AQUATIC SIMULATION ON SECONDARY COOLING FOR ECCS

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ABSTRACT

Using a series of "logical switches" this model simulates an aquatic ecosystem. The model considers the influence of physical factors such as chemical nutrients and temperature in conjunction with a study of the interaction of trophic levels. The model is constructed as a series of modules each with its own threshold conditions. This allows for a study of the possibilities starting at the lowest trophic level. The use of threshold conditions results in efficient simulation and allows for a correspondence with variables that can be observed experimentally.

INTRODUCTION

Relationship underlying complex aquatic ecosystems are studied. The approach formulates threshold conditions and critical factors in terms of "logical switches" whose dynamics will simulate the operation of the system under study. To demonstrate the approach this paper will focus on plankton in the context of the entire ecosystem. The model was developed in modular form with a system overview to allow for the integration of physical, chemical and biological conditions.

In particular the study follows the growth of single organisms under local water conditions. The results may then be used to calculate the population level due to growth, death, advective factors, climatic factors, and grazing.

Focus is on underlying nutrient requirements, their consumption and assimilation. The model design allows for a direct study of the results varying nutrients and physical conditions. Thus, questions regarding variations resulting from different limiting factors can be easily addressed. The main thrust of this paper is the presentation of the switching technique for its inherent potential general use.

Aquatic Ecosystem Models

For a lake the process of nutrient use and recycling along with population dynamics follows a seasonal cycle (1) which includes self regulating factors (4). Early formulations used a single ordinary differential equation to model the population dynamics of plankton (7,8). Complex sets of equations followed (3,9) and at present there exist comprehensive models consisting of hydrological and ecological modules (2). Riley (8) reviewed statistical models of ocean environments. He proposed a theoretical model, underlying much later work incorporating assumptions based on observation of energy accumulation and dissipation by the population. Of interest to us is the attempt by Riley to relate the biological variables of growth, respiration, and grazing to the underlying environmental variables such as available solar radiation, temperature, nutrient concentration and predation. The approach presented here is illustrated in terms of nutrient concentration and temperature. The programs consist of a series of self-contained modules which can be easily linked up. The biological module for a simple organism is presented and then the physical modules are discussed.

A "General" Organism

Let us consider a simplified general hypothetical organism and follow its ingestion of nutrients and growth. A schematic representation of our module conceives it as imbedded in the entire environmental system. The assumption is that the organism will take as much of a nutrient as it can utilize as long as a minimum concentration is available. Nutrient uptake continues until a critical level is reached at which time growth or reproduction can be achieved.

The two physiological processes of the organism that were initially considered by the module are assimilation rate and growth rate. These two processes are obviously not independent (10). In the original module, the assumption is made that the growth rate of the organism is dependent only on total nutrient assimilation. That is to say, the growth rate is indirectly dependent on temperature through the temperature dependence of nutrient assimilation. The rate of nutrient assimilation was related to, and dependent upon, nutrient availability and the temperature of the environment.

The temperature dependence of assimilation rates for the various nutrients takes the form of a Boltzmann dependence chosen because of the chemical nature of assimilation. This same type of temperature dependence may be assumed for respiration rates. However, the program is easily modified to accommodate a different functional dependence. A widely assumed form for relation growth to nutrients is that of the Michaelis-Menton enzyme kinetics equation.

The actual relationship between combinations of nutrients is often unknown and difficult to determine. The use of threshold switches avoids postulating functional forms and provides a skeletal logical structure which is easy to manipulate and understand. Each necessary nutrient is assigned a threshold value below which the organism cannot grow. The levels can more readily be determined in practice than functional relationships. The thresholds will be organism dependent. Our assumption as to limited intake has counter examples. Phytoplankton ingest and store phosphates and nitrates they no longer have a current need for. The threshold model is designed to be easily modified. The model is easily adjusted for special cases and functional dependence will be refined as incoming data indicate the reasonableness of more exact hypothesis. Suitable data has been (5), and is being, collected for Lake Champlain.

The program has been written for interactive teletype use. Nutrient data, assimilation rates and critical levels for unit growth are required as input. The program generates time interval snapshots of the organism state.

In the original module when the specified level of a nutrient is reached the switch for that nutrient is "turned on." A subroutine called SWITCH then keeps track of the state of the nutrient growth level switches. When all of the nutrients required for unit growth reach their critical threshold levels the organism will utilize them in the growth process. After the growth process is completed, all the nutrient switches are set to the "OFF" position and the process is repeated. Relative growth rates of organisms are thus simulated by setting their different threshold values. Given an initial population the resultant local nutrient change due to consumption can be monitored. The model thus exhibits the consequences of fundamental assumptions as to the nutrient requirements of an organism. Limiting and retarding factors are directly discerned as are factors leading to the relative abundance of one species over another. Factors influencing periodicity can also be studied. Population density, nutrient concentration and temperature will vary with depth. The necessary temperature profiles are obtained from the physical module as illustrated by the simulation of thermal stratification.

Temperature Profiles

Temporal and spatial temperature relationships for ice-free lakes have been accurately modeled by Dr. Glen Myer of the Lakes and Rivers Research Laboratory (6). The aquatic ecosystem model has been designed to incorporate Dr. Myer's simulation program which is rather long and complex. The switch type approach used for test runs cut down considerably on computer time. The results are a fair approximation to the complex simulation. The profiles are time-dependent. The switch approach also generated a satisfactory series of profiles.

CONCLUSION

The aquatic environment presents us with a situation where modeling is needed for insight and guidance of experimentation while insufficient data is available for rigorous modeling. In this situation people have resorted to setting up complex equations in order to reflect the complex interactions that occur. We find models that "consist of sets of coupled nonlinear partial differential equations describing the temporal and spatial distribution of nutrients and phytoplankton" (11). In setting up these complex equations many assumptions are made so that even when a solution to the equations can be obtained it is impossible to separate the effects created by the various factors. Therefore, it is not possible to determine which of the assumptions underlying the modeling are reasonable and which are inaccurate.

The alternate approach presented in this paper does not aim for exact results. It was designed to allow for a meaningful study of situations with insufficient data. The model can be easily manipulated to understand the relationship of its critical values. Much time is not spent fitting complex and irrelevant equations. Rather, the modeler goes on to determine what data are needed and improves the model for a better correspondence to reality.

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