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TOWARDS ACOUSTIC DISCRIMINATION OF TUNA SPECIES AT FADS

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SUMMARY

Purse seine fishers targeting tropical tuna use geo-locating buoys to track Fish Aggregating Devices (FADs). 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. We investigate tuna species discrimination at FADs 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). Preliminary target strength (TS) for Skipjack tunas were obtained for the different frequencies used and a frequency response mask investigated to discriminate between species. 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 discuss the potential of acoustics for both, to mitigate by-catch and undesirable sizes of tuna species and to improve our knowledge on the ecology and abundance of tunas.

RÉSUMÉ

Les pêcheurs à la senne ciblant les thonidés tropicaux utilisent des bouées géolocalisées afin de suivre les dispositifs de concentration des poissons (DCP). Un grand nombre de ces balises sont actuellement équipées d'échosondeurs afin de fournir des informations à distance sur la biomasse agrégée. À l'heure actuelle, ces estimations de la biomasse ne sont pas assez précises pour apporter des informations sur la composition par espèce. On a étudié la distinction entre les espèces thonières à l'endroit du DCP fournissant la composition par espèce in situ et à distance au moyen de trois échosondeurs opérant simultanément à trois fréquences différentes (38 kHz, 120 kHz et 200 kHz). La réponse acoustique préliminaire dans le cas du listao a été obtenue pour les différentes fréquences utilisées et un masque de réponse de fréquence a été étudié afin de distinguer les espèces. Ces travaux ont confirmé le potentiel de l'utilisation de fréquences multiples pour faire la distinction entre les poissons pourvus de vessie natatoire (albacore et thon obèse) et les poissons qui en sont dépourvus (listao). Le présent document aborde le potentiel des informations acoustiques en vue d'atténuer la prise accessoire et les tailles non souhaitées d'espèces thonières et d'améliorer nos connaissances sur l'écologie et l'abondance des thons.

RESUMEN

Los pescadores de cerco que dirigen su actividad a los túnidos tropicales utilizan boyas de geolocalización para rastrear los dispositivos de concentración de peces (DCP). Muchas de las boyas de los DCP están ahora equipados con ecosondas para proporcionar información remota sobre la biomasa concentrada. Actualmente, estas estimaciones de biomasa no son lo suficientemente precisas para proporcionar información sobre la composición por especies. Se investiga la discriminación por especies de túnidos en los DCP para proporcionar in situ y de manera remota la información sobre la composición por especies, utilizando tres ecosondas que operan simultáneamente en 3 frecuencias diferentes (38 kHz, 120 kHz y 200 kHz). Se obtuvo la respuesta acústica (TS) preliminar para el listado para las diferentes frecuencias utilizadas y se creó una máscara de respuesta en frecuencia para discriminar entre especies. Este trabajo confirmó el potencial de usar frecuencias múltiples para discriminar entre los peces con vejiga natatoria (rabil y patudo) y los peces sin vejiga natatoria (listado). Se debate

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el potencial de las técnicas acústicas tanto para mitigar la captura fortuita y la captura de tallas no deseadas de especies de túnidos como para mejorar nuestros conocimientos sobre la ecología y abundancia de los túnidos.

KEYWORDS

FAD, echo-sounder buoy, tuna, target strength,
acoustic discrimination, abundance, frequency response

1. Introduction

The target strength (TS) value is a chief magnitude used to scale active hydro-acoustic data into biological units such as abundance. 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 increasing the selectivity.

Tropical tunas are caught at FADs, where the main target species is skipjack tuna (*Katsowonus pelamis*), which is most of the time found, at different proportions, together with 2 other tuna species, bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacares*). Skipjack stocks contribute more than one half of the global catch of tunas and they are all in a healthy situation. However, recent stock assessments for bigeye tuna indicate that overfishing is occurring for this species in Pacific Ocean. About 58 percent of the world production of tuna is from the western and central Pacific Ocean. For these reasons, taking action to avoid catching undesired tuna species around FADs, is of most importance for the sustainability of this fishery.

Tropical tuna purse seiners have scientific-degree acoustic equipment, sonars, echo-sounders and echo-sounder-buoys that are used when searching for tunas (**Figure 1**). However, the capability of fishers and scientists to discriminate these 3 tuna species (skipjack, bigeye and yellowfin tunas) at FADs is nowadays very low. One possible way to discriminate between tuna species is by knowing the TS of each species and, specially, making use of possible difference in frequency response of the different species, if any.

