CRUISE REPORT "DR. FRIDTJOF NANSEN"

AN EXPERIMENTAL SURVEY OF THE ABUNDANCE, SPATIAL DISTRIBUTION, SCHOOLING BEHAVIOUR AND ACOUSTIC BACKSCATTER OF THE NAMIBIAN PILCHARD

Preliminary Report: Cruise No 1999407

14 June - 2 July 1999

O.A. Misund, W. Buckle, R. Cloete, J. Coetzee, J. Dalen, I. Fossen, E. Haugland, J. Horne, M. Jech, N. Luyeye, G. Oechslin, M. Olsen & B. Totland

Ministry of Fisheries
& Marine Resources
Republic of Namibia

Instituto de Investigação
Pesqueiro
Republic of Angola

Institute of Marine Research
Norway

TABLE OF CONTENTS

1. INTRODUCTION

1.1 OBJECTIVES

The Namibian pilchard 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.

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 during a cruise by R/V "Dr. Fridtjof Nansen" in

1995. 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 visualisation 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 occasions in 1997 and 1998. This sonar shall be capable of absolute measurements of volume back-scattering strength which enable estimation of school biomass through models of target strength of schools.

The objectives of the survey as stated in the sailing orders from Ministry of Fisheries and Marine Resources, National Marine Information and Research Centre in Swakopmund were to:

1. To test the acoustic survey capabilities of the SIMRAD SF950D sonar and to compare the results with those of the SIMRAD EK500 echo sounder.
2. To obtain a second comparative estimate of abundance using a local purse-seiner equipped with a SIMRAD SR240 sonar.
3. To conduct additional experiments such as shoal counting and biomass estimations on a few selected shoals.
4. To collect information on biological properties (i.e. growth, reproductive stage, etc.) of pilchard.

Originally, the main objective of the survey was to conduct an acoustic assessment of the pilchard stock in Namibian waters, but this objective was abandoned one week before the cruise by Namibian authorities.

1.2 PARTICIPATION

The scientific staff were:

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

  Rudi Cloete, Michael Evanson, Theofelus Kairua, Gerhard Oechslin

- From Instituto de Investigação Pesqueiro, Luanda, Angola:

  N'Kosi Luyeye

- From Marine and Coastal Management, Cape Town, South Africa:

  Janet Coetzee

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

  John Dalen, Ingve Fjelstad, Eli Haugland, Ole Arve Misund (Cruise leader), Tore Mørk, Bjørn Totland, Magne Olsen

- From National Marine Fisheries Service, North East Fisheries Centre, Woods Hole, USA:

  Michael Jech

- From University of Michigan, Cooperative Institute for Limnology and Ecosystem Research (CILER) and NOAA Great Lakes Environmental Laboratory (GLERL), Ann Arbor, Michigan, USA

  John Horne

- From the Namibian Pelagic Fishing Industry (PERMAC)

  Willem Buckle

1.3 SCHEDULE

The R/V 'DR FRIDTJOF NANSEN' departed from Walvis Bay harbour on the 16th of June 1999. It was expected, and indeed happened, that the cruise program had to be adjusted according to performance of acoustic equipment and fish distribution.

CHAPTER 1. NAMIBIAN PURSE SEINING FOR PILCHARD

1. Introduction

The purse seine method of taking fish from the sea has been used in Namibia since the early 1950s. The main species of pelagic fish caught by purseseine in Namibia are 1.Namibian Pilchard (*Sardinops Ocellatus*) 2. Horse Mackerel (*Trachurus Capensis*) 3. Anchovy (*Engraulis Capensis*) 4.Round Herring (*Etrumeus whiteheadi*).

The pelagic industry is of great importance to the people of Namibia as it is a labour intensive industry thus providing many jobs to Namibians . Presently there are five pelagic factories operating in Namibia . Three of the factories are equipped with canneries of which two are EU standard approved . The HACCP system of quality control is used by these factories . The main products these factories produce are canned fish , fish oil and fishmeal . The pelagic industry is seasonal, with the fishing season starting in mid January until the end of August. Industrial fish (for making fishmeal) is caught mainly in the summer months and from March the canneries are supplied with pilchard .

1.2 Vessels and Gear

All purse seiners in Namibia operate out of the port of Walvis Bay. In the early 1950s when purse seine operations were started in Namibia, the vessels were very small and primitive. The average purse seiner of those days were constructed of wood, was approximately 18m in length and could carry between 50 to 80 tons. The nets used then were of the Lamparra design and made of cotton fibre. The net and purse line was hauled in by hand as no power blocks and winches were used on vessels during those years. Sonar equipment was not found onboard and fish detection was done visually (e.g. by watching birds and seals) Vessels seldom worked further than twenty miles from port in those days.

As the pelagic industry was growing, bigger vessels were built in Cape Town for the Walvis Bay fleet. Towards the end of the 1960s the average purse seiner was of 23m length and could carry ± 180 tons of fish. This was also the time that skippers have started to use sonars onboard their vessels. During the early seventies a few boats with a length of 26m were built and they could carry approximately 250 tons of fish. The Simrad SK3 sonar was the most favoured sonar during that time. By this time the nets were made of nylon, it was much deeper and longer and of Norwegian design. The Triplex net winch and net stacker was also to be find on the bigger vessels. At the end of the 1970s the companies started to buy second-hand purse seiners in Norway .

Today the average purse seiner is between 40 m and 50m in length and could carry between 450 and 550 tons of fish. The average age of these vessels varies between 25 and 30 years. Namibian purse seiners make use of the Triplex 604 net winch combined with a net stacker from Petrel Engineers from Cape Town. Karmoy winches and fish pumps are very popular amongst local fishermen. All the Namibian purse seiners have had their RSW systems upgraded in order to cool down catches more quickly. Some purse seiners even converted all their tanks to RSW in order cool down large catches, especially when they have to stay out a couple of days on the fishing grounds and have to travel large distances. The main contractor of RSW systems in Namibia is PAM Refrigeration of Halden in Norway. Recently an Asconzon ozone generator was installed onboard the purse seiner Torsver in order to improve the quality of RSW fish even more.

In the Namibian pelagic industry two types of purse seines are used. Every purse seiner has an anchovy net (small meshes) and a pilchard net (big meshes 12.7mm). The design of the purse seines are very similar to the Norwegian Capelin purse seine. The purse seines used in Namibia is more or less 380 fathoms long and about 60 fathoms deep. The lead line is hanged much lighter than its Norwegian counterpart. The purse seines are also tapered more shallow towards the bunt (front wing). Purse rings are also much lighter than the Norwegian purse rings. The fact that Namibian purse seines are lighter in the lead line and purse rings is due to the fact that fishing operations are carried out in very shallow water. It is very often find that a purse seine with a depth of 60 fathoms are set in a water depth of 3 fathoms. Since the end of 1997 the latest way of hanging a purse seine (Norwegian style) is being used in

Namibia. This newly accepted way of hanging a purse seine is said to be guaranteed to last 15 years.

1.3 Purse Seine Operation

When the Namibian purse seiners are fishing for Horse Mackerel they usually fish between depths of 5 fathoms and 30 fathoms. The pursers seldom travel more than 30 hours steaming from the port of Walvis Bay. When fishing in Angolan waters they may steam 40 to 50 hours to the fishing grounds, depending on weather conditions.

The last two seasons the pilchard were fished in depths of 50 to 100 fathoms of water. Purse seine operations (when fishing for Horse Mackerel) occurs normally during the daytime in the summer months. When fishing in shallow waters (15 fathoms and less) the purse wire is hauled in as fast as possible. Purse ring bridles therefore are much longer in the back wing of the purse seine to enable the crew to unhook the purse rings from the purse wire as quick as possible.

The biggest catch of Horse Mackerel usually handled is about 350 tons per set. Fishing for pilchard normally occurs during the night time. Pilchard is an very evasive specie to catch and sometimes you have to set your net at full speed (10.5 to 11.5 knots)around the fish and it can still escapes the net. The purse wire is normally hauled at half speed or even slower. When hauling to fast in deep water the cork line may sink. The pilchard will normally take the cork line down when the fish enter the last 40 fathom of the front wing. When this occur the choke rope along the cork line is pulled carefully until the corks appear at or close to the surface. The choke rope is then slacked slowly to enable the fish to enter the bunt or front part of the front wing.

ANNEX I List of purse seiners in Namibia, June 1999.

Name	Hold Capacity	Owner
Torsver	600 tons	Gendev of Namibia
Havsurp	550 tons	Gendev of Namibia
Atlanta	450 tons	Namib Fisheries Ltd.
Nossob	250 tons	Namib Fisheries Ltd
Kunene	220 tons	Namib Fisheries Ltd
Hoddevik	450 tons	Silence Holdings (Pty) Ltd
Emerald Isle	450 tons	Dun Al Fishing(Pty) Ltd
Bokkeveld	150 tons	Eigelaars Belange (Pty) Ltd
Edelweiss	150 tons	Edelweis Visserye (Pty) Ltd
Coronella	450 tons	Eigelaars Belange (Pty) Ltd
Atlantic Leader	350 tons	Namsea
South West Falcon	250 tons	Namsea
South West Condor	250 tons	Namsea
Atlantic Pride	250 tons	Mukorob Fishing (Pty) Ltd
St. Pardarn	550 tons	Namsea
Fiskeskjer	450 tons	Namsea
Veslemari	450 tons	Namsea
Suiderkus	250 tons	Champion Fishing(Pty) Ltd
Boetie Akie	250 tons	J.C.M.Theart (WHK) (Pty) Ltd
Toliko	320 tons	Etosha Fishing Corp. (Pty) Ltd
Morgenster	450 tons	Etosha
Reinoyfisk	450 tons	NSP,NFI,SDC,MFC
Vea	350 tons	Etosha Fishing Corp. (Pty) Ltd
Accord	250 tons	Jadre Fishing Co. (Pty) Ltd
Advance	550 tons	Etosha Fishing Corp. (Pty) Ltd
Prowess	450 tons	Etosha Fishing Corp (Pty) Ltd
Alert	250 tons	Coenraad & A.C. van Dyk
Chris Andra	650 tons	Atlantic Harvesters of Namibia
Hesko 2	500 tons	Hesko Visserye (Pty) Ltd
Verdi	600 tons	Namib Fisheries Ltd
Christa List	750 tons	Consortium Fisheries Ltd
Consortium Epsilon	300 tons	Consortium Fisheries Ltd
Consortium Delta	300 tons	Consortium Fisheries Ltd

CHAPTER 2. COMPARATIVE ACOUSTIC SURVEYS OF SMALL, SHOALING PELAGIC SPECIES IN THE NORTHERN BENGUELA

1 INTRODUCTION

Horizontal guided sonars can record fish schools where conventional echo integration fails due to vessel avoidance and distribution above the transducer depth. Avoidance due to noise from the vessel have been recorded in real survey situations for herring schools in the north sea and Sardinella in the Mediterranean (Misund et al., 1996; Soria et al., 1996). Such avoidance reactions can cause significant difference in number of schools recorded and might explain differences observed when comparing fish density estimates obtained by sonar and echo integration. Previous observations in Namibian waters has shown lower estimates of pilchard densities during night than during day on average. This is usually associated with night-time scattering of pilchard shoals near the surface above the transducer. Experiments using both sonar and echo sounder simultaneously will indicate both the potential advantages and disadvantages with use of either method.

1.1 Background

Previous surveys comparing sonar and echo sounder with RV "Dr. F. Nansen" were conducted in Angola (sardinella) and in South Africa (pilchard). Due to some of the problems experienced using echo sounder for obtaining biomass of pilchard in Namibian waters, the project was extended to Namibia. The aim of the survey was to investigate the possibility of using sonar together with the echo sounder (EK500) to obtain comparative biomass estimates.

This survey was also a part of the ongoing co-operation between SIMRAD and IMR in Bergen to develop and test the SIMRAD SF950 sonar for such a purpose.

1.2 Objectives

The overall objective was to improve the survey-based pelagic assessment methodology for providing more reliable abundance estimates. A comparison of sonar and echo integration recordings from the surveys was conducted with the main objective being:

- To produce a biomass estimate based on data obtained from the sonar.

- To compare the results obtained by the echo sounder and the sonar both in respect to biomass, number of school observations and to describe the overall differences between the two methods.

- Further testing of the sonar software.

2 METHODS

2.1 Hydrography

Sea surface temperature (SST) at 5 m depth was recorded every full nautical mile along the cruise track using an Anderaa weather station.

2.2 Survey area

The area of operation was covered three times with use of parallel transects. First coverage covered the area between 20°51`-21°30`S and 13°00'- 13°10`E from South to North with the use of East-West transects 3 nm apart. The second coverage was shifted more inshore from 13°05' to 13°11.5'E. The course tracks of the three coverages are presented in **Annex IV.**

During the second coverage a narrower grid was used based on the information obtained from the purse-seiners working in the area and the first coverage. Shortened (6 nm) east-west transects 2 nm apart was used. The coverage was stopped for about 10 hours half way through on Friday (18/06) evening to conduct experiments and ended Saturday morning at 08h00 in the south.

The third coverage started Thursday 24/06 at 16h00. Due to few observations of fish and the lack of purse-seiners in the area wider transects were used to cover the area from 22° to 19°40' S and 12°50' to 13°10' E. Parallel transects spaced 5 nm apart were used to survey the area. The coverage was extended on Sunday (27/6) when high concentrations of 0-group pilchard was found inshore on 20° S. Four transects were added and the coverage ended on 19°40'S Tuesday (29/06) at 08h00.

During all coverages the sonar was directed northwards while surveying. Data from the sonar was captured for later analysis together with a printout from the observations.

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 SIMRAD EK 500 system provided measurements of fish densities, averaged over 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
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 S_A within transects and then weighting it to transect length. The area was estimated by multiplying total transect length with the transect spacing.

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

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

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 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.

Pilchard $W = 0.0046x\ L^{3.186}$

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. 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 length frequencies of all trawls in the area was then pooled. Summary list of trawl stations are given in **Annex II.**

2.4 Comparison of sonar and echo integration recordings

For comparing the acoustic recordings of fish schools near surface a model outlined by Misund and Coetzee (in press) will be used.

The sampling width of the sonar is the distance between the setting of the inner (R_1) and outer (R_2) sampling range plus the average school diameter ($2r_{school}$):

$$SW_{sonar} = (R_2 - R_1) + 2\, r_{school}$$

One possible criterion to determine the sampling width of the sonar is to use the range where the number of schools are rather constant (Anon,1974). The sampling depth of the sonar will depend on the tilt angle and the distance from the vessel. The tilt angle must be adjusted so that the sonar cover the main distribution of the fish schools. The sampling with of the echo sounder is found by means of the equation:

$$SW_{echo\ sounder} = 2\, R \tan(\theta/2) + 2\, r_{school}$$

where

R = average vertical range from transducer to school
θ = beam with of echo sounder
r_{school} = average school radius based on the recordings from the sonar

The formulas above can now be used to compare recordings of fish schools from sonar and echo sounder. The hypothesis is that the sonar and echo sounder recordings are equal and representative for the population, assuming no vessel avoidance, that the fish are distributed over the maximum recording depth of the sonar and below the upper blind zone of the echo sounder. The number of schools (N_{sonar}) recorded within the sampling width of the sonar (SW_{sonar}) and the number of schools ($N_{echo\ sounder}$) recorded by the echo sounder should be proportional.

$$N_{sonar}/SW_{sonar}=N_{echo\ sounder}/\ SW_{echo\ sounder}$$

If both the sonar and echo sounder recordings are representative for the population the expected number of schools recorded by the echo sounder should be:

$$N'_{echo\ sounder} = (N_{sonar}/SW_{sonar})/SW_{echo\ sounder}$$

Estimates of fish biomass can be calculated using a conversion from school area to school biomass. Such relationship can exist both in geometrical and logarithmic domain (Misund, 1993; Misund et al., 1992). If the relationship is linear and "a" is the conversion factor the formula will be:

$$Biomass=a*A$$

3 RESULTS

3.1 Hydrography

During the period 16 - 30 June the water was well mixed throughout the self area. The surface temperature showed cooled water in the southern region especially in Swakopmund area where the temperature was about 13°C. A strong upwelling occurred within 40 kilometres of the coast from Palgrave Pt. where the SST increased from 13°C to 16°C. The same pattern was observed in the northern region as the **Figure 1** shows.

The data were converted into IDL format for chartplotting, by using TAS software called TRACKMOD in NAN-SIS.

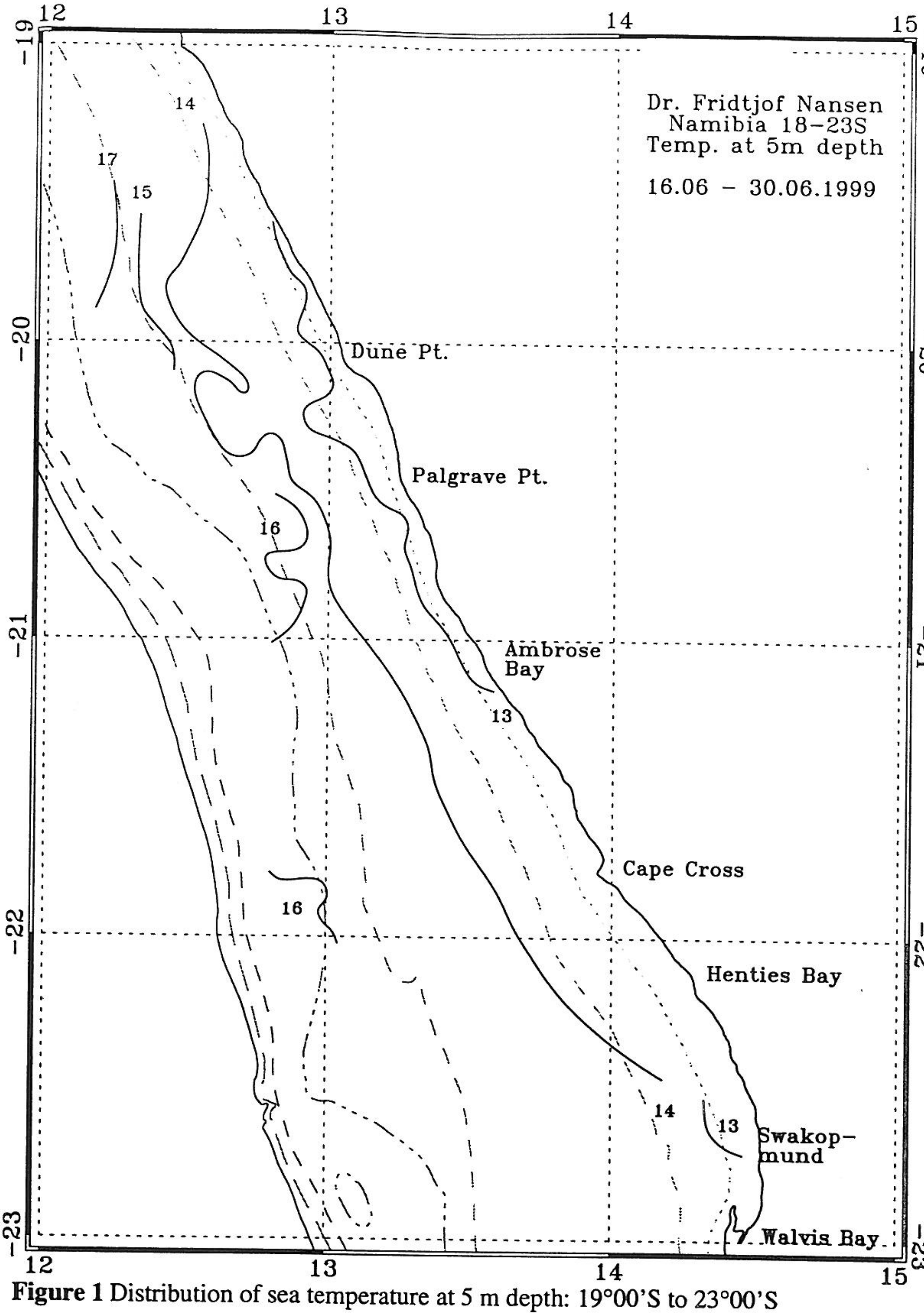


Figure 1 Distribution of sea temperature at 5 m depth: 19°00'S to 23°00'S

3.2 Comparison of sonar and echo integration recordings

Comparisons of the sonar and echo integration recordings have so far been done for mini survey 1 and 2.

As a criterion to determine the sampling width of the sonar the range where the number of schools was rather constant was used (Anon,1974) (**Figure 2**). The sampling range of the sonar was then found to be from 30 to 225 m.

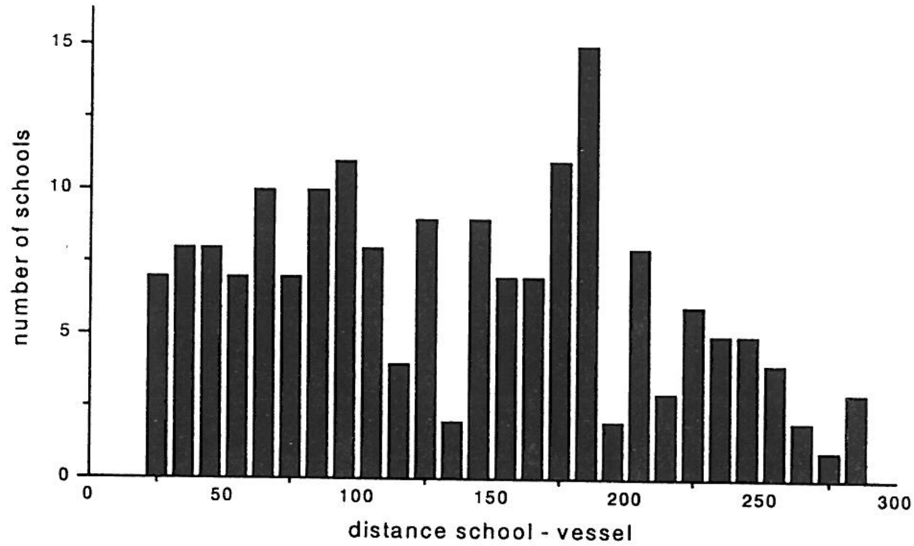


Figure 2 Number of schools in different distances from the vessel.

From the sonar a total of 179 schools where recorded in the range interval from 30 to 225 m. A total of 19 schools were observed from the echo sounder from the surface to a depth of 40 m (**Figure 3**). The sampling width of the sonar (SW_{sonar}) was calculated as 207.02 m and the sampling with of the echo sounder ($SW_{echo\ sounder}$) was calculated as 28.38 m, both based on an average school radius of 6.01 m observed from the 159 schools detected by the sonar. The expected number of schools ($N'_{echo\ sounder}$) was calculated to be 21.8, slightly higher than the observed number of 17 schools from the echo sounder ($N_{echo\ sounder}$).

The fish biomass was estimated from the total school area in coverages 1 and 2. Using a conversion factor of 18.4, estimated for herring schools in the North sea (Misund et al., 1995), the calculated fish biomass was 8508 tonnes in coverage 1 and 7264 tonnes in coverage 2. The fish biomass estimated from the sonar was in both survey 1 and 2 lower than the biomass estimated from the echo sounder (**Figure 4**).

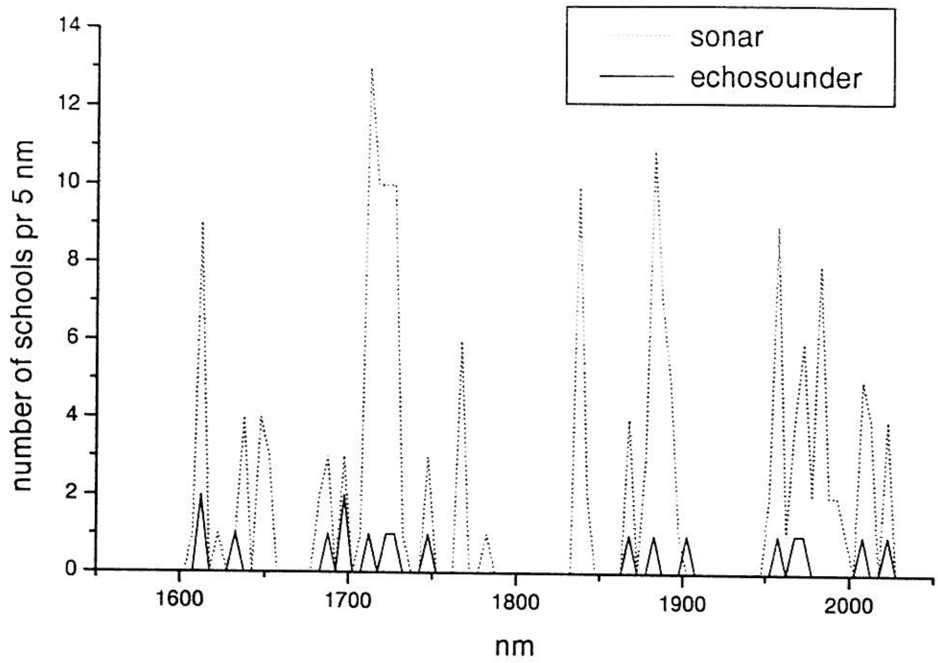


Figure 3 Number of schools recorded by the sonar and echo sounder per nm.

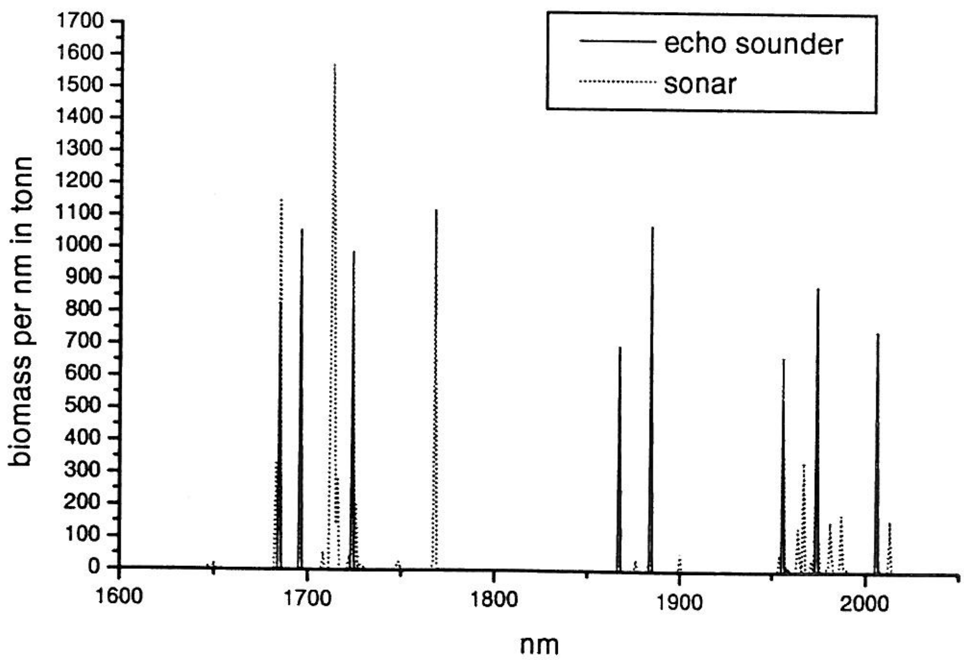


Figure 4 Biomass of sonar and echo sounder per nm

3.3 Abundance

Biomass based on integration values from the SIMRAD EK-500 was estimated three times from the three different coverages in the area of operation. The estimated biomass only reflects the amount of fish in the area where the studies were conducted and can not be used as an indication of stock size.

Although few schools were observed on the SIMRAD EK-500 the estimated biomass from the first two coverages only differed with 10 % varying from 15 797 to 17 676 tonnes (**Table I**). Higher densities were observed during night than daytime.

No observations were made of adult pilchard in the area covered by coverage 1 and 2 during the third coverage. However, a total of 24 662 tonnes of pilchard mainly small fish was estimated further North. The total biomass for the whole area can therefore be calculated by adding the result from the third coverage with the average biomass from coverages 1 and 2 (24 662 + 16 737 = 41 399). Length frequencies, total number and biomass per length group is shown in **Table II**.

