CRUISE REPORT "DR. FRIDTJOF NANSEN"

ACOUSTIC INVESTIGATIONS OF PILCHARD AND SARDINELLA SCHOOLING BEHAVIOUR IN NAMIBIA AND ANGOLA

Preliminary Report: Cruise No 1998404

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CHAPTER 2 Studies of the schooling behaviour of sardinella (*Sardinella maderensis* and *Sardinella aurita*) in Angolan waters.

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1. INTRODUCTION

1.1 OBJECTIVES

The Namibian pilchard and the Angolan sardinella are managed mainly on the basis of biomass estimates of the adult stock obtained by the standard hydro acoustic method. To acquire reliable absolute biomass estimates using this method, the entire stock must be surveyed by a vessel carrying a calibrated echo integrator. In addition, regular sampling of the acoustic recordings must be conducted by trawling, the echo values originating from fish must be allocated to species identified by the trawling, and the echo intensity reflected from individual fish of the actual species must be known. If these criteria are met, it is assumed that the biomass of fish stocks can be estimated by the acoustic method with an accuracy of about 25 %.

However, there are several possible sources of errors in acoustic abundance estimation of fish. During the last two decades most methodological and technical problems related to the methods have been investigated and solved by introduction of reliable instruments and special procedures to calibrate the instruments. Still the effects of fish behaviour on acoustic abundance estimates are of great concern. This is of particular importance if pelagic fish are schooling close to the surface or performing vessel avoidance, in which case substantial underestimation of the fish abundance may occur. The aggregation behaviour of schooling fish can also induce substantial variance and thereby uncertainty in acoustic survey estimates.

The main objective of this cruise was therefore to study and quantify aggregation, schooling and near surface behaviour of small pelagic species that may influence acoustic survey estimates in Namibian and Angolan waters. To test the replicability of acoustic survey estimates of shoaling fish, an area in the Northern Benguela was surveyed twice within 10 days by sailing the transects in opposite directions. In Angolan waters, the swimming behaviour, surface appearance and vessel avoidance of sardinella were quantified by sonar-based school tracking, visual observation and comparative surveys by R/V Dr. Fridtjof Nansen and its skiff. The representativity of trawl sampling of sardinella was also observed.

A method to overcome the difficulties connected to aggregative behaviour, near surface distribution and vessel avoidance of shoaling fish is use of a horizontal guided sonar. The instrument should be of the multi beam type so that whole schools may be insonified for each ping, and recordings of schools should be done automatically by special software implemented in a computer that is connected to the sonar. To be able to convert the sonar recordings to fish biomass, relationships between the geometric dimensions or echo intensity of schools and school biomass have been established for pilchard and sardinella during cruises by R/V “Dr. Fridtjof Nansen” in 1995 and 1996. The vessel was then equipped with a Simrad SA950 sonar and a computer-based system for school detection and recording.

With the aim of developing a user-friendly system for visualization and scrutinizing of sonar recordings, IMR and CMR have been developing a sonar data processing system (SODAPS) since 1995. The system was first installed onboard R/V “Dr. Fridtjof Nansen” in 1996, and were further debugged and tested during two cruises in 1997. In connection with the installation of SODAPS the Simrad SA950 sonar was rebuilt to a Simrad SF950D sonar. Further development and testing of the sonar was also carried out on two occations in 1997. This sonar shall be capable of absolute mesurements of volume backscattering strength which enable estimation of school biomass through models of targeth strength of schools.

Both the rebuilding of the sonar and the SODAPS system is based on fairly complicated software technology, and the systems were not fully developed during 1997. Another objective of this cruise was therefore to conduct further testing of the sonar, and debugging, development and testing of the SODAPS system.

1.2 PARTICIPATION

The scientific staff were:

- From the National Marine Information and Research Centre, Swakopmund, Namibia:

  Gerhard Oechslin

- From Instituto de Investigação Pesqueiro, Luanda, Angola:

  N’Kosi Luyeye

- From Sea Fisheries Research Institute, Cape Town, South Africa:

  Janet Coetzee

- From the Institute of Marine Research, Bergen, Norway:

  John Dalen

Magnar Mjanger

Ole Arve Misund (Cruise leader)

Bjørn Totland

Jan Einar Vågenes

- From Christian Michelsen Research Institute in Bergen:

Per Erik Nordbø (until 27/4)

1.3 SCHEDULE

The RV 'DR FRIDTJOF NANSEN' departed from Walvis Bay harbour on the 17 th of April 1998 at and started to surveying north-southwards transects along the Namibian coast. The purpose was to study the replicability of acoustic surveys by sailing transects twice in opposite directions. The vessel called Walvis Bay on 21st of April to pick up a delivery of warps which had not arrived, and to receive Steinar Olsen and wife Bendik for celebration of his 70th birthday. The replicated surveying off Namibia finished on the 26th of April, and the vessel called Walvis Bay a second time. The warp delivery, a portable echo sounder, and new SAS software were received on the morning of the 27th of April. At that day Per Erik Norbø departed, there was a meeting with Mr. Bryce Edwards, and the vessel sailed for Angola at 12:30. The surveying in Angola started in Baia dos Tigres on April 29th, the vessel arrived Luanda on the evening of May 5th, and the cruise ended in Luanda on May 6th. It was expected, and indeed happened, that the cruise program had to be adjusted according to performance of acoustic equipment, fish distribution, and especially for logistical reasons (warps for the next cruise).

CHAPTER 1: REPEATED ACOUSTIC SURVEY OF SMALL, SHOALING PELAGIC SPECIES IN THE NORTHERN BENGUELA

1 INTRODUCTION

1.1 BACKGROUND

As a thorough search of the distributional area of pilchard was to be conducted in order to meet other objectives of this survey, it was decided to use the data collected to estimate the biomass of the Clupeiforme species; pilchard, anchovy and round herring, occurring in the northern Benguela. A horse mackerel biomass was also calculated as they were particularly abundant throughout the survey area. Because of the short time available the resulting biomass estimates will probably be imprecise but it will at least provide an indication of the biomass of each species.

1.2 OBJECTIVES

A region north of Walvis Bay was surveyed to:

- Estimate the biomass of pilchard, anchovy, round herring and horse mackerel in the region between Walvis Bay and Ambrose Bay in the northern Benguela in repeated surveys.
- Investigate the replicability and variation of acoustic surveys of pilchard, anchovy, round herring and horse mackerel in Namibia.
- Investigate the existence of diurnal changes in the abundance and aggregative behaviour of pilchard, anchovy, round herring and horse mackerel.

2 METHODS

2.1 Hydrography

Hydrographic information collected during this part of the survey included surface temperature (5m depth probe), air temperature, wind speed and direction and radiation which were logged automatically every nautical mile using an Aanderaa meteorological station. In addition, a Seabird 911CTD was used to obtain vertical profiles of temperature, salinity and oxygen. Real time plotting was done using the Seabird Seasave software. Although, calibration of the CTD equipment for oxygen and salinity values was not done during this survey, it is assumed that the error margin is very small and would only have affected extreme values.

2.2 Survey area

Prior information regarding the distribution of pilchard obtained from a previous survey (March 1998) was used to design the course track. The course track with the trawling and hydrographic stations is shown in Figure 1. The course track which was surveyed twice, in opposite directions, consisted of 6 parallel transects with an inter-transect spacing of between 5 and 10 nm. Transect lengths varied between 80 nm inshore to 110 nm offshore. The offshore transect coincided roughly with the 200 m isobath and the expected offshore boundry of the pilchard distribution.

2.3 Acoustic sampling methods and data analysis

A description of the acoustic instruments and their standard settings are given in Annex I, including a description of the fishing gear used. The EK 500 system provided measurements of fish densities, averaged over 5 nm intervals. Further detailed analysis, however, was done using 1 nm intervals. The scrutinising process of the Bergen Echo Integrator, BEI, was used to partition integrator data to species or species groups by separating echo recordings horizontally or vertically. Integrator data from fish targets were allocated to the following groups on the basis of trawl sampling and acoustic character, as recognised from the echo recordings:

Pilchard
Anchovy
Round herring
Horse mackerel
Plankton and mesopelagic, including mixed layers of mesopelagic organisms containing horse mackerel

The average S_A-values within the area were then obtained by averaging all intervals measured during the coverage of the area, excluding those values obtained during searching off the transect or trawling against the course line. The area was measured in cm^2 with a planimeter and converted to nm^2.

The following target strength (TS) function was applied to convert S_A-values (mean integrator value for a given area) to number of fish:

$$TS = 20 \log L - 72 \ \text{[dB]}$$

where the total length of the fish, L is expressed in centimetres. This target strength to size relationship has been used for a number of fish species (horse mackerel, pilchard, anchovy and round herring), although originally derived from early measurements of North Sea herring.

The number of fish in each length group in an area was calculated by applying the following formula:

$$n_i = S_A . A . \frac{p_i}{\sum_{i=1}^{n} C_{F_i}}$$

where	n_i	=	number of fish in length group I
	A	=	area in nm^2
	S_A	=	mean integrator value in the area
	p_i	=	proportion of fish in length group i in samples from the area
	C_{Fi}	=	fish conversion factor for length group I

The fish conversion factor was calculated from the measured length/weight relationship of similar sized fish obtained during a previous *survey (Dr. Fridtjof Nansen* cruise report No 2/94)

Pilchard	$W = 0.0044\ L^{3.1843}$
Anchovy	$W = 0.0061\ L^{2.9850}$
Round herring	$W = 0.0051\ L^{3.0618}$

The number per length group was then summed and the total number of fish obtained. The total biomass of fish was computed using the mean weight per length class.

2.4 Trawl sampling strategy

Trawls were targeted on unidentified dispersions or shoals of fish. A random sample of fish representative of the total catch was taken from the trawl, the size of the sample depending on the size of the catch. In cases where the catch was small, the total catch was sampled.

To determine the catch composition of the trawl the number and weight for each species in the random sample was recorded. This sample was then raised to the total catch. A random sample of about 100 fish, if available, were measured to the nearest 0.5 cm below total length to obtain the size composition of the catch. The size composition of all trawls in the area was pooled after weighting by catch size.

3 RESULTS

3.1 Hydrography

Sea surface temperature contour maps for the first and second survey are presented in Figures 2a and 2b respectively. During the first survey inshore surface temperatures were generally high in the area between Swakopmund and Walvis Bay, possibly as a result of warm east winds (offshore flow) immediately prior to the survey. Further north inshore surface temperatures were slighly cooler and normal for this time of the year. The major part of the water mass between the 100 m and 200 m isobaths was characterised by temperatures of 16 ° C. A relatively steep temperature gradient was observed in the area between Swakopmund and Henties Bay where temperatures increased by 5 ° C within a distance of a few miles. Vertical sections of both temperature and oxygen concentration are shown in Annex II. These indicate a well mixed water mass throughout the area with no strong thermoclines present. Oxygen levels were consistently high in the surface layers and decreased rapidly with depth which also indicated warm conditions with no upwelling. During the second survey, the inshore waters had cooled substantially and returned to the expected normal. The 16° C iostherm was consequently also situated slightly further offshore. Vertical sections of both temperature and dissolved oxygen showed the persisting high oxygen levels at the surface, although subsurface oxygen had dropped slightly particulary in the inshore southern region. This together with slightly upward inclined isothems possibly indicates some upwelling. The wind conditions throughout both surveys was consistently from the North and of weak to moderate strength.

3.2 Distribution

The distributions of pilchard, round herring and horse mackerel from the 1st survey are shown in Figures 3a-c and those from the second survey in Figures 3d-e. As very few anchovy were caught in trawls, only a small amount of allocations were made to anchovy and therefore no distribution maps or biomass estimates were produced. The scale used in the distribution charts to illustrate different levels of density is presented in absolute acoustic units, which is the mean integrator value S_A for a given area. Contouring was done using linear kriging procedures with Surfer© software.

The distribution of pilchard during both surveys was very patchy. Generally low density aggregations usually seen as scattered layers were found in the southern part of the survey region. Higher densities, arising from dense schools in the region of Cape Cross were limited to a very small area. Towards Ambrose Bay, the distribution of pilchard which extended from the 100 m to the 200 m isobar, was again less dense and originated mainly from scattered layers close to the surface. The small distribution of pilchard in the inshore region north of Cape cross was dominated by small recruits with a mean length of 13 cm, whilst the rest of the pilchard had a mean length ranging from 17 to 22 cm. Allocation of S_A values to pilchard during the second survey was problematic due to the inability of the trawl to catch pilchard schools in most cases. Most allocations were therefore made on the basis of school characteristics. In the southern area, the distribution was similar to that observed during the 1st survey, although extending slightly further offshore. In the region of Cape Cross a few dense schools were recorded, although not as dense as in the first survey. No pilchard were recorded in the northern part of the survey area.

In the region south of Cape Cross, the round herring distribution during the first survey coincided roughly with that of the sardine distribution. This was mainly due to pilchard and round herring forming scattered layers close to the surface, particularly at night. Round herring were also found in the inshore region stretching all along the coast as far as Ambrose Bay. During the second survey, very little round herring was found in trawls and consequently few allocations were made to round herring. Only two small patches were found, one in the southern and one in the northern region.

Horse mackerel were found over the entire survey area during both coverages. The densest area during both surveys was the central part extending southwards from the region of Cape Cross. There was a slight movement of fish closer inshore during the second survey.

3.3 Abundance

The abundance estimates obtained during the surveys are not total estimates of abundance, but merely reflect the distribution and abundance as measured within the survey area. As this was not initially intended to be a routine biomass estimate, the survey was not adjusted to cover the boundaries of the fish distribution, although incidentally this seem to be the case in most respects. The estimated biomass of pilchard, round herring and horse mackerel during both surveys is summarised in Table 1 and provided in weight and number of fish per area in Annex III. Large variations in survey estimates of particularly pilchard and round herring were observed between successive coverages of the area. The biomass estimate of pilchard and round herring was considerably less during the second survey whilst that of horse mackerel was very similar

TOTAL BIOMASS BETWEEN WALVIS BAY AND AMBROSE BAY (TONNES)			
	PILCHARD	ROUND HERRING	HORSE MACKEREL
SURVEY 1	185 000	86 000	310 000
SURVEY 2	39 000	7 000	323 000

Table 1. Biomass estimates of pilchard, round herring and horse mackerel.

3.5 Length-frequency

Annex VI shows the length-frequency of the three species.

Two distinct length classes of pilchard were found. Only a small portion of small fish (recruits) were found, mostly in the inshore area north of Cape Cross. Most of the pilchard trawls, however, consisted of adult fish ranging from 19 to 25 cm. Hardly any fish were found in the length class between 13 and 19 cm, indicating the absence of an entire year class.

Similarly, round herring sampled in trawls were mostly adults ranging in size form 17 to 23 cm. A few smaller round herring between 11 and 14 cm were measured in the same area where small pilchard were found. Again one year class seems to be absent.

Horse mackerel sampled in the trawls ranged from 4 to 27 cm with a definite peak at around 9.5 cm and a smaller secondary peak at around 13 cm, possibly indicating two distinct year classes. A very small number of horse mackerel measured larger than 22 cm.

4 CONCLUDING REMARKS

This survey was a very brief assessment of the assumed area of distribution of pilchard in the northern Benguela. While the results may not be as precise as previous acoustic abundance estimates, they should be indicative of the general state of these stocks in the area surveyed.

Conditions were favourable for an acoustic survey throughout the survey period. Weather conditions were good and in general the fish seemed to be distributed within the transducer range both day and night. All of the areas where fish were found were surveyed twice in opposite directions. At this stage it does not seem as though fish were missed due to diurnal migrations taking the fish outside of the transducer range. Further detailed analysis concerning the comparison of the two surveys and possible explanations of the large differences in estimates will be completed and published in the scientific literature.

From the distribution maps, migration out of the survey area does not seem to be a reason for these large differences. In the case of pilchard further investigation into the densities measured, revealed that a single high value (5 nm average S_A of 14 000) recorded during the first coverage accounted for most of the biomass. The removal of this high value reduces the first survey estimate to approximately 59 000 tonnes which is much closer to the second survey estimate. It is therefore obvious that the survey variance is extremely high and as for many dense shoaling fish species the survey estimates rely greatly on the 'hit or miss' of these dense aggregations. This problem is further aggravated when the stock size of a particular shoaling species is very small and the chance of detecting the few remaining shoals is very low. Resulting estimates of biomass are then subject to large variance.

The area of dense pilchard encountered during the first survey was surveyed during the early morning. During the second coverage this area was surveyed at night when fishermen in the area reported large catches of pilchard. Only a few shoals were, however, recorded by the Nansen and it may be speculated that avoidance of the vessel was a factor. Furthermore species identification during the second survey was particularly problematic. Dense schools assumed to be pilchard were impossible to catch, especially at night due to trawl avoidance and allocation were made solely on the basic of shoal characteristics. Large quantities of jellyfish throughout the survey area also hampered trawling operations as jellyfish very rapidly filled up the trawl before targeted fish. It is therefore possible that allocations were not as accurate as should be expected.

CHAPTER 1: FIGURES

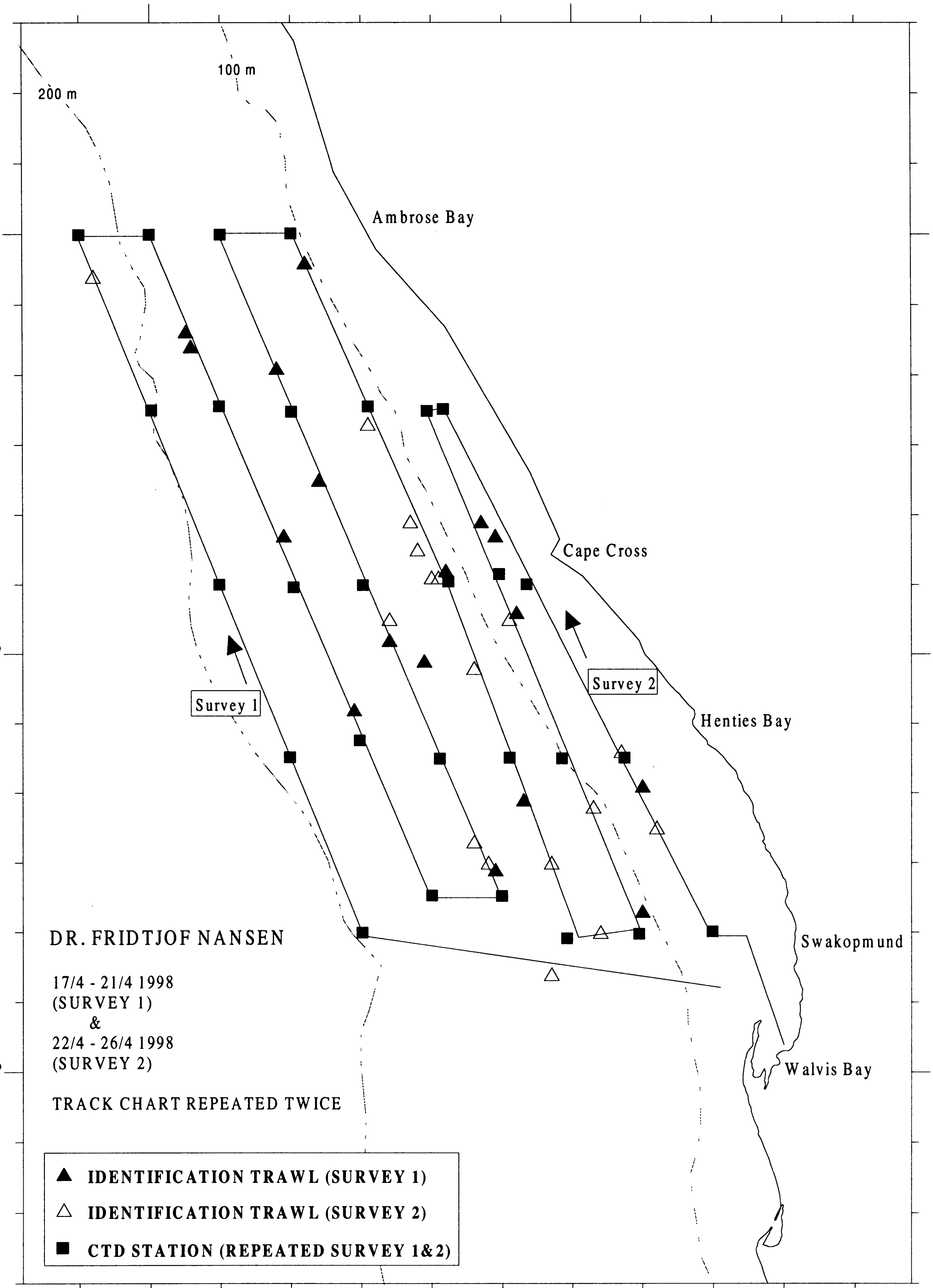


Figure 1. Course track showing trawling and hydrographic stations between Walvis Bay and Ambrose Bay.

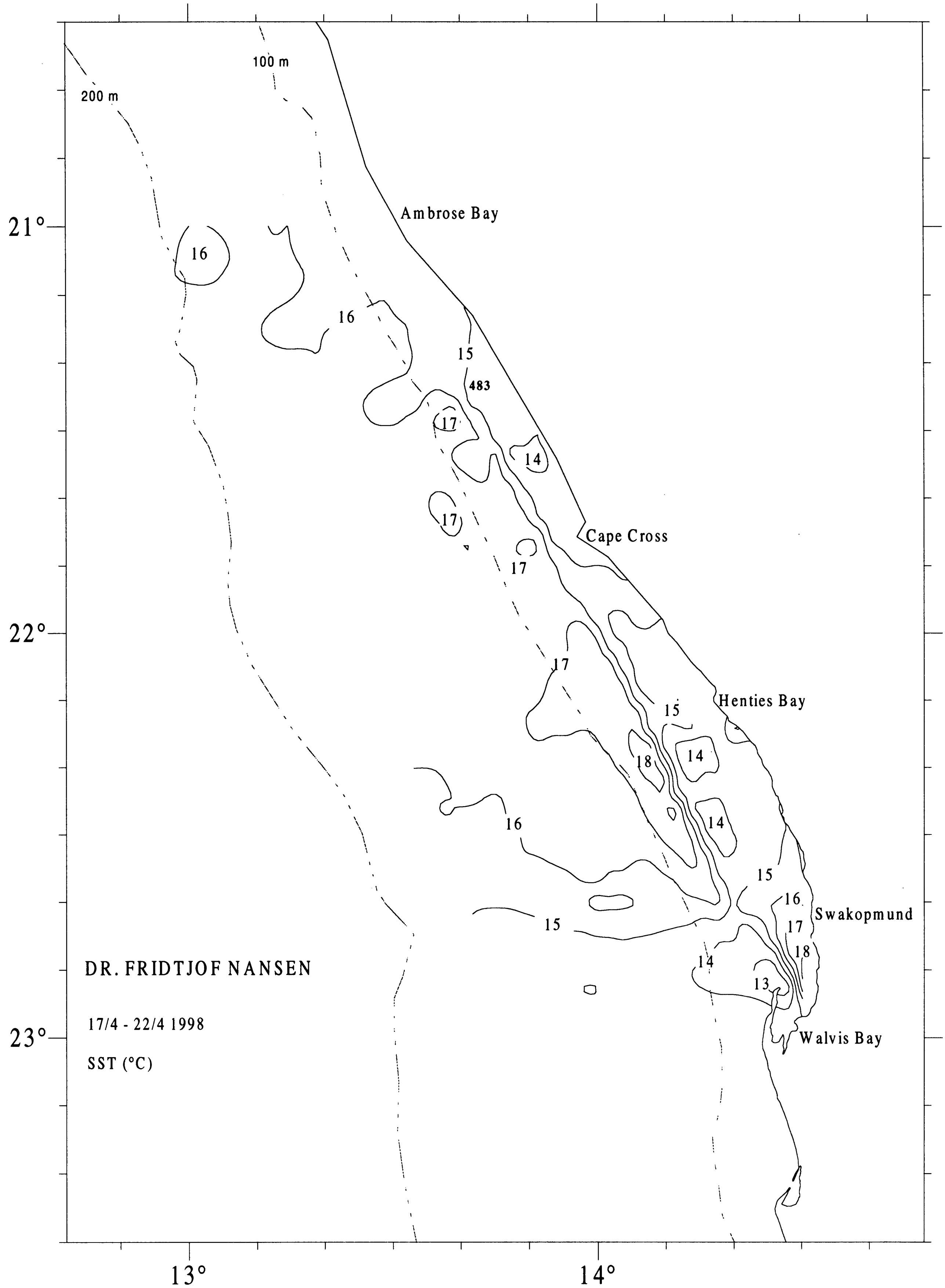


Figure 2a. Sea surface temperature distribution during the 1st survey.