In the case of the species of tunas caught around FADs, two of the species (bigeye and yellowfin) have a swimbladder, whereas the third one (skipjack) does not have swimbladder. Given that the highest contribution to the TS is given by the swimbladder, there is normally a contrasting different frequency response between swimbladdered and non-swimbladdered species. This is potentially a source of discrimination between species that has been applied in other cases, for example Norwegian mackerel (Korneliussen, 2010) and could be applied to distinguish skipjack from bigeye and yelllowfin.

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.*, 2008). *In situ* TS measurements for bigeye and yellowfin tunas were obtained by Bertrand and Josse (2000) and (Bertrand *et al.*, 1999), but these observations were insufficient to establish a reliable relationship between tuna length and TS. For skipjack tuna there is currently no *in situ* TS observations but *ex situ* observations made by (Oshima, 2008).

This paper presents undergoing research on tuna discrimination at FADs and preliminary frequency response of skipjack tuna at three different frequencies (38, 120 and 200 kHz) with the aim of working towards acoustic selectivity of the different tuna species found at FADs.

2. Material and methods

2.1 Data collection

Scientific acoustic equipment was carried onboard a commercial tuna fishing cruise in the central Pacific Ocean. The cruise took place during one month in May 2014 onboard the purse seiner F/V ALBATUN TRES, a 115 m Spanish purse seiner built in 2004 with 4,406 GT (2,260 tons carrying capacity). The cruise started in Christmas (Kiribati Is.) on May 3rd and ended in Tarawa (Kiribati Is.) on May 31st (**Figure 2**). The activity included daily purse seines around drifting FADs (Figure 2), followed by intensive spill sampling to compare acoustic data and species composition. In total, 27 sets were made, 26 of which were on drifting FADs (dFADs), and one on a free school.

A split-beam scientific echo-sounder Simrad EK60 working at 38, 120 and 200 kHz frequencies was installed onboard the “panguita” (i.e. work boat, **Figure 3**). The system was installed about 1 m depth. The acoustic parameters were pulse duration 512 us, ping rate of around 0.25 s and powers of 1200, 200 and 90 W for the 38, 120 and 200 kHz respectively, recording data down to 200 m depth. The acoustic equipment was calibrated following the methodology of Foote (1987) using a tungsten carbide sphere of 38.1 mm. During the cruise, the acoustics was used in 20 of the 27 sets. In each of these sets, the panguita was attached to the dFAD starting about 10 minutes before the set and remained attached during the purse seiner’s set. During the first part of the set, the panguita drifted with the dFAD and, afterwards, it moved slowly to keep the dFAD separated from both the net boundaries and the purse seiner. 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.

2.2 Data analysis

Spill sampling of the catch was done in each set at which acoustic EK60 data was recorded, in order to allow acoustic analysis to convert acoustic backscatter into skipjack, bigeye and yellowfin proportion at each set. Between 1 and 2 tons of fish were measured in each of these sets using a fiberglass box of dimensions 110cm x 70cm x 100cm (approximately 0.8 ton capacity, **Figure 4**). Spill samples were selected randomly during each set to avoid bias. In general, samples were taken every 6^{th} or 7^{th} 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. The sets with more than 90 % of skipjack were selected for acoustic analysis in order to extract its TS-length relationship and acoustic frequency response characteristics.

The Simrad EK60 acoustic data were backed up and then pre-processed using Echoview (Myriax inc.). The pre-processing included the following steps:

- Draw upper and lower (200 m or net) exclusion lines
- Spikes (interferences) filtering
- Wave-induced gap filtering
- A Resonant Scatterers Filter (RSF)

The single target detection filter for split beam echosounder in Echoview (Myriax, inc.) was applied, followed by a stochastic TS analysis. A variation of the method proposed by MacLennan and Menz (1996) was applied for matching the TS distributions and fish size histograms to determine the TS-L relationship, but assuming a normal (instead of a Rayleigh) scattering distribution for the TS values. The TS-L relationships were estimated with the light of the “panguita” on and off (with and without light). A slope of 20 was assumed in the TS-L relationship:

$$TS = 20 \log(L) + b20$$

Being L the tuna body length in cm.

3. Results

From all the sets of the cruise, sets number 24, 26 and 27, had a percentage of skipjack above 90 % and were selected for the acoustic analysis. Left panels in figure 5, show the raw s_v echograms at the three working frequencies, showing a resonant scatterer layer below the skipjack aggregation. Panels in the middle, show the s_v echograms filtered with the RSF with the threshold at -65 dB, removing the resonant scatterer layer. Panels on the right show the RSF-filtered single target TS echogram effectively removing the single targets from the plankton layer.

