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Deciphering the lithological consequences of bottom trawling to sedimentary habitats on the shelf

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ABSTRACT

Widespread bottom trawling on the NW Iberian shelf causes chronic sediment and habitat disturbance. The few studies that have investigated vessel-modified sedimentary-structure and texture of the seabed have typically classified their results as being either impacted by trawling or not. This study indicates that bottom trawling can result in a sequence of vastly different effects to the lithology of seabed sediment, which have in turn different ecological consequences. Here, we combined very high-resolution spatial bottom-trawling data with sedimentological (grain size, porosity) and geochemical datasets (excess ^{210}Pb, 3D petroleum fingerprinting) to study sediment disturbance, including sorting and mixing. Our results were used to develop five conceptual disturbance scenarios: minimal seabed effects, sediment overturning, complete sediment mixing, sediment grading and layering, and loss of sediment. Considering that bottom trawling is a widespread and growing global fishing technique, such impacts need to be considered in the management of habitat conservation as well as in the reconstruction of late Holocene climate history from shallow-water deposits, not just on the NW Iberian shelf, but also globally.

1. Introduction

Bottom trawling is a worldwide and steadily growing fishing practice (Watson et al., 2006). Globally, 22.36 million km^2 are subject to chronic commercial trawling and dredging each year (Halpern et al., 2008), with 9.74 million km^2 (Oberle et al., 2015) occurring in soft sediment of continental shelves. The direct physical effects of dragging demersal fishing gear over the seafloor include not only the scraping and plowing of the seafloor, but also the resuspension of sediment with an associated significant increase in near-bottom turbidity (Dellapenna et al., 2006; Durrieu de Madron et al., 2005; Jones, 1992; O'Neill and Summerbell, 2011; Palanques et al., 2001, 2014; Pilskaln et al., 1998). Few studies have documented the trawling-induced sediment advection and found bottom trawling-induced dispersal-mechanisms and erosion and depositional patterns (Ferré et al., 2008; Durrieu de Madron et al., 2005; Oberle et al., 2015). On most muddy shelves the amount of sediment resuspended by fishing practices can be substantial compared to natural resuspension processes. Indeed, recent observations have indicated that annual bottom trawling-induced resuspended sediment on a global mass basis is on the same order of magnitude as the sediment supplied to the continental shelves by the world's rivers (Oberle et al., 2015).

Chronic trawling occurs predominantly on sedimentary shelf areas where most of the shallow-infaunal organisms have their habitat (Malik and Mayer, 2007; NRC, 2002; Thrush and Dayton, 2002). These muddy shelf areas hold some of the ocean's highest benthic biodiversity and thus have a significant function as cradle of life to higher trophic levels (Gray et al., 1997; Snelgrove, 1999; Thrush et al., 2001). The NW Iberian mid-shelf (Fig. 1) is an example for one of these muddy shelf areas (Lantzsch et al., 2009a; Oberle et al., 2014a), where seabed habitats form under calm hydrodynamic conditions. Recent calculations show a six-fold increase in bottom trawling-induced off-shelf directed sediment transport when compared to the mass resuspended by natural processes in this region (Oberle et al., 2015). The sessile organisms that exist and proliferate in these areas are by nature much less resistant against sediment disturbances than those living on sandy or rocky grounds, i.e. under naturally higher energy conditions (Hiddink, 2006; Kaiser et al., 2006; NRC, 2002).

It is surprising that while the impact of trawling on benthic organisms (Bradshaw et al., 2012; Hall, 1999; Jones, 1992; Pusceddu et al., 2014; Sanchez, 2000; Thrush and Dayton, 2002) and changes in the biogeochemistry of sediment (organic content, nutrients, pollutants) (Bradshaw et al., 2012; Collie, 2000; Duplisea et al., 2001; Karageorgis

