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TOWARDS ACOUSTIC DISCRIMINATION OF TUNA SPECIES AT FADS: MEASURING ACOUSTIC PROPERTIES OF YELLOFIN TUNA

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RESUMEN

Los atuneros cerqueros que pescan túnidos tropicales utilizan boyas geo-localizadoras para seguir las trayectorias de sus dispositivos concentradores de peces (DCPs ó FADs en inglés). Hoy en día, un alto porcentaje de estas boyas están equipadas con eco-sondas, de modo que los pescadores obtienen una estima, a groso modo, de la biomasa asociada a sus DCPs. Actualmente las diferentes boyas con ecosonda que existen en el mercado, no tienen la capacidad de discriminar las especies de túnidos que están asociadas a los DCPs. Poder discriminar las especies asociadas, permitiría a los pescadores evitar zonas de pesca con alta concentración de especies o tallas no deseadas, y permitiría a los científicos obtener observaciones directas de las especies asociadas a los DCPs empleando estas mismas herramientas acústicas. Sin embargo, actualmente tanto pescadores como científicos no pueden discriminar las tres especies de túnidos asociadas a los DCPs, empleando medios acústicos. Esto se debe principalmente, a la falta de información básica sobre la señal acústica de las tres especies de túnidos asociados a los DCPs, es decir, no existe información sobre la fuerza del blanco acústico de cada especie (un valor necesario para convertir la señal acústica en biomasa) y que es indispensable para poder discriminar entre las especies. Actualmente se están llevando a cabo diversas investigaciones para lograr la discriminación acústica de las 3 especies de túnidos. ISSF ha organizado 2 campañas de investigación abordo de atuneros cerqueros faenando en los oceanos Pacífico central y Atlántico, en las cuales se ha podido estudiar la diferente respuesta en frecuencia de el barrilete (*Katsuwonus pelamis*) y del patudo (*Thunnus obesus*). Este documento presenta las investigaciones que se han realizado para obtener las carácterísticas acústicas del rabil (*Thunnus albacares*) para poder después reconocerlo en condiciones reales de pesca empleando los equipos acústicos de los buques atuneros y de las boyas con sonda.

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[3] Inter-American tropical tuna commission, USA

Introduction

Since 2010, ISSF has been organizing research cruises on-board purse seiners to test new ideas on by-catch reduction. Different fleets working with Fish Aggregating Devices (FADs) around the world have participated in cruises that yielded important insights into at-sea methods to mitigate by-catch (Restrepo et al, 2016). In relation with these approaches, ISSF is collaborating with AZTI, University of Hawaii and IATTC to develop acoustic techniques to improve tuna species identification at FADs.

The objective of the cruises on acoustic discrimination were to analyse the *in situ* acoustic properties, i.e. target strength (TS) (Simmonds and MacLennan, 2005) and frequency response (Korneliussen and Ona, 2003), of the three main tropical tuna species observed around FADs, bigeye (*Thunnus obesus*), skipjack (*Katsuwonus pelamis*) and yellowfin (*Thunnus albacares*) tunas. In order to achieve such objective, it was important to insonify each species individually to make sure that the measured acoustic properties corresponded to a single species. In the first two cruises it was possible to analyse almost monospecific aggregations of both skipjack and bigeye tunas, which allowed studying the acoustic properties of these species but there were not found monospecific schools of yellowfin tuna.

Given the low probability of finding isolated yellowfin tuna around FADs, a different approach was essayed to obtain the TS of this species, consisting in stocking a small set of isolated yellowfin tunas in an offshore cage and perform *ex situ* measurements of its acoustic properties. In July 2016 an experiment was conducted to perform the acoustic measurements in the IATTC Laboratory of Achotines in Panamá. A secondary objective was to gather data using different brands of echo-sounder buoys (used by fishers to track FADs) to improve the remote estimates of abundance and size composition of the aggregation. For this purpose, echo-sounder buoys from four different manufacturing brands were used to target the tunas of the cage. This paper describes the methodology followed as well as the work done in IATTC´s Achotines lab.

