TARGET STRENGTH OF SARGASSOM

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ABSTRACT

Communities of seaweeds are greatly important fields for coastal fisheries in Japan, since some kinds of fishes feed and grow around or in them.
A series of echo measurements at frequencies of 50 and 200kHz was made on target strength of 20 samples, 7 species of sargassoms in 1985. A bunch of target sargassom was made to have a diameter within the pulse length emitted from an echo-sounder.
The sargassoms give relatively strong echoes due to their gas-filled vesicles as compared with a kelp with no vesicles.
Whole vesicles of each sample are measured with a micrometer for their lengths of minor, ϕ_S and major axes, ϕ_L.
An equivalent radius, Re of the vesicle is:

$$Re = (\phi_S{}^2 \cdot \phi_L)^{1/3}/2 - t$$

where, t is a thickness of a vesicle shell.
Experimental formulae, t= a Re +b, for thickness, t, measured by species are given for estimating respective thickness of a given Re.
The calculated target strength, TS_C is:

$$TS_C = 10 \log (\sum_{i=1}^{n} Re_i / 4)$$

TS_C of the sargassoms agrees with observed TS. This fact may prove Urick's hypothesis on Sv.

INTRODUCTION

Sargassoms distributed commonly around Kyushu, Japan, are namely Sargassum patens, S. tortile, S. serratifolium, S. fulvellum, S. sandeifolium, S. micracanthus, S. crispifolium, etc. They grow up to 1-2m high from seabed from winter to early summer and drift on sea surface in summer.
The sargassoms are dominant seaweeds and are important to coastal fishing as feed to some coastal fish through their growing season. When these grasses are drifting, larvae of Seriola spp. of important sources for aqua-culture in Japan are frequently around the grasses [1].
Stock assessment of seaweeds have been made by means of an underwater and aerial cameras, visual observation from a boat [2] and acoustic method combined with visual observation by divers [3,4]. Hashimoto and Nishimura reported on reflection coefficients of tang fields, including sargassom [5].
Sargassom communities can be identified with an echo-sounder due to their vesicles which produce greater echoes than other seaweeds with no vesicle. The diameters of sargassom vesicles are often in a resonant range at low frequencies.
This report deals TS of the sargassoms observed and calculated which is applied to the stock assessments of sargassoms.

MATERIALS AND METHOD

A series of TS measurement on drifting sample of sargassoms at 50 and 200kHz on board the R/V Kakusui was made at smooth waters off Nagasaki from 1983-1985 with use of an echo-sounder set at about 160dB of SL for both frequencies.

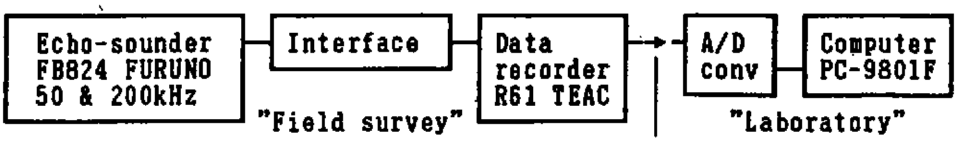

Fig. 1 System diagram

An observed target strength of the sargassom, TS_o, is determined by comparing it with a pingpong ball (TS=-40.5dB).
The calculated value, TS_c, is taken from the total sum of back-scattering cross sections of gas-filled vesicles.
A block diagram of the total system which is designed for a tank test, on this experiment is shown in the above.
The arrangements of a target grass and pingpong ball as a reference target are shown in Fig. 2.
In field experiments, a bunch of sargassom made to have a diameter ranging from 30-40cm is suspended in water over the side of the boat. It is held on the sound axis of the echo-sounder by a nylon monofilament line of 1mm diameter with a pingpong ball and a weight of 20kg at the bottom end of the line. The intervals of the above three obstacles are set at a distance longer than the pulse length of the echo-sounder.

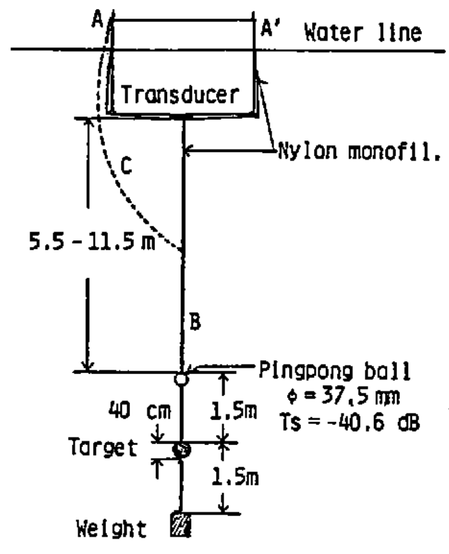

Fig. 2 Arrangement of targets

<u>Observed target strength, TS_o</u>
Echo signals, rectified as shown in Fig. 3 are recorded directly into a magnetic data recorder with trigger signals while waveforms of signals to the data recorder are checked on the screen of an oscilloscope to keep a reasonable level throughout a measurement.
A series of recordings lasts for about 2 minutes or for the duration of 200 pulses.
In a laboratory, output signals from the recorder are fed into a micro-computer (PC-9801F) via A/D converter. If both the targets of a sargassom and a pingpong ball of -40.5dB are placed just on the sound axis, the TS_o of a sargassom can be determined from the following equation.

