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Trawl sampling of small pelagic species off Angola. Effects of avoidance, towing speed, tow duration and time of day.

By

N'Kossi Luyeye[1)], Janet Coetzee[2)], David Boyer[3)] and Ole Arve Misund[4)]

[1)] Instituto de Investigação Pesqueiro, P.O. Box 2601, Luanda, Angola

[2)] Sea Fisheries Research Institute, Cape Town, South Africa

[3)] National Marine Information and Research Centre, Swakopmund, Namibia

4) Institute of Marine Research, P.O. Box 1870, N-5024 Nordnes, Norway

Abstract

A series of pelagic trawl sampling trials on pelagic species distributed near surface off Angola were conducted by R/V «Dr. Fridtjof Nansen» operating a medium sized pelagic trawl with a vertical opening of about 20 m. The results have been analysed with respect to effects such as vessel and gear avoidance, time of day, towing speed and tow duration. Numerous trawls targeting on dense sardinella shoals failed to yield large catches. Shoals that were at the trawl depth as the vessel passed over were often observed far below the foot rope of the trawl, indicating vertical avoidance. Often shoals in the net mouth were recorded by the net sonde for long periods. It was assumed that these fast swimming fish were able to swim along with the trawl, and escaped out of the trawl when slowing down the towing speed during hauling. No correlations were, however, found between towing speed in the range 2.7 - 5.0 knots and the total catch of sardinella. Increasing the tow duration during the day to more than 120 minutes also failed to yield consistently higher catches. At night, there was a negative correlation between tow duration in the range 15 - 60 min and the catch size, simply because the trawl was towed for a longer time to obtain proper samples in areas with scattered recordings. During the day sardinella was caught both inshore and further offshore, while horse mackerel was caught further offshore only. Both species were well represented in the catches made at night. There were substantial day and night differences in the length distributions of sardinella with small sardinella being caught only at night.

Introduction

Pelagic stocks are a major fish resource off Angola, and of the total catch landed in the country pelagic fish represent approximately 80 % (Anon,1991, FAO,1996). The most important pelagic fish stocks, sardinellas (*Sardinella maderensis* and *Sardinella aurita*)and horse mackerel (*Trachurus trecae and Trachurus capensis*), are managed mainly on the basis of biomass estimates of the adult stock obtained by the use of hydro acoustics.

Knowledge of the performance of fishing gear and the behaviour of fish is important for fishermen, gear designers and scientists responsible for fish stock assessment (Fernö and Olsen, 1994). Development and improvement of instruments for quantifying or measuring fish behaviour and gear performance may improve catch rates and thereby the economy of fishing vessels. On the scientific side, there are connections between knowledge, measurements and information on fish behaviour during sampling, and the precision of survey estimates of fish abundance (Ona, 1994). For pelagic schooling fish, studies of behaviour in relation to vessels and fishing gear can be conducted by sonar (Mitson, 1983).

An important part of acoustic surveys is trawl sampling for identification of fish species and the measurement of species characteristics such as fish length and weight. The accuracy of the acoustic biomass estimate depends largely on correct target identification for the allocation of acoustic energy to the various species. During pelagic surveys, the sampling operations can be rather challenging if the target species are avoiding the vessel and trawl gear. This is often the case for fish schooling close to the surface. We conducted a series of pelagic trawl sampling trials on pelagic species distributed near surface off Angola. The trials were conducted by R/V «Dr. Fridtjof Nansen» operating a pelagic trawl with a vertical opening of about 20 m. The results were analysed to investigate what effects factors such as vessel and gear avoidance, towing speed, tow duration and time of day had on the total catches of sardinella.

Materials and methods

The pelagic trawl trials were conducted during two experimental cruises off Angola by R/V «Dr. Fridtjof Nansen». The first cruise was conducted in the area between Luanda and just south of Pta. Do Moro (Fig. 1) during July 1996. A zig-zag grid with turning points spaced 10 nm apart was followed between Luanda and just north of Cabo Ledo, where after a systematic parallel grid with an inter-transect spacing of 10 nm was surveyed south to 11° 20′ S. Throughout the survey, the innermost turning point was at 20 m depth, and the offshore turning point was at the 200 m isobath. Pelagic trawls were conducted regularly throughout the survey area to identify pelagic recordings. After completion of the survey grid, more pelagic trawls were done in an area off Pta. Das Palmeirinhas and off Cabo Ledo. Throughout the 1996 survey, weather conditions were calm with relatively little or no wind. In the southern part of the survey area inshore temperatures were as high as 24 °C whilst in the north closer to Luanda inshore surface temperatures were only around 21°C. Salinity at the surface was relatively high (in excess of 35.5 ‰) and showed little change with depth.

The second survey was conducted in the area between Luanda and Lobito (Fig. 2) from 30/4 to 12/5 1997. During this survey, no systematic survey grid was followed, but pelagic trawl trials were done on recordings off Pta. Das Palmeirinhas, between Cabo Ledo and Pta. Do Moro, and in an area just north of Lobito. All trawl trials were done in areas with bottom depths < 80 m. The sea surface temperature varied from 20.3° - 24° C, and the salinity was within 35.6 - 35.8 ‰ at all depths in the respective areas. In the Palmeirinhas area, the Secchi depth varied two-fold from 8 to 15 m. In the Lobito area the Secchi depth varied five-fold from 2.5 to 9.5 m.

