The following section provides a very brief introduction to this topic, which is frequently encountered as part of addressing specific impacts within estuaries. The section is included so that these aspects are not forgotten but the reader is referred to the literature cited for more extensive coverage.

ECOLOGICAL MODELLING

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. A report 'Broad Scale Ecosystem Impact Modelling Tools: Scoping Study which was produced for DEFRA and the Environment Agency in 2003 detailed the types of approaches that are currently in use. This document serves to provide a summary of each of these types of models.

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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