Ecological Indicators 85 (2018) 570–574

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Technical note

Are trawl marks a good indicator of trawling pressure in muddy sand fishing grounds?

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ARTICLE INFO

Keywords:
Bay of Biscay
Fishing intensity
Sediments
Underwater video
Vessel monitoring system

ABSTRACT

The development of the vessel monitoring system (VMS) in the recent years has offered high-resolution data to map the distribution and intensity of fishing activities and contributed to enhancing the potential identification of fishing impacts. However, impacts could vary at very small scale and the resolution of VMS data might not be fine enough. Other proxy could be used, such as trawl marks visible on the seabed observed by underwater video or side-scan sonar to evaluate small-scale trawling effort. In the Bay of Biscay, an underwater video survey of the *Nephrops norvegicus* fishing ground was conducted and provided environmental characteristics such as depth and number of trawl marks at 152 transects. The relevance of observed trawl marks as a small-scale proxy of trawling effort was tested depending on the sediment type. The model showed a significant positive relation between density of marks and trawling effort for all sediments together but a different relation for each sediment type. Considering each sediment type separately, the unexpected high number of marks observed on sands could be linked with cohesive interactions between calcium carbonates particles while the low number of marks on fine lithoclastic muds could be due to sediment reworking and bioturbation. We conclude that the impact of trawling on the seabed varies with the type of sediments, hydrodynamic parameters, bioturbation and trawling intensity, leading to a very complex relationship. Trawl marks observed on video footage thus could be used as a proxy of trawling effort among the same type of sediment and not for fine lithoclastic muds.

1. Introduction

The Ecosystem Approach to Fisheries calls for an assessment of fishing impacts on seabed communities in order to maintain ecosystem functioning. In particular, the European Marine Strategy Framework Directive, through descriptor 6, focuses on seafloor integrity and highlights the need for indicators of pressure and state for marine management (Rijnsdorp et al., 2016; Eigaard et al., 2016b). Over the last decade, numerous advances have been made, particularly the improvement in technologies to measure physical impacts (underwater video and side-scan or multi-beam sonar) or the access to high-resolution fishing effort information through VMS data (Skaar et al., 2011). Although the VMS data makes it possible to map fishing effort quite efficiently, the recommended resolution of 0.05° ≈ 6 km (ICES, Advice, September 2014) might be too coarse to be linked to benthos data, collected at the 100-m scale (Skaar et al., 2011; Lambert et al., 2012), leading to a spatial mismatch between patterns of fishing effort and benthic biodiversity. Attempts to solve this issue were made through an increase in resolution of VMS data (Lambert et al., 2012) or the simultaneous use of several complementary devices such as video and sonar to observe trawl marks on the seabed (Humborstad et al., 2004; Smith et al., 2007; Malik and Mayer, 2007). The relation between trawling effort and trawl marks observed with video or sides-can sonar was also investigated (Krost et al., 1990; Friedlander et al., 1999; Buhl-Mortensen et al., 2016), highlighting the interest in such devices to evaluate fishing effort at fine scale.

In 2014, an underwater video survey was conducted in the *Nephrops* fishing ground of the Bay of Biscay known as the "Grande Vasière". These video recordings notably allowed the marks left by the otter trawl doors to be counted. Fishing effort was mapped based on VMS data, but the potential use of trawl marks as a useful indicator to evaluate trawling effort at a fine scale was questioned. In review of trawling impacts on the seabed, Linnane et al. (2000) reported that trawl doors might cause more or less distinct marks according to the sediment type

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https://doi.org/10.1016/j.ecolind.2017.11.016
Received 18 July 2017; Received in revised form 7 November 2017; Accepted 8 November 2017

