ESTIMATION OF TS AND ACOUSTIC DISCRIMINATION OF SKIJPACK TUNA AROUND FADS

PACS: 43.30.Vh Sistemas de sonar activo

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ABSTRACT

The objective of this work is to analyze the acoustic response properties of the main species of tuna found in tropical waters from data collected around drifting Fish Aggreggating Devices (FAD). This analysis has a double objective. On one hand the determination of the in situ target strength (TS) allows the conversion of acoustic backscattering to abundance estimations. On the other hand, the comparison of acoustic backscattering at different frequencies provides the acoustic frequency response characteristic of each species, which can be used to distinguish between species based on purely acoustic methods.

RESUMEN

El objeto de este trabajo es analizar las propiedades de respuesta acústica (es decir TS o "target strength") de las principales especies de túnidos presentes en aguas tropicales, a partir de datos acústicos registrados en las inmediaciones de DCPs (Dispositivos Concentradores de Peces). Este análisis persigue un doble objetivo. Por un lado la determinación *in situ* del TS permite convertir los registros de retro-dispersión acústica en estimaciones de abundancia. Y, por otro, la comparación de valores de TS a distintas frecuencias, proporciona la respuesta en frecuencia característica de cada especie, que puede emplearse para distinguir entre especies a partir de métodos puramente acústicos.

INTRODUCTION

The target strength (TS) value is a chief magnitude in fisheries acoustics used to convert 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 of the fishery.

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 juvenile 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 and fishing tunas (Fig 1). However, the capability of fishers and scientists to discriminate these 3 tuna species (skipjack, small bigeye and small 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 in the Pacific Ocean, two of the species (bigeye and yellowfin) have a swimbladder, whereas the third one (skipjack) lacks this organ. 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 a potential 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 yellowfin.

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 first *in situ* TS values for skipjack tuna observed at FADs in the Pacific Ocean at three frequencies (38, 120 and 200 kHz) with the aim of working towards acoustic selectivity of the different tuna species found at FADs.

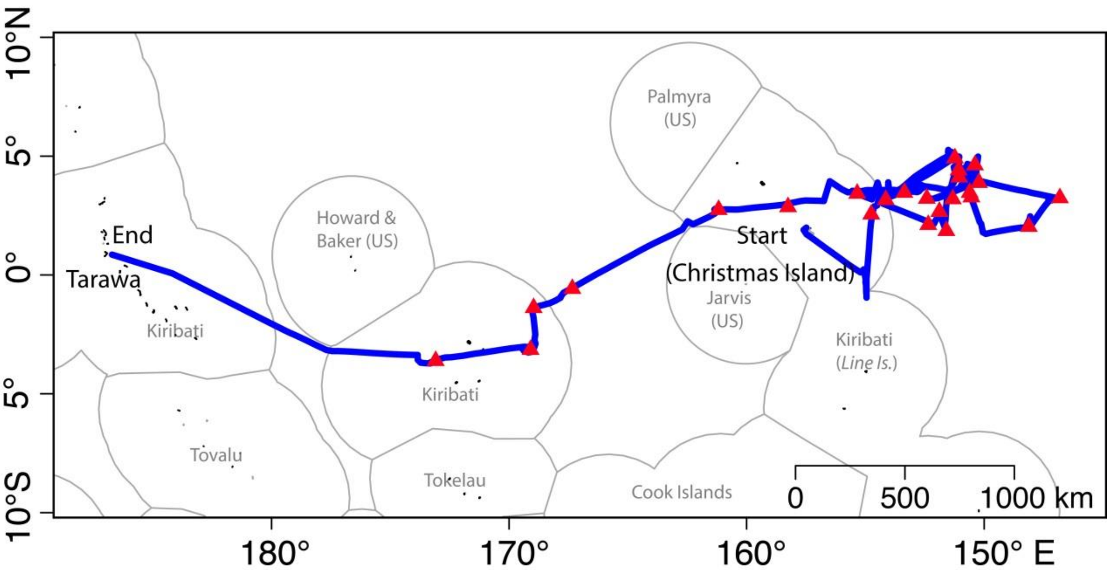

Figure 1. Map of cruise track (blue line) and set locations (red triangles) aboard the F/V ALBATUN TRES.

