SIMULATION MODEL OF A COASTAL ECOSYSTEM INFLUENCED BY EUTROPHICATION

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The integration of the complex processes occuring in physical systems is being carried out nowadays using simulation models (FASHAM *et al.*, 1990). Such an approach to describe the dynamics of a coastal ecosystem influenced by eutrophication, caused by sewage effluents, is attempted in the present work. The modelling effort is focused on the interactions between phytoplankton, heterotrophic bacteria and organic matter, with less emphasis on the phytoplankton-nutrient interrelationship. The physical system is located along the coastal area of the city of Mytilini. Physical, chemical and biological data have been collected from two stations, the first one characteristic of eutrophication, and the other one of oligotrophy. Sampling details and the analytical methodology have been given in previous work (KARADANELLI *et al.*, 1992). Two spatial compartments were defined in the model, the eutrophic receiving the sewage effluents and the oligotrophic located offshore. Interactions between the two compartments are permitted using a turbulent exchange coefficient. Physical forcing from temperature and solar radiation have also been considered. The flow diagram is presented in Figure 1.The state variables of the model are phytoplanktonic and bacterial carbon, ammonia, nitrate and dissolved organic carbon concentrations. Nitrogen was chosen for the description of the energy flow since it is recognized as the primary limiting nutrient for algal productivity in coastal waters (BLACKBURN & SORENSEN, 1988). The key processes to be modelled are photosynthesis, driven by the physical forces of solar radiation and temperature, phytoplanktonic exudation, bacterial growth and organic matter mineralization. The flow diagram inside the eutrophic compartment is presented in Fig.2. The model was run until steady-state using the Runge-Kutta fourth-order integration algorithm for the solution of the differential equations, with a time step of one day. The annual cycles of phytoplanktonic and bacterial biomass as well as the ammonia and dissolved organic carbon concentrations in the eutrophic compartment are presented in Fig. 3 and 4.

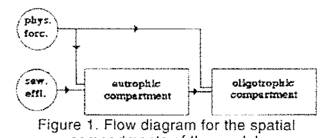

Figure 1. Flow diagram for the spatial compartments of the model.

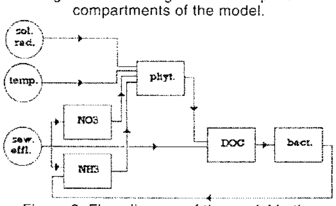

Figure 2. Flow diagram of the model in the eutrophic compartment.

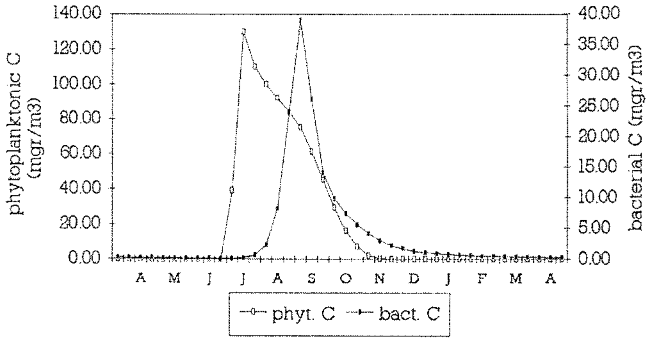

Figure 3. Annual cycles of phytoplanktonic and bacterial biomass in the eutrophic compartment.

A general pattern of low values in winter and very high in summer for phytoplanktonic and bacterial biomass was predicted by the model, in good agreement with the observed data. The bacterial peak in September can be attributed to the high concentration of dissolved organic matter, resulting from the degradation of phytoplanktonic products.

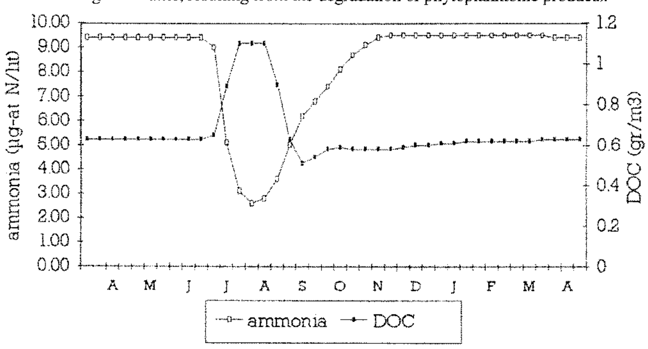

Figure 4. Annual cycles of ammonia and DOC concentrations in the eutrophic compartment.

