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PRELIMINARY RESULTS OF ACOUSTIC TARGET STRENGTH MEASUREMENTS OF BIGEYE (*THUNNUS OBESUS*) AND YELLOWFIN TUNA (*THUNNUS ALBACARES*)

by

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ABSTRACT. - Acoustics is a common method for stock assessment and to observe pelagic fish schools or individuals in their environment, but it was never applied on tuna. Knowledge about individual target strength (TS) is nevertheless the primary condition for quantitative studies and this is particularly sparse for tuna species. In this study, an original method was used to measure *in situ* acoustic target strength of 4 yellowfin tuna (*Thunnus albacares*) (4 to 30 kg) and 2 bigeye tuna (*Thunnus obesus*) (30 and 50 kg). These fish were individually caught, identified and measured, then equipped with ultrasonic tags for telemetry experiments. During the tracking operation, simultaneous underwater acoustic data were recorded with a split beam echo-sounder when the fish was inside the acoustic beam of the research vessel's echo-sounder. This experiment has shown that this method provides coherent results even if a great variability is observed. Further extensive use of this method, particularly in tuna studies, may be undertaken in the future.

RÉSUMÉ. - Résultats préliminaires de mesures de la réponse acoustique individuelle chez le thon obèse (*Thunnus obesus*) et l'albacore (*Thunnus albacares*).

L'acoustique est une méthode couramment utilisée pour l'estimation de stocks et l'observation directe des individus et des bancs de poissons pélagiques dans leur environnement, mais elle n'a jamais été appliquée aux thons. L'une des difficultés consiste à connaître l'indice de réflexion (TS) des individus observés et c'est particulièrement le cas pour les thons. Dans cette étude, le couplage entre le marquage acoustique et l'analyse par faisceau scindé a été utilisé pour mesurer *in situ* la réponse acoustique individuelle de 4 albacores (*Thunnus albacares*) (de 4 à 30 kg) et 2 thons obèses (*Thunnus obesus*) (de 30 et 50 kg). Ces poissons ont été pêchés individuellement, identifiés, mesurés puis équipés de marques ultrasoniques en vue d'un suivi télémétrique. Les mesures effectuées au passage du poisson dans l'axe de l'écho-sondeur du navire de recherche apportent des résultats cohérents même s'ils montrent une grande variabilité. De nombreuses applications de cette méthode peuvent être envisagées, en particulier dans l'étude des thons.

Key-words. - Thunnidae, *Thunnus obesus*, *Thunnus albacares*, Target strength, Acoustics, Fish tracking.

A good knowledge about individual target strength (TS) is the main prerequisite for carrying out stock assessment by acoustic methods. TS ranges of most commercially important small pelagic fish have been widely studied during the past twenty years (MacLennan and Simmond, 1992). No TS estimation has been carried out for tuna until now, except for results of Freeze and Vanselous (1986). These authors mention a range of TS data from -22 to -30 dB for large (>130 cm) bluefin tuna (*Thunnus thynnus*). However,

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these data have been estimated from theoretical considerations based on sonar observations.

Fish TS measurement is difficult, especially when the target is a fish that is vertically distributed over a large range of depths as in the case of adult tuna. A first method consists of tethered fish TS measurement (Nakken and Olsen, 1977). With such a method fish are physiologically modified and the data are not comparable with active fish responses (MacLennan and Simmond, 1992). A second method consists of TS measurement of live fish in a tank, but this method is difficult to set up for large fish. To illustrate this problem, taking into account the beam-width, a 1 m-long tuna must be at least at thirty metres below the transducer to be included in the central part of the beam. *In situ* TS measurements are considered to be the most accurate (MacLennan and Simmond, 1992). In such cases, TS measurements must be carried out on a large number of fish which have to be caught to be sampled in order to determine length and species composition. These methods are difficult to apply to scattered adult tuna because of the difficulty in catching the acoustically observed individuals.

