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Biomarkers: Are realism and control mutually exclusive in integrated pollution assessment?

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ABSTRACT

The conventional view of pollution monitoring is that any choice is a trade-off between realism and precision, as the control over confounding variables decreases with the increasing degree of organization of the test system.

Dublin Bay is subject to considerable anthropogenic pressures and there have been many attempts to quantify the status of the system at organizational levels from DNA strand breaks (Comet) to the system itself (Ecological Network analysis, ENA).

Using Dublin Bay as an example, the data show there was considerable variability at all levels of organization. At intracellular level, Lysosome Membrane Stability (LMS, assessed by Neutral Red Retention, NRR) varied almost 4-fold with season and individual condition, while the community level AZTI Marine biotic Index (AMBI) had a similar range within a single, supposedly homogeneous, site. Overall, there was no evidence that biomarkers of the lower levels of organisation reduced the variability of the measure, despite the extra control over influencing variables, nor was there any evidence that variability was additive at higher levels of organisation.

This poses problems for management, especially given the fixed limits of Ecological Quality Standards (EQSs). Clearly while the integrated approach to pollution monitoring does offer the potential to link effects across the organizational range, it should also be possible to improve their capability by widening the database for reference values, particularly at the higher level of organization, and by process models, including the confounding variables found in the field, for those at lower level.

1. Introduction

The recent imperatives imposed by the Water Framework Directive (WFD, 2000/60/EC) and the Marine Strategy Framework Directive (MSFD, 2008/56/EC) with their requirements not just to categorise ecological or environmental status but to achieve at least good status within a defined time-frame have focused attention on the means by which such assessments are made.

The conceptual model of Pearson and Rosenberg (1978) brought together much of the work that had been done to date on pollution changes at community level, and there have been many attempts to develop an index which might reliably summarise the degree of impact. These attempts have included spatial integration formulae (Leppakoski, 1977; Jeffrey et al., 1985), mathematical models such as the log-normal distribution (Gray and Mirza, 1979), and a variety of diversity/dominance measures such as the Shannon–Weiner distribution which has answered so well in fresh waters before being refined into the current species-based AMBI and Biotic Coefficient (BC) (Borja et al., 2003).

However this traditional approach is costly in both in terms of resources required and in time, not just to carry out the requisite sampling and analysis but also in terms of the lag or inertia in such large systems. An additional complication is imposed by the need to account for natural variability since few if any of the stressors can be controlled (Irvine, 2004). Accordingly other measures have been proposed by which the status of a system might be evaluated in a more timely and cost-effective fashion by measuring the performance of a component of the system, rather than the whole thing itself. In addition, these results should be less variable since more of the external variables can be controlled. Furthermore such components could be selected for their response to specific stressors or contaminants, such as metallothionein (MT) for metals (Viarengo et al., 1997), various elements of the cytochrome P-450 system (Porte et al., 1991) for xenobiotics and imposex for tributyl tin (TBT)

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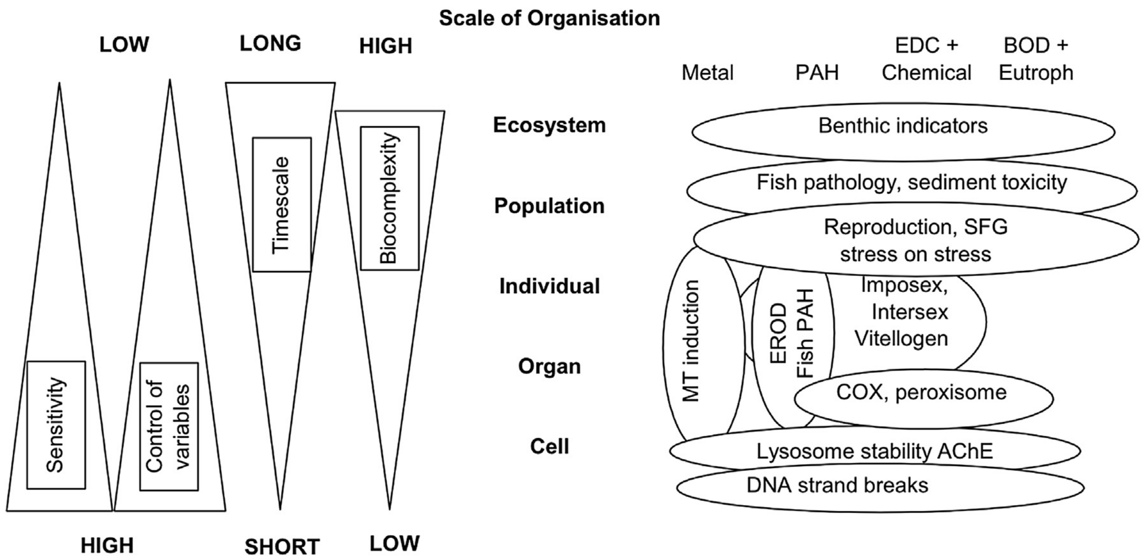

