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## Diurnal variation of the echo intensity and some biological observations on redfish in the Irminger Sea (preliminary results)

by

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### Abstract

Several acoustic surveys on oceanic redfish (*Sebastes mentella*) in the Irminger Sea and adjacent waters have been conducted by Icelandic scientists since 1991. A potential bias in the acoustic estimates of the biomass of oceanic redfish in this area is the mixing with other species. During the night a scattering layer of myctophids and other organisms ascends and mixes with the redfish to such an extent that identification between species becomes difficult. This and possibly behavioural related factors result often in considerably lower integration values during the night as compared to daytime values. In June/July 1995, a survey was conducted in order to study the observed diurnal variations of the acoustic abundance of the oceanic redfish in the Irminger Sea as well as to obtain biological information on the oceanic and deep-sea redfish.

Acoustic and biological data were collected for several days in two main areas. Areal differences were observed in the degree of mixing of oceanic redfish with the scattering layer and may be related to the progressively increasing hours and degree of darkness as one moves southward at these latitudes during the summer. The results indicate that the diurnal variations of the observed acoustic abundance and target strength of the oceanic redfish are strongly correlated.

Areal differences in the overall mean length and weight of oceanic redfish as well as in the infestation rate of external abnormalities were observed. A distinct difference in the diet of oceanic and of deep-sea redfish was recorded in the survey area.

## Introduction

Since 1991, several acoustic surveys on oceanic redfish (*Sebastes mentella*) in the Irminger Sea and adjacent waters have been conducted by Icelandic scientists (Magnússon *et al.* 1992a, 1992b and 1994). In the course of these surveys it has been established that oceanic redfish is the main scatterer in the water column from 50 down to 400 m. It is particularly common in 100-300 m depth during the feeding time period in June/July while deep-sea redfish has been observed in deeper waters (over 500 m depth) over wide areas of the Irminger Sea. During the "spawning" and "pre-spawning" time period in March to May, the oceanic redfish seeks deeper waters and the two stocks get mixed to some extent (Magnússon 1983, Magnússon *et al.*, 1995).

The acoustic conditions for the oceanic redfish is in many ways ideal, *i.e.* the fish is rather uniformly distributed over the area so that the expected variance in the measured echo intensities is relatively low, and single-fish echoes are dominant, allowing more or less continuous monitoring of the target strength of the fish. Results on the target strength of oceanic redfish from surveys in 1991 and 1992 have been presented by Reynisson (1992). Although the conditions are in many ways favourable for acoustic surveying, some problems have been identified. One is directly related to the very scattered condition of the fish. Since the received echo intensity is rather weak, in order to include all echoes of interest, the setting of the integration threshold is critical (*e.g.* Aglen 1983, Kalikhman and Tesler 1983, Foote 1991). For this particular case see Magnússon *et al.* (1994) and Reynisson (1995). Another potential bias in the acoustic biomass estimates of the oceanic redfish is the mixing with other species (*e.g.* myctophids). During the night a part of the scattering layer of myctophids and other organisms ascends and mixes with the redfish to such an extent that the lower depth limit of integration must be reduced, resulting in an underestimation of the redfish. This and possibly behavioural related factors result often in considerably lower integration values during the night as compared to daytime values. The acoustic data from the joint Icelandic/Norwegian survey in June/July 1994 indicated a systematic diurnal variation in the acoustic abundance, most notable for the difference between day and night, but also observed through the daylight hours where little or no mixing with the myctophids occurred (Magnússon *et al.* 1994). Eventual and/or partial overlapping in the depth distribution of oceanic and deep-sea redfish during the summer time has not been studied so far. Thus, a survey was initiated by the Marine Research Institute (MRI), Iceland, in order to:

1. Study the diurnal variation in the echo abundance of oceanic redfish.
2. Examine the depth distribution of the two stocks by trawling
3. Collect material for genetic stock analyses
4. Collect biological data.

## Material and methods

The survey was carried out on the Icelandic research vessel "Bjarni Sæmundsson" during the time period June 26 to July 11. The acoustic instruments were as follows; an EK500 split-beam echo sounder operating at 38 kHz (Bodholt *et al.* 1989) and a BI500 postprocessing system (Foote *et al.* 1991). Just prior to and after the survey the acoustic equipment was calibrated by the standard sphere method (Foote *et al.* 1987). The beam compensation of the split-beam system was checked on 3 cross sections of the beam, indicating that a bias less than

0.1 dB of the mean target strength was expected within the -6 dB limit of the two-way beam pattern.

During the whole survey, mean area back scattering coefficient ( $SA \text{ m}^2 / \text{nm}^2$ ) of oceanic redfish were recorded for every 5 nm sailed. Acoustic material for the study of the diurnal variations of oceanic redfish were collected in two main areas, positioned at about  $61^{\circ}07'N-36^{\circ}50'W$  and  $58^{\circ}59'N-41^{\circ}00'W$ , referred to as Area I and II respectively. The main criteria for the selection of these special areas were that the acoustic abundance should be around or above the average as observed in former surveys and that the duration and degree of darkness at night should differ from one area to the other. In each area acoustic data were collected for three consecutive days and nights, on 29 June to 2 July in Area I and 3-5 July in Area II. In Area I, a selected track of 10 nm was cruised back and forth at a speed of 10 knots on the first 24 hours. For the next 48 hours trawling was undertaken in the nearest vicinity, although the cruise tracks were not as regular. In Area II, similar cruise tracks were chosen. In this case, the first 48 hours were used for acoustic data collection undisturbed by trawling. Echo integration- and split-beam data were collected from the uppermost 500 m of the water column for postprocessing. The target strength threshold used in the collection of the split-beam data was set at -60 dB.

