Notes

In situ determination of the target strength of roach (Rutilus rutilus) in lake Bourget with a single beam sounder

Jean Guillard and Daniel Gerdeaux

INRA, Station d'Hydrobiologie Lacustre, 75, avenue de Corzent, BP 511, 74203 Thonon, France.

Détermination in situ de la taille de cible du gardon (Rutilus rutilus) du lac du Bourget au moyen d'un sondeur mono faisceau.

INTRODUCTION

There is an increasing use of acoustic methods in freshwaters. Information on the size of the fish stock, combined with information from non-acoustic studies, improve previous stock estimates. Fish target strength (TS) is essential to express echo integrator measurements in terms of fish biomass (Foote, 1987), and to estimate the proportion of the different length classes in the fish population, *i.e.* the different cohorts, especially the yearling fish population.

The measurement of target strength is problematical and a majority of authors recommend working *in situ* with dual beam or split beam systems (Ehrenberg, 1983; Foote, 1991). Nevertheless, it is possible in some conditions to apply the algorithm of Craig and Forbes (1969) to estimate statistically the echo strength distribution using a single beam transducer and sounder (Lindem, 1983). A few studies have been done, especially in lakes, using this method (Eckmann, 1991; Jurvelius, 1991; Brabrand, 1991; Walline *et al.*, 1992). Good results for target strength measurements were obtained *in situ*, under certain conditions. Comparison of Craig and Forbes analysis of single beam data with another based on a z-transformation and deconvolution technique (Rudstam *et al.*, 1988) showed that each gave similar results as to size classes, and total fish densities.

The data in this paper demonstrate the reliability of the modified Craig and Forbes method for a fish population composed of a single species, the roach (*Rutilus rutilus* L.) consisting of three length classes, representing several cohorts.

METHODS

Echosounder and transducer

The system used was a single beam echosounder EY-M, which operates at 70 kHz. The signal was recorded on a Digital Audio Tape (DAT) recorder. All recordings were made using the 40 Log R time-varied gain (TVG) function, at gain 5. The duration of the transmitted full pulse was 0.6 ms, giving a vertical resolution of about 0.8 m. The transmitted beam angle was 11° measured at the -3 dB level.

Calibration

The system was calibrated by insonifying a copper sphere of TS -39.2 dB, attached by three wires at a distance of 7 m from the transducer and its acoustical axis. An electronic calibration was made at the beginning and the end of the survey, using an oscilloscope.

Acoustic analysis system

The recorded data were analyzed by the Hydro Acoustic Data Analysis System (HADAS) developed by T. Lindem (Walline *et al.*, 1992) with echo-counting techniques (40 Log R TVG). Targets from single echoes were analyzed using the modified algorithm of Craig and Forbes with negative values set to zero. The algorithm removes statistically the effect of the beam pattern from the echo distribution received (Rudstam *et al.*, 1988).

The program divides the fish target strengths observed into 10 size classes of 2 dB width. All single fish echoes greater than -38 dB were shifted down into the $(-38, -37)$ dB size group. According to the noise level, echoes less than -56 dB were turnated.

Sampling design

The sampling was done in Lake Bourget, France, in autumn. The surveys were performed at night when fish are dispersed and it is possible to record a maximum number of single fish targets (Guillard, 1991; Appenzeller and Legget, 1992).

Acoustic data were recorded during and after trawl hauls. Four trawl hauls were made, using a pelagic trawl (*fig.* 1) (Geiger *et al.*, 1985), towed at about 1.4 knots. A calibrated depth probe was used to measure net depth. After the trawl hauls, we made two runs in the same area with the boat at a constant speed of about two knots. For each run the number of single fish echoes was greater than 1 000, with the proportion of single fish greater than 80%. The echograms (*fig.* 2) show that the fish population distribution in this area was uniform and concentrated in a layer about 6 m high at a mean depth of about 15 m.
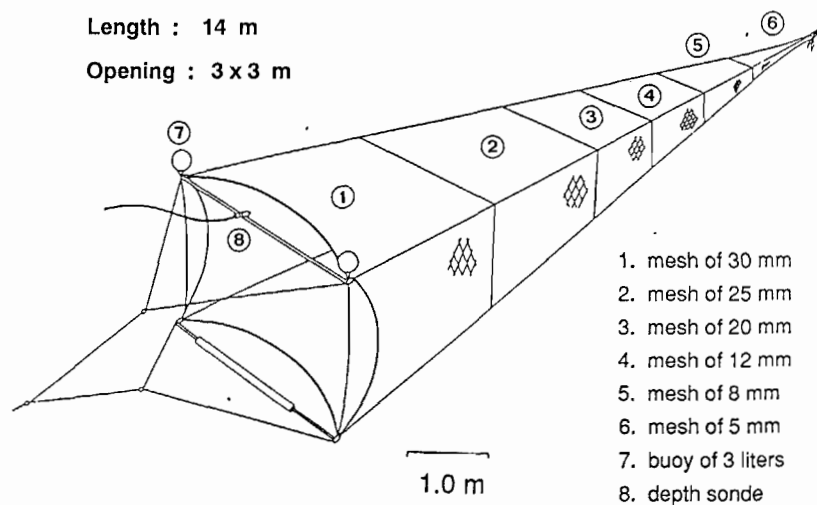
Table 1. – Mean length and estimated age of the caught fish for the four trawl hauls (110 fish).

