Towards acoustic discrimination of tuna species at FADs

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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 estudiado la diferente respuesta en frecuencia de las 3 especies de túnidos, muestreando en los DCPs con eco-sondas científicas operando a diferentes frecuencias simultáneamente. El trabajo realizado hasta ahora confirma la capacidad de discriminar las especies de túnidos que tienen vejiga natatoria (bigeye y yellowfin) respecto de las que no tienen vejiga natatoria (skipjack empleando simultáneamente diferentes frecuencias de insonificación. Este documento presenta las investigaciones que se han realizado hasta hoy y las que se realizarán próximamente para lograr la discriminación de las especies de túnidos en los DCPs.

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SUMMARY

Purse seine fishers targeting tropical tuna use geo-locating buoys to track Drifting Fish Aggregating Devices (DFADs). Many of these buoys are now equipped with echo-sounders in order to provide remote information on the aggregated biomass. Nowadays these biomass estimates are not accurate enough to provide information on species composition. Having accurate remote species biomass estimates from DFADs would allow fishers the ability to avoid undesired catches of tunas and non-tuna species as well as allow scientists to make direct observations of species at DFADs. However, fishers and scientists cannot reliably discriminate between the three tuna species found at DFADs using acoustic methods. One of the prerequisites to discriminate species and sizes is to know the target strength (TS) of each tuna species. We investigate tuna species discrimination at DFADs to provide *in situ* and remote species composition, by using 3 echo-sounders operating simultaneously at 3 different frequencies (38 kHz, 120 kHz and 200 kHz) from the workboat of a tuna purse-seine vessel working on DFADs in Central Pacific and Atlantic Oceans. This work has confirmed the potential of using multiple frequencies to discriminate between fish with swim-bladder (yellowfin and bigeye tunas) from fish without swim-bladder (skipjack). We show recently accomplished research to solve acoustic discrimination of tuna species at DFADs and upcoming research in 2016.

Introduction

Often tropical tunas are caught in association with Drifting Fish Aggregating Devices (DFADs), where the main target species is skipjack tuna (*Katsowonus pelamis*) generally mixed with a smaller proportion of bigeye (*Thunnus obesus*) and yellowfin tunas (*T. albacares*) (Fonteneau *et al.*, 2013). DFADs are used in large numbers and an increasing number of buoys to track DFAD trajectories are equipped with echo-sounders in order to provide remote information on the aggregated fish biomass.

Skipjack stocks contribute more than half the global catch of tunas and they are all currently in a healthy situation (ISSF, 2016). However, recent stock assessments for bigeye tuna indicate that overfishing is occurring for this species in some regions. Thus, taking action to avoid catching undesired tuna species and sizes while exploiting healthy stocks of tunas around DFADs is important for the sustainability of tuna populations and viability of fisheries. One of the potential measures to avoid undesired catches of tuna and non-tuna species is to provide information to fishers about the species and size composition beneath the DFADs before making a set. Potentially, remote species discrimination together with appropriate management tools would allow avoiding areas with high occurrence of undesired species and/or sizes at DFADs, thus promoting selective fishing.

Tropical tuna purse seiners have scientific high standard acoustic equipment (Fig.1) including sonars, echo-sounders and echo-sounder-buoys that are used when searching for tropical tunas (Itano 2003; Itano 2007; Moreno et al., 2007). However, the capability of fishers and scientists to discriminate between the principal 3 tropical tuna species (skipjack, bigeye and yellowfin tunas) using this acoustic technology is nowadays very low.

Target Strength (TS) values are used to scale acoustic backscatter into biological units such as biomass. Hence, knowledge about individual TS is an essential requirement for scientists to obtain accurate assessment of fish biomass and fish behavior. For other users, as fishers, TS values can help to discriminate species composition before fishing, thus aiding a more selective fishing. Unfortunately, TS values for tropical tuna are scarce, few studies have analyzed TS on aggregations around FADs (Doray et al., 2006; Josse and Bertrand, 2000; Moreno et al., 2007), *in situ* TS measurements are available for bigeye and yellowfin tunas (Bertrand and Josse, 2000 and Bertrand et al., 1999) but these observations are insufficient to establish a reliable relationship between tuna length and TS. Surprisingly, for the principal tuna species, skipjack, there are no *in situ* TS observations.

