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APPLICATION OF SIDE-SCAN SONAR IN THE MONITORING OF POSIDONIA OCEANICA AND PINNA NOBILIS

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ABSTRACT

In the present work we show the preliminary results of the use of a side-scan sonar for the monitoring of seagrass *Posidonia oceanica* and the fan mussel *Pinna nobilis* in the marine area around the "Penyal d'Ifac" in Calpe (Alicante), Spain. For *P. oceanica*, four meadows were studied different characteristics and at various depths. Direct measures of density and cover were taken to look for a correlation with the acoustic data. For P. nobilis, and due to the recent mass mortality event (MME), empty shells were used as a first step in the acoustic detection. The shells were placed in two different environments, bare sand and *P. oceanica*, their main habitat.

RESUMEN

En el presente trabajo se muestran los resultados preliminares en el uso del side-scan sonar para el monitoreo de la fanerógama *Posidonia oceainica* y el bivalvo *Pinna nobilis* en el área marina adyacente al "Penyal d'Ifac" en Calpe (Alicante), Spain. Se estudiaron 4 praderas de *P. oceanica* con caracterísitcas diversas y a diferentes profundidades. Para *P. nobilis* debido a la situación actual de la especie causada por un evento de mortalidad masivo se utilizaron conchas vacias, como un primer paso para su detección acústica. Las conchas se colocaron en dos ambientes diferentes, arena y *P. oceanica*, su hábitat habitual.

1. Introduction

The seagrass *Posidonia oceanica* and the fan mussel bivalve *Pinna nobilis* are two emblematic and endemic species to the Mediterranean Sea typically associated (Butler *et al.* 1993). *P. oceanica* is the most important and well-known seagrass in the Mediterranean, where it is endemic. It forms continuous meadows from the surface to 45m (Green *et al.* 2003). Seagrass meadows have an important ecological role in the ecosystem (O_2 production, biomass production, acting as a hatchery etc.) and provides protection to the litoral from the hydrodynamic (Green *et al.* 2003; Boudouresque *et al.* 2006). *P. nobilis* is included among the species hosted by *P. oceanica* (Garcia-March 2005). fan mussel can be found typically between 0.5 and 60m stereotypically associated to *P. oceanica* meadows. Its shell can reach 1m length, being one of the largest bivalves in the world, and the largest in the Mediterranean Sea (Basso *et al.* 2015). The situation of this species is critically due to a recent mass mortality event (MME) occurred in the western Mediterranean, provoked by a new species of Haplosporidian protozoan parasite, *Haplosporidium pinnae* (Darriba 2017; Vázquez-Luis *et al.* 2017; Catanese *et al.* 2018). The monitoring of both species is typically done by direct methods –mainly by SCUBA diving–, which entails a big sampling effort limited by the number of divers and the reduced working time underwater (Garcia-March *et al.* 2007). The use of undirected methods like a side-scan sonar (sss) could spare this work and allow exploring more extensive areas (Pasqualini *et al.* 1998; Powers *et al.* 2015).

2. Objectives

The objective of the present work is the application of the sss for the monitoring of *P. nobilis* and *P. oceanica.* For *P. oceanica* the main objective is the use of the sss to measure the acoustic reflexion of the meadow and look for a relationship between this and the shoots density and cover. For *P. nobilis* the main objective is the use of the side-scan for the location of individuals for population census and to obtain a measure of individuals sizes. A secondary objective, related to the current situation of the species after the MME, is the distinction between living and dead individuals.

3. Material and methods

3.1. Study area

The study was developed in the marine area around the "Penyal d'Ifac", in Calpe, Spain. Three locations were selected for the study. For *P. oceanica,* four transects were studied. In L2, transects L2.1 and L2.2 were placed at 8 and 12 meters deep respectively, both in *P. oceanica*. In L3, L3.1 was located in the middle of the meadow at 5m deep while the other, L3.2, was located close to the limit of the meadow at 6m deep. Density and coverage were directly measured by SCUBA diving for the calibration with the acoustic method. Density was sampled 15 times in each location with 25cm homemade squares (0.93m^2 total surface area). Cover was sampled 30 times in each location with 50cm homemade squares subdivided in four sub-squares (7.5m^2 total surface area).