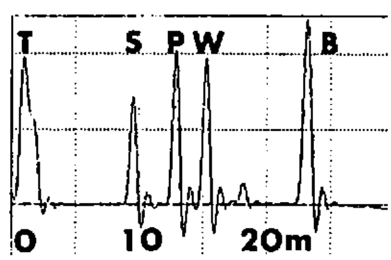

Fig. 3 Waveforms output from PC 9801F
T: trigger, S: sargassom, P: pingpong ball, W: weight, B: seabed

$$TS_o = EL_s - EL_P - 40.5 - 40 \log_{10}(r_s/r_P) - 2\alpha(r_P - r_s)$$

where, TS_o : TS of a bunch of sargassom
EL_s and EL_P : EL of sargassom and pingpong ball, respectively

r_s and r_P : range from sargassom and pingpong ball
α : 10dB/km at 50kHz and 63dB/km at 200 kHz in water of 18°C and 35 ‰ in salinity

Calculated target strength of sargassom, TS_C

Total weight of a sargassom target and of all vesicles extracted from the target sargassom are measured for each TS measurement.
The samples of sargassoms are refrigerated at +10°C and the extracted vesicles are placed in a vessel filled with sea water to keep their original conditions during dimensional measurements.
The length of major and minor axes of all vesicles are measured with a micrometer and thickness is measured at random for 50 vesicles from each sample.
An equivalent radius of a vesicle of the sargassom is expressed as:

$$Re' = (\phi_L \cdot \phi_S^2)^{1/3}/2$$

where, ϕ_L and ϕ_S are the length of major and minor axes of a vesicle respectively.
The thickness of a vesicle shell, t, determined for each vesicle by an experimental formula, t= a Re' + b, as shown in Table 1 for each species of sargassoms.
Applying the thickness,t, of the vesicle using the above formula, the equivalent radius is calculated as:

$$Re = Re' - t$$

Accordingly, TS_C of a bunch of sargassom is estimated as:

$$TS_C = 10 \log(\sum_{i=1}^{n} Re_i^2/4)$$

where, n is the pooled number of vesicles in a bunch of target sargassom.

Resonant frequency of a vesicle

Only the resonant frequency of the vesicles of minute sizes are considered.
According to Urick [6], "At a certain frequency, a bubble of a given size is in resonance with the exciting sound wave and a maximum extinction cross-section occurs." The corresponding expression of the frequency is:

$$f_r = 326(1 + 0.03\, d)^{1/2}/a$$

where, a is radius of air-bubble in cm and d, depth of water in ft.
And Ts of the bubble at resonance, TS_r is:

$$TS_r = 10 \log_{10}[a^2/\{(f_r^2/f^2-1)^2 + \delta^2\}]$$

where, f is frequency of signal and δ is total damping constant.
On TS_C-calculation, TS_r was also considered as an air-filled vesicle of Re.

RESULTS AND CONSIDERATIONS

Echo survey of Sargassom beds at 7.5kHz

A dense seaweed community was detected with an echosounder of 7.5kHz in coastal waters off Azuti Ohshima of Nagasaki Prefecture in June 27, 1983.
On an echogram of Fig. 4, recorded during the experiment, depth markers are from 5-11m at 1m step.
A strong echo layer represents a rocky seabed and a white layer along the seabed of 8-10m deep represents communities of sargassom.
The level difference of the grass and rocky seabed is estimated as 10-12.4dB from color density.

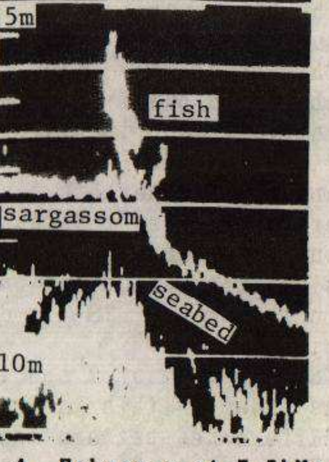

Fig. 4 Echogram at 7.5kHz of sargassom beds

According to visual observation by skin divers, the grass community consists of sargassoms, S. tortile and S. serratifolium, of 1-2m in height above the seabed and a few kelps, Eisenia bicyclis. Growing density is about 5-10 sargassoms per $1m^2$.

Vesicle of sargassom
The vesicle thickness for Re varies greatly with the species of sargassoms as shown in Table 1. These formulae on "t" are applied with Re' for all vesicles by species.