Several cohorts contributed to the observed length frequency. The smaller fish (< 17cm) is a result of the last spawning season. The two modes usually reflect spawning during spring/summer and summer/autumn. The mean length within the two modes indicate an early spawning (August-September) and one later (March-April). The adults (> 18 cm) consist mainly of two year-classes, 1,5 and 2,5 years old with a modal length of 21 and 23,5 cm respectively. The pooled length frequencies for the main species are shown in **Annex III**.

Table I Summary table for coverages 1, 2 and 3.

	Coverage 1	Coverage 2	Coverage 3
Number of transects	15	21	29
Distance between transects	3 nm	2 nm	5 nm
Mean S_A	136,8	285,1	41
CV S_A	0,34	0,44	0,63
Area (nm^2)	478,5	257	2980
Biomass	15 797 t	17 676 t	24,662

Table II For each coverage the table shows length frequencies number of fish and estimated biomass per length group. Total estimate is also given by summing the average of coverage 1 and 2 with coverage 3.

	Coverage 1			Coverage 2			Coverage 3			Total		
Lenght cm	Relative frequency	No. millions	Biomass tonnes	Relative frequency	No. millions	Biomass tonnes	Relative frequency	No. millions	Biomass tonnes	Relative frequency	No. millions	Biomass tonnes
7	0	0	0	0	0	0	0.071	35	89	0.035	35	89
7.5	0	0	0	0	0	0	0.059	30	93	0.030	30	93
8	0	0	0	0	0	0	0.029	15	56	0.015	15	56
8.5	0	0	0	0	0	0	0.007	3	15	0.003	3	15
9	0	0	0	0	0	0	0.004	2	11	0.002	2	11
9.5	0	0	0	0	0	0	0.000	0	0	0.000	0	0
10	0	0	0	0	0	0	0.000	0	1	0.000	0	1
10.5	0	0	0	0	0	0	0.000	0	0	0.000	0	0
11	0	0	0	0	0	0	0.000	0	0	0.000	0	0
11.5	0	0	0	0	0	0	0.000	0	2	0.000	0	2
12	0	0	0	0	0	0	0.002	1	14	0.001	1	14
12.5	0	0	0	0	0	0	0.006	3	47	0.003	3	47
13	0	0	0	0	0	0	0.003	1	22	0.001	1	22
13.5	0	0	0	0	0	0	0.018	9	176	0.009	9	176
14	0	0	0	0	0	0	0.057	28	619	0.028	28	619
14.5	0	0	0	0	0	0	0.143	72	1746	0.072	72	1746
15	0	0	0	0	0	0	0.166	83	2249	0.083	83	2249
15.5	0	0	0	0	0	0	0.057	28	848	0.028	28	848
16	0	0	0	0	0	0	0.002	1	32	0.001	1	32
16.5	0	0	0	0	0	0	0	0	0	0.000	0	0
17	0	0	0	0	0	0	0	0	0	0.000	0	0
17.5	0	0	0	0	0	0	0	0	0	0.000	0	0
18	0	0	0	0	0	0	0	0	0	0.000	0	0
18.5	0	0	0	0	0	0	0	0	0	0.000	0	0
19	0	0	0	0	0	0	0	0	0	0.000	0	0
19.5	0	0	0	0	0	0	0	0	0	0.000	0	0
20	0.010	2	108	0.010	2	120	0.002	1	60	0.006	3	174
20.5	0.015	2	166	0.015	3	186	0.007	4	265	0.011	6	441
21	0.067	10	812	0.067	12	909	0.039	19	1505	0.053	30	2365
21.5	0.088	14	1148	0.088	15	1285	0.029	15	1225	0.059	29	2442
22	0.157	24	2206	0.157	27	2468	0.075	38	3398	0.116	64	5735
22.5	0.149	23	2243	0.149	26	2509	0.063	31	3031	0.106	56	5407
23	0.147	23	2365	0.147	25	2646	0.064	32	3334	0.106	56	5840
23.5	0.145	23	2509	0.145	25	2807	0.035	17	1941	0.090	41	4598
24	0.126	20	2329	0.126	22	2606	0.035	17	2065	0.081	38	4532
24.5	0.064	10	1268	0.064	11	1419	0.011	5	691	0.038	16	2034
25	0.019	3	408	0.019	3	456	0.013	6	858	0.016	10	1290
25.5	0.009	1	195	0.009	2	218	0.002	1	130	0.005	2	337
26	0.002	0	40	0.002	0	45	0.002	1	138	0.002	1	181
Total	1	155	15,797	1	174	17,676	1	500	24,662	1	664	41398

The originally planned estimation of biomass based on sonar was amputated due to problems with the SODAPS system onboard "Nansen". It was also not possible to connect the sonar on the purse-seiner (Chris Andra) with a logging system. The only estimates available from the Nansen sonar is therefore based on summed area of schools (see 2.4).

4 CONCLUDING REMARKS

Biomass and distribution

A pilchard biomass of about 41 000 tonnes was estimated in the survey area. Estimated CV on the S_A values varied from 0,34 to 0,63.

The large area covered by the survey had a low pilchard biomass which made it rather difficult to detect the schools due to the clustering nature of the schools. It was also obvious that it is very difficult to find pilchard using only one vessel, this was compounded by the low range of the SF950. Observations of birds and seals where often made in areas with schools close to surface.

Previous experience has shown that fish are often missed above the transducer at night-time. During these three coverages, however, similar values were observed during day and night-time. Trawling indicated that this could be a result of pilchard both schooling and scattering at relatively deep water during day (> 90m). This rather unusual distribution pattern resulted in increased uncertainty in the scrutinising. Combined with the expected loss of fish above the transducer at night this can indicate underestimation of the fish biomass.

While adults were mostly found in a relatively narrow strip from north to south over most of the area covered, the juveniles were mostly found in the northern part of the area mixed with anchovy. This offshore distribution pattern is similar to observations made during two surveys in 1998 on board "R.V Welwitschia".

Comparison of sonar and echo sounder & behaviour

Comparison of results produced by sonar and echo sounder have to be handled with caution due to technical limitations of the equipment, behavioural effects from the fish and subjective handling of the data.

The 17 schools observed on the echo sounder was a bit higher than the calculated expected number of schools of 21.8. This could indicate no vessel avoidance by the schools, but more data have to be collected and analysed. Further analysis of the data (mini survey 3) will be carried out in Bergen after the survey.

The biomass estimates for pilchard from the sonar were lower than the estimates from the echo sounder. This may be due to the conversion factor that was used, variable densities of the school and difficulties to identify the species. It future one should extend the method to use both school area/volume and acoustic back scattering when estimating fish biomass.

References

Misund, O.A., Aglen, A. and Frønæs, E., 1995. Mapping the shape, size and density of fish schools by echo integration and a high-resolution sonar. ICES J. mar. Sci., 52.

Misund, O.A., Øverdal, J.T. and Hafsteinsson, M.T., 1996. Reactions of herring schools to the sound field of a survey vessel. Aquat. Living Resour., 9: 5 - 11.

Soria , M., Freon, P. and Geeerlotto, F, 1996. Analysis of vessel influence on spatial behaviour of fish schools using a multi-beam sonar and consequences for biomass estimates by echo-sounder. ICES J. Mar. Sci., 53: 453-458.

Annex I Acoustic 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	5.5 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	27.48 dB
TS transducer gain	27.72 dB
3 dB Beamwidth	6.8 deg
Alongship offset	0.05 deg
Athwartship offset	0.14 deg

Display menu

Echogram	1
Bottom range	12 m
Bottom start	10 m
TVG	20 log R
SV Colour minimum	-67 dB
TS Colour minimum	-60 dB

Printer settings

Range	0-100/ 250 m
TVG	20 log R
SV Colour minimum	-67 dB

Bottom detection menu

Minimum level	-45 dB

The Simrad sonar SF950 was used to observe fish behaviour, distribution and densities during the survey. The settings of the SF950 sonar was as follow during surveys and school tracing:

Tilt	-5 (-4 to -7)
Train	-90 / +70
Range	300 m
Gain	5
Display	sector
Power	full
Pulsform	FM4
Rev. filter	medium
P.p. filter	weak

Fishing Gear

The small "Åkrehamn" pelagic trawl and large pelagic trawl were used for sampling pelagic fish. Tyborøn, 7.8 (1670 kg) trawl doors were used for both trawls. In some cases the multi-sampler was used in order to distinguish between targets at different depths.

ANNEX II Records of fishing stations

```
                                                PROJECT STATION:2846
DATE:17/ 6/99              GEAR TYPE: OT No:    POSITION:Lat   S  2120
        start    stop    duration                        Long   E  1302
TIME   02:02:00 04:40:00 158  (min)  Purpose code:  2
LOG   :                              Area code    : 2
FDEPTH:    10         0              GearCond.code:
BDEPTH:                              Validity code:
       Towing dir:     ø  Wire out:     m  Speed:    kn*10

  Sorted:  17 Kg     Total catch:  50000.00    CATCH/HOUR:  18987.35
```

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Sardinops ocellatus	18987.35	198016	100.00	9661
Total	18987.35		100.00	

```
                                                PROJECT STATION:2847
DATE:17/ 6/99              GEAR TYPE: OT No:    POSITION:Lat   S  2120
        start    stop    duration                        Long   E  1302
TIME  :04:36:00 05:31:00  55  (min)  Purpose code:  2
LOG   :                              Area code    : 2
FDEPTH:    10         0              GearCond.code:
BDEPTH:                              Validity code:
       Towing dir:     ø  Wire out:     m  Speed:    kn*10

  Sorted:  23 Kg     Total catch:  83500.00    CATCH/HOUR:  91090.90
```

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Sardinops ocellatus	91090.90	909226	100.00	9662
Total	91090.90		100.00	

```
                                                PROJECT STATION:2848
DATE:17/ 6/99              GEAR TYPE: PT No: 1  POSITION:Lat   S  2121
        start    stop    duration                        Long   E  1308
TIME  :12:08:46 12:17:45   9  (min)  Purpose code:  2
LOG   :1655.29  1655.84  0.52        Area code    : 2
FDEPTH:    50        50              GearCond.code:
BDEPTH:   147       150              Validity code:
       Towing dir: 270ø  Wire out: 250 m  Speed:  4 kn*10

  Sorted:  35 Kg     Total catch:   2000.00    CATCH/HOUR:  13333.33
```

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Sardinops ocellatus	12234.67	123567	91.76	9663
Etrumeus whiteheadi	743.73	30513	5.58	9664
Aequorea aequorea	331.80	6487	2.49	
Trachurus capensis	22.87	2287	0.17	
Total	13333.07		100.00	

```
                                                PROJECT STATION:2849
DATE:17/ 6/99              GEAR TYPE: PT No: 1  POSITION:Lat   S  2121
        start    stop    duration                        Long   E  1306
TIME  :12:34:01 12:43:02   9  (min)  Purpose code:  2
LOG   :1656.83  1657.37  0.53        Area code    : 2
FDEPTH:    80         0              GearCond.code:
BDEPTH:   155       156              Validity code:
       Towing dir: 270ø  Wire out: 320 m  Speed:  4 kn*10

  Sorted:  36 Kg     Total catch:    250.00    CATCH/HOUR:   1666.67
```

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Aequorea aequorea	1022.00	20447	61.32	
Sardinops ocellatus	618.60	5453	37.12	9665
Etrumeus whiteheadi	23.27	933	1.40	9666
Trachurus capensis	2.80	280	0.17	
Total	1666.67		100.01	

```
                                                PROJECT STATION:2850
DATE:17/ 6/99              GEAR TYPE: PT No: 2  POSITION:Lat   S  2115
        start    stop    duration                        Long   E  1309
TIME  :16:22:01 16:27:53   6  (min)  Purpose code:  2
LOG   :1688.48  1688.91  0.41        Area code    : 2
FDEPTH:    30        30              GearCond.code:
BDEPTH:   136       138              Validity code:
       Towing dir: 270ø  Wire out:1689 m  Speed:210 kn*10

  Sorted:  32 Kg     Total catch:     31.94    CATCH/HOUR:    319.40
```

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Sardinops ocellatus	277.80	2410	86.98	9667
Aequorea aequorea	25.80	520	8.08	
Etrumeus whiteheadi	12.90	510	4.04	9668
Trachurus capensis, juvenile	2.90	340	0.91	9669
Total	319.40		100.0	

```
                                                PROJECT STATION:2851
DATE:17/ 6/99              GEAR TYPE: PT No: 2  POSITION:Lat   S  2115
        start    stop    duration                        Long   E  1308
TIME  :16:30:35 16:36:50   6  (min)  Purpose code:  2
LOG   :1689.10  1689.56  0.43        Area code    : 2
FDEPTH:    30        30              GearCond.code:
BDEPTH:   138       137              Validity code:
       Towing dir: 270ø  Wire out: 200 m  Speed: 40 kn*10

  Sorted:  77 Kg     Total catch:     77.17    CATCH/HOUR:    771.70
```

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Chrysaora sp.	500.00	300	64.79	
Sardinops ocellatus	207.40	1760	26.88	9672
Aequorea aequorea	46.00	920	5.96	
Etrumeus whiteheadi	15.20	520	1.97	9670
Trachurus capensis, juvenile	3.10	540	0.40	9671
Total	771.70		100.00	

```
                                                PROJECT STATION:2852
DATE:18/ 6/99              GEAR TYPE: PT No: 4  POSITION:Lat   S  2057
        start    stop    duration                        Long   E  1310
TIME  :00:15:53 00:38:09  22  (min)  Purpose code:  2
LOG   :1770.24  1771.69  1.40        Area code    : 3
FDEPTH:    10        10              GearCond.code:
BDEPTH:   120       121              Validity code:
       Towing dir: 270ø  Wire out: 150 m  Speed: 40 kn*10

  Sorted:  29 Kg     Total catch:   6000.00    CATCH/HOUR:  16363.64
```

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Chrysaora sp.	10909.09	6545	66.67	
Aequorea aequorea	2727.27	54545	16.67	
Sardinops ocellatus	2584.36	25710	15.79	9673
Trachurus capensis, juvenile	123.82	14378	0.76	9674
Etrumeus whiteheadi	19.04	665	0.12	9675
Total	16363.58		100.01	

```
                                                PROJECT STATION:2853
DATE:19/ 6/99              GEAR TYPE: PT No: 1  POSITION:Lat   S  2130
        start    stop    duration                        Long   E  1306
TIME  :06:34:37 07:10:54  36  (min)  Purpose code:  2
LOG   :2029.30  2030.88  1.54        Area code    : 2
FDEPTH:   150       166              GearCond.code:
BDEPTH:   199       195              Validity code:
       Towing dir: 345ø  Wire out: 500 m  Speed: 30 kn*10

  Sorted:   7 Kg     Total catch:   5007.12    CATCH/HOUR:   8345.20
```

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Chrysaora sp.	8333.34	5000	99.86	
Trachurus capensis	9.02	57	0.11	9676
Merluccius capensis	2.85	30	0.03	
Total	8345.21		100.00	

```
                                                PROJECT STATION:2854
DATE:18/ 6/99              GEAR TYPE: OT No:    POSITION:Lat   S  2121
        start    stop    duration                        Long   E  1309
TIME  :18:23:30 20:00:00  97  (min)  Purpose code:  2
LOG   :                              Area code    : 2
FDEPTH:     7        25              GearCond.code:
BDEPTH:                              Validity code:
       Towing dir:     ø  Wire out:     m  Speed:    kn*10

  Sorted:  13 Kg     Total catch:  85000.00    CATCH/HOUR:  52577.35
```

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Sardinops ocellatus	52577.35	495937	100.00	9677
Total	52577.35		100.00	

```
                                                PROJECT STATION:2855
DATE:18/ 6/99              GEAR TYPE: OT No:    POSITION:Lat   S  2121
        start    stop    duration                        Long   E  1307
TIME  :21:41:00 23:03:00  82  (min)  Purpose code:  2
LOG   :                              Area code    : 2
FDEPTH:     7        50              GearCond.code:
BDEPTH:                              Validity code:
       Towing dir:     ø  Wire out:     m  Speed:    kn*10

  Sorted:  16 Kg     Total catch:  60000.00    CATCH/HOUR:  43902.42
```

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Sardinops ocellatus	43902.42	393996	100.00	9678
Total	43902.42		100.00	

PROJECT STATION: 2856
DATE: 19/ 6/99 GEAR TYPE: PT No: 1 POSITION: Lat S 2117
Long E 1307

	start	stop	duration		
TIME	14:18:21	14:33:51	16 (min)	Purpose code:	2
LOG	2095.80	2096.72	0.92	Area code:	2
FDEPTH	130	130		GearCond code:	
BDEPTH	144	140		Validity code:	

Towing dir: 73e Wire out: 450 m Speed: 4 kn*10

Sorted: 32 Kg Total catch: 3000.00 CATCH/HOUR: 11250.00

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Aequorea aequorea	7500.00	150000	66.67	
Sardinops ocellatus	3580.35	35895	31.83	9681
Trachurus capensis, juvenile	159.26	7039	1.42	9679
Etrumeus whiteheadi	10.39	233	0.09	9680
Total	11250.00		100.01	

PROJECT STATION: 2857
DATE: 19/ 6/99 GEAR TYPE: PT No: 4 POSITION: Lat S 2119
Long E 1308

	start	stop	duration		
TIME	18:56:51	19:31.46	35 (min)	Purpose code:	2
LOG	2108.19	2109.64	1.42	Area code:	2
FDEPTH	10	10		GearCond code:	
BDEPTH	145	143		Validity code:	

Towing dir: e Wire out: 150 m Speed: 26 kn*10

Sorted: 3 Kg Total catch: 2012.75 CATCH/HOUR: 3450.43

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Chrysaora sp.	3428.57	2057	99.37	
Trachurus capensis, juvenile	16.71	1099	0.48	9683
Sardinops ocellatus	5.14	51	0.15	9682
Total	3450.42		100.00	

PROJECT STATION: 2858
DATE: 19/ 6/99 GEAR TYPE: PT No: 1 POSITION: Lat S 2115
Long E 1308

	start	stop	duration		
TIME	23:16:47	23:29:05	12 (min)	Purpose code:	2
LOG	2117.94	2118.72	0.76	Area code:	2
FDEPTH	50	30		GearCond. code:	
BDEPTH	137	136		Validity code:	

Towing dir: 180e Wire out: 200 m Speed: 40 kn*10

Sorted: 16 Kg Total catch: 246.14 CATCH/HOUR: 1230.70

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Aequorea aequorea	1200.00	24000	97.51	
Trachurus capensis, juvenile	29.00	1470	2.36	9684
Merluccius capensis	1.60	10	0.13	
Total	1230.60		100.00	

PROJECT STATION: 2859
DATE: 20/ 6/99 GEAR TYPE: PT No: 1 POSITION: Lat S 2117
Long E 1309

	start	stop	duration		
TIME	02:03:41	02:16:54	13 (min)	Purpose code:	2
LOG	2123.76	2124.71	0.92	Area code:	2
FDEPTH	20	20		GearCond. code:	
BDEPTH	137	140		Validity code:	

Towing dir: 180e Wire out: 200 m Speed: 40 kn*10

Sorted: 46 Kg Total catch: 72.21 CATCH/HOUR: 333.28

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Aequorea aequorea	213.97	4278	64.20	
Sardinops ocellatus	115.48	1085	34.65	9685
Trachurus capensis, juvenile	3.83	314	1.15	9686
Total	333.28		100.00	

PROJECT STATION: 2860
DATE: 20/ 6/99 GEAR TYPE: OT No: POSITION: Lat S 2123
Long E 1311

	start	stop	duration		
TIME	20:30:00	21:55:00	85 (min)	Purpose code:	2
LOG				Area code:	2
FDEPTH	0	0		GearCond. code:	
BDEPTH				Validity code:	

Towing dir: e Wire out: m Speed: kn*10

Sorted: 32 Kg Total catch: 80000.00 CATCH/HOUR: 56470.56

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Sardinops ocellatus	56470.56	556909	100.00	9687
Total	56470.56		100.00	

PROJECT STATION: 2861
DATE: 21/ 6/99 GEAR TYPE: BT No: POSITION: Lat S 2115
Long E 1310

	start	stop	duration		
TIME	11:53:14	12:07:14	14 (min)	Purpose code:	2
LOG	2321.81	2322.52	0.69	Area code:	2
FDEPTH	134	135		GearCond. code:	
BDEPTH	134	135		Validity code:	

Towing dir: 285e Wire out: 540 m Speed: 30 kn*10

Sorted: 27 Kg Total catch: 1774.90 CATCH/HOUR: 7606.71

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Chrysaora sp.	6428.57	3857	84.51	
Merluccius capensis	625.71	1157	8.23	
Trachurus capensis, juvenile	403.71	19457	5.31	9689
Sardinops ocellatus	117.43	1243	1.54	9688
Sufflogobius bibarbatus	17.57	3086	0.23	
Chelidonichthys capensis	13.71	43	0.18	
Total	7606.70		100.00	

PROJECT STATION: 2862
DATE: 21/ 6/99 GEAR TYPE: PT No: 2 POSITION: Lat S 2117
Long E 1309

	start	stop	duration		
TIME	14:22:14	14:30:47	9 (min)	Purpose code:	2
LOG	2335.82	2336.46	0.57	Area code:	2
FDEPTH	100	100		GearCond code:	
BDEPTH	138	136		Validity code:	

Towing dir: 30e Wire out: 400 m Speed: 40 kn*10

Sorted: 3 Kg Total catch: 3.40 CATCH/HOUR: 22.57

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Etrumeus whiteheadi	22.57	813	100.00	[illegible]
Total	22.57		100.00	

PROJECT STATION: 2863
DATE: 21/ 6/99 GEAR TYPE: PT No: 2 POSITION: Lat S 2116
Long E 1310

	start	stop	duration		
TIME	14:32:00	14:51:00	19 (min)	Purpose code:	2
LOG	2336.55	2337.77	1.20	Area code:	2
FDEPTH	75	75		GearCond. code:	8
BDEPTH	136	134		Validity code:	2

Towing dir: 30e Wire out: 400 m Speed: 40 kn*10

Sorted: 7 Kg Total catch: 32.55 CATCH/HOUR: 102.79

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Etrumeus whiteheadi	99.95	3000	97.24	9692
Sardinops ocellatus	2.84	32	2.76	9691
Total	102.79		100.00	

PROJECT STATION: 2864
DATE: 22/ 6/99 GEAR TYPE: PT No: 1 POSITION: Lat S 2056
Long E 1323

	start	stop	duration		
TIME	11:41:10	11:59:15	18 (min)	Purpose code:	2
LOG	2474.27	2475.52	1.22	Area code:	3
FDEPTH	25	25		GearCond. code:	
BDEPTH	55	66		Validity code:	

Towing dir: 285e Wire out: 150 m Speed: 40 kn*10

Sorted: 12 Kg Total catch: 3300.00 CATCH/HOUR: 11000.00

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Chrysaora sp.	10000.00	6000	90.91	
Trachurus capensis, juvenile	1000.00	106450	9.09	9693
Total	11000.00		100.00	

PROJECT STATION: 2865
DATE: 22/ 6/99 GEAR TYPE: PT No: 1 POSITION: Lat S 2103
Long E 1323

	start	stop	duration		
TIME	15:55:05	16:12:14	17 (min)	Purpose code:	2
LOG	2505.88	2506.96	1.07	Area code:	2
FDEPTH	25	40		GearCond. code:	
BDEPTH	82	76		Validity code:	

Towing dir: 80e Wire out: 250 m Speed: 40 kn*10

Sorted: 12 Kg Total catch: 353.01 CATCH/HOUR: 1245.92

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Chrysaora sp.	705.88	424	56.66	
Trachurus capensis, juvenile	529.41	54000	42.49	9694
Myliobatis aquila	10.62	4	0.85	
Total	1245.91		100.00	

PROJECT STATION: 2866
DATE: 23/ 6/99 GEAR TYPE: PT No: 1 POSITION: Lat S 1944
Long E 1240

	start	stop	duration		
TIME	22:01:24	22:07:05	6 (min)	Purpose code:	2
LOG	2772.45	2772.81	0.36	Area code:	3
FDEPTH	50	40		GearCond. code:	
BDEPTH	108	109		Validity code:	

Towing dir: 320e Wire out: 213 m Speed: 30 kn*10

Sorted: 7 Kg Total catch: 210.00 CATCH/HOUR: 2100.00

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis, juvenile	2029.00	239260	96.62	9695
Sardinops ocellatus	35.40	320	1.69	
Engraulis capensis	35.40	3540	1.69	9696
Total	2099.80		100.00	

PROJECT STATION: 2867
DATE: 23/ 6/99 GEAR TYPE: PT No: 4 POSITION: Lat S 1944
Long E 1239

	start	stop	duration		
TIME	22:45:29	23:00:36	15 (min)	Purpose code:	2
LOG	2774.48	2775.28	0.73	Area code:	3
FDEPTH	0	0		GearCond. code:	
BDEPTH	110	108		Validity code:	

Towing dir: 160e Wire out: 150 m Speed: 30 kn*10

Sorted: 32 Kg Total catch: 2000.00 CATCH/HOUR: 8000.00

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis, juvenile	8000.00	618180	100.00	9697
Total	8000.00		100.00	

PROJECT STATION:2868
DATE:24/ 6/99 GEAR TYPE: PT No. 1 POSITION:Lat S 1946
Long E 1243

	start	stop	duration		
TIME	:01:13:32	01:13:52	(min)	Purpose code:	2
LOG	:2787.17	2787.19	0.02	Area code	: 3
FDEPTH:	19	19		GearCond code:	
BDEPTH:	101	101		Validity code:	

Towing dir: 333ø Wire out: 160 m Speed: 40 kn*10

Sorted: 24 Kg Total catch: 216.09 CATCH/HOUR: 12965.40

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis, juvenile	11426.40	878940	88.13	9698
Aequorea aequorea	1539.00	30780	11.87	
Total	12965.40		100.00	

PROJECT STATION:2869
DATE:24/ 6/99 GEAR TYPE: PT No: 5 POSITION:Lat S 2144
Long E 1259

	start	stop	duration		
TIME	:23:09:35	23:29:02	19 (min)	Purpose code:	2
LOG	:3007.09	3008.25	1.14	Area code	: 2
FDEPTH:	10	10		GearCond code:	
BDEPTH:	287	285		Validity code:	

Towing dir: 360ø Wire out: 150 m Speed: 30 kn*10

Sorted: 28 Kg Total catch: 37.32 CATCH/HOUR: 117.85

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Brama brama	51.22	44	43.46	
Thyrsites atun	36.32	95	30.82	
Diaphus hudsoni	21.95	13708	18.63	
Krill	8.21	39755	6.97	
Total	117.70		99.88	

PROJECT STATION:2870
DATE:25/ 6/99 GEAR TYPE: PT No: 1 POSITION:Lat S 2121
Long E 1310

	start	stop	duration		
TIME	:10:43:54	11:06:09	22 (min)	Purpose code:	2
LOG	:3121.17	3122.41	1.21	Area code	: 2
FDEPTH:	25	25		GearCond.code:	
BDEPTH:		146		Validity code:	

Towing dir: 180ø Wire out: 150 m Speed: 40 kn*10

Sorted: 1 Kg Total catch: 6100.00 CATCH/HOUR: 16636.37

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Aequorea aequorea	13636.37	27273	81.97	
Chrysaora sp.	2727.27	1636	16.39	
Trachurus capensis, juvenile	272.73	24600	1.64	9699
Total	16636.37		100.00	

PROJECT STATION:2871
DATE:25/ 6/99 GEAR TYPE: PT No: 1 POSITION:Lat S 2116
Long E 1253

	start	stop	duration		
TIME	:15:04:55	15:20:16	15 (min)	Purpose code:	2
LOG	:3156.74	3157.65	0.89	Area code	: 2
FDEPTH:	250	240		GearCond.code:	
BDEPTH:	305	306		Validity code:	

Towing dir: 250ø Wire out: 820 m Speed: 35 kn*10

Sorted: 1 Kg Total catch: 1.01 CATCH/HOUR: 4.04

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Zenopsis conchifer	2.88	4	71.29	
Hyperoglyphe moselii	0.88	4	21.78	
Diaphus hudsoni	0.28	212	6.93	
Total	4.04		100.00	

