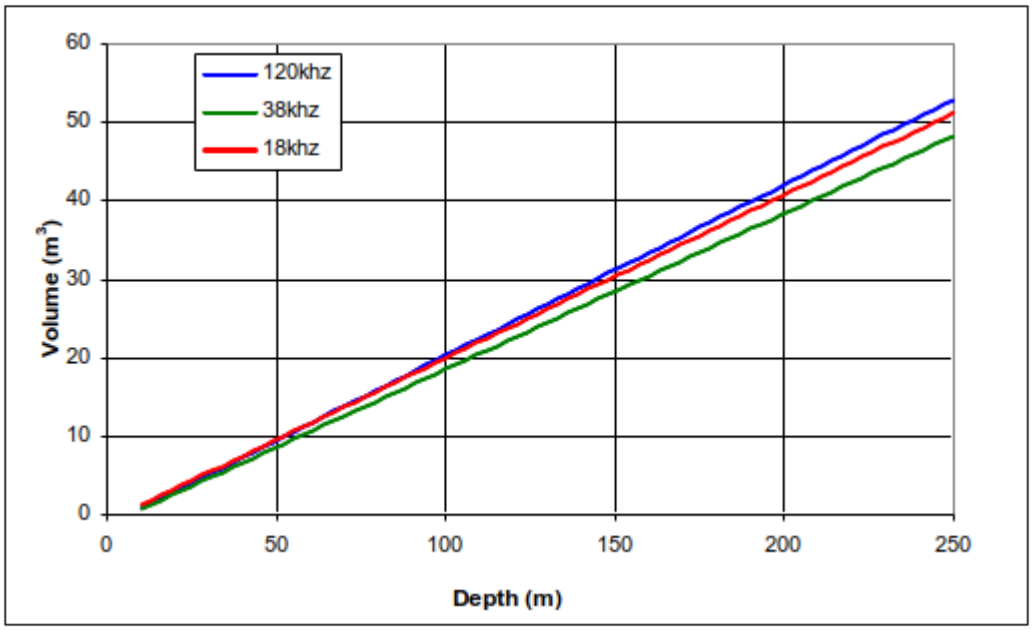


Figure 4. Volume differentials between transducers, after applying sampling volume and pulse duration corrections.

2.5 TRAWL SAMPLING

Sampling trawls used included the smallest pelagic trawl (Åkrahamn, 8-10 m vertical opening), the intermediate sized pelagic trawl (Åkrahamn, ~12 m opening) fitted with the multisampler, and a bottom trawl (Gisund super, 5 m). The multisampler was equipped with three codends, which were remotely opened and closed to obtain discrete, uncontaminated samples at different depths. Thyborøen trawl doors (8 m^2, 2000 kg) were used in all hauls, but the bracket position of the bridles on the doors were adjusted for pelagic and demrsal deployments. A brief description and illustrations of the sampling trawls are provided in Annex III. Technical specifications and recent changes to the multisampler are given in Annex IV.

All trawl catches were sampled for species composition by weights and numbers. Records of catch rates are given in Annex V. Large catches were subsampled randomly. Length frequency distributions down to the nearest 0.5 cm below total length were generated for all species ($n \geq 100$).

2.6 DIEL CYCLE EXPERIMENTS

(from 2000)

The first experiment lasted 24 hours and took place approximately 40 nm west of Cape Town (33° 52.56 S 17° 31.61 E) in about 340 m of water. The second experiment lasted for 42 hours and was done about 20 nm west of Dassen Island (33° 33.72 S 17° 33.95 E) at a depth of approximately 240 m. During these experiments, continuous monitoring by means of multifrequency acoustics, depth discrete sampling of plankton and nekton and frequent CTD casts were done. Sampling during these experiments was restricted to the same 5 nm section of track for the duration of the experiment. Sampling commenced with a bottom trawl, followed by a midwater trawl which sampled various vertically separated layers by means of the multisampler. Finally a depth-stratified zooplankton haul by means of the Hydrobios multinet sampler was done followed by a CTD cast to the bottom.

The hydrobios sampler was fitted with five 405µm mesh nets and flowmeters at the front of each net monitored the volume of water filtered by each net. The nets were hauled obliquely at 0.5 $m.s^{-1}$ whilst steaming at approximately 2 knots in a circle. The concentrated samples were preserved in 4 % buffered formalin. Hydrographical sampling was carried out after each cycle. CTD casts obtained profiles of water temperature, salinity and dissolved oxygen. Water samples were collected for callibration of both the oxygen and salinity probes. Depth specific

current speed and direction, including the vertical component and error were measured continuously throughout the experiments using an Acoustic Doppler Current Profiler (ADCP). A total of 5 cycles were sampled during the first experiment and 8 cycles during the second experiment, consisting of a total of 13 bottom trawl, 13 multisampler trawls, 13 hyrobios multinet hauls and 12 CTD casts.

Acoustic data at all three frequencies was logged continuously to determine the depths of and to integrate the various pelagic scattering layers. The species composition of the layers was determined by trawls and the size frequency of the main species was measured. A subsample of each species of hake (*Merlucccius capensis* and *Merluccius paradoxus*) were classified by stomach fullness. The stomach content analysis of hake was done on board and included classifying prey items into the lowest possible taxonomic group. Other fish species such as horse mackerel (*Trachurus capensis*), anchovy (*Engrualis capensis*), sardine (*Sardinops sagax*), redeye (*Etrumeus whiteheadi*) and mesopelagic fish (*Maurolicus* spp. and *Lampanyctodes* spp.) were frozen whole for further processing ashore.