For both surveys, the vessel was equipped with a 320 m circumference pelagic trawl with 1620 mm stretched mesh in the net mouth area and the wings. The mesh size in the bag was 36 mm stretched mesh. At bottom depths > 50 m, the trawl was normally operated with weights of 250 kg attached to the lower wings. This gave the trawl a vertical opening of 7 - 25 m depending on towing speed. At bottom depths between 35 - 50 m, the trawl was operated with weights of 130 kg. At bottom depths less than 35 m the trawl was operated without weights. During the 1996 survey a total of 33 trawls were done for the purposes of target identification and length frequency measurement. The majority of the trawls (26) were done at the surface or very close to the surface with buoys attached to the head rope of the trawl. Twenty-nine trials were done during the 1997-survey, of which 23 were at the surface.

During both experimental surveys, pelagic trawls were targeted on unidentified recordings of fish shoals observed on the 38 kHz SIMRAD EK500 echo-sounder or the 95 kHz SIMRAD SA950 sonar, or on schools visible at the surface. In many cases, especially when trawling on distinct school recordings, the SA950 sonar was used to guide the vessel towards the school. Usually, it was possible to track schools passing close to or underneath the vessel and backwards to the trawl doors which were clearly visible on the sonar display when the transducer was trained backwards. In these cases it was possible to evaluate whether schools performed vessel or trawl avoidance. To record fish in the trawl opening, a 50 kHz SIMRAD EY200 trawl sonde was attached to the headline. During 9 pelagic trawls of the 1997 survey, a FOCUS400 underwater towed vehicle (UTV) with SIT camera and 330 kHz SIMRAD FS3300 trawl sonar was used to observe the trawl geometry and the behaviour of sardinella in the trawl mouth and the tunnel of the trawl belly. The net sonde was not used during the UTV trials to avoid entangling the UTV in the net sonde cable. The UTV trials were done during daylight to enable visual observation of sardinella in the trawl belly. During these trials, the FS3300 and SIT camera recordings were taped on Hi8 Super ME cassettes for later analysis.

A random sample of about 100 fish of each species present, if available, were measured to the nearest 0.5 cm below. The size and species compositions of all trawl catches were pooled per area, depth and time period by simple adding. The species were pooled into the following groups:

- sardinellas (*Sardinella maderensis* and *Sardinella aurita*)
- horse mackerel (*Trachurus trecae*)
- other carangids (mostly *Selene dorsalis*, *Trachinotus goreensis*, *Trachinotus ovatus* and *Chloroscombrus chrysurus*)
- other pelagics (scombrids, barracudas, and hairtails-mostly *Sarda sarda*, *Scomberomorus tritor*, *Scomber japonicus*, *Sphyraena gauchancho* and *Trichiurus lepturus*)

Results

During daytime, trawls targeting on dense, surface shoals (assumed to be sardinella) in most cases failed to yield large catches. In an attempt to increase the success rate of catching sardinella the vessel was steered to pass 50 - 100 m to the side of the school, and then turned slightly so that the trawl was aimed directly at the school. Usually, these surface schools disappeared from the surface when the warps or the trawl doors approached at close range, and failed to show up on the net sonde recordings. Under these circumstances the schools probably avoided sideways when being approached by the warp or the trawl doors. On some occasions, however, parts of the schools were herded into the mouth of the trawl and recorded by the net sonde. These shoal traces were often visible on the net sonde recorder for extended periods of up to 48 minutes. It is therefore thought that these fast swimming fish were able to maintain a speed equal to that of the towing speed for relative long periods. Increasing the duration of the trawl seemed to alleviate this problem temporarily and the fish then dropped back in the trawl and disappeared from the net sonde recording. On many occasions, however, these fish then reappeared on the net sonde recording as soon as the trawl started to be hauled in, probably as a result of the slower vessel speed during hauling of the trawl. It is therefore likely that large schools of fish (probably sardinella), escaped from the trawl on numerous occasions. This reaction to trawling was most prevalent during the 1996 survey and as a result average catches of sardinella were much smaller than during 1997.

Trawl avoidance was also observed by way of the SA950 sonar. This was done by directing the sonar back towards the trawl doors after passing over a shoal and then tracking its path towards the trawl. Although this did not give an indication of the vertical aspect of the fish passage, it was possible to observe whether schools actually passed between the doors or avoided to the outside of the doors. Recordings of vertical trawl avoidance (mostly diving under the trawl) were obtained by way of the net sonde. Midwater shoals that were at trawl depth as the vessel passed over were often observed far below the foot rope of the trawl.

