ISSN: 0001-5113 AADRAY	ACTA ADRIAT., 42 (1): 103-112, 2001	UDC: 639.222.6 Original scientific paper

Target strength measurements of European Anchovy, *Engraulis encrasicolus* (L.) by the control method

H.Tuncay KINACIGİL[1] and Kouichi SAWADA[2]

[1] *Ege University, Faculty of Fisheries, 35100, Bornova, İzmir, Turkey*

[2] *National Research Institute of Fisheries Engineering, Japan*

E-mail: tkinacigil@sufak.ege.edu.tr

European anchovy, Engraulis encrasicolus (L.) *is an important commercial species on the Atlantic coasts northward to southern North Sea, Mediterranean, Black Sea and also Aegean Sea. Target strength (TS) is a scale factor to get abundance, but there are few TS information in terms of this kind of species. In this study we measured TS of European anchovy by the control method in the fresh water tank. The measuring system's frequency is 38 kHz. Samples were captured in the Aegean Sea and transported with ice by air kept in the refrigerator under –40 degree in the laboratory. After defrosted TS patterns of 12 European anchovy were measured by the control method. Target strength patterns were measured as a function of tilt angle, ranging from –50 degrees (head down aspect) to 50 degrees (head up aspect) at every 1 degree. Obtained TS pattern become broad. Normalized maximum TS become –66.5 dB. Normalized average TS become –69.8 dB and –72.2 dB assuming tilt angle distribution as N(-3.4, 10.3) and N(12.0, 23.5).*

Key Words: target strength, control method, European Anchovy, *Engraulis encrasicolus* (L.)

INTRODUCTION

The target strength of fish is a prime factor for quantitative and qualitative assessment of their stocks by acoustics techniques. The acoustic target strength of individual fish is an important parameter in most application of acoustics to fisheries research. The target strength varies with a number of factor, including fish size, its activity, orientation and behavior, and structural components of the body.

The need for a better knowledge of fish target strength has been recognized for many years and different methods have been applied for converting the backscattered acoustics energy from fish. There are several methods to measure target strength. One is a control method and the other is an *in situ* method (NAKKEN and OLSEN, 1977; EDWARDS, 1980; FORBES *et al.*, 1980; EDWARDS and ARMSTRONG, 1983; MIYANOHANA *et al.*, 1990; FOOTE, 1991).

The control method gives a good information about target strength values of different size of fish in the tank, because target strength value is a function on fish tilt angle distribution (MIYANOHANA *et al.*, 1990). This method has been used in order to find out the target strength pattern of fish (HASLETT, 1962; NAKKEN and OLSEN, 1977). Several problems are pointed out such as whether to use dead or anesthetized fish whose swim bladders size changes by fish depth (MUKAI and IIDA, 1996). By applying the control method it is easy to know the target strength pattern with range of tilt angle and signal to noise ratio is high enough to get low target strength level. *In situ* method using the split beam or dual beam is superior to the control method, because it reflects the actual tilt angle distribution of fish and we do not need to pay attention to the swim bladder condition. However, it is also pointed out that it is difficult to measure precise target strength in such a condition that fish density high or fish depth become deep (SOULE *et al.*, 1995). Since a single fish isolation technique is not perfect, the more multiply echoes become, the higher the possibility of error to look multiple echoes as a single fish in the door tank with fresh water.

In this study, we have measured target strength of European anchovy by the control method in the fresh water tank. Target strength of European anchovy is a key factor to convert acoustic energy into the quantity.

European anchovy is an important commercial species from the Atlantic coast northward to southern North Sea, Mediterranean Sea, Black Sea and also Aegean Sea. European anchovy is also one of the main pelagic fish of Turkey fisheries. According to 1994 Turkish fisheries statistics report, this specimen was produced totally 294.418 tons in Turkish sea. So target strength of this species is a very important for the acoustic stock estimation.