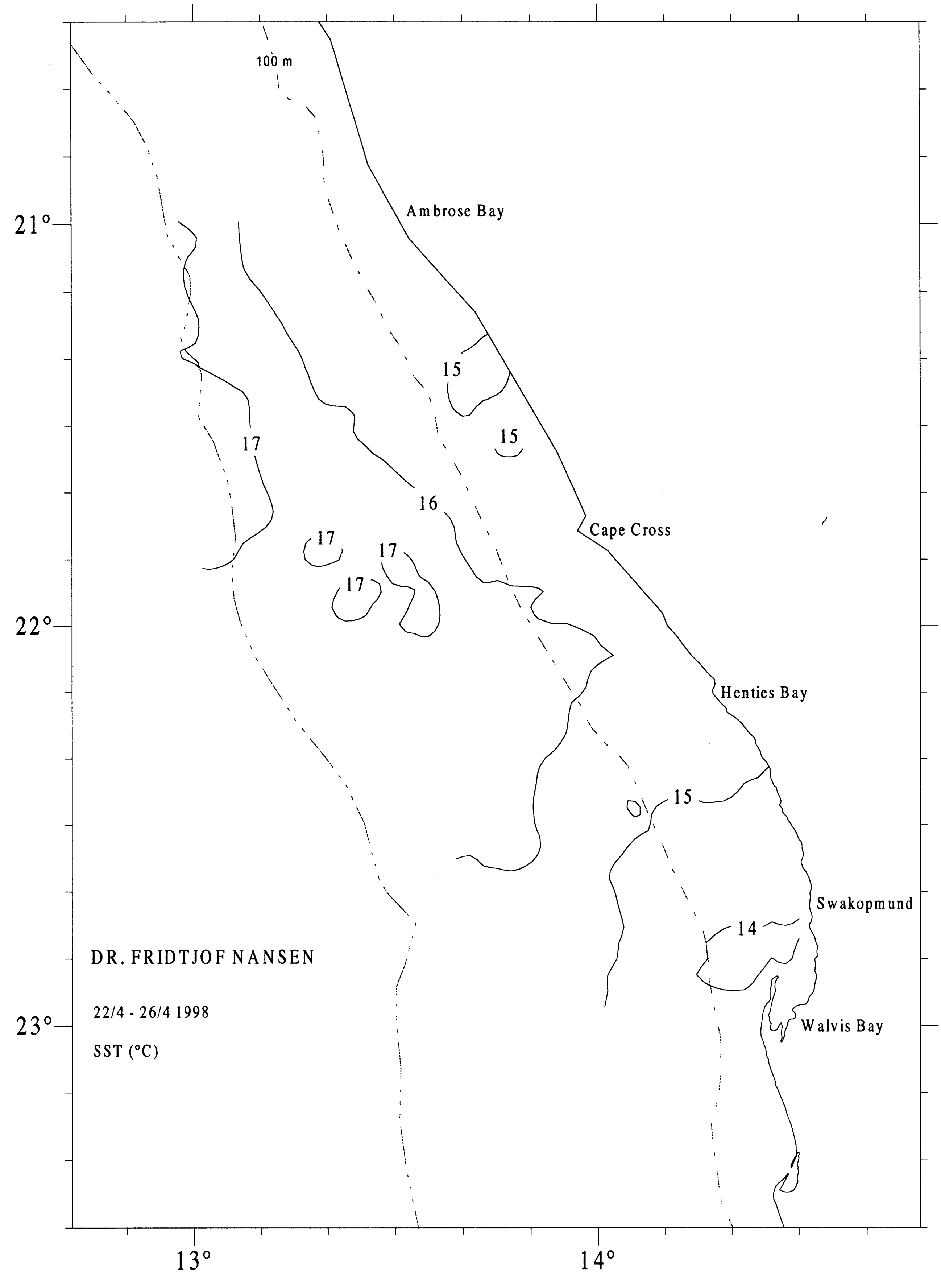


Figure 2b. Sea surface temperature distribution during the 2 nd survey.

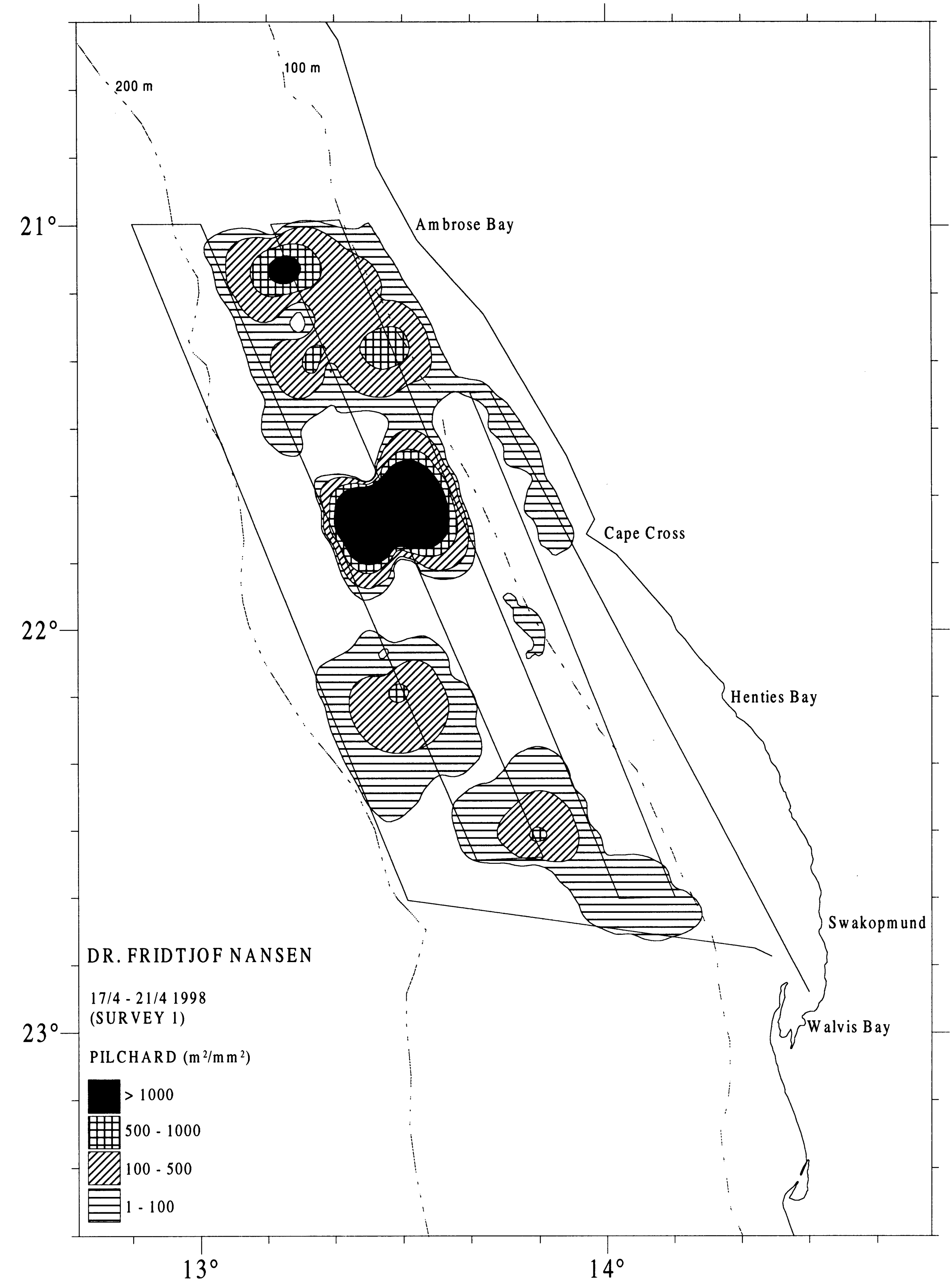


Figure 3a. Distribution and relative abundance of pilchard between Walvis Bay and Ambrose Bay as measured during the 1st coverage of the area.

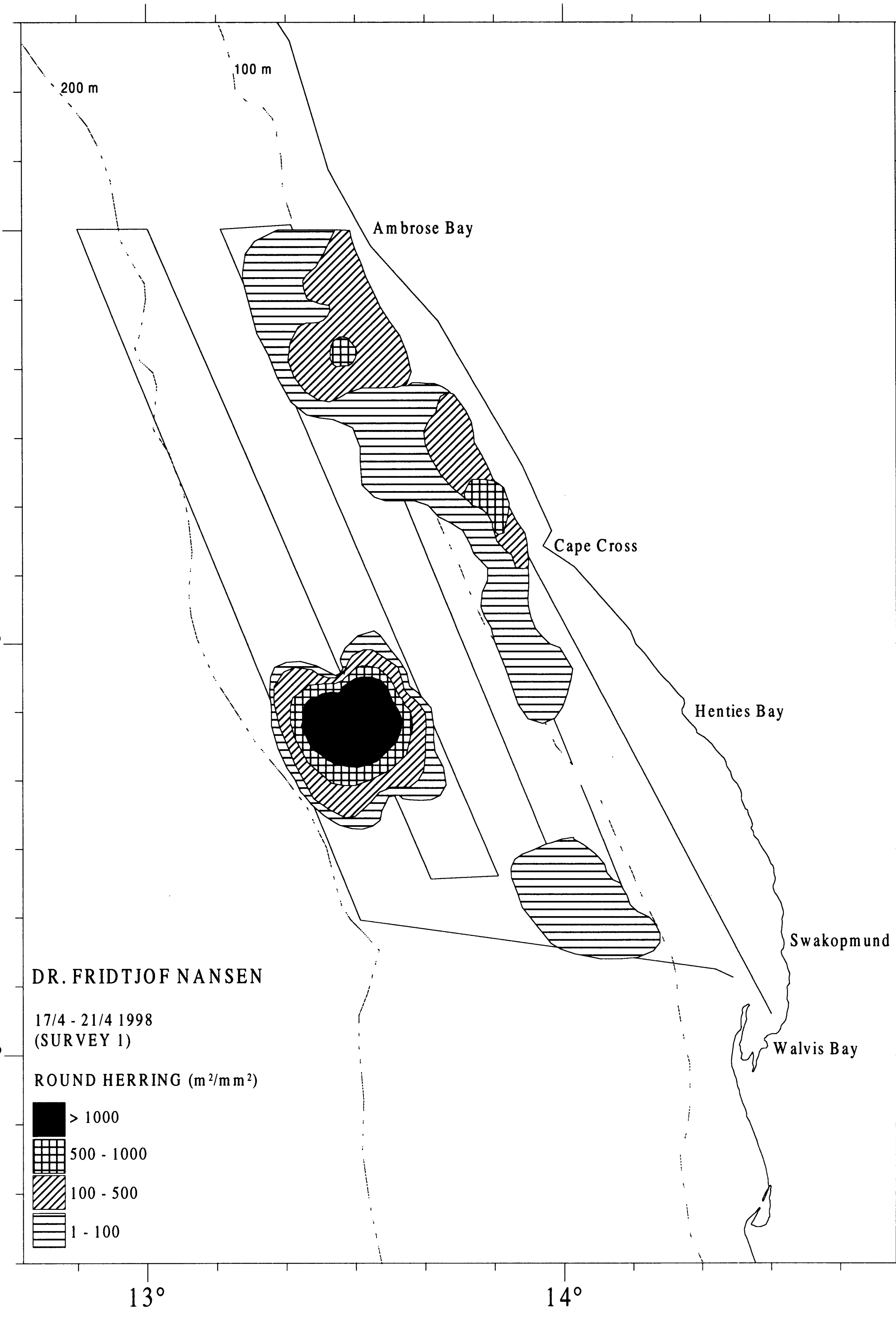


Figure 3b. Distribution and relative abundance of round herring between Walvis Bay and ambrose Bay as measured during the first coverage of the area.

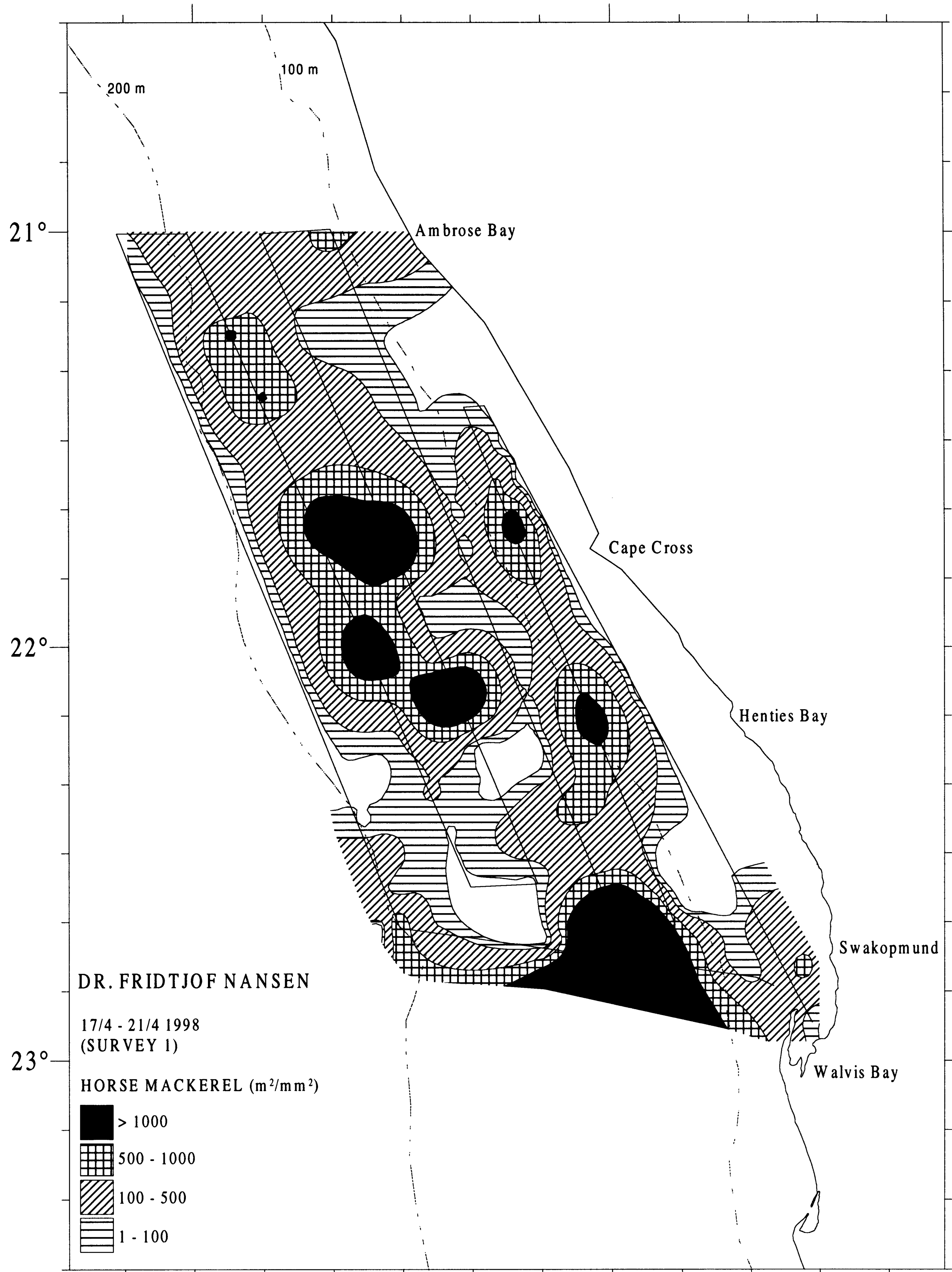


Figure 3c. Distribution and relative abundance of horse mackerel between Walvis Bay and Ambrose Bay as meaured during the 1st coverage of the area.

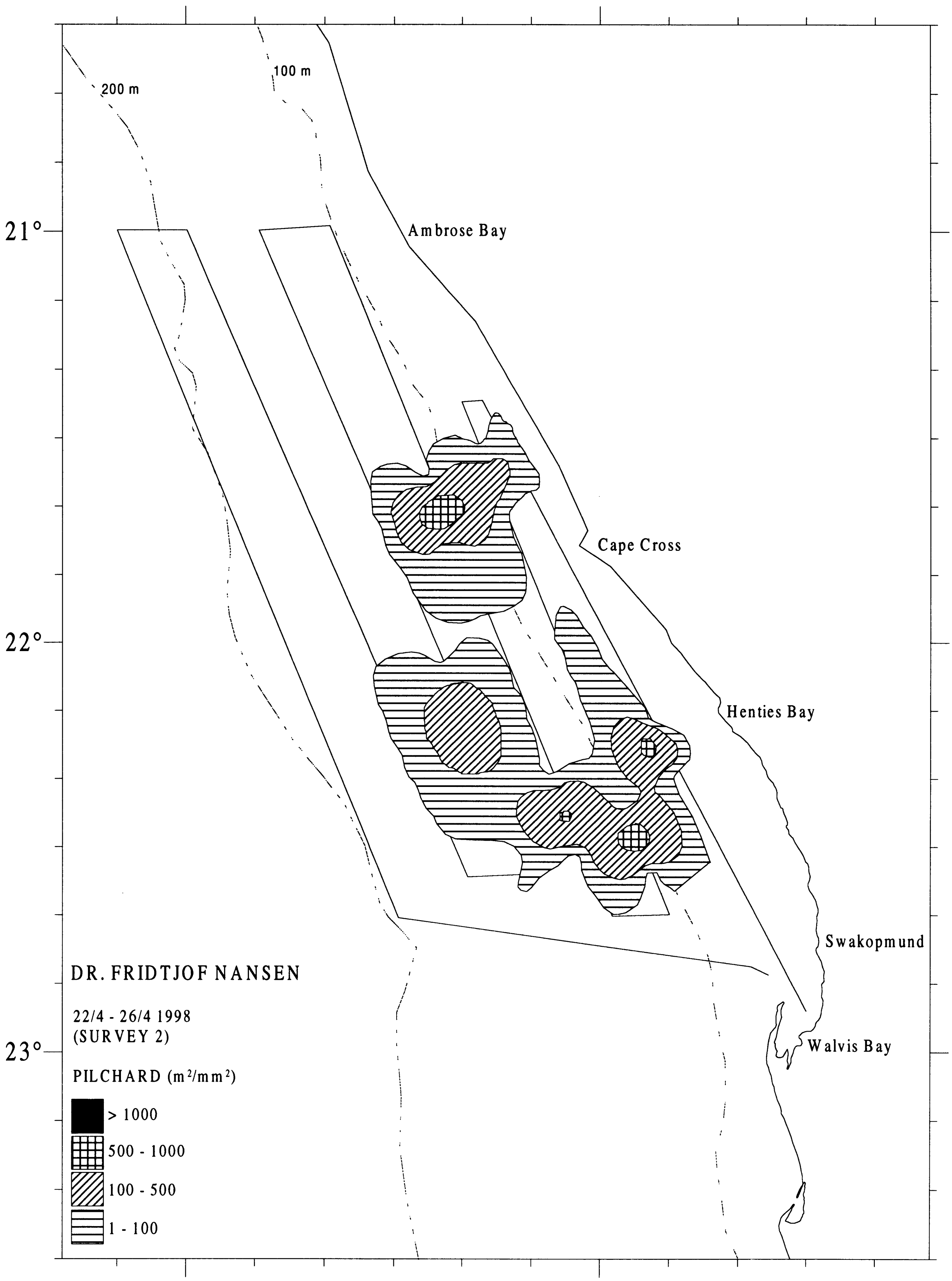


Figure 3d. Distribution and relative abundance of pilchard between Walvis Bay and Ambrose Bay as measured during the 2nd coverage of the area.

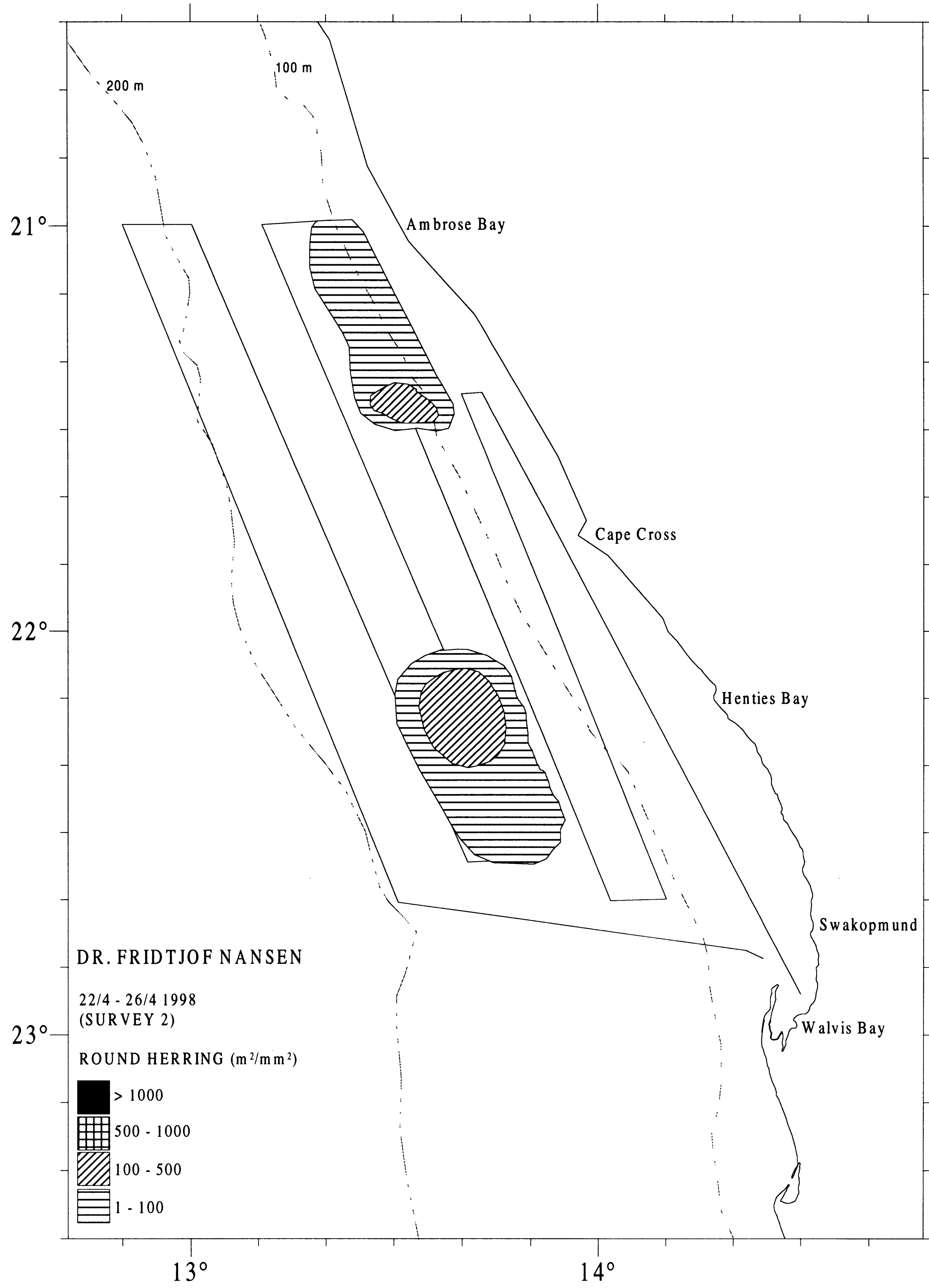


Figure 3e. Distribution and relative abundance of round herring between Walvis Bay and Ambrose Bay as measured during the 2nd coverage of the area.