The trawl catches varied from 12 - 8850 kg during the day, and from 135 - 6385 kg at night. There was no significant correlation between the catch size (log transformed) and the towing speed in the range 2.7 - 5.0 knots neither for the day ($r = -0.30$, $p>0.05$), nor the night hauls ($r = 0.10$, $p>0.05$). Similarly, there was no significant correlation between the logarithmic transformed catch size and the tow duration in the range 15 - 120 min for the day hauls ($r = 0.26$, $p>0.05$). There was, however, a significant, negative correlation between the logarithmic transformed catch size and the tow duration in the range 15 - 60 min for the night hauls ($r = -0.63$, $p<0.05$). This was simply a reflection of the longer duration of trawls done at night on scattered recordings in order to obtain adequate sample sizes.

During the 1996 survey, the pelagic species were mostly recorded in rather shallow areas with a bottom depth of less than 100 m (Fig 3.) At bottom depths < 50 m, sardinella dominated the catches during the day. Other carangids also made up significant portions of the day catches in this depth zone, whilst hardly any horse mackerel were caught during the day in water shallower than 50 m. At night, however, horse mackerel made up the bulk of the catches in this depth zone with sardinella accounting for only about 20 % of the total catches. Further offshore (50 - 100 m) the proportion of sardinella in the daytime catches decreased while the proportion of both horse mackerel and other carangids increased. Catches in the 50 - 100 m depth zone at night were dominated by horse mackerel and other carangids. Representation of sardinella in these night catches was minimal.

During the 1997 survey, the average catch of sardinella was higher both during day and night than in 1996 (1996 mean catch = 75.8, SE 26.2; 1997 mean catch = 817.2, SE 379.3). Proportional representation of sardinella in day catches at depths of less than 50 m was, however, very similar between the two years (Fig. 4). Contrary to catches made in 1996 at this depth at night, sardinella remained the dominant species in the catches whereas horse mackerel accounted for only a small percentage of the total catches. Sardinella also made up the bulk of the catches in deeper water during the day with very few other species present. During the night a slight shift in dominance of species occurred in the catches with sardinella representation decreasing and that of the other 3 species groups increasing. It was notable that the mean contribution of horse mackerel to catches made in water deeper than 50 m decreased substantially from 1996 to 1997 both during the day and the night. The catch compositions of 1997 reflected a larger contribution of sardinella to both day and night catches (Fig. 5) than was the case in 1996. In addition, horse mackerel which formed a substantial part of the catches during 1996, particularly at night, formed a much smaller part of the catches during 1997.

The pooled size distributions of *Sardinella sp.*(*Sardinella maderensis* & *Sardinella aurita*) from trawls made at <50 m bottom depths in 1996 reveal a substantial difference between day and night (Fig. 6). The mean length was 31.2 cm for the day hauls, and 23.4 cm for the night hauls. A similar pattern was found from 50 - 100 m bottom depths with mean length equal to 33.0 cm for the day hauls and 26.0 cm for the night hauls. The size distributions obtained during the 1997 survey also reveal the same pattern (Fig. 7). However, this year the smaller fish present in the night catches seem to have grown by about 10 cm since the 1996 survey. For hauls made at <50 m bottom depth, the mean length during in day time was still about 4 cm greater than for the night time hauls (33.3 cm and 29.6 cm, respectively), but for hauls made at between 50 - 100 m bottom depth, the mean length differences was 1.4 cm only (31.7 cm for the day time hauls, and 30.3 cm for the night time hauls).

Discussion

The surface schools recorded during the day off Angola during the two surveys in 1996 and 1997 presented numerous problems in respect of effective pelagic trawl sampling. In most cases the schools disappeared from the surface when approached by the trawl warps or the trawl doors. According to recordings by the Simrad SA950 sonar, these schools avoided sideways, probably when frightened by the sight of the trawl warp or the trawl doors. On numerous occasions, however, parts of the school seemed to have been herded back to the mouth of the trawl net, and were recorded on the net sonde as expected. These schools were often able to match the towing speed of the trawl, and were recorded by the net sonde for a remarkably long time. The schools seemed to drop back and disappeared from the net sonde when increasing the towing speed temporarily. These schools were, however, capable of swimming forward in the trawl again, and appeared in the net mouth area when slowing down the towing speed during hauling of the trawl. Usually, most of these schools seemed to escape during hauling, and only small catches were present in the trawl.

Midwater schools passed over by the vessel avoided vertically, and were often recorded at greater depth by the net sonde than by the echo sounder on the vessel. In 1997 two large catches of sardinella were taken in shallow water (< 50 m bottom depth) north of Lobito in daytime, and these catches were taken on small midwater recordings that did not seem to react to the approach of the vessel and the trawl. The visibility during these catches as judged by the Secchi - depth was less than 10 m, so it is possible that the fish did not see the approaching vessel or trawl.