Table 1 Experimental formulae of Re' and thickness of a vesicle, "t"

Species (50 vesicles)	Mean (mm) Re'	t	t= a Re'+ b a	b
S. micracanthus	2.02	0.30	0.1755	-0.0522
S. sandeifolium	2.28	0.37	0.1507	+0.0248
S. serratifolium	3.10	0.48	0.1723	-0.0581
S. serratifolium	3.25	0.23	0.0463	+0.0791
S. fulvellum	1.87	0.27	0.0864	+0.1060
S. patens	2.58	0.50	0.2260	-0.0846
S. patens	2.37	0.37	0.1867	-0.0711
S. crispifolium	2.90	0.42	0.1752	-0.0905
S. crispifolium	3.03	0.51	0.1853	-0.0467
S. tortile	2.18	0.26	0.1258	-0.0135

TS_o of sargassom
Fig. 5 is a histogram for TS_o of S.fulvellum and a pingpong ball output from the microcomputer. As shown in this histogram, TS_o of these samples hardly fluctuate, because this series of measurements was made in good sea conditions. TS_o is however determined at the mode of the histogram on this case.

When two pingpong balls, placed at the depth of the target sargassom are observed, TS_o of the substituted ball is within a range from -45 to -39dB and -40 dB at the mode as shown in Fig. 5. The variations of +1dB may be caused by mislocation of the reference target at the measurement.

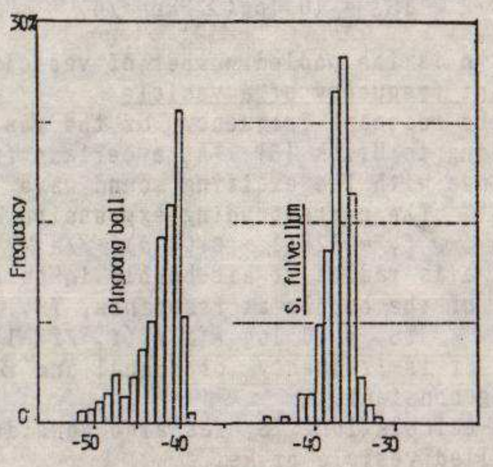

Fig. 5 TS_o histograms of a sargassom and reference target of -40.5dB

This fact may show : i) the above two balls are located relatively on the same angular direction from the sound source and ii) rather big fluctuations of TS_o of target sargassom may occur due to movements of the target grass resulting from slight sea currents. TS_o may often be taken as a smaller value, since these fluctuations increase with a current speed during the measurements. In this case, TS_o is determined by its distribution pattern on the output TS_o histogram.

TS_o and TS_c of 7 species of sargassoms are given in Table 2.
As shown in this table, TS_o and TS_c of sargassoms agree well with each other and differences between them are very small at -3dB to 4dB. This fact shows that a TS measuring method which instantly compares ELs of a target and reference

target fixed onto a same line, are applicable, if no wind and no current exsist. The resonant frequency of the sargassom vesicle does not occur at frequencies of 50-200kHz.

Table 2 Summary of observed and calculated target strengths of seven kinds of sargassoms

Scientific name	Vesicle n	Vesicle weight	Total weight	TS_o in dB 50kHz	TS_o in dB 200kHz	TS_c in dB 50kHz	TS_c in dB 200kHz	TS_c in dB 7.5kHz
S.micracanthus	624	32.1g	171g	-33	-27	-29.2	-29.2	-26.8
S.micracanthus	162	5.7	24	-34	-35	-33.2	-33.2	-31.2
S.micracanthus	72	4.8	18	-36	-34	-36.3	-36.4	-33.8
S.micracanthus	115	4.0	24	-35	-35	-34.6	-34.6	-30.1
S.crispifolium	30	1.9	17	-35	-34	-37.6	-37.6	-36.8
S.crispifolium	154	16.0	42	-32	-31	-32.3	-32.3	-28.2
S.crispifolium	232	13.8	61	-33	-34	-30.3	-30.4	-27.5
S.sandeifolium	195	19.3	91	-35	-32	-32.1	-32.1	-30.8
S.patens	199	12.0	52	-34	-33	-31.7	-31.7	-30.5
S.patens	200	14.3	54	-34	-32	-32.6	-32.7	-31.1
S.patens	196	20.3	63	-33	-33	-31.8	-31.9	-30.6
S.patens	294	12.2	51	-33	-31	-31.0	-31.1	-27.6
S.patens	124	6.8	17	-31	-31	-33.9	-33.9	-30.5
S.serratifolium	252	23.4	132	-31	-31	-30.2	-30.2	-28.4
S.serratifolium	141	12.0	70	-29	-28	-29.3	-29.4	--
S.fulvellum	1350	23.6	54	-28	-29	-25.0	-25.1	-22.9
S.fulvellum	1250	17.4	57	-26	-22	-24.4	-24.5	-22.8
S.fulvellum	795	7.3	32	-29	-27	-28.2	-28.2	-24.5
S.fulvellum	965	9.7	35	-26	-25	-26.9	-26.9	-24.3
S.tortile	459	17.0	46	-30	-29	-28.5	-28.6	-25.4

TS_o of seaweeds with no vesicle

TS_o of a sample of S. tortile with all vesicles extracted and of a kelp, Eisenia bicyclis, without the base of the plant upto about 30cm high, are shown in Table 3.
As shown in this table, TS_o of the seaweeds with no vesicles are very small compared with sargassoms in Table 1. For example, TS_o of S. tortile extracted vesicles degreeses by 20dB and TS_o of a kelp is much smaller than that of sargassom.

