MONITORING SEA MEADOWS FOR THE SUSTAINABILITY OF FISHERIES RESOURCES

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Abstract - The sea meadows are very delicate ecosystems, fundamental in the sustainability of fisheries, as they act as a natural hatchery and nursery for many species. The present paper describes the methodology to characterize and monitor these communities in a non-destructive way, using an acoustic remote sensing instrument, the side scan sonar and two different frequencies, 100 and 500 kHz.

I. INTRODUCTION: SEA MEADOWS

The complex vegetable structure of seagrasses form a labile marine ecosystem, of great importance to the fisheries sustainability, as they act as a natural hatchery. These ecosystems are threatened at the moment by different factors, being the eutrophization of the waters and the anthropic influence (trawling fisheries, construction, sediment movements, etc) the main ones. Therefore, it has been already advised in the Scientific and Politician Communities that basic research should be carried out, including cartography, classification, identification of factors impacting the meadows and a quantification of the consequences of these aggressions. Such data would enable the establishment of the necessary tools to ensure the management and conservation of the sea meadows, as well as to control the causes of their regression.

The goal of the present paper is to obtain a methodology, based in the use of the remote sensing (non disturbant) techniques, that permits the characterization and monitoring of the sea phanerogams in an efficient and reliable way. This new methodology will also result less costly as the aerial photography and diver surveys, used quite often until present.

Three phanerogam communities have been studied, Posidonia oceanica L. Delile and Cymodocea nodosa (Ucria) Ascherson in the Mediterranean, and Zostera marina L. in the Baltic, playing all of them a similar role in the ecosystem maintenance.

The three studied species have elongated leaves of different length (Posidonia up to 2m height, aprox. 1m for the Zostera leaves, and 50 cm max. for Cymodocea), growing along rhizomes, which gives them a very characteristic structure.

Posidonia sp. is an endemic specie of the mediterranean, playing an important role in the sedimentation and organic matter accumulation processes of the seabed. The plant produces 4 to 20 l of oxygen per m2 per 24h (Mustapha and Hattour, 1993). Posidonia is a specie that can be considered as a water quality indicator, as won't grow if pollution is present. This ecosystem has been found to support up to 400 plant species and over 1000 animal species in itself, but it has also to be noticed that over a 30% of the the seagrass production is exported to deeper waters (Augier, 1986), sustaining the fish stocks of other commercial fisheries.

Under certain edaphic conditions (fine texture sediments), related to hydrodynamism and pollution which prevent recolonisation by Posidonia, Cymodocea can settle permanently. This specie, with an adventurous pioneering character, can be the vanguard for the settlement by Posidonia, or, on the other hand, act as a substitute after a degradation of the Posidonia meadow. Usually, while the former meadow can appear up to 30-40 m depth (always depending of the water transparency), Cymodocea habits in shallower seabeds (5-10 m).

Zostera marina forms a similar ecosystem, that occupies a depth between the lower intermareal limit and aprox. 10 m. This specie, characteristic of northern Europe, has been studied in Oresund (Denmark), where the link with Sweden is being built, as it has been already demonstrated that seagrasses are subjected to man-made stresses (as thermal, sewage, dredging, and chemical pollution) which adversely affect seagrass growth. The subsequent reduction or loss of plants is coincident with loss of animal life and marine substrate.

II. DATA ACQUISITION: SIDE SCAN SONAR

Side scan sonar is an active remote sensing instrument that emits a beam of acoustical waves and differentially analyses the returning waves reflected by underwater structures of the seabed to produce two-dimensional images, called sonographs (Abarzuza, 1991; Sutton, 1979; Chavez, 1986). The sonographs are, therefore, a measure of the reflectance properties of the sea floor’s geomorphic features as well as those objects lying on it or floating in the water column. Imaging sonar has many operational similarities to side-looking radar, and constitutes a powerful tool for submarine research (Sanz and Rey, 1983; Duck et al, 1993; Siljeström et al, 1995).
The towed sonar vehicle (fish) carries two transducer arrays (port and starboard), each one being independent for transmitting and receiving signals. The towfish used is a Geoacoustics that works simultaneously at two frequencies, 100 and 500 kHz, linked to an Eoscan system of real time image acquisition and processing. The said system applies the anamorphic and slant corrections to the raw data, using navigation and depth data supplied from the ship computer logging system. This quantitative geometric processing eliminates the lateral and longitudinal distortions caused by the slant of the beam and by the shifting velocity of the ship carrying the sensor.

The range used has been 30 m per channel and the pixel resolution is approx. 0.25 square meter.

