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Effects of bottom trawling on the Ebro continental shelf sedimentary system (NW Mediterranean)

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ABSTRACT

A monitoring effort to address the physical effects of bottom trawling was conducted on the Ebro prodeltaic mud belt during the RESPONSE project. The monitoring was carried out for 14 months covering periods of different trawling intensities and a close season for the trawling fleet. The seabed morphology was studied by side-scan sonar and sediment texture and organic carbon content were analysed. Suspended sediment vertical distribution was recorded by CTD+turbidity hydrographic profiles and sediment transport was computed using time series from moored turbidimeters and current meters. The results show that the seabed of the fishing ground is strongly affected by scraping and ploughing induced by bottom trawling. Part of the finer fraction of the prodeltaic mud resuspended by trawling is winnowed, increasing the silt content of the settling sediment and also near-bottom turbidity. Sediment resuspended by trawling is incorporated in the bottom nepheloid layer and transported across- and along-shelf, increasing sediment fluxes. Trawling also induces an increase in the organic carbon content in the bottom sediment. All these effects induced by trawling have occurred during the last few decades, changing natural conditions in the fishing ground.

1. Introduction

Natural systems undergo constant evolution, including multiple changes induced by human activities. Many of these changes are visible on the continent but under the sea most of them go relatively unnoticed. One intense anthropogenic activity that has a significant and widespread effect on the seabed is bottom trawling, because it is very common on most continental shelves of the world. The direct physical effects of this fishing technique include scraping and ploughing of the seabed and increases in near-bottom turbidity due to sediment resuspension (Jones, 1992; Pilskaln et al., 1998; Palanques et al., 2001; Durrieu de Madron et al., 2005; Karageorgis et al., 2005a; Dellapenna et al., 2006; O'Neill and Summerbell, 2011). The degree of environmental perturbation caused by bottom trawling is related to the characteristics of the gear, the towing speed, the nature of the surface sediment, the structure of the benthic communities, and the currents in the study area (de Groot and Lindeboom, 1994; Fonteyne, 2000; O'Neill and Summerbell, 2011; Ivanovic et al., 2011).

The effects on cohesive and uncohesive sediments are different. Whereas scars caused by gears on sandy uncohesive sediments of energetic areas are covered by ripples in a few hours (Beon, 1990), trawling on muddy sediment can have longer-term effects on the seabed and on the water column. Krost et al. (1990) observed that intensely fished muddy areas have a high density of trawl tracks on the bottom and Tuck et al. (1998) and Palanques et al. (2001) observed that trawling tracks remain longer than one year on shelf muddy sediment.

Therefore, trawling has been changing the characteristics of the seabed, particularly because it incorporated important technological improvements several decades ago and is now carried out with powerful engines, fishing echosounder and accurate positional systems. In the Mediterranean trawlers are considered a semi-industrial fleet, having increased their power and capacity particularly in the 1970s and 1980s (Lleonart and Maynou, 2003). It is important to discriminate the effects of these human activities from those of natural processes, such as wave storms, and bottom currents, in order to better understand the present sediment dynamics and the consequences that may arise from it (Brown et al., 2005; Ferré et al., 2008).

In this paper we study the physical changes induced by trawling, analysing seafloor morphology, sediment characteristics and turbidity in trawled and untrawled zones located on the prodeltaic mud of the Ebro continental shelf (northwestern Mediterranean), comparing periods of high fishing intensity, low fishing intensity and seasonal fishing closure.

2. Study area

The studied fishing ground is located on the Ebro continental shelf (northwestern Mediterranean) (Fig. 1). This shelf receives