Table 3 Observed target strength of grasses with no vesicles

Specimen of no vesicles	TS_o in dB 50kHz	TS_o in dB 200kHz
S.tortile (Table 2)	-30	-29
- do - (extracted)	-53	-48
Eisenia bicyclis-1	-48	-49
E.bicyclis-2	-53	-54
E.bicyclis-3	-55	-55

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CONCLUSIONS

A low-frequency echo-sounder was very useful in detecting sargassom beds, because of the acoustic resonances of the vesicles.

The TS measuring sytem of the sargassoms in this report is also applicable to any other targets not only in a test tank. The target strength of an object can never be taken at the maximum value, since the reference target itself often moves off the sound axes due to sea currents even with a calm sea.

Observed target strengths of a bunch of the sargassoms are from -36 to -22dB at frequencies of 50 and 200kHz. This agrees well with TS calculated from the total sum of back-scattering cross-sections of individual vesicles of the grass. Stems and leaves separated from vesicles hardly contribute to echoes from the grass.

TS of a sargassom of -30dB is greatly decreased to about -50dB when all vesicles are extracted and TS_o of a kelp is much smaller than sargassoms with vesicles.

We could not prove that inter-relationships of echo strengths and weights of sargassoms changed with season. This problem should be solved as soon as possible so that stock assesments of sargassom communities can be conducted. Further studies on this technique of detecting sargassom beds may be applicable to the stock assessment of seaweeds.

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THE TARGET STRENGTH DEPENDENCE OF SOME FRESHWATER SPECIES ON THEIR LENGTH-WEIGHT CHARACTERISTICS

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INTRODUCTION

Numerous studies of target strength (TS) in fish, both under baseline, fully-controlled conditions and under in situ conditions, were basically aimed at investigation of marine species[5,6,8,9 and others], the fish size and insonification aspect being taken into account. In recent years, particular attention has been paid to the establishment of relationships between the TS of fish, their physiological state and also variation of the volume and shape of the swimbladder[1,3,4,10,11]. There is far less evidence available on the back-scattering strength in freshwater fish species[2,7,12]. The present communication discusses the results of measurements of TS in the following freshwater species: whitefish (*Coregonus lavaretus*), perch (*Perca fluviatilis* L.), bream (*Abramis brama* L.) and roach (*Rutilus rutilus* L.). In addition, data are given on analysis of current envelope values of fish species and their statistical characteristics.

EQUIPMENT AND METHODS

To measure fish TS the EY-M echo-sounder (f=70 kHz, τ=0.6 ms) with a transducer 70-24P, (-3 dB beam width 11°) was used. The echo-signals from the targets and the trigger pulse were monitored by an oscilloscope C1-93. The echo-signals from the targets and the trigger pulse were tape-recorded ("Sony TC-D5M" with a dynamic range of 50 dB).

The problem of fixing the copper sphere and the fish under study onto the acoustical axis of the transducer was solved by a rigid attachment of the target suspension structure to the transducer being towed (Fig. 1). This consisted of two perpendicular bars, whose crossing coincided with the centre of the transducer. At the end of each bar was fixed a spinning reel providing alternating changes in the length of nylon threads with the targets suspended. Such suspension design and an independent displacement of the targets in two dimensions provided means of placing them onto the acoustic axis of the transducer. The range of the displacement of each thread was ± 500 mm, regulation step 1 mm.

With displacement of the target at a definite step in the horizontal plane, n readings of the echo-signal were taken. Regarded as acceptable were the readings at which the amplitude fluctuations did not exceed 10%. A number of readings taken in subsequent steps made it possible to determine a maximal approximation of the target to the acoustic axis of the transducer which was characterized by a maximal amplitude of the signal. After that a series of measurements in another plane was made, and thus the optimal location of the target was determined.

Calibration of the equipment involved a copper sphere, which, at the frequency of 70 kHz displayed the TS value of -39.2 dB. The sphere was led out to the acoustic axis at a depth of 10 m and over 1000 echo-signals were tape-recorded. With further computer processing the value of this signal was the measure with