In the analysis of the acoustic data, an integration threshold in terms of the back scattering volume was set at  $-80 \text{ dB}/\text{m}^2 / \text{m}^3$ . The lower depth limit of integration was always set in such a way as to exclude the disturbing echoes from the scattering layer. In the preliminary analysis of the split-beam data, a lower and upper limit on target strength, -52 and -31 dB, was used in order to minimize the influence of echoes from smaller organisms as well as to exclude large echoes. A lower limit on depth was set at 200 m in order to keep the possibility of double echoes at an acceptable level. The limit of the split-beam acceptance angle was set at 3 deg from the acoustic axis. In areas I and II, a  $SA$ -value was obtained for every 1 nm sailed and the mean scattering cross section ( $\sigma$ ) was calculated for every 5 nm. Further reduction of the data was obtained by calculating a mean of these variables for every 1 hour. This was done separately for the two areas.

A specially designed pelagic trawl (Gloria type-Hampiðjan, max circumference 1152 m and stretched mesh size of 32 m) with a vertical opening of about 65 m was used for biological sampling. After two hauls, the pelagic trawl winch broke down and the Gloria trawl had to be replaced by a very inefficient small pelagic trawl. Therefore, the planned standard trawling by night and day which was intended to follow up the variations in acoustic values, and the systematic trawling in different depths to study the separation of the two stocks in depth had to be cancelled. However, the biological and the stock-genetic sampling was supplemented by samples from commercial trawlers (Area III). The biological and the stock-genetic sampling was carried out by standard procedures.

## Results

### 1. Acoustic observations

The relative acoustic abundance of oceanic redfish along the cruise tracks is shown in Fig. 1.

It was observed that during the night, the degree of mixing of the scattering layer with the oceanic redfish differed between Area I and II. In Area I the scattering layer rose no higher than to about 200 m depth. In Area II a part of the scattering layer seemed to mix thoroughly with the redfish in the whole water column.

The shape of the  $TS$ -distribution of the oceanic redfish changed quite systematically through the day. At mid-day the distribution was clearly unimodal but became progressively more

bimodal as night-time approached. As an example the *TS*-distribution obtained during half an hour at four hours intervals during one day is shown in Fig. 2.

The diurnal variations in the area back scattering coefficient (*SA*) and scattering cross section ( $\sigma$ ) are shown in Fig. 3 and Fig. 4 for areas I and II respectively. The data points are the mean values within each 1 hour time interval. The standard error is indicated. Split-beam data obtained during trawling are not included. The smoothed curves shown in the diagrams were obtained by fitting a 5th order polynom to the data. Note that for Area II, *SA*-values obtained during trawling are not included. In Fig. 5 the smoothed relative diurnal changes in *SA*,  $\sigma$  and the number of redfish (*SA*/ $\sigma$ ) according to the data shown in Fig. 3 and Fig. 4 are given.

## 2. Biological observations

In Table 1, an overview on length and weight of oceanic and deep-sea redfish is given. Sexual differences in the mean length and weight were observed, in particular for the oceanic redfish. There are also some differences in the overall mean length between the areas. Although the material on deep-sea redfish is rather limited the known differences between oceanic and deep-sea redfish are reflected in the length distribution (see Fig.6) and in the weight (Table 1).

Most of the redfish were with everted or empty stomachs, i. e. 83 % of oceanic and 91 % of deep-sea redfish. Generally, the volume of the stomach content was little. Of the nine food components identified, squids were in majority. The diet of oceanic redfish consisted besides squids mostly of amphipods, copepods and euphausiids but deep-sea redfish fed mainly on shrimps and on fish.

Areal differences in the incidence of external abnormalities were observed for both species with the highest incidence in Area I and the lowest one in Area III. Contrarily to earlier observations on the infestation of oceanic redfish (Magnússon, J.V. 1992) infested males were more numerous than females both in areas II and III. *Sphyrion lumpi* and leasons caused by this parasitic copepod were the most frequently observed abnormalities for both species although they occurred two to three times less in area III (6%) than in the other two areas. Of the three categories of spots (i.e. black, red, and mixed ones), black ones were by far most frequently observed on oceanic redfish. Only very few deep-sea redfish carried spots and if, almost exclusively red ones.

Black pigmentation in the muscular tissue was rather common in oceanic redfish (65 %). On the other hand, only 7 % of deep-sea redfish showed a slight indication of black pigment in the muscular tissue.

