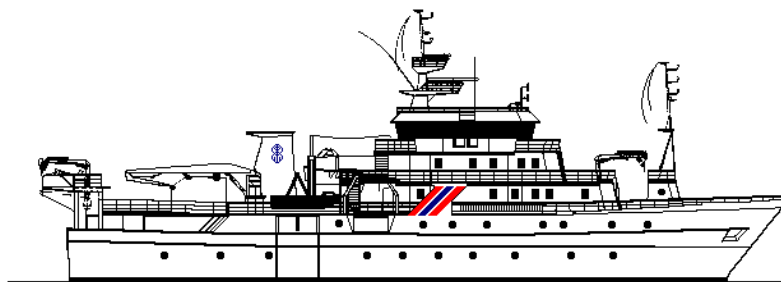


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CRUISE REPORTS "DR. FRIDTJOF NANSEN"



SURVEYS OF THE FISH RESOURCES OF NAMIBIA

Cruise Report No 5/99

**Horse mackerel target strength
21 - 27 May 1999**

**Ministry of Fisheries & Marine Resources
Swakopmund
Republic of Namibia**

**Institute of Marine Research
Bergen
Norway**

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The programme has comprised the following surveys:

Survey	1/90	25 January to 19 March 1990
"	2/90	27 May to 20 June 1990
"	3/90	11 September to 6 October 1990
"	1/91	25 January to 23 March 1991
"	2/91	23 October to 16 December 1991
"	1/92	23 April to 21 June 1992
"	2/92	20 October to 16 December 1992
"	1/93	20 January to 19 March 1993
"	2/93	21 April to 25 May 1993
"	1/94	19 January to 21 February 1994*
"	2/94	26 April to 24 June 1994
"	3/94	19 October to 24 November 1994
"	1/95	16 January to 19 February 1995
"	2/95	22 April to 21 June 1995
"	3/95	27 September to 7 October 1995
"	1/96	12 January to 19 February 1996
"	2/96	7 September to 14 October 1996
"	1/97	10 January to 20 February 1997
"	1/98	12 January to 22 February 1998
"	1/99	11 January to 21 February 1999
"	2/99	22 February to 28 February 1999

* First survey with the new R/V 'Dr. Fridtjof Nansen'.

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**Horse mackerel target strength
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by

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CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

The Cape horse mackerel (*Trachurus capensis*) in the Benguela upwelling system on the Namibian coast has been monitored acoustically since 1990. The south-African stock in the Agulhas upwelling system is monitored by means of bottom trawl surveys (swept area), but this is not feasible in Namibia due to the more pelagic distribution of the fish. Acoustic surveys or a combination of hydroacoustics and bottom trawl surveys therefore seems to be the remaining alternative. However, acoustic abundance estimation requires knowledge of the acoustical backscattering properties of the fish, specifically the dorsal aspect target strength (TS). Assuming that the target strength increases proportionally to body length, the target strength at a given frequency can be expressed as a function of mean total length (L) in the logarithmic domain using equation (1):

$$TS = x \log L + y \quad (\text{dB}) \quad (1)$$

where x and y are linear regression coefficients. If the average acoustic backscattering crosssection, σ , of the ensonified population is known, recorded area backscattering coefficient, S_A (m^2/nm^2) can be converted to number of fish (ρ_A) using equation (2):

$$\rho_A = S_A/\sigma \quad (2)$$

Split beam echosounders, like the SIMRAD EK 500/ 38 kHz system used in this investigation, combine the signals from four quadrants of the transducer (with individual signal detection and time varied gain amplification) in pairwise fashion by simple summing, forming four half beams. Selecting the larger of the arithmetical means of target strengths computed for each pair of adjacent samples, the target strength detection algorithms then compute the target strength in the range -50 dB to -20 dB with 0.375 dB resolution in several steps (described in Foote et al., 1986). In order to calculate mean average backscattering crosssection, the observations must be converted from the logarithmic domain (dB) to the intensity domain. This can be done assuming the relation (3) (Love, 1971):

$$TS = 10 \log(\sigma/4\pi) \quad (3)$$

At 38 kHz, σ has been shown to be proportional to the squared total length of the fish for commercially important species. For facilitation of direct comparison between different regressions series, equation (1) can thus be modified to a one-coefficient form, keeping $x=20$ (Love, 1977), giving equation (4):

