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ASSESSMENT AND QUANTIFICATION OF THE ANTHROPIC IMPACT ON THE *POSIDONIA OCEANICA* SEAGRASS MEADOW

Abstract
The regression of seagrass meadows has been extensively studied over the past few years. Although the causes of this regression may be locally natural, it is more generally related to human impact.
In the framework of the HalGolo (2010) and CoralCorse (2013) oceanographic campaigns, acoustic data (mosaic of sonograms and bathymetry), validated by field data (Scuba diving, ROV), were acquired at depths of -10 m and -50 m at the NATURA 2000 site "Grand Herbier de la Plaine Orientale" (Western Mediterranean, Corsica). Processing of this data provided evidence of the scale of this mechanical degradation (trawling scars, mooring, etc.), and enabled its quantification with regard to surface area and scar density. The main degradation was observed between -20 and – 40 m depth (98%); the surface area of seagrass meadow destroyed is estimated at 280 ha with more than 40 scars per hectare recorded in the northern part of the site. Given the slow growth rate of the meadow, assuming the hypothesis of the ending of these practices, it would require almost 150 years to recover these scars.

Key-words: Anthropogenic impact, Corsica, Side Scan Sonar, *Posidonia oceanica*, trawling.

Introduction

The ecological, economic and heritage importance of the *Posidonia oceanica* seagrass meadow in the Mediterranean, and notably in Corsica, has been extensively demonstrated over several decades (see synthesis in Boudouresque *et al*., 2012). Its importance has resulted in the introduction of conservation measures for this ecosystem at regional and / or national scale (UNEP-MAP-RAC/SPA, 1999; Boudouresque *et al*., 2012). Benthic mapping constitutes an essential element in this conservation strategy (reference state, patterns of change over time) and Corsica may be seen as the precursor in this field since all of its *Posidonia* meadows have been mapped since the beginning of the 1990s (Pasqualini *et al*., 1998) and monitoring over time has been carried out there, at representative sites, since 2004 (Bein *et al*., 2013; Pergent *et al*., 2007).
During the cartographical surveys undertaken between 2010 and 2013, numerous anthropic scars were evidenced, in particular at the "Grand Herbier de la Plaine Orientale" - Zone NATURA 2000 FR 9402014 site. Most of these scars would appear to be of mechanical origin and correspond to the action of benthic trawling and the mooring of large vessels off a petroleum facility. Although the legislation in force should limit the impact of trawling on the meadow (distance from the coastline, depth; CE, 2006), it is apparent that it is rarely applied in many Mediterranean countries, which results in the significant degradation of the *Posidonia oceanica* meadows, with in particular the uprooting of the leaf shoots and rhizomes, the suspension of particles, the alteration of the benthic communities in favour of opportunistic species and the reduction of the diversity and abundance of the fauna (Pergent *et al.*, 2013).

The automatic quantification of this impact, on the basis of the available acoustic data (e.g. side-scan sonar), comes up against methodological problems and is often limited to manual interpolation over limited sectors (Pasqualini *et al*., 2000; Ramos-Esplas *et al*., 1994). These measurements involve mainly the assessment of the surface areas covered by the dead matte or of the soft sediment in relation to the surface area of living seagrass, even if other factors, whether natural or anthropic, may act in synergy and be partly responsible for the absence of the seagrass meadow (Boudouresque *et al*., 2009).
The aim of the present study was therefore to test a new method for optimising the identification, characterisation and quantification of the anthropic scars on the test zone of the "Grand Herbier de la Plaine Orientale".

Materials and methods

The study site extends from the sea outlet channel of the Biguglia lagoon to south of the mouth of the Golo, on the east coast of Corsica. It was chosen because of its interest in terms of conservation, the availability of complete coverage by acoustical data and the occurrence there of trawl fishing.
The identification and the characterisation of the anthropic mechanical scars are based on the direct interpretation of sonograms (depth range 10 – 50 m) and on the map of habitats (Bonacorsi *et al., in press*). This acoustic imaging was obtained by means of a Klein 3000 side scan sonar (range 100 m and frequency 100 KHz – CoralCorse campaign), and by an interferometric sonar (frequence 250 KHz – Halgolo campaign). The depth was obtained using the same device (Halgolo campaign - frequency 250 KHz) and by a Simrad EM 2040 multibeam echosounder (CoralCorse campaign - frequency 300 Khz). The absolute decimetric position was determined using the DGPS system.
The raw data are processed with the Caraibes software (® IFREMER). The imaging data are corrected (suppression of the blind band), correction of obliquity errors, gain homogenisation, contrast enhancement and correction of the geographical position). The mosaics are integrated in a Geographical Information System (GIS - ArcGIS 10.0) at a resolution of 0.5 m. The bathymetric data are corrected by filtering and manual sounding invalidation. The MNT is meshed at 5 m resolution and integrated under GIS. Raster processing (shading, focal statistics and algebra) is used to improve the visualisation of the relief. Analysis of the anthropic scar density is performed, under GIS, by the setting of a grid of points every 200 m (Smith *et al*., 2007). For each point, within a 200 x 200 m window, an operator counts the number of scars observed and gives their dominant orientation. The points recorded by side scan sonar are weighted by a higher weighting than those recorded by interferometric sonar, which only takes into account the largest scars.
An interpolation by linear kriging is then performed in order to obtain a map of the scar density. The number of scars per point is discretised in seven classes according to the natural threshold method (Jenks method), which best fits with the statistical series. An analysis of the areas impacted is then carried out on the basis of a manual map (1/1000) of the scars on the sonograms, the scar object being considered as a polygon.
A theoretical estimation of the resilience capacity of the *Posidonia oceanica* meadow is calculated by the application of buffer zones corresponding to time periods of 10 to 150 years on the basis of a growth rate of 4 cm.year^{-1} and the calculation of the corresponding surface areas.