For *P. nobilis,* the transect L1.1 of L1 and the transect L2.1 of L2 were used. L1.1 was located on bare sand to avoid any interferences and learn about the acoustic echo of the shell. L2.1

was the same transect done in *P. oceanica* at 8m depth, and was used to locate the shells in their main habitat. 7 empty shells were used, 5 adults (Nacra 1 -63.3cm- length, Nacra 2 -61.2-, Nacra 3 -59.4-, Nacra 4 -58.9- and Nacra 5 -42.1-) and 2 juveniles (Nacra 6 -4.7- and Nacra 7 -7.7-)

3.2. Side-scan sonar

For the acoustic transects a Simrad EK60 echo sounder was used, together with a split-beam side-scan transductor. The side-scan emits fan-shaped pulses in a wide angle, which allows to explore large areas of the sea floor. The measures were done at 200KHz and 90W. For the acoustic measures, each transect of each location was replicated 6 times (6 subtransects –T1, T2, T3, T4, T5 and T6–).

3.3. Data processing and analysis

All data was recorded by the EK-60 own program as a .raw file and processed through the program Sonar 5 Pro® and Matlab®. The energy accumulated in *P. oceanica* was calculated for the 30cm right above the bottom, It was done for a 40TVGLog and 20TVGlog. First the transects in bare sand were analysed. For detection, the transects were reviewed visually. Then, individual pings of the position where the shells should be were represented together with a representation of the echogram with thresholds.

4. Results

4.1. *Posidonia oceanica.* Direct measurements.

The direct measures of density and cover can be found. L3.1 showed the higher values with a density of 1109.33 shoots/m2 and a 55.92% cover. In decreasing order followed T3.2 with 987.2 shoots/m^2 and 48.72% of cover, L2.1 with 827.63 shoots/m^2 and 36.27% of cover and L2.2 with 604.80 shoots/m^2 and 18.66% of cover. A graphical representation of density can be seen in Figure 1.

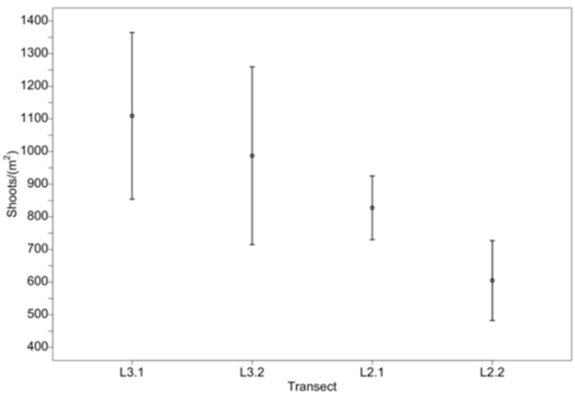


Figure 1: Density for each transect in shoots/m^2. The transects were ordered from higher to lower density.

4.2. *Posidonia oceanica* . Acoustic data.

The meadow was clearly visualised in all the subtransects. Its presence produced a different response in the echo level when compared to bare sand. The results of the energy accumulated in the 30cm above the bottom for a TVG 40. lower accumulation was in the transect L3.1 with a mean of -237.65dB and a SD of ±1.27, whereas the transect L2.2 presented the higher accumulation with a mean of -207.83 and a SD of ± 1.15. The other two transects showed intermediate values with a mean and SD, respectively for L2.1 and L3.2, of -214.52 ± 1.30 and -225.09 ± 1.69 (Figure 2). The results of the energy accumulated in the 30cm above the bottom for a TVG 20 are presented in. The pattern obtained was the same that for a TVG 40, showing T3.1 the lower accumulation, followed in order by L3.2, L2.1 and L2.2 (Figure 2).