$$TS = 20 \log L + b_{20} \quad (\text{dB}) \quad (4)$$

The function presently applied for horse mackerel (in Namibia) is the one derived by Foote (1987) (see also Foote et al., 1986) for clupeoids (5):

$$TS = 20 \log L - 71.9 \quad (\text{dB}) \quad (5)$$

Applying this TS to length relation for horse mackerel relies on the basic assumption that the acoustical back scattering properties of horse mackerel are identical to the ones for clupeoids. Horse mackerel and clupeoids have however fundamental anatomical differences, as the former is physoclistous (enclosed swimbladder) and the latter physostomous (open swimbladder). The swimbladder constitutes as much as 90 % of the sound reflection from fish (Blaxter and Batty, 1990), and swimbladder volume and shape significantly influence the acoustical target strength of the fish (Olsen and Ahlquist, 1996). Unlike physostomous species, presumably dependent on gasping air at the surface to fill the swimbladder, horse mackerel has the physoclistous ability of regulating swimbladder volume through gas secretion and resorption. Thus, if horse mackerel compensates for swim bladder compression with increasing pressure (depth) it should be expected to have generally higher and less depth- dependent target strength than physostomes, but the extent to which, if at all, horse mackerel compensates for swimbladder compression, is not documented in the literature. Being an extremely fast swimmer, maintenance of neutral buoyancy may not always be necessary by means swimming. Negative buoyancy is probably advantageous during vertical predator avoidance, and it can therefore not be ruled out that horse mackerel may take advantage from negative buoyancy resulting from swimbladder compression when avoiding predatory species such as hake (*Merluccius capensis*) (Pillar and Wilkinson, 1995; Pillar and Barange, 1998).

According to Foote (1987), $b_{20} = -67.5$ for physoclists, with a certain variation from species to species (3 dB). Although the target strength of Cape horse mackerel has been investigated from both survey data (Barange and Hampton, 1994; Barange et al., 1996; Svellingen and Ona, 1999; Lillo et al., 1996), volumetric considerations of the swimbladder (Torres et al., 1984), and by means of the comparison method (Misund et al., 1997) data are scarce and relatively few attempts have been made to establish an independent target strength-length

relation. The published equations are highly inconsistent, and considerable controversy is therefore associated with the target strength of horse mackerel.

1.2 OBJECTIVES OF THE SURVEY

The primary objective of the study was to measure the target strength of loosely aggregated horse mackerel *in situ* using hull mounted or submersible 38 kHz split-beam transducer in combination with the SIMRAD EK 500 echosounder, and to obtain representative samples of the measured population using pelagic sampling trawl and *Multisampler*. In order to ensure representative measurements, the fish should be loosely aggregated to avoid problems of accepting multiple echoes as single target echoes, and the area of the investigation should host as few other species as possible. Few length groups of the horse mackerel should be present in order to avoid biased length samples. Among the other requirements for the study site were few jellyfish and relatively low fishing activity. *In situ* TS measurements also require good weather conditions, particularly when using a submersible transducer.

The secondary objective was to carry out a study of the allometric growth of the swimbladder in horse mackerel. The validity of assuming proportionality between the size of the fish and its target strength can be achieved either through a regression on independent measurements from the full size-range of the fish, as has been done for other species, such as clupeoids (Foote et al., 1986), or by studying the size/ volume of the swimbladder for different sized fish. Since the former method requires substantial amounts of data, normally collected over a number of years, the latter approach was attempted in this study. Live and neutrally buoyant fish from the trawl samples were selected, anesthetized and shock-frozen for measuring of the cross-section of swimbladder length and perimeter in relation to fish length.

1.3 PARTICIPATION

The scientific staff consisted of:

From Namibia:

Graca D'ALMEIDA, Angie KANANDJEMBO, Manuel KORDOM, Michael EVENSON
Shean WELLS.

From Norway:

Bjørn Erik AXELSEN (Cruise leader), Ingve FJELDSTAD, Magnar MJANGER.

1.4 NARRATIVE

“Dr. Fridtjof Nansen” left Walvis Bay 21 May at 07h00, six days delayed due to reparation of one of the trawl winches. Course was set northwards for selection of study site. During steaming, the *Multisampler* was tested on the deck, and the mid sized pelagic sample trawl was rigged with the *Multisampler*. Acoustic monitoring was carried out to locate the horse mackerel by means of SIMRAD EK 500 and the hull mounted 38 kHz split beam echosounder in combination with Bergen Echo Integrator (BEI).