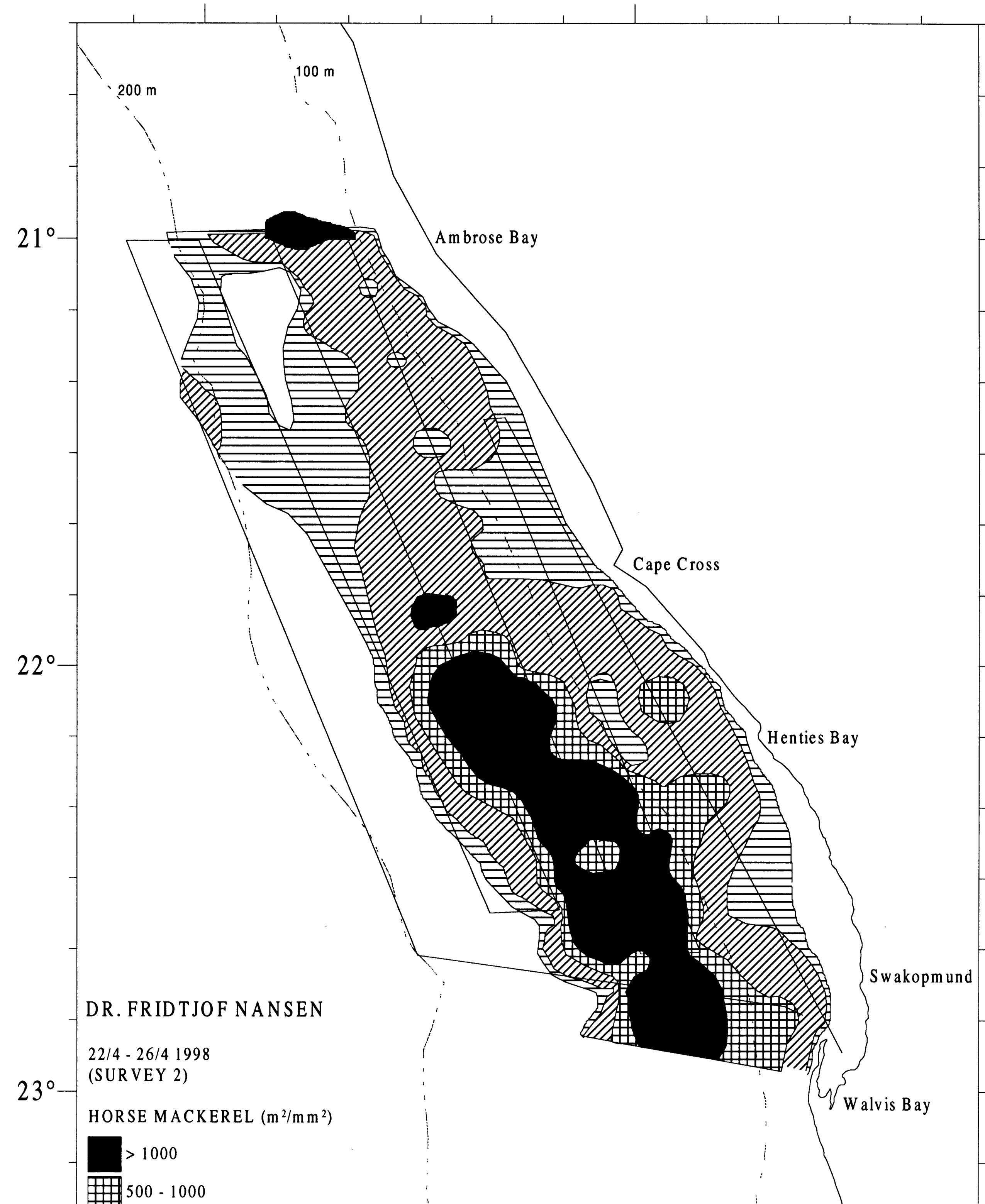


Figure 3f. Distribution and relative abundance of horse mackerel between Walvis Bay and Ambrose Bay as measured during the 2nd coverage of the area.

ANNEXES

Annex I Instruments and fishing gear

The Simrad scientific echo sounder EK 500/38 kHz was used to observe fish distributions and densities during the survey. The details of the settings of the 38 kHz echo sounder were as follows:

Transceiver-1 menu

Transducer depth	5 m
Absorption coeff.	10 dB/km
Pulse length	medium
Bandwidth	wide
Max. power	2 000 W
Angle sensitivity	21.9
2-way beam angle	-21.0 dB
SV transducer gain	27.7 dB
TS transducer gain	27.8 dB
3 dB Beamwidth	6.8 deg
Alongship offset	0.00 deg
Athwartship offset	0.04 deg

Display menu

Echogram	1
Bottom range	13 m
Bottom start	10 m
TVG	20 log R
SV Colour minimum	-67 dB
TS Colour minimum	-60 dB

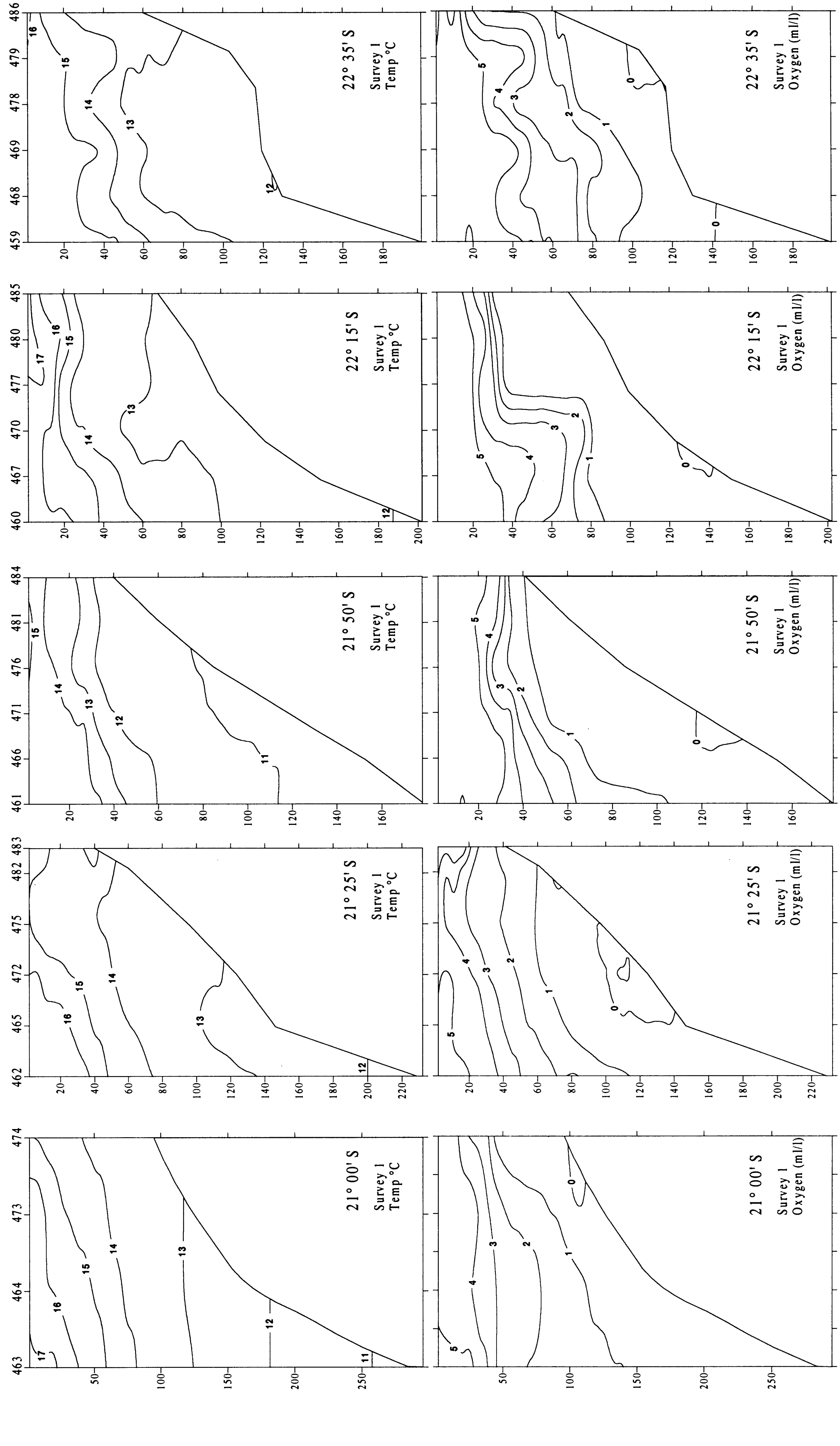
Printer settings

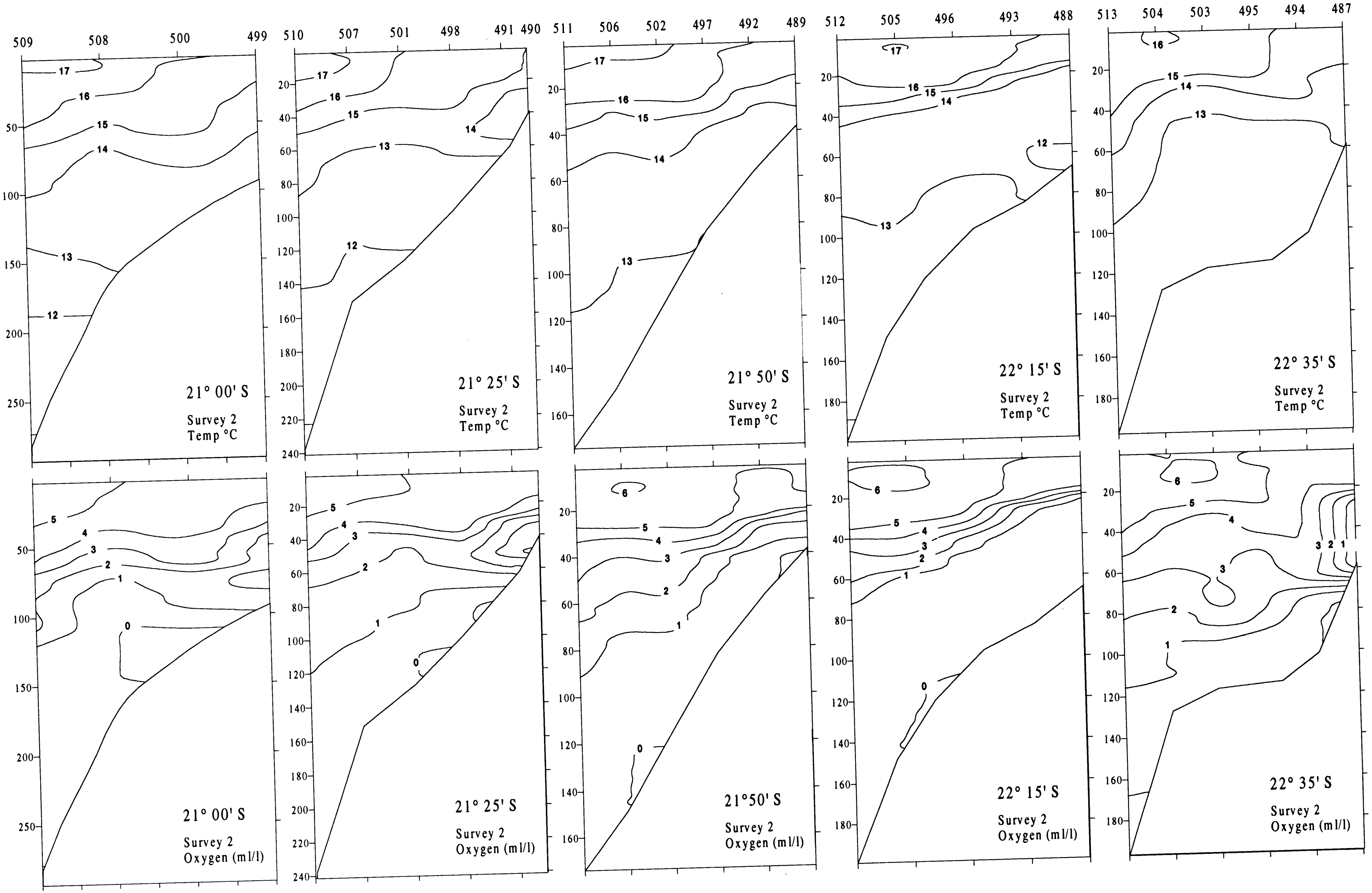
Range	0-100 m
TVG	20 log R
SV Colour minimum	-67 dB

Bottom detection menu

Minimum level	-45 dB

Annex II Hydrographic profiles




21° 00' S
Survey 2
Temp °C
21° 25' S
Survey 2
Temp °C
21° 50' S
Survey 2
Temp °C
22° 15' S
Survey 2
Temp °C
22° 35' S
Survey 2
Temp °C
21° 00' S
Survey 2
Oxygen (ml/l)
21° 25' S
Survey 2
Oxygen (ml/l)
21°50' S
Survey 2
Oxygen (ml/l)
22° 15' S
Survey 2
Oxygen (ml/l)
22° 35' S
Survey 2
Oxygen (ml/l)

ANNEX III BIOMASS AND NUMBER OF FISH IN AREA

PILCHARD BIOMASS		
	SURVEY 1	SURVEY 2
Mean S_A	151.2	32.3
Area (nm^2)	6052	6052
Biomass (tonnes)	184 348	39 375

Length class (cm)	Number (10^6)	Biomass (Tonnes)	Length class (cm)	Number (10^6)	Biomass (Tonnes)
10	5	40	10	1	9
11	221	2268	11	47	484
12	154	1927	12	33	412
13	13	204	13	3	44
14	8	157	14	2	34
15	8	189	15	2	40
16	15	487	16	3	104
17	13	486	17	3	104
18	0	1	18	0	0
19	39	2227	19	8	476
20	706	45195	20	151	9654
21	1136	82969	21	243	17722
22	429	35725	22	92	7631
23	62	5890	23	13	1258
24	39	4305	24	8	920
25	18	2275	25	4	486

ROUND HERRING BIOMASS		
	SURVEY 1	SURVEY 2
Mean S_A	90.34	7.3
Area (nm^2)	6052	6052
Biomass (tonnes)	85 716	6 926.3

Length class (cm)	Number (10^6)	Biomass (Tonnes)	Length class (cm)	Number (10^6)	Biomass (Tonnes)
10	3	17	10	0	1
11	4	33	11	0	3
12	47	542	12	4	44
13	77	1060	13	6	86
14	18	297	14	1	24
15	0	0	15	0	0
16	2	59	16	0	5
17	40	1291	17	3	104
18	78	2887	18	6	233
19	318	13867	19	26	1121
20	505	25468	20	41	2058
21	426	24799	21	34	2004
22	201	13398	22	16	1083
23	25	1859	23	2	150
24	2	139	24	0	11

HORSE MACKEREL BIOMASS		
	SURVEY 1	SURVEY 2
Mean S_A	425	442.6
Area (nm^2)	6052	6052
Biomass (tonnes)	310 017	322 855

Length class (cm)	Number (10^6)	Biomass (Tonnes)	Length class (cm)	Number (10^6)	Biomass (Tonnes)
4	16	13	4	16	13
5	52	76	5	54	79
6	81	174	6	84	181
7	148	484	7	154	503
8	481	2367	8	501	2464
9	5403	36271	9	5627	37772
10	7563	65254	10	3217	36083
11	3089	34648	11	3705	54352
12	3558	52191	12	3336	59956
13	3203	57573	13	990	22125
14	951	21246	14	456	12356
15	439	11865	15	98	3190
16	94	3064	16	8	318
17	8	306	17	0	8
18	0	8	18	0	0
19	0	0	19	0	34
20	1	33	20	4	304
21	4	292	21	17	1421
22	68	6297	22	71	6558
23	99	10036	23	102	10451
24	45	5078	24	47	5288
25	11	1377	25	11	1434
26	2	279	26	2	291

ANNEX IV SUMMARY OF TRAWL STATIONS

TRAWL NO.	LATITUDE ° S	LONGITUDE ° E	DEPTH (m)	TRAWL DEPTH (m)	TOTAL CATCH (kg)	SPECIES COMPOSITION (%) and MEAN LENGTH							
						PILCHARD	L_t (cm)	ROUND HERRING	L_t (cm)	ANCHOVY	L_t (cm)	HORSE MACKEREL	L_t (cm)
2458	21° 14'	13° 05'	143	100	1	-	-	39	-	-	-	61	-
2459	21° 16'	13° 06'	147	147	64	-	-	-	-	-	-	100	24
2460	21° 43'	13° 19'	150	150	551	-	-	-	-	-	-	100	11
2461	22° 08'	13° 29'	153	25	222	13	22	77	20	-	-	10	16
2462	22° 31'	13° 49'	128	10	10	19	22	34	21	-	-	47	15
2463	22° 10'	13° 39'	128	10	772	-	-	-	-	-	-	100	11
2464	21° 58'	13° 34'	129	20	69	-	-	-	-	-	-	100	11
2465	21° 35'	13° 24'	130	10	14	-	-	12	22	-	-	88	12
2466	21° 19'	13° 18'	127	20	5000	100	21	0	-	-	-	-	-
2467	21° 04'	13° 22'	91	10	925	77	14	19	22	-	13	3	8
2468	21° 48'	13° 42'	102	10	418	26	21	0,1	18	-	-	74	11
2469	22° 21'	13° 53'	115	10	148	-	-	0	-	-	-	100	13
2470	22° 37'	14° 00'	121	10	224	0.5	18	5,7	19	-	-	94	11
2471	22° 19'	14° 00'	100	10	20	-	-	0	-	-	-	100	11
2472	21° 54'	13° 52'	77	20	62	-	-	2,1	18	2,6	12	95	9
2473	21° 41'	13° 47'	70	30	51	-	-	3,3	17	-	-	97	9
2474	21° 43'	13° 49'	57	10	29	0,8	-	76	13	18	12	5	9
2475	22° 25'	14° 12'	69	50	21	-	-	0	-	-	-	100	10
2476	22° 14'	14° 07'	65	15	12	-	-	0	-	-	-	100	10
2477	21° 55'	13° 51'	82	5	167	-	-	12	18	-	-	88	10
2478	22° 22'	14° 03'	97	5	181	-	-	1,5	17	-	-	98	12
2479	22° 40'	14° 04'	117	10	-	-	-	-	-	-	-	-	-
2480	22° 30'	13° 57'	120	20	5	-	-	-	-	-	-	100	12
2481	22° 02'	13° 46'	108	10	36	-	-	-	-	-	-	100	10
2482	21° 49'	13° 41'	104	10	-	-	-	-	-	-	-	-	-
2483	21° 49'	13° 40'	106	10	10	-	-	-	-	-	-	100	11
2484	21° 45'	13° 38'	107	10	6	-	-	-	-	-	-	100	10
2485	21° 41'	13° 37'	107	10	20	-	-	-	-	-	-	100	10
2486	21° 27'	13° 31'	106	10	172	-	-	2	17	0,2	-	98	10
2487	21° 55'	13° 34'	126	20	382	-	-	-	-	-	-	100	12
2488	22° 27'	13° 46'	128	5	64	9,8	22	12	20	-	-	79	15
2489	22° 30'	13° 48'	128	10	107	5,5	20	0,3	-	-	-	94	15
2490	21° 06'	12° 52'	298	240	10	-	-	-	-	-	-	100	25
2491	22° 46'	13° 57'	600	129	351	27	-	-	-	-	-	73	14