PROJECT STATION:2872
DATE:25/ 6/99 GEAR TYPE: PT No: 5 POSITION:Lat S 2113
Long E 1310

	start	stop	duration		
TIME	:18:01:23	18:15:44	14 (min)	Purpose code:	2
LOG	:3177.43	3178.20	0.74	Area code	: 2
FDEPTH:	0	0		GearCond.code:	
BDEPTH:	130	130		Validity code:	

Towing dir: ø Wire out: 150 m Speed: 30 kn*10

Sorted: 37 Kg Total catch: 36.94 CATCH/HOUR: 158.31

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Aequorea aequorea	96.77	1937	61.13	
Trachurus capensis, juvenile	51.26	4337	32.38	9700
Chrysaora sp.	10.29	17	6.50	
Total	158.32		100.01	

PROJECT STATION:2873
DATE:25/ 6/99 GEAR TYPE: PT No: 2 POSITION:Lat S 2102
Long E 1301

	start	stop	duration		
TIME	:23:19:51	23:26:10	6 (min)	Purpose code:	2
LOG	:3222.93	3223.27	0.33	Area code	: 2
FDEPTH:	130	130		GearCond.code:	
BDEPTH:	170	171		Validity code:	9

Towing dir: 360ø Wire out: 440 m Speed: 35 kn*10

Sorted: Kg Total catch: CATCH/HOUR:

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

PROJECT STATION:2874
DATE:25/ 6/99 GEAR TYPE: PT No: 2 POSITION:Lat S 2101
Long E 1301

	start	stop	duration		
TIME	:23:28:50	23:34:08	5 (min)	Purpose code:	2
LOG	:3223.42	3223.70	0.27	Area code	: 2
FDEPTH:	140	140		GearCond code:	
BDEPTH:	168	166		Validity code:	9

Towing dir: 360ø Wire out: 440 m Speed: 40 kn*10

Sorted: Kg Total catch: CATCH/HOUR:

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

PROJECT STATION:2875
DATE:26/ 6/99 GEAR TYPE: PT No: 1 POSITION:Lat S 2041
Long E 1310

	start	stop	duration		
TIME	:10:52:36	11:01:50	9 (min)	Purpose code:	2
LOG	:3340.69	3341.17	0.46	Area code	: 3
FDEPTH:	25	25		GearCond.code:	
BDEPTH:	107	107		Validity code:	

Towing dir: 180ø Wire out: 214 m Speed: 30 kn*10

Sorted: 10 Kg Total catch: 500.00 CATCH/HOUR: 3333.33

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis, juvenile	1666.67	185187	50.00	9701
Chrysaora sp.	1333.33	800	40.00	
Aequorea aequorea	333.33	6667	10.00	
Total	3333.33		100.00	

PROJECT STATION:2876
DATE:26/ 6/99 GEAR TYPE: PT No: 2 POSITION:Lat S 2034
Long E 1256

	start	stop	duration		
TIME	:14:49:56	14:57:21	7 (min)	Purpose code:	2
LOG	:3376.76	3377.31	0.54	Area code	: 3
FDEPTH:	65	65		GearCond.code:	
BDEPTH:	135	135		Validity code:	

Towing dir: 270ø Wire out: 250 m Speed: 37 kn*10

Sorted: 26 Kg Total catch: 26.34 CATCH/HOUR: 225.77

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Sardinops ocellatus	155.83	1671	69.02	9702
Chrysaora sp.	50.06	34	22.17	
Etrumeus whiteheadi	19.89	934	8.81	9703
Total	225.78		100.00	

PROJECT STATION:2877
DATE:26/ 6/99 GEAR TYPE: PT No: 2 POSITION:Lat S 2035
Long E 1255

	start	stop	duration		
TIME	:14:59:42	15:06:35	7 (min)	Purpose code:	2
LOG	:3377.45	3377.88	0.44	Area code	: 3
FDEPTH:	65	65		GearCond.code:	
BDEPTH:	134	132		Validity code:	

Towing dir: 270ø Wire out: 250 m Speed: 45 kn*10

Sorted: 16 Kg Total catch: 16.34 CATCH/HOUR: 140.06

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Sardinops ocellatus	120.86	1260	86.29	9704
Etrumeus whiteheadi	9.86	463	7.04	9705
Chrysaora sp.	9.34	9	6.67	
Total	140.06		100.00	

PROJECT STATION:2878
DATE:26/ 6/99 GEAR TYPE: PT No: 5 POSITION:Lat S 2035
Long E 1255

	start	stop	duration		
TIME	:17:59:47	18:15:29	16 (min)	Purpose code:	2
LOG	:3388.53	3389.47	0.93	Area code	: 3
FDEPTH:	0	0		GearCond.code:	
BDEPTH:	135	133		Validity code:	

Towing dir: 90ø Wire out: 214 m Speed: 30 kn*10

Sorted: 38 Kg Total catch: 500.00 CATCH/HOUR: 1875.00

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Sardinops ocellatus	1437.38	16125	76.66	9706
Etrumeus whiteheadi	250.13	13136	13.34	9707
Chrysaora sp.	187.50	113	10.00	
Total	1875.01		100.00	

PROJECT STATION:2879
DATE:26/ 6/99 GEAR TYPE: PT No: 1 POSITION:Lat S 2030
Long E 1307

	start	stop	duration		
TIME	:21:20:53	21:35:12	14 (min)	Purpose code:	2
LOG	:3416.20	3417.04	0.82	Area code	: 3
FDEPTH:	40	25		GearCond.code:	
BDEPTH:	98	94		Validity code:	

Towing dir: 90ø Wire out: 200 m Speed: 40 kn*10

Sorted: 4 Kg Total catch: 51.71 CATCH/HOUR: 221.61

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Aequorea aequorea	171.43	3429	77.36	
Trachurus capensis, juvenile	42.47	5584	19.16	9708
Merluccius capensis	3.47	56	1.57	
Chelidonichthys capensis	2.96	9	1.34	
Galeichthys feliceps	0.90	4	0.41	
Engraulis capensis	0.39	60	0.18	
Total	221.62		100.02	

PROJECT STATION:2880
DATE:26/ 6/99 GEAR TYPE: PT No: 4 POSITION:Lat S 2031
Long E 1254

	start	stop	duration
TIME	:23:27:45	23:44:29	17 (min)
LOG	:3432.99	3433.85	0.83
FDEPTH:	10	10	
BDEPTH:	138	132	

Purpose code: 2
Area code : 3
GearCond.code:
Validity code:
Towing dir: 150ø Wire out: 35 m Speed: 35 kn*10

Sorted: 8 Kg Total catch: 179.99 CATCH/HOUR: 635.26

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Aequorea aequorea	458.82	9176	72.23	
Etrumeus whiteheadi	161.01	8287	25.35	9710
Galeichthys feliceps	8.58	42	1.35	
Trachurus capensis, juvenile	6.00	904	0.94	9709
Sardinops ocellatus	0.85	42	0.13	
Total	635.26		100.00	

PROJECT STATION:2881
DATE:27/ 6/99 GEAR TYPE: PT No: 4 POSITION:Lat S 2020
Long E 1301

	start	stop	duration
TIME	:04:10:08	04:24:25	14 (min)
LOG	:3474.78	3475.62	0.82
FDEPTH:	10	10	
BDEPTH:	105	101	

Purpose code: 2
Area code : 3
GearCond.code:
Validity code:
Towing dir: 90ø Wire out: 150 m Speed: 35 kn*10

Sorted: 2 Kg Total catch: 3.18 CATCH/HOUR: 13.63

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis, juvenile	11.66	1423	85.55	9711
Sardinops ocellatus	1.46	137	10.71	9712
Engraulis capensis	0.51	43	3.74	
Total	13.63		100.00	

PROJECT STATION:2882
DATE:27/ 6/99 GEAR TYPE: PT No: 2 POSITION:Lat S 2010
Long E 1252

	start	stop	duration
TIME	:10:44:09	10:54:16	10 (min)
LOG	:3536.49	3537.07	0.58
FDEPTH:	55	75	
BDEPTH:	115	112	

Purpose code: 2
Area code : 3
GearCond.code:
Validity code:
Towing dir: 90ø Wire out: 250 m Speed: 30 kn*10

Sorted: 4 Kg Total catch: 445.00 CATCH/HOUR: 2670.00

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Aequorea aequorea	2400.00	48000	89.89	
Etrumeus whiteheadi	233.94	9204	8.76	9713
Galeichthys feliceps	17.64	78	0.66	
Sardinops ocellatus	13.02	534	0.49	9714
Trachurus capensis, juvenile	5.34	690	0.20	9715
Total	2669.94		100.00	

PROJECT STATION:2883
DATE:27/ 6/99 GEAR TYPE: PT No: 1 POSITION:Lat S 2010
Long E 1237

	start	stop	duration
TIME	:13:42:55	13:53:43	11 (min)
LOG	:3560.32	3560.94	0.61
FDEPTH:	120	120	
BDEPTH:	148	150	

Purpose code: 2
Area code : 3
GearCond.code:
Validity code:
Towing dir: 270ø Wire out: 440 m Speed: 35 kn*10

Sorted: 2 Kg Total catch: 2.27 CATCH/HOUR: 12.38

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Merluccius capensis	6.16	98	49.76	
Squalus megalops	4.09	11	33.04	
Todaropsis eblanae	0.82	38	6.62	
Lepidopus caudatus	0.71	44	5.74	
Trachurus capensis, juvenile	0.60	38	4.85	9716
Total	12.38		100.01	

PROJECT STATION:2884
DATE:27/ 6/99 GEAR TYPE: PT No: 4 POSITION:Lat S 2005
Long E 1242

	start	stop	duration
TIME	:17:36:03	17:53:13	17 (min)
LOG	:3581.59	3582.39	0.76
FDEPTH:	0	0	
BDEPTH:	126	128	

Purpose code: 2
Area code : 3
GearCond.code:
Validity code:
Towing dir: 270ø Wire out: 150 m Speed: 30 kn*10

Sorted: 34 Kg Total catch: 404.40 CATCH/HOUR: 1427.29

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	1173.18	43938	82.20	9717
Aequorea aequorea	127.06	2541	8.90	
Chrysaora sp.	127.06	78	8.90	
Total	1427.30		100.00	

PROJECT STATION:2885
DATE:27/ 6/99 GEAR TYPE: PT No: 1 POSITION:Lat S 1959
Long E 1254

	start	stop	duration
TIME	:20:32:47	20:43:32	11 (min)
LOG	:3605.81	3606.43	0.58
FDEPTH:	20	20	
BDEPTH:	79	79	

Purpose code: 2
Area code : 3
GearCond.code:
Validity code:
Towing dir: ø Wire out: 150 m Speed: 30 kn*10

Sorted: 36 Kg Total catch: 15000.00 CATCH/HOUR: 81818.18

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Sardinops ocellatus	66294.54	247342	81.03	9718
Engraulis capensis	15027.27	1028907	18.37	9719
Etrumeus whiteheadi	201.82	8984	0.25	
Trachurus capensis, juvenile	157.25	13478	0.19	
Scomber japonicus	134.73	2247	0.16	
Total	81815.61		100.00	

PROJECT STATION:2886
DATE:28/ 6/99 GEAR TYPE: PT No: 4 POSITION:Lat S 2000
Long E 1244

	start	stop	duration
TIME	:00:05:14	00:14:25	9 (min)
LOG	:3622.08	3622.57	0.48
FDEPTH:	0	0	
BDEPTH:	117	116	

Purpose code: 2
Area code : 3
GearCond.code:
Validity code:
Towing dir: 90ø Wire out: 150 m Speed: 40 kn*10

Sorted: 20 Kg Total catch: 1950.00 CATCH/HOUR: 13000.00

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Aequorea aequorea	10000.00	200000	76.92	
Trachurus capensis, juvenile	3000.00	300000	23.08	9720
Total	13000.00		100.00	

PROJECT STATION:2887
DATE:28/ 6/99 GEAR TYPE: PT No: 1 POSITION:Lat S 1950
Long E 1246

	start	stop	duration
TIME	:07:10:39	07:21:16	11 (min)
LOG	:3689.59	3690.26	0.65
FDEPTH:	20	20	
BDEPTH:	98	95	

Purpose code: 2
Area code : 3
GearCond.code:
Validity code:
Towing dir: 90ø Wire out: 150 m Speed: 30 kn*10

Sorted: 31 Kg Total catch: 530.00 CATCH/HOUR: 2890.91

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Aequorea aequorea	2454.55	49091	84.91	
Chrysaora sp.	272.73	164	9.43	
Trachurus capensis, juvenile	153.87	9502	5.32	9721
Etrumeus whiteheadi	9.76	393	0.34	9722
Total	2890.91		100.00	

PROJECT STATION:2888
DATE:28/ 6/99 GEAR TYPE: PT No: 4 POSITION:Lat S 1950
Long E 1225

	start	stop	duration
TIME	:09:45:42	10:11:24	26 (min)
LOG	:3713.21	3714.49	1.22
FDEPTH:	5	5	
BDEPTH:	157	152	

Purpose code: 2
Area code : 3
GearCond.code:
Validity code:
Towing dir: 90ø Wire out: 150 m Speed: 30 kn*10

Sorted: Kg Total catch: 250.00 CATCH/HOUR: 576.92

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Aequorea aequorea	461.54	9231	80.00	
Chrysaora sp.	115.38	69	20.00	
Total	576.92		100.00	

PROJECT STATION:2889
DATE:28/ 6/99 GEAR TYPE: PT No: 1 POSITION:Lat S 1950
Long E 1226

	start	stop	duration
TIME	:10:55:48	10:58:31	3 (min)
LOG	:3716.97	3717.06	0.09
FDEPTH:	20	20	
BDEPTH:	155	156	

Purpose code: 2
Area code : 3
GearCond.code:
Validity code: 9
Towing dir: 270ø Wire out: 150 m Speed: 30 kn*10

Sorted: Kg Total catch: CATCH/HOUR:

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

PROJECT STATION:2890
DATE:28/ 6/99 GEAR TYPE: PT No: 2 POSITION:Lat S 1950
Long E 1226

	start	stop	duration
TIME	:14:11:09	14:23:32	12 (min)
LOG	:3726.08	3727.01	0.86
FDEPTH:	20	20	
BDEPTH:	153	156	

Purpose code: 2
Area code : 3
GearCond.code:
Validity code: 9
Towing dir: 310ø Wire out: 133 m Speed: 40 kn*10

Sorted: Kg Total catch: CATCH/HOUR:

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

PROJECT STATION:2891
DATE:28/ 6/99 GEAR TYPE: PT No: 4 POSITION:Lat S 1950
Long E 1226

	start	stop	duration
TIME	:15:14:41	15:16:05	1 (min)
LOG	:3730.12	3730.21	0.09
FDEPTH:	10	10	
BDEPTH:	155	156	

Purpose code: 2
Area code : 3
GearCond.code:
Validity code:
Towing dir: 270ø Wire out: 150 m Speed: 40 kn*10

Sorted: 1 Kg Total catch: 0.88 CATCH/HOUR: 52.80

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Todaropsis eblanae	52.80	3540	100.00	
Total	52.80		100.00	

PROJECT STATION: 2892

DATE: 28/ 6/99 GEAR TYPE: PT No: 1 POSITION: Lat S 1950
Long E 1226

	start	stop	duration
TIME	:15:53:11	16:17:22	24 (min)
LOG	:3732.22	3733.94	1.67
FDEPTH:	15	15	
BDEPTH:	157	153	

Purpose code: 2
Area code: 3
GearCond.code:
Validity code:

Towing dir: 360ø Wire out: [illegible] m Speed: 45 kn*10

Sorted: Kg Total catch: [illegible] CATCH/HOUR: 0.03

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis, juvenile	[illegible]	15	100.00	
Total	[illegible]		100.00	

PROJECT STATION: 2893

DATE: 28/ 6/99 GEAR TYPE: PT No: 4 POSITION: Lat S 1949
Long E 1226

	start	stop	duration
TIME	:17:52:45	18:08:25	16 (min)
LOG	:3739.44	3740.40	0.85
FDEPTH:	0	0	
BDEPTH:	155	154	

Purpose code: 2
Area code: 3
GearCond.code:
Validity code:

Towing dir: 180ø Wire out: 150 m Speed: 30 kn*10

Sorted: 6 Kg Total catch: 463.22 CATCH/HOUR: 1737.08

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Aequorea aequorea	1350.00	27000	77.72	
Chrysaora sp.	337.50	203	19.43	
Sardinops ocellatus	37.50	12098	2.16	9723
Brama brama	6.90	11	0.40	
Etrumeus whiteheadi	3.19	49	0.18	9724
TRACHIPTERIDAE	1.69	4	0.10	
Trachurus capensis	0.19	4	0.01	
Todaropsis eblanae	0.11	8	0.01	
Total	1737.08		100.01	

PROJECT STATION: 2894

DATE: 28/ 6/99 GEAR TYPE: PT No: 4 POSITION: Lat S 1945
Long E 1239

	start	stop	duration
TIME	:21:27:30	21:52:54	25 (min)
LOG	:3771.22	3772.32	1.08
FDEPTH:	10	10	
BDEPTH:	109	106	

Purpose code: 2
Area code: 3
GearCond.code:
Validity code:

Towing dir: 90ø Wire out: 150 m Speed: 30 kn*10

Sorted: 34 Kg Total catch: 757.68 CATCH/HOUR: 1818.43

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis, juvenile	807.84	58666	44.43	9725
Etrumeus whiteheadi	373.82	18691	20.56	9726
Aequorea aequorea	319.97	6384	17.60	
Chrysaora sp.	316.80	190	17.42	
Total	1818.43		100.01	

PROJECT STATION: 2895

DATE: 29/ 6/99 GEAR TYPE: PT No: 4 POSITION: Lat S 1940
Long E 1237

	start	stop	duration
TIME	:00:51:26	01:02:17	11 (min)
LOG	:3800.02	3800.65	0.61
FDEPTH:	0	0	
BDEPTH:	111	110	

Purpose code: 2
Area code: 3
GearCond.code:
Validity code:

Towing dir: 90ø Wire out: 150 m Speed: 40 kn*10

Sorted: 32 Kg Total catch: 3000.00 CATCH/HOUR: 16363.64

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Sardinops ocellatus	14729.29	566509	90.01	9729
Engraulis capensis	958.42	57949	5.86	9728
Chrysaora sp.	428.78	1009	2.62	
Etrumeus whiteheadi	216.93	13118	1.33	9727
Trachurus capensis, juvenile	0.33	55		
Total	16333.75		99.82	

PROJECT STATION: 2896

DATE: 29/ 6/99 GEAR TYPE: PT No: 1 POSITION: Lat S 1940
Long E 1207

	start	stop	duration
TIME	:04:40:25	05:14:48	34 (min)
LOG	:3832.87	3835.14	2.23
FDEPTH:	100	100	
BDEPTH:	276	259	

Purpose code: 2
Area code: 3
GearCond.code:
Validity code:

Towing dir: 90ø Wire out: 520 m Speed: 35 kn*10

Sorted: 21 Kg Total catch: 21.46 CATCH/HOUR: 37.87

SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Trachurus capensis	18.32	252	48.38	9730
Merluccius capensis	13.20	92	34.86	
Brama brama	6.35	9	16.77	
Total	37.87		100.01	

PROJECT STATION: 2897

DATE: 29/ 6/99 GEAR TYPE: BT No: 2 POSITION: Lat S 1939
Long E 1145

	start	stop	duration
TIME	:08:24:01	08:57:05	33 (min)
LOG	:3861.11	3862.84	1.71
FDEPTH:	366	362	
BDEPTH:	366	362	

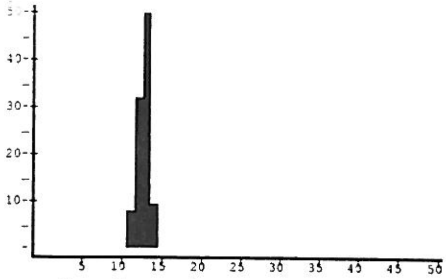
Purpose code: 2
Area code: 3
GearCond.code:
Validity code:

Towing dir: 340ø Wire out: 1100 m Speed: 32 kn*10

Sorted: 237 Kg Total catch: 355.27 CATCH/HOUR: 645.95

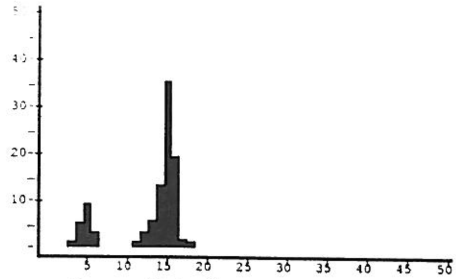
SPECIES	CATCH/HOUR weight	numbers	% OF TOT. C	SAMP
Merluccius capensis	399.71	593	61.88	9732
Helicolenus dactylopterus	113.04	1445	17.50	
Nezumia micronychodon	36.80	1184	5.70	
Galeus polli	34.18	395	5.29	
Lophius vomerinus	11.96	7	1.85	
Coelorinchus coelorhinc. polli	10.51	264	1.63	
Dicrolene intronigra	9.20	131	1.42	
Malacocephalus laevis	6.56	131	1.02	
Raja confundens	5.78	5	0.89	
TRACHIPTERIDAE	4.36	4	0.67	
Epigonus telescopus	2.64	131	0.41	
Ebinania costaecanarie	2.64	131	0.41	
Neoharriotta pinnata	2.11	2	0.33	
Todarodes sagittatus	1.75	5	0.27	
Total	641.24		99.27	

ANNEX III Length distributions of main species



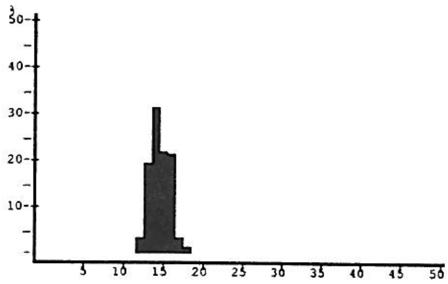
Engraulis capensis

MEAN LENGTH = 13.10cm N= 111
NUMBER OF SUBSAMPLES : 3



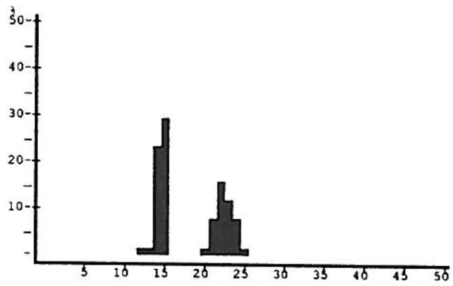
Etrumeus whiteheadi

MEAN LENGTH = 13.51cm N= 753
NUMBER OF SUBSAMPLES : 19



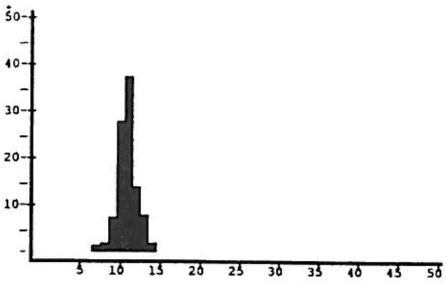
Trachurus capensis

MEAN LENGTH = 15.07cm N= 184
NUMBER OF SUBSAMPLES : 3



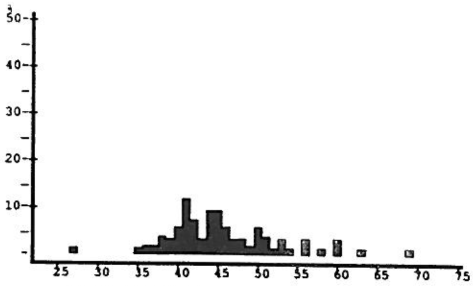
Sardinops ocellatus

MEAN LENGTH = 18.65cm N= 2015
NUMBER OF SUBSAMPLES : 26



Trachurus capensis, juvenile

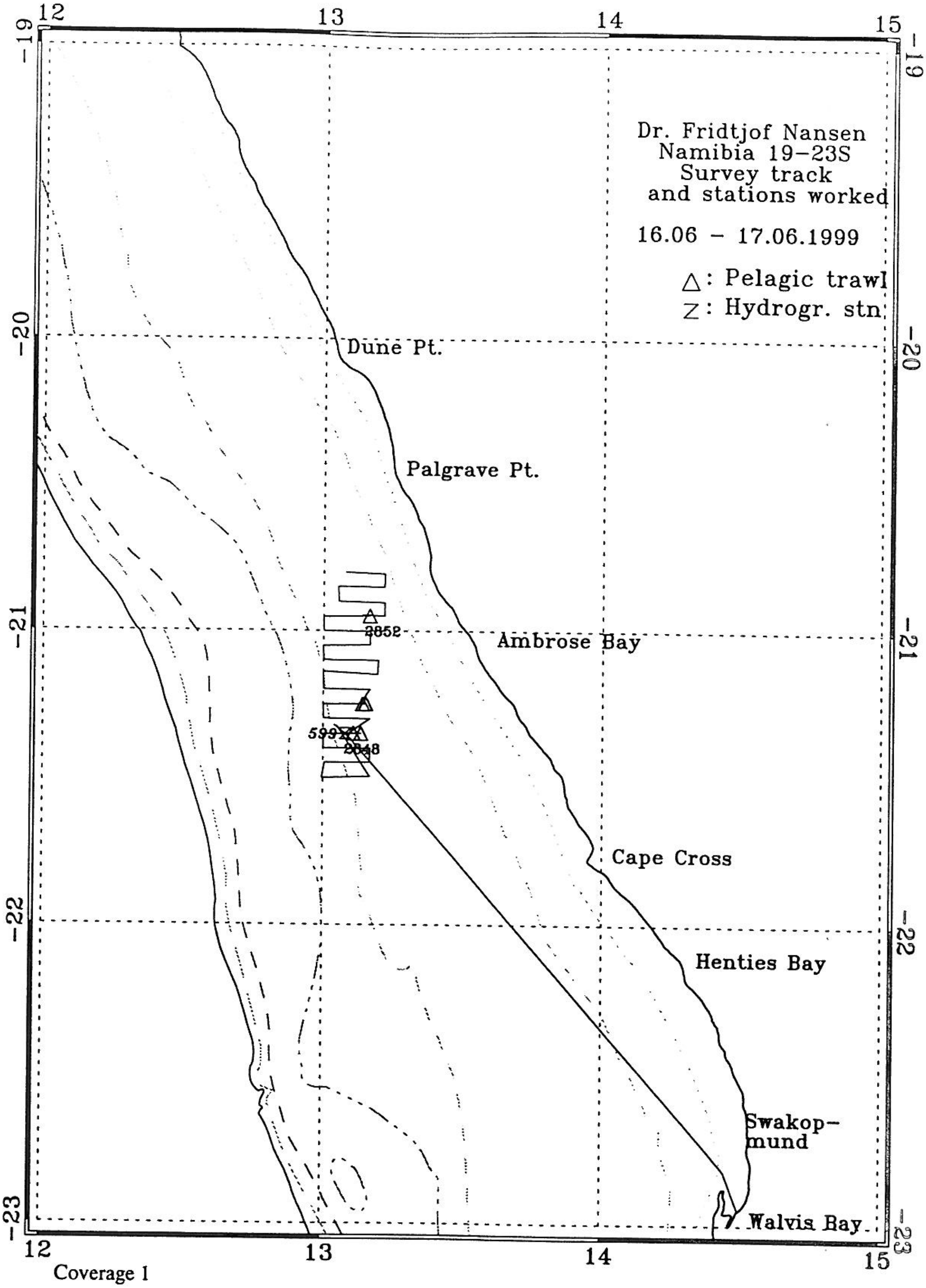
MEAN LENGTH = 11.35cm N= 1325
NUMBER OF SUBSAMPLES : 24