Mean length (cm)	Standard deviation	Catches (%)	Age (year)
5.9	10.3	49	0+
13.9	20.7	35	1+
26.3	10.3	16	>1+

RESULTS

Trawl hauls

We considered that the four trawl hauls sampled the same population, and we pooled all the data; 110 fishes were caught (*fig.* 3). The population consisted only of roach (*Rutilus rutilus*). Three modes of the histogram corresponding with different year-classes (*table* 1), were determined by reading the fish scales.

Acoustic data analyzed by HADAS

The runs made during trawling were analyzed separately from those made after (*fig.* 4). To compare these results with the catch data we divided the echo-strength distribution into three size classes (*table* 2). The distribution of fish lengths in the catches and TS distribution from the modified algorithm of Craig and Forbes have the same shape (*table* 3), even if we cannot really differentiate the two larger size classes with the TS distributions.

DISCUSSION - CONCLUSION

Results compared with the formulas of Love (1977)

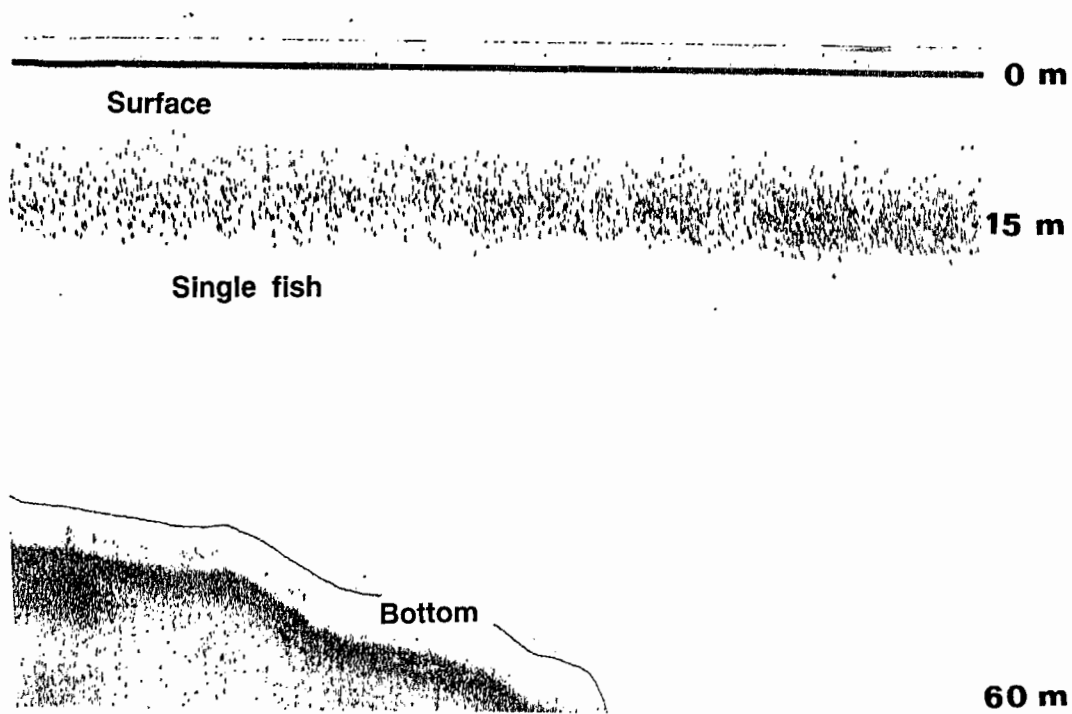The formulas of Love (1977) give the best available averaging of the relationship between fish target

Length : 14 m

Opening : 3 x 3 m

1. mesh of 30 mm
2. mesh of 25 mm
3. mesh of 20 mm
4. mesh of 12 mm
5. mesh of 8 mm
6. mesh of 5 mm
7. buoy of 3 liters
8. depth sonde

1.0 m

Figure 1. – Pelagic trawl.

