ICES Journal of Marine Science, 58: 342–345. 2001
doi:10.1006/jmsc.2000.1015, available online at http://www.idealibrary.com on IDEAL®

Short communication

In situ acoustic target strength of juvenile capelin

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O'Driscoll, R. L. and Rose, G. A. 2001. *In situ* acoustic target strength of juvenile capelin. – ICES Journal of Marine Science, 58: 342–345.

A dispersed, monospecific aggregation of juvenile (0+) capelin was detected acoustically in shallow (20–70 m) water in Bonavista Bay, northeastern Newfoundland in January 2000. This provided a rare opportunity to measure acoustic target strength (TS) of very small (mean length=51 mm) capelin *in situ*. Mean observed TS at 38 kHz was −61.0 dB. Observed TS was similar to TS predicted by the Norwegian-Icelandic capelin TS-length relationship (TS=19.1 log L (cm)−74), but ∼2 dB lower than predicted by the existing TS-length relationship for capelin in Newfoundland waters at 38 and 49 kHz (TS=20 log L (cm)−73.1). Combining present data with previous 38 kHz data indicates the relationship TS=23.3 log L (cm)−77.1 (r^2=0.95, n=6) for capelin of lengths 5–14 cm in Newfoundland waters.

Key words: capelin, *Mallotus villosus*, target strength.

Received 30 May 2000; accepted 6 November 2000.

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Introduction

Capelin (*Mallotus villosus* Müller) are small pelagic fish that are an important forage and commercial species in northern waters. Abundance of capelin is routinely assessed using acoustic echo integration methods (e.g. Vilhjálmsson, 1994; Toresen *et al.*, 1998). Despite the importance of acoustic target strength (TS) in scaling echo integrator intensity to fish density, relatively few measurements have been made of capelin TS. Target strength models currently used in Norwegian and Icelandic capelin acoustic surveys (Dommasnes and Røttingen, 1985) and Canadian surveys (Rose, 1998) are based on *in situ* and/or *ex situ* experiments conducted with a limited length range of fish. Rose (1998) measured *in situ* TS of capelin from 9.5–15.2 cm in Newfoundland waters. The TS model of Dommasnes and Røttingen (1985) incorporates *ex situ* measurements made by Dalen *et al.* (1976) on capelin from 13–18 cm as well as *in situ* measurements (by echo trace counting) on capelin of unspecified lengths. It is not known how well existing models describe capelin TS outside these length ranges. In this paper we present *in situ* measurements of acoustic target strength of very small (∼5 cm) juvenile capelin. We compare observed TS to predicted values from existing TS-length/weight relationships.

Materials and methods

We encountered a large, monospecific aggregation of juvenile capelin in Sweet Bay in the southern part of Bonavista Bay, northeast Newfoundland (48°26.4′N 53°42.4′W) on 13 January 2000. The aggregation consisted of a thick layer of capelin dispersed throughout the water column (20–70 m water depth).

Target strength measurements were made using a Simrad EK500 echosounder with a hull-mounted split-beam 38 kHz transducer. Pulse length was 1.0 ms. The echosounder was calibrated using a standard tungsten carbide sphere prior to (June 1999) and following (April 2000) this experiment according to recommended procedures (Foote *et al.*, 1987). There were no major changes in calibration between these times (<0.2 dB). Measurements of capelin TS were made during darkness (1900–2030 local time) at a vessel speed of 3–5 knots over

1054–3139/01/010342+04 $35.00/0

~8 km of acoustic transects in Sweet Bay. Data collection was limited to targets with normalised echo lengths from 0.8–1.8, gain compensation <4.0 dB, standard phase deviation <2.0 steps, and with corrected TS values > −70 dB (SIMRAD, 1997).

Following measurements of TS, species composition and size of capelin were obtained by fishing with a Campelen 1800 shrimp trawl fitted with a fine mesh codend liner towed in mid-water (~25 m depth) through the aggregation. The catch was 100% juvenile capelin. A random sub-sample of 200 fish was measured (total length from tip of the mandible to the end of the ventral lobe of the tail) and weighed.

The number of fish per effective reverberation volume (N_v) was calculated from estimates of volumetric fish density (capelin m^{-3}) and ensonified volume (m^3) according to Sawada *et al.* (1993). The beam width of the transducer was 7° between half power points with an equivalent beam angle, $\varphi = 0.0085$ sr. Approximate mean volumetric fish densities were calculated for bins 5 m deep by 30 pings (50–80 m) long using a backscattering cross-sectional area equivalent to −61 dB. Only TS values from bins with $N_v < 0.4$ were used in this paper (see below). Mean TS was calculated as the logarithm of arithmetically averaged backscattering cross-section values.