## Discussion

As shown in Fig. 2 the shape of the *TS*-distribution of the redfish changed progressively through the day. The most likely explanation for this observation is that the behavioural pattern of the redfish is changing. It is known that the tilt angle distribution of fish can greatly affect the target strength distribution observed (Nakken and Olsen, 1977). At a frequency of 38 kHz, commercial fish are highly directive scatterers of sound, and for a wide tilt angle distribution a bimodal distribution of target strength is quite likely.

It is obvious from the data shown in Fig. 3 and 4 that the diurnal variations in *SA* and  $\sigma$  are strongly correlated. However, at certain times of the day, the variation in *SA*-values are not fully accounted for by the variation in  $\sigma$ , significantly so during the night time, i.e. from around midnight until about five o'clock (GMT) in the morning. The explanation is the ascent of the scattering layer during the night. This is especially evident in Area II. In Area I, the mixing with the scattering layer was not as pronounced. At that latitude the scattering layer rose no higher

than to the 200 m depth. This difference in behaviour is most likely explained by the progressively increasing hours and degree of darkness as one moves southward at these latitudes during the summer. Possible changes in species composition of the scattering layer may also account for this difference. This suggests that the target strength values obtained during the night are not representative of oceanic redfish alone, especially in Area II. The dip in the  $SA/\sigma$ -values during the night may therefore be interpreted as showing the degree of mixing.

It is important to quantify how the diurnal variations may affect the acoustic estimates of the biomass of oceanic redfish and how the planning of the surveys may be altered in order to minimize the effect of these variations. One alternative is to simply use a target strength value averaged over 24 hours. This is more or less what has been effectively done in the acoustic surveys in 1991-1994. This does not take into account the varying degree of mixing and the resulting loss of redfish echoes in the processing of the acoustic data. Another possibility would be to use a higher integration threshold, thus often excluding the weaker echoes from myctophids and other small organisms. This could lead to an underestimation, progressively increasing with depth, unless measures were taken to correct the integrated values. A more attractive strategy might be to plan the survey in a manner that minimizes the area covered during night-time. The time lost might to a certain degree be used for obtaining biological samples, thus increasing the coverage during day-time.

The limited processing done so far on the split-beam data indicate that averaging the scattering cross section over 24 hours results in a mean value close to the target strength of -40 dB which has been used in the surveys in 1991-1994 (Reynisson 1992). Before some possible recommendations can be given on a revised target strength of oceanic redfish, based on the data described, a more rigorous selection of the split-beam data must be carried out. This would include target tracking and study of possible depth dependence of the target strength.

The areal differences in the overall mean length and weight indicate the need for a relatively dense sampling of the target species. The differences in the diet of oceanic redfish and deep-sea redfish reflect a different habitat of the two stocks at this time of the year. Apparently the deep-sea redfish feed mainly on the organisms of the scattering layer since both a variety of fish species and euphausiids are components of the scattering layer. The diet of the oceanic redfish corresponds at least partly to the zooplankton in the uppermost layers.

It appears that the infestation rate might also be linked to a certain extent to the areal distribution since the overall infestation rate for Area III was much lower than for the other two areas. Further, the higher infestation rate of external abnormalities by males of oceanic redfish in areas II and III point in the same direction since all previous observations have shown that the females are more heavily infested.

The incidence of black pigment in the muscular tissues of oceanic redfish is very high (65 %). However, a connection between the external and the muscular abnormalities could not be established.

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Table 1.

