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

Cefas

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Introduction

The macro-infauna (i.e. animals retained on a 1mm mesh sieve) are routinely sampled at most UK dredgings relocation and aggregate extraction sites, and data are available from Cefas surveys over several years. For the purposes of this study we interrogated specimen data sets in order to rank the performance of commonly used indicators (Table 1) against criteria governing their utility:

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. Provide early warning.

Table 1

Indicator	Symbol or abbreviation
Number of species	S
Number of individuals	N
Shannon-Wiener Diversity	H'
Average Taxonomic Diversity	Δ
Average Taxonomic Distinctness	Δ^*
Taxonomic Breadth	Δ^+
Average Phylogenetic Diversity	Φ^+
ES(100)	ES(100)
Infaunal Trophic Index	ITI
Index of Multivariate Dispersion	IMD
AZTI Marine Biotic Index	AMBI

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, details of which are given below. The results of these surveys have previously been published by Rees *et al.*, 1992, Rees and Rowlatt, 1994, Somerfield *et al.*, 1995, Rees *et al.*, 2002, Bolam and Whomersley, 2003 and Boyd *et al.*, 2004.

Dredgings relocation sites

Four sites, representing different geographical locations and disposal regimes, were selected. Site Z (Liverpool Bay) (Figure 1), North Tyne and Souter Point (off the River Tyne) (Figure 2) and Roughs Tower (outer Thames estuary) (Figure 3) are all offshore dredgings disposal sites whilst Westwick (Crouch estuary) (Figure 4) is a 'beneficial use' scheme that involved the recharge of an area of eroded saltmarsh.

At the offshore dredgings relocation sites transect surveys were employed using replicate 0.1 m^2 Day grabs and the macrofauna was extracted over a 1 mm sieve. At Westwick sampling was conducted using a 0.01m^2 perspex corer to a depth of 15cm employing a 0.5 mm mesh sieve to extract the macrofauna. Three replicate cores were obtained from within the recharge area and also from within an adjacent reference area outside the zone of impact of the recharge process.

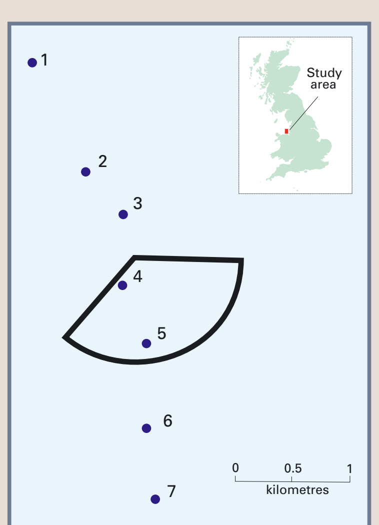

Figure 1: Location of stations in relation to Liverpool Bay Site Z disposal site

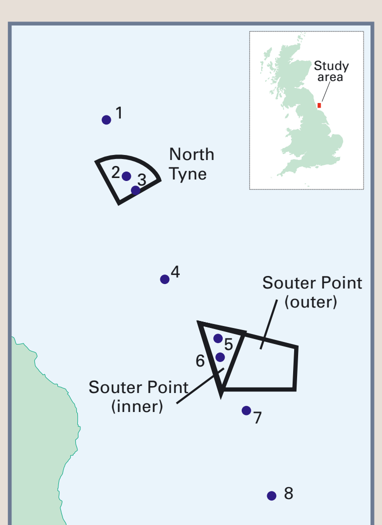

Figure 2: Location of station positions in relation to the North Tyne and Souter Point disposal sites

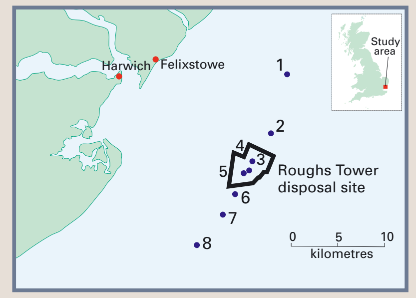

Figure 3: Location of station positions in relation to the Roughs Tower disposal site