CHAPTER 3 RESULTS

3.1 HYDROGRAPHY AND WEATHER DATA

Conditions during the survey were mostly favourable with light south-easterly winds throughout the survey. Hydrographical profiles for a selected for both diel stations are presented in Figure 7a-b.

(a)

(b)

Figure 7. CTD profiles during diel cycle experiment 1 (a) and 2 (b).

ADCP data collected during the diel cycle experiments is shown in Figure 8. The processed

data were exported to ascii format and three 5 minute ensambles averaged. Generally it indicated light northern water flow in the upper part of the water column.

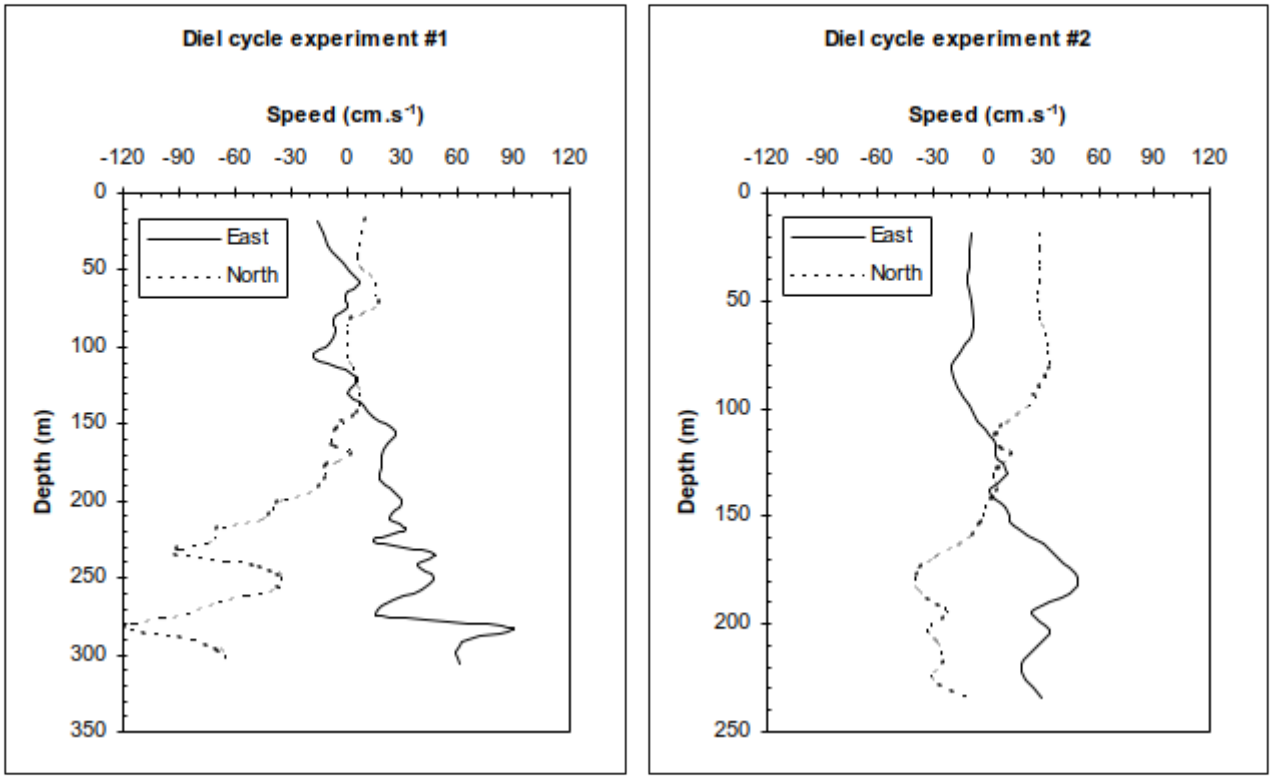


Figure 8. ADCP current profiles as recorded during the diel cycle experiments (from 2000).

3.2 ANALYSIS OF ACOUSTIC DATA

Only data from suitably identified homogeneous scattering layers are appliccable for the multifrequency target identification method. For the purposes of this report, only an example of the output is presented. The analysis of the multifrequency data requires comprehensive post-processing with special adapted software and will only be completed at a later stage and included in future publications of the BENEFIT target identification group.

An example featuring distinct scattering layers juvenile horse mackerel and ..... is shown in Figure 9. Frequency distributions of Sv (dB) values at different frequencies for each of the species were calculated. As this distribution is density dependent, ratios of different frequencies have been presented instead.