Several problems with the *Multisampler* had to be addressed prior to trawling. The motor, which was 6 months old and only had been used on two cruises previously, was leaking oil along the axle. In the release unit, 4 out of 6 release triggers were partly obstructed during release and had to be filed. A split was cut in each of the codends in order to facilitate escape if the catch would be too big. The splits were closed with thin thread to avoid undesirable escapement of fish during operation.

Horse mackerel was observed on the echosounder at about 19° latitude in the morning on 22 May. The first Multisampler haul series (PT 2829-31, 19°19'S 12°24'E) was launched at 10h00, but only a few juvenile horse mackerel were present in the samples. However, adult horse mackerel were caught in the second trawl series (PT 2832-34 at 18°56'S 12°21'E). Despite the mentioned precautions, the extension and the top panel of the trawl were torn due to high concentrations of jellyfish. The catch was confined to the first net contained, suggesting that the tearing occurred after this net was closed. During reparation of the trawl, which took about 16 hours, the ship steamed northwards to the Angolan border (17°20'S), where there are few problems with jellyfish, and horse mackerel is present throughout the year. The first trawl series in this area was carried out at 23 May 20h00 (PT 2835-37, 17°30'S 11°30' E) indicating pure concentrations of horse mackerel ranging from 18-28 cm total length (modal peak at 23-25 cm) from the bottom (160 m) to the surface.

This area was selected for TS- measurements due to the favourable fish concentrations. Measurements were carried out on 23-25 May. A distinct diurnal migration pattern was readily identified, with dense demersal layers at daytime, and dispersed pelagic scatters at night and no tendency of a size-dependent pattern in the vertical migration was evident from the samples. The target strength measurements were thus carried out at nighttime only. In the morning 25 May after the TS measurements were abruptly by the break of day, a demersal haul (PT 2843, 17°27'S 11°36'E) was launched on the inner shelf (119 m depth) in order to

get a sample of the smallest of the adult individuals in the area. However, the length distribution in this sample showed quite the same pattern as the other samples (18-28 cm, peaking at 23-26 cm), suggesting that the population in the area principally consisted of only one or two cohorts.

Later in the morning on May 25, the ship started steaming southwards in a zig-zag pattern on the outer shelf (>1500 m bottom depth), tempting to get samples and measurements from the bigger individuals (see survey reports of the horse mackerel stocks of Namibia, May/June 1997 and May/June 1998). Unfortunately, no schools were encountered. At 20°, a south-eastern course was chosen, and passing the 19° line at about 300 m bottom depth, a multisampler trawl series (PT 2844-45, 18°57'S 11°36'E) confirmed horse mackerel confined in a loose aggregation at about 100-150 m depth (bottom depth 290 m), and another series of target strength measurements measurement was carried out during the night. On 26 May at 08h00 the ship headed for Walvis Bay, docking 27 May at 10h00.

CHAPTER 2 METHODS

2.1 TARGET STRENGTH MEASUREMENTS

Horse mackerel is known as a particularly vigilant species, and obtaining reliable TS-measurements is therefore quite difficult. Furthermore, horse mackerel is mostly confined to the bottom at daytime, in dense schools or layers, and is therefore inaccessible to conventional echosounder systems. At night the horse mackerel generally comes off the bottom, but the extent of vertical migration and degree of dispersion is highly variable and hardly understood. Finding loosely aggregated fish in distinct mono-species layers is therefore a rarity. Nevertheless, this is the situation needed to enable *in situ* measurements of target strength with the technology available today. Our approach was to:

- 1) Try to identify such aggregations with the hull mounted echo sounder
- 2) Confirm species and size composition with pelagic trawl/ Multisampler
- 3) Drift freely over the sampled population with main engine and all lights except navigation lights switched off, all noisy activities suspended
- 4) to measure the target strength using a submersible transducer lowered to approximately 30 meters above the scattering layer
- 5) whenever possible, obtain a repeated sample of the fish to confirm target species and length distribution.

2.2 SAMPLING PROCEDURES

For each trawl station, catch size and species composition was estimated and punched onto NAN-SIS database. Length frequency distribution was performed for horse mackerel and all other commercially important species. Biological data including stomach fullness and gonad weight and maturity status was recorded as well (See Annex I).

Whenever a sample contained horse mackerel that was alive and in seemingly good condition, the catch was released directly in 1000 l tank with circulating saltwater pumped from the surface. The fish was then kept in the tank for a 1-3 hours for acclimatisation. Individuals floating to the surface or sinking to the bottom were removed. Apparently neutral buoyant fish were anesthetized, stretched and shock-frozen in car anti-freeze keeping -30°C.