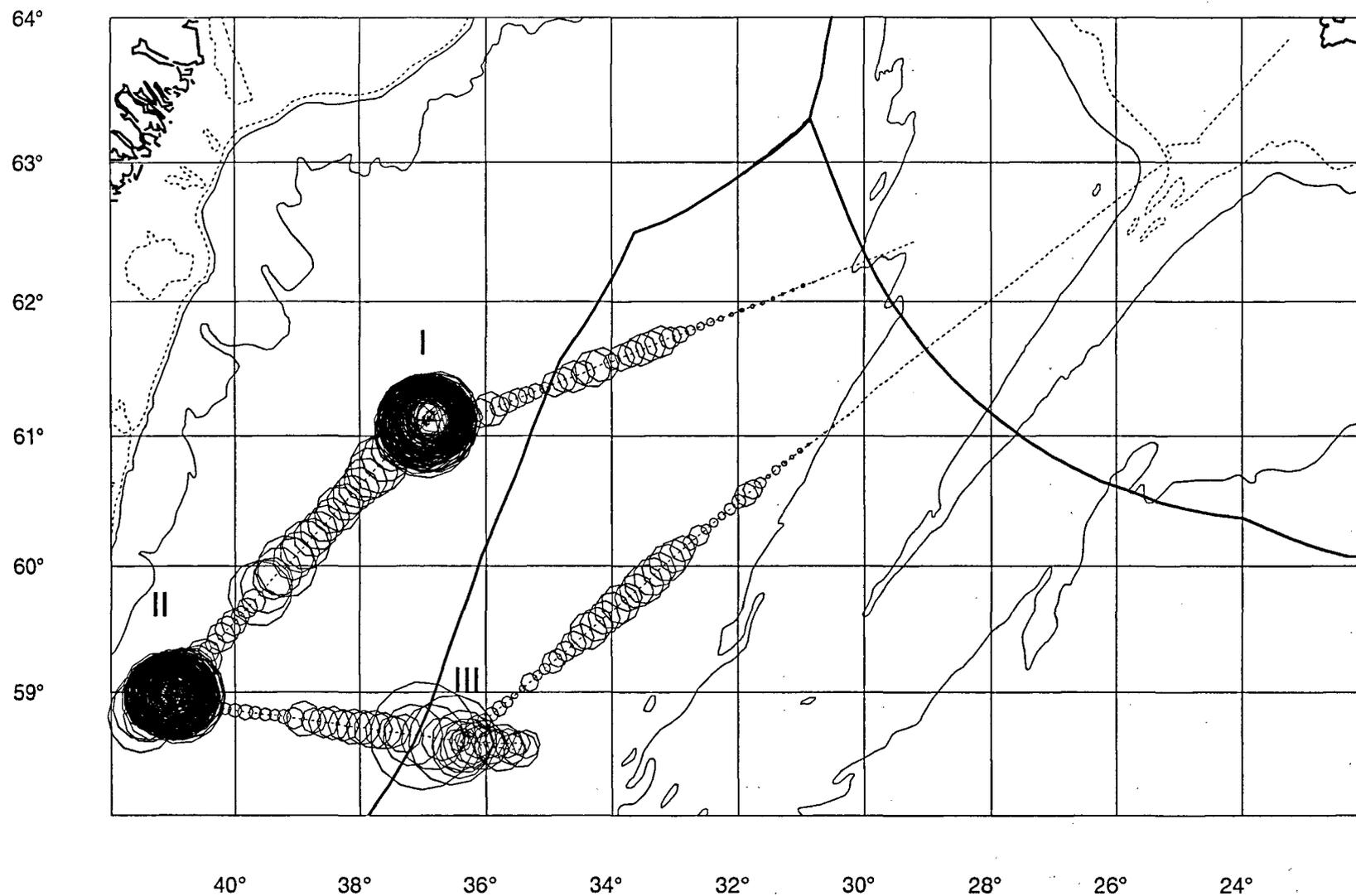
**Observations on length (cm) and weight (g) of oceanic and deep-sea redfish by areas and sex.**

**A) Oceanic redfish**

	Males		Females		Total			
	No.	Mean length	No.	Mean length	No.	Length range	Mean length	Mean weight
Area I	117	36,44	95	37,83	212	26-43	37,07	652
Area II	42	36,55	14	37,29	56	30-45	36,73	629
Area III	196	35,64	94	36,84	290	29-41	36,03	565
All Areas								
Length	335	36,01	203	37,33	558	26-45	36,49	
Weight	355	584	203	640	558		604	

**A) Deep-sea redfish**

	Males		Females		Total			
	No.	Mean length	No.	Mean length	No.	Length range	Mean length	Mean weight
Area I	31	41,65	22	40,91	53	31-49	41,34	853
Area II	2	41,50	0	0	2	41-42	41,50	913
Area III	83	41,52	64	42,22	147	32-48	41,82	882
All Areas								
Length	116	41,55	86	41,88	202	31-49	41,69	
Weight	116	871	86	880	202		875	



∞

Figure 1. Cruise tracks from the Icelandic survey in June/July 1995 and relative acoustic abundance of oceanic redfish. The size of the circles indicate the SA values of BI500 for each 5 nm. The numbers (I-III) indicate Area I, Area II and the main fishing grounds at the time of the survey.