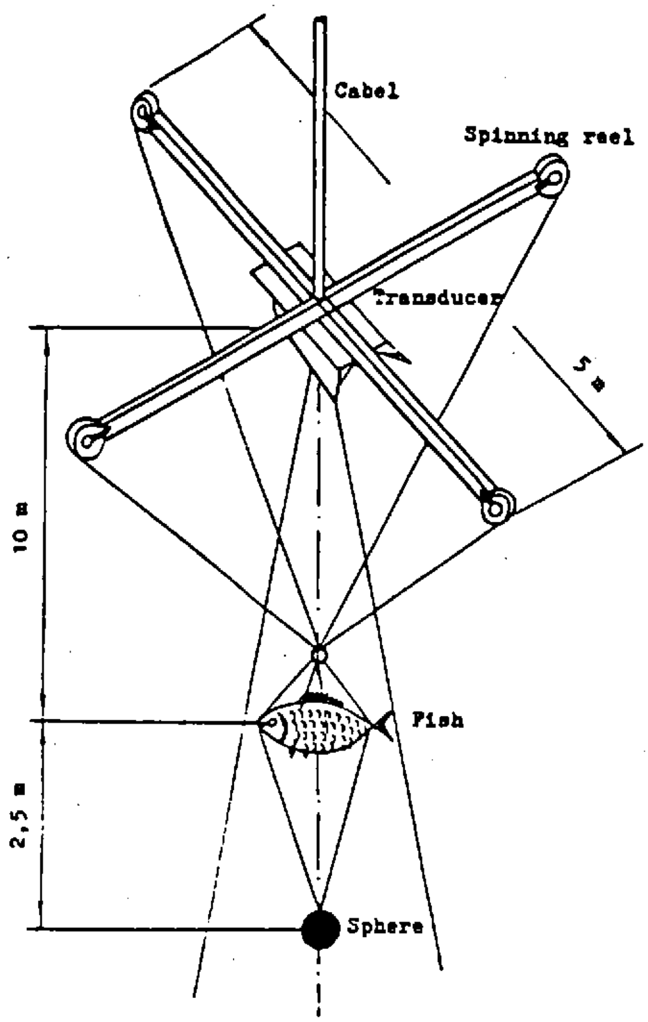

Fig. 1 Diagram of experimental measuring unit.

respect to which the TS of the fish under study was estimated. The calibration precision within the dynamic range and also taking into account the actual TVG law, was ± 0.3 dB. The processing of tape records involved two special measuring-computational units: Hewlett-Packard (USA) and the ASCOR system[13,14] (Fig. 2a, b). The Hewlett-Packard system included an analyser of the pulse form of the 5180A type, providing a dual-channel translation of the signals into a digital form at a quantization frequency from 20 kHz to 1 MHz and 8-bit computer HP-85B. A programme especially developed for 5180A calculated the statistical characteristics of the instantaneous values of the current envelope, its square, energy and duration.

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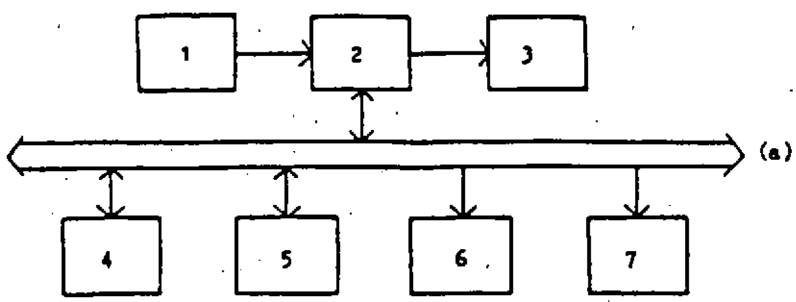
In the course of the processing, the echo signals were sampled for the maximum of the amplitudes from each measuring series which were subsequently analyzed. Analysis of the form of echo-sounder current envelope was performed by standard numerical indices, i.e. variation coefficient Cv, asymmetry Csk and excess Cex. In addition, histograms for the amplitude of the current envelope and signal intensity were plotted.



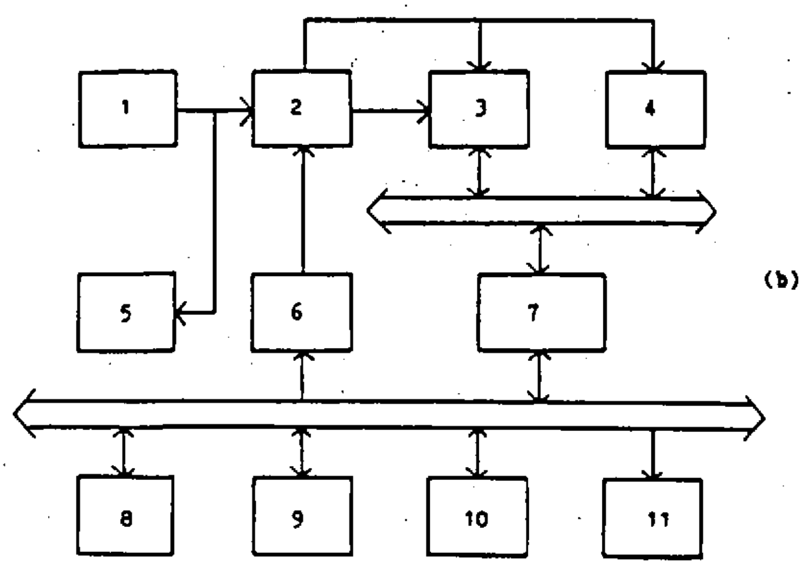


Fig. 2 Block diagrams of the measuring-computational units:
(a) Hewlett-Packard equipment - 1. tape-recorder "Sony TC-D5M"; 2. analyser of the pulse form 5180 A; 3. oscillosope 1746 A; 4. processor HP-85B; 5. flexible-disk storage 82901M; 6. graph plotter 7470A; 7. printer 2602A.
(b) the system ASCOR - 1. tape-recorder "Sony TC-D5M"; 2. block of analogue treatment; 3. 10-bit A/D converter; 4. synchroniser/timer; 5. oscilloscope; 6. converter; 7. interface for the CAMAC equipment; 8. processor DVC-3; 9. display; 10. flexible-disk storage; 11. printer.