III. SONOGRAPH PROCESSING

The image enhancement process, carried out onshore, aim to improve the recognition of objects (plants) and patterns in a digital image to permit a more effective visual interpretation and information extraction (Cervenka and de Moustier, 1993).

The images, saved in real time as raw, were afterwards cut in subscenes (400 x 600 pixels approx.) to be processed. First of all, images corresponding to the same spot but in different frequencies were registered to be compared. These images were afterwards contrast enhanced and an Edge Preserving filter (edp) was applied to each of them.

The edge preserving filter is a smoothing filter that worked very good on sonographs, removing noise while homogeneizing areas with same coverage and maintaining edges sharp. The said filter uses the variance as a measure of non-homogeneity of an area (if an area contains a sharp edge, the variance value will be large). The filter looks for the most homogeneous neighborhood around each point in the picture, and then gives each point the average grey level of the selected neighborhood area. That means, that smoothes the image by replacing the center pixel with the average of a subregion that has the least variance. This can be observed in Fig. 1 A.

The images were then classified in sets of four (100 and 500 kHz raw plus 100 and 500 kHz images with the edp filter), using a supervised classification based on the minimum distance classifier. This method computes the Euclidean distance from an unknown pixel to the mean vector of each class and assigns the pixel to the class to which is closest. Minimum distance was chosen because this method is the one that distorts less the information in the image.

Finally, a LIFE (Linear Features) Preserving filter was used on these images, as this filter allows the attenuation of singularities within classified images, while preserving relatively thin, but significantly long, linear features. This is done choosing a user-specified kernel size (5 x 5) and a neighborhood type (6). In this case, a linear feature that is one pixel wide and passes through the center of the kernel is preserved only if it extends to the edge of the kernel.

IV. ACOUSTIC CHARACTERIZATION OF PLANTS

The study area selected to characterize the acoustic behaviour of Posidonia sp. and Cymodocea sp. corresponds to Cabo de Palos (Murcia, Spain), in the Mediterranean Sea, where the sea survey was carried out. The campaign included diver verifications, video and photo sampling, and biological and chemical parameter measurements.

The Posidonia (Fig. 1A, P), as said before, is a big plant that grows on sand, and therefore appears in dark grey tones (each matt) on a light-grey bottom (the sand). When appearing as isolated mats presents a characteristic shadow at the lee side of the sonar beam, that dissipates if the meadow has a massive development. It is very important to notice that this specie has the same acoustic behaviour in both frequencies used (100 and 500 kHz).

The Cymodocea (Fig. 1A, C) shows, on the contrary, a very selective acoustic behaviour. This plant community, in the 100 kHz frequency presents a very strong acoustic response, that means, that the plant, which morphologically corresponds to a narrow, small leaf, appears as a very dark and homogeneous seabed. On the contrary, in 500 kHz, this ecosystem can be hardly distinguished, as it is almost transparent to the said frequency. The reasons for this special characteristic of this plant are being studied at present. The Fig. 2 illustrates this aspect, as it corresponds to the raw image taken in both frequencies of a Cymodocea sp. covered seabed.

Figure 1A shows a sandy area considered representative for both species, with an edp filter. Fig 1B corresponds to the same image, but classified following the "standard methodology": both frequencies were contrast enhanced independently and filtered using an edge preserving filter. Afterwards, the two filtered images and the two raw ones were introduced as four variables to be classified together in a supervised manner, using the minimum distance classifier. The corresponding error matrix is shown in Table 1.

Table 1

<table>
<thead>
<tr>
<th></th>
<th>Cymodocea</th>
<th>Sand</th>
<th>Posidonia</th>
<th>NULL</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cymod.</td>
<td>57.55%</td>
<td>02.83%</td>
<td>39.61%</td>
<td>0.00%</td>
<td>100.00%</td>
</tr>
<tr>
<td>Sand</td>
<td>00.35%</td>
<td>75.72%</td>
<td>23.93%</td>
<td>0.00%</td>
<td>100.00%</td>
</tr>
<tr>
<td>22</td>
<td>4784</td>
<td>1512</td>
<td>0</td>
<td></td>
<td>6318</td>
</tr>
<tr>
<td>Posid.</td>
<td>37.54%</td>
<td>12.00%</td>
<td>50.46%</td>
<td>0.00%</td>
<td>100.00%</td>
</tr>
<tr>
<td>1026</td>
<td>328</td>
<td>1379</td>
<td>0</td>
<td></td>
<td>2733</td>
</tr>
</tbody>
</table>

Average Accuracy: 61.24% ; Overall Accuracy: 63.78%
The overall accuracy (correctly classified pixels referred to the total of them sampled for each class) is a bit higher, 63.78%. The best recognized seabottom is the sand, classified in a 75.72% correct. This should be expected, as the sand has a low acoustic response, giving a white tone. The Cymodocea sp. was classified correctly in a 57.55% of the pixels (in midle grey tone), and this low value is due to the confusion introduced by the 500 kHz image (see Fig. 2) and to the similar DNs of this specie with the Posidonia ones.

