Marine Pollution Bulletin 99 (2015) 207–215

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

The effects of marine sand and gravel extraction on the sediment composition and macrofaunal community of a commercial dredging site (15 years post-dredging)

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ARTICLE INFO

Article history:
Received 8 May 2015
Revised 6 July 2015
Accepted 9 July 2015
Available online 5 August 2015

Keywords:
Marine aggregate dredging
Recovery
Intensity
Macrofauna
Sediments

ABSTRACT

A prediction that faunal recovery of a marine aggregate extraction site subjected to high dredging intensity was likely to take 15–20 years was investigated. Samples were collected at the high dredging intensity site and two reference sites in 2011 (15 years post-dredging). Results indicated that the high site had similar sediment characteristics to the reference sites by 2011. Macrofaunal data analyses showed no difference between the values of all calculated univariate measures (abundance, number of taxa, biomass and evenness) between the high and reference sites. Multivariate analyses found that the macrofaunal community at the high site was comparable to those of the reference sites by 2011. Overall, the results supported the predicted recovery time. The findings of the study suggest that persistent physical impacts prolonged the biological recovery of the high site.

1. Introduction

The effective management, and ultimately sustainability, of many offshore industries requires an understanding of the processes and times required for physical and biological recovery of the seabed following disturbance. Consider, for example, the UK marine aggregate dredging sector, which produces sand and gravel (aggregate) from licensed extraction areas around the coast of England and Wales (Highley et al., 2007; Russell, 2011). Primary impacts of aggregate dredging occur at the seabed, and result from the direct removal of sediment and associated benthic fauna. The severity of impact on the macrofauna varies according to the intensity of dredging, but, typically there will be a loss of species richness (11–76%), abundance (16–88%) and biomass (78–92%) (Newell et al., 1998). In some locations impacts to the fauna are also observed outside the boundaries of the licensed area, as a consequence of the fallout of material from sediment plumes (Desprez, 2000; Boyd and Rees, 2003; Newell et al., 2004; Desprez et al., 2010; Pearce et al., 2011).

Dredge plumes originate at the sea surface due to overspill (Newell et al., 1998) and screening (Hitchcock and Drucker, 1996), and at the seabed due to disturbance caused by the drag-head (Hitchcock and Bell, 2004). Finer sediment contained within such plumes can be transported away from the licence area under the influence of tidal currents (Hitchcock and Bell, 2004; Dickson and Rees, 1998), and deposition elsewhere can result in changes in the composition of sediments, with consequences for seabed macrofaunal communities (Poiner and Kennedy, 1984; Desprez, 2000; Boyd et al., 2003, 2005; Barrio Froján et al., 2011). Clearly the acceptability of a dredging project will be influenced by the capacity of the seabed to recover post dredging. However, despite its importance, understanding of this issue is not always clear at the time of licensing (Cooper et al., 2013).

In order to better understand the long-term impacts of aggregate dredging, the UK government initiated a programme of research into seabed recovery. This work was designed to address concerns that the often quoted recovery times of 2–4 years (Kenny et al., 1998; Sardá et al., 2000; Van Dalfsen et al., 2000; Van Dalfsen and Essink, 2001), which were based on short dredging events, might not be applicable to commercially exploited sites, where dredging is typically sustained over many years. Research undertaken as part of this programme has focused on three sites: Area X off the coast of Hastings in the eastern English Channel (Cooper et al., 2007a, 2008), Area 408 in the offshore Humber region of the southern North Sea (Barrio Froján et al., 2011; Cooper et al., 2011b) and Area 222 in outer Thames region of the southern North Sea (Boyd et al., 2003, 2005; Wan Hussin et al.,

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http://dx.doi.org/10.1016/j.marpolbul.2015.07.024