During daytime, there was no correlation between towing speed in the range 2.7 - 5.0 knots and towing duration in the range 15 - 120 min, and the catches obtained. For fast-swimming fish such as large sardinella, this is reasonable. The frightened response of fish following the sight of the warp, the doors, or the bridles, would lead to fish swimming faster than the approaching trawl for short periods of time. Burst-speed swimming is species, length and temperature dependent, and according to recordings of other species, it is possible that a 30 cm sardinella swimming in water of more then 20° C may reach a speed of about 5 m/s or 10 knots for a short duration (He, 1993). Towing the trawl for only up to half the burst speed of the fish or for a long time, may therefore not be expected to increase the catches. During night-time, there was a close correlation between the catch size and the towing duration in the range 15 - 60 min, because longer tows were made in areas with scattered recordings to obtain proper samples.

Both during the 1996 and 1997 surveys there were substantial differences in the pooled length distributions of sardinella between day and night. During the day, the length distributions were unimodal and the catches contained sardinella in the range 20 - 40 cm (mean length 33 and 32 cm in 1996 an 1997, respectively). At night, the length distributions were bimodal , and the catches contained sardinella from 10 - 40 cm and in 1996 and 20 - 40 cm in 1997. In 1996, the night distributions had a mode from 10 - 20 cm and another from 25 - 40 cm. In 1997 the night distributions had a mode from 20 - 25 cm and another from 25 - 40 cm. Probably, the small fish in the 10 - 20 cm range had grown by about 10 cm in average from 1996 to 1997.

The substantial differences in the day and night length distributions may have a significant impact on acoustic survey estimates. First, if trawling is restricted to day-time, surveys may fail to record and map the small sardinella. Secondly, if daytime samples are used to convert acoustic recordings made at night, the biomass may be underestimated due to a too large target strength estimate. Similarly, if night-time samples are used to convert daytime acoustic recordings, the biomass will be overestimated due to a low small target strength estimate. This is because a 20 log L - 71.9 target strength relationship as recommended for clupeiods (Foote, 1991) will give a target strength of about - 41.5 dB according to the 1996 day-time length distribution, and about - 44.5 according to the 1996 night-time length distribution. The day and night target strength differences will be less, but still substantial, when converting the 1997 length distributions.

Sardinella < 25 cm were generally absent in the day-time samples, but well represented in the night-time samples independent of depth. As most day-time trawl samples were collected from surface to about 20 m depth, the small sardinella were obviously absent from the upper pelagic zone. At night , however, the small sardinella were present in this zone, because most night hauls were also made in the upper pelagic zone. The majority of the night hauls were made a few hours after the onset of darkness. This eliminates the possibility that the small sardinella inhabit the upper pelagic zone at night in the survey area as a result of horizontal migration e.g. from inshore to offshore. The small sardinella were probably distributed near the bottom during the day, and migrated vertically towards the surface at night. However, a few bottom trawls failed to catch small sardinella, but this could merely have been incidental. This unusual distribution of juvenile clupeiods close to the bottom during the day may also raise questions as to the level of predation by horse mackerel and other bottom living predators on them. Future stomach composition analysis of horse mackerel in such areas may be beneficial to understanding this phenomenon. It would also assist in substantiating the existence of juvenile sardinella close to the bottom during the day in areas where trawls have failed to catch them.

For sardinella, the average catch size was about the same independent of day or night during both surveys. Horse mackerel and other carangids generally gave the best catches during night, probably because these species migrated from near bottom towards the surface at night. During the 1996 survey, however, the best catches of these species at bottom depths between 50 - 100 m were taken during the day. During the 1996 survey the average catches of species groups was about the same for both depth strata, whereas during the 1997 survey, the largest catches were taken at bottom depths < 50 m. This probably reflects a more near-shore distribution of these pelagic species in 1997 compared to 1996. Although the catch compositions mainly reflect the availability of the various species targeted on to the trawl it is possible that the larger proportion of sardinella in trawls during 1997 can in some ways be attributed to a combination of trawling experience, fish behaviour and hydrography. During the 1997 survey, the largest catches of sardinella were taken just north of Lobito, probably as a result of the fish being distributed in midwater combined with the fact that little avoidance of the trawl was noted during these trawls, possibly because of low visibility.

Although this is mainly a descriptive paper, it intends to highlight the importance of accurate sampling of acoustic targets. The ability of sardinella to successfully avoid the trawl is a source of major concern and could lead to substantial errors in the biomass estimate. These errors would include both an underestimation of sardinella biomass and a large overestimation of all other species present. In addition, frequent trawling throughout the duration of a routine biomass survey is essential and should not only be restricted to the surface zone or to a particular time of day. Failure to sample throughout the water column may lead to biases in the biomass estimate of particularly juvenile sardinella. Future trawl surveys where experimentation with different gear types is possible may also lead to increased success rates in the sampling of sardinella.