High concentration of ammonia is predicted by the model, in accordance to the observed data, due to the input from the sewage outfalls. Almost the same patterns, for the annual cycles of the state variables, were observed for the oligotrophic compartment, but the values were much lower. An attempt was made to model the dynamics of a coastal ecosystem influenced by eutrophication. A better parameterization is being carried out using validation data, for further evaluation of the model and its use as a tool for a better understanding of microbial processes.

ACKNOWLEDGEMENTS

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LEVELS OF ORGANOCHLORINES IN RED MULLET FROM GREEK WATERS

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Organochlorine concentrations data in the tissues of red mullet (*Mullus barbatus*), a quite abundant and commercially important fish species, have been the subject of several studies during the last decade (RAVID *et al.*, 1985; SATSMADJIS *et al.*, 1988a; GEORGAKOPOULOS-GREGORIADES *et al.*, 1991; VASSILOPOULOU and GEORGAKOPOULOS-GREGORIADES, 1993). The aim of the present study is to report on the concentrations of organochlorines in red mullet caught at five sites of the Greek Seas, in spring and autumn from 1989 to 1991.

Sampling locations appear in Figure 1. In each specimen the fork length, weight, sex and state of maturity were recorded. Then, the flesh of the fish was removed, lyophilized, ground, mixed and stored in a refrigerator till used for further analysis. The organochlorine and lipid concentrations in the flesh of red mullet was determined according to the procedure proposed by SATSMADJIS and LATRIDES (1985) as modified by SATSMADJIS *et al.*, (1988b).

Figure 1. Location of sampling stations.

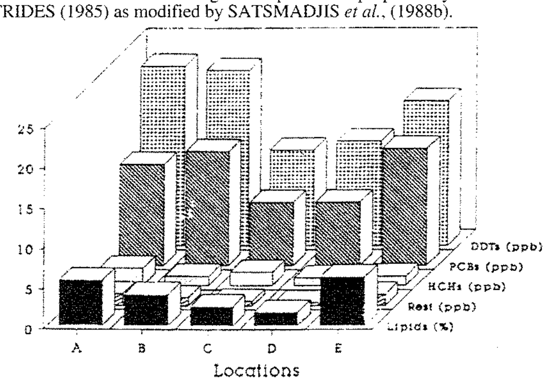

Figure 2. Mean total values of organochlorines and lipids.

Complementary clustering (group average stratery) using the Bray-Curtis similarity coefficient (BRAY and CURTIS, 1957) were performed on mean organochlorine data at the five sampling locations, using Primer algorithms (CLARKE and WARWICK, 1989). The mean total values of organochlorine concentrations (ppb wet weight) and the mean percentage of lipids in the red mullets were in all sites rather low (Fig. 2). Both parameters exhibited minimum values at sites C and D (located at the southern part the Greek Seas), which could be also influenced by the fact that specimens from sites C and D were of smaller size than those from the other three areas (t-test, P>0.05). It is known that organochlorines are lipophilic pollutants, whose concentrations generally increase as fish grow (LARSSON *et al.*, 1991; VASSILOPOULOU and GEORGAKOPOULOS-GREGORIADES, 1993). The application of cluster analysis revealed that sites A, B (NE Greece) and site E (NW Greece) exhibiting higher organochlorine concentrations, clustered together (Fig. 3). Sites C and D formed a separate group. Hence, higher organochlorine concentrations, being consistent with lipid content and size of fish, appear in mullets from the northern part of Greece in relation to those from the southern part. The organochlorine concentration pattern reported for the same sites for the period 1986-88 (GEORGAKOPOULOS-GREGORIADES *et al.*, 1991) revealed an east-west decline in organochlorine levels. The difference between the two surveys seems to be created by changes in organochlorine levels arising from the different lipid content and size of fish rather than real changes in organochlorine levels in the sampling sites.

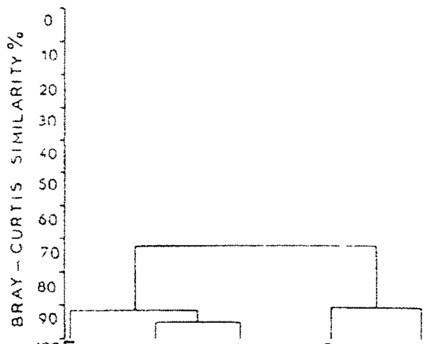

Fig. 3. Dendrogram for the mean concentrations of organochlorines in red mullet from 5 Greek locations

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