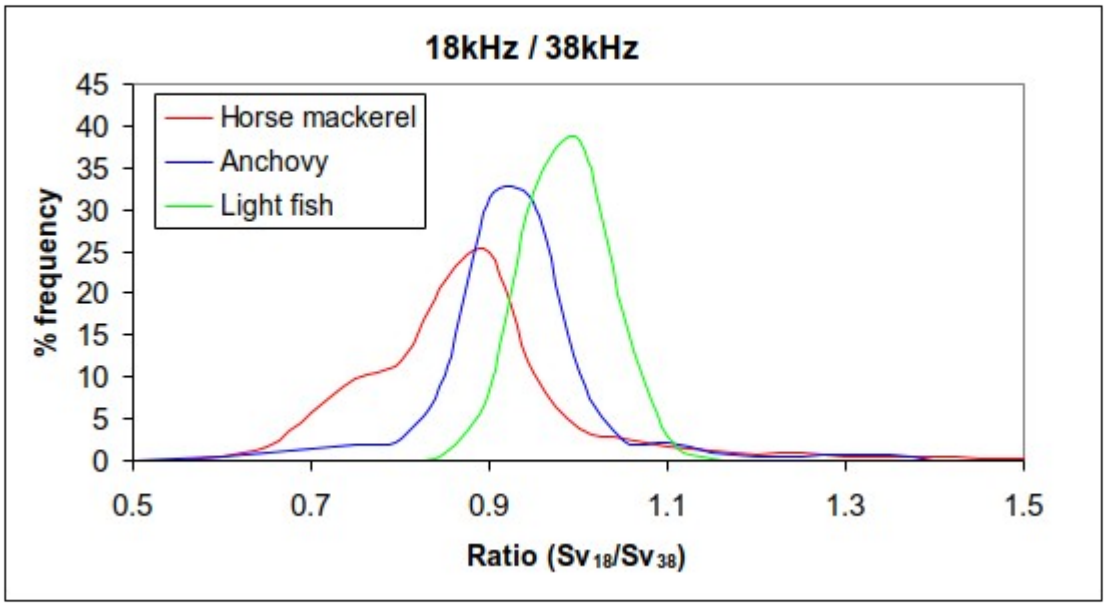


Figure 9(a). Ratios of backscatter at 18 and 38 kHz for anchovy, horse mackerel and lightfish (2000).

(text is 2000 from here)

The frequecy distribution of ratios of Sv values recorded for all three species at 18 kHz and 38 kHz shows three peaks which are slightly separated for the different species. For anchovy and horse mackerel, the peaks are less than one indicating larger backscatter at 38 kHz than at 18 kHz. Even though the peaks are close together, a slightly lower average backscatter at 18 kHz for horse mackerel is evident. These differences should become clearer when comparing the Sv values in the linear domain. Lightfish on the other hand showed relatively larger mean backscatter at 18 kHz compared to 38 kHz and could possibly be discriminated on this bases from the other two species.

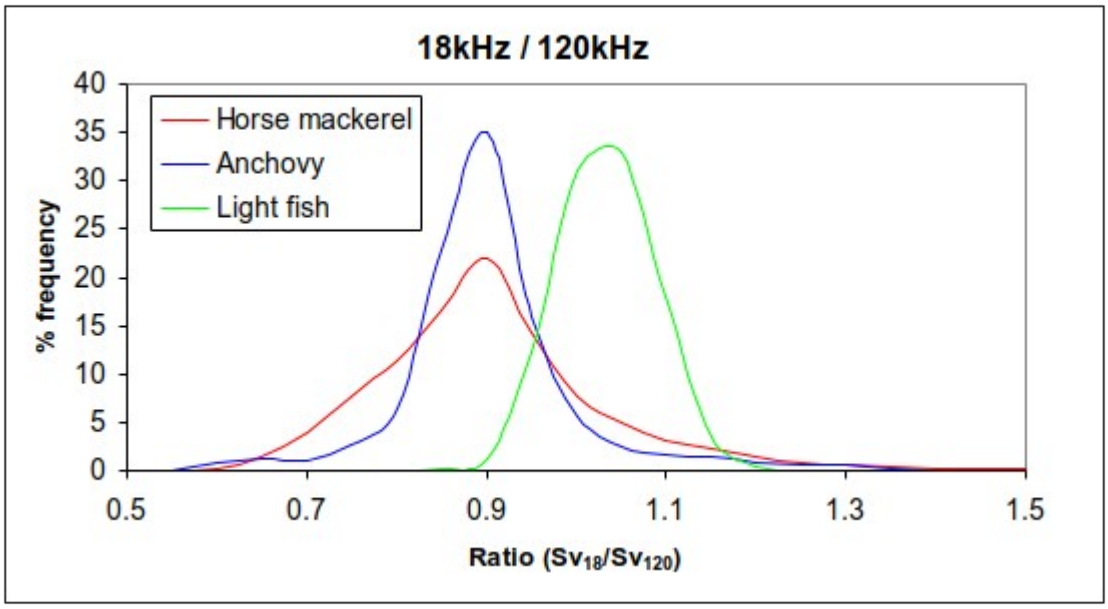


Figure 9(b). Ratios of backscatter at 18 and 120 kHz for anchovy, horse mackerel and lightfish.

The ratio of 18 kHz to 120 kHz shows identical peaks for anchovy and horse mackerel, indicating that 38 kHz is possibly the only of the three frequencies which could discriminate between these two species. The distribution is, however, wider in the case of horse mackerel and some further analysis of the data at a later stage to discern the reasons for this is required. In both cases, the Sv values at 18 kHz were lower than those measured at 120 kHz. For lightfish, the ratio of backscatter is positive, indicating higher values at 18kHz than at 120 kHz. Again this shows discrimination of lightfish from the other two species on the basis of the relatively higher backscatter at 18 kHz. The fact that the peaks overlap for horse mackerel and anchovy would at this stage rule out any discrimination between these two species based on comparison of backscatter by these two frequencies alone.

When comparing backscatter values at the frequencies of 38 kHz and 120 kHz no clear peaks are found. The 38 to 120 kHz backscatter appears stronger for lightfish compared to the other two species, but could possibly be reflecting a density dependence rather than a discriminating power. All of these data are only preliminary findings and some way of incorporating density effects needs to be taken into account. The offset of the 18 kHz from the acoustic axis would lead to more variation in higher density situations, where the homogeneity of fish scattering layers is not known. Further analysis of this data will be done ashore and the results will be published in the scientific literature. More clear signals may also emerge when doing these comparisons in the linear domain, rather than in the current logarithmic domain.