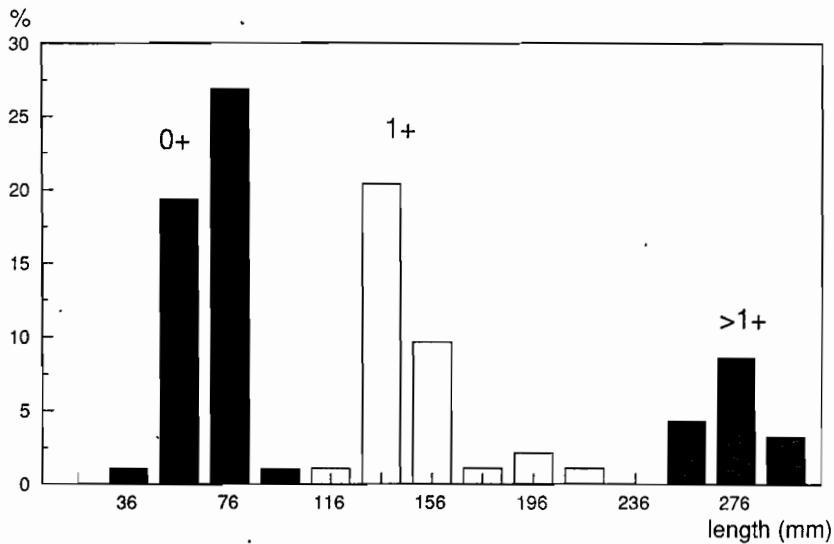**Figure 2.** – Sample chart recording (run 2), recorded in 40 Log R.

Figure 3. – Distribution of length fish from the four trawl hauls.

strength and size for various species (Burczynski and Johnson, 1986). The equations are for a dorsal aspect of the target strength (1) and for an averaging position of ±45° (2).

$$TS_D = 19.1 \log(l) - 0.9 \log(f) - 62.0 \quad (1)$$
$$TS_D = 19.1 \log(l) - 66.4$$

$$TS_{45} = 18.4 \log(l) - 1.6 \log(f) - 61.6 \quad (2)$$
$$TS_{45} = 18.4 \log(l) - 69.3$$

where TS_D is the target strength for the dorsal aspect in decibels, TS_{45} for the averaging position $\pm 45°$, l the length of the fish in centimetres, and f the frequency in kiloHertz.
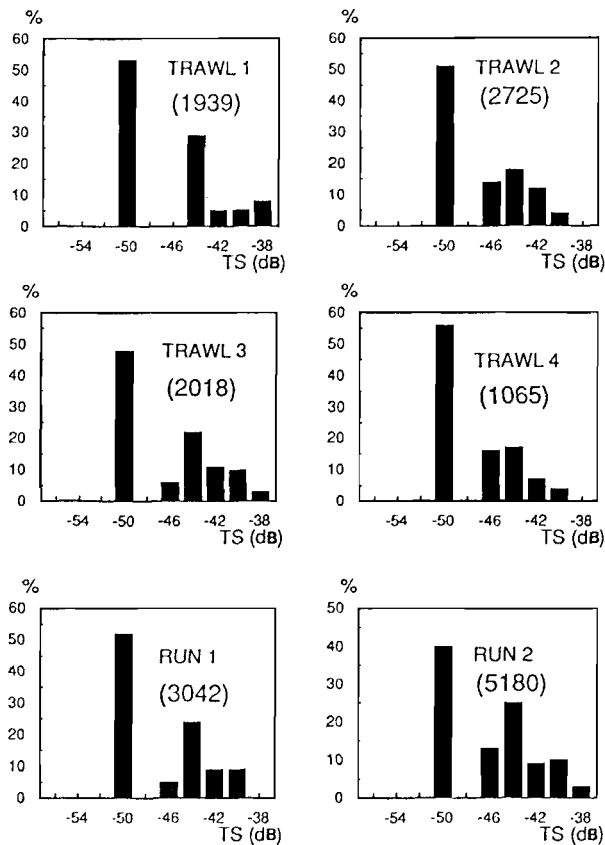
Figure 4. – Distribution of target strength estimated by HADAS (Hydro Acoustic Data Analysis System), expressed in units of target strength (log scale) for the four trawl hauls and the two runs, with indication of the number of single fish echoes in brackets.