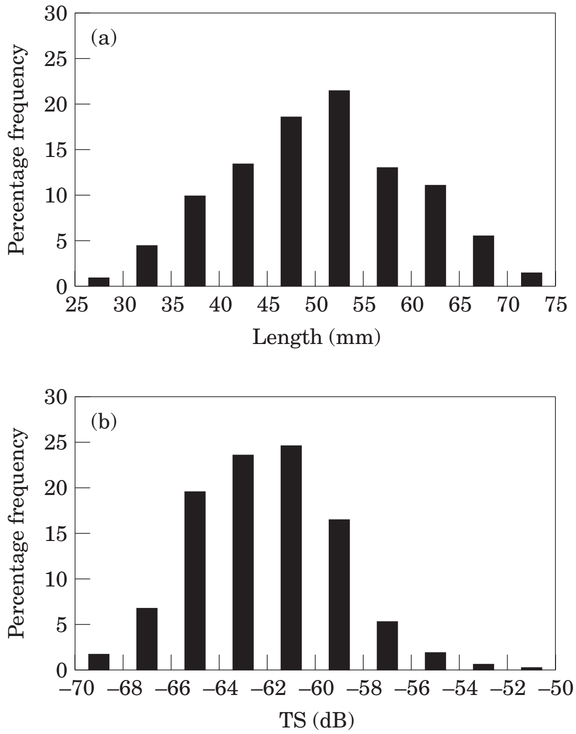

Figure 1. Histograms of (a) length frequency of capelin caught in the Campelen trawl (n=200, mean=51 mm); and (b) TS frequency at 38 kHz (n=1416, mean= −61.0 dB).

Results and discussion

Both fish length and TS histograms were unimodal (Figure 1). Mean capelin length was 51 mm. Mean weight of individual capelin was 0.30 g. Juvenile capelin were not aged, but observed lengths were consistent with fish spawned the previous summer (0+). Peak larval emergence on Bellevue Beach in adjacent Trinity Bay was on 22 July 1999 (Nakashima and Slaney, 2000), suggesting these capelin were probably ~175 days old. We are not aware of any previous TS experiments with capelin of this small size.

Our threshold density for N_v was ten times higher than that recommended by Sawada *et al.* (1993). Very few juvenile capelin could be reliably identified at densities lower than the recommended threshold of 0.04 fish per ensonified volume (Sawada *et al.*, 1993). A plot of average TS values as function of N_v (Figure 2) suggested a threshold of 0.4 fish per ensonified volume. At higher fish densities average TS increased rapidly (Figure 2) presumably as a consequence of the inclusion of multiple echoes. Average TS when $N_v < 0.04$ (−62.4 dB, n=159) was significantly lower (t-test, $p < 0.001$) than average TS when $0.04 < N_v < 0.4$ (−60.9 dB, n=1257). However, because sample sizes at low densities were small and standard errors were large (Figure 2), we are uncertain whether this apparent bias is real. Lower TS at $N_v < 0.04$ could also be explained biologically (e.g. smaller fish at lower densities around the edge of a school) and does not necessarily represent a bias in our single target detection at $0.04 < N_v < 0.4$.

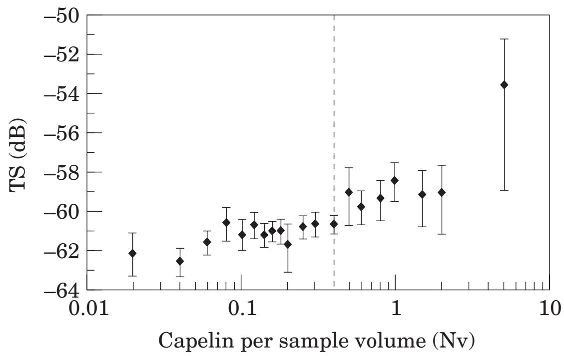

Figure 2. Relationship between mean TS (±2 s.e.) and capelin density per ensonified volume. Broken line indicates threshold density $N_v = 0.4$. Only TS values from densities lower than this threshold are shown in Figure 1(b).

Mean target strength when $N_v < 0.4$ was −61.0 dB (Figure 1). There was good agreement between observed TS and predicted TS from the capelin TS-length relationships of Anon (1985) and Dommasnes and Røttingen (1985) (Table 1). These two related TS models are currently used in Norwegian and Icelandic capelin

Table 1. Predicted values of mean TS for capelin with observed length frequency distribution [Figure 1(a)] from published capelin TS-length/weight relationships. L is fish length (cm) and W is fish weight (kg). Observed *in situ* mean TS was − 61.0 dB.