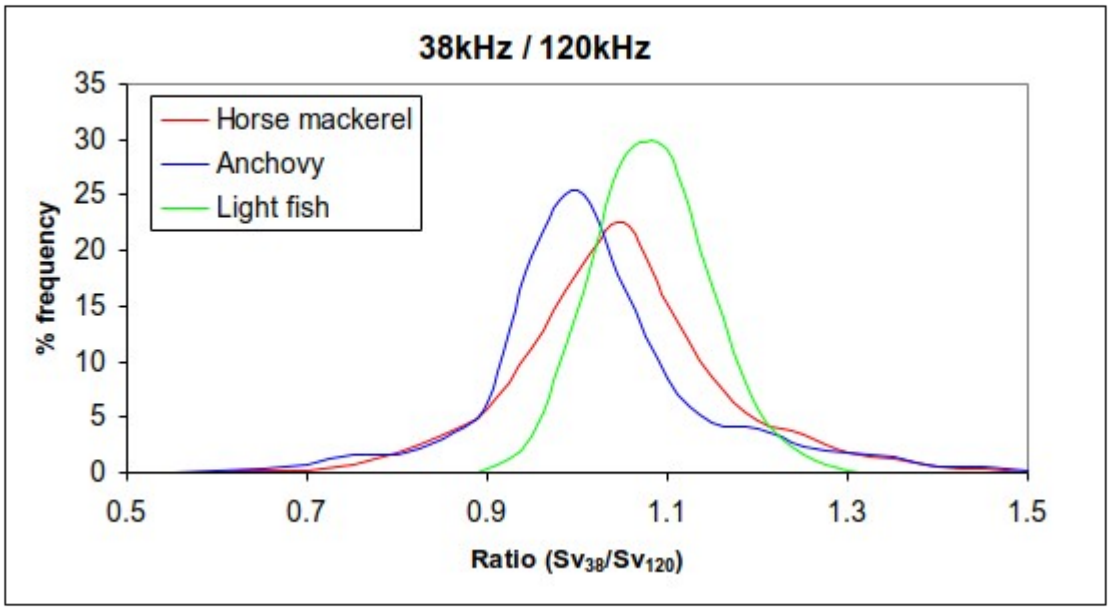


Figure 9(b). Ratios of backscatter at 38 and 120 kHz for anchovy, horse mackerel and lightfish.

3.3 TRAWL SAMPLING

(this is from 2000)

A total of 133 trawls were completed during the survey. Most of the trawls were multisampler trawls (100 in total or 34 trawls using 3 cod-ends on all occasions except two when 2 cod-ends were used). A further 18 trawls using the large pelagic trawl (mostly with floats on the headline) were done. Bottom trawls done during the diel cycle experiments made up another 15 trawls. All catches were sorted, processed and entered into the Nansis trawl data base. A summary of all trawls completed are shown in Annex V.

From 23h00 on the 13/06/2000 to 22h55 on the 14/06/2000 a twenty-four hour diel cycle experiment was conducted 40 nmiles west of Cape Town. Five bottom trawls (634, 638, 642, 646 and 650) and five multisampler trawls (635-637, 639-641, 643-645, 647-649 and 651-653) were completed alternately in the 24 hours.

Each bottom trawl lasted between 20 and 30 minutes with the catches ranging from 300kg to 823kg. *Merluccius paradoxus* (*M. paradoxus*) dominated the mass of the catches in trawls 638, 642 and 646 with *Macrouridae* (rattails) being the second most dominant. In trawls 634 and 650 the mass of the rattails exceeded the mass of *M. paradoxus*. During all the multisampler tows it was attempted to catch discrete layers of fish at different depths in the water column. Each layer was fished for approximately 20 minutes. In three of the tows M. *paradoxus* was

the dominant species in the bottom layer and in all three cases the catches were made at night. No trend could be seen between the upper two layers of the five tows but generally if fish was

caught in the middle layer of the water column of a specific trawl the same fish was seen in the upper layer of the same trawl. Closer investigation of the length frequency data will reveal if there was a difference in the mean length of the fish in the different layers.

From 12h17 on the 15/6/2000 to 10h38 on the 21/6/2000 a school and scattering layer composition experiment was completed between Cape Hangklip and Cape Agulhas. Seven large pelagic trawls (654-660), 15 multi-sampler trawls (661-681 and 683-706) and one bottom trawl was used as a pelagic trawl. Large pelagic trawl no.659 was aborted because the net twisted, while the bottom trawl caught very little fish compared to the large pelagic trawls. Most of the big pelagic trawls occurred at night and the depths ranged between 15 and 30m. *Trachurus capensis* (maasbanker), *Engraulis capensis* (anchovy) and *Etrumeus whiteheadi* (redeye) were caught in all the pelagic trawls. *Sardinops ocellatus's* (pilchard) were found in all, except trawl 660 and 682. Of the above species, anchovy was the most dominant in most cases, but redeye dominate the catch in trawl 658.