The single target detection algorithm was applied on the single target filtered TS echograms with and without RSF. The RSF was able to effectively remove the plankton, thus extracting monomodal *in situ* TS distributions from overlapping multimodal ones. The RSF showed an improved performance over the “classic” single frequency threshold filter, that is only able to cut each distribution at a given TS value, distorting the distribution fish TS without being able to completely remove plankton TS values.

The study obtained first Skipjack and consistent Bigeye tuna TS-length relationships for the three different frequencies used. Also, clearly distinct frequency responses were found between Skipjack and Bigeye tuna species (Figure 6).

4. Conclusion

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 species discrimination. This methodology for tropical tuna discrimination could be incorporated in acoustic equipment available to commercial purse seiners fishing on FADs, as some purse seiners already use directional echo-sounders to examine FADs before fishing, and echo-sounder buoys working at different frequencies, but that lack tuna discrimination capability.

Incorporating this discrimination capability, would allow, in the near future, informing fishers on the proportion of tuna species at FADs before setting. Likewise this information on species and sizes composition at FADs from echo-sounder buoys would provide scientist with indices of abundances by species, independent from the fishery.

Next steps towards acoustic discrimination:

- Measure TS values for Yellowfin tuna
- Build the discrimination mask using multiple frequencies
- Share this knowledge with fishers, scientists and buoy manufacturers
- Work with managers to develop management measures using these outcomes.

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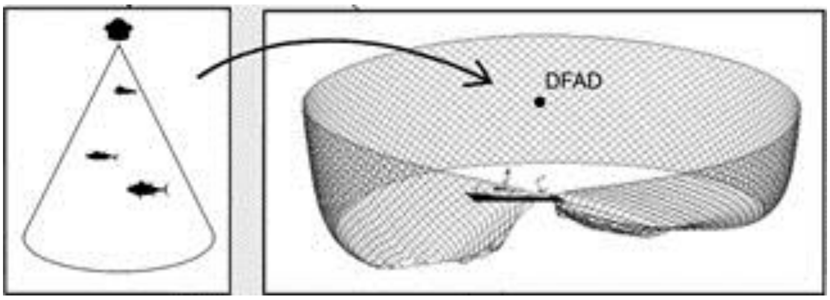

Figure 1. Conceptual drawing of the purse seine fishery operation around dFADs.

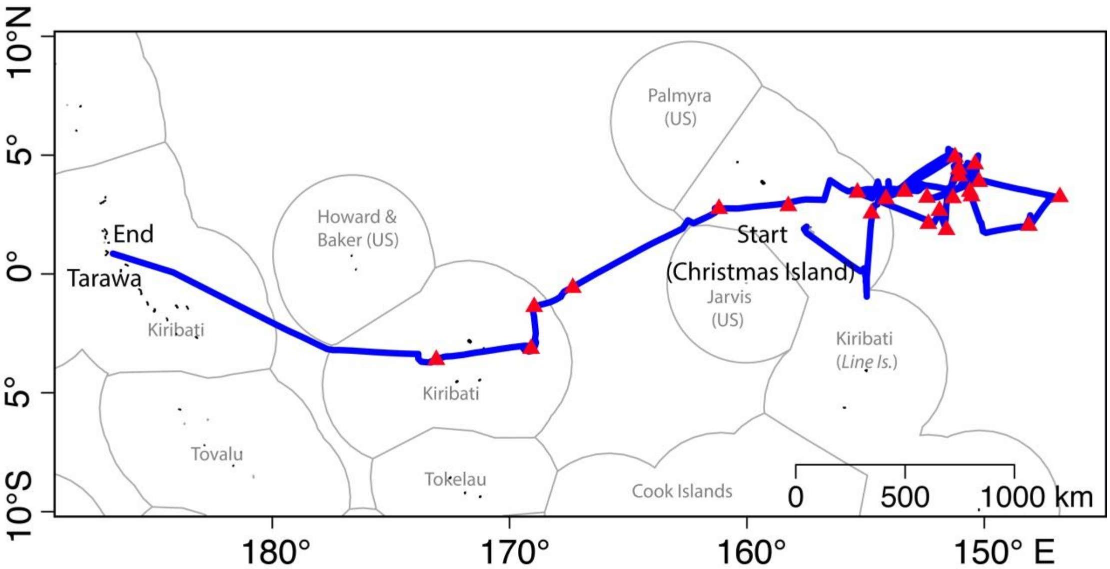

Figure 2. Map of cruise track (blue line) and set locations (red triangles) aboard the F/V Albatun tres.