The proposed method consists of coupling TS measurement with sonic tracking of a tagged tuna whose species and size are known. When the fish passes through the echo-sounder beam its acoustic response can be measured. Coupling acoustic survey with sonic tracking was used on swordfish (*Xiphias gladius*) by Carey (1990) in order to observe the fish's movement in the trophic structures, but without any attempt to measure TS.

This method was put into practice during the ECOTAP programme (study of tuna behaviour using acoustics and fishing experiments) conducted in French Polynesia by 3 research organisations: IFREMER (Institut Français de Recherche pour l'Exploitation de la MER); ORSTOM (Institut français de recherche scientifique pour le développement en coopération); and SMA (Service de la Mer et de l'Aquaculture). Tagging and tracking of yellowfin (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*) coupled with acoustic survey was undertaken. This paper presents the first results of *in situ* tuna TS measurement.

MATERIAL AND METHODS

Experiments were carried out onboard the ORSTOM R.V. "Alis" during the ECOTAP surveys 03, 07, 15 and 18, between October 1995 and August 1997 in the Society and Tuamotu Archipelagos.

The initial purpose of these surveys was to use acoustics to study vertical and horizontal tuna movements according to their biotic and abiotic environment. During these experiments it was possible to measure the TS of the tagged tuna.

Acoustic TS measurements

Acoustic data were collected with a SIMRAD EK500 echo-sounder connected to a 38 kHz split-beam transducer (full beam angle 6.9°) used with a pulse duration of 1.0 ms. The water column was prospected from the surface to a depth of 500 m. Acoustic and navigation data were stored via Ethernet on a PC through SIMRAD EP 500 software. The system was calibrated in accordance with the manufacturer's instructions (Simrad, 1993).

Telemetric tracking measurements

The tracking equipment used was a VEMCO system (Shad Bay, Nova Scotia, Canada) V16P, 50 kHz, 500 and 1,000 PSI equipped with pressure sensor. Two kinds of towed

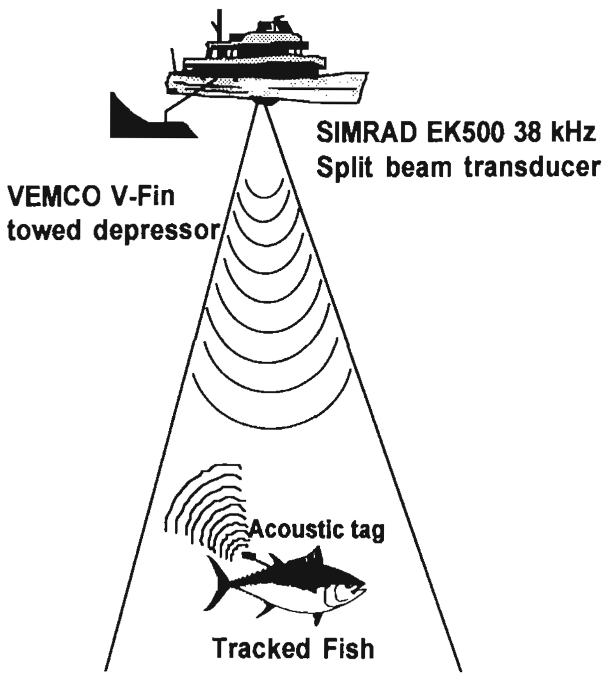

Fig. 1. - Schematic principle of target strength (TS) measurement by coupling acoustic survey and fish tracking.

hydrophones were used: a directional hydrophone VEMCO V10 and a four elements hydrophone VEMCO V41. The latter has acceptance angles in the four horizontal directions. Information was sent to a receiver system and recorded on a PC.

Tagged fish were caught by a traditional vertical handline, the drop stone fishing technique (Moarii and Leproux, 1996) or by longline onboard the R/V "Alis" and onboard professional fishing units. Depending on the fish size, two tagging methods were used. When fish were small enough, they were pulled up onboard and measured. Acoustic transmitters were fixed in the muscle of the back, close to the second dorsal fin with two nylon tie-wraps. In the case of larger fish, the acoustic tag was fixed to the anterior dorsal musculature using a tagging pole, and fish size was estimated by eye. In both cases, tuna were immediately released then tracked by the R.V. "Alis".