MATERIAL AND METHODS

Data Collection

A scientific acoustic equipment was carried onboard a commercial tuna fishing cruise in the central Pacific Ocean. The cruise took place for 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 1**). 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.

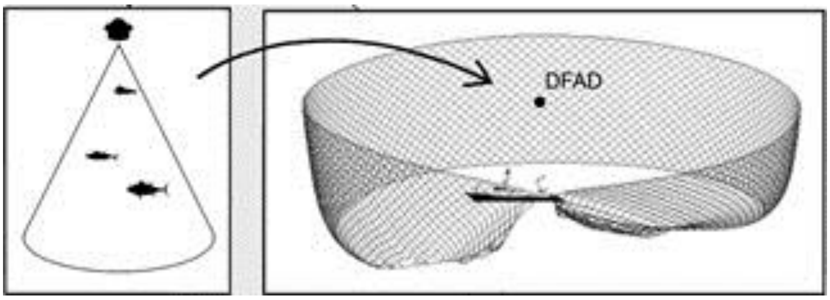

Figure 2. Conceptual drawing of the purse seine fishery operation around dFADs.

A split-beam acoustic echo-sounder Simrad EK60 of frequencies 38, 120 and 200 kHz was installed onboard the “panguita” (one of the small work boats onboard the purse seiner, Figure 3). The system was installed about 1 m depth. The main acoustic parameters were: pulse duration 512 us, ping rate of around 0.25 s and power of 1200, 200 and 90 Watts for the 38, 120 and 200 kHz respectively. The data were recorded down to 200 m depth. The acoustic equipment was calibrated following the methodology of Foote (1987) using a single tungsten carbide sphere of 38.1 mm for the three frequencies, using a nominal TS value for the sphere of -42.3, -40.0 and -39.9 dB for 38, 120 and 200 kHz respectively (Simmonds and Maclennan, 2005). 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 seine set. During these minutes, lights were off but, after that, the panguita focused bright light to the water to attract the tuna aggregation just before the start of the purse seine operation. In the first part of the operation, 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. In each set, around 60 to 70 minutes of acoustic data were recorded, with approximately 75% of the pings successfully detecting the tuna aggregation. Normally, we obtained about 10 minutes of recordings without light and about 1 hour of recording with light.

Data Analysis

Spill sampling of the catch was done in each set at which acoustic EK60 data was recorded, in order to obtain the species and size composition of the catch that allows the conversion of acoustic backscatter into skipjack, bigeye and yellowfin abundances. 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). Spill samples were selected randomly during each set to avoid bias. 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. 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.

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

The Simrad EK60 acoustic data were backed up and then pre-processed using Echoview (Myriax inc.). The pre-processing included the following steps: (i) Draw upper and lower (200 m or net) exclusion lines (ii) Spikes (interferences) filtering and (iii) Wave-induced gap filtering.

A *Resonant Scatterers Filter* (RSF) was applied to remove the resonant scatterers layers of the echograms. The filter is a mask, i.e., a matrix bitmap with the same dimension (number of rows and columns) as the acoustic echograms, which works by blocking the “pixels” (or acoustic samples) that have a backscattering value below a threshold of -65 dB. The cells of the mask have a value of 1 if the corresponding pixel at any of the frequencies of the s_v echogram is higher than the threshold and a 0 value if it is lower than the threshold. The idea is that only the pixels with high values in all the frequencies simultaneously (typically fish) will pass the filter. The pixels that have low values in all the frequencies or have high values in only one of the echograms (i.e., the “resonant” layers; typically plankton) will be removed. The same filter was applied to the TS echograms of the three frequencies (38, 120 and 200 kHz).