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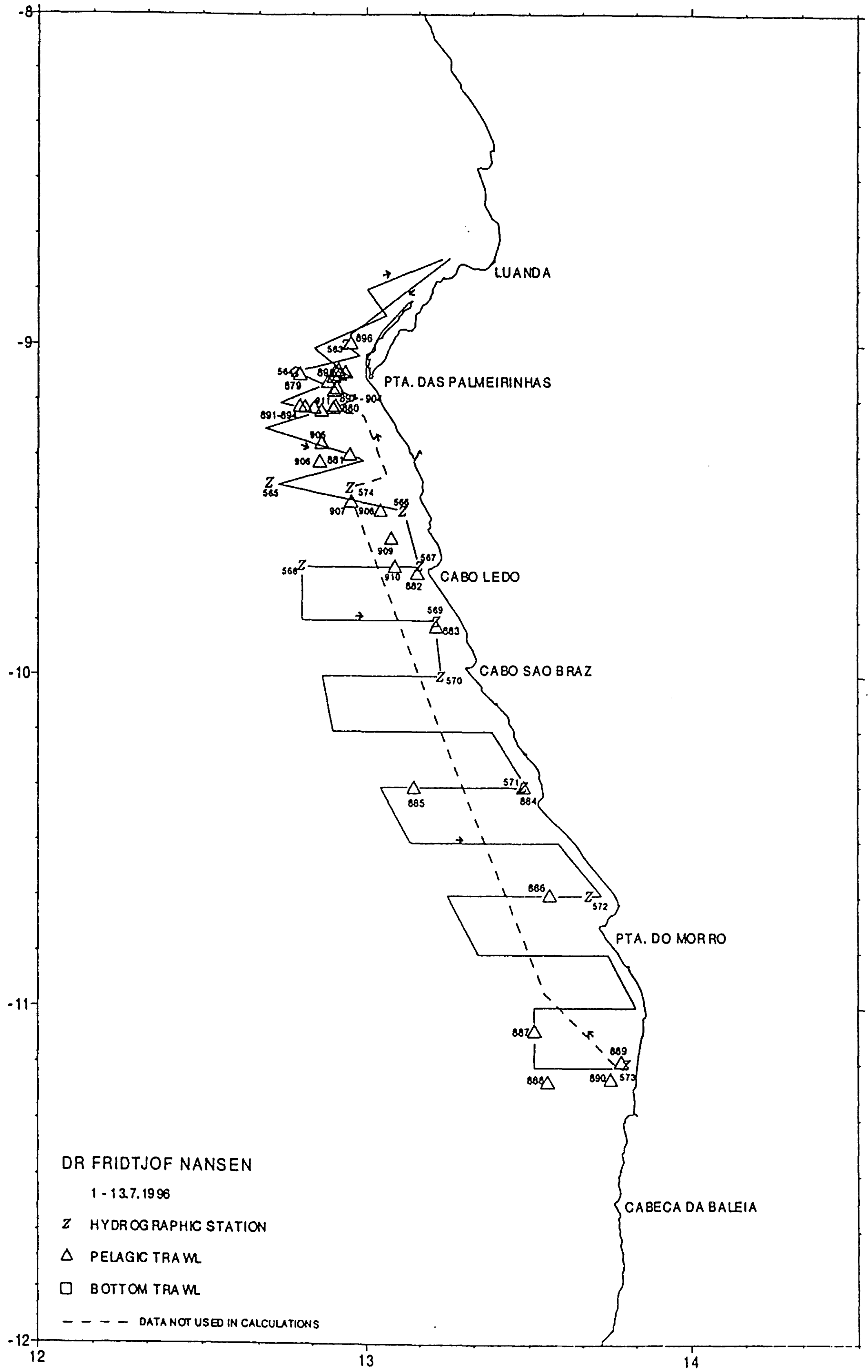

Figure 1. Course track, fishing stations and hydrographic stations during the 1996 survey.