The ASCOR system was realized on the basis of a 16-bit processor with a response of 800 thousand operations per second and CAMAC equipment (Fig. 2b). The dynamic range of 60 dB was provided by a precision detector of the current envelope and a 10-bit A/D converter. The echo-signal was translated into a numerical code with a frequency of 15 kHz (or after 5 cm in depth). During 1000 pulses, the calculation of the TS distribution according to the Craig-Forbes method and its modification with calculation of errors was performed. The fish under study was captured with stationary nets and then for no less than 24 hours was maintained under observation in a pond, for injured individuals to be eliminated. When anaesthetizing and suspending, no air was allowed to penetrate the gills or intestines. After that the fish was gradually submerged to a depth of 10 m and led out to the acoustical axis of the transducer. The echo-signals were recorded after a stable signal was received from the fish and the sphere below. According to TS measurements from fish of different species and sizes, the equations of logarithmic regression were calculated by the least squares method.

RESULTS OF MEASUREMENTS AND CALCULATIONS

The measurements were performed in May 1988 at the waterbodies Mostishte and Mogelno (Czechoslovakia). The subjects were the main fish species of these waterbodies: the roach, bream, perch and whitefish. Selected for experiments were fish with different sizeweight parameters: body size from 10 to 39 cm and body mass of 18 to 1390 g. Also performed were the measurements of the TS of pike perch (L=44 cm, W=1200 g) and two chub (L=26 cm, W=310 g and L=28.7 cm, W=390 g). The calculations as based on measurement data yielded TS regression equations for the above fish species as a function of their body length, mass and the ratio mass to length as well as generalizing equations for these fishes. The calculation results are given in Table 1. Fig. 3 shows the relationships of fish TS and their size-weight characteristics and generalized equations. On the basis of statistical treatment, data histograms were plotted of the amplitude distribution of the instantaneous values of the current envelope and intensity of the signals. The histograms of the distributions of different fish and a copper sphere demonstrated their differences from one another and from the expected theoretical distribution. On the basis of the results of treatment in terms of target classification by their statistical parameters, relationships Cv=F(Csk) and Cv=F(Cex) were developed for the instantaneous values of the current envelope and their squares (Fig. 4). To compare the calculation results for the three types of regression equations, histograms of TS distribution were plotted on the data of echo-metric survey of the Mostiste waterbody (Fig. 5).

DISCUSSION

Regression equations were obtained both from maximal values of the amplitudes of the echo-signals (energy and intensity) and from the means of 1000 pulses. The calculations of TS by these equations for a 20 cm fish showed differences up to 2.4 dB for the whitefish, roach and perch and a good fit for the bream. The generalized equations provide the best fit. The results of the experiments have demonstrated some differences in the TS of the freshwater fish under study obtained by us from those of other authors. In fact, the TS regression equation for the whitefish on its length given by different authors [2,7] yielded deviations by 2-3 dB in the sense of decline. As compared with data on measurements of TS in the roach, bream and pike perch in the Kakhovskoe Reservoir (USSR) [12] a closer fit for the bream and differences by 1-2 dB for the roach (± 1 dB) and pike perch (+ 2.2 dB) were revealed. The generalized equation obtained for 4

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Table 1 Regression equation for the dependences of the target strength and size-weight characteristics of some fishes

Species	No.	Length L (cm)	Mass W (g)	Regression equation				TS
				TS = F(Imax), dB		TS = F(U), dB		
Whitefish	13	20-39	100-1300	20.63logL -65.11 5.27logW -48.65 7.05logW/L-43.0	r=0.9 r=0.9 r=0.9	20.97logL -66.4 5.49logW -50.02 7.39logW/L-44.2	r=0.81 r=0.85 r=0.86	-1.1 +2.2 -1.3
Perch	14	18-36	150-1100	31.88logL -76.3 10.92logW -59.6 16.6 logW/L-51.3	r=0.9 r=0.9 r=0.9	23.39logL -66.75 7.99logW -54.76 12.1 logW/L-48.3	r=0.9 r=0.93 r=0.94	-2.4 -2.4 -2.4
Bream	16	10-33	27 750	26.47logL -72.06 9.87logW -59.79 14.9 logW/L-51.7	r=0.88 r=0.88 r=0.84	21.38logL -66.06 7.57logW -55.07 11.1 logW/L-48.5	r=0.95 r=0.95 r=0.76	-0.5 -0.3 -0.2
Roach	15	13.5-25.4	23.5-325	21.2 logL -62.87 9.3 logW -52.26 12.6 logW/L-47.6	r=0.95 r=0.94 r=0.7	24.87logL -69.78 5.48logW -50.07 6.94logW/L-44.4	r=0.85 r=0.77 r=0.74	-2.1 -2.4 -2.3
Generalized	58	10-39	23.5-1300	19.39logL -62.63 6.9 logW -52.95 10.5 logW/L-47.4	r=0.86 r=0.88 r=0.87	19.36logL -62.61 6.88logW -53.0 10.5 logW/L-47.1	r=0.86 r=0.83 r=0.81	0 0 0