Results

The map of the main habitats and types of bottom provides a basis for visualising the distribution of the anthropic impact within the *Posidonia oceanica* meadow (Fig. 1). Faint scars (probably old) and sharp scars, no doubt more recent, with a characteristic acoustic aspect, co-exist throughout the area.

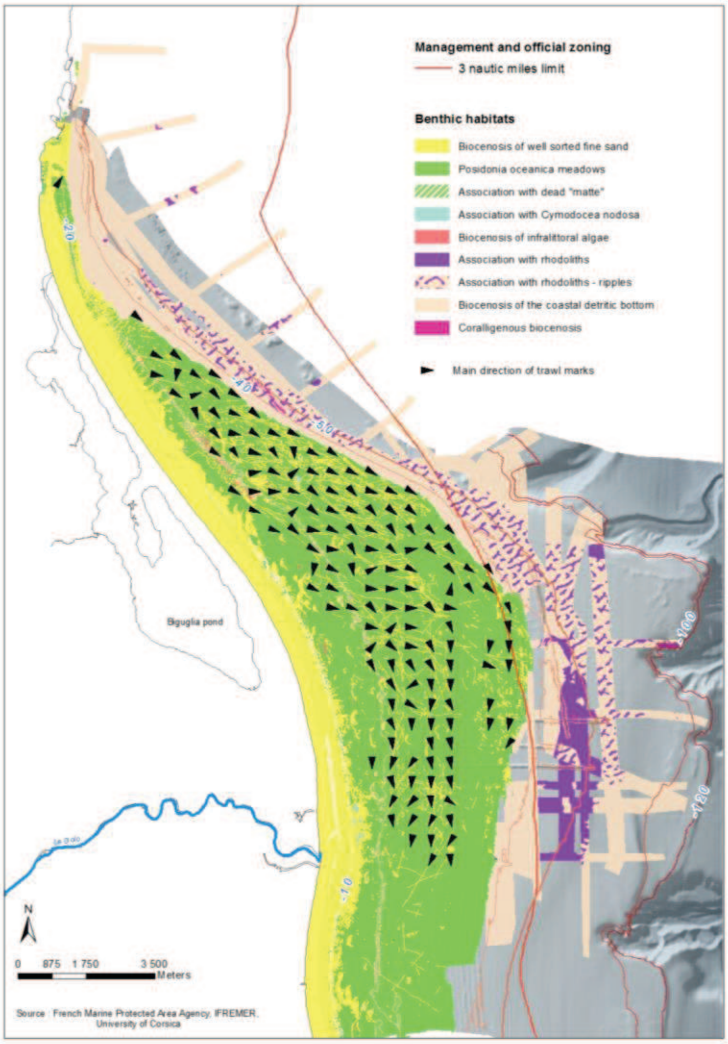

Fig. 1: Benthic habitats map and orientation of main trawling scars

Several of these scars are more than two kilometers long. In the surface zones (down to 20 m depth), there are fewer anthropic scars. The trawling scars are mainly oriented parallel with the coastline (east-south/east in the northern sector, then south). The surface area of *Posidonia oceanica* meadow 'destroyed' is estimated at 280 hectares of the 7 258 hectares covered by the meadow, or almost 4% for the whole of the sector studied. The interpolated density of trawling scars (Fig. 2) shows that most of these scars are situated between -20 and -40 m depth (98%), with a concentration in the north-east sector and greater sparseness to the south. In the most highly impacted sectors, more than 10 scars per hectare were identified (Fig. 2).