Target strength is a scale factor to derive an estimate for numerical density but there is no information especially regarding this species target strength value. However, there are few information in terms of this kind of physostome (open swim bladder) species and other anchovy species (BUERKLE, 1983; FOOTE, 1987; BARANGE *et al.*, 1994; BARANGE *et al.*, 1996; OHSHIMA, 1996).

The main aim of this study was to measure the dependence of target strength on tilt angle for European anchovy. This was done for defrosted specimens when treated in a tilting apparatus in an indoors freshwater tank. The results are compared with published values for other fish species.

MATERIAL AND METHODS

Experimental set-up

Target strength measurements were carried out in June 1996 at the National Research Institute of Fisheries Engineering, Japan. A 10-10-15 m (depth, width, and length) indoor tank was used for the target strength measurement. The tank was filled with fresh water just prior to use.

Two thin horizontal nylon lines are tied to fish snout and tail, after these nylon lines are located the specimen between the vertical suspension lines by clip. The top of these lines are connected to the two sides of a rotating bar that is mounted on the axis of stepping motor (ISHII *et al.*, 1985; MIYANOHANA *et al.*, 1990). The vertical lines are tensioned by a simple weight and pulley system. A small float is used to keep the fish in an upside down position. The bubble which is in the gill had taken by the hand in the water before the experimentation started. This provided dorsal aspect alignment with respect to the transducer, which is mounted on the tank floor below the fish. A standard sphere is suspended before and after the TS measurement to calibrate echo sounder. The distance between the transducer, specimen and weight are large enough to avoid interference. The separator between the transducer and specimen is arranging about 6 m (Fig. 1).

Instrumentation and data processing

The versatile echo sounding system (FURUSAWA *et al.*, 1993) and a split beam transducer were used to insonify the fish. As an operation frequency the 38 kHz was used. The hardware TVG was removed to obtain accurate echo waveforms. Range compensation was incorporated in the analysis (SAWADA *et al.*, 1997).

The sonar equation is used to relate the echo peak amplitude, V, to target strength, TS:

$$TS = 20 \log V - K + 40 \log r + 2\alpha r$$

The calibration constant K is obtained by measuring echoes from a 60 mm diameter copper sphere (FOOTE, 1983). Range, r, is deter-