2.3 STUDY OF ALLOMETRIC SWIMBLADDER GROWTH

The frozen fish were later cut in two halves lengthwise for photographing the cross-section of the swimbladder according to the following procedure:

- 1) Collect the frozen fish
- 2) Cut the fish in two halves precisely along the middle in the length direction
- 3) Put the fish on the yellow photo-plate with a ruler, use yellow background- plate
- 4) Take one photo of each fish using the Olympus C-1400L digital camera and the tri-pod
- 5) Use super high quality (SHQ) mode (1 MB pr. frame)
- 6) Transfer data to PC
- 7) Defreeze the fish and perform standard biological sampling procedure, but do not take stomach samples.

The photos will be analysed digitally in an image- analysing software like Image pro Plus for calculation of swimbladder length/height, perimeter, relative swimbladder angle etc., and be related to fish length and gonad maturity status.

CHAPTER 3 RESULTS

3.1 VERTICAL MIGRATION AND TS-MEASUREMENTS

A clear tendency of diurnal vertical migration was observed, but the picture was highly dynamic. In the north ($17^{\circ}30'S$), the fish was aggregated in a continuous layer right on the bottom during daytime, much too dense for TS measurements and partly distributed in the deadzone. At night, the fish dispersed in the pelagic.

The first night, 23-24 May, the fish seemed to be dispersed close to the surface. A series of Multisampler trawl was carried out at 23 May 20h00 (PT 2835-37, $17^{\circ}30'S$ $11^{\circ}30'E$), and indicated that pure concentrations of horse mackerel ranging from 18-28 cm total length (modal peak at 23-25 cm) was present from the bottom (160 m) to the surface. There was blowing a southern strong gale, and the submersible transducer could therefore not be used. Target strength measurements were thus carried out from the hullmounted transducers, resonant at 38 kHz and 120 kHz, but the density of the ensonified fish was rather high for TS measurement purposes.

The second night the same upwards migratory behaviour was observed after sunset, but in the middle of the night the fish suddenly started migrating to the bottom. This coincided with a sudden change in the prevailing weather conditions, as a cold mist fog came in and the temperature dropped substantially. The fish aggregated in a relatively dense layer at the bottom, but the density was lower than during the day. The submersible 38 kHz transducer was lowered carefully to about 30 meters over the scattering layer, in an attempt to measure single fish occurring at the border of the layer. The operation was quite successful, and an additional sample was obtained in the morning after the measurement series was completed (PT 2842, $17^{\circ}23'E$ $11^{\circ}30'E$), confirming that the fish on the bottom was horse mackerel with the same modal length (25 cm) as the night before.

During steaming southwards, a multisampler trawl series (PT 2844-45) at $18^{\circ}57'S$ $11^{\circ}36'E$ confirmed horse mackerel confined in a loose aggregation at about 100-150 m depth (bottom depth 290 m), and another series of target strength measurements measurement was executed during the night. Weather conditions were good, practically no wind, but overcast and no moonlight. However, soon after the TS measurements had started, the fish dispersed and was hard to identify. Once more, this coincided with a sudden change in the weather conditions. This time, the sky became clear, and was light up by bright moonlight. The remaining individuals were measured, and fish passing the transducer during the vertical migration to the bottom at sunrise were measured as well. This migration phase lasted longer

(approximately 1 hour) than usual (about 15 min), probably due to fog coming in in the morning.

Clearly, the vertical dynamics of horse mackerel are quite dynamic (see also survey report horse mackerel survey May/June 1998, survey report, Benefit survey October 1998) seemingly due to a quite opportunistic behaviour where food and predators probably are the primary driving factors, whereas weather conditions clearly can modulate the behaviour on a short temporal stage. The TS- data will be analysed further at a later stage.

3.2 STUDY OF ALLOMETRIC SWIMBLADDER GROWTH

The cross-sections will be transferred to Image pro Plus and analysed at a later stage.