Eight of the multisampler tows (661-675, 679-681, 683-685 and 704-706) were fished at approximately the same depths, attempting to catch discreet shoals of fish, to see if shoal compositions were similar. In all of the multisampler hauls, the three cod ends yielded catches that showed similar catch compositions, with only slight variations (if any) from cod end to cod end. In five of the eight multisampler tows, anchovy were caught and in most of the catches this was the dominant species. Seven multisampler tows (676-678 and 680-703) were done to attempt capturing discreet layers of fish. No trends could be seen between the different groups of cod ends (trawls) or between the cod ends of each trawl. Redeye, anchovy and *Chrysaora* (jelly) were caught in most of the trawls but the percentage they contributed to the catches, differed randomly.

From 20h40 on the 21/06/2000 to 8h39 on the 22/06/2000 a sonar experiment was done in False Bay. During trawling for this experiment the motor of the multisampler started to malfunction. For trawl 707 the multisampler was used but only one net opened. The large pelagic trawl was used for trawl 708 and the multisampler was attempted again for 709-711 and all three nets were successfully opened and closed. For trawls 712-713 the multisampler was used and only two nets opened and during the next multisampler tow (714-715) the motor of the multisampler failed. No multisampler trawls were done until the faulty part was replaced on the 24/06/2000. It was then decided to trawl with the large pelagic trawl. The scanmar trawleye's battery was flat for trawl 716 and trawl 717 was a test trawl for the pelagic trawl once the battery had been replaced. Trawls 718 to 724 were successful pelagic trawls and trawls 725 and 726 were bottom trawls.

From 14h53 on the 25/06/2000 to 06h02 on the 27/06/2000 a thirty-nine hour diel cycle experiment was conducted 20 nmiles west of Dassen Island. Eight bottom trawls (726, 730, 734, 738, 742, 746, 750 and 754) and eight multisampler trawls (727-729, 731-733, 735-737, 739-741, 743-745, 747-749,751-753 and 755-757) were completed alternately in the 39 hours.

Each bottom trawl lasted between fifteen and twenty minutes with the catch sizes ranging from 305kg to 1510kg. *Helicolennus dactolopterus* (jacobever), *Macrouridae* (rattails), *Paracallionymus costatus* (dragonets), M. paradoxus, M. capensis, *Lampanyctus hectoris* (lanternfish) and *Maurolicus muelleri* (lightfish) were caught in all the bottom trawls. Trawls that were done during the night dominated by rattails and those done during the day were dominated by M. paradoxus. The multisampler trawls were all done at different depths to catch different layers of fish for comparison. Lightfish and lanternfish were caught in most of the nets. Lightfish seemed to be the more dominant in the two lower layers and the lanternfish was the more dominant species in the top layers of the mulitisampler catches. The bottom net of the trawls that were done at night all contained M. paradoxus and in most of the trawls containing M. paradoxus, the hake was the dominating species.

ANNEX I

Table 1 SIMRAD EK 500 Transceiver menu settings after acoustic calibration.

Echosounder	EK 1	EK 1	EK 1	EK 2
Transceiver	1	2	3	1
Carrier frequency	38 kHz	120 kHz	18 kHz	200 kHz
Mode	Active	Active	Active	Active
Transducer type	ES 38B	ES 120-7	ES 18-11	ES 200-F7
Transducer sequence	Off	Off	Off	Off
Transducer depth (m)	5.5	5.5	5.5	5.5
Absorption coeff. (dB/km)	10	38	3	53
Pulse Length	Medium	Long	Short	Long
Bandwidth	Wide	Narrow	Wide	Narrow
Max. Power (W)	2000	1000	2000	1000
2-Way Beam Angle	-21.0	-20.6	-17.2	-20.5
Sv. Transducer Gain	27.45	26.01	21.69	25.51
TS. Transducer Gain	27.65	26.17	21.60	26.20
Angle sens. Along.	21.9	21.0	13.9	0
Angle sens. Athw.	21.9	21.0	13.9	0
3 dB Beamwidth Along	6.8	7.6	10.9	0
3 dB Beamwidth Athw.	6.7	7.6	10.9	0
Alongship offset	-0.03	-0.05	-0.04	-0.04
Athwartship offset	0.06	0.08	0.03	0.03
Sound velocity (ms^{-1})	1498	1498	1498	1498

Table 2 SIMRAD EK 500 TS detection menu settings used during the survey.

Echosounder	EK 1	EK 1	EK 1	EK 2
Transceiver	1	2	3	1
Minimum value	-80 dB	-80 dB	-80 dB	-80 dB
Min. length	0.8	0.8	0.8	0.8
Max. length	1.8	1.8	1.8	1.8
Max. gain compensation	6.0	6.0	6.0	6.0
Max. phase deviation	5.0	5.0	5.0	5.0

PROJECT STATION:1005

DATE:10/ 9/01 GEAR TYPE: BT No: POSITION:Lat S 1737
start stop duration Long E 1135
TIME :13:46:48 14:16:26 30 (min) Purpose code: 1
LOG :7725.17 7726.64 1.46 Area code : 3
FDEPTH: 132 134 GearCond.code:
BDEPTH: 132 134 Validity code:
Towing dir: 345ø Wire out: 400 m Speed: 30 kn*10

Sorted: 71 Kg Total catch: 183.65 CATCH/HOUR: 367.30

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Dentex macrophthalmus	113.36	3700	30.86	5719
Merluccius capensis, juveniles	109.88	440	29.92	5720
DASYATIDAE	56.20	4	15.30	
Chrysaora hysoscella	30.90	250	8.41	
TRIGLIDAE	19.60	36	5.34	
Aequorea aequorea	17.72	676	4.82	
Callorhinchus capensis	9.30	10	2.53	
Trachurus capensis	7.48	440	2.04	5721
Small squids	2.18	10	0.59	
ARIIDAE	0.68	2	0.19	
Total	367.30		100.00	