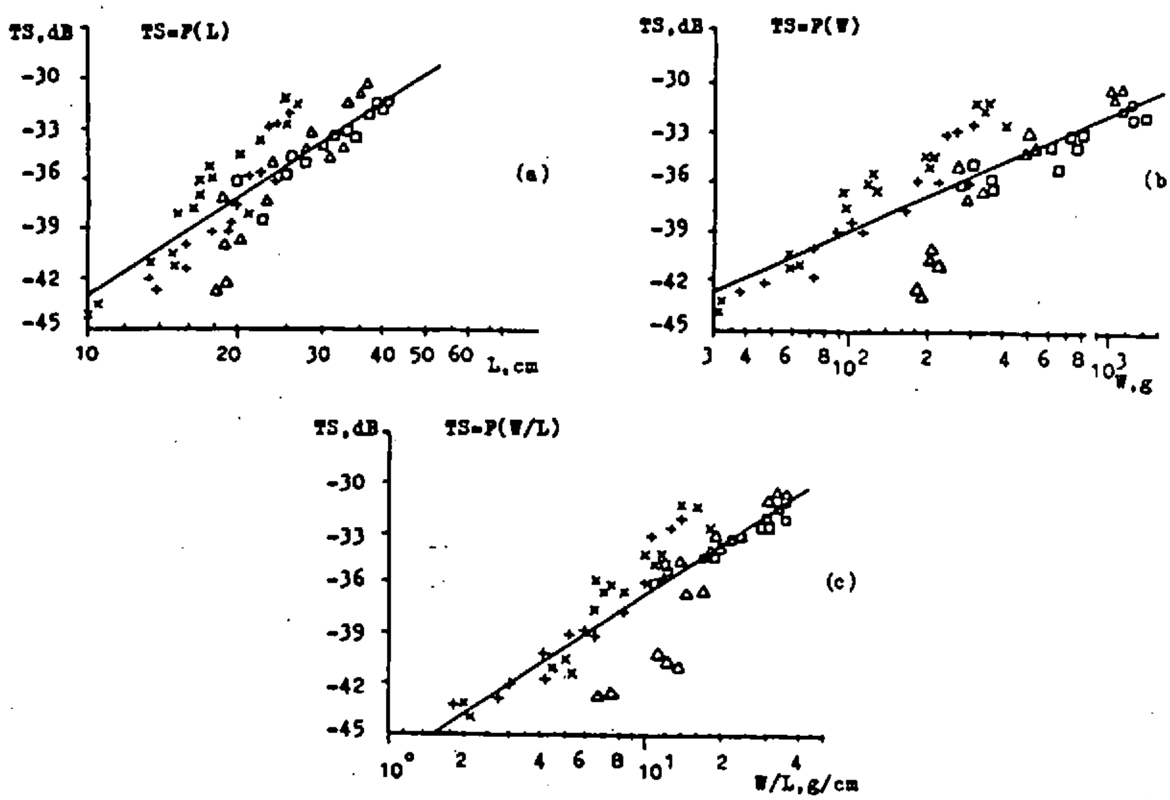

Fig. 3 Dependence of the TS on fish size-weight parameters generalized for 4 species: + - roach; x - bream; □ - whitefish; Δ - perch.

THE TARGET STRENGTH DEPENDENCE OF SOME FRESHWATER SPECIES ON THEIR LENGTH-WEIGHT CHARACTERISTICS

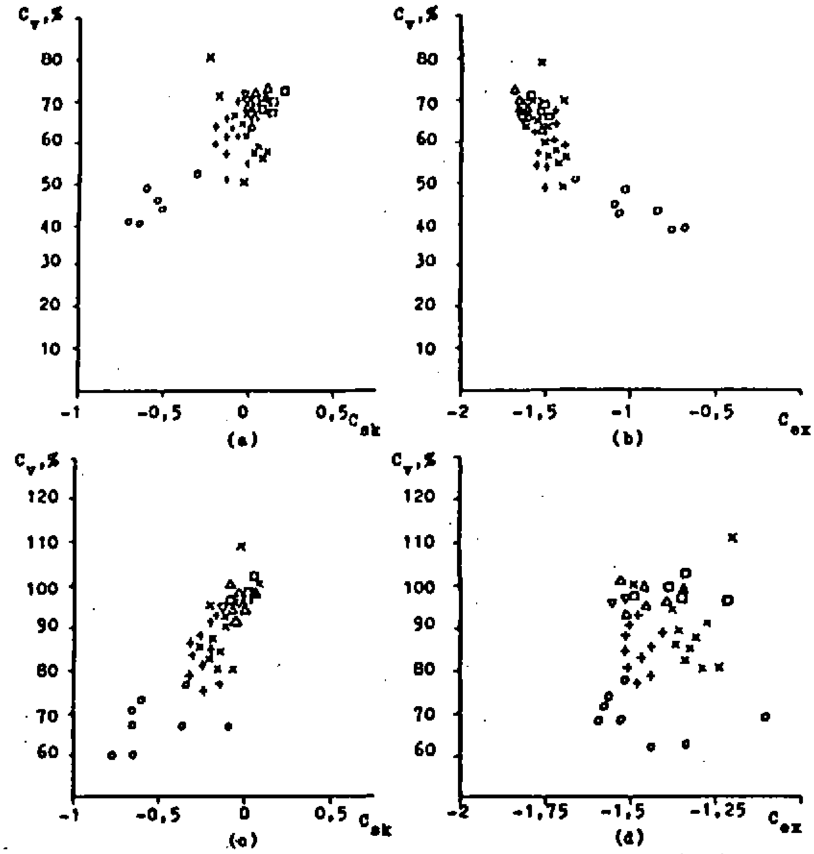

Fig. 4 Range of values of the coefficients of variation (C_v), asymmetry (C_{sk}) and excess (C_{ex}) of echo signal current envelopes (a, b) and their squares (c, d); o - copper sphere, + - roach, x - bream, □ - whitefish, Δ - perch, ∇ - chub, Δ - perch.