ANNEX V RECORDS OF FISHING STATIONS

```
                                                   PROJECT STATION:2458
  DATE:18/ 4/98           GEAR TYPE: PT No: 1    POSITION:Lat   S  2114
           start    stop  duration                         Long  E  1305
    TIME  :06:36:30 06:44:05   8  (min)  Purpose code:  1
    LOG   : 820.02   820.42  0.39         Area code     : 2
    FDEPTH:    100      100               GearCond.code: 9
    BDEPTH:    143      142               Validity code: 1
          Towing dir: 330ø  Wire out: 270 m  Speed:   3 kn*10

      Sorted:      Kg       Total catch:       0.55    CATCH/HOUR:       4.13

 SPECIES                                  CATCH/HOUR    % OF TOT. C    SAMP
                                        weight   numbers
Merluccius capensis          MERME04     2.78        8       67.31
Trachurus capensis           CARTR04     0.83       23       20.10
Etrumeus whiteheadi          CLUET02     0.53        8       12.83
                                       ________            ________
 Total                                   4.14                100.24
```

```
                                                   PROJECT STATION:2459
  DATE:18/ 4/98           GEAR TYPE: BT No:      POSITION:Lat   S  2116
           start    stop  duration                         Long  E  1306
    TIME  :07:53:28 08:13:17  20  (min)  Purpose code:  1
    LOG   : 824.83   825.93  1.10         Area code     : 2
    FDEPTH:    147      150               GearCond.code: 9
    BDEPTH:    147      150               Validity code:
          Towing dir: 150ø  Wire out: 500 m  Speed:   3 kn*10

      Sorted:  47 Kg       Total catch:     117.00    CATCH/HOUR:     351.00

 SPECIES                                  CATCH/HOUR    % OF TOT. C    SAMP
                                        weight   numbers
Trachurus capensis           CARTR04   192.30     3780       54.79     3786
Merluccius capensis          MERME04   158.70     6201       45.21     3787
                                       ________            ________
 Total                                 351.00                100.00
```

```
                                                   PROJECT STATION:2460
  DATE: 5/ 4/97           GEAR TYPE: PT No: 1    POSITION:Lat   S  2143
           start    stop  duration                         Long  E  1319
    TIME  :12:12:26 12:18:41   6  (min)  Purpose code:  1
    LOG   : 857.28   857.68  0.38         Area code     : 2
    FDEPTH:     58      100               GearCond.code: 1
    BDEPTH:    150      149               Validity code: 1
          Towing dir: 340ø  Wire out: 200 m  Speed:   3 kn*10

      Sorted:  15 Kg       Total catch:     551.00    CATCH/HOUR:    5510.00

 SPECIES                                  CATCH/HOUR    % OF TOT. C    SAMP
                                        weight   numbers
Trachurus capensis           CARTR04  5510.00   430680      100.00     3788
                                       ________            ________
 Total                                5510.00                100.00
```

```
                                                   PROJECT STATION:2461
  DATE:18/ 4/98           GEAR TYPE: PT No: 4    POSITION:Lat   S  2208
           start    stop  duration                         Long  E  1329
    TIME  :16:20:51 16:35:05  14  (min)  Purpose code:  1
    LOG   : 888.83   889.71  0.81         Area code     : 2
    FDEPTH:    153        0               GearCond.code: 1
    BDEPTH:    153      153               Validity code: 1
          Towing dir: 340ø  Wire out: 170 m  Speed:   3 kn*10

      Sorted:  28 Kg       Total catch:     268.20    CATCH/HOUR:    1149.43

 SPECIES                                  CATCH/HOUR    % OF TOT. C    SAMP
                                        weight   numbers
Etrumeus whiteheadi          CLUET02   732.86    13714       63.76     3791
Thyrsites atun               GEMTR01   192.86      643       16.78
Sardinops ocellatus          CLUSS01   120.00     1329       10.44     3790
Trachurus capensis           CARTR04    98.57     7243        8.58     3789
Prionace glauca              SHACA31     5.14        4        0.45
                                       ________            ________
 Total                                1149.43                100.01
```

```
                                                   PROJECT STATION:2462
  DATE:18/ 4/98           GEAR TYPE: PT No: 1    POSITION:Lat   S  2231
           start    stop  duration                         Long  E  1349
    TIME  :22:35:21 22:40:35   5  (min)  Purpose code:  1
    LOG   : 939.03   939.29  0.24         Area code     : 2
    FDEPTH:     10       10               GearCond.code: 1
    BDEPTH:    128      128               Validity code: 1
          Towing dir: 160ø  Wire out: 150 m  Speed:   3 kn*10

      Sorted:  19 Kg       Total catch:      38.00    CATCH/HOUR:     456.00

 SPECIES                                  CATCH/HOUR    % OF TOT. C    SAMP
                                        weight   numbers
Sufflogobius bibarbatus      GOBSU01   327.60                71.84
Trachurus capensis           CARTR04    58.80     1944       12.89     3792
Etrumeus whiteheadi          CLUET02    42.48      864        9.32     3793
Sardinops ocellatus          CLUSS01    23.52      264        5.16     3794
Merluccius capensis, juveniles MERME90   0.24       24        0.05
                                       ________            ________
 Total                                 452.64                 99.26
```

```
                                                   PROJECT STATION:2463
  DATE:19/ 4/98           GEAR TYPE: PT No: 4    POSITION:Lat   S  2210
           start    stop  duration                         Long  E  1329
    TIME  :01:45:55 01:51:47   6  (min)  Purpose code:  1
    LOG   : 964.86   965.23  1.43         Area code     : 2
    FDEPTH:      0        0               GearCond.code: 1
    BDEPTH:    128      129               Validity code: 1
          Towing dir: 160ø  Wire out: 160 m  Speed:   3 kn*10

      Sorted:  30 Kg       Total catch:     772.50    CATCH/HOUR:    7725.00

 SPECIES                                  CATCH/HOUR    % OF TOT. C    SAMP
                                        weight   numbers
Trachurus capensis           CARTR04  7725.00   610070      100.00     3795
                                       ________            ________
 Total                                7725.00                100.00
```

```
                                                   PROJECT STATION:2464
  DATE:19/ 4/98           GEAR TYPE: PT No: 4    POSITION:Lat   S  2158
           start    stop  duration                         Long  E  1334
    TIME  :04:10:28 04:18:10   8  (min)  Purpose code:  1
    LOG   : 981.72   982.15  0.42         Area code     : 2
    FDEPTH:      0        0               GearCond.code: 1
    BDEPTH:    129      129               Validity code: 1
          Towing dir: 160ø  Wire out: 160 m  Speed:   4 kn*10

      Sorted:   9 Kg       Total catch:      69.00    CATCH/HOUR:     517.50

 SPECIES                                  CATCH/HOUR    % OF TOT. C    SAMP
                                        weight   numbers
Trachurus capensis           CARTR04   517.50    38115      100.00     3796
                                       ________            ________
 Total                                 517.50                100.00
```

```
                                                   PROJECT STATION:2465
  DATE:19/ 4/98           GEAR TYPE: PT No: 1    POSITION:Lat   S  2135
           start    stop  duration                         Long  E  1324
    TIME  :07:51:28 08:02:27  11  (min)  Purpose code:  1
    LOG   :1008.22  1008.77  0.54         Area code     : 2
    FDEPTH:     10       10               GearCond.code: 1
    BDEPTH:    130      130               Validity code: 1
          Towing dir: 340ø  Wire out: 160 m  Speed:   3 kn*10

      Sorted:   5 Kg       Total catch:      13.50    CATCH/HOUR:      73.64

 SPECIES                                  CATCH/HOUR    % OF TOT. C    SAMP
                                        weight   numbers
Trachurus capensis           CARTR04    64.91     3682       88.15     3797
Etrumeus whiteheadi          CLUET02     8.73       98       11.85     3798
                                       ________            ________
 Total                                  73.64                100.00
```

```
                                                   PROJECT STATION:2466
  DATE:19/ 4/98           GEAR TYPE: PT No: 1    POSITION:Lat   S  2119
           start    stop  duration                         Long  E  1318
    TIME  :10:51:59 11:03:26  11  (min)  Purpose code:  1
    LOG   :1029.26  1029.80  0.50         Area code     : 2
    FDEPTH:     20       20               GearCond.code: 1
    BDEPTH:    127      127               Validity code: 1
          Towing dir: 155ø  Wire out:  70 m  Speed:  40 kn*10

      Sorted:  70 Kg       Total catch:   14700.00    CATCH/HOUR:   80181.81

 SPECIES                                  CATCH/HOUR    % OF TOT. C    SAMP
                                        weight   numbers
Sardinops ocellatus          CLUSS01 80181.81   933545      100.00     3799
                                       ________            ________
 Total                               80181.81                100.00
```

```
                                                   PROJECT STATION:2467
  DATE:19/ 4/98           GEAR TYPE: PT No: 4    POSITION:Lat   S  2104
           start    stop  duration                         Long  E  1322
    TIME  :16:00:27 16:13:30  13  (min)  Purpose code:  1
    LOG   :1067.21  1068.04  0.81         Area code     : 2
    FDEPTH:     10       10               GearCond.code: 1
    BDEPTH:     91       91               Validity code: 1
          Towing dir: 340ø  Wire out: 190 m  Speed:   4 kn*10

      Sorted:  64 Kg       Total catch:     922.90    CATCH/HOUR:    4259.54

 SPECIES                                  CATCH/HOUR    % OF TOT. C    SAMP
                                        weight   numbers
Sardinops ocellatus          CLUSS01  3269.08   121265       76.75     3800
Etrumeus whiteheadi          CLUET02   843.23    73749       19.80     3801
Trachurus capensis           CARTR04   132.00    27572        3.10     3802
Engraulis capensis           ENGEN04    15.23      937        0.36     3803
                                       ________            ________
 Total                                4259.54                100.01
```

```
                                                   PROJECT STATION:2468
  DATE:19/ 4/98           GEAR TYPE: PT No: 4    POSITION:Lat   S  2148
           start    stop  duration                         Long  E  1342
    TIME  :21:50:41 22:05:29  15  (min)  Purpose code:  1
    LOG   :1118.31  1119.08  0.75         Area code     : 2
    FDEPTH:     10       10               GearCond.code: 1
    BDEPTH:    102      102               Validity code: 1
          Towing dir: 160ø  Wire out: 150 m  Speed:   3 kn*10

      Sorted:  56 Kg       Total catch:     417.53    CATCH/HOUR:    1670.12

 SPECIES                                  CATCH/HOUR    % OF TOT. C    SAMP
                                        weight   numbers
Trachurus capensis           CARTR04  1240.00   112740       74.25     3803
Sardinops ocellatus          CLUSS01   428.00     5296       25.63     3805
Etrumeus whiteheadi          CLUET02     2.00       48        0.12     3804
                                       ________            ________
 Total                                1670.00                100.00
```

```
                                                   PROJECT STATION:2469
  DATE:20/ 4/98           GEAR TYPE: PT No: 4    POSITION:Lat   S  2221
           start    stop  duration                         Long  E  1353
    TIME  :02:28:16 02:41:42  13  (min)  Purpose code:  1
    LOG   :1154.38  1155.21  0.83         Area code     : 2
    FDEPTH:      0        0               GearCond.code: 1
    BDEPTH:    115      115               Validity code: 1
          Towing dir: 340ø  Wire out: 160 m  Speed:  36 kn*10

      Sorted:  21 Kg       Total catch:     148.00    CATCH/HOUR:     683.08

 SPECIES                                  CATCH/HOUR    % OF TOT. C    SAMP
                                        weight   numbers
Trachurus capensis           CARTR04   683.08    38562      100.00     3806
                                       ________            ________
 Total                                 683.08                100.00
```

PROJECT STATION:2470
DATE:20/ 4/98 GEAR TYPE: PT No: 4 POSITION:Lat S 2237
Long E 1400

	start	stop	duration		
TIME	:05:06:04	05:19:50	14 (min)	Purpose code:	1
LOG	:1174.18	1174.97	0.78	Area code	: 2
FDEPTH:	0	0		GearCond.code:	1
BDEPTH:	121	122		Validity code:	1

Towing dir: 160ø Wire out: 160 m Speed: 4 kn*10

Sorted: 32 Kg Total catch: 223.78 CATCH/HOUR: 959.06

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	CARTR04	900.00	74310	93.84	3807
Etrumeus whiteheadi	CLUET02	54.86	1170	5.72	3808
Sardinops ocellatus	CLUSS01	4.20	90	0.44	3809
Total		959.06		100.00	

PROJECT STATION:2471
DATE:20/ 4/98 GEAR TYPE: PT No: 4 POSITION:Lat S 2219
Long E 1400

	start	stop	duration		
TIME	:09:57:12	10:03:59	7 (min)	Purpose code:	1
LOG	:1213.16	1213.53	0.37	Area code	: 2
FDEPTH:	10	10		GearCond.code:	1
BDEPTH:	100	100		Validity code:	1

Towing dir: 160ø Wire out: 160 m Speed: 40 kn*10

Sorted: 4 Kg Total catch: 20.10 CATCH/HOUR: 172.29

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	CARTR04	172.29	11571	100.00	3810
Total		172.29		100.00	

PROJECT STATION:2472
DATE:20/ 4/98 GEAR TYPE: PT No: 1 POSITION:Lat S 2154
Long E 1352

	start	stop	duration		
TIME	:13:48:28	14:01:04	13 (min)	Purpose code:	1
LOG	:1243.88	1244.70	0.82	Area code	: 2
FDEPTH:	20	20		GearCond.code:	1
BDEPTH:	77	77		Validity code:	1

Towing dir: 160ø Wire out: 120 m Speed: 4 kn*10

Sorted: 6 Kg Total catch: 61.90 CATCH/HOUR: 285.69

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	CARTR04	272.31	35368	95.32	3811
Engraulis capensis	ENGEN04	7.38	462	2.58	3812
Etrumeus whiteheadi	CLUET02	6.00	138	2.10	3813
Total		285.69		100.00	

PROJECT STATION:2473
DATE:20/ 4/98 GEAR TYPE: PT No: 1 POSITION:Lat S 2141
Long E 1347

	start	stop	duration		
TIME	:16:10:13	16:17:24	7 (min)	Purpose code:	1
LOG	:1261.86	1262.28	0.42	Area code	: 2
FDEPTH:	30	30		GearCond.code:	1
BDEPTH:	70	70		Validity code:	1

Towing dir: 160ø Wire out: 120 m Speed: 35 kn*10

Sorted: 7 Kg Total catch: 51.30 CATCH/HOUR: 439.71

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	CARTR04	421.71	56229	95.91	3814
Etrumeus whiteheadi	CLUET02	14.40	480	3.27	3815
Callorhinchus capensis	SHACI11	3.86	9	0.88	
Total		439.97		100.06	

PROJECT STATION:2474
DATE:20/ 4/98 GEAR TYPE: PT No: 4 POSITION:Lat S 2143
Long E 1349

	start	stop	duration		
TIME	:21:16:28	21:41:56	25 (min)	Purpose code:	1
LOG	:1304.23	1305.55	1.30	Area code	: 2
FDEPTH:	10	10		GearCond.code:	1
BDEPTH:	57	56		Validity code:	1

Towing dir: 340ø Wire out: 160 m Speed: 3 kn*10

Sorted: 10 Kg Total catch: 29.50 CATCH/HOUR: 70.80

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Etrumeus whiteheadi	CLUET02	52.56	3341	74.24	3816
Engraulis capensis	ENGEN04	12.48	922	17.63	3817
Trachurus capensis	CARTR04	3.31	346	4.68	3818
Galeichthys feliceps	ARDGA01	1.90	7	2.68	
Sardinops ocellatus	CLUSS01	0.58	22	0.82	
Total		70.83		100.05	

PROJECT STATION:2475
DATE:22/ 4/98 GEAR TYPE: PT No: 1 POSITION:Lat S 2225
Long E 1412

	start	stop	duration		
TIME	:12:30:21	12:38:48	8 (min)	Purpose code:	1
LOG	:1447.04	1447.62	0.55	Area code	: 2
FDEPTH:	15	15		GearCond.code:	1
BDEPTH:	69	69		Validity code:	1

Towing dir: 155ø Wire out: 100 m Speed: 40 kn*10

Sorted: 2 Kg Total catch: 20.50 CATCH/HOUR: 153.75

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	CARTR04	153.75	16800	100.00	3819
Total		153.75		100.00	

PROJECT STATION:2476
DATE:22/ 4/98 GEAR TYPE: PT No: 1 POSITION:Lat S 2214
Long E 1407

	start	stop	duration		
TIME	:14:42:22	14:48:41	6 (min)	Purpose code:	1
LOG	:1463.47	1463.89	0.41	Area code	: 2
FDEPTH:	15	15		GearCond.code:	1
BDEPTH:	65	65		Validity code:	1

Towing dir: 155ø Wire out: 100 m Speed: 42 kn*10

Sorted: 2 Kg Total catch: 11.60 CATCH/HOUR: 116.00

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	CARTR04	116.00	11450	100.00	3820
Total		116.00		100.00	

PROJECT STATION:2477
DATE:23/ 4/98 GEAR TYPE: PT No: 4 POSITION:Lat S 2155
Long E 1351

	start	stop	duration		
TIME	:01:13:04	01:25:11	12 (min)	Purpose code:	1
LOG	:1555.19	1555.86	0.65	Area code	: 2
FDEPTH:	5	5		GearCond.code:	1
BDEPTH:	82	83		Validity code:	1

Towing dir: 160ø Wire out: 160 m Speed: 40 kn*10

Sorted: 11 Kg Total catch: 166.90 CATCH/HOUR: 834.50

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	CARTR04	735.00	85640	88.08	3821
Etrumeus whiteheadi	CLUET02	99.50	2925	11.92	3822
Total		834.50		100.00	

PROJECT STATION:2478
DATE:23/ 4/98 GEAR TYPE: PT No: 4 POSITION:Lat S 2222
Long E 1403

	start	stop	duration		
TIME	:05:18:18	05:26:53	9 (min)	Purpose code:	1
LOG	:1585.33	1585.79	0.45	Area code	: 2
FDEPTH:	5	5		GearCond.code:	1
BDEPTH:	97	97		Validity code:	1

Towing dir: 340ø Wire out: 160 m Speed: 3 kn*10

Sorted: 20 Kg Total catch: 180.60 CATCH/HOUR: 1204.00

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	CARTR04	1185.33	81120	98.45	3823
Etrumeus whiteheadi	CLUET02	18.00	660	1.50	3824
Chelidonichthys capensis	TRGCH06	0.67	7	0.06	
Total		1204.00		100.01	

PROJECT STATION:2480
DATE:23/ 4/98 GEAR TYPE: PT No: 1 POSITION:Lat S 2230
Long E 1357

	start	stop	duration		
TIME	:12:02:55	12:12:40	10 (min)	Purpose code:	1
LOG	:1632.92	1633.55	0.64	Area code	: 2
FDEPTH:	20	20		GearCond.code:	1
BDEPTH:	120	120		Validity code:	1

Towing dir: 160ø Wire out: 100 m Speed: 4 kn*10

Sorted: 1 Kg Total catch: 5.25 CATCH/HOUR: 31.50

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	CARTR04	31.50	1980	100.00	3825
Total		31.50		100.00	

PROJECT STATION:2481
DATE:23/ 4/98 GEAR TYPE: PT No: 4 POSITION:Lat S 2202
Long E 1346

	start	stop	duration		
TIME	:16:14:32	16:25:18	11 (min)	Purpose code:	1
LOG	:1665.96	1666.61	0.63	Area code	: 2
FDEPTH:	10	10		GearCond.code:	1
BDEPTH:	108	107		Validity code:	1

Towing dir: 160ø Wire out: 180 m Speed: 4 kn*10

Sorted: 5 Kg Total catch: 36.40 CATCH/HOUR: 198.55

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	CARTR04	198.55	24169	100.00	3826
Total		198.55		100.00	

PROJECT STATION:2483
DATE:23/ 4/98 GEAR TYPE: PT No: 4 POSITION:Lat S 2149
Long E 1340

	start	stop	duration		
TIME	:20:12:24	20:13:20	1 (min)	Purpose code:	1
LOG	:1688.99	1689.05	0.09	Area code	: 2
FDEPTH:	10	10		GearCond.code:	1
BDEPTH:	106	105		Validity code:	1

Towing dir: 100ø Wire out: 140 m Speed: 4 kn*10

Sorted: 2 Kg Total catch: 9.90 CATCH/HOUR: 594.00

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	CARTR04	594.00	43800	100.00	3827
Total		594.00		100.00	

PROJECT STATION:2484

DATE:23/ 4/98 GEAR TYPE: PT No: 4 POSITION:Lat S 2145
start stop duration Long E 1338
TIME :22:11:26 22:26:01 15 (min) Purpose code: 1
LOG :1701.51 1702.16 0.63 Area code : 2
FDEPTH: 10 10 GearCond.code: 1
BDEPTH: 107 107 Validity code: 1
Towing dir: 150ø Wire out: 160 m Speed: 3 kn*10

Sorted: 1 Kg Total catch: 6.10 CATCH/HOUR: 24.40

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	CARTR04	24.40	2340	100.00	3829
Total		24.40		100.00	

PROJECT STATION:2485

DATE:23/ 4/98 GEAR TYPE: PT No: 4 POSITION:Lat S 2141
start stop duration Long E 1337
TIME :23:41:56 23:51:46 10 (min) Purpose code: 1
LOG :1708.94 1709.44 0.49 Area code : 2
FDEPTH: 10 10 GearCond.code: 1
BDEPTH: 107 107 Validity code: 1
Towing dir: 160ø Wire out: 160 m Speed: 4 kn*10

Sorted: 2 Kg Total catch: 19.50 CATCH/HOUR: 117.00

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	CARTR04	117.00	10860	100.00	3830
Total		117.00		100.00	

PROJECT STATION:2486

DATE:24/ 4/98 GEAR TYPE: PT No: 4 POSITION:Lat S 2127
start stop duration Long E 1331
TIME :02:01:59 02:10:50 9 (min) Purpose code: 1
LOG :1726.26 1726.74 0.47 Area code : 2
FDEPTH: 0 0 GearCond.code: 1
BDEPTH: 105 105 Validity code: 1
Towing dir: 160ø Wire out: 160 m Speed: 4 kn*10

Sorted: 12 Kg Total catch: 172.05 CATCH/HOUR: 1147.00

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	CARTR04	1120.00	131833	97.65	3831
Etrumeus whiteheadi	CLUET02	25.00	800	2.18	3832
Engraulis capensis	ENGEN04	2.00	100	0.17	
Total		1147.00		100.00	

PROJECT STATION:2487

DATE:24/ 4/98 GEAR TYPE: PT No: 1 POSITION:Lat S 2155
start stop duration Long E 1334
TIME :13:33:34 13:44:10 11 (min) Purpose code: 1
LOG :1828.40 1829.08 0.68 Area code : 2
FDEPTH: 20 20 GearCond.code: 1
BDEPTH: 126 126 Validity code: 1
Towing dir: 340ø Wire out: 110 m Speed: 4 kn*10

Sorted: 10 Kg Total catch: 382.00 CATCH/HOUR: 2083.64

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	CARTR04	2083.64	121527	100.00	3832
Total		2083.64		100.00	

PROJECT STATION:2488

DATE:24/ 4/98 GEAR TYPE: PT No: 4 POSITION:Lat S 2227
start stop duration Long E 1346
TIME :17:47:43 17:55:35 8 (min) Purpose code: 1
LOG :1865.74 1866.10 0.36 Area code : 2
FDEPTH: 5 5 GearCond.code: 1
BDEPTH: 128 127 Validity code: 1
Towing dir: 340ø Wire out: 160 m Speed: 3 kn*10

Sorted: 10 Kg Total catch: 71.50 CATCH/HOUR: 536.25

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	CARTR04	374.33	11865	69.81	3836
Merluccius capensis	MERME04	59.85	420	11.16	3835
Etrumeus whiteheadi	CLUET02	55.65	1500	10.38	3833
Sardinops ocellatus	CLUSS01	46.73	525	8.71	3834
Total		536.56		100.06	

PROJECT STATION:2489

DATE:24/ 4/98 GEAR TYPE: PT No: 4 POSITION:Lat S 2230
start stop duration Long E 1348
TIME :19:40:00 19:51:00 11 (min) Purpose code: 1
LOG :1874.00 1875.00 1.00 Area code : 2
FDEPTH: 10 10 GearCond.code: 1
BDEPTH: 128 128 Validity code: 1
Towing dir: 20ø Wire out: 160 m Speed: 4 kn*10

Sorted: 15 Kg Total catch: 106.70 CATCH/HOUR: 582.00

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	CARTR04	548.18	19587	94.19	3836
Sardinops ocellatus	CLUSS01	32.18	344	5.53	3837
Etrumeus whiteheadi	CLUET02	1.53	38	0.26	
Total		581.89		99.98	

PROJECT STATION:2490

DATE:25/ 4/98 GEAR TYPE: PT No: 1 POSITION:Lat S 2106
start stop duration Long E 1252
TIME :14:31:20 14:40:50 10 (min) Purpose code: 1
LOG :2028.22 2028.71 0.47 Area code : 2
FDEPTH: 240 240 GearCond.code: 1
BDEPTH: 298 299 Validity code: 1
Towing dir: 340ø Wire out: 720 m Speed: 4 kn*10

Sorted: 18 Kg Total catch: 17.90 CATCH/HOUR: 107.40

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Merluccius capensis, juveniles	MERME90	61.20	522	56.98	3839
Trachurus capensis	CARTR04	46.20	348	43.02	3838
Total		107.40		100.00	

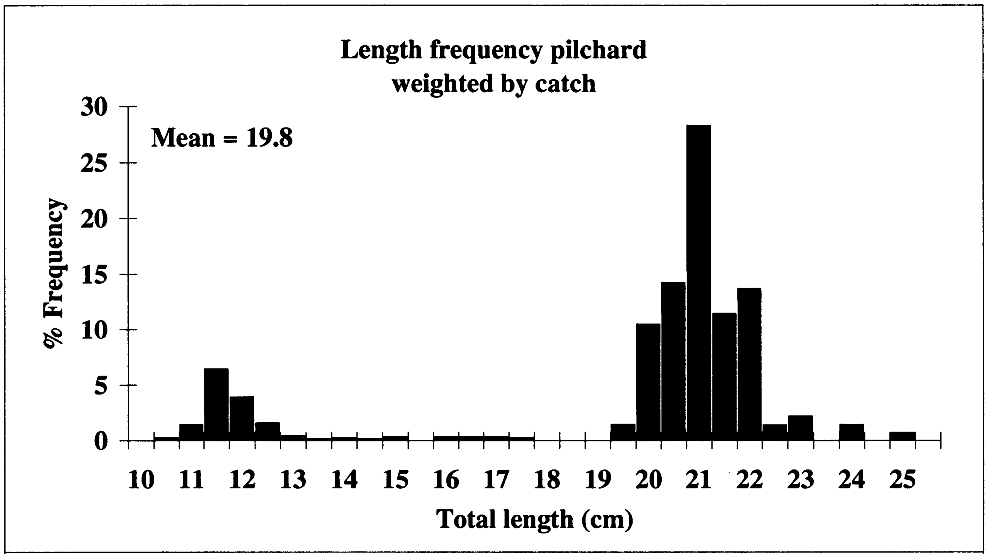
PROJECT STATION:2491

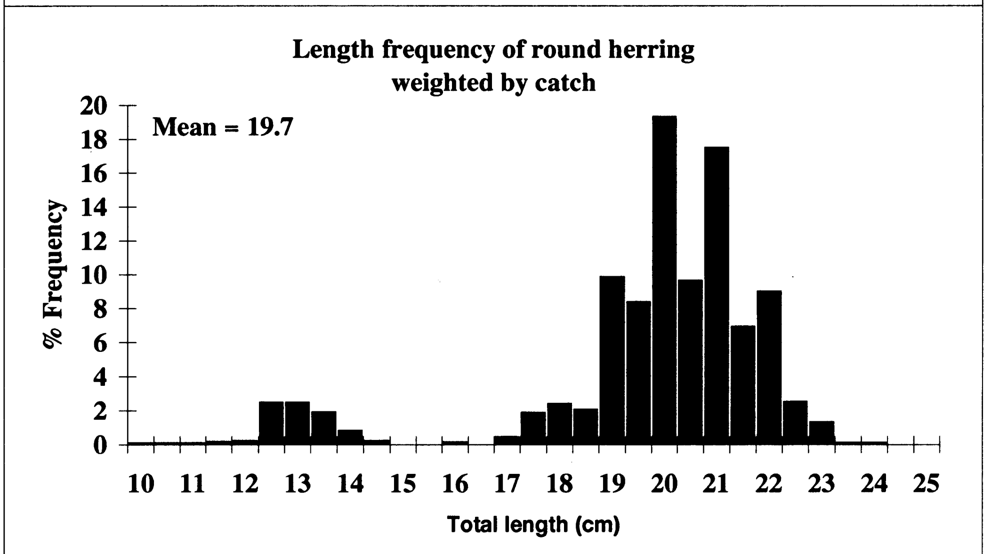
DATE:26/ 4/98 GEAR TYPE: PT No: 1 POSITION:Lat S 2246
start stop duration Long E 1357
TIME :05:29:38 05:41:54 12 (min) Purpose code: 1
LOG :2160.87 2161.56 0.68 Area code : 2
FDEPTH: 600 700 GearCond.code: 1
BDEPTH: 129 129 Validity code: 1
Towing dir: 270ø Wire out: 250 m Speed: 3 kn*10

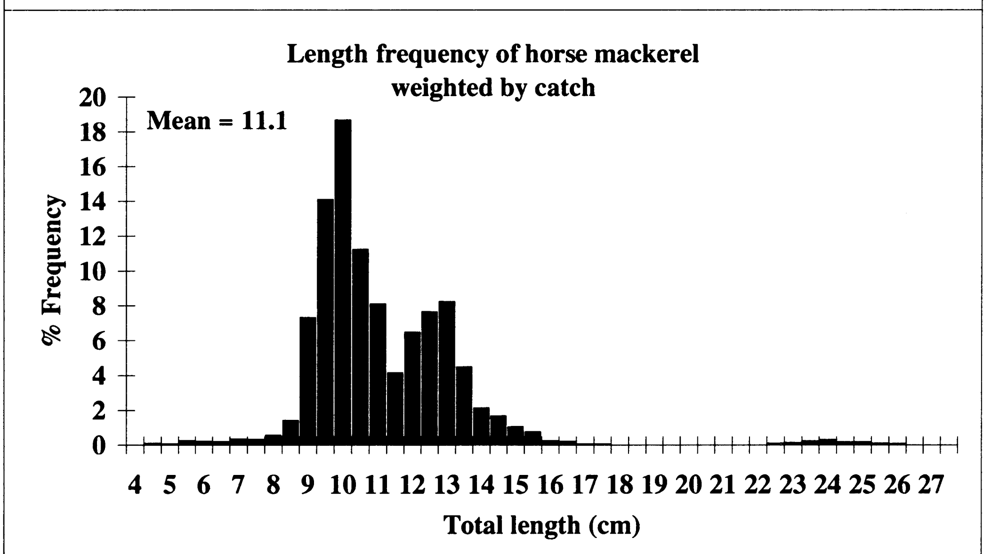
Sorted: 27 Kg Total catch: 351.30 CATCH/HOUR: 1756.50

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Sufflogobius bibarbatus	GOBSU01	1661.00	745875	94.56	
Trachurus capensis	CARTR04	67.60	2925	3.85	3840
Sardinops ocellatus	CLUSS01	25.35	325	1.44	
Todarodes sagittatus	SQUOM31	6.50	195	0.37	
Lepidopus caudatus	TRILE01	2.60	195	0.15	
Total		1763.05		100.37	

ANNEX VI LENGTH FREQUENCY DISTRIBUTIONS







CHAPTER 2: STUDIES OF SCHOOLING BEHAVIOUR OF SARDINELLA (*SARDINELLA MADERENSIS* AND *SARDINELLA AURITA*) IN ANGOLAN WATERS.

