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Target Strength Measurement of Myctophid (*Benthosema pterotum*) in the Oman Sea

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Abstract

Through a series of research cruises conducted by the R/V Ferdows-1 to assess Myctophid resources, using a SIMRAD EK500 scientific echosounder carried out the Target Strength measurement of *Benthosema pterotum* in the Oman Sea. The principal method was based on a direct in-situ split-beam measurement technique, which is implemented in the EK500 system. For real-time observations ,the target strengths corresponding to resolved single-fish echoes were collected in a histogram. Associated statistics included the number of observations and the depth range. The processing of the TS-telegram data took place in the Procomm software (version 1.16), which converted into a tabular form and based on one-coefficient regression analysis to express the TS. The second method that also yielded information on target strength of myctophid through estimation of the mean, effective backscattering cross-section of the target fish related to the method of integrating the fish layer in the front of the trawl mouth during towing and related it to the total catch observed. The final results showed the approximate equation: TS=20logL-71.7 (dB), where L is the total length of the fish in cm. The collected data can be applied to improve later biomass-backscattering cross section analysis.

Keywords: *In-situ split-beam, Backscattering cross-section, Target strength, Myctophid*

1. Introduction

Lantern fishes are found in all oceans from the Arctic to the Antarctic but, they have the highest density in tropical and subtropical seas, both oceanic and neritic species. The mesopelagic resources of the world oceans and seas consist of many different families but among them the Myctophidae (lantern fishes) and Gonostomatidae are more important in the Oman Sea (Johannesson and Valinassab, 1994). Lantern fishes of the family Myctophidae are more in the energetic of oceanic ecosystems. They are exteremely abundant in virtually all of the world oceans (Clarke, 1973; Backus et al., 1977; Hulley, 1981). 27 Genera with a total of 115 species known of likely to be found in our area that among the different species of this family, the species of *Benthosema pterotum* (Fig. 1) is the dominant one (Valinassab et al., 2007).

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Fig. 1: Lateral view of *Benthosema pterotum*

Mesopelagic species exhibit diurnal migration between the surface and water depths to about 400 m respectively, during night and day-time. Their habit of migrating between the mesopealgic and epipelagic depths (Marshall, 1971) over each dial cycle represents a huge movement of energy through the water column (Gartner et al., 1987; Backus et al., 1977).

The Mesopelagics are important predators on many groups of zooplankton (Hopkins and and Baird, 1985; Gartner et al., 1987; Hopkins and Baird, 1977; Hopkins and Baird, 1985; Gartner, 1992) and in turn, serve as pray for a wide variety of predators, including mesopelagic piscivore, cetaceans and seabirds (Borodulina, 1972; Fitch and Brownell, 1968; Robinson, and Craddock, 1983; Ainley et al., 1986).

Data based on acoustic methods have become reliable methods for estimating fisheries resources (e.g. fish density) (Furusawa and Amakasu, 2010.). Split-beam echosounders can be used to study the behavior of individuals and the volume backscattering is the accumulated TS (Target Strength; dB) of organisms in a given time and depth interval (Kaartvedt et al., 2008; Godø et al., 2009). Visual analyses of such echograms were used in studies of the vertical distribution and behavior of mesopelagic fish (Gjøsaeter, 1983; Godø et al., 2009; Staby et al., 2011). For instance, the density estimation of *Diaphus theta* based on TS model was carried out (Yasuma et al., 2008).

Studies of the mesopelagic fish fauna in the Arabian Sea back to 1975, including: (1) the Fishery Survey and Development Project (Gjøsæter and Kawaguchi, 1980), (2) Cruises with R/V "Dr. Fridtjof Nansen" conducted during the period 1975-1983,(3) Survey of Mesopelagic Fish Resources in the Oman Sea (Gjøsæter and Tilseth, 1983), and (4) Experiment fishing on the mesopelagic resources in the Iranian waters by Korean vessel (Jeng Bang Son) in 1981. Hence, as a part of Iranian fisheries development policy, it was decided to undertake a stock assessment of mesopelagic resources in the Oman Sea.

Whereas, *B. pterotum* plays an important ecological role in oceanic food webs and chains in the Oman Sea, understanding, reliable biomass estimates of this species is needed. This study is to propose a reliable length vs. average TS relationship of *B. pterotum* by the trawl sampling. Also, through the *in situ* TS calculations, indirect methods were explored.