Fig. 1. Summary of index properties against scale of organization. See also text for explanation and discussion.

(Gibbs et al., 1987). The disadvantage of using components of the system is that the effects at system level may be masked by various homoeostatic mechanisms in the system – for instance where one component may be able to compensate for decreased performance in another – or by intrinsic problems such as hormesis in the component response itself (Stebbing, 1981). As a consequence, the choice of monitoring is often depicted as a compromise between realism at community or system level and speed and sensitivity at lower levels of organization as depicted in Fig. 1.

A further advantage of measurements at lower levels of organization is that some at least of the confounding variables can be controlled, which means that a more specific response is being measured and unwanted sources of error and variability are eliminated.

The current recommendation from the International Council for the Exploration of the Sea (ICES) Working Group on Biological Effects of Contaminants (Davies and Vethaak, 2012) is that a suite of indices be employed from a range of organizational levels to obtain as complete an assessment as possible.

In this study, we present the results from a series of indices of status in Dublin Bay, Ireland, specifically to test whether a) the assessments are consistent among themselves; and b) whether in fact indices at lower levels of organization are less variable.

2. Materials and methods

The test site, Dublin Bay is shown in Fig. 2, along with the locations mentioned in the text. Dublin Bay is a shallow, largely sandy system, dominated by various *Venus* (*sensu* Thorson, 1957) communities, and is surrounded on three sides by the conurbation of the city of Dublin. The major riverine input is the River Liffey whose estuary hosts Ireland's largest shipping port and which also receives the city's sewage discharge. Following substantial upgrading in the 1990s, the effluent now receives secondary treatment.

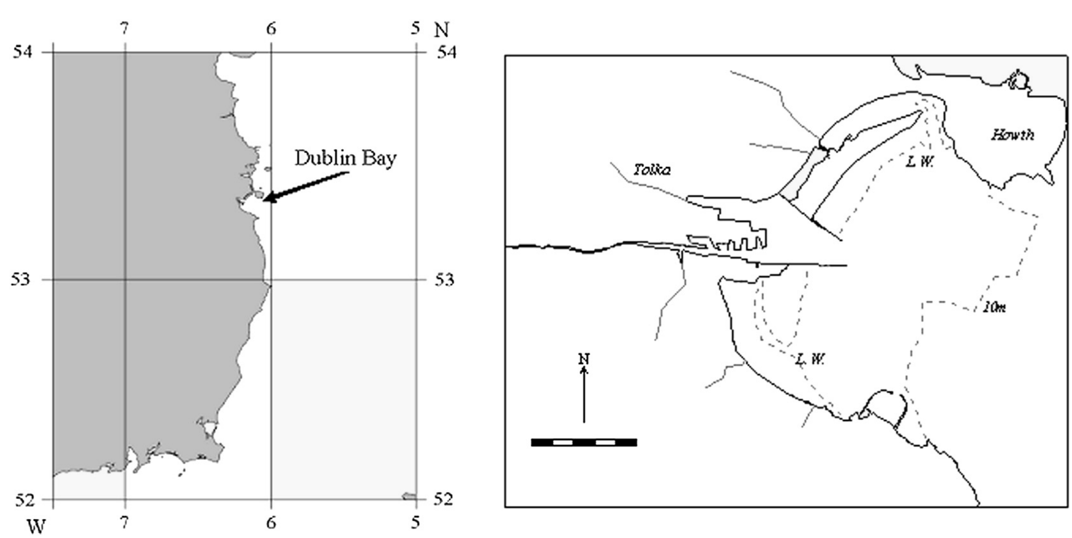

Fig. 2. Dublin Bay showing Liffey and Tolka estuaries and extent of the littoral area (dotted line).

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