Material and methods

The research took place in the IATTC Achotines Laboratory from 20th to 30th July 2016, located on the Pacific side of the Republic of Panama. The laboratory has ready access to a provision of yellowfin tuna along the year and is one of the few research facilities in the world designed specifically for studies of the early life history of tropical tuna. An offshore cage of 25 m of diameter and about 20 m depth was deployed about 1 km offshore from Achotines Bay.

Figure 1. Location of the cage with yellowfin tuna outside the Achotines Bay.

Yellowfin tuna fishing activity by IATTC staff started two weeks before the acoustic measurements. Seventeen yellowfin tunas were captured and kept in tanks in the laboratory. The 15th of July the net was placed on the cage and, from this day on, the captured wild fish was directly stocked into the offshore cage. Six yellowfin tunas were fished and transferred to the cage and, from those, four survived and settled in the cage, starting to behave "naturally"[4]. The tuna were fed on a daily basis. Finally, only the tunas that were stocked directly into the cage were used for the acoustic measurements, because the transfer was supposed to cause stress on the new individuals and we preferred to keep less tuna in the cage but more established, in order to make TS measurements on "naturally" behaving tunas.

Initially, other fishes were also found inside the cage that had probably entered the cage through the mesh. A diver was used to remove and fish the bigger ones. However a school of around 200 Cojinuas or Blue runners (Caranx crysos) of around 20 cm long was also found inside the net, those individuals were too numerous and small to be fished. Consequently, the cojinuas were present in the cage along with the tunas during the measurements.

[4] Tunas need some time to get used to the cage and start swimming calmly. This is the behaviour needed to successfully measure acoustic properties of fish.

Scientific echosounders

The acoustic equipment was installed onboard Kihada Maru, a 10 m long fishing boat, which was attached to the side of the cage during the experiment (Figure 2). Another support boat was used to transport the scientists from the laboratory to the Kihada Maru every day.

Table 1: Configuration of the acoustic equipment and calibration parameters

Frequency (kHz)	38	120	200
Pulse duration (us)	512	512	512
Power (W)	1200	150	90
Gain (dB)	21.73	25.17	26.04
SaCorrection (dB)	-0.83	-0.37	-0.31
Ath. Beam Angle (deg)	7.06	6.75	6.51
Along Beam Angle (deg)	7.00	6.74	6.42

A narrowband scientific acoustic echo-sounder Simrad EK60 of frequencies 38, 120 and 200 kHz was installed and routinely used on-board the Kihada Maru (Figure 2). The transducers were installed in a metallic plate deployed at around 0.25 m depth, attached to an arrangement of small buoys to achieve floatability. In addition, a Simrad EK80 wideband system with a 120 kHz frecuency transducer was installed. Both acoustic systems were calibrated before and after the measurements with the sphere method (Foote et al., 1987) using a tungsten carbide ball of 38.1 mm (Table **1**) for the EK60 and a 38.1 plus a 12.1 mm sphere for different portions of the band of the EK80. Both acoustic systems were set up to work simultaneously, pinging alternately through the same 120 kHz transducer with the aid of a multiplexor. A set of two batteries of 12 V and 6 A connected in parallel was used as power supply, which allowed for about 6 hours of continuous operation before replacing the batteries.

Echosounder buoys

Acoustic data was also recorded with echosounder buoys of four different brands: Marine Instruments, Satlink, Zunibal and Thalos. The first buoys to arrive to the cage facilities in Achotines were the Thalos and the Satlink models. These were added to the cage in July 21th and were kept recording until July 26th. The recordings using the Marine Instruments and Zunibal echosounder buoys were done the nights of the 27th and 28th of July.

Acoustic raw data collected with the different buoys will be compared to the species composition and biomass obtained by spill sampling of the catch , to help understanding differences between different buoys' selectivity of by-catch and tuna. The results from these analyses will be presented at a later date.

Figure 2. The offshore cage that contained the tuna. Attached to the cage, the fishing boat “Kihada Maru”, where the acoustic equipment was installed, and the transducers in the middle of the cage.

