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Historic scale and persistence of drill cuttings impacts on North Sea benthos

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ABSTRACT

Despite its long history of hydrocarbon exploitation, the United Kingdom lacks scientific protocols to monitor ecological impacts of drill cuttings (mixtures between rocky material excavated from wells and drilling mud). The present study used the UK Benthos industry database to apply standardised variance partitioning and measure the scale and persistence of these effects at 19 sites across the UK sector of the North Sea. Generally, effects were limited to within 1 km from the platform, but two platforms historically drilled with oil-based mud were impacted up to 1.2 km away. Impacts persisted for at least 6–8 years in the northern and central North Sea, but were undetectable in the south where cuttings piles do not accumulate. This study underpins new recommendations to implement regional, phase-based approaches to drill cuttings monitoring, and to apply a precautionary approach in considering decommissioning options that will minimise disturbance to cuttings piles.

1. Introduction

1.1. Operational landscape and environmental impacts of the North Sea oil and gas industry

The North Sea is a mature hydrocarbon province in the north-east Atlantic that continues to be explored for new reserves that are being extracted in new ways via enhanced oil recovery methods (Muggeridge et al., 2014). North Sea oil and gas reserves have been exploited for over five decades, with over 770 subsea installations currently in place in the waters around the United Kingdom alone (Fig. 1a). The proliferation of artificial structures in the sea, or "ocean sprawl", has necessitated an evolving but complex policy landscape with the dual purpose to manage licensed activities and foster economic growth (Firth et al., 2016). In Europe, policy is underpinned by the Oslo-Paris Convention for the protection of the marine environment of the north-east Atlantic (OSPAR) and the Marine Strategy Framework Directive (MSFD). The North Sea region borders many nations party to OSPAR, yet despite historically high levels of environmental pressure from fisheries and petroleum industries, the environmental status of this region is improving (OSPAR, 2010). With regards to the petroleum industry, declining hydrocarbon production levels, improved management, and industry uptake of best available techniques and environmental practices have largely contributed to these improvements.

However, the emerging new era of decommissioning offshore oil and gas installations in the North Sea brings a high degree of uncertainty regarding environmental impacts of infrastructure removal and how these might affect environmental status. With few decommissioned sites to date, there are not many empirical studies on the environmental impacts of decommissioning in the North Sea. This lack of synthesis precludes scientific evidence-led assessments about impacts of different decommissioning scenarios e.g., whether the "rigs-to-reefs" concept could apply in the North Sea (Jørgensen, 2012), although decision-making frameworks that incorporate uncertainty are being developed (Fowler et al., 2014). Furthermore, some North Sea nations, such as the United Kingdom, have under-utilised the vast amount of environmental survey data held by industry that could help design monitoring strategies and ensure regional environmental status continues to improve in future. With more than 770 oil and gas installations operational in the UK sector alone, these data could significantly increase the spatial and temporal scales of understanding how to monitor and manage environmental impacts of the industry.