Fish tracking and acoustic survey coupling

The telemetric tracking system provides us the vertical and horizontal fish position in relation to the vessel. The fish was located in the echo-sounder beam when the vessel was exactly vertical to it (Fig. 1). In this case, fish TS and echo depth were automatically recorded (Fig. 2). Data validation was performed over four stages: (1) TS data were extracted with the EP 500 software at depths surrounding the tagged fish depth; (2) only echoes above -40 to -43 dB, depending on the fish size, were considered to eliminate echoes of smaller targets; (3) depth of both TS and tracked fish were compared at equal times in order to select the precise tracked fish echoes; and (4) a final control was made by looking at the paper records and EP 500 monitoring.

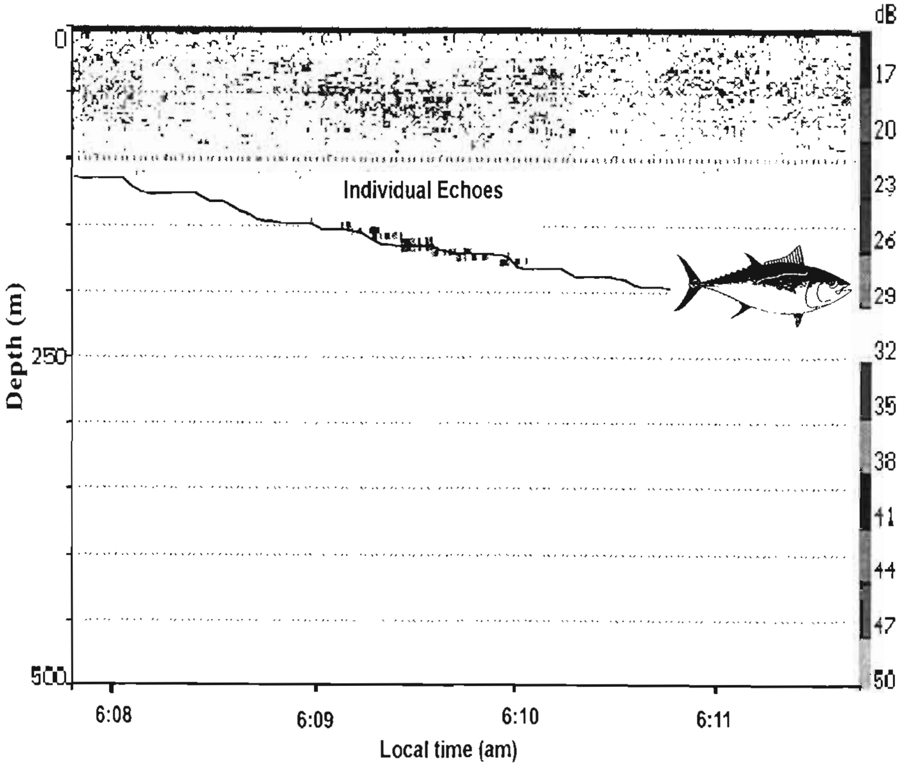

Fig. 2. - Individuals echoes (points) and depth of fish (solid line) during the track of 50 kg bigeye tuna (BE22).

TS of acoustic tag

Acoustics measurements verified that the tag could not produce an echo high enough to change fish TS. The values obtained were close to -50 dB. The addition of a -50 dB energy to a -30 dB energy increases the latter by only 1%. The acoustic effect of the tag has been neglected in the present study.

RESULTS

This experiment was difficult to carry out for several reasons: (1) sonic tagging experiments necessitate a combination of optimal natural opportunities (good weather condition, availability of tuna) to be successfully undertaken (Cayré, 1991); (2) because of the beam angle (at 200 m depth, the beam diameter is about 24 m), it is unlikely that the fish will be detected acoustically; and (3) in the area of the study TS measurements could only be recorded during daytime. At night, the tracked fish moved too close to the surface to be easily detected. Furthermore, a dense scattering layer at night prevented any TS measurement with our settings.