Biological sampling

After the acoustic measurements, the surviving tunas and a subsample of the cojinuas were fished, and then sized and weighted (Table **2**). We tried to fish and biologically sample the cojinuas contained in the cage, but due to difficulties in the dismantling of the cage, the remaining fish escaped.

The captured tunas and cojinuas were transported, conserved in ice, to a veterinary hospital to perform dorsal and ventral X-rays. The X-rays are expected to provide information about the internal anatomy of both species, especially the size of the swimbladder, helping to interpret the results.

Table 2: Sizes and weigths of the tunas and subsampled cojinuas of the cage.

	yellowfin		cojinúa	
	Size (cm)	Weight (kg)	Size (cm)	Weight (kg)
1	57	2.9	21.5	0.16
2	70.8	3.9	21	0.14
3	45.2	1.52	20	0.14
4	59	3.16	20	0.12
5			21.5	0.16
Mean	58	2.87	20.8	0.144

Preliminary results

The unexpected cojinuas (Blue runner)

Although in the beginning, the presence of another species within the cage was considered a drawback for the acoustic measurements on yellowfin tunas, having that the other species was the cojinua (*Caranx crysos)* resulted in a unique opportunity.

The cojinuas are distributed in the Eastern Atlantic Ocean from Senegal to Angola. Juveniles are found in big schools associated to FADs in the Atlantic Ocean. This schooling species have swim-bladder which makes their acoustic signature strong. A recent research cruise by ISSF in the Atlantic, during May 2016, reported the presence of big schools of cojinuas at FADs (see report of Mar de sergio vessel in the Atlantic 2016):

"the spill sample showed the relevancy of some non-tuna bycatch percentages in the tuna biomass estimation done by buoy providers in dFAD sets. Moreover, it confirmed the high acoustic signal backscattered in the Satlink buoy's echo-sounders most likely caused by Blue Runner (Caranx crysox). Sets 12 (80% of Blue runner in number) and set 33 (56% of Blue runner in number) are examples of sets on dFADs where the buoy's software showed tuna biomass estimations over 40T and then the set yielded 10T of tunas with large percentages in number of individuals of Blue runner. Underwater visual observations confirmed that blue runners seemed to extend their habitat deeper than first 10-20 m layer".

One of the problems of encountering this species at FADs is the fact that their echoes are mistaken from that coming from tunas. Moreover, when small, they are never found in the catch, as they escape through the mesh, which makes even more difficult for fishers the understanding of the acoustic signal coming from a given FAD when cojinuas are present.

Given the importance of better interpreting the acoustic signal coming from tunas and that coming from other species (for tuna biomass estimates and species discrimination) we considered the cojinua as another target of the present study. Thus acoustic measurements and X-Ray images were also proccessed for cojinuas in order to obtain their TS and frequency response.

Acoustic data

The tunas were seen swimming in the cage at different places and depths (Figure 3), but in general, well separated from the cojinuas (Figure 4), mostly because the latter actively avoided the former. Also, given the low abundance of tuna in the cage, they showed clear single target detections, so that *a priori* multiple echoes are not expected in the single target detection algorithm when determining TS-length relationship.