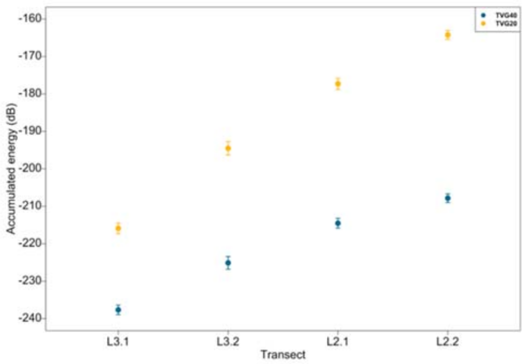
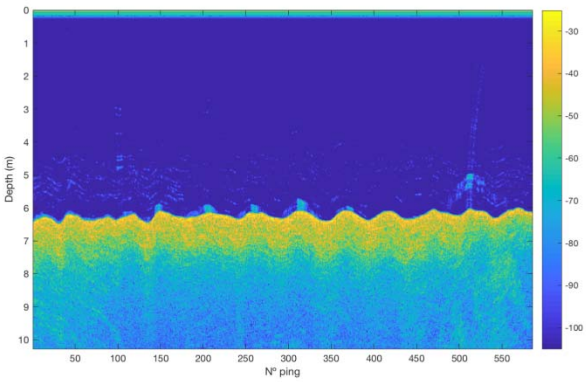


Figure 2: Accumulated energy in dB for TVG 40 and TVG 20. The transects were ordered as Figure 1 for the comparative.

4.3. Pinna nobilis in bare sand

Adult shells were placed successfully in a linear transect leaving 3m distance between them. The measure of the unburied part of the shell can be found in (**¡Error! No se encuentra el origen de la referencia.**). The adult shells were clearly detected visually in two of the six subtransects made (T5 and T6) (Figure 3) partially in one (T3) and undetected in the other three (T1, T2 and T4). The juvenile's shells were undetected in all the subtransects. The TS values for the shells ranged from -80 to -55dB. In Figure 3 can be seen a Matlab® representation of L1.1 with the shells. The individual pings represented of the shells and bare sand showed the difference in the echo reflexion (Figure 3 (left): Echogram representation with Matlab® of L1.1 - T5. Above, the original transect, down, the transect with the correction.
Figure 4).



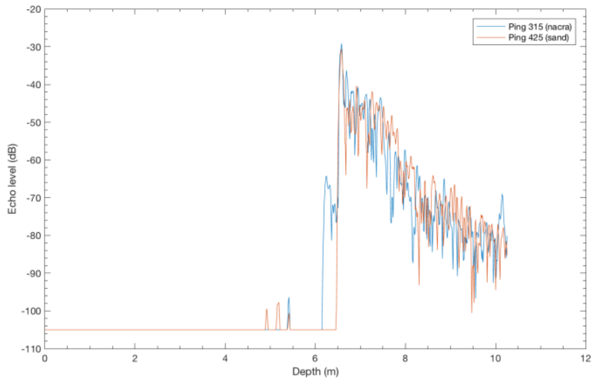


Figure 3 (left): Echogram representation with Matlab® of L1.1 - T5. Above, the original transect, down, the transect with the correction.
Figure 4 (right): Graphical representation of ping 315 (nacra) and 425 (bare sand) in transect L1.1 – T5.

The acoustic height of the shells (Figure 5) was measured in transects 5 and 6. The size measured acoustically was always inferior to the real size. Since they were undetected, no size was measured for Nacra 6 and 7. The results can be found in **¡Error! No se encuentra el origen de la referencia.**. For the measure, the higher single ping was used.

Individual	Nacra 1	Nacra 2	Nacra 3	Nacra 4	Nacra 5	Nacra 6	Nacra 7
Unburied length (cm)	39.1	39.8	28.3	35.8	16.9	2.4	3.8
Acoustic length (cm) T5	22.1	23.3	24.5	30.8	11.1	—	—
Acoustic length (cm) T6	29.4	28.3	24.6	33.2	16.0	—	—

Table 1: Measure of the unburied part of the shells, and the size measured acoustically for subtransects T5 and T6.

