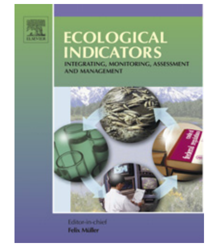
available at www.sciencedirect.com

ScienceDirect

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



Performance of selected indicators in evaluating the consequences of dredged material relocation and marine aggregate extraction

Suzanne J. Ware *, *Hubert L. Rees*, *Sian E. Boyd*, *Silvana N. Birchenhough*

The Centre for Environment, Fisheries and Aquaculture Science, Lowestoft Laboratory, Pakefied Road, Lowestoft, Suffolk, NR33 OHT, United Kingdom

ARTICLE INFO

Article history:
Received 20 June 2007
Received in revised form
12 August 2008
Accepted 10 September 2008

Keywords:
Indicator
Dredgings relocation
Aggregate extraction
Criteria
Benthic macrofauna

ABSTRACT

Eleven indicators were applied to macrofaunal species abundance data obtained from four dredged material relocation sites and four aggregate extraction sites in UK waters. Indicators were subsequently scored on a scale of 0 (very poor) to 5 (excellent) according to their performance in relation to six criteria governing their utility. Number of species (S) and number of individuals (N) generally scored highest in terms of understandability, sensitivity and linkage to the human activity whilst biotic indices were assigned relatively low scores, particularly in relation to aggregate extraction activities, according to the same criteria. As the immediate consequences of dredged material relocation and aggregate extraction activities are largely physical in nature the relative insensitivity of these indices may be explained by their dependence on species responses principally to organic enrichment. Indicators that incorporated measures of relatedness of species (i.e. average taxonomic distinctness, taxonomic breadth and average phylogenetic diversity) were assigned relatively low scores due to inconsistency in identifying spatial trends, and relative insensitivity. However, such indices may have the potential advantage of illuminating the causes as well as simply the existence of change and merit further examination. The adopted approach to quantifying indicator utility is critically examined and recommendations are made for future refinements.

1. Introduction

In the UK the disposal of dredged material at sea is licensed under the Food and Environment Protection Act (FEPA) (1985) (Great Britain Parliament, 1985). The licensing process requires that information be obtained regarding the physical and chemical properties of the material destined for disposal in order that potential impacts can be identified (Murray et al., 1999). Subject to issue of a license, dredged material is deposited at sea at one of c. 150 sites around the UK coast and these are selectively monitored to ensure that predictions concerning the continuing acceptability of disposal are met, and to feed back relevant new information to guide the future decision-making process (MEMG, 2004).

Licence applications for marine aggregate extraction around the UK coast have been considered since 1968 under the Government View (GV) procedure. Since 1989, a licence application has required an Environmental Impact Assessment (EIA) and recently a Coastal Impact Study (CIS) and a baseline benthic survey have become routine accompaniments. Receipt of a favourable GV results in the issue of a UK

* *Corresponding author*. Tel.: +44 1621 787286; fax: +44 1621 784989.
E-mail address: suzanne.ware@cefas.co.uk (S.J. Ware).
1470-160X/$ – see front matter
doi:10.1016/j.ecolind.2008.09.010

production licence by the Crown Estate, which has ownership of the seabed in territorial waters.

Numerous metrics have been developed that utilise aspects of benthic community structure or function to summarise changes arising from both anthropogenic and natural disturbance (e.g. Sanders, 1968; Hurlbert, 1971; Clarke and Warwick, 1998, 2001a; Borja et al., 2000). The options range from the straightforward primary variables of species number and densities, to more complex derivatives, exemplified by biotic indices which combine information on species-specific tolerances to human influences, principally (to date) those resulting in organic enrichment of soft sediments (e.g. Word, 1979; Borja et al., 2000, 2003; Muxika et al., 2003). However, recent studies have subjected many of the existing metrics to increased scrutiny in terms of their capability to detect responses to a wider range of impacts (e.g. physical disturbance, toxic pollution) in a variety of sediment types (e.g. Maurer et al., 1999; Marin-Guirao et al., 2005; Labrune et al., 2006).