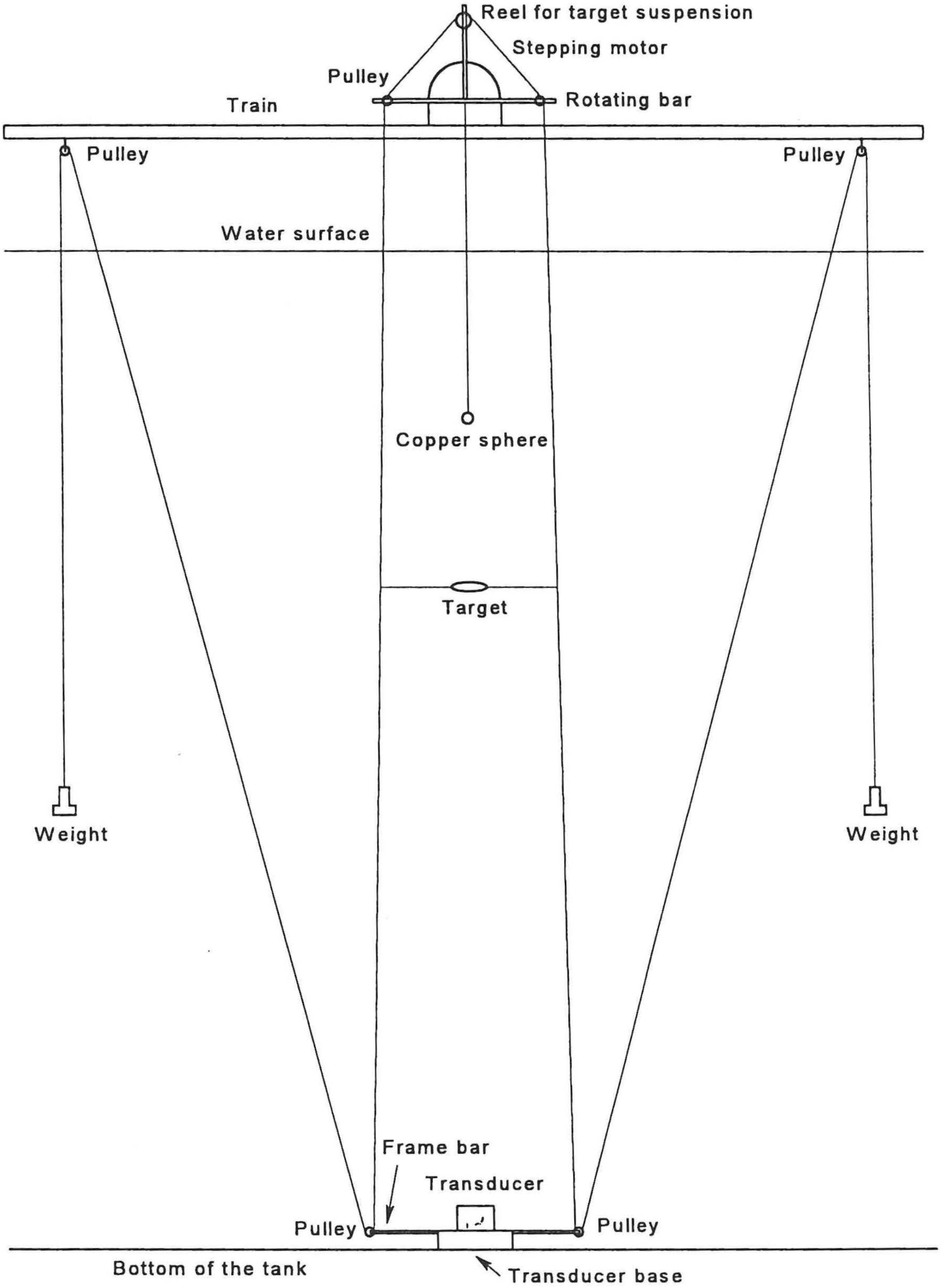

Fig. 1. Schematic of fish suspension and rotating system

mined from the echo delay and short-range absorption loss, $2\alpha r$, is negligible. The beam factor is omitted as fish and targets are on axis. The echo shape and voltage were monitored and recorded with a digital oscilloscope (LE CROY 9304 Am).

The target strength were measured as function of fish tilt angle, ranging from –50 degrees (head-down aspect) to + 50 degrees (heat-up aspect) at every 1 degree. The back scattering cross section of fish is approximately proportional to the squared fish length (FURUSAWA, 1988). Therefore, experimental values of the target strength have been normalized by the square of body length L (cm) and expressed as follows:

$TS = 20 \log L + TS$ cm

The maximum dorsal aspect target strength values (*TS* max.) and the average dorsal aspect target strength values (*TS* avg.) were calculated and compared. The average dorsal aspect target strength values were calculate with respect to fish tilt angles distribution, which were assumed to have average and standard deviation values of $N(0, 5)$, $N(-5, 15)$, $N(-10, 15)$, $N(-15, 15)$, $N(12, 23.5)$, $N(-3.4, 10.3)$.

Approximately six echoes were collected for each fish aspect or tilt angle. All target strength measurements are based on narrow beam echo data.

The Fish

The examined fish species was European anchovy. This species has a slender, oral, belly rounded and not keeled with scutes: snout prominent and pointed well in front of tip of lower jaw, mouth inferior; long upper jaw, reaching well back behind eye. Dorsal and anal fins short, the latter behind dorsal fin base. Its color is black, clear green or blue/green flanks with a silver stripe. Generally, its total length varies between 8-14 cm. This fish has a physostomous type swim bladder. After dissection of swim bladders we saw that they have revealed a swollen part in the narrow and relatively short middle section (Fig. 2).