1 INTRODUCTION

1.1 Background

Previous work on the sardinella stocks of Angola (methodological surveys by R/V "Dr. FRIDJOF NANSEN" in 1996 and 1997) has shown that sardinella frequently shoal close to, and even at, the surface, and therefore considerable amounts of fish may be missed during standard hydro-acoustic biomass surveys in the surface "blind" zone and are likely to actively avoid the research vessel. It has also been noted that sardinella are particularly difficult to catch in targeted mid-water trawls during day-light, indicating that this species also performs trawl avoidance behaviour.

Surveys by the RV "Dr. FRIDTJOF NANSEN" in July 1996 and April/May 1997 investigated some of the behavioural characteristics of sardinella which may be of importance to acoustical surveys. Acoustic observations from a transducer mounted near the surface on a small boat indicated that the hull mounted transducer of the RV "Dr. FRIDTJOF NANSEN" does indeed miss significant amounts of fish at certain times of day. Amongst other behavioural characteristics, sardinella were found to migrate to the surface in an apparently bimodal diurnal cycle; peaking at 10h00 and 16h00 local time. It was however found that biomass estimates of shoals positioned below the surface "blind" zone obtained through traditional vertical echo-sounding techniques and shoal counting with a horizontally directed sonar (and assuming a constant density of shoals) produced similar results, indicating that sonar may be a useful tool for surveying surface distributions of sardinella.

Tracking of school movements using a sonar, and trawling catch rates in different depth zones, suggested that horizontal shoal movements may have a diurnally pattern, being shorewards at night. Trawling experiments during the surveys in 1996 and 1997 not only confirmed the ability of sardinella to avoid capture during daylight, but showed that substantial amounts of fish entered the net opening during trawling, and during fast tows fell back into the belly of the net, only to swim out when the trawl slowed to begin hauling.

This current cruise was conducted co-operatively between the Angolan and Namibian national fisheries research institutes and the Institute of Marine Research, Bergen and NORAD through the BENEFIT Programme. It was intended to further investigate the behavioural characteristics of sardinella, particularly those which may cause biases or errors in acoustically derived biomass estimates. In addition the cruise was to further develop both technical and methodological solutions to alleviate these problems. These developments included testing of the new Sonar Data Processing system (SODAPS). It was intended that any developments made during this cruise should be applicable to improving the accuracy of biomass estimates derived from other surface shoaling pelagic species elsewhere.

1.2 Objectives

This cruise had a number of objectives, primarily:

- comparative sonar and echo integrator survey
- sonar tracking of sardinella shoals
- visual observation of surface appearance of sardinella
- comparative surveying by Nansen and its small boat (M.O.B.)
- pelagic trawl sampling with underwater video observations

2 METHODS

The present status of the SODAPS sytem did not fullfill vital criterias (see Chapter 3) for enabling a comparative sonar and echo integrator survey, and this objective was therefore not realized.

2.1 Sonar school tracking

To study the swimming behaviour of pelagic, schooling fish off Angola, the Simrad SF 950 sonar was used to observe dynamics, swimming speed and direction of movement of individual schools. In addition interactions with other shoals were also observed and recorded.

The sonar was set to full transmission power with gain, range and filters set to provide an optimal picture of the target school. These were usually; gain 5, display gain 5, and with the AGC off, the reverberation filter set from off in good conditions to medium in more difficult conditions, and with the ping-to-ping filter set from off to weak according to conditions. The direction, range and tilt were continuously varied to track the schools.

The observation strategy was to find regions where suitably distinct, but numerous, schools of sardinella occurred. The vessel approached a selected school as gently as possible until the school was at a distance of about 200 m, and then stopped carefully. The vessel was then manoeuvred carefully to keep the school within a distance of 100 to 250 m. If the school came closer then the vessel was stopped. During the tracking the sonar was trained and tilted to obtain an optimal recording of the school. When a tracking situation was established with the school in a rather stable distance from the vessel, the position and depth of an individual school was recorded at 2 minute intervals for as long as possible. The tracking was stopped when the school disappeared. Any observations which lasted for less than 4 minutes (3 records) was disregarded, the longest period of observation was 64 minutes. Approaches and coalescing with other schools, or splitting of the target school, were recorded and a drawing of the outline of the school was made each time the school changed shape significantly. The sonar recordings of tracked schools will be analysed by programs written in the SAS software to visualise the swimming behaviour of the schools, and quantify the swimming speed and swimming direction of the schools.

Similar schools in the area of tracked schools were sampled by trawling to determine the species composition and size of the fish observed.

2.2 Surface school observations

Sardinella have previously been noted as occurring at the surface, even during daytime. In an attempt to determine the frequency and periodicity of this behaviour the occurrence of schools of sardinella at the surface was recorded visually from the wheelhouse of the RV “Dr. FRIDTJOF NANSEN” between sunrise and sunset (06h00-18h00 local time) each day. Numbers of shoals sighted were pooled into 15 minute intervals for reporting purposes.

Solar radiation intensity was recorded automatically at 10 minute intervals by the ship-borne weather station. These data were used to investigate the relationship between surface occurrence of shoals and light intensity.

2.3 Small boat experiments

A set of six experiments using a small (5.3 m) Man-Over-Board (M.O.B.) boat equipped with a portable scientific echo sounder (Simrad EY500) were conducted to study near-surface schooling and vessel avoidance.

The echo sounder was calibrated in Baia dos Tigres 29/4 according to standard procedure, and the first experiment also took place in that location. Experiments 2 - 5 took place north-west of Lobito in areas of abundant sardinella schools, and the last experiment was conducted off Cabo Ledo. Three experiments were conducted during day-light and three after dark. Each experiment was between 8 and 10 nm in length. During each experiment the small boat kept a parallel course with the RV “Dr. FRIDTJOF NANSEN”. A constant speed of 5 knots and an inter-vessel spacing of 0.3 nm was maintained. Synchronised intervals of equal length (1 nm) were surveyed by both vessels.

Table 1 Some technical details of the small boat experiments.

	Time	NANSEN	M.O.B.Boat	Transect length
Expt. 1	Day	Inshore	Offshore	10 nm
Expt. 2	Night	Offshore	Inshore	10 nm
Expt. 3	Day	Inshore	Offshore	8 nm
Expt. 4	Night	Inshore	Offshore	10 nm
Expt. 5	Day	Offshore	Inshore	10 nm
Expt. 6	Night	Offshore	Inshore	10 nm

The EY500 was set to record from a depth of 5 m down to the bottom and the EK500 from 10 m down to the bottom. Each interval was printed out in 10 m vertical channels. The data collected were scrutinised visually, allocating total area back-scattering coefficients, or $_{Sa}$ values, per nautical mile to either schools or scattered targets. Schools were defined as any targets on the printed echogram which gave a jump of 10 m^2/nm^2 on the cumulative (analog) integrator line. The number of schools detected by each system was recorded in 10 metre depth channels.

2.4 Trawl sampling strategy

Trawling was conducted for several reasons during this cruise; to determine the identity of suitable concentrations of fish for further observations, to identify fish observed during shoal tracking, surface sightings or small boat experiments and to observe the behaviour of sardinella in the trawls opening with an underwater video. All trawl stations were taken with a 320 m circumference, medium sized pelagic trawl of the Åkra-type. The stations were taken on locations with bottom depths ranging from about 30 - 50 m, and two large floats with 5 - 10 m extension were attached to each wing to prevent the trawl from touching bottom. In many cases, especially during trawling on discreet shoals, the SF 950 sonar was used to guide the vessel onto shoals. In total 12 trawls were done during the cruise and positions, catch and other relevant data are summarised in Annex I.

A random sample of fish representative of the total catch was taken from the trawl, the size of the sample depending largely on the species mixture of the catch. In cases where the catch was small, the total catch was sampled. To determine the catch composition of the trawl the number and weight for each species in the random sample was recorded. This sample was then raised to the total catch. A random sample of about 100 sardinella, if available, were measured to the nearest 0.5 cm below total length to obtain the size composition of the catch. Maturity stage and stomach contents of about 20 sardinella were recorded for each trawl.

The size and species composition of all trawls was pooled per area, depth and time period by simple adding. In many of the analyses the species were pooled into the following groups:

- sardinella (*Sardinella maderensis* and *S. aurita*)
- horse mackerel (*Trachurus trecae*)
- other carangids (mostly *Selene dorsalis*, *Trachinotus goreensis* and *Chloroscombrus chrysurus*)
- other pelagics (scombrids, barracudas, and hairtails - mostly *Sarda sarda*, *Scomberomorous tritor*, *Scomber japonicus*, *Sphyraena guachancho* and *Trichiurus lepturus*)

2.5 Underwater trawling observations

In order to observe the behaviour of sardinella in the trawl net, an RS 600 system was mounted in the upper panel of the trawl square where the mesh size change from 200 to 100 mm. An RS 600 system consist of a frame with a tiltable SIT camera cabeled to a waterproof cylinder housing with a VHS HI8 video recorder and a battery. The camera frame was laced to the net in the centre of the upper net-panel section, and the cylinder housing put in a bag that was mounted to the net just behind the camera. Standard mid-water trawls were then conducted in regions where schools of sardinella had previously been recorded.

The swimming behaviour in relation to the net was observed at trawling speeds of 4.0 knots for periods ranging from a few minutes to about one hour. Video recordings were taken to IMR for qualitative analysis.

Table 2 Details of trawls when the RS system was used during the methodological cruise in Angola, May 1998.

Trawl no.	Trawl depth (m)	Bottom depth (m)	Speed (knots)	Time (min)	Secchi depth (m)	Total catch (kg)	Sardinella (kg)
PT2495	15	69	4.0	8	11	153	52
PT2496	10	49	4.0	49	10	30	12
PT2497	10	55	4.1	61	9	501	482
PT2500	5	40	4.0	35	9	388	213
PT2501	10	51	4.0	99	17	42	22
PT2502	5	36	4.0	67	17	51	14
PT2503	5	44	4.0	109	13	17	0
PT2504	5	36	4.0	55	11	662	620

2.6 Environmental characteristics

Wind (direction and speed), air temperature, global radiation and sea surface temperature (5 m) data were collected throughout the survey area and logged automatically every nautical mile using an Anderaa meteorological station. In addition, a Seabird 911 CTD Plus Sonde was used to obtain a general overview of temperature, salinity and oxygen at 7 stations. The profiles were taken from the surface down to within a few metres of the bottom. Current measurements were also made at these stations with the use of the ship-born Acoustic Doppler Current Profiler

(ADCP) from RD Instruments. All measurements were made at depths greater than 20 m and where bottom tracking was obtainable, i.e., at bottom depths less than 350 m. The ADCP was set to ping every 8 seconds, the depth cell was set to 4 m and the number of cells to 40. Transducer misalignment was kept at 0° and averaging time was 300 seconds. Only processed data files were stored to disk and current vectors were plotted for each data point.

3 RESULTS

3.1 School tracking

During the cruise, 26 schools were tracked for 4 - 72 min. In many cases the tracking was initiated on schools that appeared at the surface, and that also could be recorded by the sonar. Some schools appeared in mid-water so that the recorded schools were distributed from average depths in the range 5 - 34 m. The schools were swimming at horizontal speeds of 0.31 - 2.18 m/s, and moving in the direction of migration at speeds of 0.53 - 1.92 m/s.

The schools were rather dynamic, and splitting, joining, change of shape, and fragmentation occurred rather frequently. In many cases the rather short duration of the tracking was caused by fragmentation or dispersion of the schools so that the school echo on the sonar display became too small or too weak to perform further tracking. Intra-school events such as change of shape, reorganizing, and splitting occurred at an average rate of 0.33 per min which means that an intra-school event occurred each 3rd min. Most schools adopted a rod-like or fragmented shape, but circles and ovals were also quite frequent. Ring-shaped schools were rather rare. Interactions between neighboring schools as approach and join occurred at rates of 0.06 per min which means that such events occurred on average at time intervals of 16 min 40 sec.

The schools seemed little disturbed by nearby predators. Seabirds were remarkably absent when considering the large number of surface schools. Two gannets were observed in the Lobito area, but they were only once observed to attack the sardinella schools. Fish predators as barracuda were caught during aimed trawling on sardinella schools. Sharks were observed at surface both off Lobito. However, it was not observed that schools were chased by fish predators during the trackings. Several seals were also observed in the Lobito region. Nevertheless, a distinct, noisy, and water splashing flash could occasionally be seen to be performed in sardinella schools at surface. This flash is probably an antipredator manoeuvre which can be effective to scare and confuse both bird and fish predators.

During this years methodological cruise, the SF 950 sonar performed better than last year. The problem with weaker centre beams seem to have been solved so that the problem with school recordings fading in the centre beam did not occure. However, in many cases, the sonar produced a “shadow” echo of dense schools somewhat to the side of the real school projection. This “gost school” caused some confusion during the school trackings. Other shortcommings is the lack of the ability to set out school markers, and that the AGC and Pulseform functions do not seem to function according to specifications. These problems are considered in more detail in Chapter 3. The new automatic target detection and tracking function is not functioning as expected. Numerous detected targets seem to move around on the screen more or less constantly. The real schools are also detected and tracked, but they are then usually considered as multiple targets and disturbingly occupied by a number of target markers.

Several of the cruise participants have experience in recording school with the SA 950, and it was generally agreed that the images of school recordings on the SF 950 seem different from the school images displayed at the SA 950. On the SF 950 the 32 sonar beams are clearly visible. This induce a seemingly coarser resolution of the school images on the SF 950 than on a SA 950. It seems that “functions” to smooth images are not operating on SF 950 as on the SA 950. Nevertheless, the SF 950 has high resolution, and the images displayed seem to reflect the natural shape of the schools. This was confirmed in many cases when the schools could be seen at the surface and recorded by the sonar simultaneously.

3.2 Surface school observations

Surface school counts performed in the Lobito (3 days) and Cabo Ledo (1 day) area during the 1998 cruise revealed the same pattern as seen in 1996 and 1997 which showed schools at surface bimodally from 06h00 to 10h00 and from 14h00 to 18h00 in the evening. During the school sightings, the movements of the surface schools was also attempted quantified. A specific direction of movement was not found, but schools seemed eighter to move towards (eastwards) or away (westwards) from the coast, or along the coast (northwards or southwards). There seems to be a connection with sunrise and the appearance of schools at surface in that the fisrt schools usually came to surface about one hour after sunrise. Generally, many schools were then active at surface untill abut 10:00. Big schools then appeared and were active at surface from 14:00 to 18:00. The schools tend to be appearing at surface for about 10 min.

The shoal counts at the surface have shown a relationship between a number of shoals and solar radiation intensity (Figure 3.1). It is presumed that solar radiation can affect the behaviour of fish schooling at the surface (e.g. sardinella) throughout the day. Daily recordings indicate that from 06h00 to 10h00 a large numbers of schools are seen at the surface. In contrast, when it is bright from 11h00 to 13h00 less shoals are observed at the surface. On days when the solar radiation intensity was below about 700 W/m^2 during the middle part of the day, the number of shoals at surface seems to be considerably more than during brighter days.

These data and analyses must be treated with some care as the probability of detecting shoals was likely to be greatly influenced by the time of day, wind (and hence wave formation), direction in relation to the sun and observer. In addition counting continued throughout the cruise, including in some areas where, in hind-sight, it proved that there were few sardinella present.

3.3 Small boat experiments

The total S_a values per nautical mile attributable to shoals and scattered targets are presented in Figure 3.2. Table 3 summarises these results. The conditions for conducting such experiments were excellent, as the weather fine and calm and during most of the experiments there was considerable near-surface schooling activity.

For purposes of quantitative comparison these data should be analysed in far greater detail than that which is shown in this report. This will be done later this year in Bergen. For preliminary investigations, the Sa values of each nautical mile were separated into schools and scatterers. No of schools per nautical mile were also compared. Comparison of the number of schools recorded by the Nansen and the M.O.B are quite variable as can be expected, adding variability into the total Sa values as shown in Figure 3.2 as well. Furthermore, no corrections has at this stage been applied to either data set to account for the difference in draft of the two vessels. It does, however, seem as though higher values per nautical mile and higher average values per experiment were recorded by the M.O.B than by the Nansen during at least four of the six experiments. Overall values recorded by the M.O.B. boat were 50 % higher.

Table 3. Sa value and number of shoals per nautical mile for each experiment.

		RV "Dr FRIDTJOF NANSEN			M.O.B Boat			
		S_a of shoals	No. of shoals	S_a of scatterers	S_a of shoals	No. of shoals	S_a of scatterers	Transect Length
Expt. 1	Day	4380	28	2622	2830	20	1477	10
Expt. 2	Night	17505	15	35176	76264	30	84968	10
Expt. 3	Day	28060	21	30205	15190	22	18575	8
Expt. 4	Night	25840	17	33385	46960	15	55842	10
Expt. 5	Day	26671	29	15448	84100	56	71975	10
Expt. 6	Night	0	0	33845	3680	5	42857	10
Mean		17076	18	25113	38171	25	45949	

3.4 Trawling

A total of 12 pelagic trawls were conducted during the methodological cruise survey, 8 of these with RS 600 camera unit to study the swimming behaviour of sardinella during pelagic trawl sampling. The main objective of all pelagic trawls were target identification, and to obtain samples regarding species composition, and length and weight of the main species. 11 of the trawls were taken during daytime, one in darkness in the evening.

As the sardinella shoals were generally found close inshore, the trawls were conducted between 30 and 50 m bottom depth. The trawls were mainly midwater trawls at or close to the surface.

The highest catches of sardinella were taken in late afternoon/early evening when the fish tended to disperce and react less to the approach of the vessel and the trawl. This periode of the day therefore seem favourable to obatin representative catches of sardinella. In daytime the sardinella seem to be strictly schooling and fast swimming, and therefore rather difficult to catch representatively by pelagic sampling trawl.

3.7 Underwater trawling observations

During 8 pelagic trawl hauls, the RS 600 was used to record swimming behaviour of sardinella in the trawl belly (200 mm stretched mesh section).

Sardinella schools that were recorded in the trawl mouth by the Scanmar trawleye, seem to appear in the 200 mm stretched mesh section of the trawl within about 1 minute when towing at 4.0 knots. In the tunnel of the trawl belly, the swimming behaviour of the sardinella seem determined by the optomotor response so that the fish were trying to maintain position alongside the diamond patterns of the meshes of the trawl net. At a speed of about 4.0 knots the sardinella were observed to lose position slowly and fade backwards in the trawl tunnel. However, some fish were also observed to be capable of swimming forward faster than the towing speed of the trawl, and even 30 minutes after entering the trawl, much fish were still capable of swimming in the 200 mm section of the trawl belly. More remarkably, there were also fish that were capable of swimming in the 200 mm section of the trawl belly about 60 minutes after the first entrance.

For enabling haul back of the trawl, the vessel speed must be slowed down to about 2 knots. The warp winches are then hauling the trawl back until the doors are locked in the blocks. The sweeps and net are then hauled in by the net drum. When the vessel slowed down and haul back of the trawl started, the sardinella that were schooling in the trawl belly reacted by a flash, some individuals turning and swimming backwards, others towards the net, some escaping through. When the net was hauled back 10 minutes after the main entrance of fish, the trawl belly was empty after these initial flashes. Only sardinella entangeled in the meshes, mostly in the 100 mm section of the trawl belly, were caught. In cases where the trawl had been towed for 30 minutes and more, the initial flashes was followed by forward swimming of substantial number of fish along the bottom of the net. This coincided with recording of fish on the net sonde, and thereby confirming the hypothesis from the 1996 and 1997 methodological surveys that sardinella is capable of escaping out of the trawl by forward swimming during haul back. The RS 600 recordings have therefore provided scientific evidence for an explanation of why recordings of sardinella on the echo sounder and trawl sonde during pelagic trawl sampling in many cases are not reflected in significant catches of these fast swimming species. However, not all fish were able to escape out by forward swimming during haul back, and when towing for up to one hour after first entrance catches of up to about 500 kg of sardinella were obtained.

3.8 Environmental characteristics

The environmental characteristics in the areas where the sardinella schools were sighted and tracked, and where the pelagic trawl hauls and small boat experiments were conducted are summarized in Table 5. The sea temperatures at 5 m depth in the respective areas varied by 2.2° - 3.3° C. As several of the CTD stations were taken at nearby positions within these areas, the substantial temperature variations at 5 m depth probably reflected internal waves influencing the surface layer. At 20 m depth, the sea temperature varied by maximally 1.5° C, and was about 19° - 21° C in the respective areas. The salinity was within 35.01 - 35.70 ‰ in all depths of the respective areas. In the Cabo Ledo area, the Secchi depth was rather constant from 11 - 13 m. In the Lobito area the Secchi depth varied two-fold from 9 to 17 m.

Table 5. Environmental characteristics in the areas where the school studies and

pelagic trawl hauls were conducted.

Area	Temperature (°C)		Salinity (‰)		Secchi-depth
	5 m	20 m	5 m	20 m	(m)
Cabo Ledo	23.7 - 26.9	19.8 - 21.3	35.01 - 35.12	35.62 - 35.70	11 - 13
Lobito	24.6 - 26.8	19.5 - 20.7	35.25 - 35.48	35.65 - 35.69	9 - 17

4 CONCLUDING REMARKS

Twenty-six schools were tracked manually during the cruise. The schools were rather dynamic, and intra- and interschool events occurred at average rates of 0.33 and 0.06 per min respectively. This means that intra-school events such as change of shape, reorganising and splitting occurred each 3rd minute on average, and that interschool events such as joining and approaching occurred at time intervals of 16 min 40 sec on average. The schools were moving at horizontal speeds of 0.31 - 2.18 m/s in average, and the speed in the direction of migration varied from 0.53 to 1.92 m/s in average. The results regarding school dynamics and swimming behaviour are remarkably similar to those observed in 1997 and 1996.