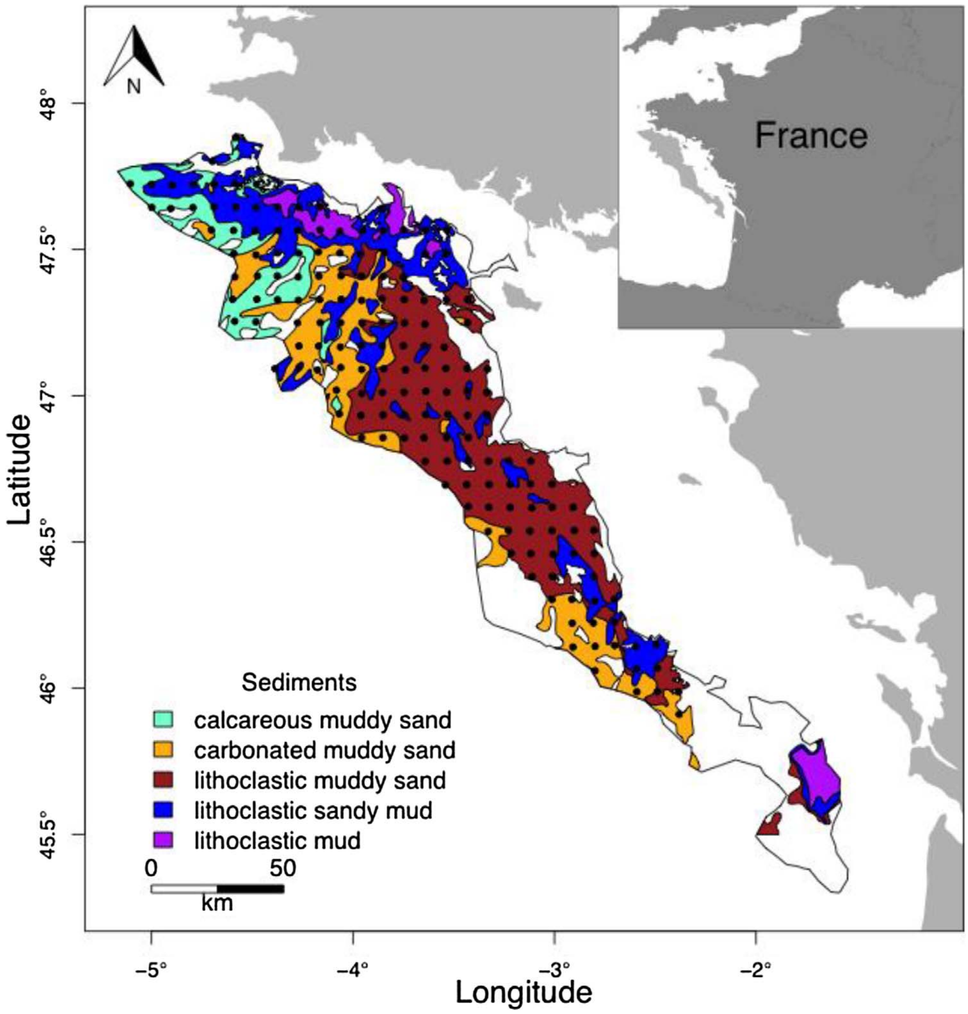

Fig. 1. Map of the sampling area. Black dots indicate transects.

and characteristics of the fishing gear. Different authors have observed highly variable delays before the disappearance of these marks from the continental shelf: from several hours (Margetts and Bridger, 1971, cited in Linnane et al., 2000) to a year (Schwinghamer et al., 1998) while on the deep seafloor, they could remain longer than 50 years (Dyment et al., 2014).

Here, we made a comparison between trawling effort estimated with VMS data and the observed marks, accounting for sediment type. Since no information was available about the persistence of trawl marks on the different sediment types considered in our study, two time frames were used for trawling effort: a short one corresponding to the week before the survey and a longer one of 4 months, corresponding to the whole *Nephrops* fishing season.

2. Material and methods

The area studied is 225 km long by 40 km wide and lies in the north-east Bay of Biscay, France (Fig. 1) (Bourillet et al., 2006). The sampling sites were located on the continental shelf at depths ranging from 66 m to 133 m. In September 2014, 152 video transects were realized on board of the R/V Celtic Voyager. Their locations were chosen along a regular square grid of 8.7 × 8.7 km resolution, built from a first point picked randomly inside the limits of the study area. A camera was fixed on a sledge dropped onto the seabed and towed for a 10 min haul at an average speed of 0.85 knots (methodology developed by Lordan et al., 2011). Transects were, on average, 183.7 m long for a filmed area of 143.9 m^2 (for more details see Merillet et al., 2017).

Twin and single otter trawls account for the major part of fishing effort in the Grande Vasière (89.7% of the total fishing hours over the period considered here). Otter trawl doors are the part of the gear that has the strongest impact on the seabed (Eigaard et al., 2016a) whose most visible sign being marks in the sediment. In this study, a trawl mark was defined as the linear depression of circa 5 cm deep and 15–20 cm width, dug by one door (See supplementary data for trawl marks pictures). Every visible track (hereafter named trawl marks) on the video footage, crossing the course of the sledge, was counted. With underwater video, it is impossible to find out which door tracks were paired, *i.e.* which door tracks result of the 2 doors of one trawl. At the exception of some turbidity clouds, images of the seabed were clear. The number of observed trawl marks was summed for each transect and divided by the sampled area to get a homogenized measure of the number of trawl marks per m^2 (hereafter referred to as density of marks).

VMS effort data were obtained from the French Direction of Maritime Fisheries (DPMA) and processed using the SACROIS algorithm (Demaneche et al., 2010) at a resolution of 3′ × 3′. For the long time frame, fishing hours were summed in each grid cell over 26 weeks from the beginning of April to the end of September 2014, which corresponds to the *Nephrops* fishing season, when most trawling activity takes place in the Grande Vasière. To account for the potential rapid disappearance of marks, a short time frame trawling effort assessment was made, based on the week before the sampling campaign. The type of sediments at each sampling site was obtained from Bouysse et al. (1986) (Table 1).

The trawling effort (fishing hours) was plotted by sediment type for the two time frames. A non-parametric Kruskal–Wallis multi-