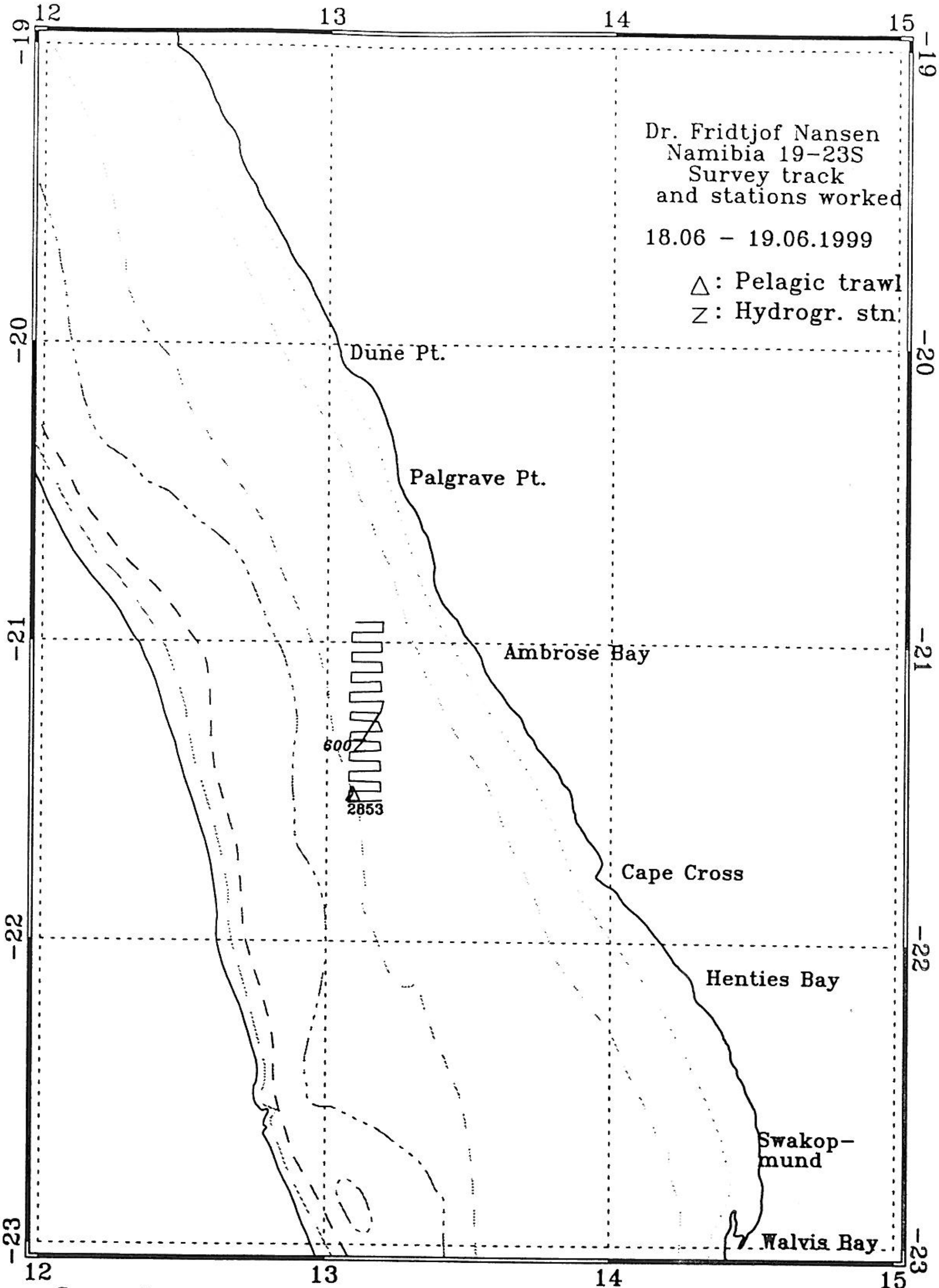
Merluccius capensis

MEAN LENGTH = 46.00cm N= 90
NUMBER OF SUBSAMPLES : 1

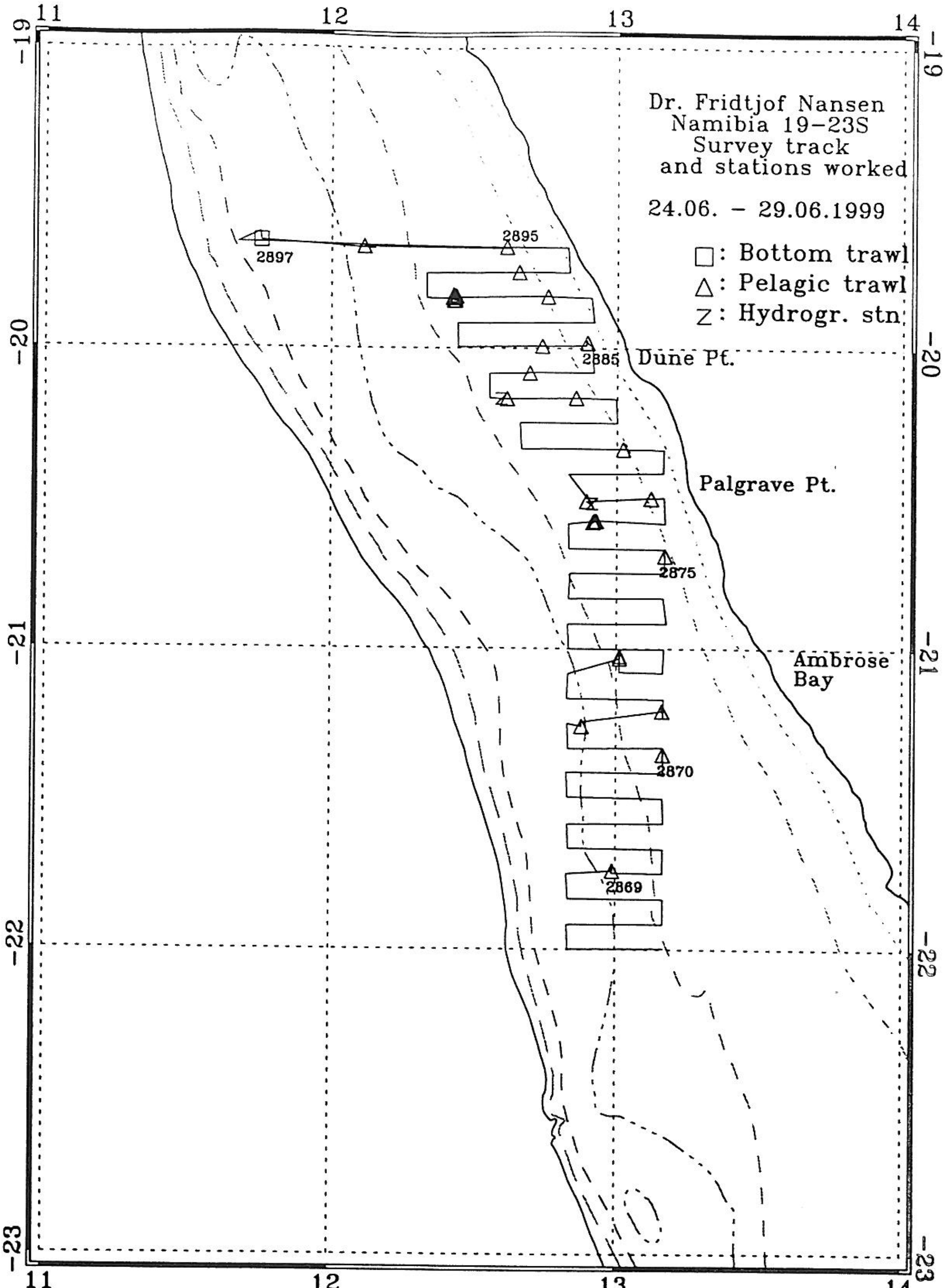
Annex IV Course tracks - coverages 1,2 & 3



Coverage 1


12
13
14
15
-19
-20
-21
-22
-23
Dr. Fridtjof Nansen
Namibia 19-23S
Survey track
and stations worked
18.06 - 19.06.1999
△: Pelagic trawl
Z: Hydrogr. stn
Dune Pt.
Palgrave Pt.
Ambrose Bay
600
2853
Cape Cross
Henties Bay
Swakop-
mund
Walvis Bay

Coverage 2


Dr. Fridtjof Nansen
Namibia 19-23S
Survey track
and stations worked
24.06. - 29.06.1999
□: Bottom trawl
△: Pelagic trawl
Z: Hydrogr. stn
Dune Pt.
Palgrave Pt.
Ambrose Bay
2897
2895
2885
2875
2870
2869
11
12
13
14
-19
-20
-21
-22
-23

Coverage 3

CHAPTER 3. STUDIES OF SCHOOLING BEHAVIOUR OF PILCHARD (*SARDINOPS OCELLATUS*) IN NAMIBIAN WATERS.

1 INTRODUCTION

1.1 Background

Previous work on the pilchard stock in Namibia has shown that pilchard frequently shoal close to 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.

This current cruise was conducted co-operatively between the 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 pilchard, particularly those which may cause biases or errors in acoustically derived biomass estimates.

1.2 Objectives

This part of the cruise had three major objectives, primarily:

- acoustic recordings of schools to be purse seined
- detailed analysis and imaging of school structure
- sonar tracking of pilchard shoals

2 METHODS

2.1 Acoustic recordings of schools to be purse seined

One of the main objectives of this experimental cruise was to conduct acoustic measurements of selected pilchard schools. These measurements should be conducted both by sonar, echo sounder and echo integration and should result in reliable information concerning absolute biomass of schools, school dimensions and geometry, true packing density of schools, and effective back scattering cross section of individual pilchards in the schools. Such demanding objectives required a rather challenging procedure known as the comparison method. The basis of this method is acoustic measurements of school dimensions by sonar and echo sounder, and echo integration of the school by a calibrated system. Then the whole school must be captured by purse seine and pumped onboard so that the absolute biomass can be determined accurately. Since R/V "Dr. Fridtjof Nansen" can not operate a purse seine, this method implied co-operation with Namibian purse seiners. Co-operation for this purpose was therefore established by M/V "Chris Andra" before departure from Walvis Bay, and with M/V "Advance" during the experimental survey.

The procedure for the school measurements is outlined in Fig. 3.1. First the school was located by the purse seiner using low frequency sonar (24 kHz Simrad SR240 onboard "Chris Andra" and 23 kHz Furuno CHS23 onboard "Advance") with long detection range. When the size and behaviour of the school was found acceptable for a purse seine set, the position of the school was communicated to R/V "Dr. Fridtjof Nansen" which followed 0.5 - 1.0 nautical mile behind the searching purse seiner. To guide R/V "Dr. Fridtjof Nansen" over the school, the purse seiner stopped or moved slowly with the school on its starboard side at a distance of 250 - 500 m. The range and direction to the school was updated frequently to R/V "Dr. Fridtjof Nansen" to enable a perfect passage over the school. When the research vessel approached, its hull could be detected by the low frequency sonar of the purse seiner, and the direction between the school and the research vessel as observed from the purse seiner was communicated to the research vessel for necessary adjustment of its course. When the R/V "Dr. Fridtjof Nansen" had located the school by its high frequency sonar, further adjustment of course was carried out so that the vessel made a transect through the central part of the school. R/V "Dr . Fridtjof Nansen" approached and passed over the school at a speed of about 5 knots (2.5 m s^{-1}).

When approaching and passing over the school, a set of school parameters was recorded by the acoustic equipment by R/V "Dr. Fridtjof Nansen". The Simrad SF950 D sonar recorded school volume, and mean and maximum back scattering strength of the school, and these data were logged "raw" by the SODAPS system. The sonar display was also recorded on videotape. The sonar data will be processed at IMR, Bergen, during autumn 1999 to estimate horizontal area and volume back-scatter of the school.

Based on the Simrad EK500 recordings of the school the following parameters were estimated on the echo sounder paper:

School height	$H = (r_2 - r_1) - c\tau/2$	(m)
Transect length	$TL = tl' \cdot 1852/s$	(m)
School area	$A = \pi (TL/2)^2$	$(m)^2$
School volume	$V = 4/3\ A\ (H/2)$	$(m)^3$
Back scattering cross section	$\sigma = 10^{1/10\ TS}$	$(m)^2$
Target strength	$TS = 20 \log L - 72$	(dB)
Estimated packing density	$\rho_A = s_{A/4}.\pi \cdot \sigma \cdot H \cdot TL \cdot 1852$	$(n/m)^3$
Estimated back scattering cross section	$\sigma_e = s_{A/4}.\pi \cdot \rho_A \cdot H \cdot TL \cdot 1852$	$(m)^2$
Estimated school biomass	$B = V \cdot \rho_A \cdot W$	(kg)

In these calculations r_2 is maximum depth of the school, r_1 is minimum depth of the school, c is speed of sound, τ is pulse length of echo sounder (1 ms), tl' is measured transect length of school on echo sounder paper, s is a scaling factor for length of one nautical mile on the echo sounder paper, L is average fish length of the pilchard (L = 22 cm from the purse seine sets with "Chris Andra" and "Advance"), W is average fish weight (W = 0.08712 kg from the purse seine sets with "Chris Andra" and "Advance").

In cases where the purse seine sets gave absolute biomass of schools (i.e the whole school was caught and pumped onboard), absolute packing density was calculated by dividing absolute number of fish with school volume.

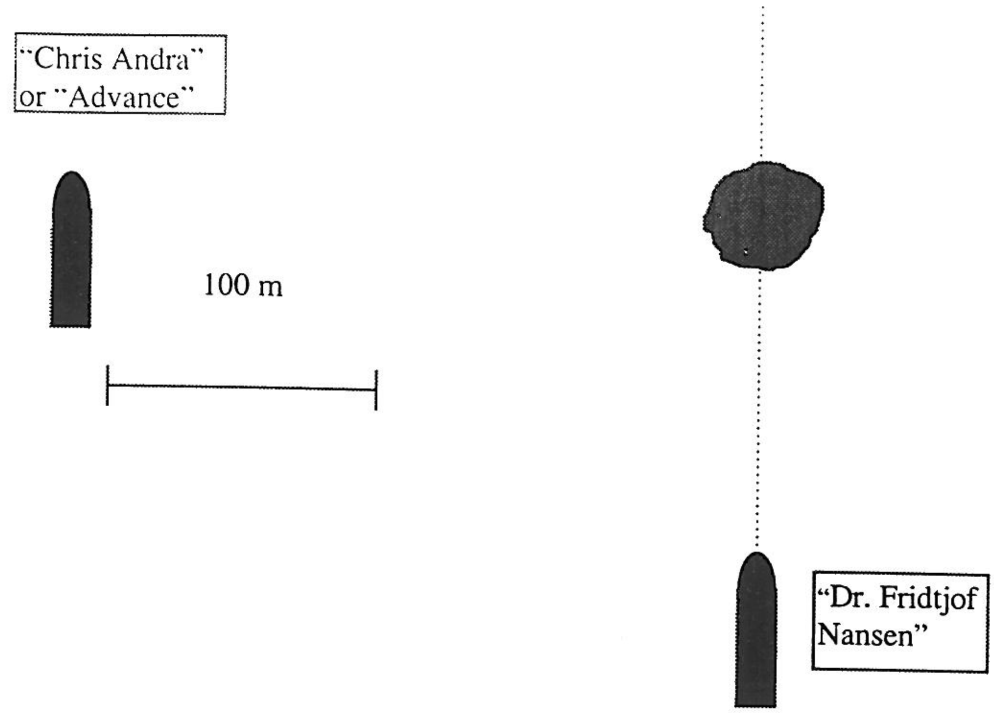


Figure 1 a) Location of school by Namibian purse seiner and acoustic measurement of school by R/V "Dr. Fridtjof Nansen".

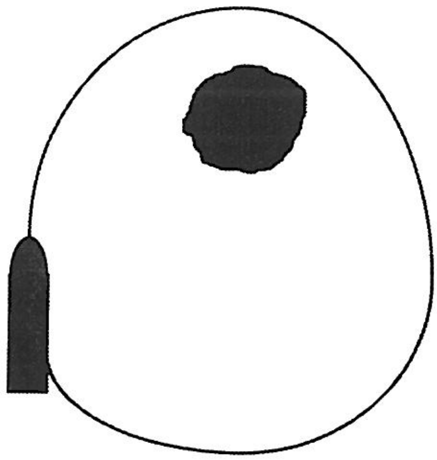


Figure 1 b) Capture of school by purse seine

Figure 1 c) Pumping of catch onboard in RSW holds for biomass estimation and delivery to canning factory.

2.2 Detailed analysis and imaging of school structure

Image analyses of 34 pilchard schools was performed using SHAPES (Shoal analysis and patch estimation system). This is a Sea Fisheries Research Institute (SFRI) - developed software capable of detecting, extracting and statistically characterising fish shoals in an automated and objective manner from acoustic data. SHAPES has recently been incorporated as a separate module of the Sonardata Echoview© post processing software and although used during this survey is still in the testing phase. It provides statistics for more than 20 school descriptors. These descriptors can be divided into three main groups. The first set of descriptors includes size and shape variables such as length, height, area, volume, perimeter and fractal dimension. Variables describing internal features and energetic characteristics of the schools (i.e. mean and standard deviation of the acoustic intensity, horizontal and vertical roughness, skewness and kurtosis of the acoustic energy) make up the second set of descriptors. The third set includes relational statistics such as nearest neighbouring school distance and angle.

Acoustic data is processed in four steps, as follows. First, a matrix consisting of *n* columns (one per echo return) and *m* rows (two per 1-m vertical depth channel) is generated. Second, applying a threshold reduces the matrix to eliminate any unwanted noise. This threshold is applied interactively, and a graphic interface is used to ensure accurate filtering and shoal definition. In this study, a threshold of -55dB was applied which corresponds to a minimum fish density of 0.1 individuals per m^3 for a 22 cm fish. In the third step, shoals are identified from the filtered matrices using routines based on the principle that a shoal is composed of a number of super-threshold adjacent cells. A maximum linking distance is used to accommodate non- adjacent cells. These so-called sub-schools are linked only if they conform to set minimum school dimension criteria. In this study sardine schools were adequately detected using a minimum school length of 20 m, a height of 10 m, a maximum linking distance of 10 m and a sub-school length and height of 10 m. An example of a pilchard school detected and analysed by SHAPES using these school recognition criteria is shown in Figure 2.1.

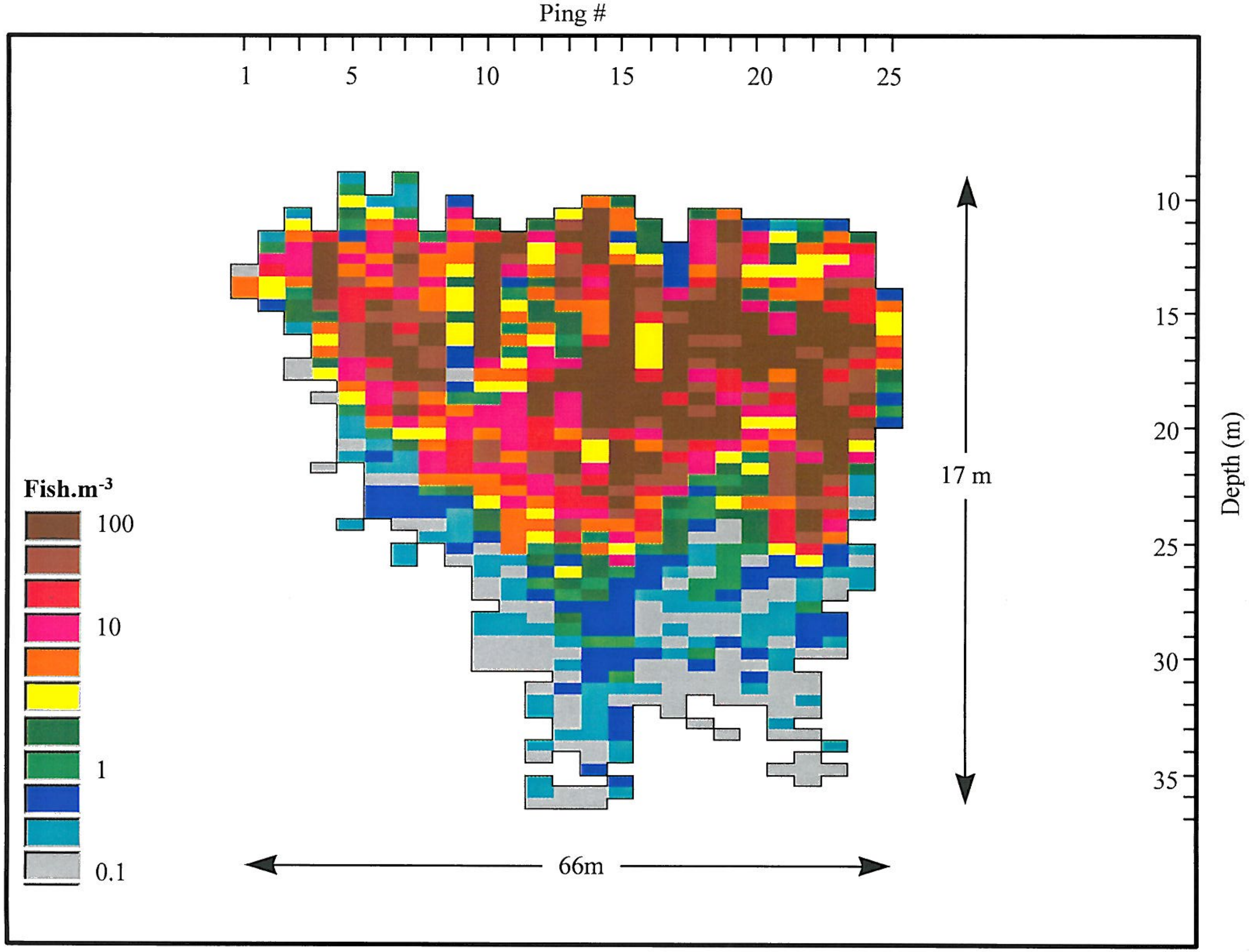


Figure 2.1. An example of a pilchard school detected by SHAPES.

The fourth step involves the extraction of school characteristics. Morphological variables based on earlier definitions by Nero and Magnuson (1989), Reid and Simmonds (1993) and Barange (1994) are used. Definitions of the variables used in this study and the corrections made are included (Table 2.1). The basic assumption is that schools are circular (Pitcher and Partridge, 1979). It is assumed that the schools are intercepted at random and that very few would therefore be intercepted through the centre. A correction of $4/\pi$ is applied to compensate for this effect and obtain the real school length (Maclennan and Simmonds 1992).

Table 2.1. Definitions of variables calculated during this study and corrections made for beam width and pulse length effects.

Variable	Definition	Notes
$Height_{apparent}$	Σdepth bins.vertical resolution	
$Length_{(apparent)}$	Σ pings.k	where k is the number of metres per ping (calculated using vessel speed and ping rate.
$Height_{real}$ (H) m	$HEIGHT_{appar} - (c\gamma/2)$	where c = speed of sound, γ = pulse length , θ = the half angle of the beam and assumed to be 5°, D = shoal mean depth and k as above.
$Length_{real}$ (L) m	$[(LENGTH_{appar}) - (2.\tan\theta.D)]4/\pi$	
Area (A) m^2	$(L/2)^2.\pi$	
Volume (V) m^3	$(L/2)^2.\pi.H$	
Number of cells (N)	Σ(cells)	
Pings to discard (each side)	$(\tan\theta . D)/k$	Where θ, D and k are as above.
Mean Echo intensity (E_m) $m^2.nm^{-2}$	$(\Sigma E_{ij})/(N)$	
Packing density ($P\gamma$) $ind.m^{-3}$	$\dfrac{E_m}{4\pi.10^{\frac{TS}{10}}.1852^2.\Delta R}$	Where TS = 20logL-72 and ΔR is the vertical integration range and L = 22 cm.
Mean density (γ) $g.m^{-3}$	$P\gamma.W$	Where fish weight (W) is derived from the length-weight relationship, $W = 0.0046L^{3.186}$
School Biomass (B) Tons	$\gamma.V.10^{-6}$	

Before the calculation of averaging parameters, corrections to school shape variables to account for pulse length effects were performed. In addition, artefacts due to beam width were corrected for by removing pings that had not completely insonified the shoal on both sides. This was done according to procedures described in Barange *et al.* (1993) and assuming that the beam width is 5° (the approximate position of the -3dB points).

2.3 Behaviour of pilchard during purse seining

After R/V "Dr. Fridtjof Nansen" had passed over the school, and the echo of the propeller wake of the vessel faded, the purse seiner manoeuvred in position to shoot the net. In many occasions it was necessary to circle around the school to identify it clearly, outline its extent and find out of its swimming behaviour and direction. The net was shot when the purse seiner was circling the school at a distance of 150 - 200 m and when running at a speed of 8 - 10 knots. An observer on the bridge noted the time (local time) when shooting started, when half the net was shot, when shooting was finished, when pursing started, when hauling started, when pursing finished and finally when the net was hauled so that the catch was confined in the bag along the side of the vessel. The observer made occasional drawings of the school and the purse seine as they appeared on the sonar during the capture process. Attention was also given to the cork-line to observe if it submerged due to the pressure of the fish.

After shooting the net, the vessels were manoeuvred actively to prevent being drawn into the net when pursing and hauling. Wakes from the main propeller and the side thrusters made it often impossible to obtain recordings of the school and the net during this phase of the capture process. Onboard "Chris Andra" the Simrad SR240 sonar could be operated in a partially retracted position, and was in function most of the time during pursing so that a recording of the school and the net could be made when manoeuvring allowed. Onboard "Advance" the Furuno CHS23 sonar was hoisted in during pursing to prevent damage on the transducer from the purse warps. On this vessel it was therefore impossible to observe the school and the net during the critical pursing operation. On both vessels the echo sounders was operated continuously to observe if the school escaped out under the vessel during pursing.

2.4 Behaviour of seals during purse seining

A particular habit during Namibian purse seining on pilchard is attraction of nearby seals. To quantify the activity of seals in connection with Namibian purse seining, the observer at the bridge took occasional notes on the number of seals present in the purse seine. The counts were made possible when the light projector on the roof of the wheel house were swept over the purse seine to observe the cork-line. Usually this was done towards the end of the hauling when pressure of the fish may submerge the cork-line. Only seals at surface could be counted, and due to the low light intensity at night, only rough estimates could be made. The number of seals was therefore estimated to the nearest 10 if below 100, and to the nearest 100 if above 100.

2.5 Sonar school tracking

To study the swimming behaviour of pilchard, the Simrad SF 950D 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 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 pilchard 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 about 90 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.

3 RESULTS

3.1 Acoustic recordings of purse seined schools

The absolute biomass of the six pilchard schools caught varied from 40 - 167 tons, with an absolute packing density varying from 2.0 - 22.4 fish/m^3 (average packing density 18.5 fish/m^3, SD = 13.5 fish/m^3). Using the 20 log L - 72 equation to calculate the target strength of the pilchard, the estimated packing density varied from 0.7 - 40.4 fish/m^3 (average packing density 12.4 fish/m^3, SD = 8.6 fish/m^3), and the estimated biomass from 14 - 249 tons. The estimated acoustic backscattering strength from the pilchard averaged $3.40 \cdot 10^{-5}$ m^2 (SD = $1.91 \cdot 10^{-5}$ m^2), giving an average target strength of -44.7 dB. The derived target strength varied by 8 dB between the different sets, however. For comparison the predicted target strength of a 22 cm pilchard using the 20 log L - 72 equation is -45.15 dB.

School nr.	Set nr.	Transect length (m)	Vertical extent (m)	Area $(m)^2$	Volume $(m)^3$	Absolute Biomass (kg)	Absolute packing density $(n/m)^3$	s_A (m^2/nm^2)	Estimated back scatterings trength $(m)^2$	TS' (dB)	Estimated packing density' $(n/m)^3$	Estimated biomass (kg)
3	3	86.9	22	5928	86 944	55 000	7.3	20 610	$6.38 \cdot 10^{-5}$	-42.0	15.2	115 133
4	4	103.3	31	8377	173 125	167 000	11.1	37 392	$4.52 \cdot 10^{-5}$	-43.4	16.5	248 863
7	5	102.0	8	8167	43 557	85 000	22.4	7151	$1.68 \cdot 10^{-5}$	-47.7	12.4	47 054
12	6	76.4	13	4582	39 711	60 000	17.4	18 624	$4.63 \cdot 10^{-5}$	-43.3	26.4	91 334
13	8	179.5	30	10 740	214 800	80 000	4.3	11 539	$2.14 \cdot 10^{-5}$	-46.7	3.0	56 140
14	9	115.5	14	10 472	230 177	40 000	2.0	760	$1.01 \cdot 10^{-5}$	-50.0	0.7	14 037

Table 3.1. Results of acoustic measurement of pilchard schools that were caught by the purse seiners "Chris Andra" and "Advance". s_A = area backscattering strength, TS': estimated target strength

3.2 Detailed analysis and imaging of school structure

Results of calculations of morphological variables and energetic features of 34 pilchard schools are presented in Table 3.2. Results of this study suggest a general trend in which the horizontal dimensions are larger than the vertical extent. The frequency distribution of height of the shoals indicates that approximately 80% of the identified shoals were less than 20 m in height. The mean shoal height for all surveys was 14.7 (SD = 8.5), but varied from a minimum of 4.5 m to a maximum of 43 m. The mean shoal length calculated for all the surveys is 71 m (SD = 39.5) but also varies greatly from less than 20 m to a maximum of over 200 m. Most of the shoals (80%) are, however, less than 100 m in length. No correlation was found between height and length of the schools.