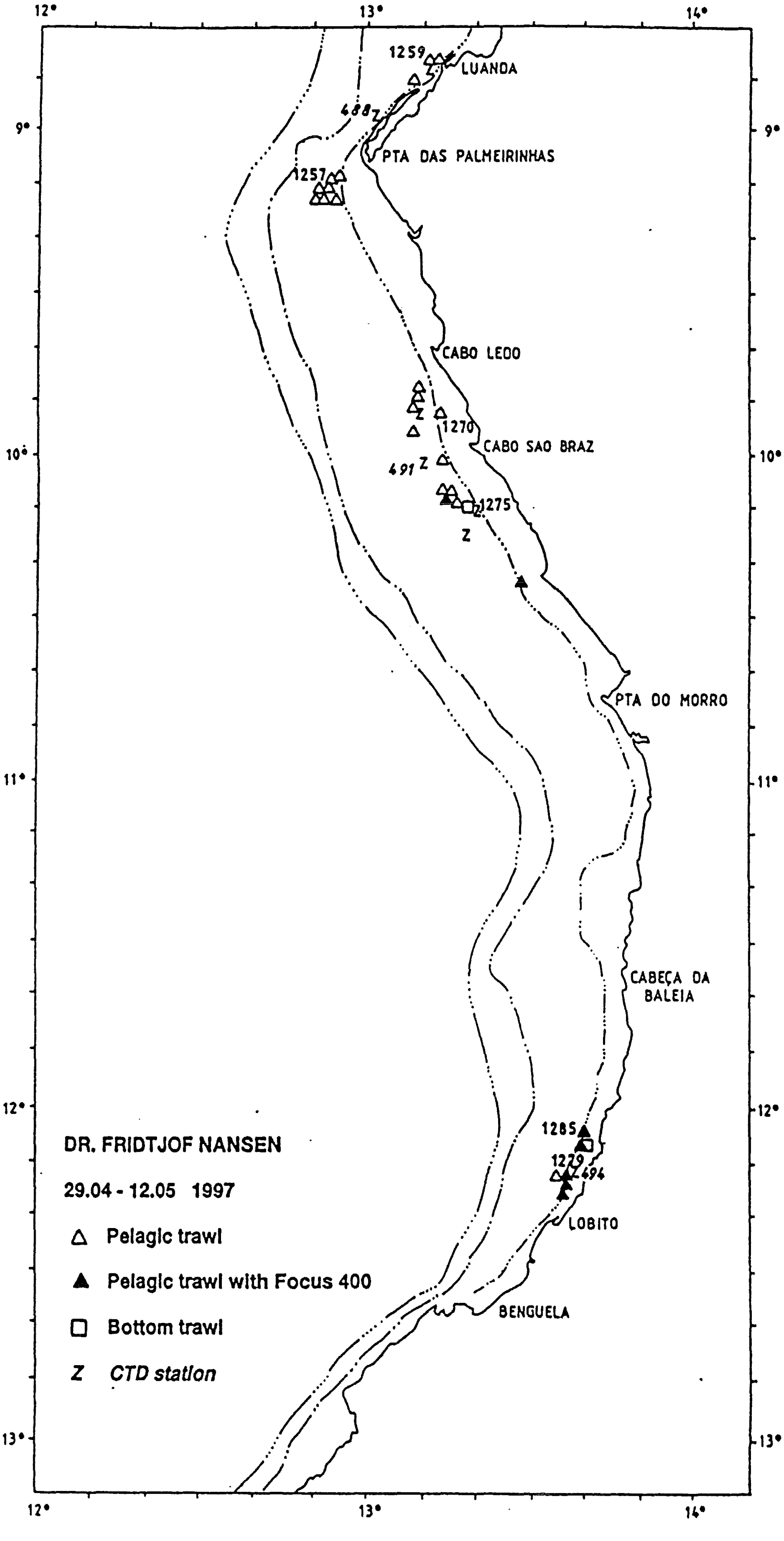

Figure 2. Course track, fishing stations and hydrographic stations during the 1997 survey.

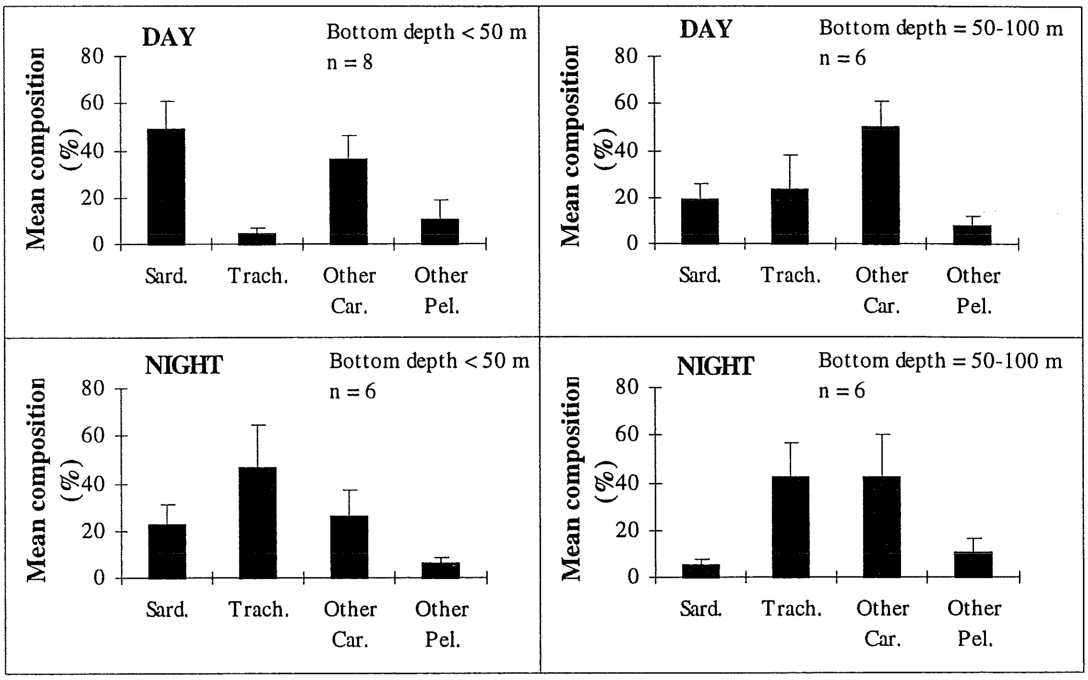

Figure 3. Mean percentage composition of trawls in different depth zones by day and by night during 1996. Error bars indicate the standard errors of the means.