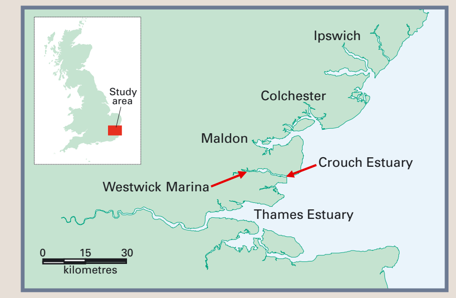

Figure 4: Location of Westwick Marina beneficial use of dredged material scheme

Aggregate extraction sites

Four licensed aggregate extraction sites, representing various geographical locations and dredging regimes, were selected (Figure 5). Stations representative of high and low intensities of dredging along with nearby reference stations were initially identified. This was achieved through interrogation of Electronic Monitoring System (EMS) data from the dredging vessels, comprising the date, time and position of all dredging activity recorded at 30 second intervals. High intensity locations were defined as >5 hours of dredging recorded in a 100 x 100m block per annum and low intensity locations as <1hour of dredging recorded in a 100 x 100 m block per annum. Five replicate 0.1m^2 Hamon grab samples were obtained from each location and a 1mm mesh sieve used to extract the macrofauna.

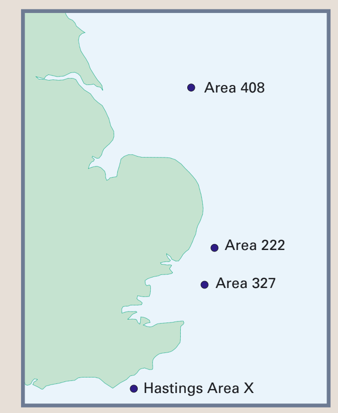

Figure 5: Locations of aggregate extraction areas included in this study

Evaluation of indicator performance against utility criteria

This was examined for each case study through a comparison of multivariate outputs with results obtained from univariate statistical analyses. Each metric was then scored independently by a team of benthic ecologists against each criterion on a range of 0-5 (0=very poor, 5=excellent).

Results

The between-individual relationships in scores were deduced to be linear, and all possible comparisons (i.e., between each pair of scorers for each activity) were significantly positively correlated ($P<0.001$).

Scores were subsequently investigated, using Principal Components Analysis (PCA) and cluster analysis, in order to identify any patterns in the performance of the metrics in relation to the pre-determined criteria.

Dredgings disposal sites

PCA of score data at dredgings disposal sites indicated that the PC1 axis accounted for 93.4% of the variation in the data (Figure 6). Little further variation was explained by PC axis 2 and 3 (2.9% and 1.7% respectively).

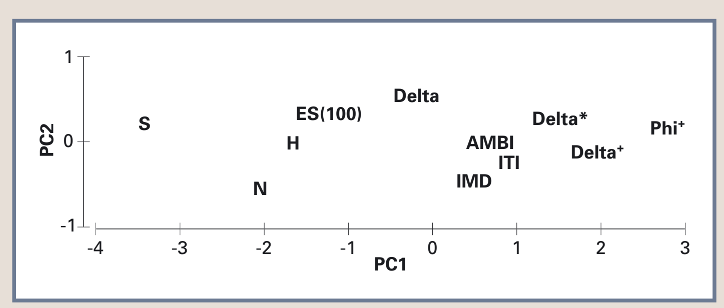

Figure 6: Outcome of PCA of scores for biological measures against criteria at dredgings disposal sites

Examination of the eigenvector values indicated that most variability along PC1 could be attributed to differences between the metrics in terms of criteria 1, 2, 3 and 6, with scores decreasing from left to right. Little difference could be identified between the metrics in terms of criteria 4 and 5. The rank order of metrics is further illustrated through examination of mean scores (Figure 7).