Management and protection of the marine environment requires reliable decisions to be made using appropriate measures that convey all the necessary information (Dale and Beyeler, 2001; Kurtz et al., 2001; Bockstaller and Girardin, 2003; Cloquell-Ballester et al., 2006; Sneddon et al., 2006; Donnelly et al., 2007). In order to achieve this indicators must meet certain criteria governing their utility. Whilst numerous lists of criteria have been produced (e.g. ICES, 2001; Defra, 2003, 2004; Hanson, 2003; EEA, 2005) there are several common elements, typically relating to sensitivity or linkage to a given human activity, relevance to the study, understandability or communicability and statistical robustness.

Such criteria are undeniably important in indicator development and application, but determining whether they are met in practise presents a considerable challenge, particularly in the current climate of rapidly changing EU and UK marine policy and associated strategic objectives aimed at sustainable development and the implementation of an ecosystem approach to environmental management. Increasing recognition of the need for a process of formal validation as an essential step in the development and adoption of a promising indicator is reflected in the recent literature, where a commonly used approach involves an evaluation of indicators against criteria or guidelines by a multidisciplinary team of experts (Bockstaller and Girardin, 2003; Cloquell-Ballester et al., 2006; Donnelly et al., 2007).

This paper explores the efficacy of a similar validation process in a comparative analysis of selected indicators based on benthic community structure using datasets collected at four dredgings relocation sites and four aggregate extraction areas. Performance was assessed according to six criteria governing utility that were selected to represent those identified by a variety of national and international organisations (above), using those of ICES (2001) as the core set. The criteria utilised for the purpose of this study were:

(1) Relatively easy to understand by non-scientists and other users.
(2) Sensitive and relevant to a manageable human activity.
(3) Tightly linked to the human activity but not to other causes of change.
(4) Easily and accurately measured, with a low error rate.
(5) Affordable and feasible in terms of data collection and manipulation.
(6) Capable of providing early warning (of an adverse event or trend).

2. Materials and methods

The capability of a variety of indicators to identify alterations in benthic faunal communities arising from dredged material relocation at sea and marine aggregate extraction was explored using data from a total of 8 field surveys. As a result of prior knowledge of the nature and extent of the activities, and of the targeted survey designs, the data were known to exhibit gradients of change associated with near-field impacts.

2.1. *Dredgings disposal sites*

The three offshore disposal areas Liverpool Bay, North Tyne and Souter Point (off the River Tyne) and Roughs Tower (outer Thames estuary) were selected for evaluation of indicator performance in relation to the pre-determined criteria (Fig. 1). Additionally a survey carried out at Westwick Marine (Crouch estuary), involving the recharge of an area of eroded saltmarsh (Bolam and Whomersley, 2003), was included in order to examine indicator performance in relation to 'beneficial' deposition of dredged material in an inter-tidal environment (Fig. 1).

The disposal sites were selected in order to represent both a range of environmental characteristics along with differing disposal regimes. Liverpool Bay, established in 1982, is a relatively shallow disposal site (approximately 10 m) which typically receives approximately 2 Mt of mud and sand per annum from maintenance dredging of docks and navigational channels in the Mersey estuary and its approaches (Somerfield et al., 1995). Roughs Tower, which consists of a complex of licensed areas, is similarly shallow (10–20 m) and has historically received relatively large quantities of both maintenance and capital dredgings (Rees et al., 2002). This disposal site was effectively relinquished in 2000. North Tyne and Souter Point disposal sites are comparatively deeper (approximately 40 m) and have both been subject to a long history of disposal, some of which pre-dates statutory control. Prior to the early 1990s materials disposed of at the sites included minestone, colliery tailings, fly ash from coal burning power stations and dredged materials from estuaries (Rees and Rowlatt, 1994). Westwick marina differs from the three offshore disposal sites both in terms of its environmental setting (i.e. inter-tidal muddy channels within a saltmarsh system) and disposal regime which involves placement of maintenance dredgings from an adjacent navigational channel onto an area of eroded saltmarsh (Bolam and Whomersley, 2003).

Surveys at the three offshore dredgings disposal sites involved replicate grab samples obtained from transects located along the main tidal axis (Fig. 1). Macrofaunal samples were subsequently extracted over a 1-mm mesh sieve. At the Westwick 'beneficial use' site three replicate