The mean school depth varied considerably from 15 m to a maximum of 128 m. A diurnal vertical migration of schools was evident. During the day the mean depth at which schools were recorded was 53.8 (SD 40.0) and varied considerably. At night the mean depth of schools was much less 21.2 (SD5.6) and the variation was also less. This supports the trend observed in the purse seine fishery where most of the catches are made at night when the fish are closer to the surface.

Large variations in the area and volume of schools recorded was also observed. This is expected given that it is not possible to determine how the school was transected by the ship. Furthermore it is evident that most schools recorded by the sonar were not circular in shape. It is therefore probably better to make use of the sonar recordings of school area when these become available.

The mean packing density of the schools was calculated to be 21.6 (SD 16.5). This is considerably higher than that proposed by Fréon and Misund (1999). They describe mean packing density as a function of fish length. If their conversion (packing density = $2.44L^{-3}$) is applied to the measured pilchard schools, a packing density of less than 10 fish.m^{-3} is expected. Mean packing density between schools did, however, vary a lot from a minimum of 2.1 fish.m^{-3} to a maximum of 65.7 fish.m^{-3}. A large variation in packing density was also observed within schools.

Table 3.2. School variables calculated for 34 pilchard schools

School	Height (m)	Length (m)	Depth (m)	Mean intensity ($m^2.nm^2$)	Area (m^{-2})	Volume (m^{-3})	Density ($ind.m^{-3}$)	Density ($g.m^{-3}$)	Biomass (Tons)
1	14.6	22.8	21.4	592554.0	406.7	5942.2	29.3	2553.8	15.2
2	16.4	79.6	20.9	1151780.3	4975.3	81744.3	50.9	4438.1	362.8
3	19.1	87.6	23.4	629614.3	6027.8	115312.4	24.1	2096.5	241.8
4	29.8	88.4	26.7	1044311.0	6137.5	182589.2	26.0	2266.6	413.9
5	7.1	94.1	15.4	157586.4	6948.0	49469.6	15.2	1325.5	65.6
6	25.8	14.9	39.0	669074.9	174.3	4498.9	19.1	1667.6	7.5
7	4.5	114.1	17.1	32728.0	10226.9	46430.3	4.7	409.6	19.0
8	13.0	112.3	25.5	79685.6	9896.7	128261.7	4.4	384.8	49.3
9	10.9	90.0	19.5	80315.7	6355.5	69401.7	5.2	455.6	31.6
10	17.2	27.1	90.1	245552.6	576.5	9899.2	10.4	907.1	9.0
11	13.8	65.8	128.2	412652.8	3401.0	46764.1	21.6	1883.9	88.1
12	35.4	204.6	58.0	1005496.8	32854.5	1162720.9	21.1	1841.8	2141.5
13	5.8	75.6	17.4	381102.7	4486.3	26065.5	44.1	3845.8	100.2
14	9.3	48.3	21.4	158015.1	1832.0	16945.8	12.0	1046.0	17.7
15	9.4	38.2	19.4	87090.4	1142.6	10762.9	6.5	566.9	6.1
16	9.3	105.2	19.4	403377.2	8688.4	80367.6	30.7	2670.3	214.6
17	7.8	121.3	18.2	509485.3	11546.8	89834.3	45.4	3953.9	355.2
18	13.9	92.7	20.6	461222.8	6749.3	93748.1	23.9	2085.5	195.5
19	18.7	40.1	31.8	398527.6	1261.3	23561.0	15.6	1357.8	32.0
20	9.9	49.3	16.9	917640.4	1909.1	18823.8	65.7	5725.4	107.8
21	7.2	72.8	15.2	294428.0	4165.5	29908.3	28.2	2457.8	73.5
22	10.3	38.5	17.8	926119.8	1163.2	11992.5	63.6	5543.2	66.5
23	6.3	43.8	15.0	63046.0	1509.3	9524.0	6.8	591.2	5.6
24	8.9	38.4	18.1	220987.6	1159.7	10274.9	17.5	1522.3	15.6
25	15.3	49.1	26.6	833539.0	1893.7	28879.2	39.6	3448.7	99.6
26	6.5	13.2	16.5	62703.6	136.0	877.4	6.6	576.5	0.5
27	13.3	51.9	21.4	260238.0	2111.5	28146.0	14.0	1223.5	34.4
28	19.6	40.0	58.8	236290.7	1255.3	24579.6	8.8	769.4	18.9
29	43.4	131.0	39.5	1175286.9	13470.6	584895.0	20.2	1761.4	1030.2
30	18.1	40.3	22.9	457535.6	1275.6	23037.4	18.5	1610.2	37.1
31	14.2	73.6	17.4	213610.8	4254.4	60241.9	10.9	948.4	57.1
32	15.3	97.8	21.7	237089.0	7509.3	114742.0	11.2	979.1	112.3
33	19.7	57.5	24.5	314156.4	2591.3	51023.5	11.7	1017.4	51.9
34	9.3	91.0	15.0	28368.2	6504.1	60358.4	2.1	187.2	11.3

The structure within schools was very patchy with both high density regions and even regions with empty vacuoles within the schools. This seem to be a common observation amongst all pelagic schooling fish. The densest areas were usually found closer to the top of the school. Obviously this is to some extent as a result of absorption within the school which would be responsible for an overall underestimation of packing density and fish abundance.

Large variations in all the measured parameters are evident. This is expected because the manner in which fish occupy space may not always be the same. The shape, size and density of schools may vary appreciably from species to species and within species, from age class to age class. Within species school characteristics might also be dependent on external factors such as hydrological features and the presence or absence of predators and prey. Furthermore, the effect of the ship passing over the school and the position of the transect through the school is not known.

3.2 Behaviour of pilchard during purse seining

When encircled by the purse seine, the pilchard schools moved towards the net wall as far away from the noisy and maneuvering purse seiner as possible. 8.5 - 22 minutes after the net was shot the pilchard school spread out along the net wall. The pilchard seemed to keep along the net wall during pursing which lasted from 13 - 19 minutes, and during most of the hauling of the net. In one of the ten sets observed there were no catch as expected, probably the school escaped out under the boat during pursing. In the other nine cases, the whole school was caught, and pumped onboard.

Two schools larger than 85 tons of pilchard were able to submerge the cork-line frequently. The 167 ton school did that just 8.5 minutes after the net was shot, and then in three other occasion during hauling of the net. To submerge the cork-line, the pilchards must haven been swimming downwards towards the net wall , and thereby created such a heavy force on the cork-line that it submerged. The seals seemed to prey very active on the pilchard during these events, probably scaring the fish to swim against the net.

3.4 Behaviour of seals during purse seining

All purse seine sets were made after 18:00 local time and in darkness, but when searching through the area during daytime, many seals were seen at surface, either as individuals or in flocks. When shooting the purse seine there were no lights on the purse seiners, and it was therefore impossible to see if there were seals nearby the target school. The light-projector on the roof of the wheel-house was used frequently to see if the cork-line submerged due to the pressure of the fish when most of the net was hauled in about 25 - 35 minutes after it was shot. In such cases the number of seals counted in the purse seine varied from 10 to 400 individuals when counted from about 15 - 40 minutes after the shooting of the purse seine (Fig. 3.2). The seals were located above the school as inferred from the sonar onboard "Chris Andra", and they seemed very active by diving after a quick breath at surface. The seals were active in the net until the fish started to be concentrated in the bag along the side of the purse seiner. Most seals left the purse seine quickly when the pump was lifted off the deck. When the pump was lowered into the catch there were usually no seals left in the bag. In one occasion only there were a seal in the bag during pumping, and the pumping had then to be stopped when there were about 3 tons of fish left in the bag to avoid getting the seal in the pump. Still, the seals were active outside the bag, and picked fish that was leaking out through small wholes in the bag, or if parts of the bag was submerged during a large swell. Also when the pumping was finished, and a small amount of fish left in the bag was being washed out under the Triplex the seals were very active, and obviously competing to get as much prey as possible.

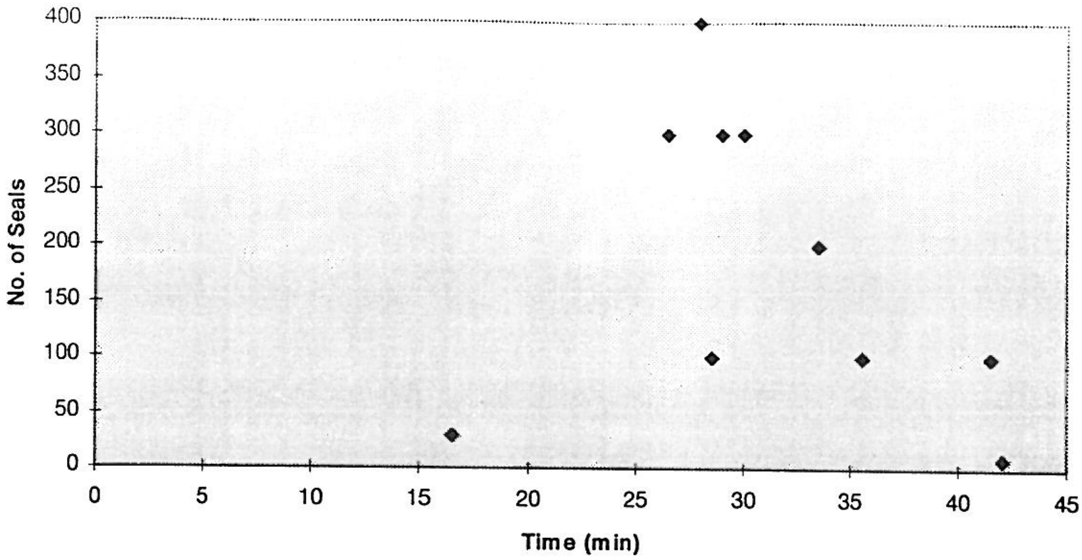


Figure 3.2. Number of seals observed in a pilchard purse seine during 6 sets by M/V "Chris Andra" and 4 sets by M/V "Advance", June 1999. The time is recorded from start shooting the net.

3.5 School tracking

During the cruise, 19 pilchard schools were tracked for 8 - 100 min. The recorded schools were distributed from average depths in the range 11 - 43 m. The schools were swimming at horizontal speeds of 0.41 - 2.20 m/s, and moving in the direction of migration at speeds of 0.06 - 1.79 m/s. The average swimming speed of the 22 cm pilchard was 1.06 m/s or 4.8 bodylengths/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 0.14 per min which means that an intra-school event occurred each 7th 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

0.05 per min which means that such events occurred on average at time intervals of 20 min.

The schools were obviously disturbed by nearby predators. Individuals and flocks of seals were often seen to be active in the vicinity of the schools, and during the sonar tracking, small objects that possibly were seals were observed to approach and move near the schools. Seabirds (gulls and gannets) were in many occasions seen to launch attacks from above.

4 CONCLUDING REMARKS

Nineteen pilchard schools were tracked manually during the cruise. The schools were rather dynamic, and intra- and inter-school events occurred at average rates of 0.14 and 0.05 per min respectively. This means that intra-school events such as change of shape, reorganising and splitting occurred each 7th minute on average, and that inter-school events such as joining and approaching occurred at time intervals of 20 min on average. The schools were moving at horizontal speeds of 0.41 - 2.20 m/s in average, and the speed in the direction of migration varied from 0.06 to 1.79 m/s in average.

REFERENCES:

Barange, M., D.G.M. Miller , I. Hampton and T.T. Dunne 1993. Internal structure of Antarctic krill Euphausia superba swarms based on acoustic observations. *Mar. Ecol. Prog. Ser.* **99**,205-213.

Barange, M. 1994. Acoustic identification, classification and structure of biological patchiness on the edge of the Agulhas Bank and its relation to frontal features. *S. Afr. J. mar. Sci.* **14**,333-347.

Barange, M., Hampton, I. and M. Soule 1996. Empirical determination of in situ target strengths of three loosely aggregated pelagic fish species. *ICES J. Mar. Sci.* **53**, 225-232.

Fréon P. and O-A Misund. 1999. Dynamics of pelagic fish distribution and behaviour: Effects on Fisheries and Stock Assessment. Fishing News Books. Xii + 348 pp.

MacLennan D.N. and E.J. Simmonds 1992. *Fisheries Acoustics.* London; Chapman & Hall: ix + 325 pp. + 4 pp. Plates.

Nero, R.W. and J.J. Magnuson. 1989. Characterization of patches along transects using high resolution 70-kHz integrated acoustic data. *Can. J. Fish. Aquat. Sci.* **46**,2056-2064.

Pitcher, T.J. and B.L. Partridge 1979. Fish school density and volume. *Mar. Biol.* 54,383-394.

Reid, D.G. and E.J. Simmonds. 1992. Image analysis techniques for the study of fish school structure from acoustic survey data. *Can. J. Fish. Aquat. Sci.* **50**, 886-893.

ANNEX I. Records of purse seine sets by Namibian vessels on schools recorded acoustically by R/V "Dr. Fridtjof Nansen"

1. Set, "Chris Andra", "Nansen" over school 00:40, s_A = 8644 m^2/nm^2.

17/6 - 99, Position: S21° 20,42', E13° 03.36'

00:43:30	Shooting
00:45:00	½ net shot
00:46:45	Net shot
00:48:00	Pursing started
00:53:00	Hauling of net
01:00:00	~ 30 seals active in net at bossom where the fish is
01:07:00	Pursing finished
01:25:00	~ 100 seals active in net
01:27:00	Net hauled and ready for pumping.

Result: Failure, fish probably out under vessel during pursing

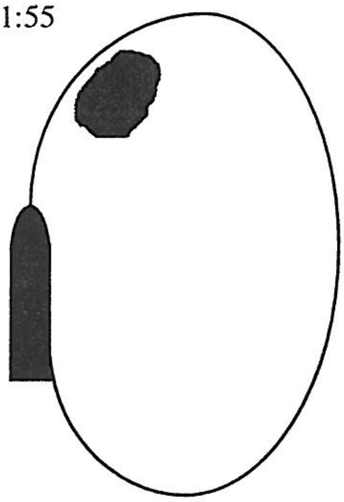
2. Set "Chris Andra", "Nansen" over school before shooting net, s_A = 44 701 m^2/nm^2, SF950 raw-data. School from 10 - 50 m depth.

17/6 - 99, Position: S21° 21.3', E13° 03.1'

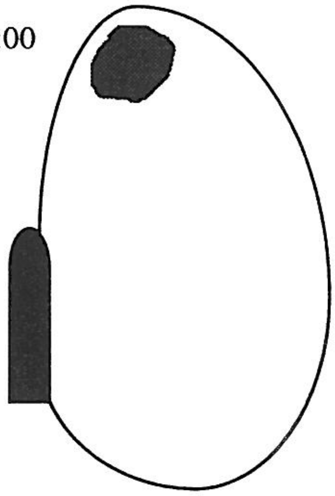
01:48:30 Shooting
01:50:00 ½ net shoot
01:52:15 Net shoot
01:56:00 Pursing started
02:11:00 Pursing finished
02:30:00 Net hauled inn, ready for pumping
Catch: 40 ton in net, but released due to much jellyfish, 6 fathoms hole in net near the bag, probably causing much loss of fish

Events:

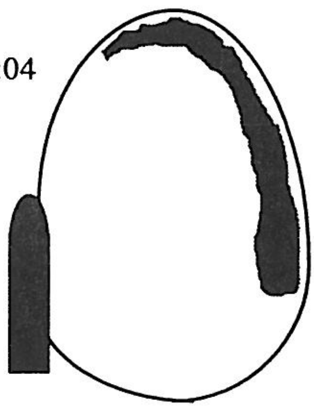
01:55



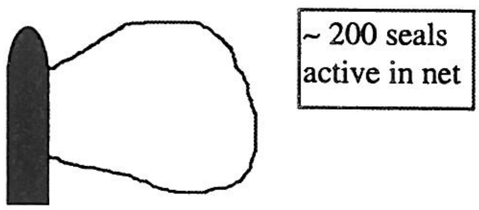
02:00



02:04



02:22



3. Set "Chris Andra", school detected at 1500 m range by SR240. "Nansen" over school 03:00, school from 10 - 30 m depth, s_A = 20 610 $m^2 nm^{-2}$

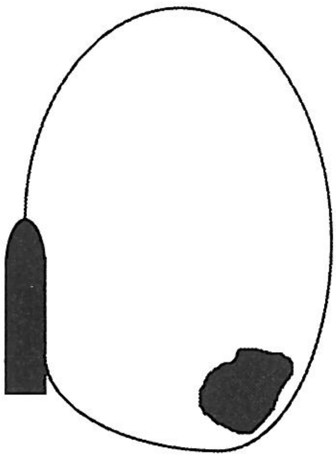
17/6 - 99, Position: S21° 20.3', E13° 02.68'

03:02:00	Shooting
03:03:30	½ net shot
03:06:30	Net shot
03:08:00	Pursing starts
03:12:00	Hauling of net
03:24:00	Pursing finished
03:40:00	Net hauled, ready for pumping of catch

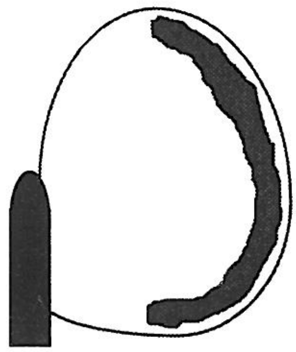
Catch: 55 tons of pilchard

Events:

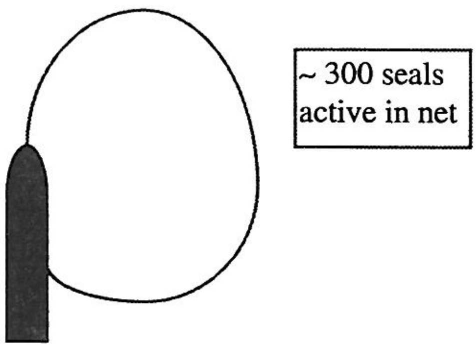
03:17



03:24



03:30



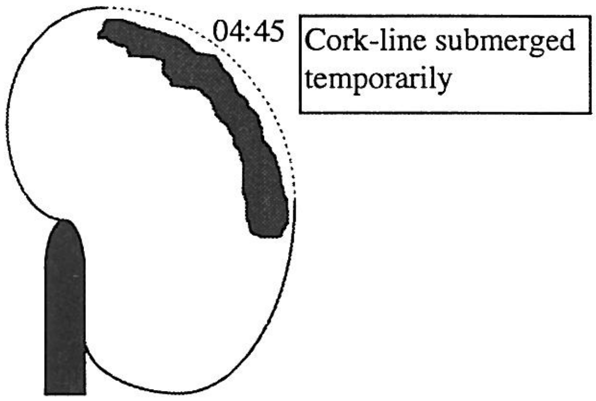
4. Set "Chris Andra", detected school at 2000 m on SR240. "Nansen" over school at 04:30, s_A = 37 392 m^2/nm^2, school depth from 8 - 40 m.

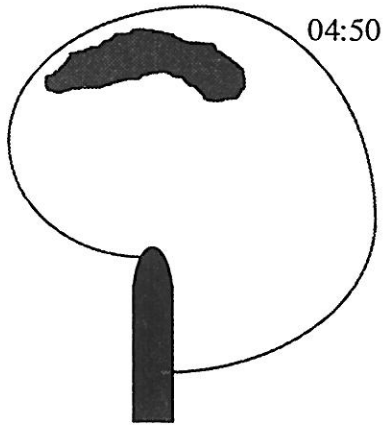
17/6 - 99. Position: S21° 19.49', E13° 02.7'

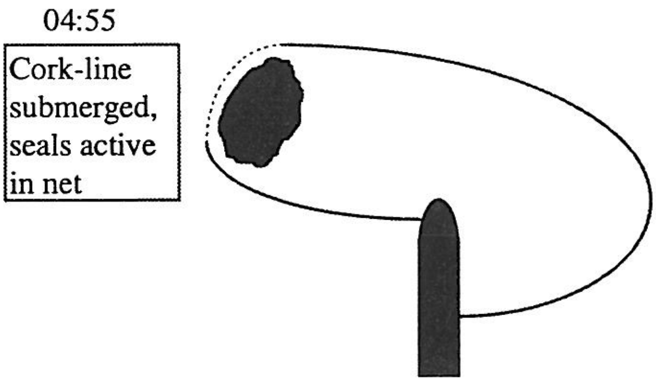
04:36:30	Shooting
04:39:30	Net shot
04:43:00	Pursing and hauling starts
04:56:00	Pursing finished
05:15:00	Ready for pumping

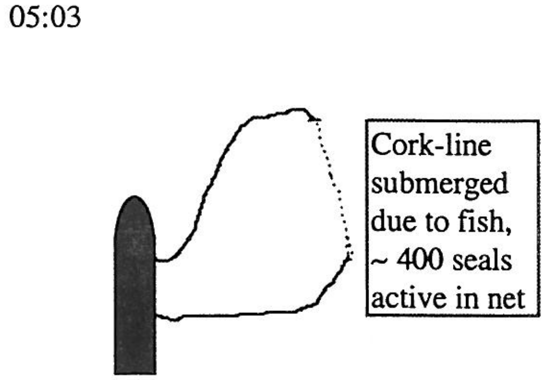
Catch: 167 tons of pilchard

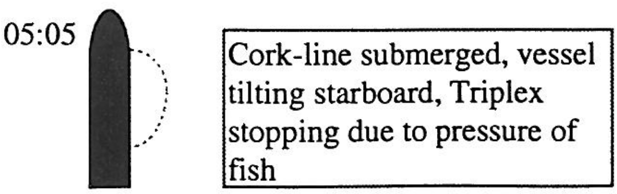
Events:

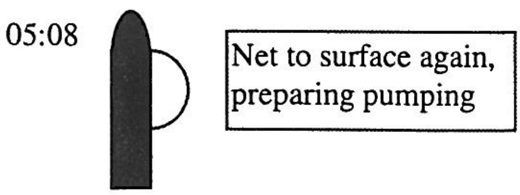












5. Set "Chris Andra", "Nansen" over school 18:15, s_A = 7151 m^2/nm^2, school from 7 - 25 m depth.

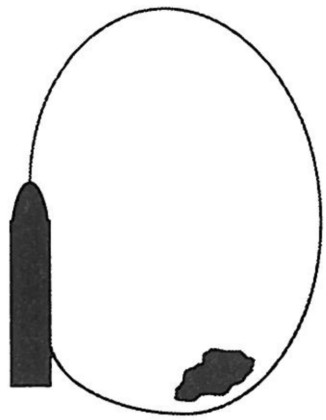
18/6 - 99, Position: S 21° 20,99' E 13° 09.36'

18:23:30	Shooting
18:24:50	½ net shot
18:26:30	Net shot
18:28:00	Pursing started
18:33:00	Hauling started
18:44:00	Pursing completed
19:00:00	Net hauled, ready for pumping

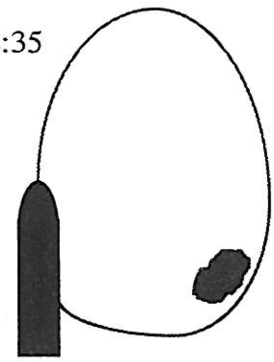
Catch: 85 tons of pilchard

Events:

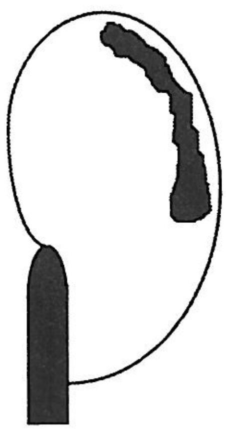
18:32



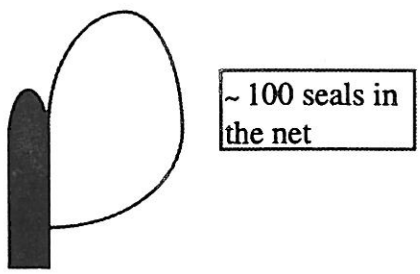
18:35



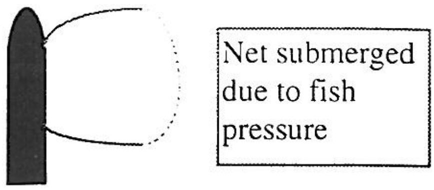
18:38



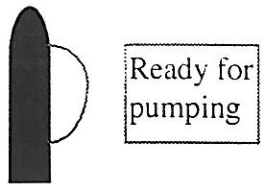
18:52



18:56



19:00



19:15 About 100 pilchard taken alive by a brail from the net, the pilchard emptied from the brail to a bucket with sea water, and then transferred to a large holding tank with sea water on deck, the tank about 1.5 m in diameter, and about 1.2 m in height, the tank supplied with running sea water from a hose in the bottom of the tank, the tank covered with a net to prevent the pilchard from jumping out of the tank. The pilchard appeared to be very stressed after transfer to the tank. A weak deck light under the wheel house just above the tank.

20:50 The pilchard schooling, and slowly milling in the tank.

6. Set "Chris Andra", "Nansen" over the school at 21:35, s_A = 18 624 m^2/nm^2, school from 7 - 50 m depth.

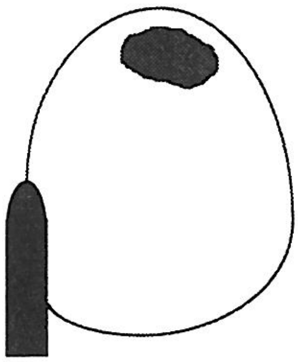
18/6 - 99, Position: S 21° 21.47', E 13° 06.98'

21:41:00	Shooting
21:42:30	½ net shot
21:44:00	Net shot
21:50:00	Hauling started
22:03:00	Pursing completed
22:15:00	Net hauled, ready for pumping
22:18:00	Pumping

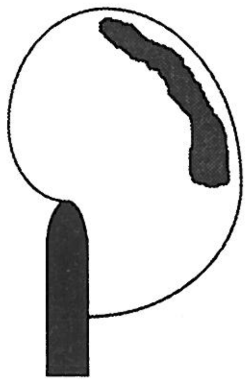
Catch: 60 tons of pilchard

Events:

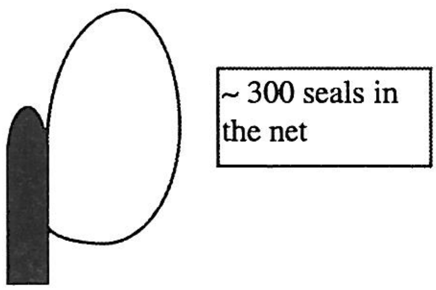
21:50



21:58



22:10



22:50 John Horne onboard to take the live pilchard to the veterinary in Swakopmund for X-raying.

23:00 "Chris Andra" heading for Walvis Bay.

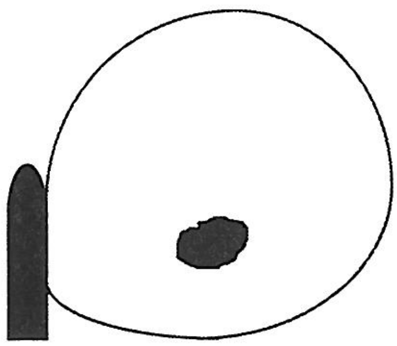
7. Set "Advance", "Nansen" having main engine breakdown and not available for school recording. Sonar of "Advance" hoisted during pursing.