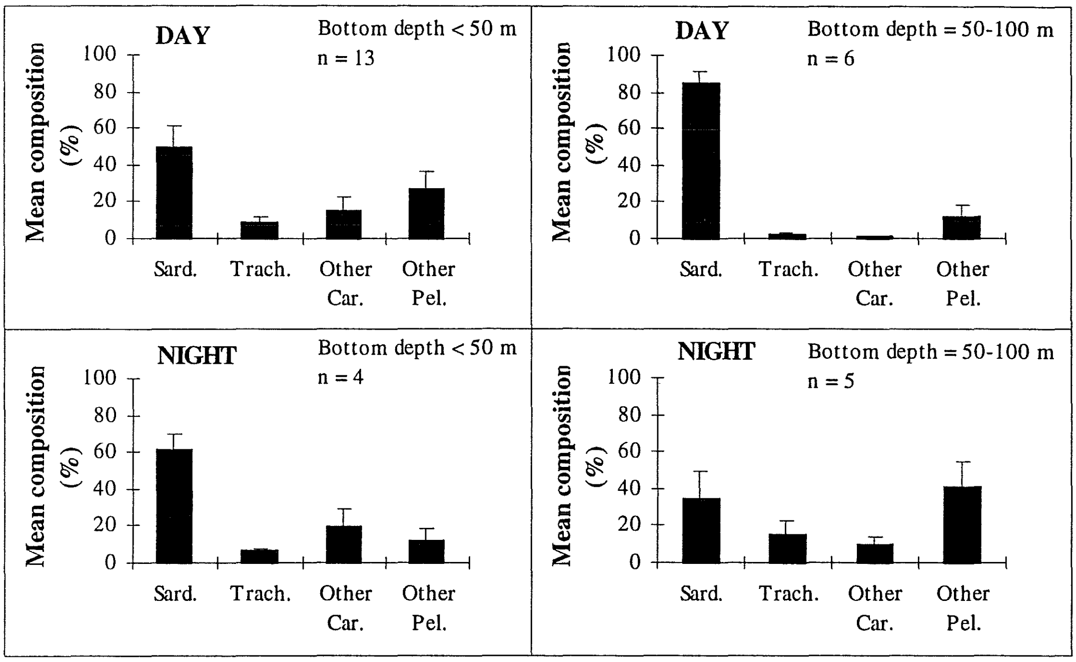

Figure 4. Mean percentage catch composition of trawls in different depth zones by day and by night during 1997. Error bars indicate the standard errors of the means.

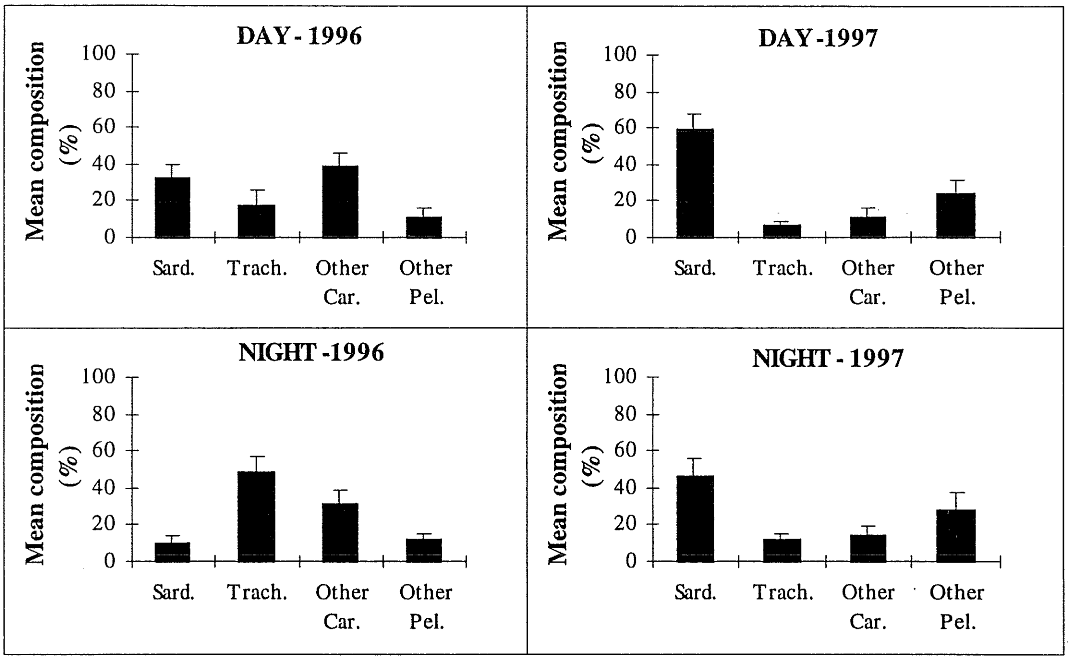

Figure 5. Mean catch composition of trawl for all areas combined by day and by night during 1996 and 1997.