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-length relationship, but assuming a normal (instead 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-length relationship:

$$TS = 20 \log(L) + b_{20},$$

being L the fish body length in cm.

RESULTS

Sets number 24, 26 and 27 had a percentage of skipjack above 90% and were selected for the acoustic analysis. An example of the result of the application of the RSF on the echograms of set 24 is shown in Figure 4. The left panels show the raw s_v echograms at the three frequencies, showing a resonant scatterer layer below the skipjack aggregation. The center panels show the s_v echograms filtered with the RSF with the threshold at -65 dB, removing the resonant scatterers (plankton) layer. The right panels show the RSF-filtered single target TS echogram effectively removing the single targets from the plankton layer.

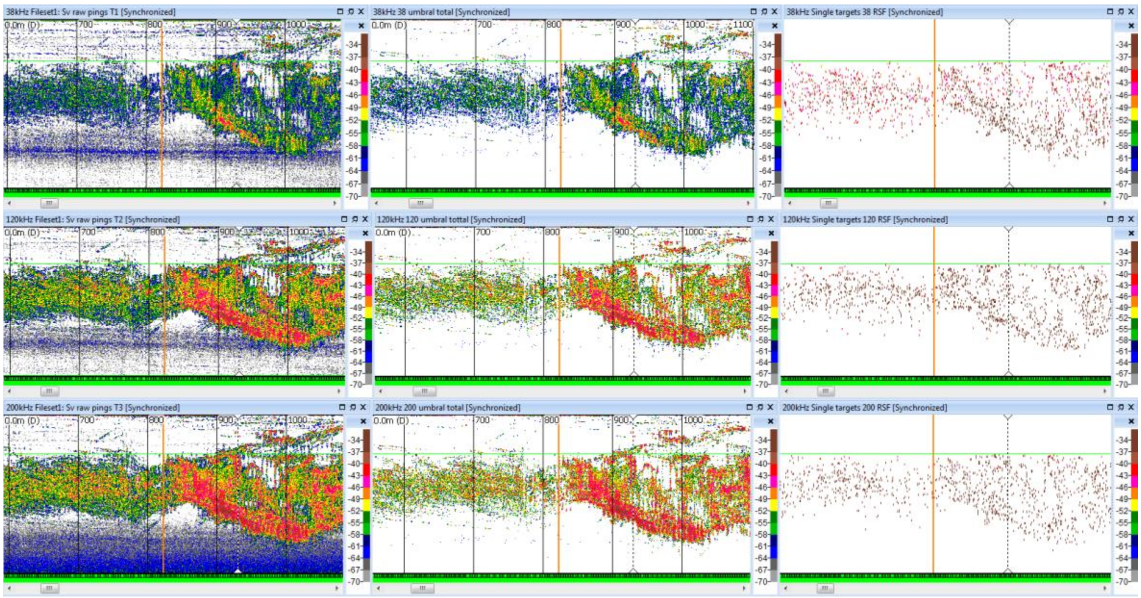

Figure 4. Echogram example corresponding to set number 24.

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 (Figure 5). 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 the plankton TS values.

The match of the expected versus observed single target TS distributions provided good agreement (Figure 6, with coefficient of determinations between 67 and 92 % (Table 1). The average TS-length relationships for skipjack and for the three frequencies are shown below.