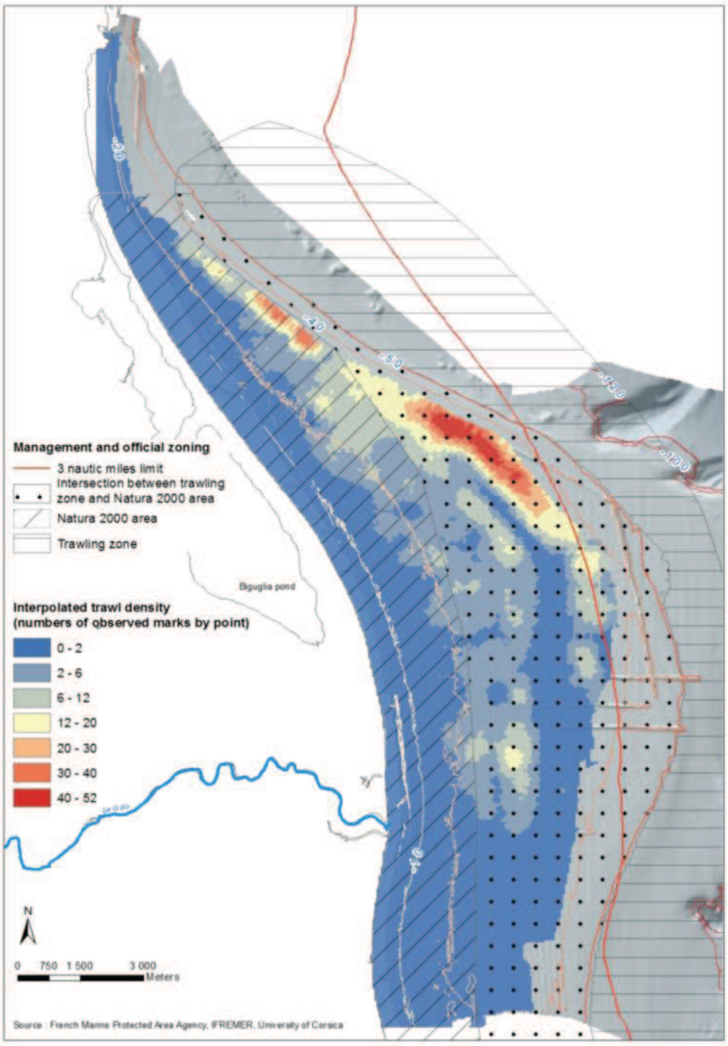

Fig. 2: Interpolated trawl density map (in a 200 x 200 m grid)

On the hypothesis of the ending of these practices, the complete regeneration of the *Posidonia* meadow is estimated at 150 years, even if the first decade would enable a recovery of more than 30%, allowing the recolonisation of the narrowest scars.

Discussion and conclusions

In the light of our results, the effectiveness of acoustic sensors in characterising the mechanical scars within the *Posidonia oceanica* meadow is clearly demonstrated, while side scan sonar would appear to be more effective than interferometric sonar. Nevertheless, the strategy of acquisition may play a major role in the quantification of the scars in that they are less easily detected when they are perpendicular to the direction of navigation (Coggan *et al*., 2001). Similarly, the speed of the boat, the frequency of the acoustic impulse and the position of the towfish above the bottom are all parameters that require optimisation (Humborstad *et al*., 2004). Carrying out a continuous video survey, in parallel with the acoustic survey, would also offer a means to better characterise the scars (Humborstad *et al*., 2004 ; Smith *et al*., 2007).

The method chosen to analyse the scar density, while faster and more representative than the ‘destroyed areas’ methods of assessment, requires improvement in order to attempt to overcome the bias inherent in the subjectivity of the operators. An automatic scar surface area analysis would complete the density values and provide a better characterisation of the phenomenon. The first trials along these lines, carried out on small areas, are encouraging (Pasqualini *et al*., 2000) and should be pursued, in particular with the use of a 'canny filter' contour detection algorithm. Nevertheless, the discrimination between the different types of anthropic scars (anchoring, trawling) and 'natural destruction' (e.g. intermattes) merits particular attention that is poorly compatible with automatic methods.

This work has made available a first assessment of mechanical anthropic impact, in particular trawling pressure, on one sector of the Zone NATURA 2000 site of the "Grand Herbier de la Plaine Orientale", and has provided a basis for identifying the worst affected areas. Of the 7 258 hectares covered by the *Posidonia oceanica* meadow, 6 ha have been destroyed between 0 and -20 m depth and 274 ha between -20 and -40 m. Even if the data available for other sectors of the Corsican littoral would appear to show much higher values, between 12% (Pasqualini et *al*., 2000) and 38% (Bonacorsi, 2012), they only concern very limited areas (a few tens of hectares). However, in the Gulf of Gabes, Tunisia (Zaouali 1993) and in the region of Alicante, Spain (Ramos-Esplas *et al*. 1994), trawling may be responsible for the loss of extensive areas of *Posidonia* meadows (respectively 80% and 50%).

The rate of recolonisation, and therefore of the resilience of the *Posidonia oceanica* meadow to mechanical damage, constitutes an essential element in terms of conservation management, and even of the natural restoration of this ecosystem. The mean growth rate values used here are only given as an indication, and only growth rate measurements *in situ* in the sector where the impact no longer occurs would provide a suitable basis for recalibrating the model. Because of the degradation of the substrate (matte) and of the introduction of replacement species (e.g. *Caulerpa racemosa* var cylindracea), the rate of recolonisation might be much slower (Delgado *et al*., 1999; Kiparissis *et al*., 2011).

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