18/6 - 99. Position: S 21° 23.3', E 13° 11.2'

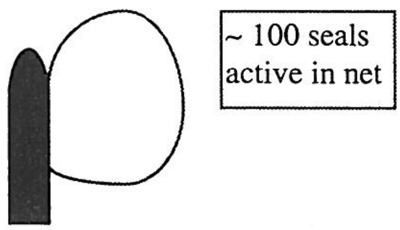
18:12:30 Shooting
18:13:50 ½ net shot
18:16:00 Net shot
18:20:00 Pursing started
18:23:00 Hauling started
18:38:00 Pursing completed
19:00:00 Net hauled, pumping starting
Catch: 80 tons of pilchard

Events

18:23



18:48



8. Set "Advance", "Nansen" over school 20:20, $s_A = 9000\ m^2/nm^2$, school from surface to m depth.

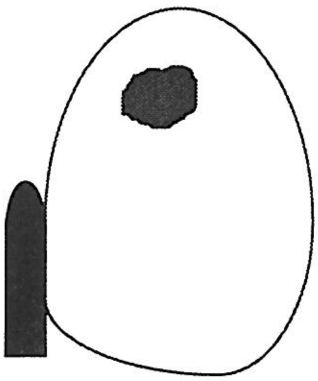
20/6 - 99, Position: S 21° 24.59', E 13° 12.23'

20:30:00	Shooting
20:31:50	½ net shot
20:34:50	Net shot
20:39:00	Pursing started
20:40:00	Hauling started
20:57:00	Pursing completed
21:13:00	Pursing cork-line, seals leaving
21:15:00	Net hauled, ready for pumping

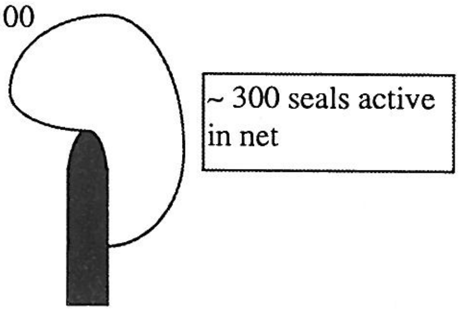
Catch: 75 tons of pilchard

Events:

20:37



21:00



21:55:00 Pumping stopped because of seal in the pump, about 2 tons of pilchard released.

9. Set "Advance". "Nansen" over school at 22:35. school from 5 - 40 m depth. s_A = 760 m^2/nm^2, "Nansen" may have passed over just small fraction of the school.

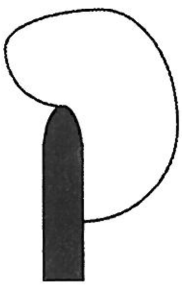
20/6 - 99, Position: S 21° 20,69', E 13° 09,82'

22:43:00	Shooting
22:47:00	Net shot
22:52:00	Pursing started
22:54:00	Hauling started
23:10:00	Pursing completed
23:30:00	Net hauled, ready for pumping

Catch: 40 tons of pilchard

Events:

23:25



Only ~ 10 seals active in the net, the rest probably occupied or satisfied by the remains from the previous set

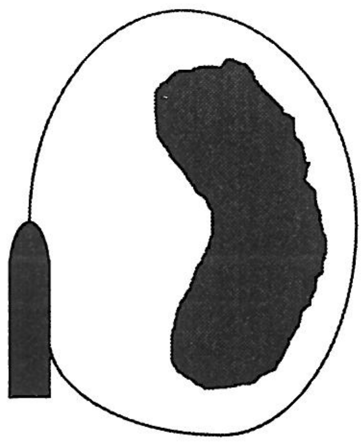
10. Set "Advance", "Nansen" over school at 18:20, school from 0 - 40 m depth, s_A = 17 000 m^2/nm^2.

23/6 - 99, Position S 19° 41.16', E 12° 41,08'

18:24:15	Shooting
18:25:45	½ net
18:28:00	Net shot
18:34:30	Pursing
18:40:00	Net hauling
18:45:00	School on echo sounder 10-30 m depth going out of purse seine
18:49:00	Small pilchard gilled in net appearing in the Triplex
18:50:00	No more fish on echo sounder
18:51:00	Pursing completed
18:58:00	Small pilchard heavily entangled in net
19:05:00	Release breast of purse seine so that the fish can swim out of the net
21:00:00	Net hauled

Events:

18:29



ANNEX II
Shoal Tracking   Namibia 1999

	Speed (m/s)	N speed (m/s)	E speed (m/s)	Heading (°)	Depth (m)	Time	South (°)	East (°)	N (Observ.)
School 1	0.67	-0.05	0.23	101.8	39.19	15.47	21.32	13.14	1
School 2	0.53	0.3	0.13	23.52	43.45	16.47	21.34	13.13	2
School 3	0.72	0.091	0.08	41.88	25.30	17.38	21.35	13.14	3
School 4	0.85	0.32	0.07	12.33	25.61	18.14	21.33	13.14	4
School 5	1.34	-0.33	0.45	126.1	25.64	20.49	21.29	13.14	5
School 6	2.2	0.22	-1.77	277	35.90	21.37	21.27	13.15	6
School 7	0.87	0.07	-0.54	277.8	25.11	21.85	21.27	13.14	7
School 8	1.03	-0.05	0.03	148.8	15.69	22.47	21.24	13.14	8
School 9	0.57	0.09	-0.24	290.3	20.85	1.76	21.29	13.15	9
School 10	1.33	0.19	-1.23	278.7	18.90	3.62	21.32	13.13	10
School 11	1.68	-0.88	1.43	121.6	11.36	8.23	21.68	13.17	11
School 12	0.93	-0.33	-0.46	233.7	12.53	9.04	21.27	13.19	12
School 13	1.54	-0.42	-0.45	227.2	25.62	18.40	19.68	12.66	13
School 14	0.98	0.02	-0.74	271.3	35.00	19.92	19.69	12.66	14
School 15	1.73	-0.01	1.41	90.49	29.00	17.43	20.58	12.92	16
School 16	0.47	0.19	0.3	57.96	22.00	21.22	19.97	12.9	17
School 17	1.31	0.12	0.2	60.27	22.16	22.37	19.99	12.89	19
School 18	0.41	0.05	0.29	80.92	11.63	12.82	19.84	12.44	20
School 19	1.43	0.21	1.33	81.09	16.20	1.12	19.84	12.45	21

ANNEX III
Shoal Behaviour Namibia 1999

			SHAPE							INTRASCHOOL EVENTS					INTERSCHOOL EVENTS		
	Time	Duration	Circle	Oval	Rod	Crescent	Ring	Amorph	Fragmented	Change of shap(	Re- organising	Splitting	Leaving	No. of events	Join	Approach	No. of events
School 1	15:08	36	2	2	-	-	-	-	2	1	2	1	1	5	1	1	2
School 2	16:00	60	18	16				3	17		2	18	1	21		1	1
School 3	17:13	22						3	4			4	1	5		1	1
School 4	17:49	50	4	2		1	1	7	4	4	1	3		8			
School 5	20:00	60			2	2		21	1	3		1		4		1	1
School 6	21:12	18			3	1		1	16		1	5		6			
School 7	21:43	14						1	15			2	1	3			
School 8	22:14	26			2	1		4	5		1	5	1	7	2		2
School 9	01:02																
School 10	02:48	100	11	6	4			20	2			1		1	1		1
School 11	08:04	20	1	1		1			6	1	1	1	1	4	1	2	3
School 12	08:32	60	1	7	6	10		4	2	2		3		5	3	4	7
School 13	18:52	44	1	4	1	4		7	3			3		3	2	5	7
School 14																	
School 15																	
School 16	17:18	18	2	2				2	1			1	1	2			
School 17	21:09	8				1		2	2			1	1	2			
School 18																	
School 19	21:50	62			3	3		13	12			4	1	5			
School 20	12:44	12	1	1	2	1			1			3	1	4			
School 21	01:01	12		3	1			1	1			1	1	2			
School 22																	
School 24																	
School 25																	
School 26																	
School 27																	
TOTAL	-	**622**	**41**	**44**	**24**	**25**	**1**	**89**	**94**	**11**	**8**	**57**	**11**	**87**	**10**	**15**	**25**

CHAPTER 4. APPLYING AND TESTING THE SIMRAD SF 950D SONAR, AND THE SODAPS LOGGING AND POST PROCESSING SOFTWARE SYSTEM

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 and completely new software. The upgrade i.e. the installation, commissioning and some system testing took place during three short cruises onboard "Dr. Fridtjof Nansen" in December 1996, April-May and December 1997. A considerable part of the December 97 version of the software and thereby some of the sonar performance could not be sufficiently tested due to time shortage and unfavourable weather condition during that cruise.

During our corresponding cruises in 1997-98 we experienced that the sonar did not fulfil our requirements compared to the performance and functioning of the original SA 950H and other comparable sonars. This was fairly well tested and documented during the 1998 cruise.

Simrad provided us with new beam forming software for the sonar for the North-West Africa pelagic fish cruise taking place during October-December 1998. The SF 950D was thereafter undertaken an extensive performance and functioning test during the first part of that cruise, and was qualified as "substantially improved and acceptable" except for the automatic gain control (AGC) function and some remaining minor functions to be improved.

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 post processing 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 volume 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 return. During these detections it forms so-called echolines and echoblocks. Thereafter it tests and compares between consecutive pings to form echoblock chains or school candidates. Echolines, echoblocks, echoblock chains, and school candidates are all elements of potential schools.

We have previous to this cruise worked with SODAPS onboard RV "Dr. Fridtjof Nansen" during four short periods from December 1996 to April-May 98. Then we have carried out testing and tuning of the system, developed software modules for storing school data as well as for mapping the echogram data from the computer to a colour printer. Storing of both raw and processed data has taken place. A considerable part of this effort have had reduced benefits due to the malfunctioning sonar.

2 METHODS

2.1 Performance of the Simrad SF 950D sonar

As said the sonar was qualified as "substantially improved and acceptable" since November 1998 compared to previous cruises since December 1996. This was confirmed during this cruise although there are still functions that we want to be improved.

2.2 Sonar testing and calibration with an aluminium sphere

Specific controlled testing of the sonar was performed against a calibration target - an hollow aluminium sphere of 15 cm outer diameter and filled with 96 % alcohol. Its target strength has been measured to -17.0 dB at 95 kHz (92.5 kHz: -17.2 dB and 97.5 kHz: -17.7 dB).

The first activity was to test the range detection capabilities of the sonar against the sphere. The sphere was put on a rig with a buoy at the surface, the sphere at a depth of 30 m and a sinker of approx. 4 kg 50 m below the sphere.

In order to establish a calibration procedure for the SF 950 we were to do some initial experiments to proceed tentatively of different subtopics of the total calibration operation. The calibration sphere was to be hanging in three nylon lines being winch operated from the vessel's rail. A sinker of approx. 5 kg was hanging in a nylon line 7 m below the sphere. A list of several tentative tests and operations was made prior to the activity. Available time and values of the activities to be done were determinants for what we put into this task. During the exercise SODAPS was to log and store to files the sonar target data and the sonar raw data as well as the sonar display was to be recorded on video tape.

2.3 Applying and testing the SODAPS

During the period from December 1996 to November 1998 the sonar has produced noisy, incorrect and non-acceptable data to the SODAPS system which has made a considerable part of our SODAPS testing, tuning, development and improvement activities to some extent worthless and wasted. This accounts both for these activities during the previous cruises and at the data lab in Bergen.

Prior to this cruise we have put some effort into testing and improvements based on stored data from the last November cruise along Mauritania and Southern Morocco. Particularly we have focused on the selection algorithms and mechanisms for echoblock chains and school candidates. Likewise we have provided a second data report format to produce data of more raw and comprehensive character than the one we produced last year. These reports may be read by host computers with the necessary data analysing and presentation software.

3 RESULTS

3.1 Applying the sonar SF 950D

The sonar conditions (sound propagation conditions) were rather excellent for the surveyed area. South of S 21° 10" and at bottom depths more than 100 m we had nearly constant sound velocity profiles from the surface to 45-55 m depth with an average sound velocity of 1508 m/s. From this depth to the bottom the sound velocity was slightly decreasing with an average gradient of - 0.04 m/s per metre. North of S 21° 10" and at bottom depths less than 100 m the sound velocity profiles were more varying around and average sound velocity of 1504 m/s in the upper 0 to 40 m and an average gradient of - 0.03 m/s per metre to the bottom. For this area of depths exceeding 100 m we observed an averaged sound velocity of 1506 m/s down to 100 m and average gradient of - 0.03 m/s.

Even though the beam forming now is as required the applied signal noise criteria (fixed +10 dB dynamically linked to the estimated noise level) for the sonar target detection and identification module as previously noted, in many cases still seems to be too low. Having schools of high through medium to low packing density or school entities of varying clusters the target estimator identifies the school target entity as several smaller entities giving them individual identifiers. Suggested solutions were put forward in the last year report from a similar cruise.

When doing dedicated school tracking of one and one school we still find it a serious shortcoming compared to SA 950H that the manual marker function for positioning and tracking is lacking.

Other observations

Now and then the sonar still 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 does not 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. As traced and documented in November 1998 the automatic gain control (AGC) is not functioning properly and has to be switched off during proper sonar operations.

When operating the sonar connected to the 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 at some decided frequency and update them when remote controlled changes have been detected.

Since October 1998 we have got the new Operator Manual for the SF 950 from Simrad. Compared to that of SA 950 and the effort we put into revision of the former ones, we have to regret that the SF 950 Manual is lacking useful information. This should rather be considered from Simrad during the next revision.

3.2 Sonar testing and calibration with a sphere

First we made a short test of the maximum detection range of the calibration sphere. As the vessel approached the rig in two runs it came out that the sphere could be picked up at a distance of ≈ 310 m. Other collected parameters were applied to check the minimum sampling volume and the estimations of mean and maximum volume backscattering strength of the sonar. The pulse form and the filter settings were equal to those mainly used throughout the cruise for school mapping and tracking. The sonar display was recorded on video tape during the exercise and SODAPS data were stored to files. In Annex I, Fig. 4.1 is displayed two graphs from the experiment; the upper one showing the sonar estimated target volume vs. range and the lower one the maximum and mean volume backscattering strength of the sphere vs. range. NB! The volume backscattering strength is not corrected for additional range compensation due to the sonar is applying the 20 log R instead of 40 log R (not available) for single targets.

For the calibration activity the following main tasks were carried out in the outer part of Walvis Bay harbour:

- Tried one out of four potential rigging locations on the vessel for the sphere positioning. One winch was located at the bow while the two other ones were one on each side of the foreship. The positioning of the sphere was rather easy to carry out with this rigging location.
- Evaluated the proposed default settings of relevant sonar parameters with recommendations for changed settings. Details may be found in the instrumentation report from the cruise.
- Measured and mapped the directivity of the whole beam fan. Fig. 4.2, Annex I, displays the maximum and mean of the measured volume backscattering strength vs. beam angle at 1° training steps. The same remark applies here for the range loss compensation as mentioned for Fig. 4.1.

The depth at the calibration cite was approx. 17.5 m which for coming calibration operations should be deeper since we experienced some impediments due to the bottom reverberation.

3.3 Applying and testing the SODAPS

The very first day were devoted to implementing and testing the slightly changed software to that of 1998 to run satisfactory as well as the connection to the sonar to communicate with and deliver specified data to SODAPS.

The revised SODAPS version was qualified as "running to our satisfaction" on our work stations in Bergen before leaving where we stored it on a CD ROM to bring to the vessel. When we were to apply it on school detection some part of the system was not satisfactorily functioning as it did not carried out the final school candidate detection and selection. During the cruise we were not able to detect specific bugs responsible for this. A possible reason might be having introduced faults or imperfections to the CD during writing (burning) to it.

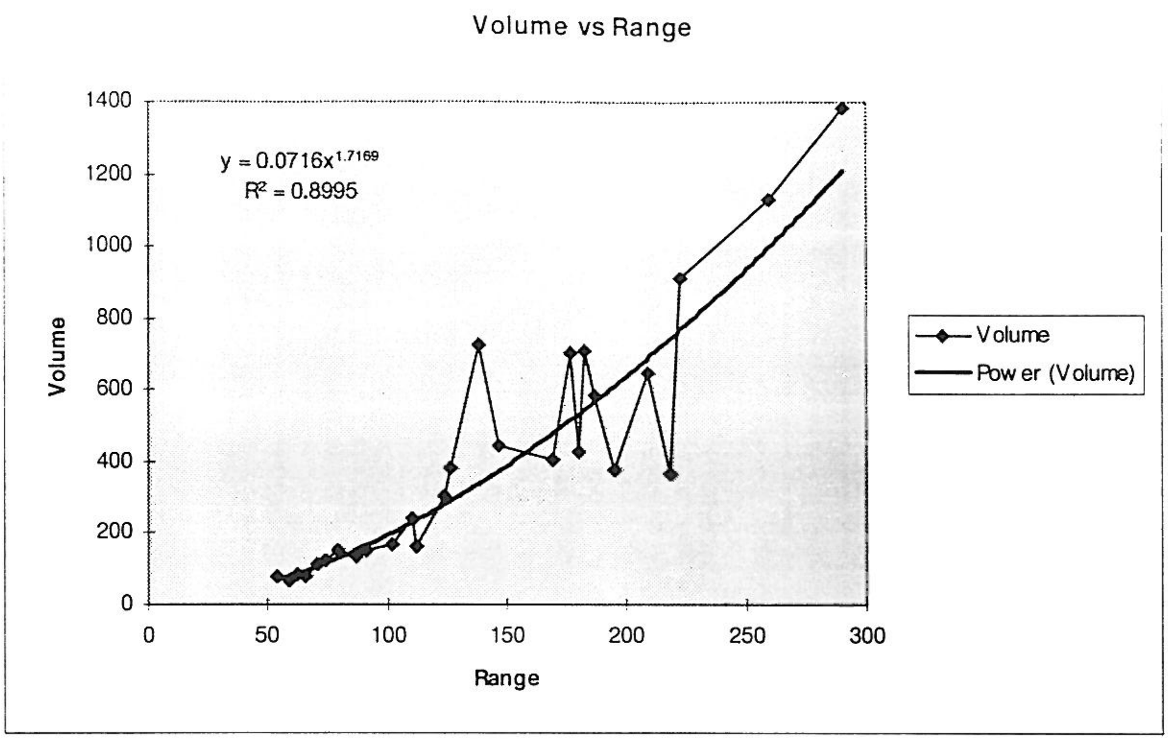
To account for some of these impediments in our acquisition of school data we made special programs to read the raw data telegrams from the sonar and to list out all relevant information of the sonar detected school candidates. These data were then analysed by host computers. For detailed information, see chapter 5. In addition we have made a minor shift of the colour scale range of the SODAPS printer to be better tuned to the sonar display dynamic range.

4 CONCLUDING REMARKS

At the present state the SF 950D is fulfilling our major quality requirements. It will be advantageous that some improvements and necessary testing of certain functions of the sonar take place at Simrad.

The SODAPS system did not function as planed, and severely restricted the possibilities for conducting an automated comparative sonar and echo sounder survey which was the major objective of the cruise.

While we now have a proper functioning sonar partially seen from the SODAPS side and thereby proper data, we should use the opportunity for the rest of 1999 to put concentrated effort into improving and optimising the SODAPS system to function properly.



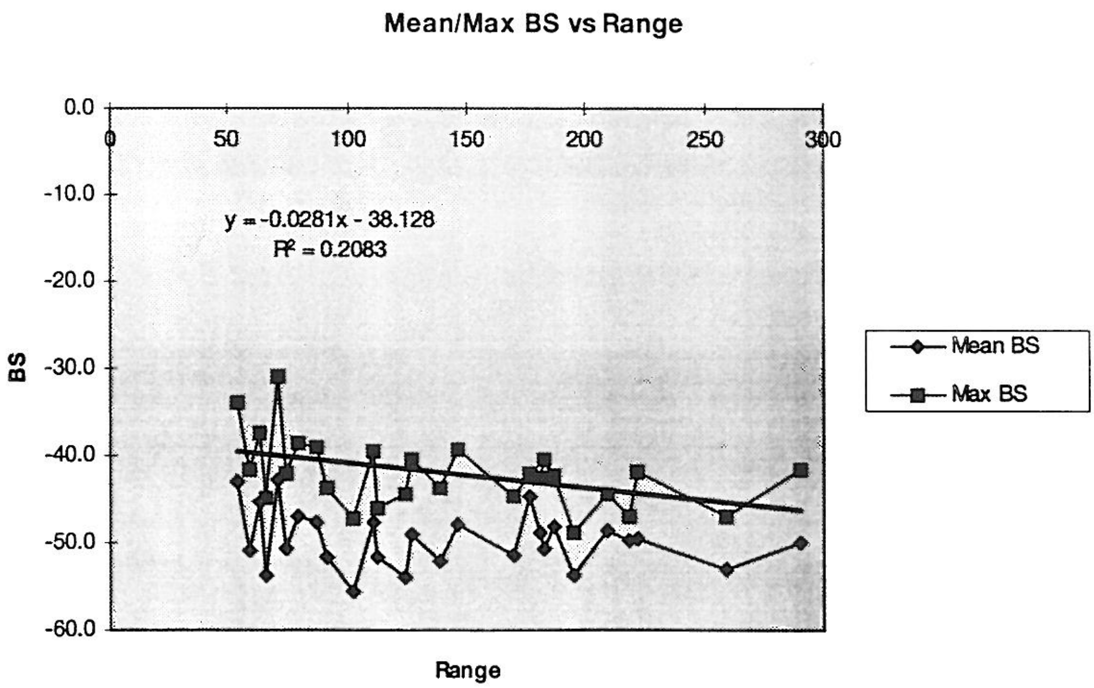


Figure 4.1. Measured target volume from the SF 950 of the calibration sphere vs. range (upper part) and mean and maximum volume backscattering strength of the sphere vs. range (lower part).

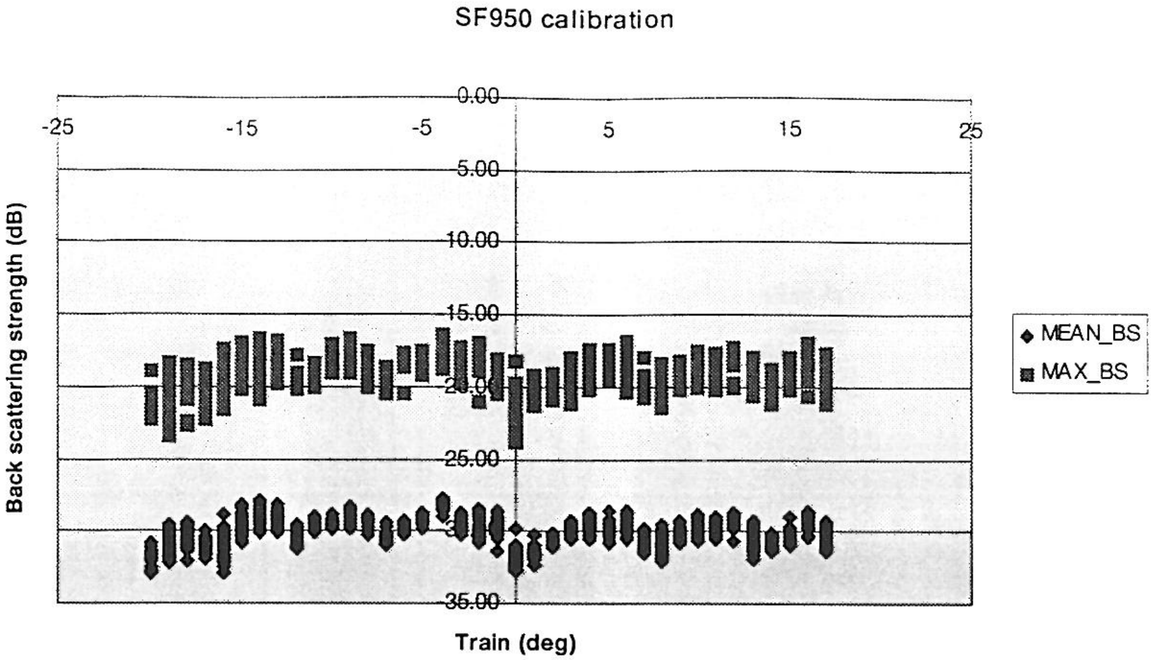


Figure 4.2. Maximum and mean volume backscattering strength of the sphere vs. beam angle of the total beam fan. Training increments of 1°. The sphere was at approx. 3° to port side (negative numbers).

CHAPTER 5. DEVELOPMENT OF SOFTWARE FOR THE EXTRACTION OF SONAR TRACKING DATA

1 INTRODUCTION

1.1 Background and objectives

The specification for the upgrade of the SF950 sonar included a target tracking function which should supply data on echo targets within each ping. Implementation of this function was carried out by Simrad at the end of 1997 and supplies tracking data on up to 32 targets simultaneously. Logging of the tracked target telegrams from SF950 has been incorporated in the SODAPS software. During this cruise it was decided to start development of software for the extraction of sonar target data to create data files that would be suited for import in general data analysis software. Software development was carried out in the latter part of the cruise resulting in programs for data extraction and a SAS program for reading and filtering the generated data files.

2 METHODS

2.1 Reading of data files logged by SODAPS

By turning on output of tracked targets from the Simrad SF950 sonar the SODAPS will store information from these data telegrams in separate tracked target files on the workstation. To get target data in a form that can be easily imported in programs like Excel and SAS we have developed the program *targetprint*. By supplying the names of SODAPS tracked target files (with .TT filename extension) as parameters it will read and interpret these files and combine this with information from the accompanying ping information files (.PI extension) to produce a formatted output with information on tracked targets. The output contains general vessel information as well as sonar target data. A heading is preceding the output indicating what data the specific columns contain. In the annex section I there is a description of the output format generated by targetprint.

Since targetprint lists its result to the screen, although it can be redirected to a file, a scriptfile named *target-report* for generating report files, was also created. Just as targetprint, it takes the names of tracked target files as parameters but generates report files with the filename extension of *.targets*.

A few examples of how to run targetprint and target-report:

targetprint *.TT >target.lst	Write target data from all tracked target (TT) files to the file target.lst
targetprint *_19990701_*.TT	List TT data from all files created on 1st of June 1999.
target-report *.TT	Create target report files for all TT files in current directory

2.2 SAS algorithms for filtering the sonar tracking data

The tracking function in SF950 seems to give multiple detections of the same sonar target within each ping. This poses a problem since information on several targets transferred to SODAPS will actually refer to the same sonar echo, possibly with small variations in position and as a result different values for speed. In an attempt to filter the superfluous information a SAS program was written. It will keep only one of several targets that have the same volume, mean- and max. backscattering strength within one ping. As this filtering is done in a rather crude manner, keeping only the first occurrence , a more sophisticated algorithm should me implemented in the next version of the program. The filtered target SAS dataset is also written to an external text file for use by other software. Program code for the SAS filtering program is listed i annex section II.

3 RESULTS

3.1 Application of sonar tracking data

During this cruise the main use of the sonar tracking data have been during calibration of the SF950. Raw data was recorded using the sonar train to move the aluminium calibration sphere target to all sonar beams. Target tracking data files were created from the raw data and target information written to a file by the targetprint program. After processing the listfile in SAS, the filtered output was imported in Excel to produce a plot showing backscattering strength for the different beams of the sonar fan. This plot is presented in chapter 4.

Recording of sonar tracking data was only done in the last part of the cruise and these data have not yet been processed. There still remains some work to establish what the criteria to be used for extracting the valid targets that.

4 CONCLUDING REMARKS

As of now the tracking data have proved their use during calibration of the sonar. To improve the quality of the data from the sonar, its software should be updated to include a few improvements. Ability to set the lower backscattering limit for acknowledged targets would enable us to let the sonar drop small targets of no interest. The sonar should also be able to recognise when two target detections actually represent the same target and store only one. Interpretation of the data would then be much easier and it would also free up space in the sonar target table for more targets. Provided that these modifications are made we should be able to get school data that can be used for tracking and counting schools.