In the case of the main tropical tuna species, bigeye and yellowfin have a swim bladder, whereas skipjack do not. Given that the highest contribution to the TS, comes from the swim-bladder (when present), there is a strongly contrasting frequency response between swim bladdered and non-swim bladdered species (Foote, 1980; Korneliussen, 2010). It is possible that the different frequency response of the 3 main tropical tuna species could be applied to distinguish skipjack (non-swim bladdered fish) from bigeye and yellowfin tunas (swim bladdered fish) during DFAD fishing operations.

Fig.1 A captain using the information from the echo-sounders in the bridge

ISSF is sponsoring research to develop a method to discriminate tuna species at DFADs. Main objectives are to gather consistent TS values for the 3 tuna species as well as to work with the frequency response of each species to discriminate between them, by using acoustic improvements for equipment onboard purse seiners and from the echo-sounder buoys.

Acoustic discrimination of tuna species would allow fishers and scientist to improve their estimates of species and size composition of fish aggregations at DFADs. The aim of this technical report is to present a summary of the recent and upcoming research on acoustic discrimination of tuna species at DFADs.

Ongoing research

The method being used to discriminate tuna species is based on the different frequency responses of tropical tunas, i.e. each species presents different TS to different frequencies. Hence, the goal is to investigate the different responses (TS) of skipjack, bigeye and yellowfin tunas to different frequencies used.

In situ Target Strength measurements

To test the potential of multi-frequency acoustics to discriminate tunas and to get *in situ* TS values for the three species, two research cruises have been completed onboard purse seiners fishing with DFADs. The first cruise took place during May 2014 in the central Pacific Ocean and the second one in the Atlantic Ocean during March -April 2016.

For the cruise in the Pacific Ocean, 3 scientific echo-sounders, Simrad EK60 operating at 3 different frequencies, 38, 120 and 200 kHz were installed onboard the "panguita" (i.e. workboat used by purse seiners). For the second cruise in the Atlantic Ocean, it was also used a wideband echo-sounder, Simrad EK80 with split-beam transceiver with operating software for the frequency band from 85 kHz to 170 kHz. Scientist followed the same protocol during the 2 cruises (Fig. 2). In each set, the panguita was attached to the DFAD starting about 10 minutes before the set and remained attached during the purse seiner's set. The transducers were focused vertically downwards, to acoustically

sample the fish aggregation down to 200 m below the surface. In each set, around 60 to 70 minutes of acoustic data were recorded, with approximately 75% of the pings successfully detecting the tuna aggregation.

Spill sampling of the catch was conducted each time acoustic EK60 data was recorded. This was done in order to be able to compare the actual catch species composition with the signals recorded by the echo-sounders. Between 1 and 2 tons of fish were measured in each of these sets. In general, samples were taken every 6th or 7th brail, which provided enough time for the entire sample to be processed before the next sample was chosen. Scientists identified species and measured each fish in the sample to the nearest centimeter on flat measuring boards. The weights of sampled individuals were estimated using length-weight relationships available for each species. These proportions by weight were then extrapolated to the total tonnage of each set, as estimated by the fishing master.

