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Effects of commercial trawling activities in the diet of the flat fish *Citharus linguatula* (Osteichthyes: Pleuronectiformes) and the starfish *Astropecten irregularis* (Echinodermata: Asteroidea)

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Abstract

This study assesses the effects of commercial trawling on benthic fauna, by analysing differences in the population structure and diet of benthic organisms inhabiting fishing grounds. The study is focused on two epifaunal species collected from a fishing ground in the north-western Mediterranean, which included a portion of un-trawled seabed used as a reference of undisturbed community. The selected species were the flatfish *Citharus linguatula*, more abundant at the undisturbed site and previously characterised as a surface predator and vulnerable to trawling, and the starfish *Astropecten irregularis,* which dominated the epibenthic community and had been characterised as an opportunistic species with low vulnerability to trawling. Both species were selective feeders and ingested similar prey species at each of the two sites, although differences in the relative prey abundance found in the stomachs occurred between sites. *A. irregularis* at the fished site mainly ingested gastropods, whereas higher proportion of bivalves was ingested at the undisturbed site. *C. linguatula* diet mainly composed of crustaceans at both sites, but there was an increase in the ingestion of small fish at the fished site. Moreover, prey ingestion of these two species generally increased with fishing activity. Trawling appears to modify the diet of these two species in terms of relative abundance of ingested prey, nevertheless, increased opportunism due to trawling disturbance was not detected and the density of these predators over fishing grounds was more closely related to their vulnerability to trawling.

Keywords: Benthic communities; Feeding intensity; Northwestern Mediterranean; Stomach contents; Trawling impact

1. Introduction

The spatial distribution of benthic organisms is conditioned by numerous external factors that modify habitats and are important in structuring benthic populations (Dayton, 1971). Commercial trawling is considered one of the largest anthropogenic impacts on marine ecosystems that can strongly modify benthic community structure (de Groot, 1984; Kaiser and Spencer, 1996). Consequently, species distribution should be highly dependent on fishing effort distribution (Rijnsdorp and Vingerhoed, 2001; Bremner et al., 2003).

Fisheries management must consider the protection of ecosystems and include within its objectives the reduction of the negative consequences of trawling on non target species and habitats (Gislason et al., 2000; Link et al., 2002; Frid et al., 2005; Jennings et al., 2005). But to achieve this objective, knowledge about the effects of

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commercial trawling in the communities' structure and functioning must be improved (Agardy, 2000; McConnaughey et al., 2000; Bremner and Frid, 2005).

Amongst the effects that trawling has on benthic communities, we highlight two important consequences for species' populations. First, trawling directly disturbs benthic organisms with consequences that depend on organisms' vulnerability and populations' resilience to fishing activities. Several authors have observed that vulnerable species, such as large surface organisms that are directly impacted by the gear, are replaced by less vulnerable organisms, such as small burrowing fauna (Collie et al., 1997; Thrush et al., 1998; Bergman and Van Santbrink, 2000). Secondly, trawling can indirectly affect specific organisms by modifying habitat conditions. Food availability is an important aspect of habitat suitability for organisms, and species distribution at a small scale can be determined by the presence and quantity of specific prey (Pearson and Rosenberg, 1987; Roth and Wilson, 1998; Frid and Hall, 1999). Selectivity of an organisms' diet determines their ability to adapt to changes in prey availability (Serrano et al., 2003; Hinz et al., 2005). Thus, less selective species may be less affected by changes in community composition and prey availability. The predicted consequences of trawling can be either positive, increased food availability for opportunistic species, or negative, the disappearance of specific prey for the most selective organisms (Ramsay et al., 1996; Garrison and Link, 2000; Groenewold and Fonds, 2000; Jennings et al., 2002). These studies have observed aggregations of scavengers in recently fished areas, potentially benefiting from the carrion generated by trawling, and the elimination of more vulnerable species like sessile filter feeders (Collie et al., 1997; Lindeboom and de Groot, 1998; Groenewold and Fonds, 2000; Kaiser et al., 2000b).

Overall, trawling causes reductions of vulnerable fauna, such as sea urchins, sponges and large bivalves, and disturbed communities become dominated by opportunistic species, such as swimming crabs, gastropods and starfish (de Groot, 1984; Auster et al., 1996; Hill et al., 1999; Lindeboom and de Groot, 1998; Ramsay et al., 1998; Thrush et al., 1998; Prena et al., 1999). These changes can have wider consequences for ecosystems by decreasing spatial heterogeneity and reducing functional diversity, resulting in impoverished communities (Dayton et al., 1995; Auster and Langton, 1999; Thrush and Dayton, 2002). The most intensively fished areas are likely to be in a permanently altered stated, dominated by resilient fauna adapted to frequent trawling disturbance regime (Kaiser et al., 2000a; Thrush and Dayton, 2002). However, there is still a lack of knowledge on the specific effects of commercial trawling on the diet of benthic organisms, which may be important in explaining species' distribution patterns and responses to disturbance events.

The main objective of the present study was to investigate the consequences of commercial trawling on benthic organisms from a fishing ground, comparing populations from a chronically impacted area and an undisturbed area. The species selected were the flatfish *Citharus linguatula* (Linnaeus, 1758) and the starfish *Astropecten irregularis* (Delle Chiaje, 1825), that according to SIMPER analysis, were two of the most important species discriminating epifaunal communities from fished and undisturbed areas (Demestre, 2006). *C. linguatula* is a target species of the local trawling fleet and, according to different literature sources, is a large surface predator, vulnerable and not very resilient to fishing activities. *A. irregularis* is generally classified as a scavenger with low vulnerability and high resilience to trawling due to its regeneration capacity, burrowing and fast growth (further detail included in de Juan et al., 2006). As a first approach to understanding the functioning of a chronically disturbed community, *A. irregularis* and *C. linguatula* population structure, feeding intensity and diet composition were analysed to detect changes originating from fishing activities. Moreover, relating the abundance of ingested prey with prey density in the environment was considered important to understand changes in diet patterns that might be indirectly originated by the alteration of benthic fauna by trawling activities (Frid and Hall, 1999; Serrano et al., 2003; Hinz et al., 2005).

2. Materials and methods

2.1. Study area

The study area is located in a fishing ground on the continental shelf off the Ebro Delta, north-western Mediterranean (Fig. 1). The continental shelf is 70 km wide, with a gentle slope, and is highly homogenous in sediment and physical parameters. The fishing ground encompasses 400 km^2, between 30 and 80 m depth, with sediments of >95% mud content (Palanques et al., 1990; Salat et al., 2002). The activity of the trawling fleet operating in this selected area was characterised by marked seasonality, with periods of high and low activity, and regulated by a two-month fishing closure in July and August. This fishing ground included 2.7 km^2 of undisturbed seabed, which has not been trawled for the last twenty years due to the remains of an abandoned oil platform. The oil platform was exploded eliminating