

STATISTICAL ANALYSIS, DATA MANAGEMENT AND
ECOSYSTEM MODELING AT LAKE GEORGE, NEW YORK

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ABSTRACT

The Lake George modeling group has had primary responsibility for implementation of the Biome aquatic model (CLEAN). CLEAN has been re-programmed and expanded; it now consists of 28 coupled ordinary differential equations and can be used to simulate several different lakes in one execution. Numerous submodel terms have been refined as a result of rigorous evaluations. A general numbers-biomass algorithm was developed, and the benthos submodel has been improved significantly. Nutrient cycling has been added to the decomposition submodel. A pelagic version of CLEAN has been implemented in a step-wise fashion and subjected to extensive experimentation.

A new procedure for sensitivity analysis was developed and applied to the pelagic model. Experimental designs and data collection procedures were formulated and data were retrieved for Lake George investigators. Cluster analysis and ordination were applied to IBP/PF data as a part of the international effort. The FIND system was refined and procedures for automated error checking were examined. Data-sets were transmitted to the Biome Information Office.

Appreciable effort was made to disseminate results through workshops, briefing sessions and publications.

INTRODUCTION

Much of the Lake George modeling effort this past year was directed toward Biome-wide synthesis. The modeling group has had primary responsibility for the Biome aquatic model; this determined the priorities for simulation modeling and required substantial data-management support. In addition, the group continued to serve the statistical, data management, and modeling needs of the other Lake George investigators.

DATA ANALYSIS AND MANAGEMENT

Statistical Analysis

Procedures to determine the sensitivity and values of parameters in the phytoplankton model have been investigated. A new methodology has been developed and used extensively. The procedure involves the use of spline functions to estimate values of dP/dt from actual data; the model is then run with values of the parameters at two levels in accordance with a fractional experimental plan. The difference of predicted and actual values of dP/dt are squared and summed for each observation. The resultant sum of squares is related to the parameter values by a step-wise linear regression. The parameters

significant in the regression are those that affect the performance of the model.

In line with our policy to adapt both internal and external computing packages to our needs, we acquired a non-linear regression program from Professor Watts of Queen's University. This is being adapted for our computer configuration to assist in the sensitivity analysis.

Experimental designs have been formulated for benthos population sampling (Dr. W. Perrotte) and zooplankton remineralization experimentation (Dr. E. LaRow).

Multivariate Analysis for IBP/PF

In cooperation with Dr. M. Brylinsky of Dalhousie University, cluster analysis and ordination techniques developed at Rensselaer were applied to data from the 86 lakes and reservoirs representing the Freshwater Productivity section of IBP. This represents a major synthesis of information from this international effort and will appear in the IBP/PF summary volume.

Data Management

The primary emphasis on data management this year has been to refine and de-bug the FIND system and build up the database. The majority of data at the Lake George site are on the database. Twenty data sets are on file in the Biome Information Office at Oak Ridge.

Procedures for error-checking datasets and merging data files have been examined. A flowchart for merging has been formulated and the computer code is being written. Automated error checking of data has proven to be most difficult because of the great diversity of the data. At this point, no satisfactory algorithm has been developed.

A time-sharing program is being written for water chemistry analysis. The program will determine standard curves and then convert absorbance measurements to concentrations. Such a program will greatly reduce the time needed for water chemistry analysis. The transformation programs written last year for Dr. D. McNaught and Dr. L. Clesceri are also continuing to be used. Aid has been given to several investigators in retrieving data from the database as well as determining data collection procedures for Dr. C. George (Fish) and Dr. H. Howard (Primary Productivity). The group also hosted a workshop for other data managers in the Biome.

A paper was presented in October 1972 to the American Society for Information Science describing the data management system at Lake George. A preliminary user's manual describing

the bibliographic retrieval system (EDFB Memo Report 73-9) has been written. A more comprehensive manual describing the entire system has also been completed. The group has been invited to present a paper at the Special Session on Statistics in Environmental Research at the Annual Meetings of the American Statistical Association.

SIMULATION MODELING

Implementation of CLEAN

The principal effort of the modeling group this past year was to implement the Biome aquatic model, CLEAN (Comprehensive Lake Ecosystem ANalyzer). Starting with the basic formulation and computer code (which was developed the previous year) CLEAN has been refined so that it now stands as one of the most detailed and versatile lake ecosystem models in existence.