Acoustic sampling   Catch   Spill sampling
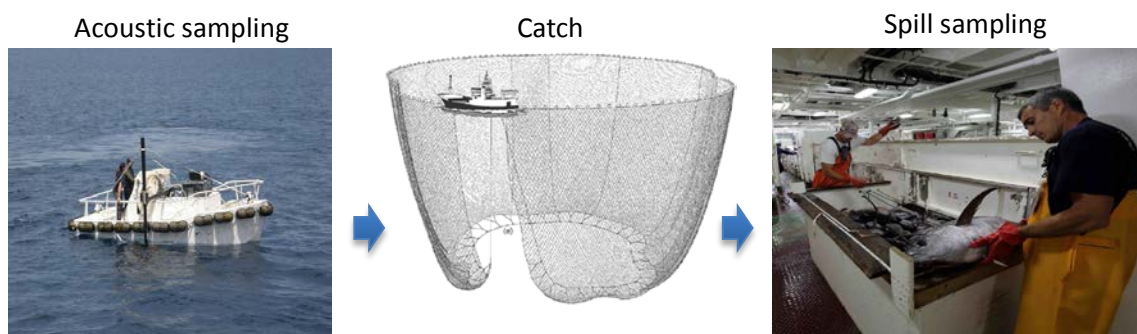

Fig 2. Protocol at sea: Acoustic sampling before the catch and species and sizes sampling after the catch.

A similar protocol was followed to work with echo-sounder buoys by attaching the buoys to the DFAD before the catch. This was to be done upon arrival, the night before to the set. In this way, the echo-sounder would record data throughout the night until the set was made in the morning.
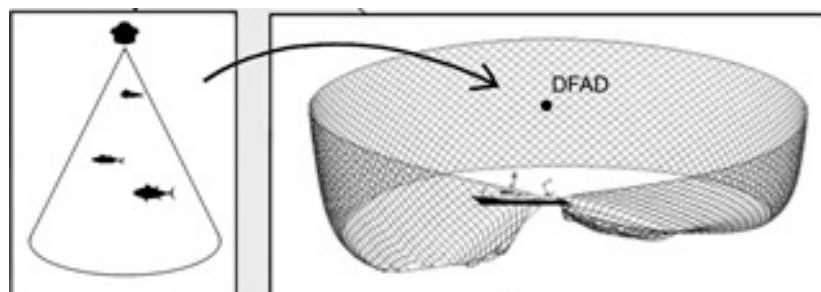

Fig 3. Conceptual drawing of data collection. The different echo-sounder buoys brands where attached to the same DFAD, then the set was conducted to obtain by spill sampling the species composition

Interpretation of Target Strength measurements based on theoretical models

During our research, relationships of TS to tuna length were estimated empirically measuring *in situ* target strength of tunas and deriving fish length from purse seine catches. However, in order to achieve a complete understanding of sound scattering by aquatic organisms it is necessary to combine, empirical and theoretical methods (Henderson and Horne, 2011). Thus, the aim of this theoretical research is using analytical and numerical scattering models to predict acoustic backscatter from the 3 main tropical tuna species (yellowfin, bigeye and skipjack tunas). The target (tuna) shape, anatomy and morphometry are used as input to the models and are obtained through X-rays.

The experiment to obtain accurate data on tunas anatomy and morphometry is being conducted in the Hawaiian Institute of Marine Biology (HIMB). Anchored FADs in Hawaiian waters are used to catch yellowfin and bigeye tunas that are kept in captivity in tanks in Coconut island. In order to provide accurate information on the anatomy and morphometry of tunas, eighty five YFT were captured during multiple fishing trips, of which 25 were placed into captivity at HIMB. Up to date, 16 YFT between 38 – 74 cm FL (the most frequent size at which they are found at FADs), were X-rayed during two sessions and satisfactory dorsal and lateral images of the swim-bladder have been obtained (Fig. 4). To date, although no bigeye tuna have been captured for this experiment, efforts to do so are on-going. Also, thirteen yellowfin tunas are currently being held in captivity to allow them to grow to larger sizes before being X-rayed. Data from this experiment will be used to predict backscatter for target strength of individual scatterers, and to corroborate *in situ* acoustic measurements.
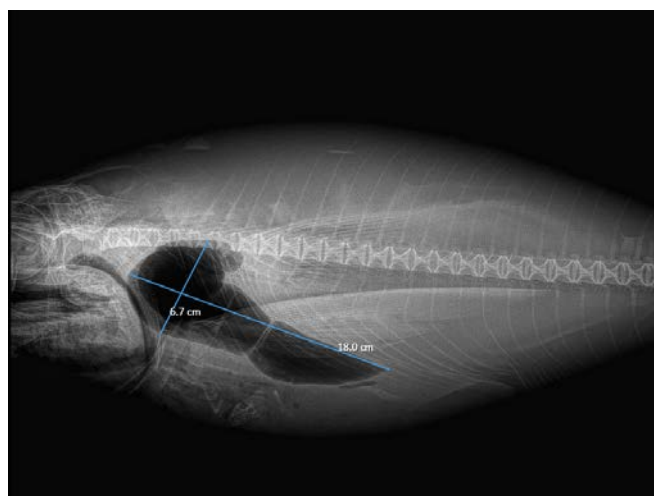