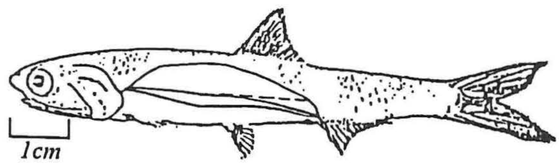

Fig. 2. The European anchovy and the original size of swim bladder

The specimens were captured in Aegean Sea by the purse seine and were kept alive in tank for more than 24 hours. After 24 hours these specimens were killed and frozen immediately. Fifteen specimens, all in apparently good conditions, were chosen and transported with ice by air. Before kept in the refrigerator under –40 degree in laboratory all specimens body weight, fork lengths were measured by electronic balance and caliper rule. After defrosted, *TS* patterns of fifteen European anchovy were measured by control method in the acoustics tank. After the measurement, specimens were dissected and swim bladder condition and size were checked and measured. During the measurement we have noticed that three specimens were deflated and thus excluded from further calculations.

RESULTS

It is desired to investigate whether the difference occurred in the swim bladder size. By this aim it is requested to dissect fishes and determine swim bladder size of the same length group individuals, after keeping them live in the tank more then 24 hours in Turkey. In conclusion no difference appeared in the size of swim bladder. Additionally, the results were supported statistically.

Body weight, fork length and swim bladder size measurements of specimens in Japan and in Turkey are shown (Table 1).

Since, *b/a* ratio of the data, obtained in Turkey and Japan suitable for normal distribution and was accepted as equal variance, whether any difference between averages in