Despite these constraints, it was possible to record 6 series of TS measurements corresponding to four yellowfin (YF10, YF13, YF14 and YF19) with an estimated weight between 4 and 30 kg and two bigeye (BE21 and BE22) with an estimated weight between 30 and 50 kg (Table I). Individual TS varies between -34.8 and -21.4 dB (Table II). For equivalent sizes, TS is widely higher for bigeye than for yellowfin, which is in accordance with the swimbladder volume of both species (Table II). Nevertheless, TS histograms show a large variability for a same fish. Data are spread in a range of + or - 10 dB around the average (Fig. 3) with a coefficient of variation between 51.1 and 92.8% (Table II).

DISCUSSION - CONCLUSION

This experiment, consisting of coupling fish tracking and acoustic survey, allowed *in situ* TS measurement of individually identified adult tuna. Measured data seem to be consistent as average TS increase with the fish size for a same species and with the swimbladder volume for both species. This last parameter is important because the swimbladder is supposed to be responsible for 90-95% of the backscattering energy (Foote, 1980b).

The range of TS variation exceeds 15 dB for one fish. It is well known that fish TS are widely variable (more than 20 dB) even for the same fish (Ona, 1990; MacLennan and Simmonds, 1992). Several hypotheses can explain this. Rose and Porter (1996) assumed it was due to changes in fish's swimming behaviour. Many authors such as Nakken and Olsen (1977), Foote (1980a), Foote and Ona (1985), MacLennan and Simmonds (1992), McClatchie *et al.* (1996a, 1996b) and Mukai and Ida (1996) have shown the influence of the tilt angle on TS. Nevertheless, all these kinds of experiments are usually carried out *ex situ*. *In situ* TS measurements integrate a large range of behaviour (so of tilt angle) and changes in swimbladder volume which both play an important role (Foote, 1980b; Blax-

Table I. - Characteristics of the fish tracked used in TS analysis. *: Estimated length.

Fish No.	Survey	Species	Fishing gear	Fork length (cm)	Estimated weigh (kg)	Track duration (h)	Date of track
YF10	ECOTAP03	*T. albacares*	Drop stone	60	4	22	27-28/Oct/95
YF13	ECOTAP06	*T. albacares*	Drop stone	90	14	80	2-5/Mar/96
YF14	ECOTAP07	*T. albacares*	Drop stone	108	25	91	20-24/Avr/96
YF19	ECOTAP15	*T. albacares*	Longline	120*	30	28	16-18/Avr/97
BE21	ECOTAP15	*T. obesus*	Longline	110*	30	12	20-21/Avr/97
BE22	ECOTAP18	*T. obesus*	Longline	130*	50	33	01-03/Aug/97

Table II. - Mean TS of tracked tuna. *: Estimated length. Data in parenthesis: Coefficient of variation in %. The swimbladder volume was estimated by the data of ECOTAP (unpubl. data).

Fish No.	Fork length (cm)	Estimated swimbladder volume (cm^3)	$\overline{TS}$	Number of observations
YF10	60	80	-34.8 (51.1)	18
YF13	90	130	-33.0 (86.4)	102
YF14	108	215	-30.4 (92.8)	189
YF19	120*	270	-26.1 (52.2)	26
BE21	110*	1000	-24.4 (85.1)	141
BE22	130*	2500	-21.4 (60.1)	70