A large number of surface schools were sighted during the cruise. The schools seem most active at the surface during early morning and in the afternoon, and with a minimum of surface school activity during mid-day. The number of surface schools seem inversely related to the level of solar radiation.

A total of 12 pelagic trawl stations were conducted during the cruise. The catches of sardinella during this cruise were comparable to that obtained during the methodological cruise in 1997.

The RS 600 camera system was used to record the behaviour of sardinella in the trawl belly during 8 pelagic trawl stations. These observations confirmed that the sardinella were capable of swimming along in the trawl mouth for a remarkably long time when towing at 4 knots. The sardinella seemed to perform the optomotor response in trying to swim along with the diamond shaped patterns of the trawl net. The sardinella seemed loose position slowly and faded backwards in the trawl tunnel when towing at 4 knots, but fish were also seen swimming forward. Up to one hour after the fisrt entrance there were still fish keeping position in the trawl belly. When slowing down for hauling, the fish were scared, and flashed towards the net wall and backwards in the trawl. This behaviour could be repeated several times, and were followed by large number of sardinella swimming forward and escaping out of the trawl. During short tows, only sardinella entangeled in the meshes were caught. During tows for 30 min and more after the first entrance, catches up to 500 kg of sardinella were obtained.

To compare the echo integration recordings of sardinella obtained by a small and large vessel, six experiments were conducted by running the 6 m man-overboard vessel equipped with a EY500 in parallel and 600 m to the side of R/V “Dr. FRIDTJOF NANSEN” steaming at 5 knots. During these experiments the average back scattering strength of sardinella was about 25 % higher and the number of schools recorded about 35 % higher on the m.o.b. boat than on R/V “Dr. FRIDTJOF NANSEN”, respectively. There were also substantial differences in the vertical distribution of the schools recorded by the m.o.b. boat and R/V “Dr. FRIDTJOF NANSEN”.

Despite the circumstances and the short time available for the cruise in Angola, the objectives were definitely met with regard to school tracking, visual school sightings, pelagic trawl stations with UTV observations, and the small boat experiments. For these tasks substantial amounts of data were collected, and further analysis are required to justify significant conclusions. The data for these tasks will be analysed with respect to the influence of the schooling behaviour of sardinella in relation to acoustic abundance estimation, and the results are intended to be reported in referee-based scientific journals. The first main objective, that of a proper comparative sonar and echo integration survey, was not met because of the present status of the SODAPS system (see Chapter 3).

CHAPTER 2: FIGURES

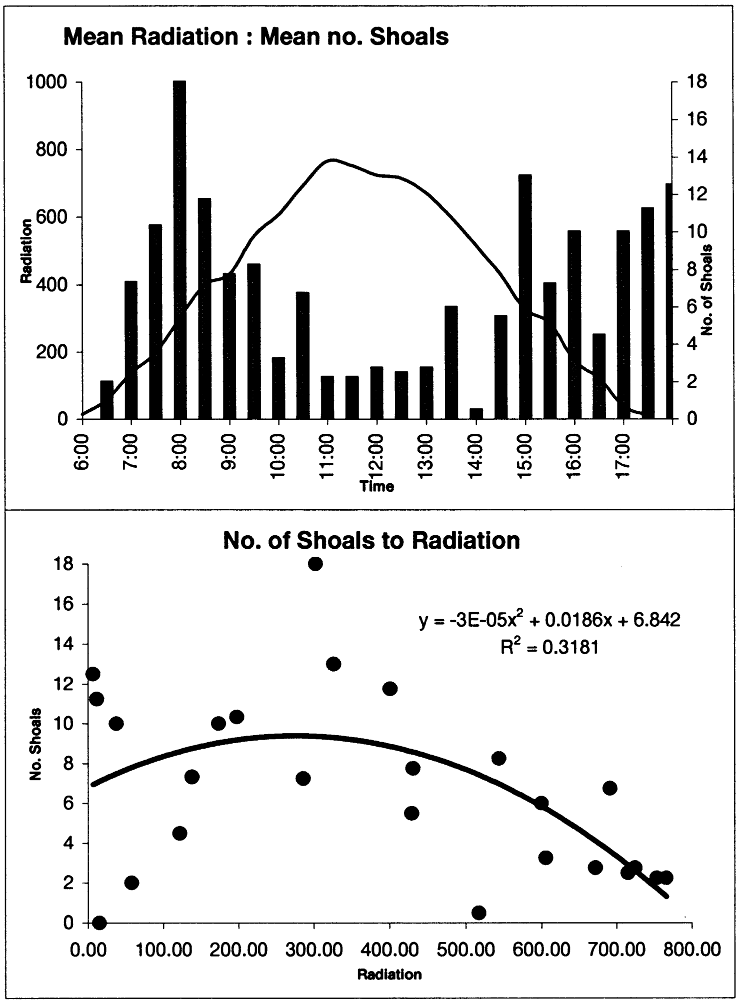


Figure 3.1. Mean number of shoals sighted in 1998 compared to solar radiation levels

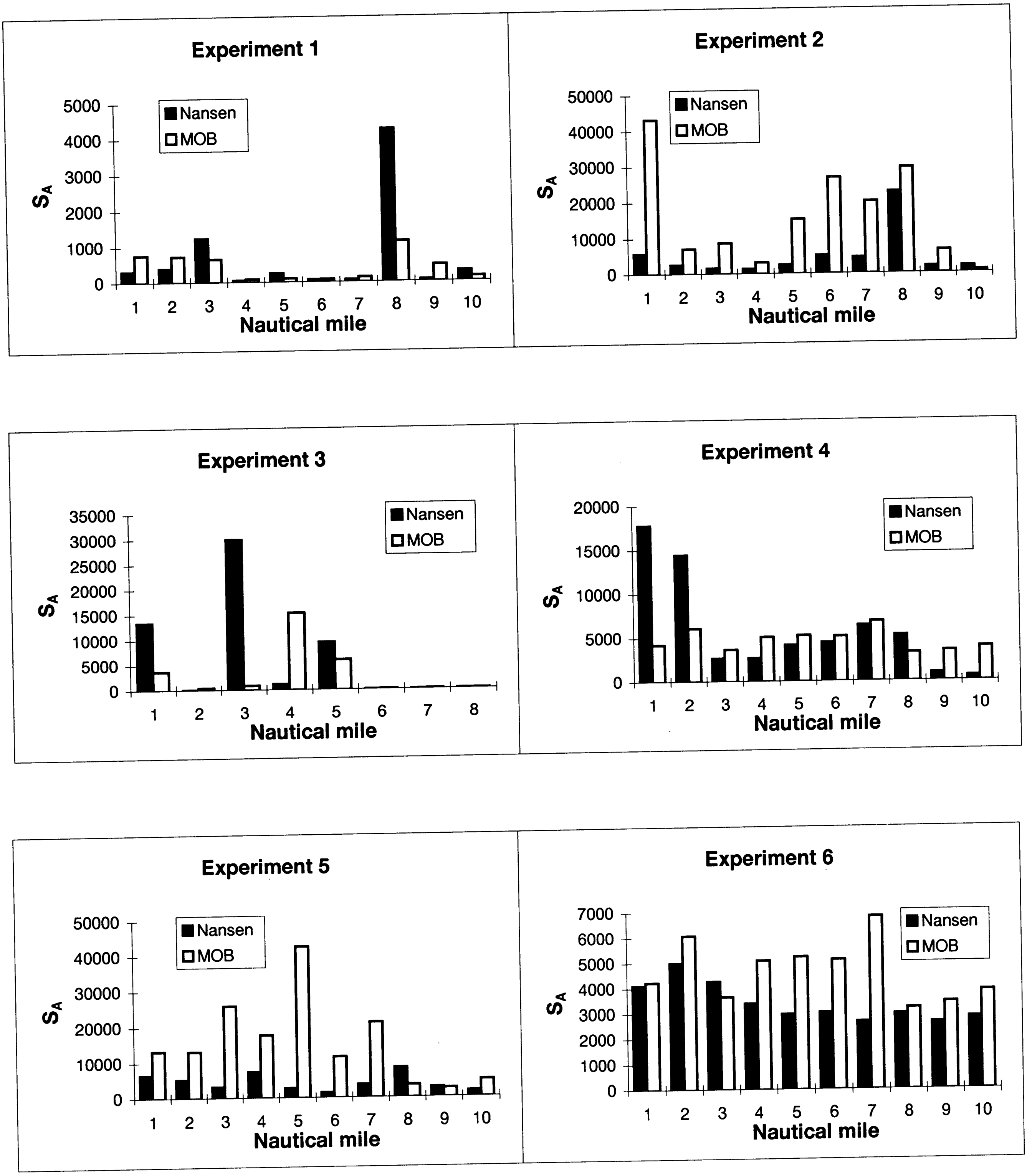


Figure 3.2. Comparison of EK500 and small boat S_a values for each nautical mile during 6 experiments.

ANNEXES

ANNEX I Small boat and portable echo sounder specifications and settings.

The Simrad EY500/38 kHz portable scientific echo sounder fitted with a split beam transducer was operated from a small boat during several exercises to study fish schooling behaviour. All raw data were stored to tape and a colour printout of echograms was generated. The details of the settings of the portable 38 kHz echo sounder were as follows:

Transceiver menu

Transducer type	ES38-12
Transducer depth	0 m
Absorption coeff.	10 dB/km
Pulse length	medium
Max. power	125W
2-way beam angle	-15.8 deg
SV transducer gain	22.7 dB
TS transducer gain	22.7 dB
3 dB Beamwidth along.	11.9 deg
3 dB Beamwidth athw.ship	11.7
Alongship offset	0.01 deg
Athwartship offset	-0.02 deg

Man-Over-Board boat

Length	5.3 m
Width	2.1 m
Power	40 Hp
Draught	1.2 m
Weight	2000 kg

ANNEX II RECORDS OF FISHING STATIONS

PROJECT STATION:2492
DATE:29/ 4/98 GEAR TYPE: BT No: 7 POSITION:Lat S 1639
start stop duration Long E 1146
TIME :08:50:45 09:21:07 30 (min) Purpose code: 1
LOG :2667.82 2669.43 1.61 Area code : 2
FDEPTH: 19 19 GearCond.code: 1
BDEPTH: 19 19 Validity code: 1
Towing dir: 360ø Wire out: 110 m Speed: 3 kn*10

Sorted: 28 Kg Total catch: 407.50 CATCH/HOUR: 815.00

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Decapterus rhonchus	CARDE02	813.00	9210	99.75	3841
Sarda sarda	SCMSA01	1.84	2	0.23	
SOLVA01		0.06	2	0.01	
Total		814.90		99.99	

PROJECT STATION:2493
DATE:30/ 4/98 GEAR TYPE: PT No: 1 POSITION:Lat S 1315
start stop duration Long E 1230
TIME :10:00:14 10:24:02 24 (min) Purpose code: 1
LOG :2896.71 2897.53 0.79 Area code : 2
FDEPTH: 150 150 GearCond.code: 1
BDEPTH: 1335 1386 Validity code: 1
Towing dir: 210ø Wire out: 450 m Speed: 3 kn*10

Sorted: Kg Total catch: CATCH/HOUR:

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
MYCTOPHIDAE	MYCAA00	0.00			
Total					

PROJECT STATION:2494
DATE:30/ 4/98 GEAR TYPE: PT No: 4 POSITION:Lat S 1216
start stop duration Long E 1328
TIME :19:00:34 20:01:18 61 (min) Purpose code: 1
LOG :2987.41 2990.65 3.29 Area code : 3
FDEPTH: 50 5 GearCond.code: 1
BDEPTH: 98 97 Validity code: 1
Towing dir: 10ø Wire out: 150 m Speed: 3 kn*10

Sorted: 24 Kg Total catch: 48.20 CATCH/HOUR: 47.41

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trichiurus lepturus	TRITR01	47.41	167	100.00	
Total		47.41		100.00	

PROJECT STATION:2495
DATE: 1/ 5/98 GEAR TYPE: PT No: 1 POSITION:Lat S 1208
start stop duration Long E 1337
TIME :07:01:58 07:41:16 39 (min) Purpose code: 1
LOG :3011.83 3014.10 1.95 Area code : 3
FDEPTH: 10 10 GearCond.code: 1
BDEPTH: 60 59 Validity code: 1
Towing dir: 210ø Wire out: 160 m Speed: 4 kn*10

Sorted: 78 Kg Total catch: 153.40 CATCH/HOUR: 236.00

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus trecae	CARTR02	84.00	215	35.59	3943
Sardinella maderensis	CLUSL02	77.23	268	32.72	3942
Trachinotus ovatus	CARTC03	72.15	182	30.57	
Sardinella aurita	CLUSL01	2.54	8	1.08	3944
Total		235.92		99.96	

PROJECT STATION:2496
DATE: 1/ 5/98 GEAR TYPE: PT No: 4 POSITION:Lat S 1211
start stop duration Long E 1337
TIME :12:14:07 13:02:40 49 (min) Purpose code: 1
LOG :3024.26 3028.00 3.48 Area code : 3
FDEPTH: 10 10 GearCond.code: 1
BDEPTH: 43 56 Validity code: 1
Towing dir: 350ø Wire out: 190 m Speed: 4 kn*10

Sorted: 18 Kg Total catch: 27.60 CATCH/HOUR: 33.80

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Sardinella maderensis	CLUSL02	14.45	49	42.75	3945
Trachinotus ovatus	CARTC03	8.08	31	23.91	
Sarda sarda	SCMSA01	7.35	5	21.75	
Stromateus fiatola	STRST01	2.35	2	6.95	
SCMEU01		1.49	1	4.41	
Lagocephalus laevigatus	TETLA01	0.05	2	0.15	
Total		33.77		99.92	

PROJECT STATION:2497
DATE: 1/ 5/98 GEAR TYPE: PT No: 4 POSITION:Lat S 1207
start stop duration Long E 1338
TIME :15:10:18 16:11:23 61 (min) Purpose code: 1
LOG :3032.89 3037.53 4.29 Area code : 3
FDEPTH: 10 10 GearCond.code: 1
BDEPTH: 41 69 Validity code: 1
Towing dir: 350ø Wire out: 160 m Speed: 4 kn*10

Sorted: 59 Kg Total catch: 501.30 CATCH/HOUR: 493.08

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Sardinella maderensis	CLUSL02	454.33	1956	92.14	3946
Trachurus trecae	CARTR02	9.03	210	1.83	
SCMEU01		0.93	1	0.19	
Total		493.05		99.99	

PROJECT STATION:2498
DATE: 1/ 5/98 GEAR TYPE: PT No: 4 POSITION:Lat S 1206
start stop duration Long E 1336
TIME :21:36:55 22:05:09 28 (min) Purpose code: 1
LOG :3055.76 3057.70 1.94 Area code : 3
FDEPTH: 10 10 GearCond.code: 1
BDEPTH: 68 68 Validity code: 1
Towing dir: ø Wire out: 150 m Speed: 4 kn*10

Sorted: 57 Kg Total catch: 423.80 CATCH/HOUR: 908.14

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Sardinella maderensis	CLUSL02	811.71	3360	89.38	3948
Trichiurus lepturus	TRITR01	54.64	178	6.02	
Engraulis encrasicolus	ENGEN01	18.17	643	2.00	
Scomber japonicus	SCMSC01	7.71	49	0.85	
Trachurus trecae	CARTR02	4.82	17	0.53	
Sardinella aurita	CLUSL01	4.50	17	0.50	
SQUSQ00		2.25	64	0.25	
PODBR01		2.25	49	0.25	
SYNSA01		1.46	114	0.16	
Bregmaceros sp.	BREBR00	0.64	161	0.07	
Total		908.15		100.01	

PROJECT STATION:2499
DATE: 2/ 5/98 GEAR TYPE: PT No: 4 POSITION:Lat S 1135
start stop duration Long E 1342
TIME :12:00:09 13:02:05 62 (min) Purpose code: 1
LOG :3108.94 3113.36 3.89 Area code : 3
FDEPTH: 5 5 GearCond.code: 1
BDEPTH: 36 39 Validity code: 1
Towing dir: 360ø Wire out: 160 m Speed: 4 kn*10

Sorted: Kg Total catch: 20.02 CATCH/HOUR: 19.37

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachinotus ovatus	CARTC03	9.29	25	47.96	
Scomberomorus tritor	SCMSM01	6.39	4	32.99	
Stromateus fiatola	STRST01	2.53	3	13.06	
Sphyraena guachancho	SPHSP01	0.94	2	4.85	
Pomadasys incisus	PODPO02	0.23	1	1.19	
Total		19.38		100.05	

PROJECT STATION:2500
DATE: 2/ 5/98 GEAR TYPE: PT No: 4 POSITION:Lat S 1143
start stop duration Long E 1342
TIME :16:56:03 17:31:15 35 (min) Purpose code: 1
LOG :3130.57 3133.00 2.37 Area code : 3
FDEPTH: 5 5 GearCond.code: 1
BDEPTH: 41 38 Validity code: 1
Towing dir: 250ø Wire out: 180 m Speed: 4 kn*10

Sorted: 39 Kg Total catch: 388.00 CATCH/HOUR: 665.14

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus trecae	CARTR02	276.00	1406	41.50	3949
Sardinella aurita	CLUSL01	243.43	909	36.60	3951
Sardinella maderensis	CLUSL02	121.71	55	18.30	3950
Engraulis encrasicolus	ENGEN01	12.69	3086	1.91	
Scomber japonicus	SCMSC01	11.31	17	1.70	
Total		665.14		100.01	

PROJECT STATION:2501
DATE: 3/ 5/98 GEAR TYPE: PT No: 4 POSITION:Lat S 1148
start stop duration Long E 1342
TIME :07:24:19 09:02:55 99 (min) Purpose code: 1
LOG :3173.46 3180.45 6.41 Area code : 3
FDEPTH: 10 10 GearCond.code: 1
BDEPTH: 44 59 Validity code: 1
Towing dir: 360ø Wire out: 180 m Speed: 4 kn*10

Sorted: Kg Total catch: 41.78 CATCH/HOUR: 25.32

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus trecae	CARTR02	10.79	26	42.61	3954
Sardinella maderensis	CLUSL02	10.64	42	42.02	3952
Sardinella aurita	CLUSL01	2.94	9	11.61	3953
Scomber japonicus	SCMSC01	0.62	1	2.45	
SCMEU01		0.33	1	1.30	
Total		25.32		99.99	

PROJECT STATION:2502
DATE: 3/ 5/98 GEAR TYPE: PT No: 4 POSITION:Lat S 1150
start stop duration Long E 1343
TIME :15:55:45 17:02:47 67 (min) Purpose code: 1
LOG :3198.92 3203.77 4.82 Area code : 3
FDEPTH: 5 5 GearCond.code: 1
BDEPTH: 37 35 Validity code: 1
Towing dir: 360ø Wire out: 180 m Speed: 4 kn*10

Sorted: Kg Total catch: 50.58 CATCH/HOUR: 45.30

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus trecae	CARTR02	16.43	58	36.27	3956
Sardinella maderensis	CLUSL02	11.33	49	25.01	3954
Trachinotus ovatus	CARTC03	8.42	23	18.59	
Sphyraena guachancho	SPHSP01	6.17	11	13.62	
Sardinella aurita	CLUSL01	2.28	8	5.03	3955
Trichiurus lepturus	TRITR01	0.42	1	0.93	
PODBR01		0.11	2	0.24	
Total		45.16		99.69	

PROJECT STATION:2503

DATE: 4/ 5/98 GEAR TYPE: 11 No:11 POSITION:Lat S 942
Long E 1307

	start	stop	duration	
TIME	:11:12:41	13:01:16	109 (min)	Purpose code: 1
LOG	:3355.57	3363.10	0.32	Area code : 3
FDEPTH:	10	10		GearCond.code: 1
BDEPTH:	44	44		Validity code: 1

Towing dir: 350ø Wire out: 180 m Speed: 4 kn*10

Sorted: Kg Total catch: 17.25 CATCH/HOUR: 9.50

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachinotus ovatus	CARTC03	5.61	15	59.05	
Scomberomorus tritor	SCMSM01	2.86	1	30.11	
Sarda sarda	SCMSA01	1.02	1	10.74	
Total		9.49		99.90	

PROJECT STATION:2504

DATE: 4/ 5/98 GEAR TYPE: PT No: 4 POSITION:Lat S 942
Long E 1309

	start	stop	duration	
TIME	:16:07:05	17:02:19	55 (min)	Purpose code: 1
LOG	:3372.44	3376.28	3.74	Area code : 3
FDEPTH:	5	5		GearCond.code: 1
BDEPTH:	31	42		Validity code: 1

Towing dir: ø Wire out: 180 m Speed: 4 kn*10

Sorted: 61 Kg Total catch: 662.10 CATCH/HOUR: 722.29

SPECIES		CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Sardinella maderensis	CLUSL02	399.05	1968	55.25	3957
Sardinella aurita	CLUSL01	277.85	1164	38.47	3958
CARCH01		25.64	168	3.55	
Scomber japonicus	SCMSC01	8.18	12	1.13	
Sphyraena guachancho	SPHSP01	5.35	12	0.74	
Trachinotus ovatus	CARTC03	5.13	12	0.71	
Trachurus trecae	CARTR02	1.11	48	0.15	
Total		722.31		100.00	

ANNEX III

Shoal Tracking Angola 1998

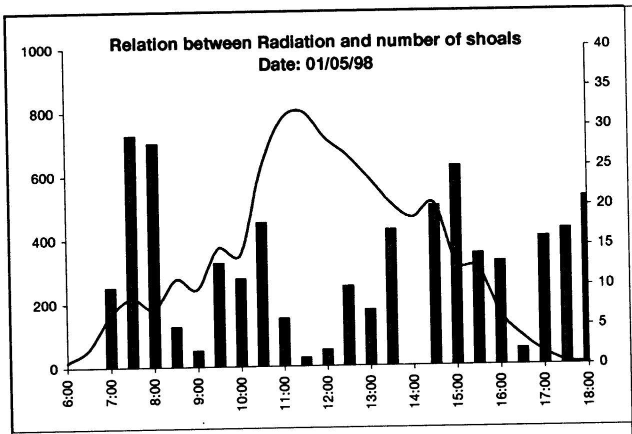
	Speed (m/s)	N speed (m/s)	E speed (m/s)	Heading (°)	Depth (m)	Time	South (°)	East (°)	N (Observ.)
School 1	1.28	1.27	0.14	8	5	12:14	16.65	11.77	1
School 2	1.14	0.23	-0.67	223	11	09:47	12.13	13.61	2
School 3	0.31	0.05	0.75	81	34	10:05	12.14	13.62	3
School 4	1.34	-0.15	-1.1	266	9	10:22	12.15	13.62	4
School 5	1.06	0.59	-0.11	180	15	11:06	12.16	13.62	5
School 6	1.2	0.4	-0.76	290	25	12:07	12.18	13.61	6
School 7	1.67	-1.07	1.28	130	14	15:00	12.1	13.63	7
School 8	-	-	0.3	-	12	15:24	12.11	13.63	8
School 9	1.57	0.2	1.5	84	7	08:37	11.74	13.7	9
School 10	1.18	0	1.2	90	8	09:21	11.74	13.71	10
School 11	1.14	0.76	-0.33	272	17	16:12	11.69	13.72	11
School 12	0.36	-0.08	0.02	258	7	16:35	11.7	13.71	12
School 13	2.18	0.61	-1.82	284	8	16:54	11.7	13.71	13
School 14	2.04	-0.41	-1.96	257	17	17:17	11.71	13.71	14
School 15	2.15	-0.21	2.1	96	12	07:28	11.84	13.7	15
School 16	1.95	-0.34	1.6	97	12	11:01	11.69	13.66	16
School 17	2.09	0.88	1.74	65	11	12:07	11.7	13.69	17
School 18	1.1	0.04	0.95	86	11	12:40	11.71	13.7	18
School 19	1.57	0	1.51	91	11	15:35	11.87	13.72	19
School 20	1.26	-1.05	0.6	161	8	16:01	11.87	13.72	20
School 21	1.86	-1.56	0.63	157	8	16:15	11.86	13.72	21
School 22	-	-	1.07	-	22	06:55	9.71	13.03	22
School 23	1.27	0.5	0.77	73	10	08:31	9.68	13.12	23
School 24	1.66	-0.38	1.41	104	7	09:24	9.69	13.13	24
School 25	0.53	-0.24	0.48	121	7	09:44	9.69	13.13	25
School 26	1.76	0.05	-0.2	201	12	15:36	9.68	13.12	26