Fig 4. X-ray image of 74 cm yellowfin tuna

Results

Until today, the study has obtained for the first time skipjack tuna and consistent bigeye tuna TS-length relationships for the three different frequencies used (38, 120 and 200 kHz). Regarding frequency response, weaker response was found for the skipjack in the low frequency (38 kHz) compared to the high frequencies (120 kHz and 200 kHz) (Fig 5), in accordance with what has been found in previous studies for other species (Korneliussen, 2010), i.e stronger acoustic backscatter in high frequencies for individuals lacking a swim bladder. In contrast, weaker response was found for bigeye tunas in high frequencies compared to low frequencies (Fig. 6). Given the clearly distinct frequency responses found between skipjack and bigeye tuna species (Fig 5 and 6), the potential of multi-frequency acoustics for tropical tuna discrimination is confirmed. This positive result encourages further research to obtain the acoustic mask needed for tropical tuna discrimination, which would allow, in the near future, informing fishers on the proportion of tuna species at FADs before setting.
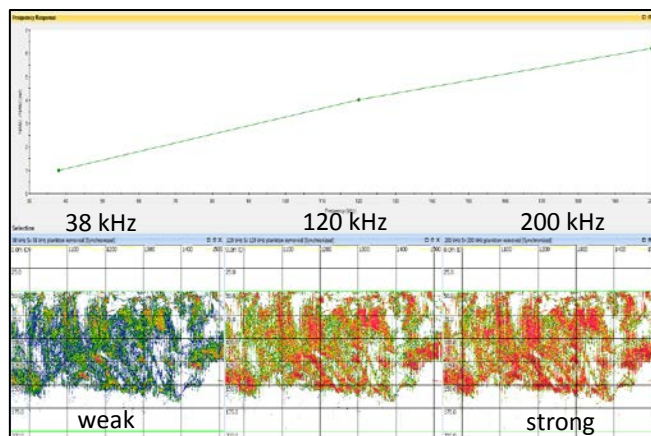

Fig 5. Frequency response of sSkipjack tuna where weak response can be observed in the low frequency (38 kHz, on the left) compared to high frequencies (120 and 200 kHz, on the right).
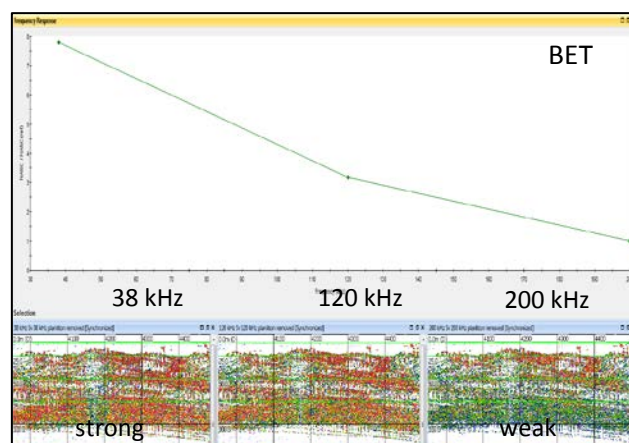

Fig 6. Frequency response of bBigeye tuna where strong response can be observed in the low frequency (38 kHz, on the left) compared to high frequencies (120 and 200 kHz, on the right)

Upcoming research

Ex situ TS of yellowfin tunas

During the research cruises, TS of tunas were measured from biological targets in their natural environment (i.e., *in situ*), however, TS can be also measured in controlled experimental conditions (i.e., *ex situ*). Skipjack and bigeye tunas TS were gathered *in situ* at DFADs but in order to discriminate between the 3 tuna species found at DFADs, TS of yellowfin tuna is also needed.