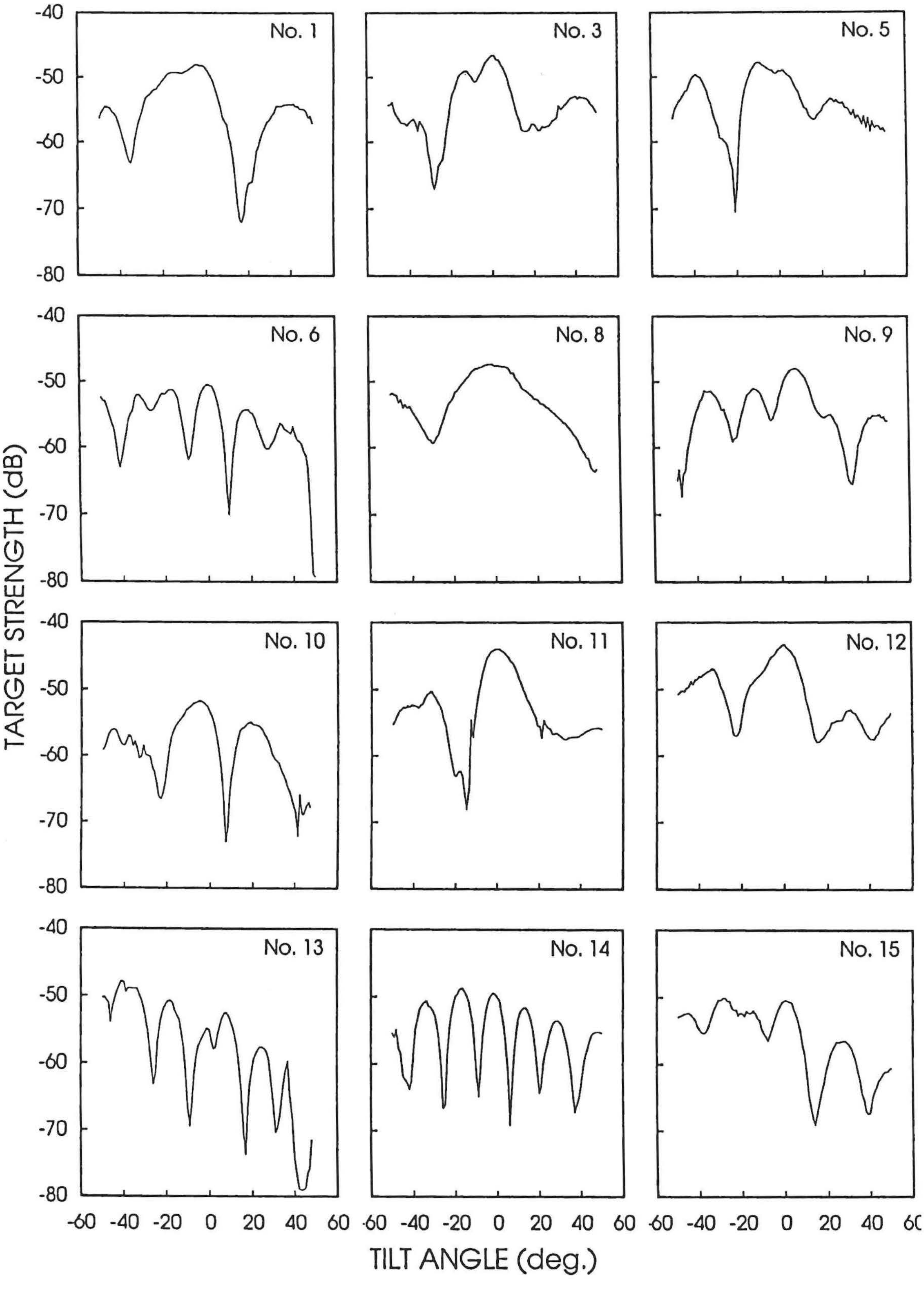

Fig. 3. TS pattern of twelve specimen

Table 1. Fork length, weight and swim bladder size measurement of specimen in Japan and Turkey

	Fish Number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Measured in Japan	Fork Length (mm)		102	104	103	88	96	95	97	84	101	103	107	92	87	76	81
	Weight (g)		9.01	9.01	8.99	5.26	6.73	8.68	8.69	4.51	7.98	8.99	9.31	7.03	5.09	4.49	4.91
	Swim bladder	2a	28.4	26.8	28.2	25.8	27.9	26.8	26.1	25.1	28.4	29.7	29.8	27.8	26.5	20.1	22.1
	Size (mm)	2b	2.4	1.7	2.5	1.6	2.7	2.5	1.7	2.4	2.4	2.4	2.6	2.5	2.2	1.9	2.1
	Condition		O	X	O	X	O	O	X	O	O	O	O	O	O	O	O
Measured in Turkey	Fork Length (mm)		102		103		96	95		8.6	101	103	107	92	87	76	81
	Weight (g)		9.90		9.01		6.80	8.70		4.62	7.78	8.89	9.28	7.14	5.11	4.32	4.80
	Swim bladder	2a	28.6		28.3		27.4	26.9		25.2	28.5	29.3	29.7	27.9	26.9	20.8	22.3
	Size (mm)	2b	2.5		2.4		2.6	2.5		2.4	2.5	2.4	2.5	2.4	2.3	1.9	2.0
	Condition		O		O		O	O		O	O	O	O	O	O	O	O

Table 2. Normalized maximum TS and normalized average TS assumed several tilt angles distribution (Unit:dB)