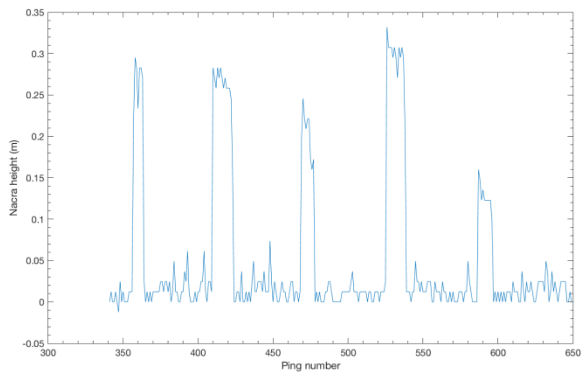


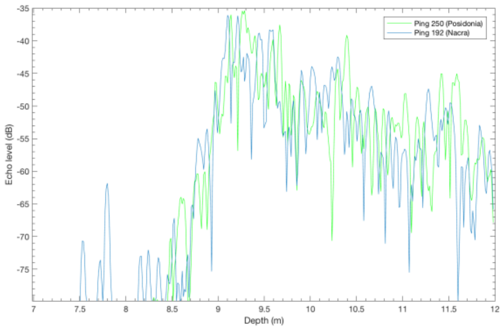
Figure 5: Graphical representation of the height of each shell measured with single pings.

4.4. Pinna nobilis in *Posidonia oceanica*

The shells were not detected visually in any of the 15 transects made. Individual pings of the locations where the shells were supposed to be were graphically represented (Figure 6) for two of the subtransects. A small difference in the echo level was detected, being higher for the pings where the shell was supposed to be than the ones with only *P. oceanica.*

For the representation of the shells in *P. oceanica*, -70, -60 and -50dB thresholds were used (

Figure 6 (left): Ping representations of L2.1 – T6 with shells. Blue lines represent pings with a shell and green lines represent pings with only *P. oceanica*.
Figure 7). The location of the shells through different thresholds was not clear.



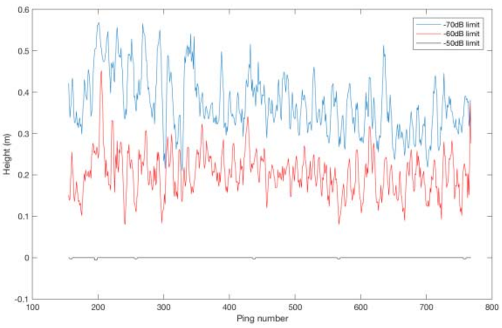


Figure 6 (left): Ping representations of L2.1 – T6 with shells. Blue lines represent pings with a shell and green lines represent pings with only *P. oceanica*.
Figure 7(right)*:* Height representation for -70, -60 and -50dB thresholds (mean of each three pings) in transect L2.1 – T6.

5. Discussion

This work presented a first step in the monitoring of *P. oceanica* and *P. nobilis* through a side-scan. The sss proved to be a useful tool in this task, although futher work must be done to improve the methodology.

Four stations of *P. oceanica* were monitored. The direct measurements indicated a clear difference between the locations. L3.1 and L3.2 showed a higher density and cover, which could be expected due to the shallow water (5-6m) where are located, forming a barrier reef. L3.1, higher, was located in the middle of the meadow whereas L3.2 was located near the limit, more exposed to hydrodynamics. L2.1 and L2.2, located deeper, presented lower density and cover, being L2.1, at 8m, higher than L2.2, at 12m.

P. oceanica was clearly detected in all the subtransects realized in the four transects (L2.1, L2.2, L3.1 and L3.2). The energy accumulated in the 30cm over the bottom showed a correlation with the direct measures of density and cover, but it was inverse to what was supposes to be. A greater reflexion could be expected in denser and more cover meadows, giving a higher echo level. However, the data obtained showed how denser and more covered meadows result in a lower energy accumulated. It is known that the acoustic response of phanerogams depends on the biomass and the tissue characteristics but also on the photosynthetic activity, which produce gas bubbles (De Falco *et al.* 2010). This was also one of the reasons to expect a direct correlation: air gives a strong echo and the photosynthetic activity was expected to be higher in denser and shallower meadows. By the other side, it is known that fibers are acoustic absorbers, and the explanation to the inverse correlation could be that leaves act more as an absorber than as echo reflector, besides, the period of work matches with the beginning of *P. oceanica* losing leaves which could be related to a lower photosynthetic activity and, therefore, less gas bubbles. Seasonal monitoring could help to understand this effect.

