SCOR WORKING GROUP 59

MATHEMATICAL MODELS IN BIOLOGICAL OCEANOGRAPHY (WITH IABO)

Report of meeting

Wormley, UK

6–9 December 1977

Working Group 59, *Mathematical Models in Biological Oceanography* was set up on the advice of IABO, in 1977, with the following terms of reference:

- To suggest mathematical methods in marine ecology for the design of research programmes in the open sea and the nearshore waters.
- To suggest experiments for the treatment of biological data collections with particular reference to the development of mathematical models.
- The working group should maintain contact with SCOR WG 49 on mathematical modelling of oceanic processes.

The first meeting was held at the Institute of Oceanographic Sciences, Wormley, UK from 6 December to 9 December, 1977.

Present were: K.H. Mann, Canada Chairman; T. Platt, Canada, Vice Chairman; J.M. Colebrook, UK; D. Smith, Australia; M.J. Fasham, UK; R. Ulanowicz, USA; F. Wulff, Sweden, J. Field, S. Africa.

Regrets were received from G. Radach, F.R.G.; M. Vinogradov, U.S.S.R.; V. Menshutkin, U.S.S.R.

J.W. Horwood, UK was invited to be present to contribute expertise in fisheries modelling.

The working group recommends that its first contribution to meeting the terms of reference should be production of a review of the state of the art in biological oceanographic modelling with implications for the design of research programmes. Such a review may well be suitable for publication in the series of UNESCO Technical Papers in Marine Science.

The group discussed the form and content of this review, and the members have agreed to produce drafts of their sections which will be the basis for integration into a coherent document at a future meeting. Attached is a provisional outline of the review, with indications of the possible allocation of responsibility for writing. The suggested date for submitting draft sections to the Chairman is 1 December 1978, and we *recommend* that a second meeting of WG 59 take place in February or March 1979.

The working group noted the item in the terms of reference requiring us to interact with those concerned with mathematical modelling of oceanic processes, and *recommends* that the group be allowed to invite to its next meeting a physical oceanographer with experience of interacting with biologists.

The group discussed a request to advise GIPME on the value of biological modelling in marine pollution studies, (see SCOR Proceedings Vol. 14 Annex XI).

A request for liason with WG 57 was received. We *recommend* that Dr G. Radach of Hamburg attend their next meeting, in Hamburg 28 August to 1 September, 1978.

Proposed UNESCO Technical Paper on "Mathematical Models in Biological Oceanography"

Chapter 1. **THE CLASSES OF MODELS IN BIOLOGICAL OCEANOGRAPHY** (Mann)

(i) **Ecosystem models**

(a) Compartmental flow diagrams.

(b) General simulation models of fluxes to produce time and/or space series of state variables.

(c) Holistic approaches to whole ecosystems.

(ii) **Process models**

(a) Models of single processes.

(b) Models with several processes coupled. These grade into ecosystem models.

(iii) **Choosing the appropriate model**

Comments on defining the problem and choosing the appropriate methods, including models.

Chapter 2. **ECOSYSTEM MODELS** (Wulff)

(i) **Conceptual diagrams**

On the need to consider conceptually how the ecosystem appears to be functioning, before embarking on mathematical modelling.

(ii) **General simulation models** (Wulff/Mann)

The current 'state of the art' usually involves expanding compartmental flow diagrams into mathematical models designed to produce time or space series of state variables. The chapter discusses value and limitations.

(iii) **Holistic approaches to ecosystems**

(a) Topology of food webs. (Ulanowicz)

(b) Size spectral analysis. (Ulanowicz)

(c) Unstructured food webs. (Fasham)

(d) Statistical mechanical (e.g. Kerner) (Fasham)

(e) Irreversible thermodynamics including Odum and Pinkerton (Platt)

(f) Levins' Theory of the Niche and other system properties. Loop analysis. (Platt)

(g) Other approaches. (Collaborative)

Chapter 3. **PROCESS MODELS**

(i) Models of single processes, all variables observable and capable of experimental manipulations, e.g. Primary production as function of light, zooplankton grazing as function of food, fish stock recruitment. (Field)

(ii) Models of single processes, all variables observable, but not all capable of experimental manipulation; e.g. models of plankton patchiness, larval fish mortality, seasonal succession in the phyto-plankton etc. (Colebrook)

(iii) Models with several processes coupled, e.g. multi-species fish management models. (These grade into ecosystem models). (J. Horwood (Lowestoft))

Chapter 4. **IMPLICATIONS FOR DESIGN OF RESEARCH PROGRAMMES**

(i) Measurement of size spectra where appropriate. (Ulanowicz)

(ii) Food web analysis using isotope tracers, dyes or gut analyses; trace element analysis. (Smith)

(iii) Implications for sampling of knowledge of scales of variability in time or space. To be considered in relation to biomass or growth.

(a) General considerations. (Platt)
(b) Survey design. (Colebrook)

(iv) Power spectrum of state variables, as a diagnostic tool (with applications to model validation). (Fasham)

(v) Instantaneous measurements, in situ, of rate processes in populations (e.g. metabolism). (Smith)

(vi) Critical physical qualities of interest to biological modellers. (Platt/Fasham/Radach)

(vii) On interfacing biological and physical models - a case history. (Colebrook)

(viii) The need for simultaneous time series of adequate duration and resolution of important biotic and abiotic variables, (Colebrook)

(ix) Indices of response to stress. (Ulanowicz)

Note: Dr Ulanowicz will contact Dr Tibor Polgar, Martin Marietta Laboratories, Baltimore, for the input of a benthic ecologist wherever appropriate, but especially in Chapter 4.

THE USEFULNESS OF MODELLING IN RELATION TO STUDIES OF MARINE POLLUTION

By SCOR WG 59

The working group encourages the application of simple process models to marine pollution problems. Such models have been successfully applied to pollution episodes in the past, they provide a good framework upon which to organize measurement programmes; they are usually tractable mathematically and they are prerequisite to the construction of larger community simulations.

We further encourage the construction and employment of qualitative compartmental flow diagrams. They are a significant help in organizing thinking about biological communities and frequently point out gaps in knowledge about an ecosystem. Even without detailed knowledge of the processes involved along each pathway, they can often foster one's understanding of total system behaviour. In our review article we hope to expand upon this latter point by referring to methods for analyzing compartmental networks in lieu of numerical or analogue simulation.

We would caution investigators not to rely too heavily on the results of whole ecosystem simulation models, until the individual component processes are better understood. There are not many validated models of whole ecosystems available for use. Even those community models purported to be validated under unpolluted conditions are not necessarily valid under polluted conditions.

Finally, we should like to call attention to attempts to develop holistic measures of community behaviour which may provide reliable indices of ecosystem response to pollution stress. Again, we hope to provide more details of this approach in our review document.