1.2 On modelling

The word ?model? has several meanings; for scientists, and more specifically for biologists working at the ecosystem level, ?models? may be defined as consistent descriptions, emphasizing certain aspects of the system investigated, as required to understand their function.

Thus, models may consist of a text (?word models?) or a graph showing the interrelationships of various components of a system. Models may also consist of equations, whose parameters describe ?states? (the elements included in the models) and ?rates? (of growth, mortality, food consumption, etc.), of the elements of the model. The behaviour of mathematical models is difficult (often impossible) to explore without computers. This is especially the case for ?simulation models?, i.e., those representations of ecosystems that follow, through time, the interactive behaviour of the (major) components of an ecosystem.

Traditional simulation models are difficult to build, and even more difficult to get to realistically simulate, without ?crashing?, the behaviour of a system over a long period of time. This is one reason why many biologists shied away from constructing such models, or even interacting with ?modellers? (who, traditionally being non-biologists, may have had scant knowledge of the intricate interactions between living organisms). However, ?modelling? does not necessarily imply ?simulation modelling?. There are various ways of constructing quantitative models of ecosystems which avoid the intricacies of traditional simulation Modelling, yet still give most of the benefits that can be expected from such exercise viz:

> requiring the biologist/ecologist to review and standardize all available data on a given ecosystem, and identify information gaps;requiring the would-be modeller to identify estimates (of states, or rates) that are mutually incompatible, and which would prevent the system from functioning (e.g., the production of a prey being lower than the food requirements of its predators);requiring the same would-be modeller to interact with disciplines other than her/his own, e.g., a plankton specialist will in order to model a lake ecosystem have to either cooperate with fish biologists and other colleagues working on the various consumer groups in the lake, or at least read the literature they produced.

To avail oneself of these and other related advantages, one's models should be limited to describing the situation prevailing during a certain ?average? period. This limitation is not as constraining as it may appear at first sight. It is consistent with the work of most aquatic biologists, whose state and rate estimates represent ?averages?, applying to a certain period (although this generally is not stated). It is also consistent with the practice common in traditional simulation modelling of using the mass-balance assumption to estimate the parameters of simulation model. This justifies the approach proposed here, to use state and rate estimates for single species in a multispecies context for describing trophic flows in ecosystems in rigorous, quantitative terms, during the (arbitrary) period to which their state and rate estimates apply.

In many cases, the period considered will be a typical season, or a typical year, but the state and rate estimates used for model construction may pertain to different years. Models may represent a decade or more, during which little changes have occurred. When ecosystems have undergone massive changes, two or more models may be needed, representing the ecosystem before, (during), and after the changes. This can be illustrated by an array of models of the Peruvian upwelling ecosystem representing periods before and after the collapse of the anchoveta fishing there (Jarre et al., 1991a). Several other examples for this may be found in Christensen and Pauly (1993b).

When it is seasonal changes which must be emphasized, different models may be constructed for each month, season, or for extreme situations (?summer? vs. ?winter?). As an example Baird and Ulanowicz (1989) constructed four models describing the seasons in Chesapeake Bay, and an ?average? model to represent the whole year. The same idea can be applied to aquaculture situations, where a pond and its producers and consumers can be described for instance at the beginning, midpoint, and end of a growing season. Examples of this can be found in Christensen and Pauly (1993b).

Judicious identification of periods long enough for sufficient data to be available, but short enough for massive changes of biomass not to have occurred, will thus solve most problems associated with the lack of an explicit time dimension. Moreover, when a build-up of biomass is known to have occurred, this can be considered explicitly as ?accumulated biomass?, a component of biological production.

The Ecopath system is built on an approach presented by Polovina (1984a; 1984b) for the estimation of the biomass and food consumption of the various elements (species or groups of species) of an aquatic ecosystem, and subsequently combined with various approaches from theoretical ecology, notably those proposed by R.E. Ulanowicz (1986), for the analysis of flows between the elements of ecosystems.

Once a model of the type discussed here has been built, it can be used directly for simulation modelling thanks to the time dynamic model, Ecosim, and the spatial dynamic model, Ecospace, both fully integrated with Ecopath in the present software.