2. Material and Methods

The R/V Ferdows-1 is a 673 GRT stern trawler equipped with following equipment for acoustic surveying:

-Simrad EK500 scientific sounder system, dual frequency 38-120 kHz.

-Simrad BI500 scientific post processingsystem.

-A personal computer with lobe programme used for TS-measurement including sunspark workstation.

The area studied by the survey for TS-measurement was in different parts of the Iranian waters of the Oman Sea spreading from 57°00′E to 61°25′E (Fig. 2).

Fig. 2: Map of study area in the Oman Sea

2.1. *In- Situ* Target Strength Measurements

The principal method was based on a direct split-beam measurement technique which is implemented in the EK500 system and described by Sawada et al. (2011) and Foote (1991). For real-time observations the Target strengths (TS) corresponding to resolved single fish echoes are collected in a histogram that is displayed in a special TS window of the system's screen. Associated statistics include the number of observations and the depth range.

For more exact study of TS distributions and their means, the system also offers ping-based output telegrams from serial communications ports. This facility was used for collection of all TS data (in-situ) analyzed in this paper. Hence, personal computer was connected to one of the serial interfaces. Measurements of *in situ* target strength on fish were made with a 70 kHz split-beam transducer that was installed in a pressure housing (Sawada et al., 2011).

For extraction of single fish echo data from the successive transmission (pings) over the whole water column of interest, according to predetermined criteria. These data comprise the depth and angular positions of the detected targets and the TS levels before and after beam compensation (MacLennan and Simmonds, 1991).

The relevant instrument and their controls are given in Table 1.

Table 1. The relevant instrument and their controls follow

Instrument	Controls
Echo sounder / Integrator	EK500
Working frequency	38 kHz
Transducer	ES38/29
Absorption coefficient	10 dB/km
Transmitter power	2000 watt
Pulse duration	0.6 ms short
Bandwidth	3.8kHz(wide)
Equivalent beam angle	- 20.7 dB
TS threshold	-70.0 dB
Max echo length	1.4 *pulse width
Max gain compensation	6.0 dB
Angle sensitivity	21.9
Min echo length	0.7 pulse width

The immediate processing of the TS-telegram data took place in the PC's PROCOMN (ver.1.16) software which converted it into a tabular form (text file). These file were then promoted out, carefully examined and compared with the corresponding echograms and trawl samples before decision was made as to what depth ranges should be specified for further analysis of the data. That general type of analysis (descriptive statistics, regression analysis and graphics etc.) was performed in STATISTICA software package (MacLennan and Simmonds, 1991).

In this paper, it was found most suitable to follow Foote et al. (1987) and, based on one coefficient regression analysis, to express the TS on the form.

$$TS= 20 \log L+b \text{ (dB)} \tag{1}$$

In Equation (1) L is the fish length in cm and b is a constant . This also follows a later practice by Love (1977). Hence, the abundance estimates are based on the above equation expressing TS as function of fish length.

2.2. Indirect TS Measurement

The second method that also yielded information on target strength through estimation of the mean, effective backscattering cross-section of the target fish, related to the method of integrating (and thus determine absolute fish density) the fish layer in the front of the trawl mouth during towing and relate it to the total catch obtained. While this method is mathematically simple, it depends critically on the underlying assumptions. The relevant equations are given below (Equations 2-4).

Equation (2) can be expressed by

$$Vs= 1852 \times d \times A \tag{2}$$

In Equation (2) Vs= volume swept by the trawl, d= distance towed and A= mean effective area of the trawl mouth (opening).

$$\text{Volume density of fish } \rho = N/Vs \tag{3}$$

Where, ρ= mean density of fish within the swept volume, N= total number of fish caught in the trawl during a tow in Equation (3).

Equation (4) was calculated total number of fish.

Where, C= total catch in kg and W= mean weight of the fish in g.

$$N=C/W \quad (4)$$

Hence, by weighting or estimating the total catch; determining the mean weight of the fish by sampling the catch reading the trawled distance from GPS and by considering the net opening; it is possible to estimate the mean fish density. At the same time, the EK500 sounder can measure the apparent density in the swept volume.