ANNEX I Output format of the targetprint program

The output from targetprint (and target-report) is presided by a heading telling the contents of each column. Heading text and column meanings are as follows:

PING_NO	Sequential ping number starting at zero for each target file
T_NO	Target number supplied by the sonar
DATE	Date (DD/MM/YY)
TIME	Time (HH:MM:SS)
SF_TIME	Time of SF950 (HH:MM:SS, internal clock)
LOG	Vessel log counter (nautical miles)
LATITUDE	Vessel latitude (south is negative)
LONGITUDE	Vessel longitude (west is negative)
COURSE	Vessel course (degrees)
SPEED	Vessel speed (knots)
TILT	Sonar tilt angle (degrees, down is negative)
TRAIN	Sonar train angle (degrees, starboard is negative)
T_LATITUDE	Latitude of tracked target (degrees)
T_LONGITUDE	Longitude of tracked target (degrees)
DEPTH	Depth of target (m)
NS_SPD	North/south speed of target (m/s)
EW_SPEED	East/west speed of target (m/s)
SNK_SPEED	Sink speed of target (m/s)
VOLUME	Volume of target (m^3)
MEAN_BS	Mean back scattering strength of target (dB)
MAX_BS	Max back scattering strength of target (dB)

ANNEX II SAS algorithm for filtering sonar tracking data

The filtered data produced by this program includes a limited number of parameters for the targets. It can easily be modified to include other parameters from the original data or calculate new ones.

```
/*
 *     File: targetfilter.sas
 *
 *     Read data from target report file generated by
 *     targetprint (or target-report) from tracked
 *     SODAPS tracked target datafiles.
 */

data ttdata ;
  infile "/data/reports/SONAR_19990622_124531.targets"
         firstobs=2 ;
  informat date ddmmyy. time sf_time time. ;
  format ping_no t_no 4. date ddmmyy. time sf_time time.
         dist tilt depth vol 6. mean_bs max_bs 6.2 ;
  input PING_NO T_NO DATE TIME SF_TIME
      LOG LAT LON COURSE SPEED TILT TRAIN T_LAT T_LON DEPTH
         NS_SPD EW_SPD SNK_SPD vol MEAN_BS MAX_BS ;

  a = abs((lat - t_lat)) * 60 ;
  b = abs((lon - t_lon)) *
      cos ((((lat + t_lat) * 2 * 3.141592654) / 360) / 2) ;
  dist = sqrt (a**2 + b**2) * 1852 ;
run ;

/*
 *    Sort dataset prior to removal of duplicate target
 *    detections.
 */

proc sort data=ttdata ;
  by ping_no dist depth vol mean_bs max_bs ;
run ;

/*    Remove tracked targets within one ping which have the
 *    same value for volume, mean and max BS.
 *    The sonar seems to identify several targets for
 *    the same school. Keep just one.
 */

data ttstrip ;
  set ttdata ;
  keep ping_no t_no sf_time dist tilt depth vol
       mean_bs max_bs ;
  retain L_pingno L_vol L_meanbs L_max_bs ;
  if ping_no=L_pingno AND
     vol=L_vol AND
     mean_bs=L_meanbs AND
     max_bs=L_max_bs
     then delete ;
```

```
  L_pingno=ping_no ;
  L_vol=vol ;
  L_meanbs=mean_bs ;
  L_max_bs=max_bs ;
run ;

/*
 *    Write filtered dataset to a listfile
 */

proc printto file='/data/reports/target.lst' new ;
run ;

options pagesize=9999 ;

proc print data=ttstrip ;
run;

proc printto print=printer ;
run;

proc fsview data=ttstrip ;
run ;
```

CHAPTER 6. SWIMBLADDER IMAGING AND ACOUSTIC BACK SCATTER MODELLING OF PILCHARD

1. INTRODUCTION

Accurate conversion of echo intensity to numeric abundance requires representative acoustic sizes. Acoustic size is influenced by a variety of biological and physical factors including fish species, length, tilt, and acoustic carrier frequency. We were interested in modeling acoustic backscatter of two commercially important fish species common to the southern Benguela region – pilchard (*Sardinops ocellatus*) and horse mackerel (*Trachurus trachurus capensis*).

Acoustic backscatter models should accurately represent the organism being modeled. The Kirchhoff-ray mode (KRM) model estimates backscatter using a low mode cylinder solution and a Kirchhoff-ray approximation. The morphology of the fish body and swimbladder are laterally and dorsally imaged using x-radiography. The two images are combined to create a three-dimensional representation of the fish body and swimbladder. The fish body is represented using contiguous fluid-filled cylinders that surround a set of contiguous gas-filled cylinders representing the swimbladder. Backscattering cross-sectional area from each cylinder is summed over the swimbladder and body and then added coherently. Backscatter from the swimbladder at $ka < 0.2$ is estimated using a low-mode cylinder solution. A Kirchhoff-ray approximation is used to calculate swimbladder backscatter at ka values greater than 0.2. For full descriptions of the model see Clay and Horne (1994), Jech et al. (1995) or Horne and Jech (1999).

Objectives for cruise Nab99 were to image the anatomy of pilchard and horse mackerel, model acoustic backscatter of pilchard, compare variability of TS estimates among conspecifics, and to visualize representative fish body, swimbladder, and backscatter volumes.

2. FISH BODY AND SWIMBLADDER IMAGING

Eight frozen pilchards, stored at the Fisheries Inspectorate in Walvis Bay, were taken to the Swakopmund Veterinary Clinic. An additional three frozen mackerel (*Scomber japonicus*) were obtained from a sample at the Ministry of Fisheries and Marine Resources, National Marine Information and Research Center (NatMRC) in Swakopmund.

To examine the efficacy of the x-ray equipment (Acoma model PX-40H), a single pilchard (245 mm TL) was radiographed at four exposures:

Table 1. Plate number, voltage, and exposures used to radiograph a frozen Pilchard (245 mm TL).

Plate (#)	Voltage (kVP)	Exposure (s)
1	40/50	0.25
2	40/50	0.2
3	60	0.2
4	40/50	0.16

The first combination of exposure settings resulted in the highest contrast between the fish body and swimbladder boundaries. This combination was used for all subsequent x-rays of pilchard. Exposure time for the horse mackerel radiographs was increased to 0.4 seconds. Three x-ray plates were used to image dorsal and lateral planes of 8 pilchard ranging from 215 to 238 mm TL. The three mackerel with lengths ranging from 325 to 340 mm TL were radiographed on three separate plates. After x-ray, dorsal and lateral body outlines were traced on wax paper for each fish. Total and caudal lengths were measured to the nearest millimetre.

Radiograph clarity and fish body part contrast remained constant among radiograph images. Unfortunately, swimbladders of all 8 frozen pilchard were underinflated or had collapsed. All mackerel swimbladders appeared to remain inflated in dorsal and lateral radiographs. We do not know if the underinflation of pilchard swimbladders was due to the initial condition of the fish, to being caught by purse seiners, or to freezing.

A fisheries inspector collected a second sample of fresh pilchard during the evening of June 14th. Half of the sample was frozen at –20°C and the other half was refrigerated in seawater overnight. Three fresh and three frozen fish were radiographed the following morning (June 15th). Clarity of radiograph images remained constant but swimbladders appeared underinflated as in the previous sample. In an effort to simulate fully inflated swimbladders, the three fresh fish that had been x-rayed were dissected and a syringe was used to inject air into swimbladders. The fish and syringe were then radiographed for each fish. Two additional frozen fish were dissected, had swimbladders inflated using a syringe, and radiographed. Results of the dissections and attempted inflations were mixed. The bladders would hold the injected air during the x-ray but we did not know the 'appropriate' level of inflation for a surface-adapted pilchard. We continue to recommend the use of only surface-adapted, live fish for swimbladder imaging.

In response to concerns over the misrepresentation of swimbladder size and shape in radiographs, a live sample of pilchard was obtained from a purse seine catch by the vessel 'Chris Andra'. Fish were maintained in a tank on the deck of the vessel and continuously supplied with fresh seawater using a deck hose. The fish were transported to Walvis Bay aboard the vessel and then to the veterinary clinic by flatbed truck. The seawater supply was stopped just prior to the vessel entering Walvis Bay harbour. A total of 16 hours elapsed between fish capture and subsequent x-ray.

A total of 12 live pilchard were selected from the tank after arrival at Swakopmund. Individual fish were carried into the veterinary in separate buckets. Fish were an anaesthetic supplied by the Namibian Fisheries Laboratory and radiographed using the same exposures as previous x-rays. All resulting radiographs clearly showed body outlines, skeletal elements, and 'fully' inflated swimbladders.

Table 2. Fish number, total, and caudal length of live pilchard used in radiographs.

Fish (#)	Total Length (mm)	Caudal Length (mm)
17	230	201
18	250	215
19	240	210
20	251	222
21	220	193
22	244	215
23	240	210
23	228	200
25	230	200
26	230	202
27	240	208
28	245	214

To convert x-ray images to digital data files, the body and swimbladder are traced on acetate. The maximum and minimum length and depth of the body and swimbladder are recorded to the nearest 0.5 mm and the silhouette images are scanned into a PC graphics program (Corel PhotoPaint). Extraneous marks are removed from the scanned image and the line quality is inspected for all traces. Separate .gif files are created for the dorsal and lateral body images, as well as the dorsal and lateral swimbladder traces. A digitizing program written in IDL (Interactive Data Language) then reads each file. Fish body parts are scaled to their true size using maximum and minimum measurements, and the x, y, and body width co-ordinates are combined in a single digital data file.

3. PILCHARD BACKSCATTER MODELLING

3.1 Methods

The KRM model is used to estimate backscatter amplitude for any specified fish as a function of length, tilt angle (i.e. aspect), and acoustic wavelength. Backscatter amplitudes are reported as reduced scattering lengths or backscatter cross-sectional area. Reduced scattering lengths (RSL) can be converted to target strengths using:

$$TS = 20\log(RSL) + 20\log(L_m)$$

For each of the 12 live, x-rayed fish (pilchard 17-28) backscatter amplitude was calculated at the fish's caudal length, over a frequency range of 12 to 200 kHz, and through an aspect range of 70° to 110° (angles >90° are head up). Intra-species backscatter variability was examined by calculating the mean and standard deviation for the group of 12 fish using the group mean length of 208 mm. The resulting L/λ range (1.65 to 27.64) includes acoustic frequencies used by research and commercial fishing vessels in the southern Benguela region. To compare model predictions to conventional TS-length relationships, target strength as a function of caudal fish length was estimated for each fish at 38 kHz, 90° and plotted over a length range of 100 mm to 260 mm. A mean RSL was calculated for the group, converted to TS and added to the graph. To illustrate the dependence of backscatter amplitude on aspect angle, individual and mean RSL for a small (pilchard 17 = 195 mm), average (pilchard 20 = 209 mm), and large (pilchard 18 = 217 mm) pilchard were calculated at 38 kHz over an aspect range of 60° to 120°. To simulate the effect of natural aspect deviation on backscatter amplitude, a program was written to estimate 'effective target strength'. A specified number of normally distributed aspect angles, within a specified one standard deviation range, are generated and the average target strength is tabulated. The backscatter curve from the original model and the frequency distribution of aspect angles are displayed on the screen for comparison. To provide a comparison of model predictions to sonar measurements, the KRM backscatter programs were extended to compute RSL and backscattering cross-section as a function of fish roll. A combination of 360° roll and 180° tilt can now be calculated for any length at any frequency to produce the acoustic backscatter ambit of a fish. To summarize and provide further understanding of KRM backscatter model predictions, an object-oriented backscatter visualization was written in IDL. The visualization provides interactive 3-dimensional viewing of the cylinder representation of fish body and swimbladder, and associated acoustic backscatter ambit.

4. RESULTS

The IDL program accurately converted the silhouette tracings of fish radiographs to quantitative measures fish length, width, and depth (Fig. 1). All fish bodies and swimbladders were digitized at 1 mm resolution. The digital resolution of the data file determines the maximum resolution of the cylinders used in KRM model predictions.

The general shape of the KRM backscatter response surface was similar for all 12 fish. Example backscatter response curves are provided in Figure 2. Along the fish aspect axis θ at low L/λ values, backscatter amplitude remains similar over a broad aspect range. As the ratio of fish length to acoustic wavelength increases, backscatter amplitude decreases as aspect angles deviate from the aspect at peak amplitude. This angle ranged from 85 to 80 degrees and corresponds to the angle of the fish swimbladder axis relative to the saggital axis of the fish. Along the fish length to acoustic wavelength axis, if fish length is kept constant then higher L/λ values correspond to higher acoustic frequencies. Keeping the frequency constant illustrates the effect of changes in fish length on echo amplitude. In all backscatter response surfaces a ridge of maximum backscatter occurs at all L/λ values. The periodic peaks and valleys along the 'ridge' correspond to constructive and destructive interference. The KRM model predicts a non-monotonic backscatter amplitude response to fish aspect, length, and acoustic wavelength.

The mean backscatter response surface of the 12 pilchard maintained general characteristics of individual fish response surfaces (Fig. 3). Backscatter amplitudes are less sensitive and vary little at low aspect angles compared to aspect angles at higher L/λ values. The upper contour surface of predicted backscatter standard deviation contains a strip of maximum echo amplitude variability corresponding to the maximum backscatter amplitude ridge on the lower response surface.

Target strengths at 38 kHz were predicted for each of the 12 x-rayed pilchard over a length range of 100 to 260 mm. The KRM model proportionately scales the fish body and swimbladder as it steps through the fish length calculations. No correction for changes in body or swimbladder shape is made for allometric growth. Scattering curves for all but three of the fish (pilchard 19, 25, 26) were similar in shape (Fig. 4). Target strengths were all close to –40 dB at the small end of the length range and gradually decreased as length increased. Variability among predicted target strengths increased among fish as length increased. Two fish (pilchard 19, 25) had dramatic drops in target strength between 230 mm and 240 mm. The anomalous drops in target strength is attributed to an extension of the swimbladder near the ventral surface and large deviation angles between the saggital axis of the fish body and longitudinal axis of the swimbladders. Body and swimbladder shapes and positions of pilchard 26 were similar to the other two anomalous fish and the resulting backscatter curve also decreases in amplitude with increasing length. The mean target strength decreases with increasing fish length and is influenced by the drops in target strength of pilchard 19 and 25.

Target strength at 38 kHz as a function of aspect angle was plotted for pilchard 17, 18, and 20 (Fig. 5). All backscatter curves peak at approximately 82° and decrease non-monotonically as aspect angle increases or decreases. All three fish show a local decrease in target strength at 90°. Based on KRM model predictions, target strengths derived from dorsally oriented 38 kHz sound sources are very sensitive to pilchard aspect angles. Sensitivity to aspect at 38 kHz was investigated by examining the effective target strength when aspect angles were allowed to deviate from 90°. Selecting a minimum of 1000 normally distributed, simulation trials and standard deviation values of 3° to 4° from horizontal resulted in increased target strength by approximately 2 dB. This was an expected result as KRM predicted target strengths increased as aspect angels increased or decreased from 90° (Fig. 6).

Estimation of backscatter amplitude by the KRM suite of models was increased to include fish roll. RSL or backscattering cross-section can be calculated at any roll angle relative to the longitudinal axis of the fish. A polar plot of pilchard 18 predicted backscatter at 38 kHz as a function of roll (top panel, Fig. 7) and tilt (bottom panel). The sound source is rotated about the fish body from 0 to 360° for roll predictions and from tail to head (180°) for tilt predictions. Scattering at lateral angles was greater than from dorsal or ventral angles with respect to roll. Maximum backscatter amplitude results when the incident sound source is perpendicular to the swimbladder.

5. DISCUSSION

Predicted backscatter amplitudes from the KRM model differed from those used in the target strength to length relationship used in acoustic assessments of pilchard in the southern Benguela. The pilchard TS-L regression equation is based on *in situ* measurements of herring in the North Sea. A 20 cm pilchard is predicted to have a target strength of –45.2 dB ($TS = 20\log(L_{cm}) - 72$). The mean backscatter amplitude of the 12 x-rayed fish is predicted to be –41.8 dB, an absolute difference of 3.4 dB. The two predicted target strength values for a 23 cm fish are much closer: herring/pilchard equation –44.77, KRM –44.53. The paucity of dedicated pilchard TS experiments and the lack of verified single pilchard *in situ* TS measurements restricts the ability to comment on the validity of either prediction. The intercept from a '20log' equation used by Barange et al. (1996) based on *in situ* measurements of 13 pilchard is higher (-70.51) than the herring based '20log' equation used for pilchard and would result in higher target strengths than those currently used.

5.1 KRM Model Visualizations

Results from KRM model predictions have traditionally been displayed as two-dimensional plots or pseudo-three dimensional surfaces. An interactive, three-dimensional visualization can provide a dynamic summary of data used in model calculations and subsequent results.

The first step in the backscatter visualization was to portray the fish body and swimbladder as cylinders. Object-oriented programs were written in IDL to strip data from digitized fish data files and to construct solid or wire mesh body and swimbladder graphics in an interactive viewer. KRM model output is used to construct an acoustic backscatter ambit for a specified fish, at a specified length and frequency, and for 360° of tilt and roll. The acoustic ambit is displayed as a solid surface, points or a wire mesh in the same interactive viewer used to display the fish body and swimbladder. Next steps planned for the visualization include: warping digital pictures of the fish body and lateral radiograph over the cylinder fish body as texture maps, simultaneously displaying the fish body and/or swimbladder with the associated backscatter ambit at a specified frequency.

A separate visualization exercise that was initiated during the cruise was a three-dimensional representation of a pilchard school. Digital images of school slices were taken with a camera and imported into IDL. The intent is to reconstruct the shape and relative density of the school and display it in an interactive viewer. If calibration of the sonar permits the conversion of relative intensities to backscatter volume, the KRM model and length-frequency data can be used to predict the biomass of a school.

5.2 Model-based Pilchard Biomass Estimation

Independent estimates of pilchard school backscattering cross-section caught by commercial purse seine boats are possible using KRM backscatter amplitude predictions. If school diameter and depth can be measured, and if a pilchard length frequency-distribution sample is available, then, given assumptions of fish density, aspect, and tilt, the backscatter of the school can be estimated and compared to sonar measurements.

6. REFERENCES

Barange, M., Hampton, I., and Soule, M. 1996. Empirical determination of *in situ* target strengths of three loosely aggregated pelagic fish species. ICES J. mar. Sci. 53: 225-232.

Clay, C.S. and Horne, J.K. 1994. Acoustic models of fish: The Atlantic cod (*Gadus morhua*). J. Acoust. Soc. Am. 1661-1668.

Horne, J.K. and Jech, J.M. 1999. Multi-frequency estimates of fish abundance: constraints of rather high frequencies. ICES J. mar. Sci. 56: 184-199.

Jech, J.M., Schael, D.M., and Clay, C.S. 1995. Application of three sound scattering models to threadfin shad (*Dorosoma petenense*). J. Acoust. Soc. Am. 98: 2262-2269.

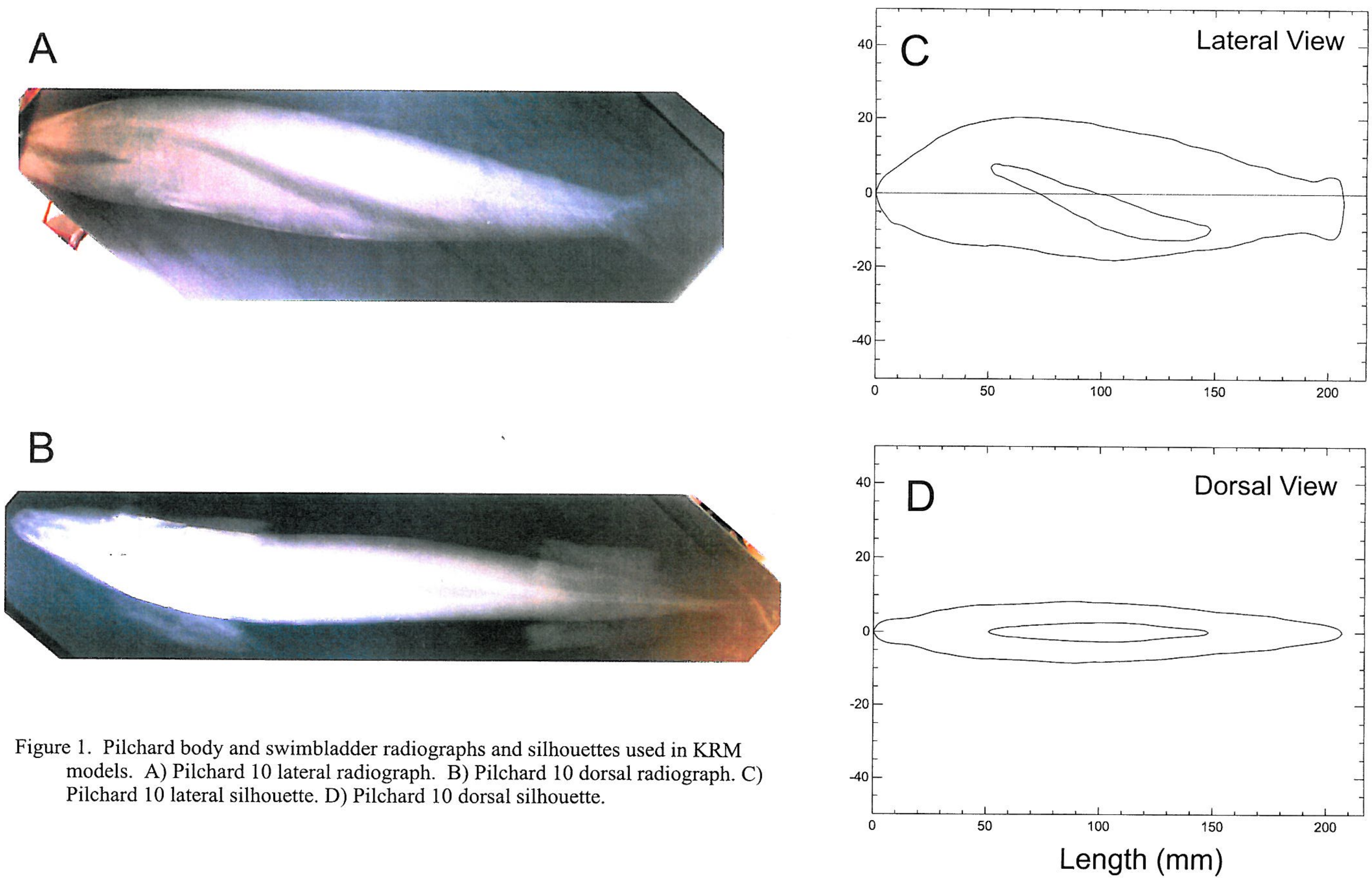


Figure 1. Pilchard body and swimbladder radiographs and silhouettes used in KRM models. A) Pilchard 10 lateral radiograph. B) Pilchard 10 dorsal radiograph. C) Pilchard 10 lateral silhouette. D) Pilchard 10 dorsal silhouette.

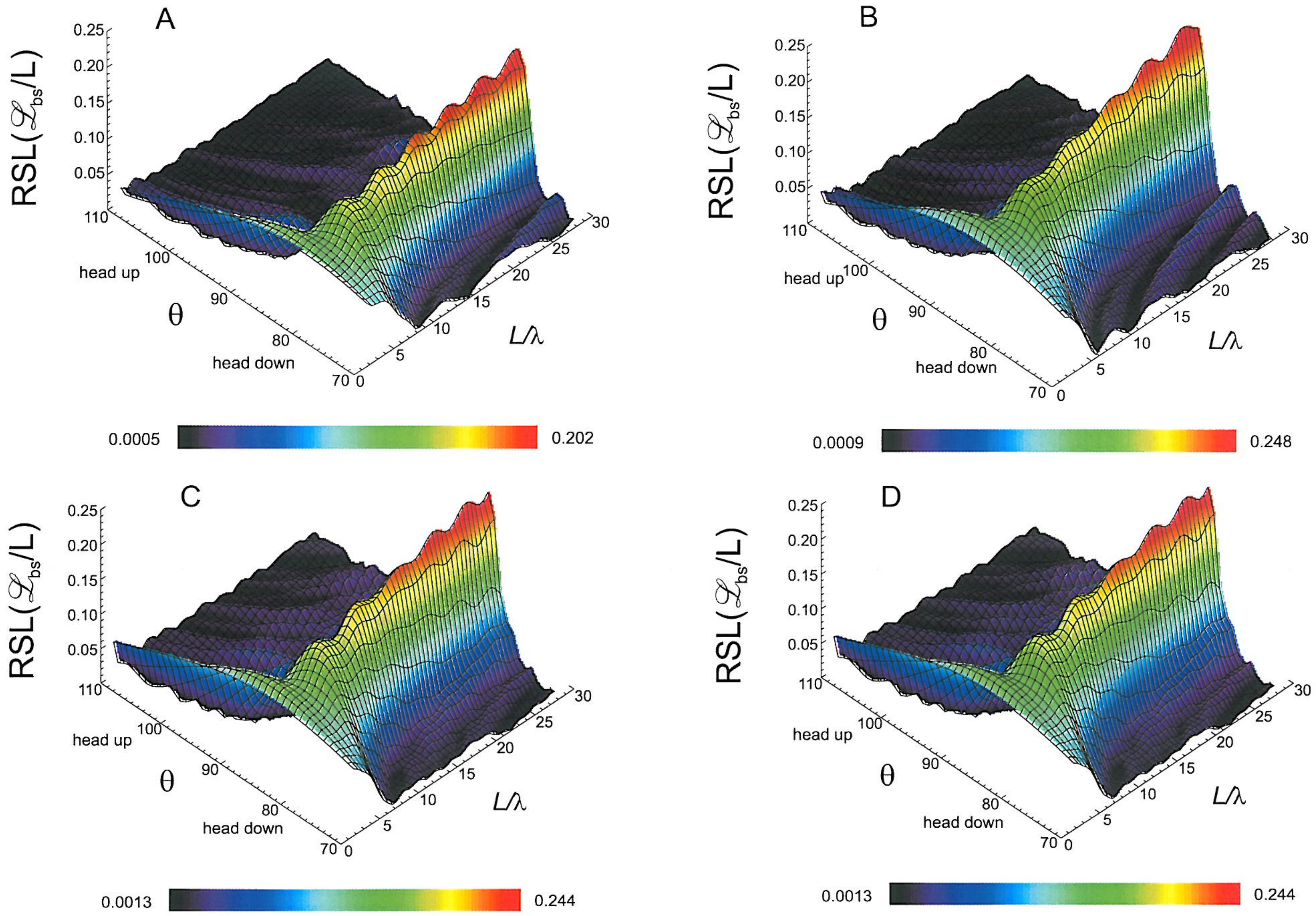


Figure 2. Reduced scattering length (RSL) of A) pilchard 19 (208 mm), B) pilchard 20 (209 mm), C) pilchard 23 (207 mm) and D) pilchard 26 (207 mm) plotted as a function of fish aspect θ, fish length L, and acoustic wavelength λ. Acoustic frequency ranges from 12 kHz to 200 kHz.