PROJECT STATION:1006

DATE:10/ 9/01 GEAR TYPE: PT No:1 POSITION:Lat S 1740
start stop duration Long E 1136
TIME :15:36:40 15:46:44 10 (min) Purpose code: 1
LOG :7734.73 7735.29 0.54 Area code : 3
FDEPTH: 110 110 GearCond.code:
BDEPTH: 126 128 Validity code:
Towing dir: 345ø Wire out: 300 m Speed: 35 kn*10

Sorted: 32 Kg Total catch: 31.95 CATCH/HOUR: 191.70

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	187.92	11670	98.03	5722
TRIGLIDAE	1.98	6	1.03	
Merluccius capensis, juveniles	1.74	24	0.91	
Chrysaora hysoscella	0.00	6		
Total	191.64		99.97	

PROJECT STATION:1007

DATE:10/ 9/01 GEAR TYPE: PT No:1 POSITION:Lat S 1739
start stop duration Long E 1136
TIME :15:54:41 16:04:53 10 (min) Purpose code: 1
LOG :7735.69 7736.23 0.53 Area code : 3
FDEPTH: 65 65 GearCond.code:
BDEPTH: 131 130 Validity code:
Towing dir: 345ø Wire out: 180 m Speed: 30 kn*10

Sorted: 30 Kg Total catch: 30.00 CATCH/HOUR: 180.00

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
CLUPEIDAE	173.22	9618	96.23	5723
Chrysaora sp.	3.84	300	2.13	
Trachurus capensis	2.94	216	1.63	5724
Total	180.00		99.99	

PROJECT STATION:1008

DATE:10/ 9/01 GEAR TYPE: PT No:1 POSITION:Lat S 1738
start stop duration Long E 1135
TIME :16:16:57 16:27:51 11 (min) Purpose code: 1
LOG :7736.80 7737.40 0.59 Area code : 3
FDEPTH: 28 28 GearCond.code:
BDEPTH: 127 128 Validity code:
Towing dir: 345ø Wire out: 73 m Speed: 30 kn*10

Sorted: 25 Kg Total catch: 25.40 CATCH/HOUR: 138.55

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Aequorea aequorea	137.02	3082	98.90	
Chrysaora sp.	0.98	11	0.71	
CLUPEIDAE	0.49	27	0.35	
SYNGNATHIDAE	0.05	5	0.04	
Total	138.54		100.00	

PROJECT STATION:1009

DATE:10/ 9/01 GEAR TYPE: BT No:8 POSITION:Lat S 1739
start stop duration Long E 1136
TIME :18:22:16 18:51:56 30 (min) Purpose code: 1
LOG :7742.89 7744.31 1.42 Area code : 3
FDEPTH: 128 126 GearCond.code:
BDEPTH: 128 126 Validity code:
Towing dir: 165ø Wire out: 370 m Speed: 30 kn*10

Sorted: 96 Kg Total catch: 311.13 CATCH/HOUR: 622.26

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	367.80	18764	59.11	5726
Merluccius capensis, juveniles	92.56	128	14.87	5725
Chrysaora hysoscella	70.56	1296	11.34	
Dentex macrophthalmus	52.54	1186	8.44	
Aequorea aequorea	22.62	60	3.64	
DASYATIDAE	7.30	2	1.17	
Small squids	6.32	12	1.02	
Chrysaora hysoscella	2.56	6	0.41	
Total	622.26		100.00	

PROJECT STATION:1010

DATE:10/ 9/01 GEAR TYPE: PT No:1 POSITION:Lat S 1740
start stop duration Long E 1136
TIME :19:43:33 19:54:33 11 (min) Purpose code: 1
LOG :7746.28 7746.87 0.59 Area code : 3
FDEPTH: 110 110 GearCond.code:
BDEPTH: 128 131 Validity code:
Towing dir: 345ø Wire out: 330 m Speed: 30 kn*10

Sorted: 12 Kg Total catch: 11.90 CATCH/HOUR: 64.91

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	57.44	660	88.49	5727
Small squids	2.24	22	3.45	
TRIGLIDAE	1.91	5	2.94	
Dentex macrophthalmus	1.42	27	2.19	
Chrysaora hysoscella	0.98	44	1.51	
Merluccius capensis, juveniles	0.71	11	1.09	
Aequorea aequorea	0.22	16	0.34	
Total	64.92		100.01	

PROJECT STATION:1011

DATE:10/ 9/01 GEAR TYPE: PT No:1 POSITION:Lat S 1739
start stop duration Long E 1136
TIME :20:00:45 20:11:24 11 (min) Purpose code: 1
LOG :7747.15 7747.73 0.58 Area code : 3
FDEPTH: 75 75 GearCond.code:
BDEPTH: 131 130 Validity code:
Towing dir: 345ø Wire out: 200 m Speed: 30 kn*10

Sorted: Kg Total catch: 65.48 CATCH/HOUR: 357.16

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Aequorea aequorea	355.04	6404	99.41	
TRIGLIDAE	1.64	5	0.46	
Trachurus capensis	0.49	16	0.14	
Total	357.17		100.01	