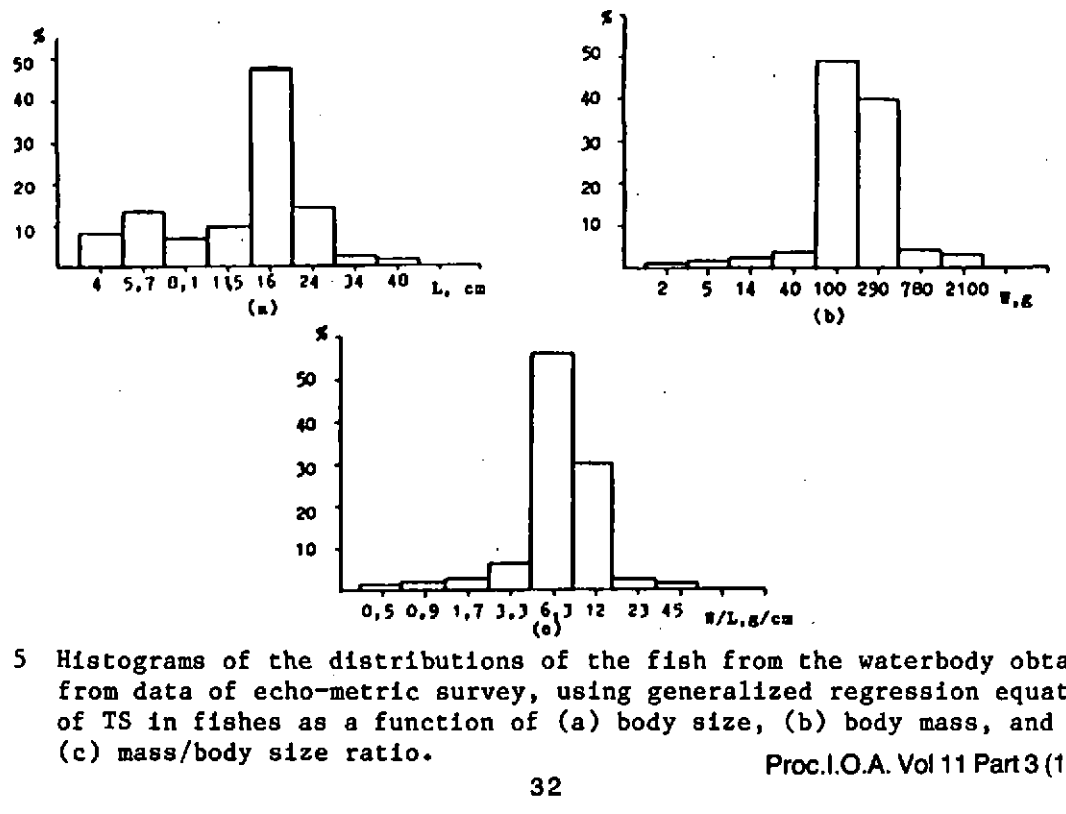

Fig. 5 Histograms of the distributions of the fish from the waterbody obtained from data of echo-metric survey, using generalized regression equations of TS in fishes as a function of (a) body size, (b) body mass, and (c) mass/body size ratio.

fish species shows fairly close estimated values of TS for the whitefish, roach and bream. As to the generalized equations obtained for marine fish[6,8], the difference in the results of calculations is 2 dB and over.

Along with that, considering signals from different fish one can see differences in their form. These differences are found in the statistical distribution of the echo-signals and can be quantitatively revealed by means of parameters of these distributions. Given in Fig. 4 the relationships Cv=F(Csk) and Cv=F(Cex) are most informative. Considering them one can infer the quite satisfactory possibilities of classification of some individual fish species groups in terms of the relationships of the statistical parameters. Using the data of echo-metric survey, the size-weight characteristics of the waterbody fishes were calculated from generalized equations. The closest to normal are the distributions obtained from the relationships TS=F(W/L) and TS=F(W) (Fig. 5).

Analysis has revealed that the selection of respective dependences of TS in fish may substantially affect the estimation of ichthyomass and sizing of fish. Thus, the problem of size classification in fish and identification of species requires an integrated approach to acoustical measurement. There are grounds to believe that determination of back-scattering strength in fishes as well as statistical spectral analysis of echo-signals can reveal the major important parameters for identification. For that, both acoustical parameters and physiological properties of the fishes under study apparently should be relied upon.

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