Table 2. – Percentage of each target strength (TS) class from the acoustic data.

	TS ≤ –50 dB %	–48 < TS < –44 dB %	TS ≤ –42 dB %
Trawl 1	53	34	13
Trawl 2	51	32	16
Trawl 3	48	39	13
Trawl 4	56	33	11
Run 1	52	29	18
Run 2	40	38	22
Total	50	34	16

Table 3. – Percentage of each target strength (TS) class from the acoustic data compared with the percentage of the length (l) in cm of the caught fish.

	TS ≤ –50 dB 50 %	–48 < TS < –44 dB 34 %	TS ≤ –42 dB 16 %
Total	l ≤ 96 cm 48 %	96 < l < 216 cm 36 %	l ≤ 296 cm 16 %

The estimated target strength for the fish in the trawl samples was calculated with both equations (*table* 4). The resulting values are very close to the values estimated by HADAS.

Table 4. – Estimated target strength (TS) of fish sampled by trawl calculated by the equations of Love (1997), with a dorsal aspect (TS_D) and an averaging position for ± 45° (TS_{45}).

Average length (cm)	TS_D (dB)	TS_{45} (dB)
5.9	–48.9	–50.4
13.9	–41.8	–43.5
26.3	–36.5	–38.4

Assigning – 50 dB TS class to the 5.9 cm average length of the 0_+ year class and using the equation of Foote *et al.*, 1986.

$$TS = 20 \log (l) - b \qquad (3)$$

where b is a constant, results in the formula (4) which gives the relation between target strength in dB and fish length in cm for roach, at 70 kHz.

$$TS = 20 \log (l) - 64.4 \qquad (4)$$

This formula gives for the mean lengths of 13.9 and 26.3 cm a TS of – 42.4 and – 36.9 dB. These results are in close agreement with the calculations from Love's equations for the dorsal view.

The experiments made on roach in Lake Bourget show that the modified algorithm of Craig and Forbes used by HADAS gives a good estimation of the length distribution of the observed fish population in this situation. For Degnbol *et al.* (1985) the estimation of the target strength distribution through the Craig and Forbes algorithm is highly dependent on the correct sampling of the few very high energy peaks and the least-square fitting technique is more robust. However, in the present studies, results of acoustic data are in good agreement with the trawl catches. Because of the method the TS of the little fish are only in one peak, in the 50 dB class. In reality, the distribution of the TS must be more extended to several classes.

In this experiment conditions were very good ; the fish were located in a uniform scattering layer, only 6 m high, in deep water. The speed boat was slow, the pulse repetition rate of the sounder was high, and the number of the single fish echoes greater than 1 000. Furthermore, the pelagic fish population was composed only of roach, in three size classes of very different lengths. The results given in this paper concern only the roach population sampled in this lake at this particular time ; a change in the sampling period, the behaviour, the physiology, or the feeding diet, will modify the average target strength. Of course, the conditions in our study were exceptional. In many lakes the fish community is not composed of only one species, distributed in a narrow

layer. Furthermore, if the population consists mainly of small fish, which are very close to each other, a multiple target may be classified as a single large one. In this case the proportion of large fish can be overestimated.

The behaviour of fish in front of the trawl is dependent on fish length. Avoidance is not the same for all cohorts. Both large or small fish may be underestimated by net. We cannot exclude that the position of the fish was not exactly the same for each cohort, and that the TS aspect was identical. Differences between estimations by trawl data and

acoustic data can result from the biases of the methods, which were not quantified in this study.

Despite the biases the two methods (acoustic and trawls) give results which are compatible, confirming that, when conditions are very good, and the number of single echoes sufficient, it is possible with a single beam transducer to find the mean target strength of an observed fish population. Unfortunately, this is not the general case. This would be a great help to estimate the exact biomass of fish in lakes, the proportion of the different cohorts for a whole population, and then the strength of the yearling fish cohort.

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