The objective of the next research activity is studying acoustic properties of yellowfin tunas. On one hand measuring acoustic TS related to the length and behaviour of the individuals, and on the other hand studying frequency response of yellowfin tunas.

The experiment will be conducted with yellowfin tunas in captivity in an off-shore sea cage in the IATTC laboratory in Achotines, Panama. TS will be measured together with images of tuna behaviour, so that TS measurements can be related to the fish length and behaviour. Yellowfin tunas will be approximately 40-60 cm in length, one of the most common sizes at which yellowfin tunas are found in DFADs in association with skipjack and bigeye tunas.

The protocol would comprise working with 4 different echo-sounders, 3 Simrad Ek60 operating at 3 different frequencies (38, 120 and 200 kHz) and a wide-band, Simrad EK80 with split-beam transceiver with operating software for the frequency band from 85 kHz to 170 kHz. Echo-sounder buoys of 4 different brands will be also used to measure the signal received by the echo-sounder buoy from a known target (tunas in the tank). Echo-sounders will be placed floating in the sea-cage (Fig. 7) and simultaneously to echo-sounder recordings tuna behaviour images will be recorded through cameras.
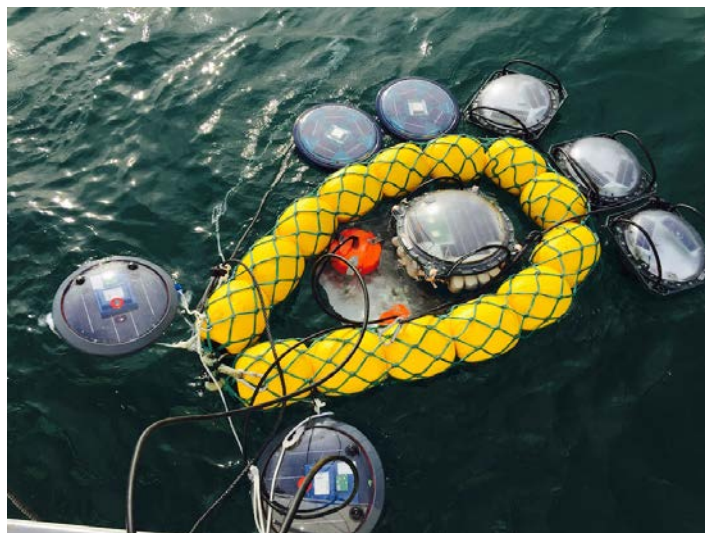

Fig 7. Example of Scientific echo-sounders and echo-sounder buoys sampling

Conclusion

The different frequency response found for skipjack and bigeye tunas, confirms the potential for tuna species discrimination at DFADs, by using simultaneously multiple frequencies incorporated to fishing acoustic equipment.

The methodology for tropical tuna discrimination could be incorporated in vessels' acoustic equipment available to commercial purse seiners fishing on DFADs, as some purse seiners already use directional echo-sounders (which currently lack tuna discrimination capability) to examine FADs before fishing . However, the most efficient option would be the ability to remotely assess species composition using echo-sounder buoys attached to FADs so that fishers could avoid lengthy transits to areas and DFADs having a high proportion of tunas of undesirable size or species of conservation concern, i.e. bigeye tuna in some regions.

The knowledge acquired in this study will be shared with fishers through ISSF skipper workshops, scientists, and buoy manufacturers to ensure that the acoustic selectivity of tuna species at DFADs can be achieved in the near future by all. Finally, working with managers to develop management measures using these outcomes will be an important step towards the sustainability of tuna stocks using selective technology.

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