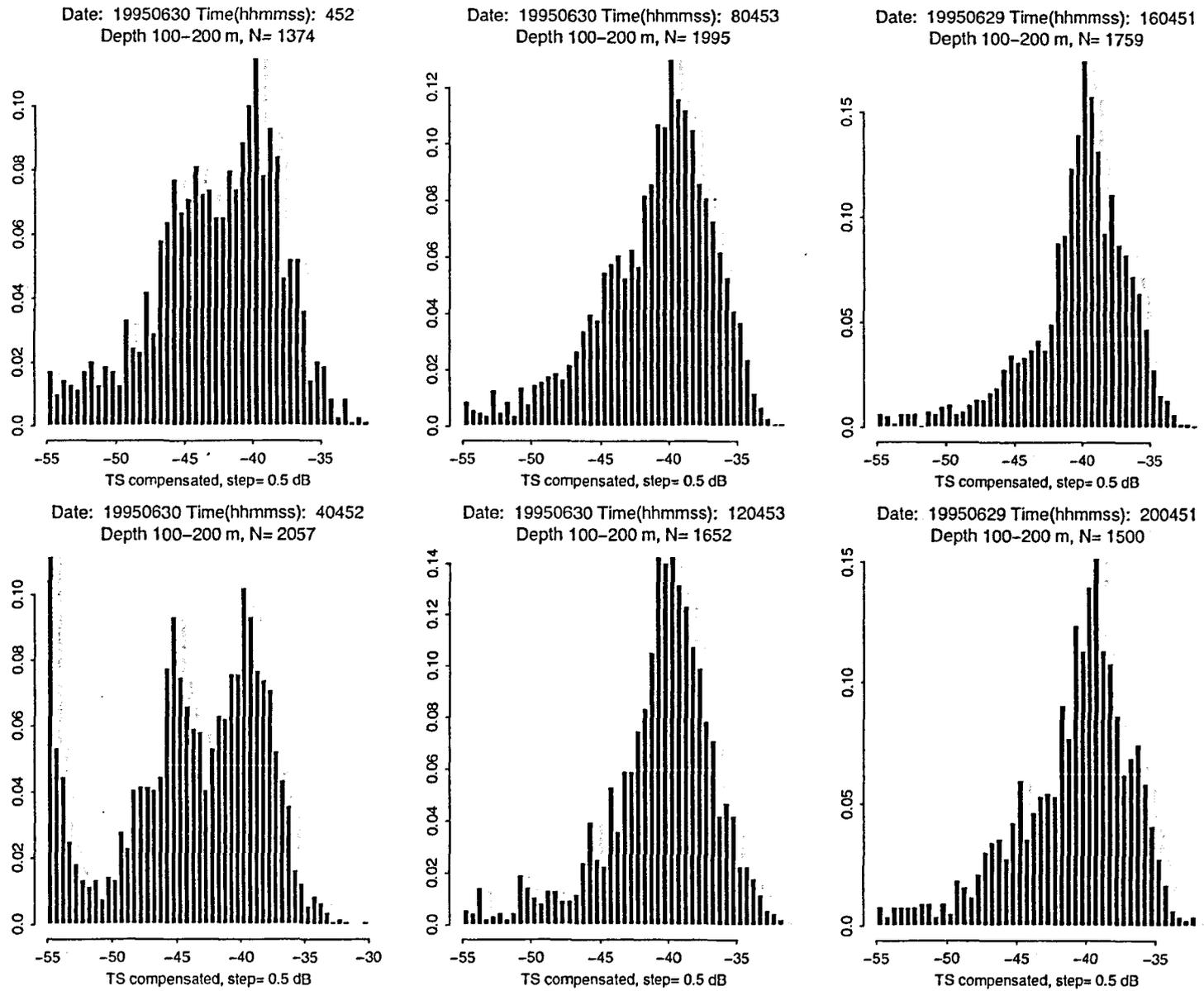


Fig. 2. An example of TS-distributions of oceanic redfish obtained during half an