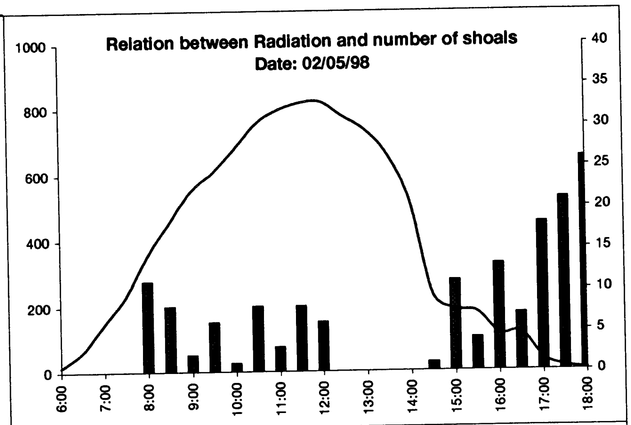
ANNEX IV

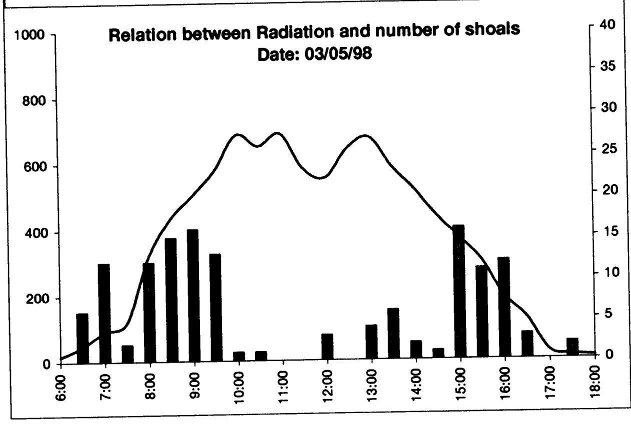
Shoal Behaviour   Angola 1998

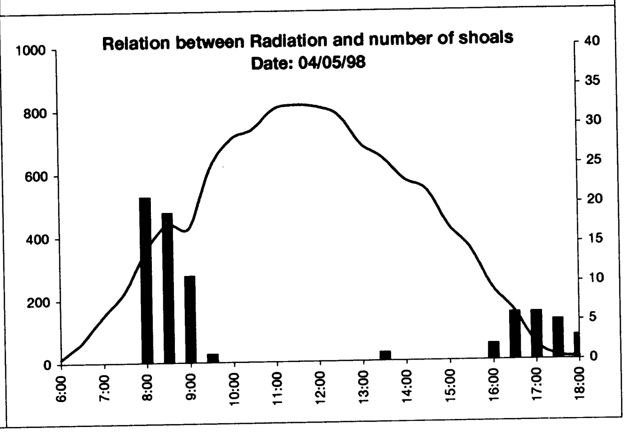
			SHAPE							INTRASCHOOL EVENTS					INTERSCHOOL EVENTS		
	Time	Duration	Circle	Oval	Rod	Crescent	Ring	Amorph	Fragmented	Change of shape	Re- organising	Splitting	Leaving	No. of events	Join	Approach	No. of events
School 1	12:12	6	-	-	-	-	-	-	5	5	-	1	-	6	-	-	-
School 2	09:34	37	-	-	-	1	1	3	1	4	2	-	-	6	1	-	1
School 3	10:03	5	-	-	1	-	-	-	1	1	-	-	-	1	-	-	-
School 4	10:17	10	-	-	1	1	-	2	-	4	-	-	-	4	-	-	-
School 5	10:32	72	6	6	4	6	-	2	3	27	-	1	1	19	3	-	3
School 6	11:48	44	5	1	2	1	-	-	-	5	-	2	-	7	-	-	-
School 7	14:55	14	-	3	2	-	-	-	3	8	-	2	-	10	-	-	-
School 8	15:23	4	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-
School 9	08:11	50	1	4	5	2	-	1	-	13	-	2	-	12	2	-	2
School 10	09:11	30	-	2	3	4	-	-	1	9	-	1	-	10	3	-	3
School 11	16:05	14	-	1	1	-	-	1	1	4	-	1	-	5	-	1	2
School 12	16:33	4	-	1	1		-	-	1	2	-	-	-	2	-	-	-
School 13	16:45	20	1	3	-	2	-	2	1	9	-	-	-	9	2	-	2
School 14	17:09	12	-	1	1	-	-	1	2	5	-	2	-	7	1	-	3
School 15	07:13	30	1	-	1	1	-	-	1	4	-	-	-	4	-	1	1
School 16	10:46	35	4	1	1	-	-	-	2	8	-	1	-	9	1	1	3
School 17	11:49	36	3	4	5	1	-	-	-	13	-	2	1	16	2	-	2
School 18	12:33	16	-	-	3	1	-	-	1	5	-	-	-	5	2	-	2
School 19	15:26	20	-	1	-	-	-	-	1	2	-	1	-	3	2	-	2
School 20	15:52	16	-	-	-	1	-	-	2	5	-	-	-	3	-	-	-
School 21	16:10	10	-	-	-	-	-	-	1	1	-	-	-	1	2	-	2
School 22	06:54	4	-	1	-	-	-	-	-	1	-	-	-	1	-	-	-
School 24	08:02	57	1	-	4	2	-	2	2	11	-	1	1	13	2	1	3
School 25	09:15	16	-	-	2	-	-	1	-	3	-	3	-	6	1	-	1
School 26	09:39	10	-	2	-	-	-	-	-	2	-	1	-	3	-	-	-
School 27	15:28	22	-	-	-	1	-	-	2	3	-	2	-	5	2	-	2
TOTAL	**-**	**594**	**22**	**31**	**37**	**24**	**1**	**15**	**34**	**154**	**2**	**23**	**3**	**167**	**26**	**4**	**34**

ANNEX V: Relation between radiation and number of shoals at surface (Times in UTC)

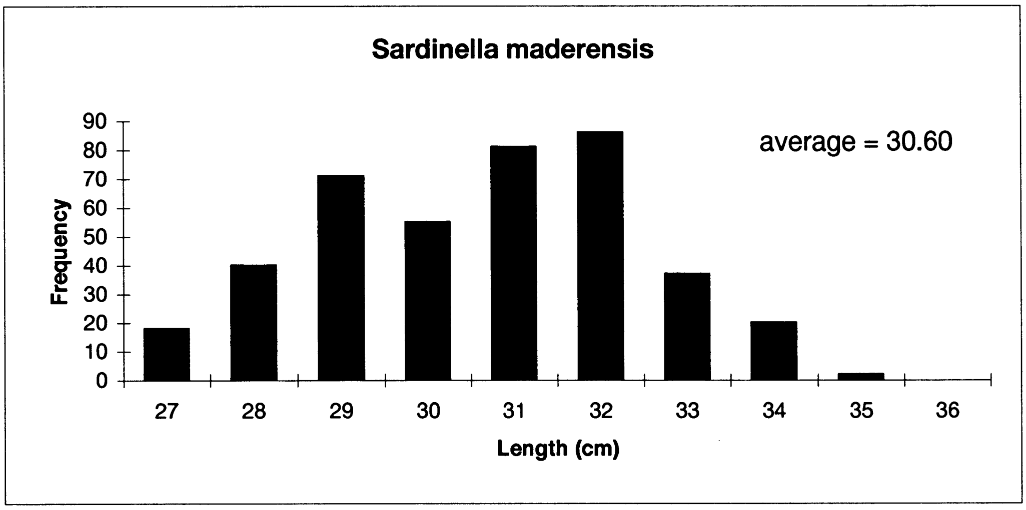


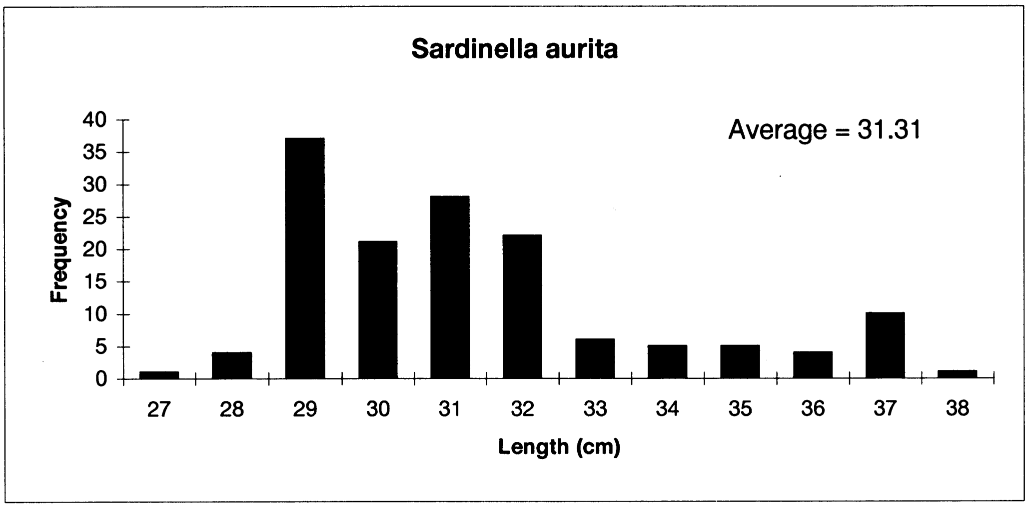






ANNEX VI Length frequency of each sardinella species





CHAPTER 3 Testing of the Simrad SF 950D, and development and testing of SODAPS

1 INTRODUCTION

1.1 Background and objectives

The fish school mapping sonar Simrad SF 950D is a rebuilt and upgraded version of the mine hunting sonars Simrad SA 950H and SF 950M. This has required partly new hardware (HW) and completely new software (SW). For the HW case the rebuilding has mainly been performed ashore in Horten, Norway while the upgrade i.e. the installation, commissioning and system testing took place during two short cruises in December 1996 and April-May 1997 onboard "Dr. Fridtjof Nansen" by personnel from Kongsberg Simrad AS, Horten, Norway and from the Institute of Marine Research (IMR). For the SW case the upgrade took place during the aforementioned cruises plus an additional one in December 1997. The last version of a considerable part of the SW and thereby some of the sonar performance could not be tested due to time shortage and unfavourable weather condition during the last cruise.

SODAPS (Sonar Data Processing System) is a work station based software system to be connected to the SF 950D for logging, on-line monitoring and postprocessing of sonar data. The system has been specified, modelled and coded during a co-operative R&D project between the IMR and Christian Michelsen Research AS (CMR), Bergen, Norway. The system is rather complex by its structure as well as by its performance, particularly when running in the on-line mode (under-way mode). It runs comparative tests between every sample of the backscattering coefficient (s_v) to a maximum sampling frequency of 5 kHz (range resolution 0.15 m) of all 32 sonar beams and likewise between neighbouring beams - all in each ping up to a pulse repetition frequency (ping rate) of 175 per minute (shortest sonar range 75 m). During these detections it forms so-called echo lines and echo blocks. Thereafter it tests and compare between consecutive pings to form echo block chains or school candidates. Echo lines, echo blocks, echo block chains, and school candidates are all elements of potential schools.

We have previous to this survey worked with SODAPS onboard RV “Dr. FRIDTJOF NANSEN” during three short periods: The first period was in Moroccan waters during 7 to 13 Dec 1996 when we implemented and carried out the first testing and tuning of the system, version (V) 1.00, developed software modules for storing school data as well as both raw and processed data storing took place. The spatial distribution of mainly small schools was not favourable for testing and further development neither during the survey nor at the data lab in Bergen. The second period was during a survey in Angolan waters with major activities during 25 - 28 April and reduced activities further on to 13 May 1997. The SODAPS, V1.01, was again implemented, debugged and modified where this was required, and functionally tested on school data. The third period was in Moroccan waters during 6 to 17 Dec 1997 when we implemented an improved system version, V 1.02, carried out testing, tuning and increasing the efficiency of the system as well as storing data for later applications. The conditions regarding school occurrences were unfavourable and rather similar to those of December 1996.

2 METHODS

2.1 Performance of Simrad SF 950D sonar

Since the last version of a considerable part of the SW and thereby some of the sonar performance could not be fully tested during the cruise in December 1997 we had to put special attention to the performance of the sonar from both quality control aspects as well as the importance of being the first qualified user of the SF 950D being able to set some standards. This was to be done by systematically changing sonar parameter settings under different target tracking situations and watch its performance against specifications and sonar operation experience from the previous SA 950Hs and other sonars.

2.2 Sonar measurement of a buoy target

Specific controlled testing of the sonar was performed against an artificial target made up from six air filled hard plastic spheres mounted stringwise. The diameter of each sphere was 13” = 0.33 m with a penetrating hole right through it. Its target strength was roughly estimated to -21.7 dB while for the whole string it was - 13.9 dB plus a smaller contribution from a weight of ≈120 kg hanging ≈5 m below the sphere string. The target was hanging ≈15 m below a large surface buoy.

A special operation programme was designed. This included runs with the vessel going against the target, runs while passing the target at different distances at port side, and finally a number of runs lying the vessel quiet having the target at a favourable position while systematically changing specific sonar settings. During the whole programme the sonar display was to be recorded on video tape and SODAPS data were to be stored to files and thereafter to DAT tape.

2.3 Implementing, testing and tuning of SODAPS

The software system was to be implemented on a new work station (HP Visualize C160 with monitor HP A43331D). Thereafter the system was to be optimised, made more efficient, and improved where this will be required, and functionally tested on school data. Particular emphasise had to be put into target detection and selection modules, the status and control rulers of the different windows, efficient storing of large data quantities, and a report generator for data to be read by host computers. A HP PaintJet colour printer is connected to the computer with its interface and driver. Specific software modules to map the echogram data from the computer to the printer as well as operational sonar data had to be specified, coded and tested. SODAPS data should be stored on tapes for further testing, tuning and improvements at CMR and IMR.

3 RESULTS

3.1 Performance of the sonar SF 950D

During the survey in Namibian waters 17 to 27 April the spatial distribution of mainly small schools of pilchard and horse mackerel was rather scattered. There were large amounts of jellyfish distributed over the major part of the survey area. These high jellyfish densities were responsible for strong volume reverberation. Therefore the conditions for detailed sonar performance testing were not favourable. The sonar conditions (sound propagation conditions) were rather excellent for the surveyed area south of S 21^{o} 40” and at bottom depths more than 100 m having nearly constant sound velocity profiles from the surface to 25-40 m depth with an average sound velocity of 1511 m/s. From these depths the sound velocity was slightly decreasing with an average gradient of - 0.07 m/s per metre down to the bottom. Outside this area i.e. north of S 21^{o} 40” and at bottom depths less than 100 m the sound velocity profiles were more varying around and average sound velocity of 1512 m/s in the upper 0 to 20 m and an average gradient of - 0.09 m/s per metre to the bottom.

During considerable effort on sardinella school tracking in Angolan waters we were able to evaluate the sonar performance during good weather and low volume and surface reverberation conditions. During these exercises we had nearly constant sound velocity around 1536 m/s from 0 to ≈5 m and then a negative sound velocity gradient varying between - 0.47 to - 0.90 m/s per metre to the bottom. This made the sonar conditions worse than in Namibian waters.

Target identification and tracking:

In medium to strong volume reverberation situation (high jellyfish densities) - sea state 1, wind force v_w: 3-5 m/s: Weak targets (small schools): The sonar target identification module seems to have a too low signal/noise criteria (fixed +10 dB dynamic linked to the estimated noise level). Many surface reverberation echoes are classified as targets. Having schools of medium to low packing density or school entities of small and varying clusters the target estimator identifies the real target entity as many smaller entities giving them individual identifiers. Suggested solutions: 1): Extend the target or markers menu with appropriate communication to control this process from the keyboards (sonar and computer) from which one may vary the fixed signal/noise interval in steps of 3 dB from approximately 10 to 20 dB. 2): Put a new module on top of the present target estimator which relates a range environs of controllable radius to each identified target. If two or more target environs overlap join them into one targets. 3): Put a new module on top of the present target estimator which bases its detection algorithm on a “school” concept. The detection criteria should be founded on the principle that schools yield high backscatter, have horizontal extents, and move within certain limits from ping to ping.

We have observed that for small and medium sized schools artificial targets (ghost schools) of slightly reduced size and strength compared to the real targets are generated 5-15^o to one side of the real target in the middle 30^o of the beam fan. By training the transducer 10-20^o the artificial target disappears. This was consistently observed during the controlled observations of the buoy target as well as during many school trackings in Angola. An underlying feature of this artifact may also be demonstrated with no targets on the display. While increasing the gain two beams 20-30^o apart regardless any targets are amplified and appear "stronger" than neighbouring beams. Likely reasons may come from the beamforming itself and/or if any element(s) of the transducer or preamplifier and its A/D converter are malfunctioning.

An improved train angle indicator which highlights when the beam fan is directed forward would be advantageous particularly for the navigators.

A serious shortcoming was impeding much our target tracking activities due to the lacking manual marker(s) function for automatic tracking. This function should be reinstalled (compared to SA 950H) at the very first occasion.

Transmission modes:

CW short/medium/long:

* In medium to strong volume reverberation situation (high jellyfish densities) - sea state 1, wind force v_w: 3-5 m/s : Minor stretching of the target along each beam, clearer displaying as the pulse length increases (within specification).

FM 1/2/4/8:

* Test conditions as for the CW case: Switching from FM 1 (equals CW short) to FM 2 thereafter to FM 4: Improved presentation -suppressing reverberation and clearing the school target (within specification). Switching from FM 4 to FM 8: School target is displayed also by the sidelobes - appears across the whole beam fan (outside specification).

AGC test:

* In low reverberation situation - sea state 0, wind force v_w: 2-4 m/s : Start position AGC off, transducer tilt -5^o, excellent clear display with strong targets

(schools) and minor surface reverberation: Switching the AGC on introduces considerable amounts of weaker surface reverberation echoes (noise) and reduces the target presentation in extent and colour strength regardless the gain response. Switching the AGC off again. The weaker reverberation echoes being over the whole display disappeared i.e. excellent picture (outside specification). The “phenomena” resembles as if there was a constant gain regardless the backscattering strength and distribution when having the control on.

* AGC on - setting: Slow => medium => fast: The surface reverberation echoes does not disappear and the target is increasingly degraded (smeared out) and the reverberation echoes are chopped up by increasing gain response (outside specification).

Reverberation filter test:

* In low reverberation situation - sea state 0, wind force v_w: 1-3 m/s, transducer tilt -5°, reverberation filter off. Display with small to medium targets (schools), some surface reverberation. Reverberation filter on - setting: Weak => medium => strong: Suppressing more and more of the reverberation by increasing filtering while the targets appear unchanged (within specification). To good weather conditions for a qualified test.

Ping to ping filter test:

* In low reverberation situation - sea state 0, wind force v_w: 1-3 m/s, transducer tilt -5°, p-p filter off. Display with small to medium targets (schools), some surface reverberation. P-p filter on - setting: Weak => medium => strong: Suppressing more and more of the reverberation by increasing filtering and stabilising the targets but smoothing them out by area to some extent (within specification). To good weather conditions for a qualified test.

* The smoothing and extending of echoes along their tracks is often conceived as a noisy presentation unlike the original SA 950H sonars.

Other observations

Now and then the sonar goes down. The most simple action getting it operative again is to make a soft restart from the two specific buttons on the display unit keyboard. If that doesn´t work further action is to switch off and on the automatic main fuses within the Servo Unit. During the down state some of the controls from the display unit keyboard may virtually still be operated. We have not traced any particular reasons for the down states. It has happened occasionally when hoisting the transducer, but not as rule.

When operating the sonar connected to a computer and utilising the remote control to change sonar settings the menu on the internal sonar control is not updating the changed settings on the display. Suggested solution: Watch any changes or read the sonar settings and update them when remote controlled changes have been detected.

We experienced some impedes during failure findings both in hardware and operation cases due to lack of updated sonar documentation i.e. due to the revised operation manual which is not completed as well as other manuals which cover the original SA 950H version and not the SF 950D rebuilding and upgrade.

3.2 Sonar measurement of a buoy target

The operation programme was followed as planed. We made two runs with the vessel going against the target, three runs while passing the target at distances of 60, 150, and 205 m at port side, and finally seven runs lying the vessel quiet with the target at ≈150 m distance while systematically changing the automatic gain control (AGC), the gain, the reverberation filter, and the peak to peak filter. The sonar display was recorded on video tape during the whole exercise and SODAPS data were stored to files. All details of the different observation modes and sonar settings are presented in Table 3.1 with supplement, Appendices I. Preliminary results and gained experience are evaluated and included in chapter 3.1 while more results will be achieved during analysing stored SODAPS data and the video tapes.

3.3 Implementing, testing and tuning of SODAPS

During this survey we performed similar tasks to those in April and December last year with major effort from 17 to 27 April and slightly reduced effort till 5 May.

The very first days of this cruise in Namibian waters were devoted to commissioning the new computer and implementing and testing the software to run satisfactory on it as well as the connection to the sonar to communicate with and deliver specified data to SODAPS. The replaced work station was also connected to the network so two persons were able to work with SODAPS related tasks at the same time. Thereafter while working in Namibian waters the work was concentrated on improving the school candidate detection and selection modules, on providing specific data report formats to be read by host computers with data analysing and presentation software. The spatial distribution of mainly small pilchard and horse mackerel schools in Namibian waters was not favourable for high quality testing and improvements.

Specifying, coding and testing software for the colour printer functioning continued during the survey in Angolan waters. The main effort was put into providing improved algorithms and codes to relate the total echo intensity interval to the selected colour palette for the printer. The software for the colour printer was worked up to a certain degree of completion depending to some extent on the performance of the other SODAPS software.

Figures 3.1 and 3.2 display some present versions of the echogram printouts where the sonar has a constant train angle of 90° to port side and where the sonar is directed forward. A number of school are displayed as they pass through the 45° beam fan and approaching the vessel respectively.

Along the Southern Angolan coast we also made some simplified SODAPS performance tests on mainly sardinella schools of varying size and density as well as stored data for later analyses at the data lab in Bergen.

The main modules of SODAPS which are not functioning as required are: The detection algorithms related to echo lines, echo blocks, and echo block chains with their thresholds and parameter limits of absolute character (can be changed), and the selection algorithms for echo blocks and echo block chains tends systematically to break up school entities into many smaller entities i.e. school candidates with own identifiers. These features make it very difficult, problematic and time consuming to perform postprocessing and interpretation of the recorded data. Related to this is also that the specific “join” function during these occasions doesn´t perform as expected.

Cues for redesign and improved functioning are: Include elements of adaptive data processing, combine relative thresholding with absolute ones, acceptance of losing a few “micro schools” on achievements of handling school candidates over a rational size to simplify the postprocessing and interpretation of school candidates.

We have provided a specific data report format to be read by host computers with data analysing and presentation software. This format is at a decided data level, but for some qualified users and software applications we should decide on providing another data report level to pick up data of more raw character.

We have not till now put enough attention into the total man-machine interface to make the system user-friendly as required. This is specially the case for postprocessing and interpretation activities but also for typical underway operated windows as for instance the ShowPing and LogParameters. Dedicated effort must allocated for this task.

4 CONCLUDING REMARKS

At the present state the SF 950D is not fulfilling specific quality requirements. Target images are displayed in different ways depending of where within the beam fan they appear, it creates ghost targets, and some of the main signal controls are malfunctioning. The marker tracking function is not implemented neither in the true motion mode nor in the sector mode. The target estimator and tracking functions make mono-target entities into multi-target entities. It is vital that the final rebuilding, upgrade and testing of the SF 950D continue at Simrad and onboard the vessel.