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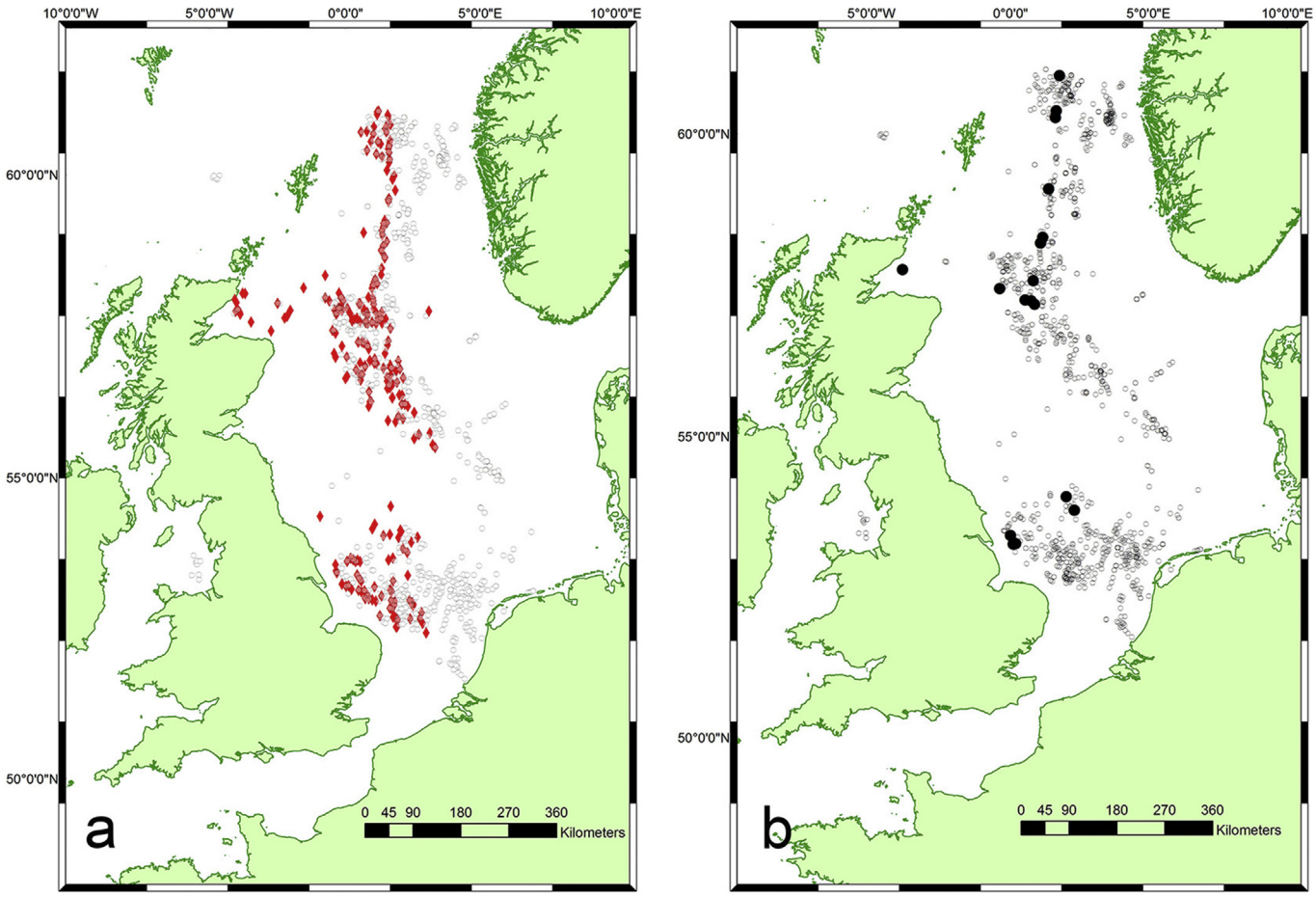

Fig. 1. Occurrence of platforms, manifolds and wells from the oil and gas industry in the North Sea overlaid with UK Benthos v4.06 survey data from the North Sea only, and the 19 study sites examined in the present study. UK Benthos surveys (closed orange diamonds) give good coverage of existing oil and gas installations (open circles) (1a); the 19 study sites (closed black circles) shown against the backdrop of all installations (open circles) (1b). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Understanding the scale of industry impacts in the region remains a complex task: the North Sea has been considerably transformed by the oil and gas industry since the late 1960s, but also by fisheries, shipping, and eutrophication over the last century (Kingston, 1992; Callaway et al., 2007). The result is that the North Sea's ecological baseline has been lost, making it difficult to understand the scale and persistence of historical impacts of the industry. Trend-based approaches to impact assessment can distinguish background/non-target disturbance or pollution effects from industry-specific impacts. Such approaches provide a means to gain greater understanding the actual scale and persistence of industry-specific impacts.

1.2. Biological impacts of drill cuttings

Industrial discharge of contaminated drill cuttings is a significant source of disturbance and pollution to benthic communities, and can have far-reaching consequences for ecosystems via the rapid transport of aggregates of phytodetritus and cuttings to the seafloor (Pabortsava et al., 2011). Drill cuttings are commonly discharged onto the seafloor in the vicinity of the well head to form a cuttings pile (Breuer et al., 2004). The spatial extent of the cuttings pile depends on the volume of cuttings discharged and the tidal current regime in the area: in areas with strong currents, the cuttings piles often have an elliptical footprint with the long axis of the ellipse aligned with the predominant current direction (Breuer et al., 2004). Physical impacts on the benthos are due to smothering by the discharged cuttings, these effects are usually localised to the vicinity of the well or platform; nevertheless, cuttings piles are overall a significant source of smothering on the UK seabed (Foden et al., 2011). Ecological impacts are often characterised by reduced species diversity, enrichment of opportunistic and/or pollution-tolerant fauna and a loss of more sensitive species (Ellis et al., 2012; Paine et al., 2014a). In the OSPAR region, proposed management of cuttings include options such as allowing natural *in situ* degradation as well as options such as complete removal of cuttings piles.

Toxicity of the discharged cuttings can also impact the benthos. Drill cuttings typically consist of a mixture of the rocky material excavated from the well and the artificially introduced drilling mud. The mud functions as a drill lubricant and contains weighting agents such as barite and associated mineral impurities including metals, and other additives to enhance drill lubrication and prevent blowout (Neff, 2008). Over the history of exploration and production in the North Sea, growing concerns from various agencies about toxicity of drill cuttings led to increased regulation of drill mud composition.

Oil-based mud (OBMs) and the discharge of OBM-contaminated cuttings are now prohibited in the OSPAR region, the use of alternative water-based mud (WBMs) help to significantly reduce the