With light:

$$TS38 = 20 \log(L) - 69.49$$
$$TS120 = 20 \log(L) - 62.76$$
$$TS200 = 20 \log(L) - 60.85$$

Without light:

$$TS38 = 20 \log(L) - 73.95$$
$$TS120 = 20 \log(L) - 67.65$$
$$TS200 = 20 \log(L) - 65.82$$

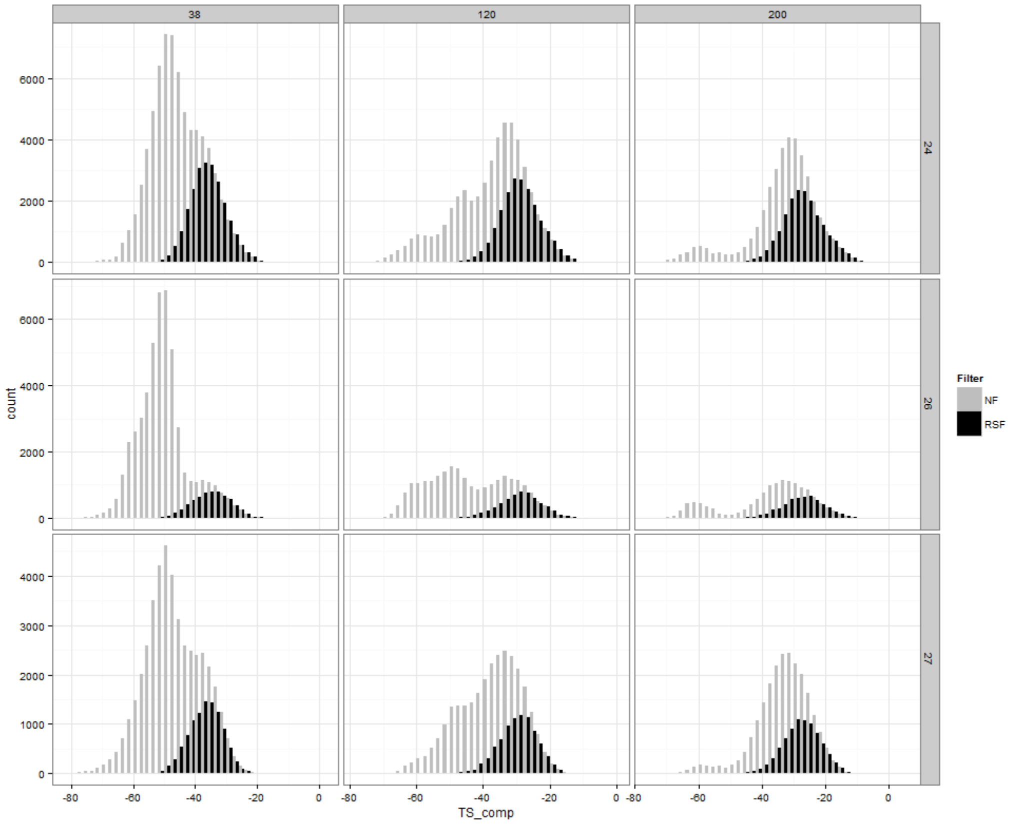

Figure 5. Comparison of the histograms of the distribution of in situ TS values with (RSF) and without (NF) Resonant Scatterer Filtering per set and frequency.

Table 1. Optimized b20 values per set and light conditions.

set	light	freq	b20	sd	R2
24	1	38	69.5	5	89.8
24	1	120	62.4	5	87.0
24	1	200	60.6	5	78.7
26	1	38	69.1	5	75.4
26	1	120	63.1	5	82.1
26	1	200	61.3	5	75.0
27	1	38	69.8	5	92.3
27	1	120	62.8	5	89.3
27	1	200	60.7	5	89.2
24	0	38	73.1	3	83.3
24	0	120	66.5	3	81.8
24	0	200	64.7	3	83.8
27	0	38	75	3	67.4
27	0	120	68.9	3	75.7
27	0	200	67.1	3	73.8