hour at four hours interval in Area I.

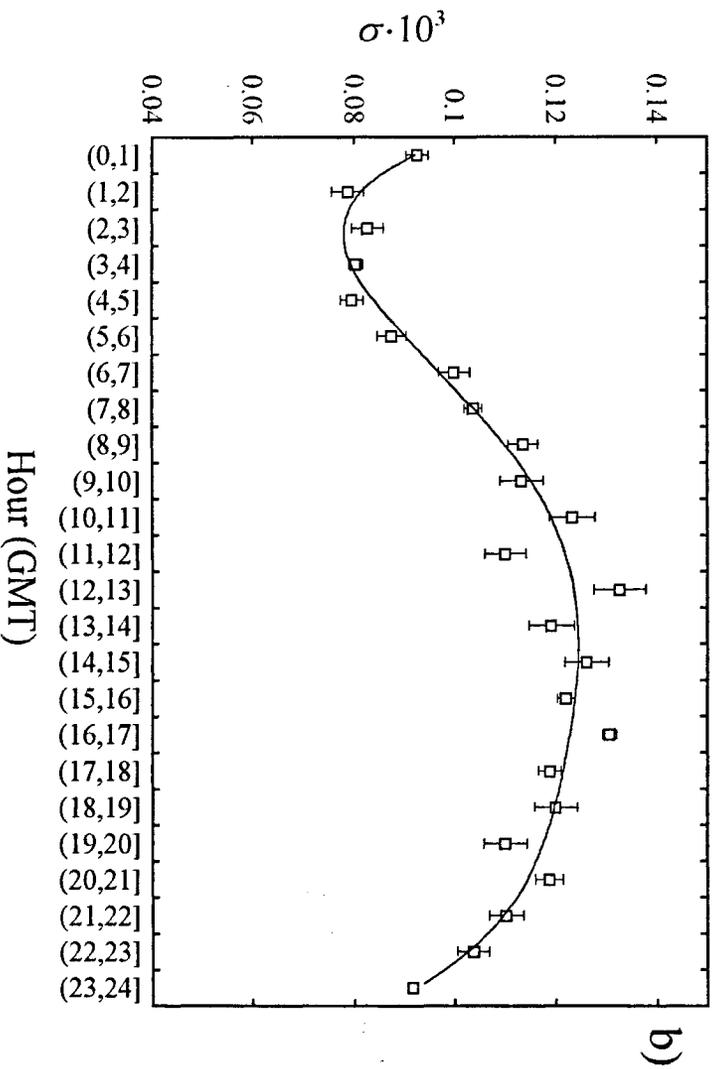
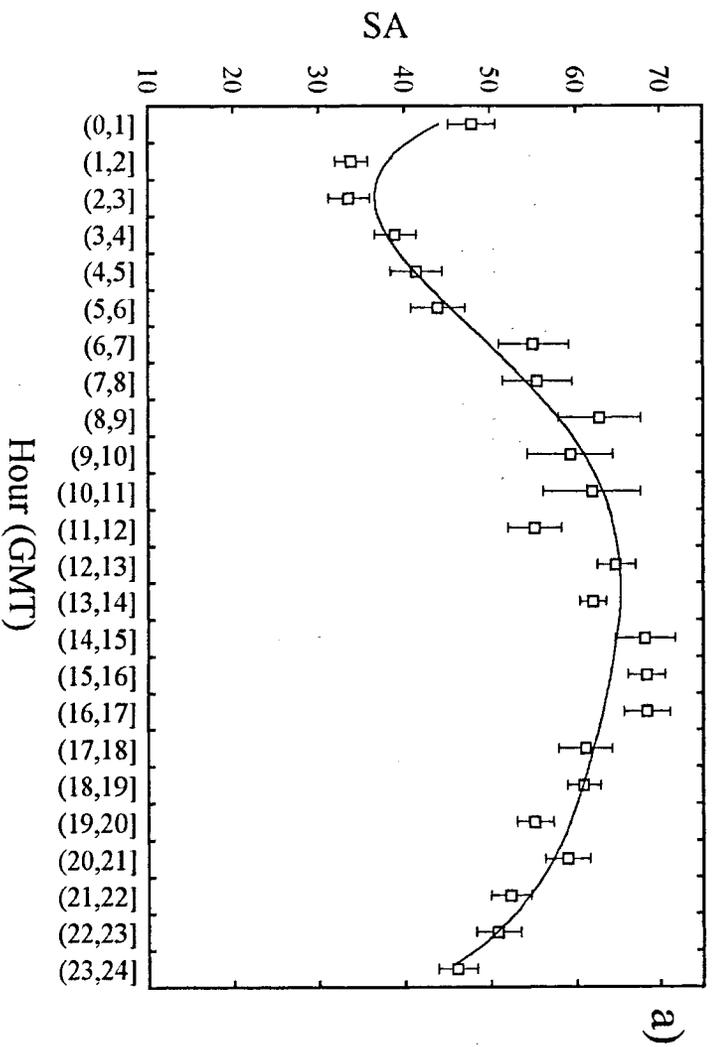