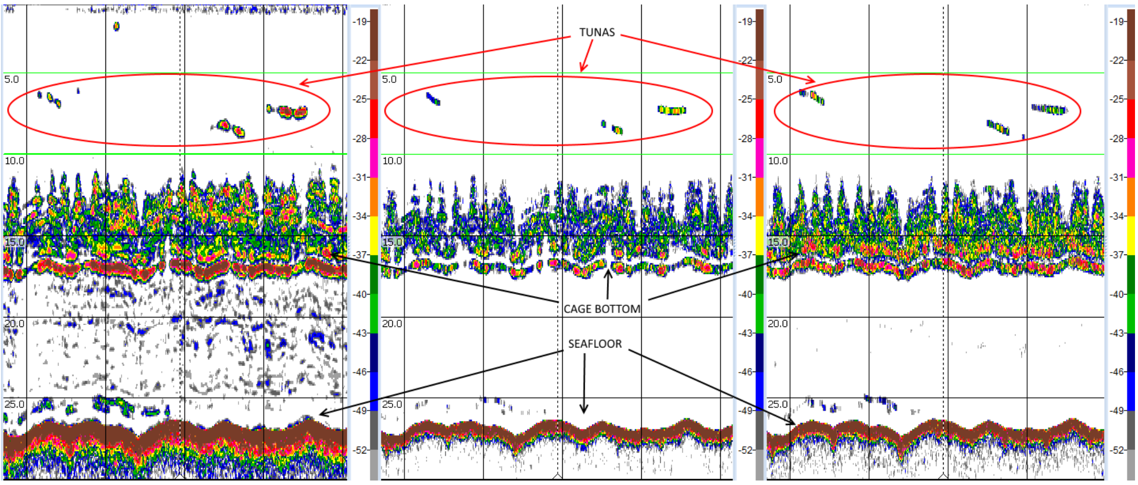

Figure 3. Example of TS echogram showing tunas at the three frequencies 38 (left), 120 (middle) and 200 (right) kHz. The minimum threshold is set at -55 dB.

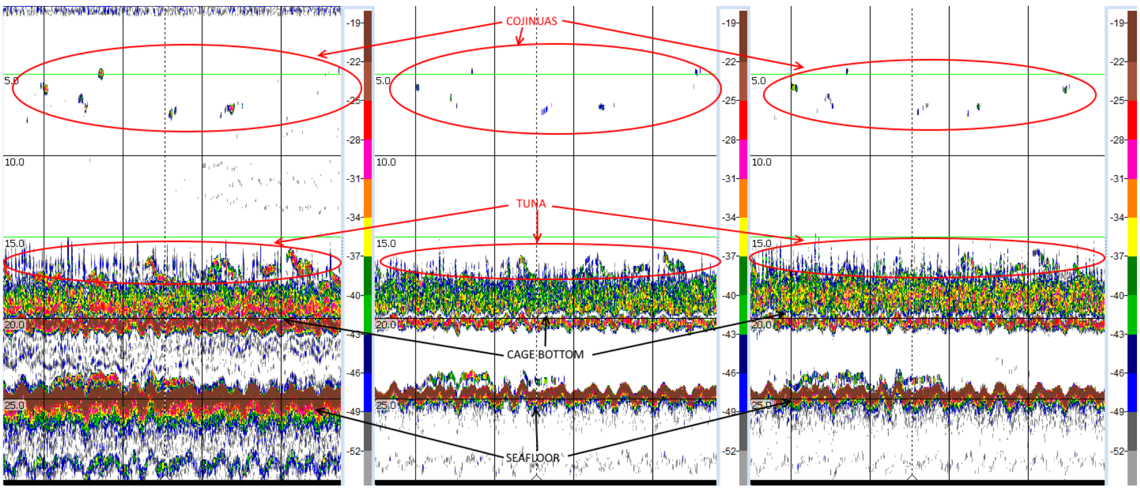

Figure 4. Example of TS echogram showing cojinúas and tunas at the three frequencies 38 (left), 120 (middle) and 200 (right) kHz. The minimum threshold is set at -55 dB.