CHAPTER 4 DISCUSSION

4.1 REVIEW OF PUBLISHED TS-EQUATIONS

The Table below Gives an overview of b_{20} - values published in the literature:

b_{20}	Method	Species	Reference
-74.6	In situ, submersible transducer	T. capensis	Axelsen (unpublished)
-73.4	Comparison method	T. trachurus	Misund et al. (1997)
-71.9	Various in situ methods	Clupeoids	Foote (1987)
-68.9	In situ survey data	T. symmetricus murphyi	Lillo et al. (1996)
-67.5	Various in situ methods	Physoclists	Foote (1987)
-66.8	In situ survey data	T. capensis	Barange et al. (1996)
-66.8	In situ survey data	T. capensis	Svellingen and Ona, 1999
-66.7 *	Swimbladder volume	T. symmetricus murphyi	Torres et al. (1984)
-65.2	In situ survey data	T. capensis	Svellingen and Ona, 1999

* this figure was not presented in Torres et al. (1984), it is calculated in the present study for comparison from published values of average TS and average total length for fish at 38.7 cm and 31.4 cm.

ANNEX I Standard procedure for biological sampling of horse mackerel

- 1) Collect a random sample of +200 individuals (roughly the equivalent of one full basket) from each Multisampler-codend. To randomise, mix catch well on deck, separate the part of the catch to be sampled from the rest and collect all of it in baskets.
- 2) Take length frequency distribution of all individuals in sample. Measure the total length, down to the nearest 1 cm group.
- 3) Collect a random subsample of 20 individuals from each sample. To randomise, mix sample well on sorting table and separate subsample as in 1). If time does not allow 20 individuals in each subsample, reduce to 15 or minimally 10 in each sample.
- 4) Biological sampling of all individuals in subsample:
 - a) total length (cm, 0.1 cm accuracy)
 - b) total weight (g, 0.1 g accuracy)
 - c) gutted weight (g, 0.1 g accuracy)
 - d) sex (M/F/J)
 - e) gonad maturity stage (1-7)
 - f) gonad weight (g, 0.1 g accuracy)
 - g) stomach fullness (0-5)
 - h) stomach weight (g, 0.1 g accuracy)
 - i) cut stomach as close to mouth cavity as possible and put entire stomach (unopened) in sample glasses one by one. Add formalin immediately, and cut open to ensure that the contents are preserved immediately. This work must be done in ventilation cabinet. Mark glasses with date, sample no., st. no and ind. no. Put all stomachs from each subsample in a plastic bag or sample tube, marked date, species, station number and sample number.
 - j) collect both otoliths in envelopes. Otoliths must be carefully rinsed in clean water before preservation. Mark envelopes with date, sample number, station number and individual number.

Biological data for horse mackerel

Gonad maturity stages (1-7) are specified on sheet on the wall in the lab, if in doubt confer with Graca/Bjorn. Stomach fullness is to be given subjectively on the scale 0-5; 0 corresponding to absolutely empty, 1: 1-25 %, 2: 25-50 %, 3: 50-75 %, 4: 75 -99 %, 5: 100 % (absolutely full or overfilled/ bulky). Collect stomach samples from the catch. Note dominating taxon in stomach content and degree of digestion below the data for the other fish on the biological sample form for horse mackerel (use whatever columns available). Degree of digestion is graded 1-4; 1: prey with skin intact, crustaceans (copepods/krill) clearly distinguishable; 2: skin digested, crustaceans fairly distinguish-able; 3: bodies no longer intact; 4: well-digested remains. Indications of eating in the catch process (e.g food in mouth cavity or in digestive duct before stomach or apparent fresh food items only partly into stomach) and of regurgitation (e.g stomach everted or loose, as for gonads in spent stage, and no or almost no stomach content) must be noted on the form.

All biological parameters (4a-h) are to be recorded on the biological sample form for horse mackerel. Parameters 4 a (total length), b (total weight), d (sex) and e (maturity stage) must be plotted on the standard biological sample form for the NAN-SIS data base as well. Note that total length should be given in cm down to the nearest cm group and weight in grams

(up/down to the nearest g) on the NAN-SIS form, whereas on the biological sample form for horse mackerel, length and weight should be given in cm with 0.1 cm accuracy and gram with 0.1 g accuracy, respectively. Length frequencies are to be recorded on the standard length frequency form. Use one station form for each codend-sample and remember to fill in species name, species code, station number and sample number on all forms. Punch into NAN-SIS database from the lab-PC only (not the conference room/acoustic centre) if familiar with NAN-SIS database.

Hake stomachs

Stomachs of hake and other big predatory fish should be collected in the same manner as for horse mackerel. Use the same form and procedure as for horse mackerel but indicate species clearly on form and sample tube. Always check if there is HMX in the stomachs, and if so this must be noted. If the stomachs can not fit into the sample tubes, use perforated plastic bags instead.