Posidonia (in black tone) presents a lower recognition value, a 50.46%. The Posidonia plant, as said before, is a tall plant with an acoustic shadow at the lee side of the beam, surrounded by the light-toned sand. The training set characterizing the Posidonia class includes the matt (strong response, dark grey) and the shadow (no signal, white), which gets confused with the dark response of the Cymodocea in 100 kHz and with the bright areas of sand, respectively. This can be observed in the error matrix, as the Cymodocea-Posidonia confusion reaches a value higher than 37%, while the confusion with the Sand class is of a 12%.

From this image it is concluded that, even though the image classification is considered as an information extraction process, in the sonographs it can lead to confusion results due to the fact that this processing is based in the digital numbers (DN) of the pixels, and both species have a similar distribution along the histogram.

In the present studied case, it was more important in the species differentiation the texture visual information, as the Cymodocea sp. is characterized by a selective acoustic response, as well as a massive texture.

The Posidonia sp. is characterized by it’s size and external appearance. It shows a dotted texture when the distribution is in isolated mats, and a massive texture, if it is a well developed, very dense meadow. Anyway, this meadow can not be confused with the Cymodocea one, as the Posidonia will always show at the edges the characteristic shadow, and presents the same acoustic response in both frequencies.

The image representing Zostera marina L. corresponds to the sea survey carried out in Oresund (Denmark), placed in the Baltic Sea.

The Zostera sp. is a plant that presents the same acoustic characteristics in both frequencies used, and a well defined structure. The rhizome and leaves have a strong acoustic response, showing up in dark grey tones against the sandy bottom where they settle, that appears in light grey. The leaves are long and thin, and the plant has little volume, so that there is no acoustic shadow. This can be observed in Fig. 3 A, corresponding to a raw image with an edp filter. The images corresponding to both frequencies were classified following the standard methodology: Supervised classification based on Minimum Distance performed on raw 100 and 500 kHz images plus the same images with an edp filter. The resulting classified image is shown in Fig. 3 B, and the error matrix of the said classification is presented in Table 2. In the said table it is to be noticed the high average accuracy value (98.04%), very similar to the overall accuracy (98.07%), meaning that the classes were were homogeneously sampled and with a similar number of

<table>
<thead>
<tr>
<th>Sand</th>
<th>Zostera</th>
<th>NULL</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>97.61%</td>
<td>1.63%</td>
<td>0.75%</td>
<td>100.00%</td>
</tr>
<tr>
<td>2332</td>
<td>39</td>
<td>18</td>
<td>2389</td>
</tr>
<tr>
<td>0.50%</td>
<td>98.46%</td>
<td>10.04%</td>
<td>100.00%</td>
</tr>
<tr>
<td>14</td>
<td>2746</td>
<td>29</td>
<td>2789</td>
</tr>
</tbody>
</table>

| Average Accuracy: 98.04% ; Overall Accuracy: 98.07% |
of pixels, as can be verified through the pixels characterizing each class, 2389 for Sand, and 2789 for Zostera. The Sand (depicted in white) and Zostera (in a dark grey tone) classes show very high recognition values (97.61% and 98.46%, respectively). Therefore, the classification in the interpretation of this particular plant, in this environment, can be considered successful. The problem appears when other artifacts with similar acoustic response (as boulders or mussels) appear inserted with the Zostera community, as all of them can be found in the same area.

IV. CONCLUSIONS

In general it can be concluded the following:
1) Side scan sonar image acquisition systems are a good tool for visualizing the seabed, and the benthic communities placed on it. In that sense, using the adequate methodology, specific phanerogam species can be recognized and monitored along time.
2) The methodology to monitor each phanerogam specie has to be based in their specific and, sometimes selective, acoustic response.
3) The search of the adequate filter type has demonstrated to be the most important part of the processing, as the interpretation of the classified images can be very confusing. This is due to the fact that classification is based ONLY in the pixel digital value (DN). This value presents a high variability in the same specie and, at the same time, different species present the same DN distribution along the histogram.
4) The information contained in a sonograph can be used through a visual interpretation (Posidonia and Cymodocea) of the plant morphology and acoustic response for the monitoring and the status description of the meadows. In other cases (Zostera), when no other confusing artifacts and/or species with the same digital values are present, information extraction techniques as classification, may be useful in describing the plant distribution.