



Sensitivity of macrobenthic secondary production to trawling in the English sector of the Greater North Sea: A biological trait approach

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ABSTRACT

Demersal trawling constitutes the most significant human impact on both the structure and functioning of coastal seabed fauna. While a number of studies have assessed the impacts of trawling on faunal community structure and the degree to which different taxa are vulnerable to trawling, few have focused on how these impacts affect important ecological functions of the seabed. In this study, we use biological trait analysis (BTA) to assess the relative sensitivity of benthic macrofauna to trawling, in both the short- and long-term, and use this information to describe the spatial variation in sensitivity of secondary production for the Greater North Sea (GNS).

Within the GNS, estimates of total production varied by almost three orders of magnitude, from $1.66 \text{ kJ m}^{-2} \text{ y}^{-1}$ to $968.9 \text{ kJ m}^{-2} \text{ y}^{-1}$. Large-scale patterns were observed in the proportion of secondary production derived from trawling-sensitive taxa. In the southern North Sea, total production is predominantly governed by taxa with low sensitivity to trawling, whereas production is relatively trawling-sensitive in the northern North Sea and western English Channel. In general, the more sensitive and productive regions are associated with poorly-sorted, gravelly or muddy sediments, while the less sensitive and less productive regions are associated with well-sorted, sandy substrates. These relationships between production sensitivity and environmental features are primarily due to variations in long-term recovery; total production of most assemblages is highly sensitive to the direct impacts of trawling. We discuss the implications of these findings for management decisions to improve the environmental sustainability of trawling.

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1. Introduction

Human activity has comprehensively altered marine ecosystems and will continue to do so, some workers reporting 41% of marine areas are already strongly affected by multiple anthropogenic perturbations (Halpern et al., 2008). Coastal and marginal seas are particularly susceptible as they host a disproportionately large fraction of productivity and, because of the economic benefits that humans accrue from living in close proximity to the coast, such regions tend to be densely populated (Gray, 1997; Hinrichsen, 2010). Ecosystem function and biodiversity of coastal and shelf seas are, therefore, under pressure from a multitude of threats such as pollution, eutrophication, physical modification and habitat loss (GESAMP, 1990; Gray, 1997). One of the most widespread yet manageable pressures we impose on the seabed is disturbance of the substrate by towed demersal fishing gear (bottom trawling and dredging) (Collie et al., 2000; Eastwood et al., 2007; Kaiser et al., 2002). In UK waters for example, the footprint of trawling is reckoned to account for over 99% of the

known footprint of all human pressures on the seabed (Foden et al., 2011). It follows, therefore, that if current and future management of trawling activities can be based on an improved scientific rationale, potentially large improvements in the sustainability of this activity should result.

Over the past forty to fifty years, many studies have specifically aimed to understand the impacts of the various bottom trawling gear on the seabed communities (e.g. Bergman et al., 2002; Dayton et al., 1995; Hall, 1999; Jennings and Kaiser, 1998; Jennings et al., 2001; Kaiser et al., 2000; Queiros et al., 2006). Such studies show dramatic effects of bottom trawling on the structure of marine ecosystems although impacts tend to be wide-ranging, depending upon the gear, intensity, spatial area and the nature of the seabed habitats (Hall, 1999; Kaiser and de Groot, 2000; Smith et al., 2000; Tillin et al., 2006). With improved comprehension of the impacts of trawling comes the realisation that some habitats and/or biological assemblages are predisposed to relatively greater change from trawling, while others either show little impact and/or recover relatively rapidly (de Juan et al., 2007; Hiddink et al., 2007; Kaiser et al., 2006). For example, communities dominated by sedentary organisms, large-bodied individuals and those not protected by a hard shell tend to change most following trawling (Auster et al., 1996; Bergman and Hup, 1992; Blanchard et al., 2004; de Juan et al.,

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2007; Thrush et al., 1995). Unfortunately, however, marine scientists have traditionally suffered from a lack of quantitative methods for delineating areas that are sensitive or vulnerable to a particular stress (Zacharias and Gregr, 2005).

One notable feature regarding the studies above, however, is the focus on structural impacts. It has been observed that, following both natural and anthropogenic stressors, functional impacts and functional recovery trajectories are not always matched by their structural counterparts (Bolam, 2012; Cooper et al., 2008; Grilo et al., 2011; Wan Hussin et al., 2012). Conserving marine ecosystems, the *raison d'être* of the ecosystem approach, requires knowledge of not only how species may be affected by ecosystem change, but also how the system works and the effects of multiple and potentially interacting pressures. The ecosystem approach, therefore, must aim to safeguard function as well as biodiversity, but trawling impacts on benthic community function need to be understood before they can be managed.

In this study, we address this knowledge gap by assessing the relative sensitivity of secondary production to bottom trawling within the English sector of the Greater North Sea (*sensu* Marine Strategy Framework Directive (MSFD) – comprising the North Sea and English Channel). Relative sensitivity of benthic assemblages in this study is determined using biological trait analysis (BTA, Dolédec and Statzner, 1994). This ecological approach looks beyond the mere zoological identity of taxa by focusing on the form and function of the biota, or ‘what they do’ rather than ‘who they are’. Secondary production, estimated as the rate of incorporation of organic matter or energy per unit area of seabed (Cusson and Bourget, 2005), links energy flow through ecosystems. Recognition of the important role that benthic productivity plays in managing the marine environment is exemplified by recent UK and European policy drivers (e.g. the MSFD, CEC (2008)) which require an understanding of how this functional attribute responds to various anthropogenic and natural pressures (Bolam, 2012; Bolam et al., 2010; Cooper et al., 2008). Thus, we aim to provide fisheries managers and policy-makers an improved insight regarding the potential implications of bottom trawling on an important ecosystem function, and how it varies among different habitat types.