Fish Number	*TS* cm max.	*N*(0,5)	*N*(-5,15)	*N*(-10,15)	*N*(-15,15)	*N*(12,23.5)	*N*(-3.4,10.3)
1	-68.1	-69.6	-70.8	-70.7	-70.9	-73.1	-70.1
3	-66.8	-68.3	-70.6	-70.9	-71.5	-72.3	-69.6
5	-67.4	-69.1	-70.4	-70.5	-70.9	-72.1	-69.5
6	-69.9	-72.3	-73.3	-73.1	-73.1	-74.8	-73.1
8	-65.7	-66.1	-67.8	-68.1	-68.7	-63.3	-67.1
9	-68.1	-70.7	-71.8	-72.2	-72.6	-72.8	-71.4
10	-71.9	-73.6	-75.5	-75.8	-76.2	-76.9	-74.6
11	-64.5	-65.6	-68.7	-69.3	-70.1	-70.3	-67.6
12	-62.5	-64.1	-66.5	-66.7	-67.1	-68.5	-65.5
13	-66.5	-75.1	-73.7	-73.1	-72.3	-73.3	-74.4
14	-66.5	-69.7	-70.2	-70.1	-70.1	-71.7	-70.1
15	-68.2	-70.1	-71.3	-71.1	-70.8	-73.4	-71.2
AVG	-67.2	-68.4	-70.2	-70.4	-70.7	-71.9	-69.5
STD+	-64.9	-65.9	-68.2	-68.4	-68.8	-70.1	-67.3
STD-	-69.6	-74.6	-74.1	-73.9	-73.9	-75.5	-74.1

95% confidence interval, the zero hypothesis would be:

$H_O=\mu_J=\mu_T$

$H_A=\mu_J\neq\mu_T$

Because of the obtained F=0.2538 value is smaller than $F_{1:22:0.05}$=4.30 value in the Table in 95% confidence interval, 0.2538<4.30, H_O hypothesis is refused and there is no meaningful variation between Japan and Turkish data in 5% confidence interval.

In this study, as it can be seen from Table 1, body weight and length of the *TS* measured specimens change between 4.99 to 9.31 g and from 76 to 107 mm. Also the length and height of the middle section of the swim bladder were found to change between 20.1 to 31.3 mm and 1.6 to 2.7 mm respectively.

TS pattern of twelve specimen and normalized maximum *TS* and normalized average *TS* assumed several fish tilt angle distribution for twelve specimen as shown in Fig. 3 and Table 2.

Average value of average normalized maximum *TS* was found to be – 67.2 *dB* for twelve specimen and average *TS* were found to change form –68.4 to –71.9 *dB* for each assumed several tilt angle distribution.

As can be seen in Table 2 among the assumed several tilt angle distribution, the average value of normalized average *TS* for *N*(0, 5) was found to be –68.4 *dB*. However, other assumed tilt angles average values of normalized average *TS* were found to be close to each other.

DISCUSSION

The aim of this study is to determined *TS* values of various size classes of European anchovy by using control method, the average values of average normalized maximum *TS* was found as –67.2 *dB*. This value was the average of the fish varying from 7.7 to 10.7 cm in fork length. The individual *TS* values of twelve European anchovy were found to vary between –62.5 to –71.9 *dB*. These maximum differences between size classes were thought to be the result of fish conditions. On the other hand, the small size of swim bladders suggests that both maximum and average TS values will be close to these values.

The average dorsal aspect target strength values were assumed to have average and standard deviations values of *N*(0, 5), *N*(-5, 15), *N*(-10, 15), *N*(-15, 15), *N*(12, 23.5) and *N*(-3.4, 10.3). Among these selected average and standard deviation values, *N*(-5, 15) are the suggested values by FOOTE (1987) and MIYANOHANA *et al.* (1990). Although FOOTE (1987), in his study, reported this value as *N*(-4.4, 16.2), we used *N*(-5,15). Because of the negligible amount of difference *N*(12, 23), *N*(-3.4,10.3) is the *in situ* observation values of mature herring for day and night time, respectively BUERKLE (1983). In addition to these values, we assumed *N* (0, 5), *N* (-10, 15) and *N*(-I5, 15) for this study. The reason for assuming these particular values as with other assumed average and standard deviation values is to see how to extend fish tilt angle pattern is effective to the average *TS*.