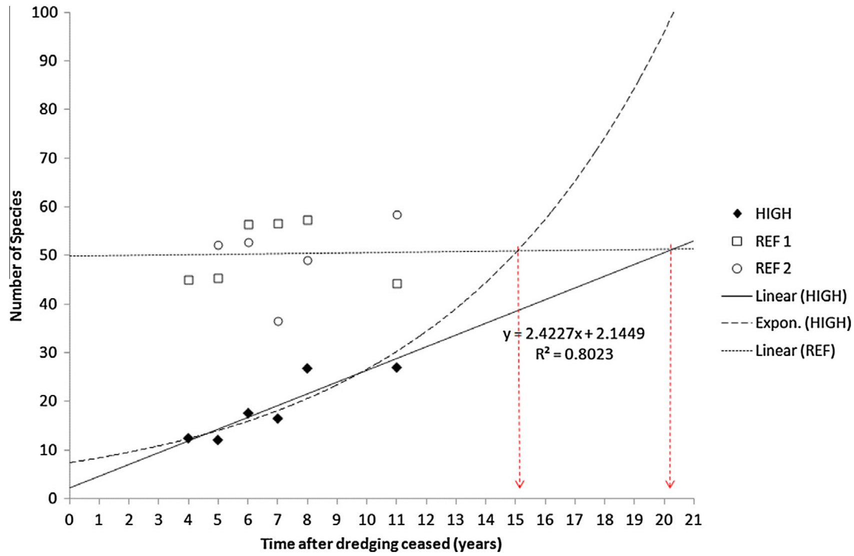

Fig. 1. Recovery projection based on the mean number of species observed at the high dredging intensity site at former aggregate extraction site, Area 222 (from Cooper et al., 2011a). The expected recovery period (dashed red lines) is based on a linear and an exponential model.

2012; Cooper et al., 2013). These three sites were chosen to be representative of different geographical regions where dredging takes place in the UK, and of different dredging practices. All studies employed the same survey design, with grab samples acquired within areas of seabed previously subject to relatively higher and lower dredging intensity, and at two reference sites. Recovery was judged to have occurred when the impacted (high or low) and reference sites were virtually indistinguishable, based on univariate and multivariate statistical comparisons of the data (Cooper et al., 2007a).

Work to monitor seabed recovery at Area 222 commenced in 2000, and the site was revisited in 2001, 2002, 2003, 2004, 2007, that is 3, 4, 5, 6, 7, and 11 years after dredging. Results showed a faunal recovery within the low intensity site after 7 years (Wan Hussin et al., 2012). In contrast, faunal recovery at the high intensity site has been slower, with Wan Hussin et al. (2012) noting that the site remained disturbed after 11 years, most likely as a result of an initially greater impact on the fauna, and elevated levels of coarse sand, which have gradually winnowed away over time. Based on a projection of available data points, Cooper et al. (2011a) suggested that faunal recovery at the high site was likely to take 15–20 years (see Fig. 1). The purpose of the present study was to test this hypothesis, through the collection of samples from 2011, 15 years after dredging.

2. Methodology

2.1. Sample site

A full description of the study site (Area 222) together with an account of the dredging history, and an acoustic dataset showing the status of the seabed between 2000 and 2003, are reported in Boyd et al. (2003, 2004), Cooper et al. (2011a), and Cooper et al. (2013).

The site is situated 20 miles east of Felixstowe, off the south-east coast of England. Water depths at the site range between approximately 27–35 m Lowest Astronomical Tide, and maximum tidal velocity is 2.3 kn (1.17 ms^{-1}) (Boyd et al., 2004). The site occupies an area of 0.3 km^2 and was first licensed for aggregate dredging in 1971 (Fig. 2). Extraction activity was at rates of >100,000 tonnes per annum until 1995. However, a peak extraction rate of 872,000 tonnes took place at the site in 1974. The last dredging activity took place in 1996 when approximately 12,000 tonnes of aggregate was removed (Boyd et al., 2004). In total, 10.2 million tonnes of sand and gravel was extracted from the site over a 25 year period (1971–1996), before the site was relinquished in 1997. The site was subjected to screening processes, where the sand:gravel ratio of the dredged cargo was adjusted (Boyd et al., 2004; Cooper et al., 2005).

In 1971, when an extraction licence was granted at Area 222, there were no requirements for an Environmental Impact Assessment (EIA) under the European EIA Directive (2011/92/EU) and extraction did not have any associated environmental monitoring conditions, except the need to conduct regular bathymetric surveys (Boyd et al., 2004; Cooper et al., 2013).

2.2. Sample collection

Electronic Monitoring Systems (EMS) have been fitted to all vessels dredging with a Crown Estate's licence in the UK since 1993 (Boyd et al., 2004). This remotely and automatically records the location, date and time of all dredging operations to disc. The information provided by the EMS was utilised to determine different levels of dredging intensity within Area 222. The selected sampling area was split into sites subjected to high dredging intensity (referred to as high hereafter i.e. >10 h of dredging within a 100 m by 100 m block during 1995), and two undisturbed (referred to as reference/ref hereafter) sites that were considered to be representative of the wider environment surrounding the extraction site (Fig. 2). The identification of appropriate reference sites was assisted by the use of sidescan sonar and video images of the seabed (see Boyd et al., 2003 for methodology).

Single 0.1 m^2 Hamon grab samples were collected, using the *RV Cefas Endeavour* in 2011, from ten randomly positioned sampling stations located within the high intensity box. In addition, five random stations were sampled within each reference site (the area of each reference box was half that of the high intensity box). The reference areas were considered to be representative of 'baseline' conditions due to limited information on what constitutes the likely pre-dredging status of the area (Cooper et al., 2007a).