PROJECT STATION:1012

DATE:10/ 9/01 GEAR TYPE: PT No: POSITION:Lat S 1738
start stop duration Long E 1135
TIME :20:18:31 20:28:47 10 (min) Purpose code: 1
LOG :7748.07 7748.61 0.54 Area code : 3
FDEPTH: 30 30 GearCond.code:
BDEPTH: 131 130 Validity code:
Towing dir: 345ø Wire out: 75 m Speed: 30 kn*10

Sorted: Kg Total catch: 12.45 CATCH/HOUR: 74.70

SPECIES	CATCH/HOUR	% OF TOT. C	SAMP

	weight	numbers	
Aequorea aequorea	61.44	1104	82.25
Chrysaora hysoscella	12.36	156	16.55
Hyperoglyphe moselii	0.84	6	1.12
Trachurus capensis	0.06	12	0.08
Total	74.70		100.00

PROJECT STATION:1013

DATE:10/ 9/01 GEAR TYPE: BT No:8 POSITION:Lat S 1739
start stop duration Long E 1136
TIME :22:22:40 22:52:01 29 (min) Purpose code: 1
LOG :7753.30 7754.66 1.36 Area code : 3
FDEPTH: 129 126 GearCond.code:
BDEPTH: 129 126 Validity code:
Towing dir: 165ø Wire out: 400 m Speed: 30 kn*10

Sorted: Kg Total catch: 147.05 CATCH/HOUR: 304.24

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	141.83	7014	46.62	5728
Dentex macrophthalmus	52.53	1092	17.27	
DASYATIDAE	51.99	10	17.09	
Aequorea aequorea	21.12	689	6.94	
Merluccius capensis, juveniles	18.06	184	5.94	5729
Chrysaora hysoscella	17.83	184	5.86	
Austroglossus microlepis	0.87	10	0.29	
Total	304.23		100.01	

PROJECT STATION:1014

DATE:11/ 9/01 GEAR TYPE: PT No:1 POSITION:Lat S 1740
start stop duration Long E 1136
TIME :00:03:37 00:13:56 10 (min) Purpose code: 1
LOG :7757.87 7758.42 0.54 Area code : 3
FDEPTH: 110 110 GearCond.code:
BDEPTH: 127 130 Validity code:
Towing dir: 345ø Wire out: 330 m Speed: 35 kn*10

Sorted: Kg Total catch: 4.15 CATCH/HOUR: 24.90

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	9.48	624	38.07	5730
Merluccius capensis, juveniles	6.72	102	26.99	5731
Small squids	2.10	12	8.43	
ARIIDAE	2.04	6	8.19	
Chrysaora hysoscella	1.98	24	7.95	
CLUPEIDAE	1.44	78	5.78	
Aequorea aequorea	0.60	18	2.41	
Dentex macrophthalmus	0.54	12	2.17	
Total	24.90		99.99	

PROJECT STATION:1015

DATE:11/ 9/01 GEAR TYPE: PT No:1 POSITION:Lat S 1739
start stop duration Long E 1136
TIME :00:21:18 00:31:22 10 (min) Purpose code: 1
LOG :7758.79 7759.35 0.55 Area code : 3
FDEPTH: 75 75 GearCond.code:
BDEPTH: 128 128 Validity code:
Towing dir: 345ø Wire out: 240 m Speed: 35 kn*10

Sorted: 42 Kg Total catch: 42.15 CATCH/HOUR: 252.90

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Aequorea aequorea	217.44		85.98	
TRAGAA0	15.00	18	5.93	
Chrysaora hysoscella	11.40	60	4.51	
Callorhinchus capensis	8.70	6	3.44	
Trachurus capensis	0.18	24	0.07	
CLUPEIDAE	0.18	12	0.07	
Total	252.90		100.00	

PROJECT STATION:1016

DATE:11/ 9/01 GEAR TYPE: PT No:1 POSITION:Lat S 1738
start stop duration Long E 1135
TIME :00:42:17 00:53:19 11 (min) Purpose code: 1
LOG :7759.92 7760.57 0.65 Area code : 3
FDEPTH: 25 25 GearCond.code:
BDEPTH: 129 131 Validity code:
Towing dir: 345ø Wire out: 90 m Speed: 35 kn*10

Sorted: Kg Total catch: 23.55 CATCH/HOUR: 128.45

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Chrysaora hysoscella	65.18	289	50.74	
Aequorea aequorea	62.67		48.79	
Trachurus capensis	0.27	55	0.21	
CLUPEIDAE	0.16	11	0.12	
C E P H A L O P O D A	0.11	5	0.09	
SYNGNATHIDAE	0.05	11	0.04	
Total	128.44		99.99	

PROJECT STATION:1017
DATE:11/ 9/01 GEAR TYPE: BT No: POSITION:Lat S 1739
start stop duration Long E 1136
TIME :02:54:43 03:23:22 29 (min) Purpose code: 1
LOG :7765.98 7767.31 1.34 Area code : 3
FDEPTH: 127 125 GearCond.code:
BDEPTH: 127 125 Validity code:
Towing dir: 164ø Wire out: 400 m Speed: 30 kn*10

Sorted: Kg Total catch: 57.63 CATCH/HOUR: 119.23

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	51.91	2609	43.54	5733
Dentex macrophthalmus	41.17		34.53	
Aequorea aequorea	10.06	265	8.44	
C E P H A L O P O D A	6.06	19	5.08	
Chrysaora hysoscella	5.21	39	4.37	
Merluccius capensis, juveniles	4.37	145	3.67	5732
Zeus faber	0.33	6	0.28	
Austroglossus microlepis	0.12	6	0.10	
Total	119.23		100.01	