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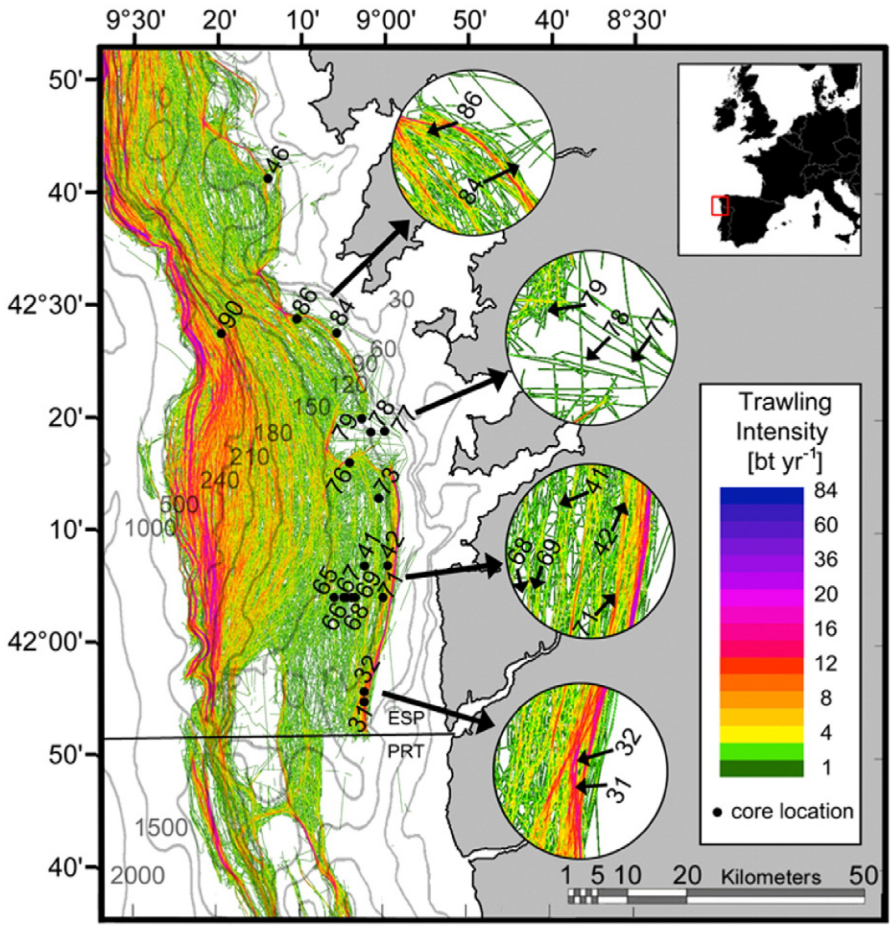

Fig. 1. Trawling intensity map of the Northwest Iberian shelf utilizing Jan.2013–Jan.2014 AIS data (adopted from Oberle et al., 2015). ESP — Spanish territorial waters; PRT — Portuguese territorial waters. This figure shows the number of times any given point was bottom trawled per year [bt yr^{-1}]. The locations of the sediment cores used in this study are indicted (black dots with station number).

et al., 2005; Pusceddu et al., 2014; Trimmer et al., 2005) have been well documented, what happens to the bottom trawling-induced changes in sediment lithology and texture remains largely unknown. While a large part of the effected sediment is resuspended and transported laterally, bottom trawling may also bury or mix remaining substratum (Churchill, 1989; Duplisea et al., 2001; Simpson and Watling, 2006). The structure of the seabed (e.g., porosity, grain size, water content) not only strongly influences the benthic community structure (Ellingsen, 2002) but its natural habitat complexity also appears to be an important feature for many fish species (Auster et al., 1997) thus underlining the necessity of better understanding of bottom trawling-induced lithological seabed changes. While it is well studied (i.e. Letey, 1985) that the mechanically similar agricultural activity of soil tilling causes changes in bulk density, pore size distribution, clay content, mineralogy, water content, and penetration resistance, effects of bottom trawling induced ground penetration are currently poorly understood. Existing studies on bottom trawling-induced changes to sediment texture have come up with conflicting results ranging from no effects (Bhagirathan et al., 2010; Dellapenna et al., 2006) to major winnowing effects (Palanques et al., 2014). Beyond environmental-habitat concerns, the deep reach of bottom trawling gear of up to 30 cm into the sediment (Linnane et al., 2000) can affect the interpretation of sediment core data used in late Holocene climate reconstructions from areas with high bottom trawling frequency (González-Álvarez et al., 2005; Martins et al., 2006).

This study compares sediment core data from trawled and untrawled sites (Fig. 1) on the NW Iberian shelf (Galicia) and systematically analyses and interprets the lithological and structural changes caused by sustained bottom trawling. A previous study showed that the use of Automated Information System (AIS) vessel tracking data provided a high-resolution vessel track reconstruction and the accurate calculation of the spatial distribution of bottom trawling intensity and associated resuspended sediment load (Oberle et al., 2015). This analysis also showed that otter board fishing vessels and associated gears used on this shelf are exceptionally homogeneous, resulting in a common door-spread of 80 m as observed by seabed surveys using high-resolution echosounder multibeam equipment. The existing AIS dataset (Fig. 1) is used in the present study to evaluate the frequency with which sediment core locations have been impacted by bottom trawling.

In conjunction with other datasets this study also presents a novel method that is based on hydrocarbon fingerprinting to detect remnants of heavy fuel oil (HFO) in sediment samples from sediment cores. More specifically, this method focuses on the latest major oil tanker accident that occurred in the study area, the *Prestige* oil spill in 2002, that resulted in the release of more than 76,000 m^3 (20 million gal) of HFO into the ocean (Albaigés et al., 2014). A spill of this magnitude involved the deposition of non-buoyant oil in particulate and aggregate form within the study area (Franco et al., 2006) and in a multitude of habitats from the coast across the shelf down to the abyss (Sánchez et al., 2006). With continued natural deposition, the time-specific (date of oil spill) injected HFO consequently becomes incorporated into the stratigraphy of the seabed. This principal holds true for all large oil spills involving non-buoyant oil. Consequently, the detection of a specific