3. Results and Discussion

Among different principal approaches (i.e. theoretical, *ex situ*, and *in situ*) to fish target strength estimation, the measurement of fish TS *in situ* is the most reliable and recommended approach (Ehrenberg, 1983; Stepnowski and Moszynski, 2000).TS *in situ* method requires removing the effect of unknown random location of a fish in the acoustic beam, which can be achieved either directly or indirectly, from each individual echo (Ehrenberg, 1983). Direct methods are generally less attractive because they are more complex and more costly than indirect techniques. In addition, direct methods require a special configuration of the transducer providing multiple beam (dual-, split-, or quasi-ideal-beam) and multi channel echo sounder receiver. Application of indirect methods through the use of the same single-beam echo sounder as used for routine echo integration surveys, but they require knowledge of the transducer's beam pattern and assume uniform distribution of fish in sampled volume of water that might be often not the case (Ehrenberg, 1983; Stepnowski and Mitchell,1990; Stepnowski and Moszynski, 2000).

Considering the upward and downward migration of myctophids, the day/night variability in acoustic backscattering data has been a source of much attention on the part of Norwegian scientists that pioneered research on mesopelagic fish in the Oman Sea, e.g. Gjøsæter and Tilseth (1983). The most comprehensive discussion on the subject is probably given in Saetersdal (1984) which included a particular discussion of the possibility that a resonance phenomena might have taken place in the swimbladder of the *B. pterotum* and thus, inflated the characteristic mean back-scattering cross-section of the species.

A valid reminder in this respect is the graphical results presented in Fig. 3, related to simple experiments on downward migration as part of the dial movement of the lanternfishes. These results suggested that the apparent target strength of the fish might be in a state of continuous changes about a certain mean value of the TS that was used in the present work to convert acoustic measurement into absolute biomass in tons.

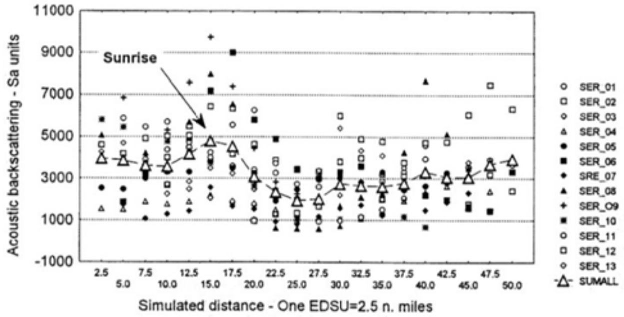

Fig. 3: Variations in acoustic data during day to night myctophid migration in the Oman Sea (based on 13 separate experiments)

One may further note from these results that they render additional relevance to an important statement made in MacLennan and Simmonds (1991), namely, that: "The TS is highly variable. Even for the same fish, the target strength is unlikely to be constant, owing to changes in the orientation of the body, the physiological state of the swimbladder and possibly other factors, too. It is best to think of target strength as a quantity having a distribution of values and a mean value which is the average of a large numbers of measurements, while individual measurements will be widely scattered about this mean".

According to the echograph (Fig. 3), the average daytime backscattering strengths of *B. pterotum* was higher than the nocturnal values, similar to other observations reported for layers of mesopelagic fish in the Red Sea (Klevjer et al., 2012) and northwest Indian Ocean (Luo et al., 2000; Ashjian et al., 2002).

Hence, it is important that in future research, attempts be made to improve the reliability of the measurements on the smaller class fishes to enhance the accuracy of the TS vs. length regression. The approximate equation: TS= 20 log L- 71.7 (dB). where L is the total length of the fish in cm. A comparison with other results indicated a rather striking similarity with those presented in Foote (1991), where a least-squares regression of target strength on log L for common clupeoid species (physostomes) gave the relationship: TS =20logL–71.9 (dB) for 38 kHz frequency as used in the present survey. This equation is presented as the best average estimate of the different methods, whether experimented or theoretical in origin and including the results of both caged-fish and *in-situ* experiments.

Again, the results of the TS measurements obtained during the present survey were very close to the target strength relationship assumed for the *B. pterotum* for estimation of mesopelagic fish densities during the “Dr. Fridtj of Nansen” surveys in 1981 and 1983 (Schaerfe, 1983; Gjøsæter and Tilseth, 1983) i.e. TS=20logL–72.0 (dB), which made the results directly comparable at the practical level.

Similar to this study, Sawada et al. (2011) showed the relationship between standard length (SL; cm) and average TS of lanternfish (Diaphus theta) as TS= 20logSL–70.6 at 38 kHz frequency in the subarctic North Pacific Ocean. Although, Yasuma et al. (2008) have also shown SL vs. TS for *D. theta* in the northwestern Pacific as TS = 18.5log SL-71.7 at 38 kHz with approximately 5dB higher than -71.7 dB of this study.

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