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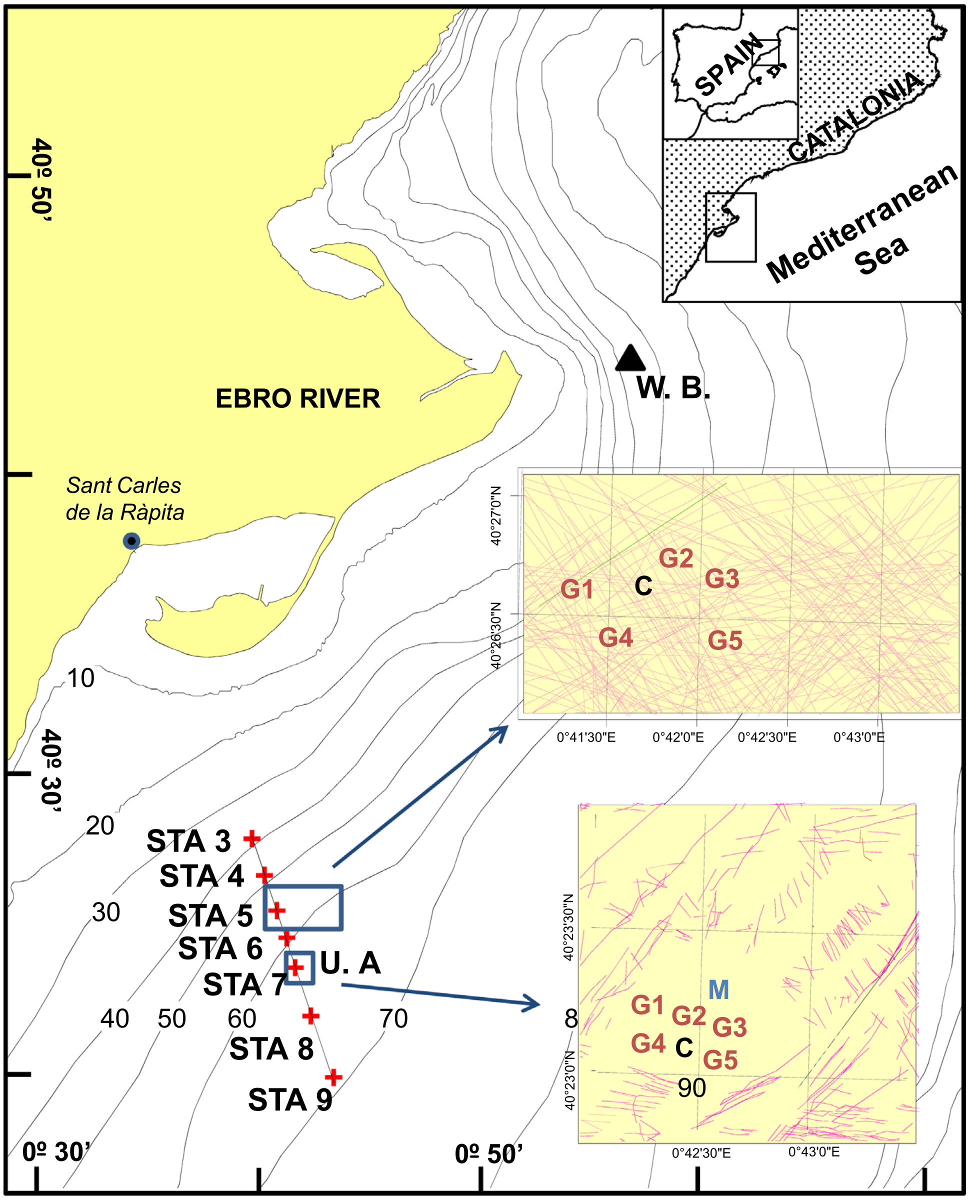

Fig. 1. Location of the study area on the Ebro continental shelf (northwestern Mediterranean Sea). The rectangle shows the position of the sediment samples taken on the fishing ground (see the density of trawled marks). The square shows the position of the sediment samples and the moored instruments from the untrawled area (UA). Red crosses, CTD+turbidity stations; G, grabs; C, sediment cores; M, mooring. Black triangle W. B., wave buoy. Red lines in the rectangle and the square correspond to trawl tracks. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

sediment supplies mainly from the Ebro River, which has an average annual water discharge rate ranging between 300 and 600 $m^3 s^{-1}$ and quite an irregular flow regime. Maximum water discharge (>900 $m^3 s^{-1}$) takes place in spring and autumn, while minimum water discharge (<200 $m^3 s^{-1}$) takes place mainly in summer (Maldonado, 1972). The present sediment discharge of this river is highly affected by the many dams constructed along its hydrographic basin and is less than 1% of the discharge in pre-dam conditions (Palanques et al., 1990; Guillén and Palanques, 1992).

The Ebro continental shelf has a microtidal (<0.3 m) regime with a low-period mean wave climate. Wave periods range between 2 and 10 s and heights are lower than 4 m for 98% of the time. Maximum significant wave heights are about 5–6 m from a northeastern direction. The average offshore significant wave height is 1 m and the average wave period is about 3.5 s (Gracia et al., 1989; Jiménez, 1996). Over the inner and mid-parts of the shelf, surface wind-generated currents are increasingly important landward (Font, 1983) and on the outer shelf the flow is dominated by the geostrophic Northern Current, which flows southward at speeds of about 15 cm s^{-1} and appears to be little affected by local wind variations. This southward flow also extends shoreward onto the shelf but with decreased velocities (Font et al., 1990). In this context, fine sediment is mainly distributed by dominant SW along-shelf currents and modern deposition takes place on the inner and mid-shelf during prolonged low-energy conditions, mainly of southwest transport (Palanques and Drake, 1990; Cacchione et al., 1990). A prodeltaic mud deposit extends along this continental shelf between 20 and 80 m water depth up to 110 km southward from the present river mouth, showing a gentle slope and relatively homogenous sediment and physical parameters (Díaz et al., 1990). The mean grain size of the prodeltaic mud ranges from 1 to 4 μm and the finest sediment accumulates in a mud belt at a water depth of between about 60 and 80 m.

South from the Ebro Delta, a major fishing ground is located on the prodeltaic mud deposit, with a surface area of approximately