TS Model	Source	Predicted TS (dB)
20 log L − 73.1[1]	Rose (1998) – standard form	− 58.8
21.1 log L − 74.3	Rose (1998) – best fit regression	− 59.2
68.6 log L − 15.2 log W − 157.3	Rose (1998)	− 55.2
19.1 log L − 74.0[2]	Dommasnes and Røttingen (1985)	− 60.4
19.1 log L − 74.5[3]	Anon (1985)	− 60.9
− 34 dB kg^{-1}	Miller (1991)	− 69.2
20 log L − 71.9	Foote (1987) – general clupeoids	− 57.6
23.3 log L − 77.1	Present data combined with Rose (1998) (Figure 3)	− 60.4

[1]TS model currently used in Newfoundland capelin surveys (O'Driscoll *et al.*, 2000).
[2]TS model currently used in Barents Sea capelin surveys (Toresen *et al.*, 1998).
[3]TS model currently used in Icelandic capelin surveys (Vilhjálmsson, 1994).

surveys (Vilhjálmsson, 1994; Toresen *et al.*, 1998). Observed TS of juvenile capelin was approximately 2 dB weaker than would be predicted by the TS-length relationships of Rose (1988) determined from *in situ* measurements on larger capelin in Newfoundland waters (Table 1). The general TS-length relationship for clupeoid fishes proposed by Foote (1987) overestimated TS of juvenile capelin by 3.4 dB. Likely because of size-related differences in body shape (post-larval capelin are more elongate than older fish, Templeman, 1948), TS relationships based on fish weight (Miller, 1991) or incorporating a weight term (Rose, 1998) did not predict TS of juvenile capelin well (Table 1).

In situ TS data in this study and in Rose (1998) were collected in Newfoundland waters using similar methods. We added our new data point to 38 kHz measurements made by Rose (Table 1 in Rose, 1998) and fitted TS-length regression models to the combined data set (Figure 3). The best fit regression was TS=23.3 log L (cm) − 77.1 (r^2=0.95, n=6). This new TS-length relationship gives TS values similar to the Norwegian-Icelandic model (Dommasnes and Røttingen, 1985) at small capelin lengths (Table 1).

Our experiences in Newfoundland waters indicate small juvenile capelin are an important contributor to total acoustic backscattering in some locations at some times of the year. Elsewhere, acoustic biomass is estimated for capelin as young as 1-group (Toresen *et al.*, 1998). The validity of applying TS-length relationships established for larger capelin to these small (<10 cm) individuals has been questioned (Gundersen and Gjøsæter, 1998). The high r^2 of our new combined model (Figure 3) suggests that single logarithmic length-TS models can be used for capelin of lengths from 5–15 cm. However the slope of the regression may not conform closely to the standard (20 log L (cm) − b, where b is a constant) quadratic dependence of TS on fish length (McClatchie *et al.*, 1996). The lack of quadratic dependence may be due to size-related changes in capelin morphology. Further measurements of *in situ* target strength of capelin are still required, particularly in the 5–10 cm length range.

Acknowledgements

We thank all the sea-going scientific staff and crew of the "CGSS Teleost", and Stéphane Gauthier for his assistance with the analysis. This paper was improved by critical reviews by Gareth Lawson and an anonymous referee. Funding for this work came from the NSERC Industrial Chair in Fisheries Conservation and from a New Zealand Foundation for Research, Science and Technology Post-Doctoral Fellowship held by R.L.O'D.

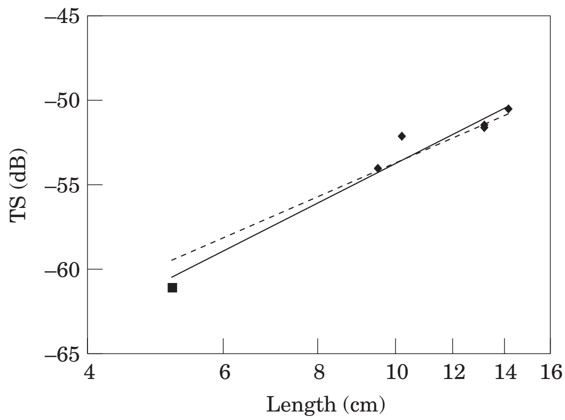

Figure 3. Relationship between fish length and mean target strength at 38 kHz for capelin from Newfoundland waters. Plot combines data from Rose (1998) (diamonds) and from this study (square). Solid line is the best-fit regression equation TS=23.3 log L (cm) − 77.1 (n=6, r^2=0.95). Broken line is the standard form regression TS=20 log L (cm) − 73.7 (95% CI: − 74.4 to − 72.9; r^2=0.71).

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