Lack of similar *TS* measurement studies with control method on European anchovy caused some problems to our interpretation. BARANGE *et al.* (1994, 1996) in these studies with *Engraulis capensis* L. reported average *TS* as -57.84 to -57.73 *dB* and –76.10 *dB* for the fish with total length of 7.50 - 7.34 cm and 6.00 - 15.00 cm respectively. We were not able to compare our results with this study directly, but we think that this difference may become from different measurement criteria and natural conditions of this species. Also due to the same reasons, it our results were not comparable with OHSHIMA's (1996) results.

Among the dorsal aspect target strength values which were assumed average fish tilt angle distribution, the maximum average value of normalized average *TS* was found to be -68.4 *dB* for *N*(0, 5). However, other assumed tilt angle values especially *N*(-5, 15), *N*(-10, 15) and *N*(-15,15) were found to be close to each other. The broadness of the *TS* pattern is thought to be the reason for the closeness between assumed average fish tilt angle distributions. On the other hand, average value of normalized average *TS* values of -71.9 *dB* for N(12, 23.5) and -69.5 *dB* for N(-3.4, 10.3) were found to be close to the values which were reported for other phsostomeus species by FOOTE (1987). The closeness of our results to all other average normalized *TS* values suggests that average *TS* value does not depend on fish tilt angle distribution in this range and is stabile. Thus operation frequency of 38 kHz can be successfully used for determination of the *TS* value and acoustic stock estimation of this species. Assuming a high average value of normalized average *TS* values for *N*(0, 5) indicates that this species gives high *TS* values in horizontal position in water column.

CONCLUSIONS

TS patterns of 12 European Anchovy were measured by control method in indoor tank. In this system, we can measure *TS* at the tilt angle of –50 up to 50 degrees at intervals of 1 degree automatically. The results of the measurement, the operation frequency of 38 kHz can be successfully used for determination of the *TS* value and acoustic stock estimation of this species.

REFERENCES

BARANGE, M., I. HAMPTON, S.C.PILLAR and M.A. SOULE.1994. Determination of composition and vertical structure of fish communities using in-situ measurements of acoustic target strength. Can. J. Fish. Aquat. Sci., 51 : 99-109.

BARANGE,M., I. HAMPTON and M. SOULE. 1996. Empirical determination of in situ target strengths of aggregated pelagic fish species. ICES Journal of Marine Science, 53 (2).

BUERKLE, U. 1983. First look at herring distributions with a bottom referencing underwater towed instrumentation vehicle. Brutn. FAO Fish. Rep. 300, pp. 125-130.

D.I.E.1994. Turkiye su ürünleri anket sonuclari. (Fishery statistics, in Turkey), Devlet Istatistik Enistitusu. (State Institute of Statistic), Ankara.

EDWARDS, J. I. 1980. A preliminary investigation of the target strength of herring. ICES, Fish Capture Committee, CM 1980/B, 19, 18 pp.

EDWARDS, J. I. and F. ARMSTRONG.1983. Measurements of the target strength of live herring and mackerel. Symposium of Fisheries Acoustic, Bergen, Norway, 21-24 June 1982. Selected papers, 67-77. O. Nakken and S. C. Venema (Editors). ICES/FAO Fish. Rep., 300, 331 pp.

FOOTE, K. G. 1983. Maintaining precision calibrations with optimal copper spheres. Journal of The Acoustical Society of America, 73 :1054-1063.

FOOTE, K. G. 1987. Fish target strengths for use in echo integrator survey. Journal of The Acoustical Society of America, 82(3) : 981-987.

FOOTE, K. G. 1991.Summary of methods for determining fish target strength at ultrasonic frequencies. ICES J. Mar. Sci., 48:211-217.

FORBES, S. T., E.J. SIMMONS and J.I. EDWARDS. 1980. Progress in target strength measurements on live gadoids. Int. Counc. Explor. Sea. Fish. Capture Committee, CM 19808:20, 39 pp.

FURUSAWA, M. 1988. Prolate spheroidal models for predicting general trends of fish target strength. Journal of The Acoustical Society of Japan, (E) 9 :13-24.