For *P. nobilis* not all the objectives were achieved. The current situation of the species, with a MME provoked by the protozoa *Haplosporidium pinnae (*Catanese *et al. 2018)* which already exterminate the Spanish Mediterranean populations, difficulted the development of the work. In that situation, the work was limited to the measurement of empty shells in bare sand and *P. oceanica.* The data obtained from the bare sand transect would give useful information about the acoustic response of the shell, since no other interference was present. This information would be useful for the location of the shells in *P. oceanica,* however, the transmission power used for bare sand transect L1.1 (100W) was not the same that for the other measurements (90W). Because of this the data were not comparable, and the TS observed in bare sand could not be used for the location of the shells in *P. oceanica.*

The shells in L1.1 were visually detected in three of the subtransects. The huge size of the shell, being 2/3 of it over the bottom, together with the lack of any interference made them easily locatable. However, the juvenile shells were not found, probably due to their small size. A clear difference in the echo reflexion was observed. In bare sand, the echo reaches sharply the maximum level, whereas with the shell, the echo level presents two increments before reaching the maximum level.

The height of the shells was measured for T5 and T6, since in T3 the visualization was partial. The measurements made were always lower than the real data. Besides, the higher sizes measured did not correspond to the higher shell sizes.

Transect L2.1 was at 6m deep, which entails 2.7m of bottom surveyed to each side. Although the superficial buoys marked the transect, that the transductor didn't pass right over the shells could be also the reason why in T3 the shells were only partially visualized and why the measures of the height were lower. The transductor would have to pass right over the shell to get and accurate measure. In the other three subtransects the shells were visually undetected. Maybe if, as previously commented, the transductor passes too far away from the shells, the echo reaches before the bottom right below the boat than the shell, masking the signal. This data should be reviewed in detail to try to locate the shells in this subtransects.

The detection of the shells in *P. oceanica* was much less clear than in bare sand. The interference of the meadow made impossible to locate them visually, difficulting the posterior analysis. This, together with the problems associated when the transductor doesn't pass directly over the shells and the lack of information relative to the TS values of the shells made it even harder. The representation of individual pings where the shells should be placed seems to indicate that could be possible to locate the shells. For the different threshold representation, the result was unclear. Despite the lack of information, it seems that *P. oceanica* and *P. nobilis* present a similar TS (it should be checked). This could be due to the higher volume of the meadow compared to an individual shell, despite the shell being a more rigid target. Extra work and deeper analysis should be done to improve the methodology and try an effective location.

6. Conclusions

The sss proves to be a useful tool in the location of *P. ocenica.* Sss data and direct measures of *P. oceanica* density and cover showed an inverse correlation. Although further analysis should be done to understand the basics of the correlation, the possibility of using the side-scan as a tool for the monitoring of *P. oceanica* meadows should be considered. The sss can be used to estimate the height of the targets. Mainly for seagrass, where you obtain a mean of an extension. A specific height of a target is highly dependent of the position of the transductor in relation to the target.

In future works, including more sampling should be done to strengthen the correlation showed between the side-scan data and *P. oceanica* metrics (understanding which parameters rule the correlation is essential). Besides, is recommended the monitoring of the same meadow during different seasons, which could help to understand the seasonal variability of the echo reflexion, which could variate with the photosynthetic state. All this could help validate the methodology for its use as a tool in the monitoring of seagrass.

This work expects to be a first step in the location of *P. nobilis* individuals using acoustic. Shells of *P. nobilis* can be clearly located using a side-scan in bare sand, although the possibility of locating individuals when they are in the middle of a meadow needs further revision. Future analysis should be done looking for unique characteristics in the echo of the shell. The critical state of *P. nobilis* population require of new methodologies for the monitoring of its populations, which allows to explore larger areas for both, monitoring the populations that are still unaffected by the MME and look for individuals that survive and could be resistant to it. Although the side-scan is still far from accomplishing this objective, the advantages of using this methodology, make it advisable to continue this studies in the future.

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