We have to put more effort into improving and optimising the SODAPS system to function properly. While the system at present state tends systematically to break up mono-school entities into multi-school entities led to that we were not able to do any proper school measurements which was supposed to be a likely outcome of the cruise. Dedicated effort on SODAPS has to be carried out at the SODAPS Lab in Bergen.

CHAPTER 3: FIGURES

ANNEXES

ANNEX

I Operational data with supplement from the buoy target measurement.

Table 3.1. Testing of sonar performance, April 25 1998. Abbreviations: CWx- continous wave, x - short, medium or long pulses, FM# - frequency modulated pulses, # - number, 1-4 different frequencies used in a puls series, p - port side, v_w - wind force [m/s].

	Observation mode & settings							
Run no	**Sonar range [m]**	**Tilt [°]**	**Train [°]**	**Puls form CW x/FM #**	**Vessel cource [°]**	**Vessel speed [knots]**	**Time [hrs min s]**	**Comments**
							08 55 xx	Target dropped and ready for the test.
1	1200	- 5	0	FM 4	75	5	09 10 xx	SE wind, v_w = 4.1 m/s. AGC off, rev. filter off, p.p. filter off,
								power - full, gain 5. Target from 650 m (0.35 NM),
	600							Changed range.
	300							Changed range.
2	300	- 5	90 p	FM 4	78	5	09 41 xx	v_w = 5.6 m/s. **Target distance** 60 m off port side. Other ones as 1.
3	300	- 5	90 p	FM 4	75	5	10 09 30	v_w = 4.8 m/s kn. **Target distance** 150 m + seals =>. Other ones as 1.
4	300	- 5	90 p	FM 4	75	5	10 34 55	v_w = 4.8 m/s. **Target distance** 205 m. Other ones as 1.
5	600	- 5	0	FM 4	90	5	11 36 xx	v_w = 6.2 m/s. As run 1.Target from 495 m.
	300	- 5	0	FM 4	90	5	11 37 40	Target out of beam - right side ≈ 60 m, 11 39 10 hrs.

6	300	- 5	0	FM 4	90	0	11 45 00	v_w = 5.9 m/s. An artificial target generated at the same distance
								250 =>150 m and 10-15° to sb of original target. Other ones as 1.

Table 3.1, cont. 1

Run no	Sonar range [m]	Tilt [°]	Train [°]	Puls form CW x/FM #	Vessel cource [°]	Vessel speed [knots]	Time [hrs min s]	Comments
6, c.	300	- 5	0	FM 4	90	0	11 54 05	**AGC** on. AGC generates noise.
							11 56 30	**AGC** off. The noise disappears.
7				FM 1=CW sh			11 57 30	To FM 4 at 11 58 43 hrs.
8							11 59 07	**TVG** to 30 log R
							12 01 10	**TVG** to 10 log R. Generates noise near the vessel.
9							12 02 50	TVG to 20 log R. **Gain** to 7.
							12 04 05	**Gain** to 3. Back to 5 at 12 05 10 hrs.
10		0					≈12 05 30	Varying **tilt angles**.
		- 7					≈12 06 00	
		- 12					≈12 06 15	

		- 16					≈12 06 50	
		- 19					xx xx xx	Target out of beam. Tilt to - 5 at ≈ 12 07 45 hrs.
11		- 5					12 09 00	**Rev. filter** to weak.
							12 09 35	**Rev. filter** to medium.
							12 10 05	**Rev. filter** to strong.

Table 3.1, cont. 2

Run no	Sonar range [m]	Tilt [°]	Train [°]	Puls form CW x/FM #	Vessel cource [°]	Vessel speed [knots]	Time [hrs min s]	Comments
12	300	- 5	0	FM 4	90	0	12 10 30	Rev. filter off. **P.p. filter** to weak.
							12 10 55	**P.p. filter** to medium.
							12 11 25	**P.p. filter** to strong.

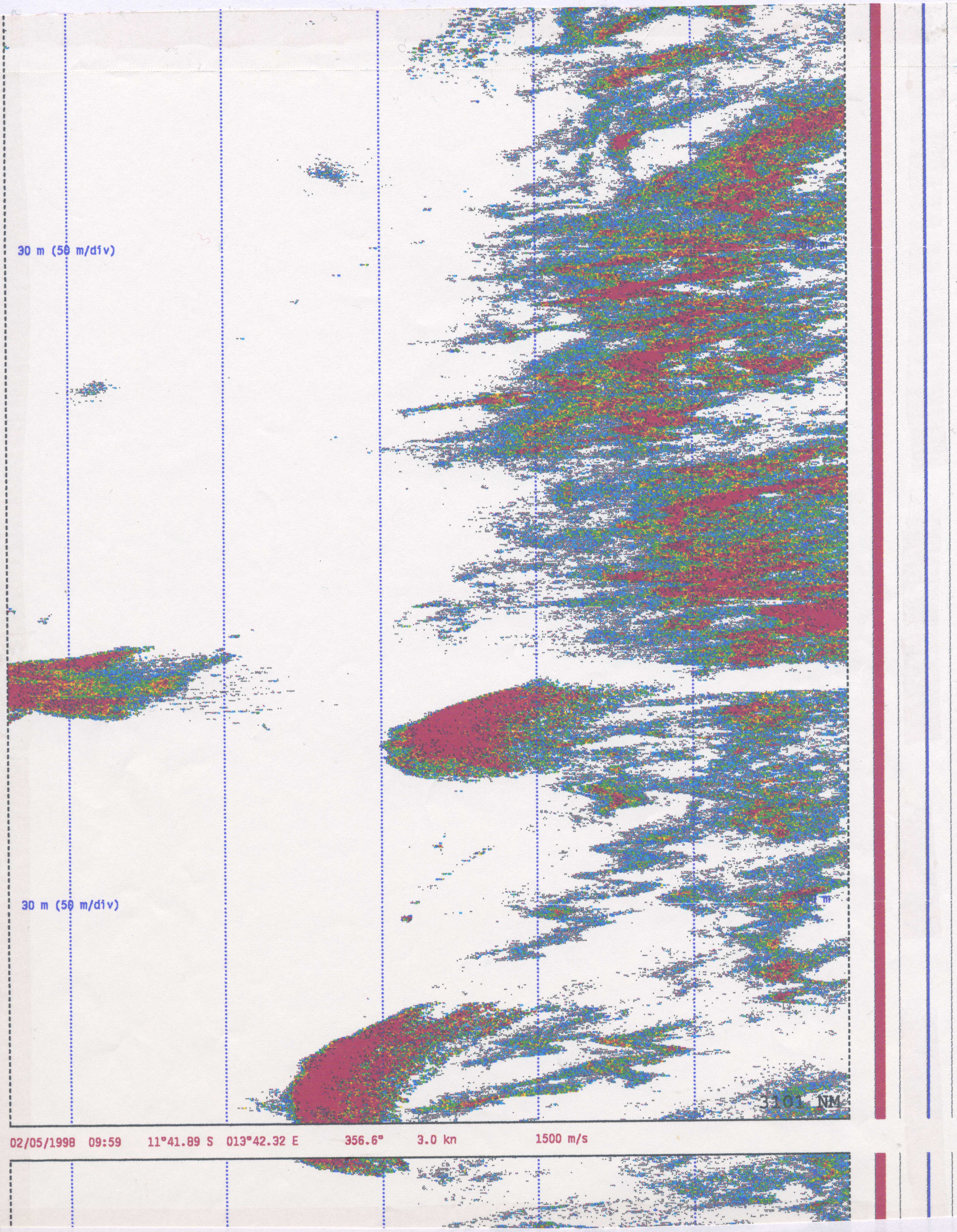


Figure 3.1. Sonar echogram during school tracking activities. Train angle 90° port side.

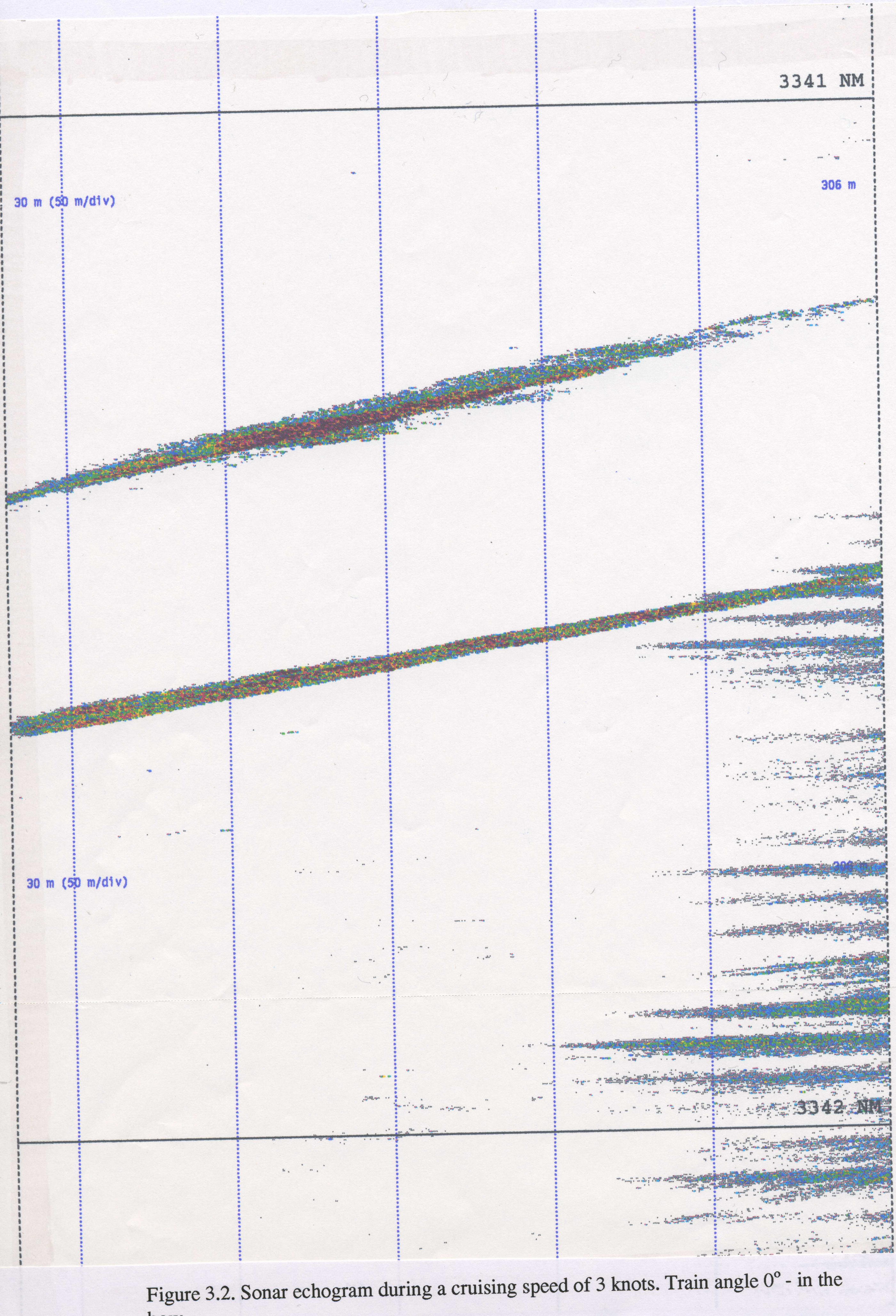


Figure 3.2. Sonar echogram during a cruising speed of 3 knots. Train angle 0° - in the bow.

Supplement to Table 3.1: Details from the buoy target experiment

Run 1:
Surface reverberation (SR), r < 200 m, varying with the swell/ship´s motion, volume reverberation low.
r ☜ 650 m: real target (TR) visible,
r < 300 m: TR in 3-4 beams,
r < 100 m: TR sometimes hidden in SR.

Run 2:
SR at 50 < r < 200 m, SR weaker as in Run 1 (beam fan (BF) parallel to swell),
TR weaker in outer 10^o of BF on both sides.

Run 3:
An artificial target (TA) at 10-15^o to the side of TR, TA weaker than TR by area and strength, TA visible in the central 30^o sector of BF.

Run 4:
TR in 3-4 beams => ≈ 15-20 m width,
TA seen before TR when coming into BF upper right.

Run 5:
SR at 30 < r < 200 m,
r ☜ 495 m: TR in 1 beam, 1 range ring,
150 < r < 300 m: TR in 2-3 beams.

Run 6:
SR at 40 < r < 300 m,
TR in 2-4 beams,
TA at sb side of TR for r < 250 m, TA weaker than TR by area and strength,
TR out of BF 11 47 25 hrs,
TR into BF for r = 222 m, 11 48 00 hrs,
TA visible 11 48 20 to 11 53 50 hrs.

AGC test:
AGC off => on, slow, TR at r ≈ 195 m, SR increased 30 < r < 250 m, TR well visible,
=> AGC off => SR decreased.

Run 7:
Transmission modes - short test: r ≈ 172 m, FM 4 => FM 1 (CW short): SR decreased substantially, to very weak, i.e. excellent picture.

Run 8:
TVG (x log r) test: FM 4: TVG (20) => TVG (30), lower SR than TVG (20),
TVG (30) => TVG (10), increased SR to strong (red).

Run 9:
Gain (G) test: r ≈ 185 m, TVG (20), TR and TA well visible: G 5 => G 7 => increased SR substantially 0 > r > 300 m, SR more pronounced at the left part of BF,
G 7 => G 3: SR decreased substantially, clear display, TR visible.

Run 10:
Visible TR vs. transducer tilting (θ) test: θ(- 5^{o}) => θ(0^{o}): TR well visible, increased SR at 60 < r < 300 m, TA also well visible.
θ(0^{o}) => θ(- 7^{o}): TR well visible, decreased SR for r_{tot}, clean display.
θ(- 7^{o}) => θ(- 12^{o}): TR visible, clean display.
θ(- 12^{o}) => θ(- 19^{o}): TR not visible,
back to θ (- 5^{o}); => TR well and TA visible.

Run 11:
Reverberation filter (RF) test: FR off => weak; TR well visible, SR slightly decreased, SR more grained.
FR weak => medium; TR as previously, SR even more decreased and even more grained,
FR medium => strong; SR even more grained, SR colour from blue to light blue and white.

Run 12:
P-p filter (P-p F) test: (P-p F) off => weak: TR more distinct (as is TA), visible SR slightly decreased, SR smoothed.
(P-p F) weak => medium: TR more stable, SR attenuated and even more smoothed,
(P-p F) medium => strong; TR very stable, SR even more attenuated/removed, SR chopped.

Record of daily activities, cruise 1998404, R/V "Dr. Fridtjof Nansen"

16/4

Dalen, Misund, Norbø, Totland arrived 22:30 after having been delayed due to car breakdown near Windhoek International airport. Short meeting with Bendik and Steinar Olsen.

17/4

Meeting with Dave Boyer after breakfast 07:30. Departing Walvis Bay harbour 09:00. Cruise meeting at 12:15 - 13:00. Start surveying north along the coast at the 200 m isobath. No recordings.

18/4

Surveying southwards along the coast. SODAPS meeting 09:00 - 14:00. Very nice weather. PT2458, catch 0.6 kg, mostly Trachurus. Trawl full of jellyfish after few minutes trawling. BT2459, catch 117 kg hake and horse mackerel, jellyfish. PT2460: 551 kg horse mackerel, Jellyfish. PT2461: 268 kg, mostly round herring, pilchard and horse mackerel, jellyfish. PT2462: 38 kg, Sufflogobius bibitaratus, round herring, pilchard.

19/4

Surveying northwards/southwards along the coast. Good weather. Recordings of round herring, pilchard and horse mackerel. PT2463, 773 kg horse mackerel. PT2464: 69 kg horse mackerel. PT2465: 14 kg horse mackerel, jellyfish. PT2466, 15 tons pilchard, "surgical" trawling, shooting trawl doors when school recorded by echo sounder, entrance recorded at net sounde two min later, jellyfish. Haul lasted 11.5 min. PT2467: 923 kg, pilchard, round herring, and some horse mackerel. PT2468: 418 kg horse mackerel and pilchard, jellyfish, haul lasted 15 min.

20/4

Surveying southwards/northwards along the coast. Very good weather. Recordings of round herring and horse mackerel. Passing through fleet of 3 local purse seiners which was pumping onboard cathes from night-time sets (one of them former “Klaring”) when heading eastwards around 07:00. PT2469: 148 kg horse mackerel, haul lasted 13 min before trawl was full of jellyfish. PT2470: 224 kg horse mackerel. Trawl full of jellyfish after 14 min. PT2471: 20 kg horse mackerel. PT2472: 62 kg horse mackerel, jellyfish filled trawl after 13.5 min. PT2473: 51 kg horse mackerel, 17 min trawling. PT2474: 30 kg mostly round herring.

21/4

Arriving Walvis Bay 11:00. Steinar and Bendik Olsen onboard for Official Lunch for celebrating his 70th birthday. Partizipated in Birthday Reception at NATMIRC in Swakopmund at 17:00, and at Birthday Dinner at Hansa Hotel.

22/4

Vessel cleared for departure at 08:00. Permission to leave harbour 09:30. Planned to run same survey tracks but in opposite direction. This will give data-sets for comparing replicability of acoustic survey estimates, and possibilities to study day/night influence on estimates as most of the tracks now will be covered at different times of day. Good weather, some swell from west. PT2476: 12 kg horse mackerel.

23/4

Fresh breeze from south west. Heavy swell. PT2477: 167 kg, horse mackerel and 20 kg round herring. PT2478: 181 kg, 3 kg round herring. PT2479: jellyfish. PT2480: 5 kg horse mackerel. PT2481: 36 kg horse mackerel. PT2482: jellyfish. PT2483: 10 kg horse mackerel.PT2484: 6 kg horse mackerel, jellyfish. PT2485: 20 kg horse mackerel: jellyfish. Some pilchard recordings in the area S 21 41’ E 13 37’, but none of the trawl trials were successful (PT2482 - PT2485).

24/4

Very good weather.PT2486: catch 172 kg, horse mackerel, a few kilo round herring, PT2487, 382 kg horse mackerel, PT2488, 72 kg horse mackerel, round herring, pilchard, PT2489: 107 kg horse mackerel, sardine and round herring.

25/5

No wind. Sunny. Sonar measurement of buoy target with varying range and sonar settings according to specified procedure. Measurements documented by video of sonar image and recording by SODAPS. Surveying southwards along the outer transect. PT2490：catch 18 kg horse mackerel and hake.

26/4

Surveying towards Walvis Bay. PT2491: Catch 351 kg, mostly *Sufflogobius Bibarbatus*, cleaning trawl. Arriving Walvis Bay 11:00, a warm sunny day.

27/4

At quay in Walvis Bay. Agent onboard 10:30. Sending home HP workstation. Warp, echo sounder and SAS software delivered onboard 11:00. Per Erik Norbo leaving the vessel for travelling to Norway tomorrow. Meeting with Bryce Edwards and skipper of Chris Andra about use of lights for attraction of horse mackerel for purse seining. Departure 12:30. Steaming north to Angola.

28/4

Steaming to Angola, good weather, working on Cruise report, sending ICES abstracts (3 abstracts based on activity during the sonar cruises, and one on aggregation behaviour of sardinella) to IMR for transmission to ICES Secretariate.

29/4

Arriving at Baia dos Tigres at 08:00. Surface school observer at bridge, Calibration of EY500, BT2492, catch horse mackerel (Decapturus), 1st small boat experiment in Baia dos Tigres, 14:00 - 16.00. Tereafter sailing north towards Lobito.

30/4

Sailing northwards close to the coast. Surface school observer at bridge, Passing Benguela 16:00, observing several dolpin herds, more than 100 animals in many of them, dolpins cruising in front of the bow, one with two parasitting shark-succers attached. PT2494 off Lobito, catch: *Lepthurus*. Stopp at 21:30.

1/5

Start 06:00 at sunrise, overcast but nice weather, transecting closer to shore, surface school observer at bridge, PT2495 on dense school recordings 07:30, plenty of schools appear at surface when shooting trawl, RS-camera mounted in roof of trawl at end of 200 m mesh section. 10 m enlogation of floats, aiming at surface schools, schools diving when 50 - 100 m away from vessel, trawl out of propeller wake, 3 schools passing under fishing line, slowing down speed from 4 to 3 knots to obtain greater opening, fish school entering trawl, increasing speed, towing at 4.5 knots for 10 min to get fish back in trawl, fish visible on RS-camera, slowing down speed during hauling, fish escaping out of trawl, through meshes (RS-camera) and out of entrance (Sonde). Catch: 153 kg, *Trachinotus*, sardinella and horse mackerel. Secchi depth: 10 m. School tracking. Plenty of schools at surface throughout the day. No bird attacks. Schools often convex, moving normal the front of the school, highest density at front of school, fish seem to be feeding, occational surface flashes throuh school, fish in front clearly polarised and synchronised, but low density, fish visible from bow of Nansen, diving slowly when entering the shadow of the vessel. PT2496: 4.1 knots, tow for 0.5 hour after fish entered trawl, RS-recording show fish keeping up with speed of trawl, flash when slow down for hauling, catch: 30 kg, sardinella, Trcahinotus, Sarda sarda. PT2497: 4.1 knots, tow for 1.0 hour after first fish entrance, RS-recording show fish keeping up with speed of trawl for most of the time, seal outside of trawl scare the fish, Scamnar catch sensor alarm after 35 min, flash when slowing down for hauling, large quantities of fish swimming forward and out of the trwl during hauling, catch: some hundred kilos of sardinella. Catch: 501 kg Sardinella, Secchi-depth: 11 m. M.O.B.-transect with EY500 from 19:30 - 21:30 in darkness. Skiff inshore, Nansen offshore, northwards. Moonlight from a rising moon. PT2498: aimed trawling at rather dense shoal, nice entrance and catch sensor alarm after 2 minutes, catch: 424 kg sardinella, and some anchovy, most fish probably swimming out again in this case also.

2/5

Start 06:00 at sunrise, transecting north of Lobito, school tracking from 08:15, M.O.B. transect nr. 3 northwards, skiff offshore, Nansen inshore, 8 nm., good recordings on both. PT2499, no recordings, catch: 20 kg, some *Trachinotus*. Secchi-depth: 9 m. School tracking until 17:30. Then PT2500. Sone-sounder not working properly, catch sensor alarmed after about 15 min. 4.1 knots, dark when ended at 18:30. Catch: 388 kg, Sardinella, horse mackerel, and 11 large Sphyraena guachacho, 17 - 28 kg. Today many schools at surface from 08:00 to 10:00, then nothing until about 15:30 when many small school appeared, obviously moving westwards and offshore, schools seem bigger and moving faster offshore towards sunset. M.O.B. tansect nr 4. Southwards, skiff offshore, Nansen ran nearly into a cano which made a fire and shouted when just in front of the bow.

3/5

Started 06:00 at sunrise, very nice weather, transecting southwards to Lobito, surface school observations, see special notes, school tracking, PT2501 with RS camera, catch 42 kg, only 23 kg sardinella, M.O.B 5, good recordings on both Nansen and skiff, school tracking, PT2502, catch 51 kg, again only 14 kg sardinella, most escaped forward during hauling, sailing north to Cabo Ledo 19:30.

4/5

Transecting north easthwards to Cabo Ledo, about 10 nm off at 06:00, some swell but nice weather, Tracked schools from 08:15, observed schools at surface. PT2503 on recordings, floats teared off, two hours to fix trawl for proper shooting, towed for two hours but no catch of sardinella despite some school recordings during start of tow. School tracking 14:30 - 16:00. PT2504, again problems with shooting, one hour before trawl properly shot off, towed for one hour on good recordings near surface, catch 650 kg sardinella, good RS recordings which again demsontrates flash and forward swimming during hauling. M.O.B 6 northwards off Cabo Ledo, little recordings, M.O.B. crew heared sardinella splashing in surface in several occations, indicates that fish at surface. M.O.B onboard 22:30, sailing north to Palmeirinhas.

5/5

School sighting from 06:00, no recordings of surface or underwater schools from Palmeirinhas to Luanda, vessel entering Luanda harbour 13:00, at quay 14:30. Cruise report production.

6/5

Cruise report production. Sum up meeting. Cruise ended 15:00. Participants depart vessel.