PROJECT STATION:1018
DATE:11/ 9/01 GEAR TYPE: PT No:1 POSITION:Lat S 1740
start stop duration Long E 1136
TIME :04:13:53 04:25:20 11 (min) Purpose code: 1
LOG :7769.77 7770.36 0.58 Area code : 3
FDEPTH: 110 110 GearCond.code:
BDEPTH: 126 130 Validity code:
Towing dir: 345ø Wire out: 320 m Speed: 30 kn*10

Sorted: Kg Total catch: 47.40 CATCH/HOUR: 258.55

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Aequorea aequorea	200.07	3829	77.38	
Chrysaora hysoscella	51.98	720	20.10	
TRIGLIDAE	4.20	5	1.62	
OCTOPODIDAE	1.31	5	0.51	
Aequorea aequorea	0.87	71	0.34	
Small squids	0.11	5	0.04	
Total	258.54		99.99	

PROJECT STATION:1019
DATE:11/ 9/01 GEAR TYPE: PT No:1 POSITION:Lat S 1739
start stop duration Long E 1136
TIME :04:33:02 04:42:59 10 (min) Purpose code: 1
LOG :7770.72 7771.23 0.50 Area code : 3
FDEPTH: 60 60 GearCond.code:
BDEPTH: 130 129 Validity code:
Towing dir: 345ø Wire out: 190 m Speed: 30 kn*10

Sorted: Kg Total catch: 40.00 CATCH/HOUR: 240.00

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Aequorea aequorea	208.98	4020	87.08	
Chrysaora hysoscella	24.66	174	10.28	
TRIGLIDAE	5.10	12	2.13	
Small squids	0.84	6	0.35	
Trachurus capensis	0.42	78	0.18	
Total	240.00		100.02	

PROJECT STATION:1020

DATE:11/ 9/01 GEAR TYPE: BT No:8 POSITION:Lat S 1739
start stop duration Long E 1135
TIME :06:50:42 07:09:45 19 (min) Purpose code: 1
LOG :7776.59 7777.53 0.95 Area code : 3
FDEPTH: 130 0 GearCond.code:
BDEPTH: 130 Validity code:
Towing dir: 165ø Wire out: 360 m Speed: 30 kn*10

Sorted: Kg Total catch: 53.30 CATCH/HOUR: 168.32

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	100.96	5283	59.98	5735
TRIGLIDAE	19.58	57	11.63	
Chrysaora hysoscella	18.44	208	10.96	
Dentex macrophthalmus	12.06	275	7.16	
Merluccius capensis, juveniles	10.99	152	6.53	5734
Aequorea aequorea	5.40	120	3.21	
Small squids	0.95	3	0.56	
Total	168.38		100.03	

PROJECT STATION:1021

DATE:11/ 9/01 GEAR TYPE: PT No:1 POSITION:Lat S 1739
start stop duration Long E 1136
TIME :08:06:29 08:17:53 11 (min) Purpose code: 1
LOG :7781.16 7781.76 0.60 Area code : 3
FDEPTH: 110 110 GearCond.code:
BDEPTH: 131 128 Validity code:
Towing dir: 345ø Wire out: 330 m Speed: 30 kn*10

Sorted: Kg Total catch: 1.40 CATCH/HOUR: 7.64

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Chrysaora hysoscella	3.44	245	45.03	
Hyperoglyphe moselii	1.53	5	20.03	
Small squids	0.93	5	12.17	
Dentex macrophthalmus	0.76	16	9.95	
Trachurus capensis	0.65	38	8.51	
Merluccius capensis, juveniles	0.33	5	4.32	
Total	7.64		100.01	

PROJECT STATION:1022

DATE:11/ 9/01 GEAR TYPE: PT No:1 POSITION:Lat S 1739
start stop duration Long E 1135
TIME :08:23:30 08:34:22 11 (min) Purpose code: 1
LOG :7782.00 7782.60 0.59 Area code : 3
FDEPTH: 60 60 GearCond.code:
BDEPTH: 130 131 Validity code:
Towing dir: 345ø Wire out: 180 m Speed: 30 kn*10

Sorted: Kg Total catch: 90.26 CATCH/HOUR: 492.33

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	414.44	45540	84.18	5736
Aequorea aequorea	54.76	2122	11.12	
CLUPEIDAE	14.95		3.04	5737
ARIIDAE	6.38	16	1.30	
Chrysaora hysoscella	1.80	16	0.37	
Total	492.33		100.01	

PROJECT STATION:1023

DATE:11/ 9/01 GEAR TYPE: PT No:1 POSITION:Lat S 1738
start stop duration Long E 1135
TIME :08:40:59 08:52:30 12 (min) Purpose code: 1
LOG :7782.97 7783.54 0.56 Area code : 3
FDEPTH: 85 85 GearCond.code:
BDEPTH: 132 131 Validity code:
Towing dir: 345ø Wire out: 240 m Speed: 30 kn*10

Sorted: Kg Total catch: 80.01 CATCH/HOUR: 400.05

SPECIES	CATCH/HOUR weight	CATCH/HOUR numbers	% OF TOT. C	SAMP
Trachurus capensis	290.25	16305	72.55	5738
CLUPEIDAE	99.60	12000	24.90	
Callorhinchus capensis	7.50	10	1.87	
TRIGLIDAE	2.70	10	0.67	
Total	400.05		99.99	