Fig. 3. Diurnal variations of a) the mean area back scattering coefficient (SA) and b) scattering cross section ( $\sigma$ ) of oceanic redfish averaged over 1 hour time intervals in Area I. Standard error is indicated.

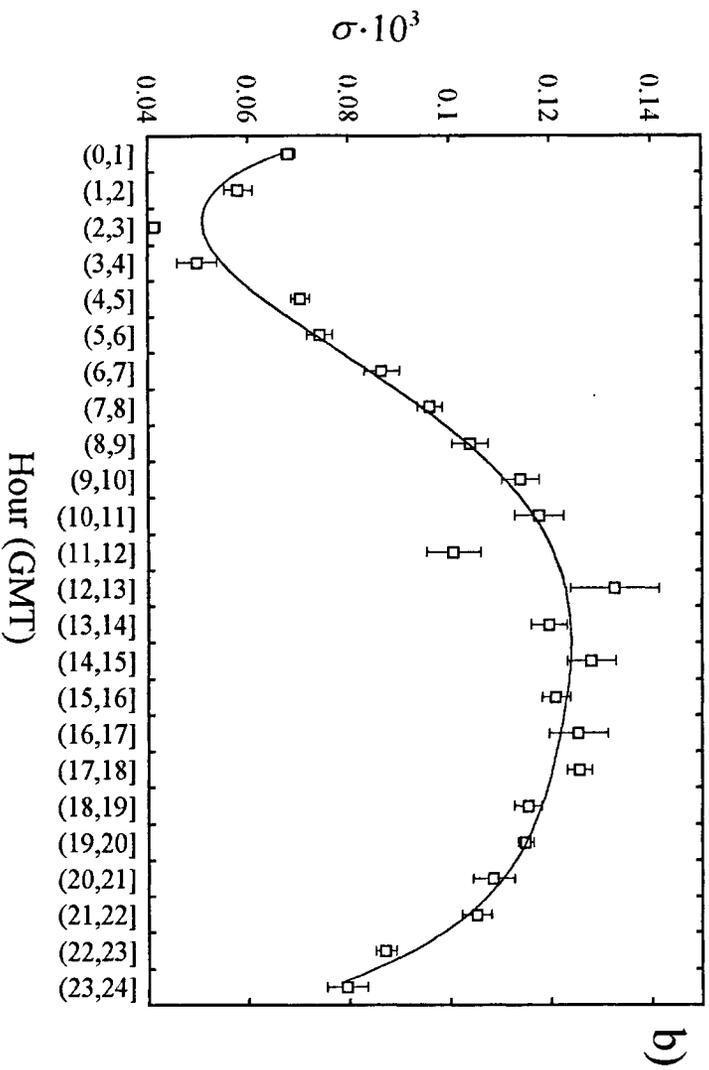
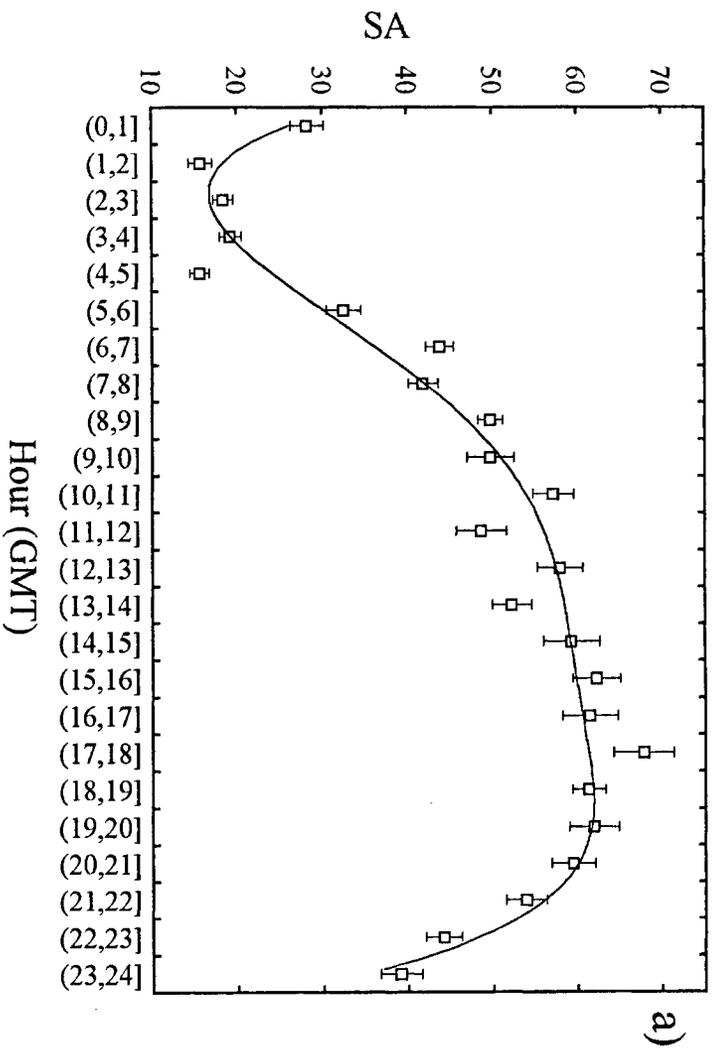