Figure 3. Scientific echo-sounders installed on the work boat ("panguita").

Figure 4. Size and species composition in the lower deck.

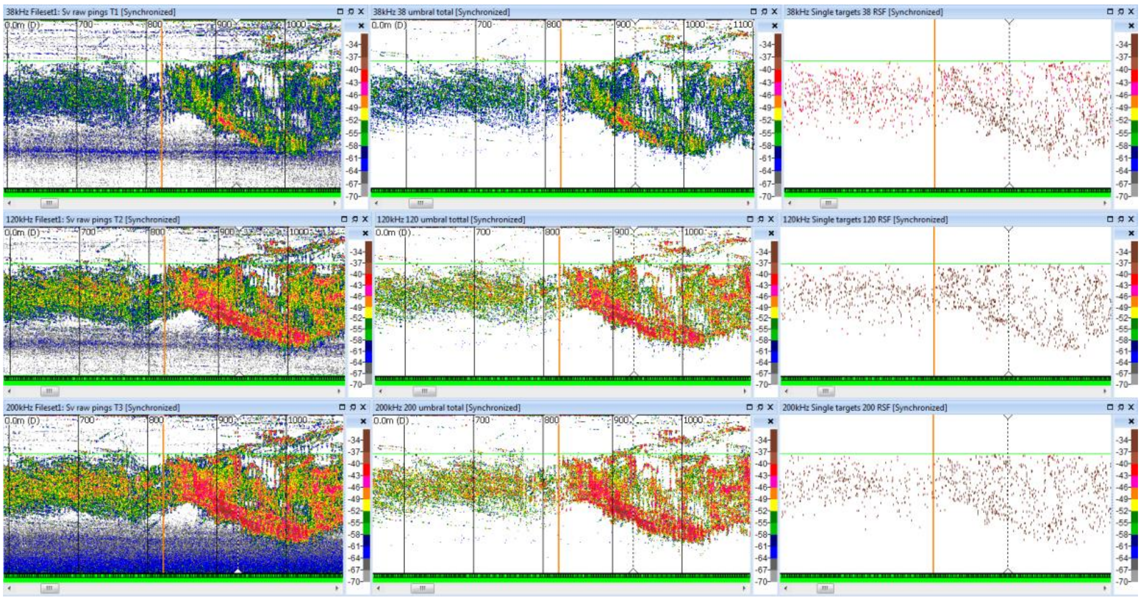

Figure 5. Echogram example corresponding to set number 24.

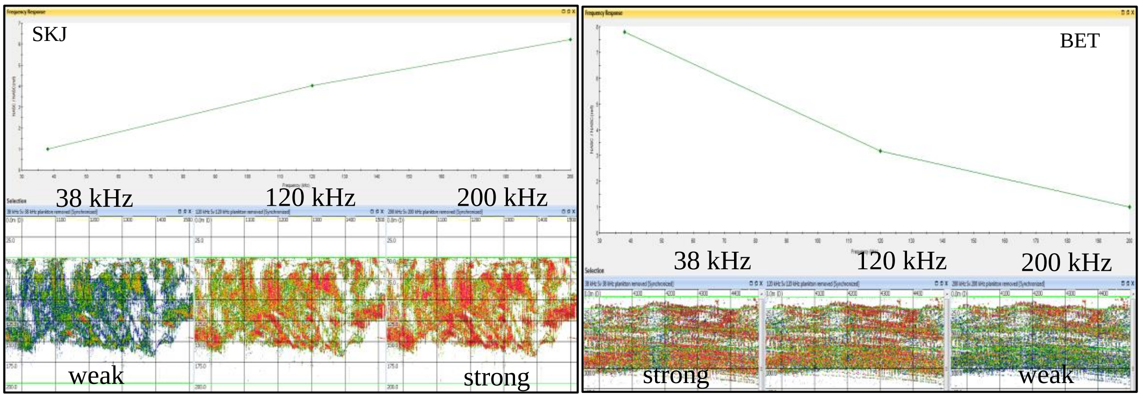

Figure 6. Example of frequency response of skipjack (non-swimbladdered fish, left) and bigeye (swimbladdered fish, right) tunas during the survey.