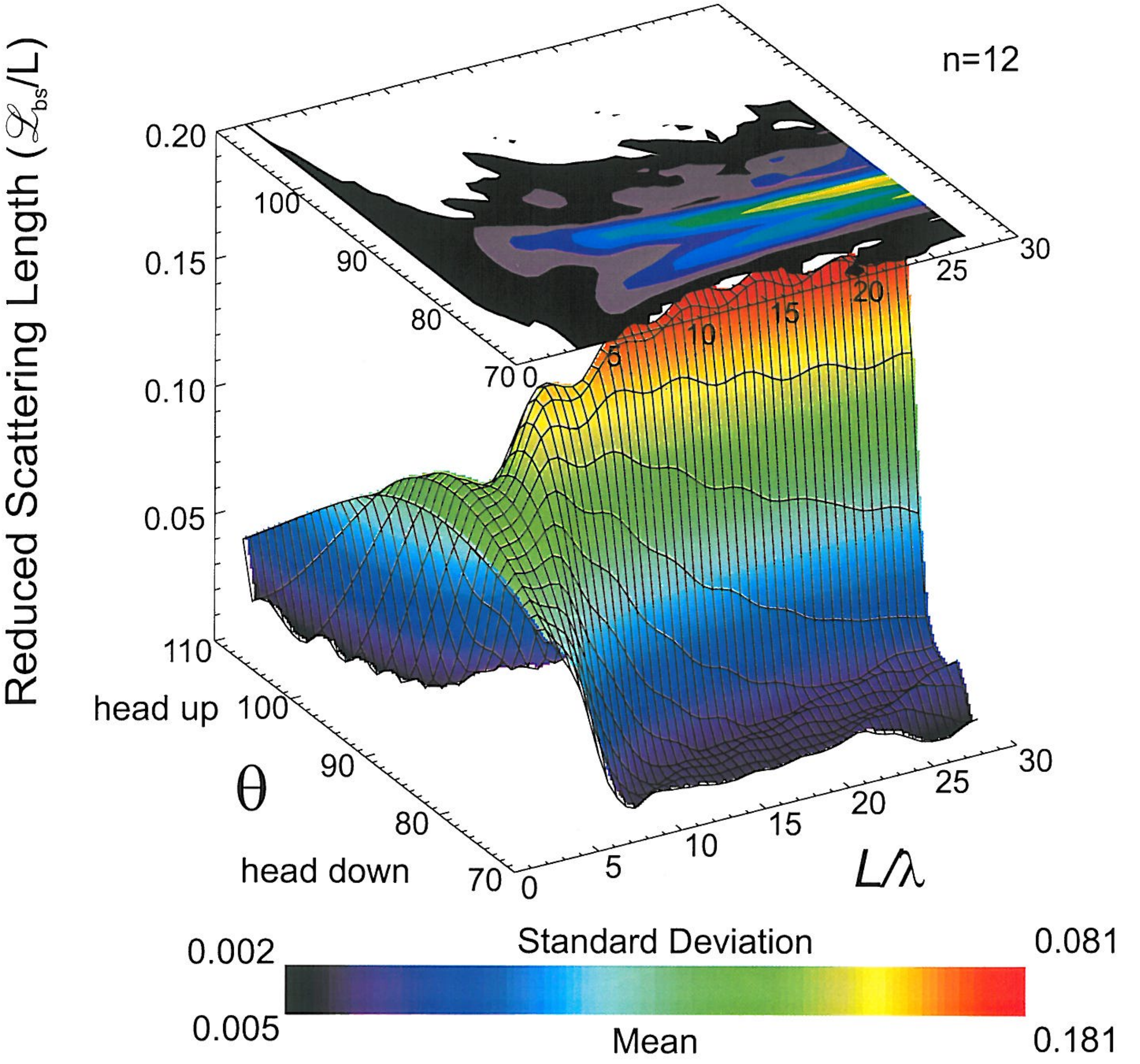


Figure 3. Mean (surface) and standard deviation (upper contour plot) reduced scattering length of 12 pilchard plotted as a function of fish aspect θ, fish length L, and acoustic wavelength λ. Fish length was set at 208 mm and frequency was cycled from 12 kHz to 200 kHz.

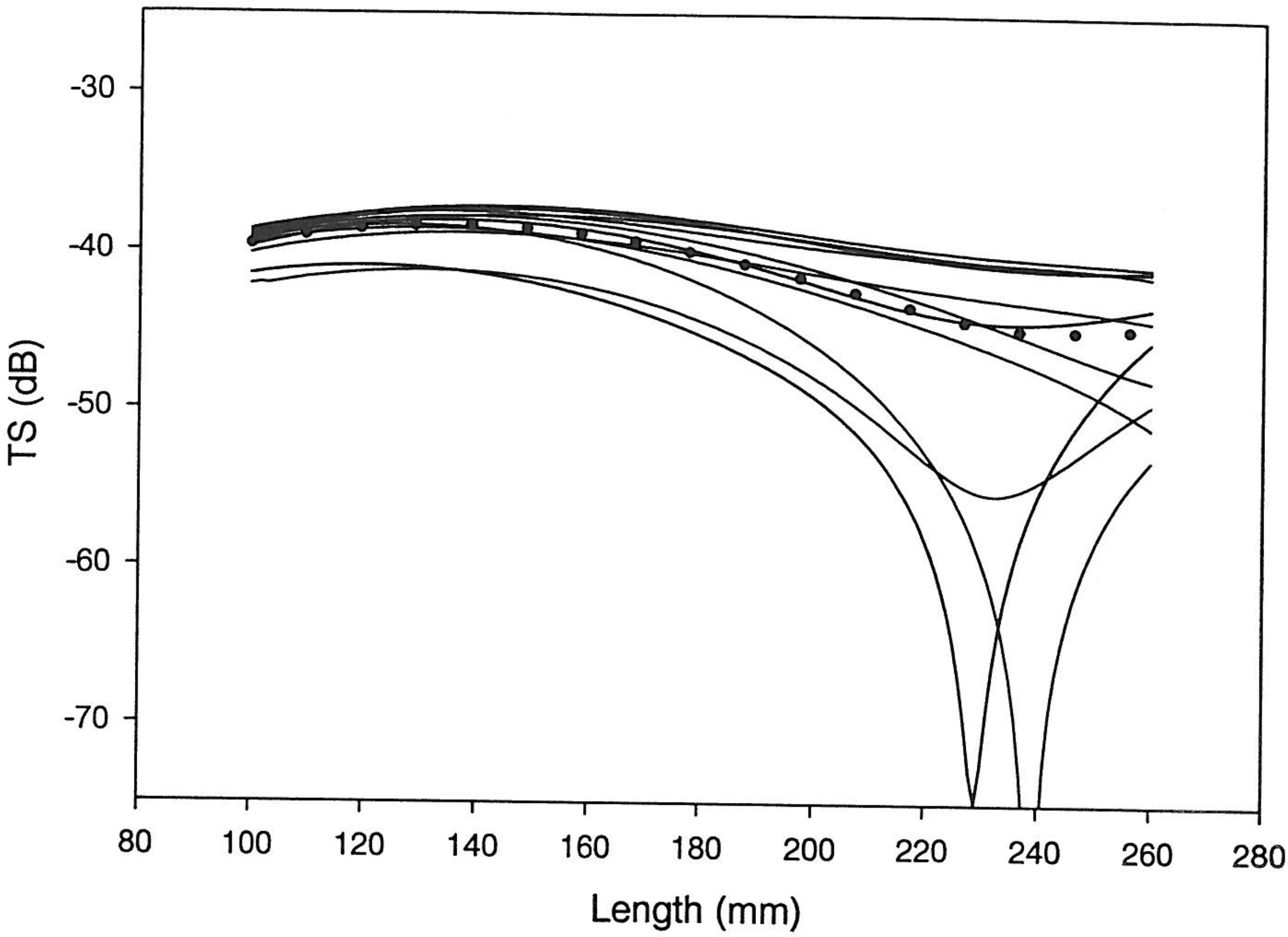


Figure 4. Target strength (dB) plotted as a function of fish caudal length (mm) at 38 kHz for 12 pilchard at 90° aspect. Dotted line represents mean length.

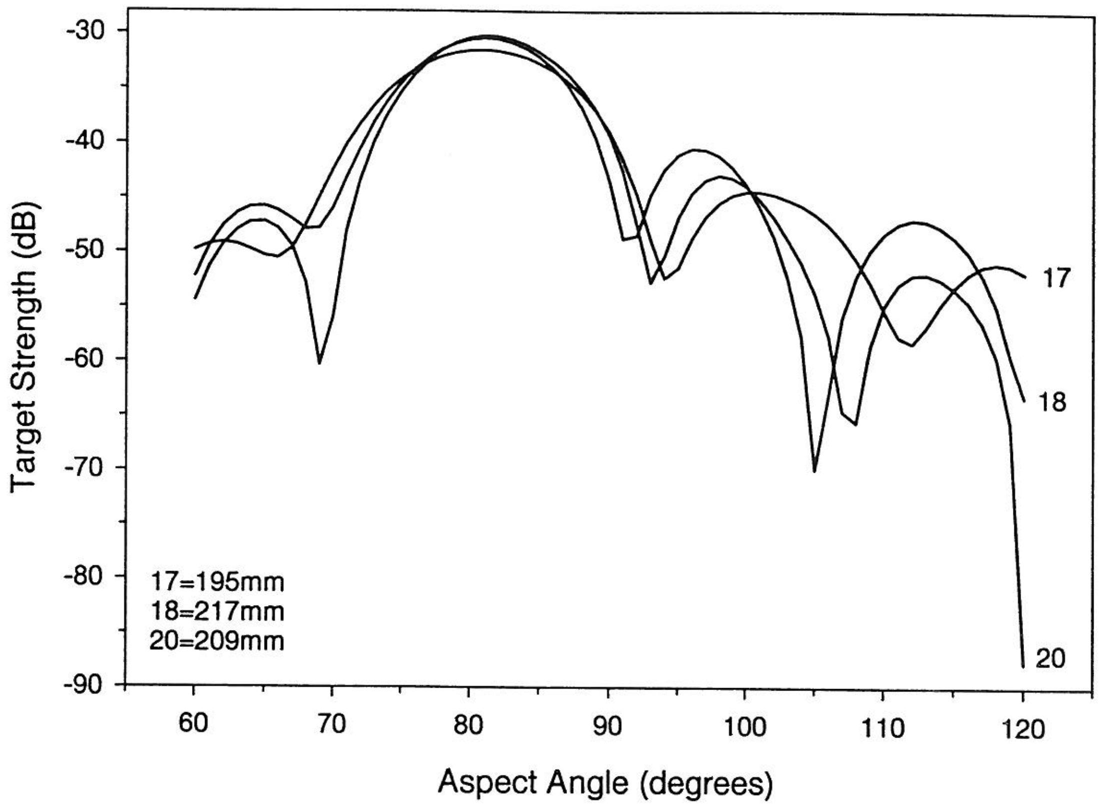


Figure 5. Target strength (dB) plotted at 38 kHz as a function of aspect angle for pilchard 17, 18, and 20.

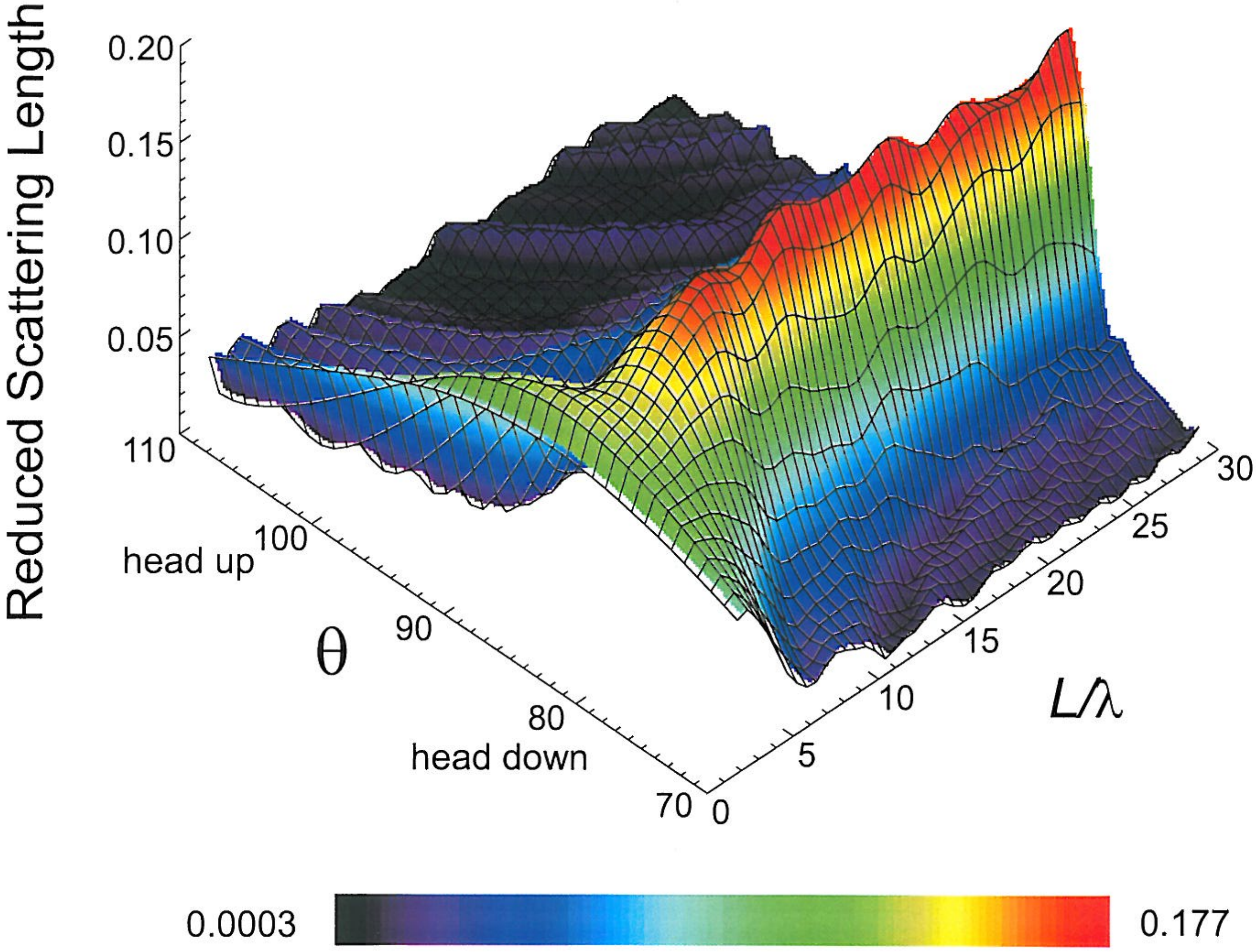


Figure 6. Reduced scattering length of pilchard 18 plotted as a function of fish aspect θ, fish length L, and acoustic wavelength λ. Fish length was set at 217 mm and frequency was cycled from 12 kHz to 200 kHz.

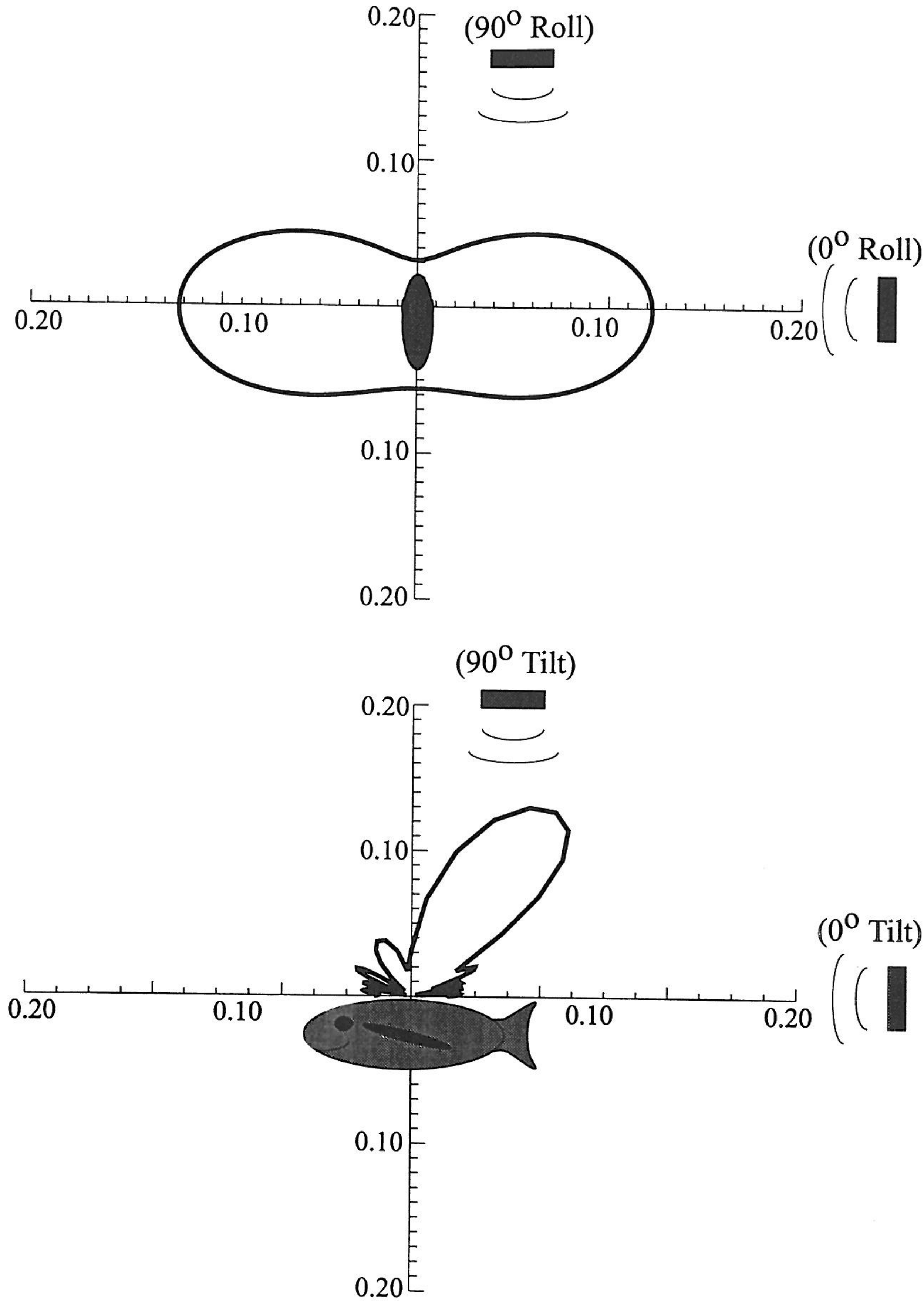


Figure 7. Polar Plots of Pilchard #18 Reduced Scattering Length at 38 kHz. Top plot: backscatter as a function of fish roll. Bottom plot: backscatter as a function of fish tilt.

Record of daily activity, cruise 1999407, R/V "Dr. Fridtjof Nansen"

13/6

1530: New Norwegian crew and Norwegian Scientific Crew (Dalen, Haugland, Misund, Totland) and American guests (Horne, Jech) arriving R/V Dr. Fridtjof Nansen in Walvis Bay Harbour.

14/6

10:00 1st Cruise Meeting with Norwegian scientific crew, Namibian crew (Cloete, Boyer, Oechslin, and Fossen), fishermen representatives (Buckle, De Wet) and American guests. Americans getting pilchard and horse mackerel from boat at fish meal factory for swim-bladder X-raying at a veterinary in Swakopmund. M/V "Hesko II" with captain De Wet arriving alongside Nansen to install SR240 school recording software. Vessel without purse seine and rigged for bottom trawling. Sonar of type SR2414 and not compatible with SR240 school recording software. "Hesko II" leaving for fishing boat harbour at 16:00. Cloete contacted about the situation. Fresh pilchard sample for X-ray imaging in the evening.

15/6

07:30 Horne and Jech to Swakopmund for X-ray imaging of pilchard. Cloete negotiating about another purse seiner. Ingvar and Hilde Huse onboard for lunch and discussions. 14:00 inspecting M/V "Chris Andra" in fishing boat harbour. Sonar SR240, purse seine teared but taken on quay for repair. Decided to wait for "Chris Andra" to join us tomorrow. Totland working on sonar software and preparing installation on "Chris Andra".

16/6

09:00: Installation of SR240 sonar-logging software on "Chris Andra" in fisheries harbour, Walvis Bay. The SR240 did not function with the new PROM's installed in display and transceiver unit, functioned as normal with original PROM's again. Installation therefore cancelled. 13:00: Departure with "Chris Andra" from Walvis Bay harbour with Ole Misund onboard, "Nansen" left about 14:00, meet "Welwitchia" to take onboard equipment. 23:00: on fishing grounds at S 21 21' E 13 05'.

17/6

"Nansen" measuring schools that "Chris Andra" shall catch by their purse seine.
00:43. 1st set with "Chris Andra", no catch. 01:48 2nd set with "Chris Andra" net ruptured, about 40 tons of pilchard let out. 03:02 3rd set with "Chris Andra" catch 50 tons of pilchard, 04:36 4th set with "Chris Andra" 167 tons. Misund onboard "Nansen" about 06:30, "Nansen" conducting mini-survey, "Chris Andra" to port for delivery. PT2848-2851.

18/6

"Nansen" continuing mini-survey. 2nd Cruise meeting 16:30 - 17:30. Recaption of cruise activity and cruise results so far. 1) Chris Andra co-operation: absolute biomass of two schools with corresponding sA. + SF950 raw-data. 3 additional schools with sA + SF950 raw-data. 2) Mini-survey through area: EK500 recordings + SF950 paper recordings to be worked up manually for comparing SF950 and EK500. 3) Planning next "Chris Andra" exercise + live pilchard transport to Swakopmund veterinary for X-raying. 4) John Horne explaining X-ray results for pilchard and horse mackerel, and about swim-bladder imaging and corresponding scattering characteristics.
18:05 OAM onboard "Chris Andra". 18:23 5th set, 85 tons, about 100 pilchard taken by a brail from purse seine bag and transferred in bucket with water to holding tank with water on deck, hose with running water in bottom and net on top, 21:41 6th set 60 tons. John Horne onboard "Chris Andra" to take live pilchard to Swakopmund veterinary, OAM onboard "Nansen" again. "Nansen" continuing mini-survey, "Chris Andra" to port for delivery of its last pilchard concession this season. PT2852.

19/6

"Nansen" finishing mini-survey, started school tracking. Live pilchard brought by "Chris Andra" to Walvis Bay, just a few pilchard in holding tank dead at arrival in port, and to Swakopmund for X-raying, tracking school F1 - F8, several up to 1 hour, low event rate compared to the Angolan Sardinella.

19/6

Tracking school F9 - F12. PT2853-2858.

20/6

13:30 Onboard "Advance" ex. "Klaring" with skipper Toy Meyer. 16:00 "Nansen" getting engine trouble and had to stop for repair for 3 hours. 18:12 7th set 80 tons of pilchard, no school recordings before capture due to engine repair. 20:30 8th set, school recording by "Nansen" before capture, catch 80 tons. 22:43 9th set, again school recording before capture, catch 40 tons. PT2859.

21/6

Windy, no school recordings, co-operating with "Morgenster", no school recordings before capture, "Morgenster" made a set at about 20:00 and caught 70 tons. No further recordings. Strong wind in the evening. PT2861-2863

22/6

Co-operating with purse seiners, no school recordings or catches, searching northwards towards the coast. 3rd Cruise meting at 12.30. Results so far: - 6 sets with absolute biomass, s_A, SF950 raw-data, mini-survey with manual sonar data from paper, 12 school trackings, about 10 trawl stations, X-rays of live pilchard, swim-bladder and acoustic back-scatter modelling. What next? - Continue co-operation with purse seiners to get recordings of absolute biomass (3 days), - school tracking (2 days), - mini survey (2 days), recording sonar raw data, - sonar calibration (1 day), -live horse mackerel for X-ray imaging (1 day), - trawling on deep schools/near bottom recordings of pilchard, - cruise report production (1 day). Totland start developing software for reading target tracking data from SF950 after evening discussion. PT2865, 2866 gave juvenile horse mackerel catches.

23/6

Searching near-shore northwards along the coast together with the purse seiners "Toliko" and "Advance", "Toliko" detected area with large schools at about 10 nm offshore, 10th set by "Advance" at 18:24, "Nansen" measured the school at 18:20, huge school, fast pursing to chase some of the fish out under the boat, fish out under the boat for 5 minutes, "Nansen" measured school that went out of the purse seine, still large catch in purse seine, pilchard about 15 cm, gilled in the net that get clogged, breast of purse seine released to let fish escape. Tracking of schools F13 - F15, trawl stations to identify the tracked schools. PT2866, 2867 gave juvenile horse mackerel catches

24/6

Windy. Searching southwards with the purse seiners. Purse seiners called to port at noon. 4th Cruise meeting 12:30; Rudi oriented about present situation, purse seiners going back to Walvis Bay, possibly out again next week, co-operation with Namibian purse seiners come to an end, Rudi to set up survey from S20 - S22 with 5 nm transect spacing, and out to about 200 m depth, going south to start surveying northwards. PT2868, 2869.

25/6

Surveying northwards, PT2870 - 2874 gave catches of mostly horse mackerel juveniles.

26/6

Surveying northwards, PT2875, recorded pilchard along transect at S20 35, catches of pilchard and round herring in PT2876, 2877, 2878. PT2879-2880 with horse mackerel juveniles and round herring.

27/6

Calm sea. Surveying northwards, sonar calibration I and II with aluminium sphere at 30 m depth and slow approach by research vessel. PT 2881-2884. 4th cruise meeting at 18:30. Decided not to repeat survey, planned to go south for further surveying from Sandwich Harbour to Meob Bay, then catch live horse mackerel, and further sonar calibration. Recording of large schools with smaller pilchard at S20 00, PT2885 gave catch of at least 15 tons, Tracking schools F16 - F19. Extended survey further north to S 19 30'.

28/6

Surveying Northwards, PT2886, 2887. Recorded large schools near end of transect at S19 50', several attempts (PT2892, 2891, 2890, 2889, 2888) to catch schools from UTC 09:45 - 16:15 gave no catch even if school were recorded to pass between doors and in opening of trawl, PT2893 in darkness at 18:00 UTC gave catch of juvenile pilchard, 7.5 cm. Continuing survey further north. PT2894 gave catch of horse mackerel and round herring.

29/6

PT2895 gave horse mackerel in live fish tank, survey ended. Further west to take BT2896 for large horse mackerel, caught hake for fish cakes. Going east to Terrace Bay for school tracking for imaging.

30/6

Heading for Walvis Bay. Anchoring north of Bay 19:00. Cruise report production.

1/7

Sonar calibration, successful. 5th Cruise meeting to coordinate cruise report production. Most of live fish dead so going for a new trawl station off Walvis Bay, no catch. then a bottom trawl followed, also no catch. 6th Cruise meeting at 20h00 to plan cruise products.

2/7

Arriving Walvis Bay at 09:00.

File list for sonar survey in Namibia during June 1999

Directory = G:\surveys\99\Nam4\

Survey Report *report99.doc*

Chapter 1: **Namibian purse seining for pilchard**

Chapter 2: **Comparative Acoustic surveys of small, shoaling pelagic species in the Northern Benguela**

FIGURES

I Distribution of sea temperature at 5 m depth
G:\surveys\99\Nam4\Fig\Surtemp.doc

2 Number of schools in different distances from the vessel
G:\surveys\99\Nam4\Eh\Antavst.ogg

3 Number of schools in different distances from the vessel
G:\surveys\99\Nam4\Eh\Antmils.ogg

4 Number of schools in different distances from the vessel
G:\surveys\99\Nam4\Eh\Bioma3.ogg

ANNEXES

II Records of fishing stations
G:\surveys\99\Nam4\Eh\Bioma3.ogg

III Length distributions of main species
G:\surveys\99\Nam4\Eh\Bioma3.ogg

IV Course tracks - coverages 1,2 & 3
G:\surveys\99\Nam4\Fig\Survn21.doc
G:\surveys\99\Nam4\Fig\Survn22.doc
G:\surveys\99\Nam4\Fig\Survn23.doc

Chapter 3: Studies of the schooling behaviour of pilchard in Namibian waters

FIGURES

2.1 An example of a pilchard school detected by shapes
G:\surveys\99\Nam4\Shapes.pre

ANNEXES

II Shoal tracking Namibia 1999
G:\surveys\99\Nam4\Shtrack.xls

III Shoal behaviour Namibia 1999
G:\surveys\99\Nam4\Behave.xls

Chapter 4: Applying an testing of the Simrad SF 950D sonar, and the SODAPS logging and post processing software system

FIGURES

4.1 Measured target volume from the SF 950 of the calibration sphere
G:\surveys\99\Nam4\Sodaps\Cal_1_2.xls

4.2 Maximum and mean volume backscattering strength of the sphere
G:\surveys\99\Nam4\Sodaps\Cal_4.xls

Chapter 5: Development of software for the extraction of sonar tracking data

ANNEXES

II SAS algorithm for filtering sonar tracking data
G:\surveys\99\Nam4\SAS\tfilter.sas

SUPLEMENT

1. Photos taken during the survey
G:\surveys\99\Nam4\pic*.*

CRUISE REPORT

G:\surveys\99\Nam4\report99.doc

Data sheets:

Forms used to collect data for shoal surface sightings and tracking with sonar.

H:\surveys\98\Ben1\forms.xls

File list:

List of whereabouts of data and reports

G:\surveys\99\Nam4\Filelist.doc