Fig. 4. Diurnal variations of a) the mean area back scattering coefficient (SA) and b) scattering cross section ( $\sigma$ ) of oceanic redfish averaged over 1 hour time intervals in Area II. Standard error is indicated.

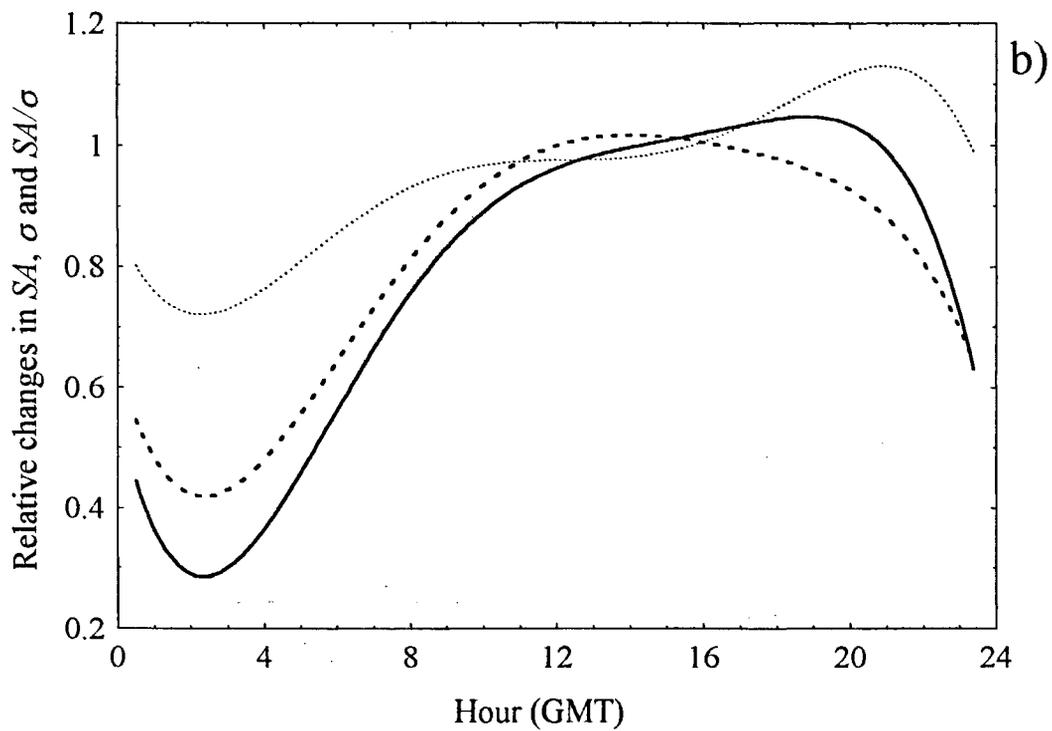
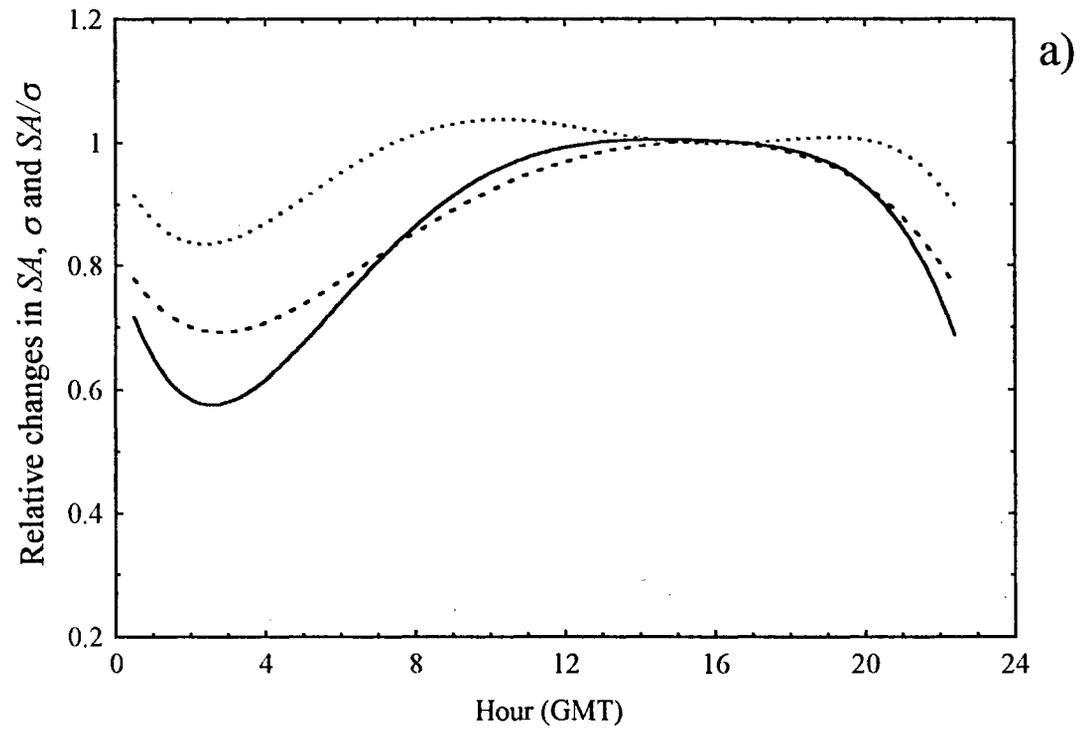


Fig. 5. Relative changes in the mean area back scattering coefficient ( $SA$ , —), mean scattering cross section ( $\sigma$ , - - -) and the number of fish ( $SA/\sigma$ , ..... ) of oceanic redfish in a) Area I and b) Area II.

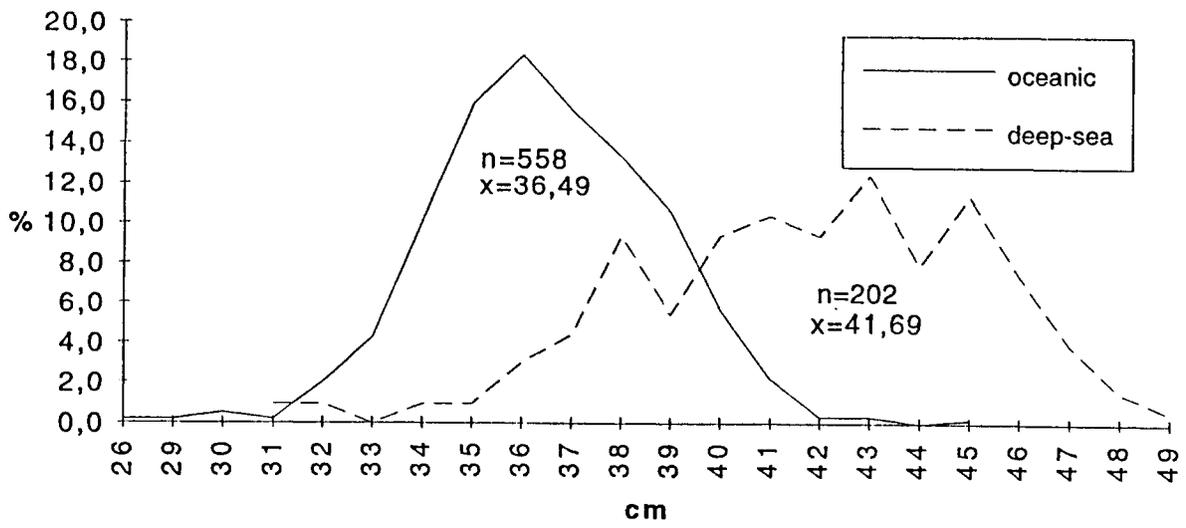


Fig. 6. Length distribution of redfish.