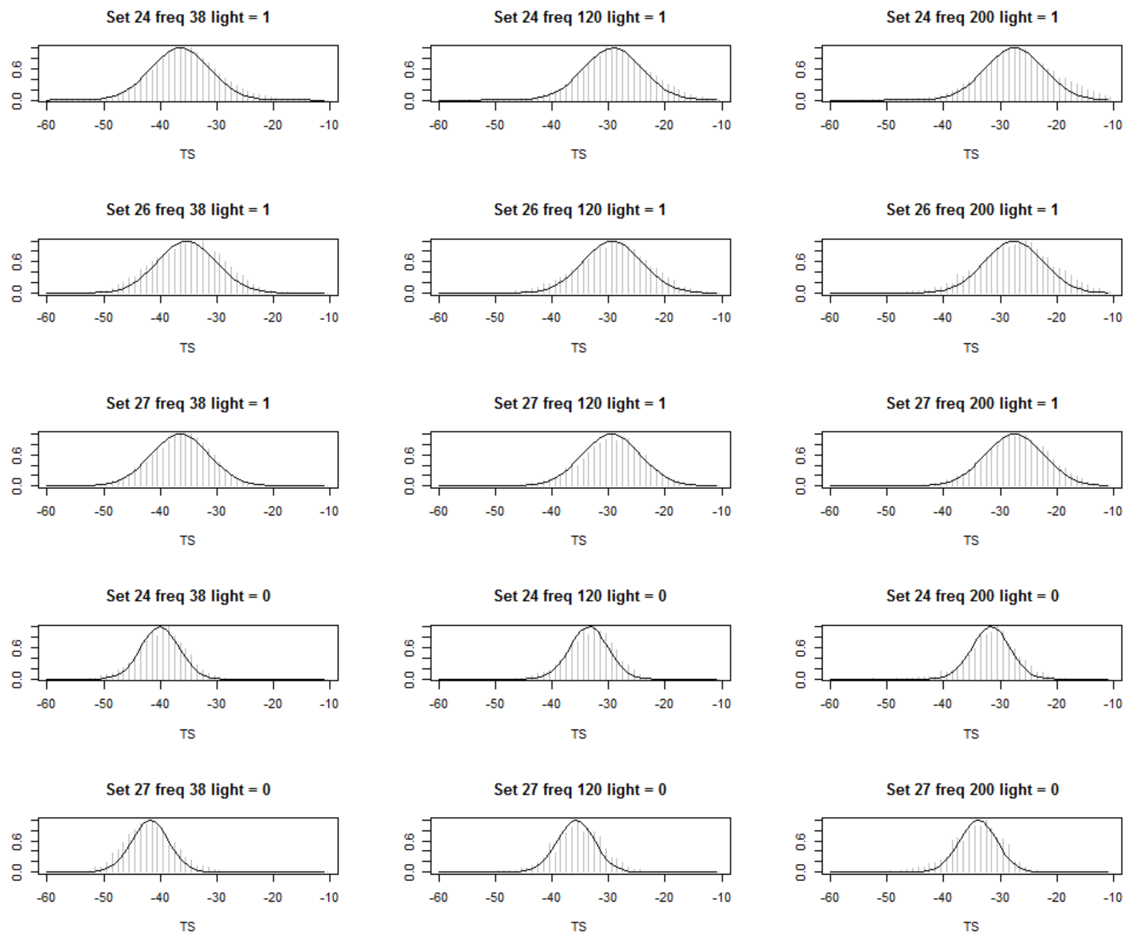

Figure 6. Expected (black line) versus observed (vertical grey bars) TS values for each set and light condition. The expected distributions were obtained by optimization of the TS-length relationship. The width of the gaussians were fixed at 5 dB for light = 1 and 3 dB for light = 0.

ACKNOWLEDGEMENTS

We would like to thank the following organizations and people for their invaluable assistance in completing this work: First, to Kiribati, Tuvalu and Tokelau on whose EEZs the vessel was licensed for their consent to carry out research. We would also like to thank the fishing master Euken Mujika, the captain and the entire crew of the F/V ALBATUN TRES, as well as the Albacora company for allowing us to use their vessel crew assistance to us for this work. Finally, we would like to thank the ISSF for financial and logistical support of this cruise.

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