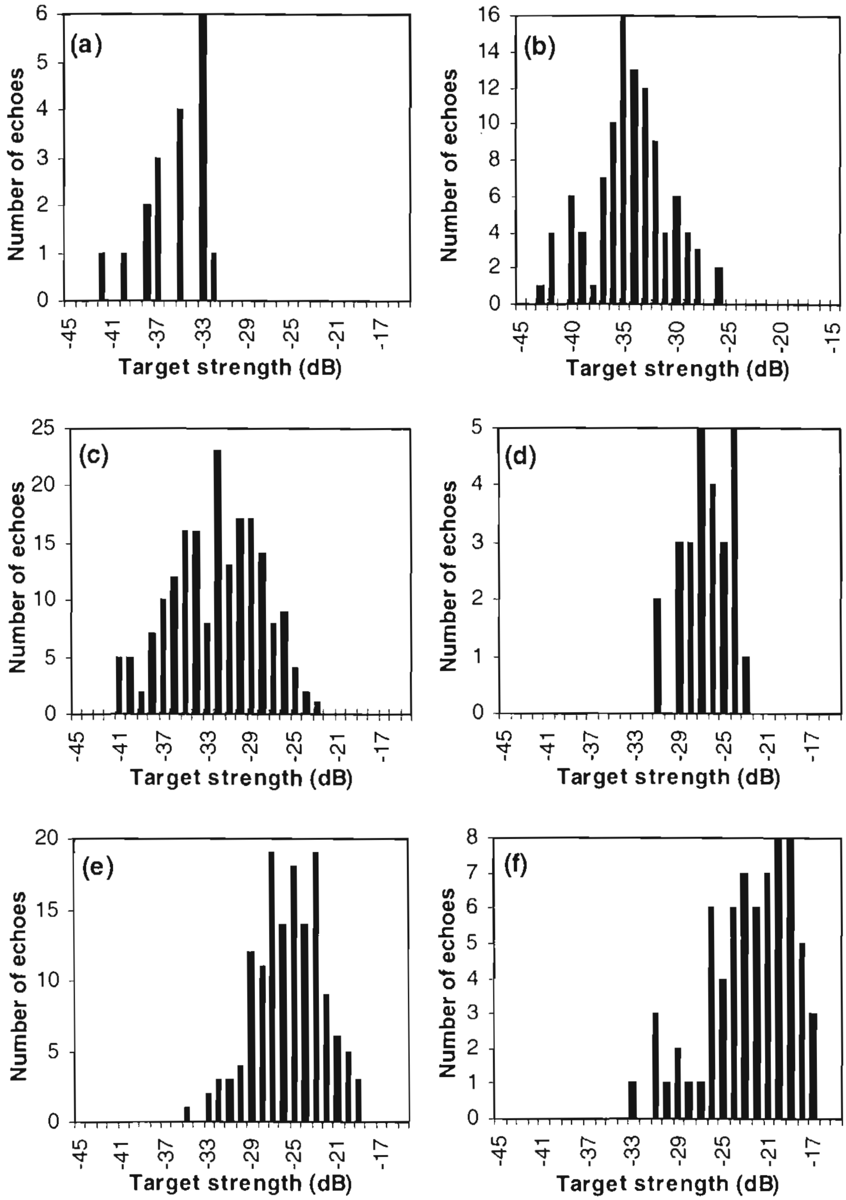

Fig. 3. - Target strength histograms of the tracked fish: Yellowfin tuna (YF) and bigeye tuna (BE). (**a**): YF10. (**b**): YF13. (**c**): YF14. (**d**): YF19. (**e**): BE21. (**f**): BE22.

ter and Batty, 1990; MacLennan and Simmonds, 1992; Misund, 1997). Classic methods of TS analysis do not allow us to determine the respective influence of these factors, which may be particularly important in the case of tuna because those fish often exhibit vertical oscillations (Holland *et al.*, 1990) changing the tilt angle.

The results presented above are insufficient to establish a reliable relationship between tuna length and TS, as it is known that it is much more difficult to establish such a relationship for organisms with a swimbladder than for fish without swimbladder (Koslow *et al.*, 1997). Nevertheless, they show that TS measurement of an identified fish swimming free in its environment is possible. Further observations with the same method, but with TS measurement as a specific objective should lead to this reliable relationship in the future. This method could be extended to other large pelagic fish as billfish.

To conclude, the specificity of this method, which allows the study of acoustic response of a fish moving freely in its environment, opens new horizons in TS research. Observation from the surface to 500 m in depth should allow us to improve our knowledge of depth influence on TS. Furthermore, the acoustic track of a tagged fish could be used to study the relationship between TS and *in situ* fish movements, while tilt angle and the effects of changes in swimbladder volume could be analysed independently. In addition this work provides the first data on *in situ* tuna TS measurements, thus could be used for future acoustic studies for tuna stock assessment.

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