FURUSAWA, M., Y. TAKAO, K. SAWADA, T. OUKUBO and K. YAMATANI. 1993. Versatile echo sounding system using dual beam. Nippon Suisan Gakksishi, 59 : 967-980.

HASLETT, R.W.G. 1962. Determination of acoustic back-scattering patterns and cross section of fish. Brit. J. Appl. Phys., 13.

ISHII, K., M. FURUSAWA and Y. MIYANOHANA. 1985. A design of fish suspension and tilting system for the fish target strength measurement. Tech. Rep. Nat. Res. Inst. Fish. Eng. (Fish. Boat Inst.), 6:71-109 (in Japanese)

MIYANOHANA, Y., K. ISHII and M. FURUSAWA. 1990. Measurements and analysis of dorsal aspect target strength of six species of fish at four frequencies. Rapp. P. -V. Réun. Cons. Int. Explor. Mer., 189 : 317-324.

MUKAI, T. and K. IIDA. 1996. Depth dependence of target strength of life kokanee salmon in accordance with Boyle's law. ICES J. Mar. Sci., 53:245-248.

NAKKEN, O. and K. OLSEN. 1977. Target strength measurements of fish. Rapp. P. -V. Réun. Cons. Int. Explor. Mer., 170 : 52-69.

OHSHIMA, S. 1996. Acoustic estimation of biomass and school character of anchovy (Engraulis japonicus) in the East China Sea and the Yellow Sea. Japanese Society of Fisheries Science, 62(3) :344-349.

SAWADA, K., Y. MIYONOHANA and K. ISHII. 1997. Precise target strength pattern measurement in an indoor tank. Journal of the Acoustical Society of Japan, (E)18 (5):231-238.

SOULE, M.A., M. BARANGE and I. HAMPTON. 1995. Evidence of bias estimates of target strength obtained with a split-beam echosounder. ICES J. Mar. Sci., 52:139-144.

Accepted: 8 November 2000

Mjerenje snage odjeka europskog inćuna, *Engraulis encrasicolus* (L.) kontrolnom metodom

H.Tuncay KINACIGİL[1] i Kouichi SAWADA[2]

[1] *Egejsko Sveučilište, Ribarstveni fakultet, 35100, Bornova, Izmir, Turska*
[2]*Državni institut ribarstvenog inžinjeringa, Japan*
E-mail:tkinacigil@sufak.ege.edu.tr

SAŽETAK

Europski inćun (*Engraulis encrasicolus* L.) je gospodarski važna vrsta na obalama Atlantika, i to od sjevera prema jugu u Sjevernom moru, u Sredozemnom moru, Crnom moru kao i Egejskom moru. Snaga odjeka (*TS)* je mjerni čimbenik koji se koristi pri određivanju obimnosti, ali o njemu postoji vrlo malo informacija za ovu vrstu. U ovom radu mjerili smo snagu odjeka (*TS*) europskog inćuna kontrolnom metodom u bazenima sa slatkom vodom. Mjerenje je izvršeno pri frekvenciji od 38 kHz. Uzorci su uhvaćeni u Egejskom moru, pohranjeni u hladnjak s ledom na temperaturi od –40°C i prevezeni zrakoplovom do laboratorija. Nakon odmrzavanja, *TS* značajke 12 europskih inćuna su izmjerene upotrebom kontrolne metode. Značajke snage odjeka su bile mjerene u odnosu na nagib ribe u rasponu od -50° (glavom prema dolje) do +50° (glavom prema gore) pri svakoj promjeni nagiba od jednog stupnja. Dobivene *TS* obuhvaćaju širok raspon vrijednosti. Najveća vrijednost (*TS*) bila je -66.5 *dB*, dok je srednja vrijednost bila -69.8 *dB* i 72.2 *dB* pretpostavljajući raspodjelu nagiba ribe kao *N* (-3.4; 10.3) odnosno *N* (12.0; 23.5).