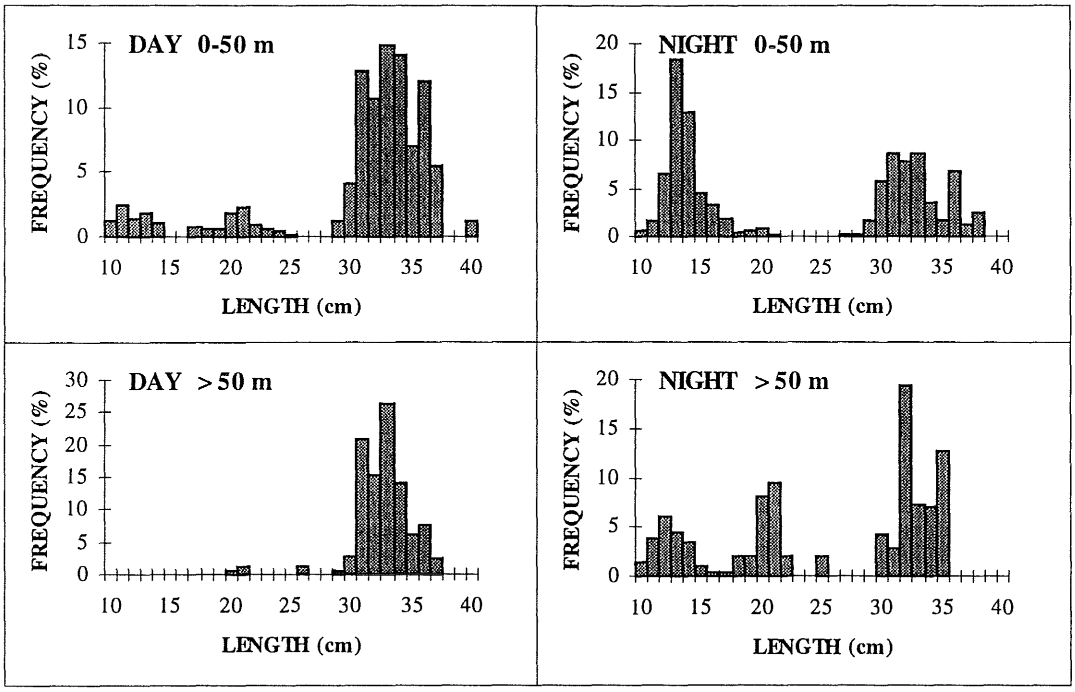

Figure 6. Length frequency distributions of sardinella (*S. aurita* & *S. maderensis combined*) in different depth zones by day and by night during 1996.

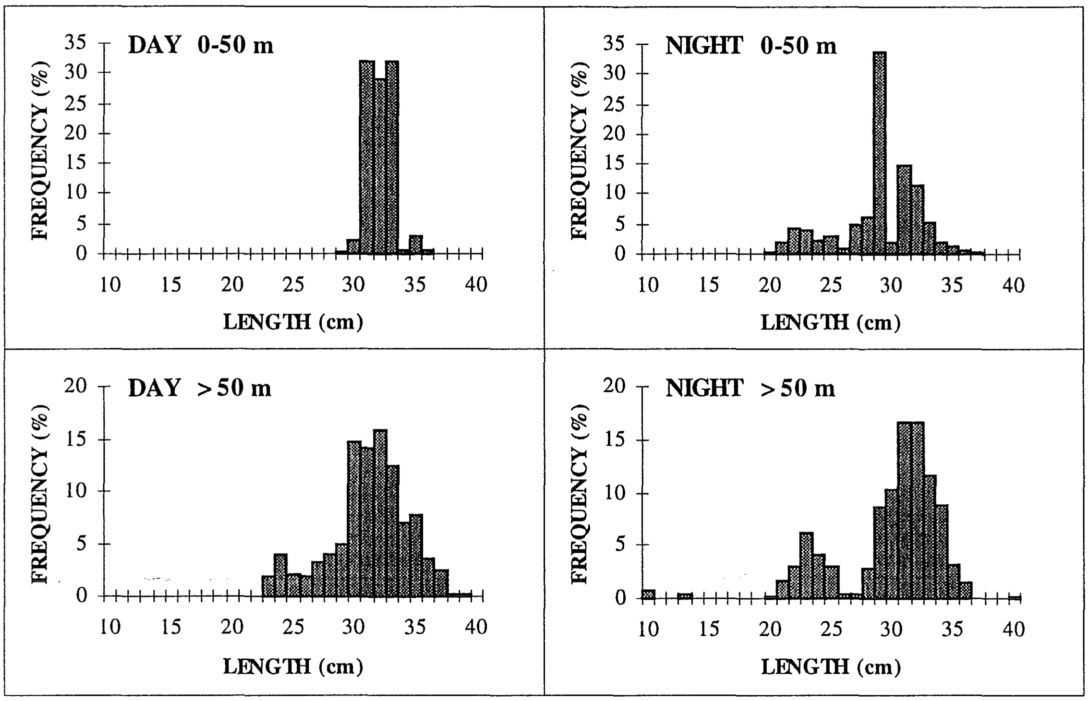

Figure 7. Length frequency distributions of sardinella (*S. aurita* & *S. maderensis combined*) in different depth zones by day and by night during 1997.