CLEAN has been re-programmed to run in demand mode on the UNIVAC 1108 and is presently being adapted to the TSO system on the IBM 370/165. The model currently consists of 28 coupled ordinary differential equations. These include equations for nanno- and net phytoplankton, herbivorous copepods and cladocerans, predatory zooplankton, numbers and biomass of benthic insects, bluegill, carp, bass, macrophyte leaves, roots and carbohydrates, decomposers, particulate and dissolved organic matter, carbon, nitrogen, and phosphorous in both the water column and sediments. Submodels can be linked in any meaningful combination with efficient input and output, including in-line editing of parameters, site constants and initial conditions. Because of the complexity of the model, particular attention has been paid to incorporating the most efficient integration routine; Gear's method is now used to handle "stiff" combinations of submodels.

Several sets of driving variables for different lakes are available to be called. Thus, a user can run successive simulations for diverse lakes during a single execution of CLEAN. At present it is possible to simulate Lake George, New York, Lake Wingra, Wisconsin, Saratoga, New York, Char Lake, Canada, and Vorderer Finstertaler See, Austria. Additional lakes can be simulated with a nominal investment of time in developing equations for the driving variables.

Refinement of Submodels

Development and implementation of an ecologically realistic model has required careful attention to content, construct and concurrent validity. Each submodel has been

evaluated separately, considering its relationship to the total ecosystem model. During the course of this year small but significant changes have been made, including changes in the consumer feeding term, the fish gamete-loss and mortality terms, and the macrophyte carbohydrate-dependent switches. The decomposer submodel has been substantially revised and expanded so that nutrient cycling can be simulated. A different formulation has been considered for sedimentation, based on the relationships between wave agitation and wind and between wind and barometric pressure gradient.

Benthos Submodel

In order to simulate benthic insects, which are characterized by complex population dynamics, it was necessary to develop a combined numbers-biomass algorithm to take the place of the original population construct in the general consumer model. The present submodel predicts promotion from third to fourth instar (including exuvial loss) and emergence in chironomids as a function of mean weight; multiple food sources and differences in quality of food are considered in predicting the increase in mean weight; low levels of dissolved oxygen affect respiration, feeding and mortality rates. The submodel has been linked with the three fish submodels, and zooplankton and particulate organic matter have been included as chart functions, forming a benthic version of CLEAN suitable for testing.

Analysis of life forms and behavior and derivation of distribution functions for population required appreciable effort; however, the submodel can be applied directly to a variety of benthic arthropods and the general formulation can be adapted to other consumers with little difficulty.

Pelagic Model

A number of different versions of CLEAN representing the pelagic ecosystem have been subjected to extensive experimentation. At the beginning of the year the model consisted of two phytoplankton and two herbivorous zooplankton groups; since then equations for predatory zooplankton, bluegill, decomposers and particulate and dissolved organic matter have been added; chart functions have been included for bass and benthos. This model has been implemented in a step-wise fashion in order to calibrate individual submodels most efficiently and to facilitate model evaluation. Following development of a new procedure for sensitivity analysis (see "Statistical Analysis"), the model was analyzed to determine the statistical significance and relative importance of the various parameters, thus laying the groundwork for the continuing evaluation and refinement of all parts of CLEAN.

Dissemination of Results

Following the participation of one member of the modeling team (R.A.P.) at the Reading, England, Conference of IBP/PF, the team participated in a workshop at Dalhousie University, Halifax, Nova Scotia, and hosted a workshop at Rensselaer to discuss how to apply simulation modeling to the other lakes in the program. One result of this activity has been the fostering of correspondence with several national IBP groups. Inter-biome cooperation has been strengthened through participation in two workshops, one in Seattle and the other in Raleigh, North Carolina.

Members of the modeling team have conducted two briefing sessions for EPA personnel and one for NOAA personnel. They have also given a brief presentation at an IFYGL modeling workshop and have participated in an EPA-sponsored symposium. Since August 1 the group has been linked with the NIH computer in Washington to facilitate the sharing of CLEAN in accordance with an interagency agreement with EPA.

Two invited and three contributed papers were presented at the meetings of professional societies during the year. Two of these papers were subsequently published in the proceedings. At present one paper is in press, one is in review, and several others are in the final stages of preparation (see 'BIBLIOGRAPHY').

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