X-rays

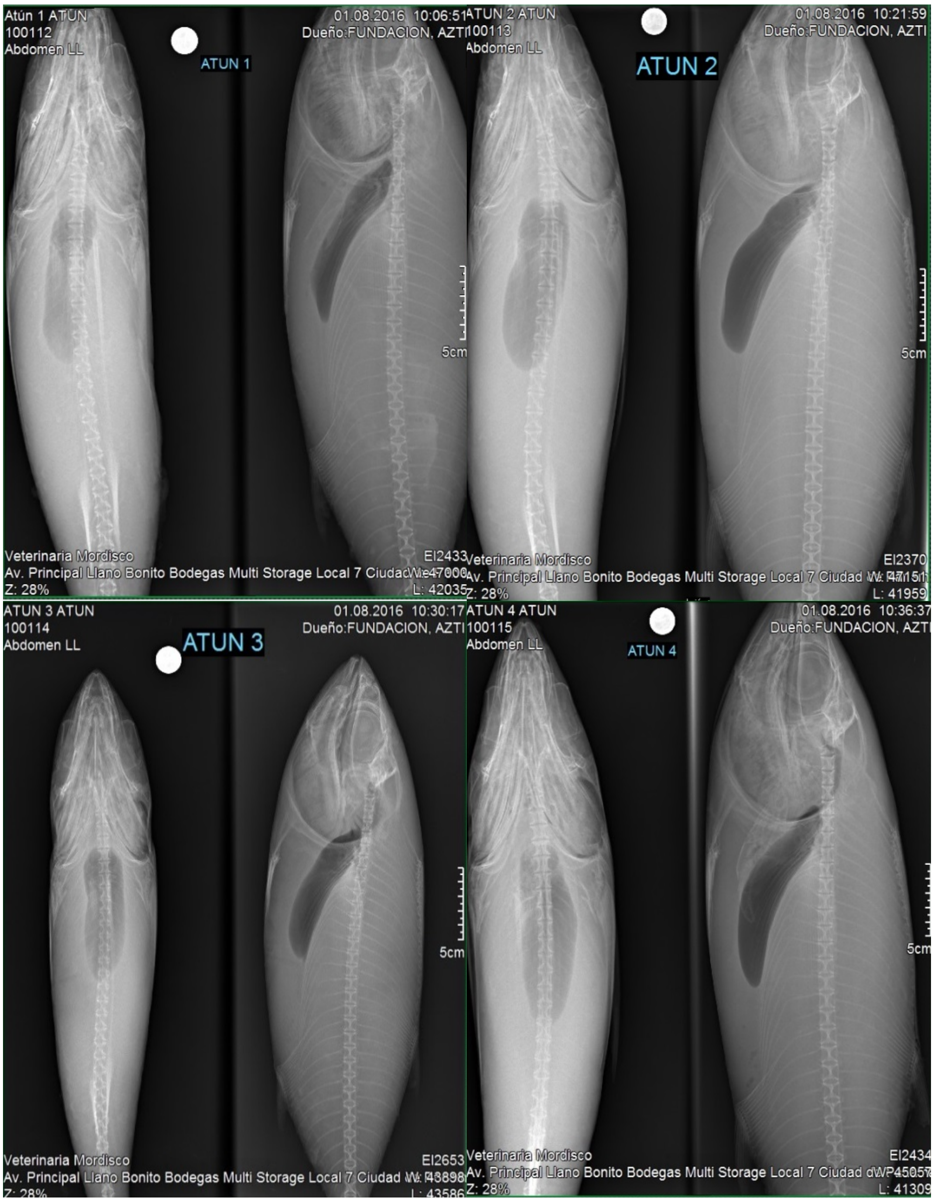

Figure 4. Dorsal and lateral x-rays of the tunas.

The x-rays showed that tunas presented swimbladder length of about 11 cm, that is around 20 % of the tuna body length at dorsal view. For cojinuas, the swimbladder length at dorsal view was about 5 cm, which represented on average about 25 % of the body length. Therefore, the cojinuas have a smaller swimbladder than the tunas, but comparatively bigger with respect to the fish size. This foresees that, even if the TS of the tunas are (likely) higher than that of the cojinuas, the b20 values (i.e., the TS-length relationship) could be higher for cojinua than for tuna.

Figure 5. Lateral and dorsal x-rays of the cojinúas.

Ongoing research

Currently analyses are being conducted to:

- Determinine yellowfin tunas TS-lenght relationship
- Determinine yellowfin tunas frequency response
- Determinine cojinuas TS-lenght relationship
- Determinine cojinuas frequency response

Conclusion

Recently skipjack and bigeye tuna´s acoustic properties have been defined, as well as the potential to discriminate between species with (YFT and BET) and without (SKJ) swimmbladder. Obtaining yellowfin tuna´s acoustic properties would allow in the near future knowing the proportion of each tuna species found at FADs using acoustic equipment onboard purse seiners and also using echo-sounder buoys. This information will be very useful for science, to obtain fishery independent indices of abundance of tunas and to address knowledge gaps on the associate behaviour of species at FADs, as well as to inform fishers on tuna species composition at FADs and help them making sustainable choices when deciding the fishing zone.

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