2. Methods

2.1. Data

The study area was nominally the English part of the Greater North Sea (hereafter referred to as GNS) (Fig. 1). However, sampling was extended by 85 km (approximately 45 nautical miles) into Dutch waters to incorporate a fixed sampling station at the Oyster Grounds where concurrent studies of sediment geochemistry amassed valuable legacy data (Painting et al., 2012). The study area covered *circa* 170,000 km² within the bounds 56° 36′ N to 49° 7′ N and 6° 00′ W to 4° 6′ E.

Biological and granulometric data were obtained for 304 stations selected to provide equitable spatial coverage across the study area (Fig. 1). Samples were collected between 2000 and 2010 using Hamon grabs, Day grabs and Box cores (all sampling 0.1 m² of the seabed) from which sub-samples were taken for granulometric analysis. The remaining material was washed over a 1 mm mesh sieve and preserved in 10% buffered formaldehyde. Faunal samples were processed in the laboratory recording abundance and biomass at the lowest practical level of taxonomic resolution.

While the gear types (above) used to acquire the faunal data provide quantitative density estimates of the smaller, more abundant infaunal taxa, they do not effectively sample the larger, less abundant epifaunal species. This latter faunal component of the benthos (e.g., sponges, hydrozoans) is more appropriately sampled using trawls (or equivalents) and are thus not included in the production

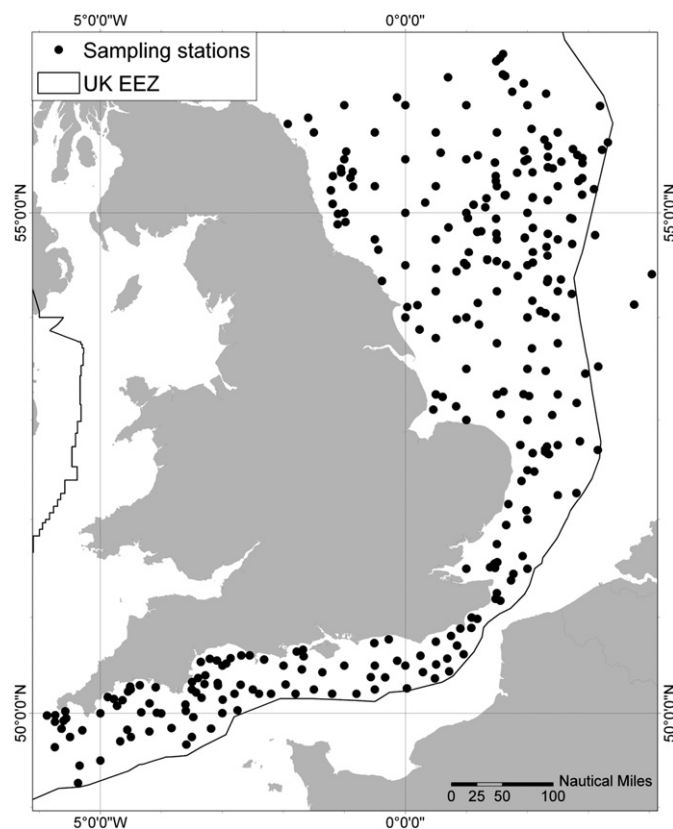


Fig. 1. Distribution of 304 grab sampling stations for faunal and granulometric data.

assessments in the present study. This constraint must be considered during any subsequent comparisons of our findings with those of studies where trawls may have been adopted.

The number of replicates varied among stations; some stations (69%) were sampled with only one replicate, but others (31%) had two, three or four replicates. For computation of the biological traits (see Section 2.3), only the first replicate from each station was used to ensure that trait diversity was not biased by the level of replication. However, for the production assessments the data from all replicates were used when calculating species abundance and biomass to improve the accuracy of such estimates. The collated data were aggregated to the genus level to circumvent misidentification at the species level and to standardise the taxonomic resolution across the various contributing surveys. As we were interested in estimating trait composition and total production, we do not believe that aggregating to the genus level resulted in any loss of information. The final dataset comprised 756 genera in 279 families.

Despite the need for a relatively large number of taxa with trait information, all genera were used for trait analysis. That is, unlike some comparable studies (e.g. de Juan et al., 2007; Tyler-Walters et al., 2009), we did not limit the taxon list to just community-discriminators or the most frequently sampled. We based this decision on several criteria. Firstly, production assessment was (and should be) based on all taxa present, which compels the inclusion of all taxa for BTA. Secondly, given the large spatial scale of our study we assumed some of the less frequently occurring taxa could be restricted to specific stations/regions. Thirdly, as Bremner (2008) warns, such reductions of taxon lists assume that trait composition behaves in the same way as species structure; we do not currently know whether this assumption is supported.

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