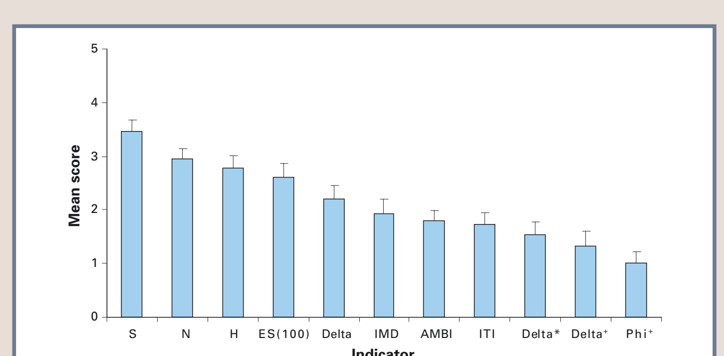

Figure 7: Mean scores assigned to metrics at dredgings relocation sites

Aggregate extraction sites

For scores at aggregate extraction sites, the PC1 axis accounted for 92.9% of the variation in the data (Figure 8). Little further variation was explained by PC axes 2 and 3 (3.3% and 2.7% respectively). Examination of eigenvector values indicated that most variability along PC 1 could be attributed to differences between the metrics in terms of criteria 1, 2, 3 and 6, with scores decreasing from left to right. This was a similar finding to that for dredgings disposal activities. Little difference could be identified between the metrics in terms of criteria 4 and 5. The rank order of metrics is further illustrated through examination of mean scores (Figure 9).

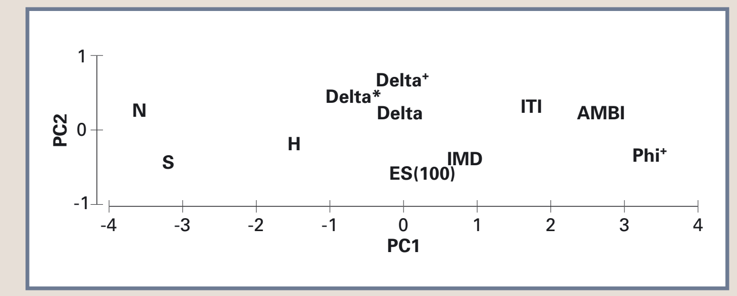

Figure 8: Outcome of PCA of scores for biological measures against criteria at aggregate extraction sites

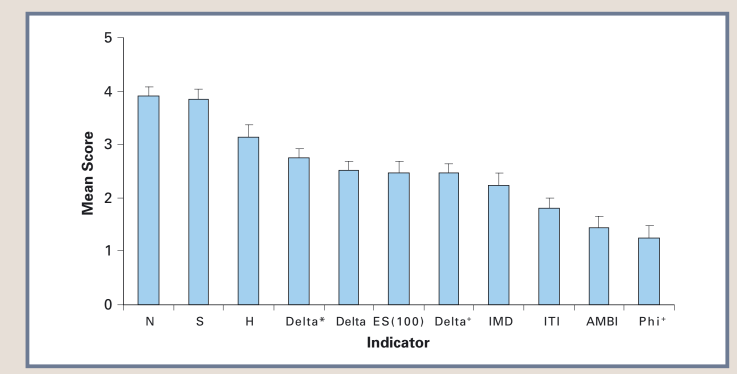

Figure 9: Mean scores assigned to metrics at aggregate extraction sites

Discussion

Primary variables 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. 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.

We consider that there is scope to further refine the approach, in particular through wider 'stakeholder' and institutional involvement, along with larger sample sizes. Similarly, it is recognised that the criteria used here may themselves be subject to refinement. In some circumstances, there may be 'trade-offs' between indicators valued for their relative sensitivity on the one hand or their capability to operate over larger spatial scales on the other. This may be allowed for through the weighting of criteria according to their perceived importance.

References

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