ECOLOGICAL MODELLING

Method Indicator		
Bottom-Up	Hybrid	Top-Down
		YES

Summary of key issues

Issue	Description
Description	A variety of tools for the assessment of ecological change within estuaries, catchments and coastal cells.
Temporal Applicability	From short to long-term, dependent on the aim of the assessment.
Spatial Applicability	Broad scale assessment, whole catchment or coastal cell, to individual species models for an element of the estuarine system.
Links with Other Tools	Ecological modelling can inform a variety of assessment tools, including EGA.
Data Sources	Dependent on the assessment aims and methodology.
Necessary Software Tools / Skills	Dependent on the assessment aims and methodology.
Typical Analyses	Broad scale ecosystem assessment is required in the context of flood management and coastal defence initiatives and its associated SEA requirements.

Ecological models have been developed to describe the interactions between physical, chemical and biological components of a system. Generally the models are limited to specific interests of a study, for example, fish or bird populations, benthic communities or habitat types. There are a number of ecological modelling tools that have been developed and the type of model used will depend on the type of data that is available and the question that is being asked. Ecological assessment is based on the Broad Scale Ecological Assessment (BSEA) Toolbox 1 (Defra/EA R&D Project FD2112, Conlan *et al*., 2006), which seeks to provide a user-friendly package of guidance, data sources and broad ecosystem impact modelling techniques to practitioners undertaking SMP/ CHaMP work within the coastal flood management field.

In order to predict coastal ecosystem impacts, an approach is required that:

- Identifies the location, nature, extent and significance of coastal habitats;
- Describes the current shoreline location/ configuration;
- Predicts the change in shoreline location/ configuration over time;
- Explains the reasons for the changes predicted;
- Predicts and evaluates the impacts of the changes identified; and
- Provides tools/ guidance for avoiding/ minimising adverse impacts and maximising beneficial outcomes.

The recommended approach to coastal systems is to have a two tier methodology, with the level of study complexity dependent on two factors:

- Ecosystem interest and sensitivity to change (given potential policy options) in the identified coastal cell, and
- Quality and quantity of input data (hydrology, geomorphology and ecology).

Where there is little likelihood of ecosystem change, or where there are too few data to make a detailed analysis of ecosystem impact, a High Level analysis should be performed. The study can then be promoted to a mid level analysis where there are potentially significant ecosystem implications that need to be explored further by means of more complex assessment. The two tiered approach is analogous to environmental impact assessment (EIA), with the high level method similar to the Scoping phase in EIA. However, where initial studies recognise that a more detailed approach may be beneficial, but too few data of reasonable quality exist to support the analysis, care must be taken to flag this as a significant issue.

Principal sources of data for the BSEA Toolbox

Data on the key factors highlighted is potentially available from a wide variety of sources such as European agencies, British government agencies, local authorities, academic institutions and consultancy organisations. There is, however, great variation in data availability and data quality in terms of attributes such as format, coverage and resolution.

It is appropriate to employ the UK National Marine Habitat Classification (NMHC) for Great Britain and Ireland as the basis for assessment. This system is both well developed and well understood. It is also currently being used to develop reference conditions for UK waters as part of the implementation of the WFD. The NMHC defines marine habitats in terms of both physical (elevation, salinity, substratum etc) and biological characteristics (species abundance/coverage).

High level ecosystem assessment

This approach is relatively quick and straightforward seeking to highlight potential threats and/or opportunities on the broadest scale. Nevertheless, it will require a substantial degree of professional knowledge and judgement for proper interpretation.

The steps in the process are as follows:

1. Define broad habitat baseline and ecosystem drivers;
2. Prediction of change to ecosystem drivers;
3. Identify biodiversity opportunities and constraints and develop Broad scale Ecosystem Criteria (BEC);
4. Expert consultation and review;
5. Policy development; and
6. Policy assessment using BSEA.

The approach is GIS-based and driven by a qualitative review of appropriate current baseline and historic data for coastal habitats and the key drivers for their dynamic evolution.

Mid level ecosystem assessment

The high level assessment as described above will serve to facilitate identify and prioritise areas for mid level analysis. This will involve more detailed assessment of specific areas over shorter timescales ideally using site-specific data on key variables. Top-down or bottom-up approaches can be adopted.

Specific modelling approaches that can be applied in the more detailed ecological studies (Conlan, 2002) are described below:

Empirical models

Empirical models are usually based around the collection of baseline ecological data from a wide range of ecosystem and habitat types, followed by database development that seeks to identify 'natural', 'typical' and 'atypical' community structures based on the description of patterns and links between the biological and physio-chemical variables. The databases can then be used to type or predict what sort of communities should or could exist for given circumstances (e.g. Elliot & O'Reilly, 1991; Gray *et al*., 1995; Wright *et al*., 2000).

Dynamical systems

Dynamical systems models are used to track species interaction over time, usually in a homogenous (non-spatial) environment. The typical input data is population densities. This type of model has been used to investigate ecological interactions such as competition, predation and parasitism.

Proprietary deterministic mathematical models

These models are typically process driven and have started to be used to investigate the links between hydrology, hydrodynamics, geomorphology and ecology (e.g. Reynolds *et al*., 2001). These models can be data intensive.

Metapopulation models

In metapopulation models, an area is described as a collection of patches (Hanski, 1999). The total population across all patches is known as a metapopulation, and is regarded as stable over a significant timescale. The individual patches are linked through migration or other patch-to-patch contact processes and within patch dynamics are also defined. Metapopulation models have been used to study both single species and multi-species communities. For example, insights have been gained from this approach into species succession, species richness and composition, and the food web structure of communities.

Cellular automata

In Cellular Automata models, space is represented by a uniform grid, with each cell in a specified state. Updating of a cells state depends on the states of neighbouring cells, and is governed by either deterministic or stochastic rules representing local ecological interactions. These models are particularly useful for demonstrating spatial processes (Ermentrout & Edelstein-Keshet, 1993).

Individual based models

Individual based models are spatial and based on the behaviour of interacting individuals, whose states are specified by attributes (DeAnglis & Gross, 1992). This includes the responses to different environments and to other individuals. Space is modelled by cells that are either occupied or empty and time is updated in discrete steps.

Conceptual network models

Network analysis is a collection of nodes, pairs of which are joined by a collection of edges. Typically nodes are assigned with attributes, which may be quantitative or qualitative, indicating what features of an ecosystem they represent. Similarly edges have both a direction, indicating which node is the source of an influence and which is the recipient, and a parameter indicating the sign and/or the strength of the influence carried. Nodes representing the 'outside world' can also be added to the model. This type of modelling can be used to accommodate several layers of sophistication, depending on the degree of detail entered into the sub-networks (e.g. Voinov *et al*., 1999).

Bayesian or belief networks

A Bayesian Network represents conditional probability dependencies between possible events in the form of a graphical network (Jensen, 1996). A complex system is built by combining simpler parts, with probability theory providing the glue, ensuring the system as a whole is consistent, and providing ways to interface the model. The approach can be very flexible, in particular for representing systems that have unobserved components.

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