Book Reviews

Nonlinear Population Dynamics

On the Volterra and Other Nonlinear Models of Interacting Populations. N. S. Goel, S. C. Maitra, and E. W. Montroll. Academic Press, New York, 1971. viii, 146 pp., illus. $5.50. Reviews of Modern Physics Monographs.

The Volterra equations are a system of linked first-order differential equations which have been used to describe food-web dynamics of multiply interlocked predator-prey pairs. In the monograph under review, a group of physicists confronts this complex problem, which is one of the most fundamental in ecological theory. Their emphasis is on statistical and stability properties of Volterra systems under various conditions of partial information and individual detail. The book is by far the most extensive compendium of technical results in the area of nonlinear population dynamics and provides a one-volume entrée to some of the most sophisticated analytic methods that have appeared in the literature. For these reasons it will be of use to workers in mathematical biology, demography, and sociology for some time to come.

In spite of the importance of the subject and the evident technical competence of the authors, the book suffers throughout from an insensitivity to the special problems of biological and—in particular—of ecological theory. This shortcoming is revealed strikingly in the opening paragraphs:

> There exist numerous examples of assemblies which consist of a number of elements that influence each other through competition or cooperation. Some important cases are: populations of various biological species; political parties; businesses; countries; coupled reacting chemical components in the atmosphere, in bodies of water, and in organisms as a whole or in part; components of the nervous system; and elementary excitations in fluids (for example, eddies in a turbulent fluid).
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> One can construct models of many of these assemblies, either from first principles or intuitively, for the description of the competitive or cooperative phenomena. They yield rate equations, generally nonlinear, which contain a number of rate constants which must be determined empirically or be calculated from some auxiliary equations.

At no time in the ensuing exposition is it made clear what these "first principles" or "intuitions" are for any one of the kinds of assemblies listed. At no point do the authors discuss the meaning of the critical rate constants which they introduce (chapter 2), randomly vary (chapter 7), and generalize (chapter 10). The result is a proclivity throughout the monograph to consider alternatives simply because they exist, a kind of unbounded branching process through a space of formal possibilities.

For example, in chapter 3, the authors develop a model for population growth of Gompertz type with a random forcing term $N(t)F(t)$, where $N(t)$ is the population size at time t. The factor $F(t)$ is assumed to have a mean of zero. It is also assumed to satisfy the "standard hypothesis made in the theory of Brownian motion and random processes" (p. 25) that its autocorrelation is zero. This last very strong postulate is not discussed further; in fact it is contravened by evidence that the environment exhibits strong positive autocorrelation. Working from this assumption about $F(t)$, Goel *et al.* spend pages 25 through 31 finding the distribution and moments of $N(t)$. This discussion takes them successively through a Fokker-Planck equation, the Bloch equation for a quantum mechanical harmonic oscillator, Mehler's formula, and much more. In the end, they find that the mean value of $N(t)$ differs from the deterministic solution corresponding to $F(t) = 0$ by a factor asymptotic to $\exp(\sigma^2/4k)$, where k is a constant of the growth process and σ is the variance of $F(t)$. Having arrived at this result, the authors drop the model, and we never hear of it again. The reader is left wondering what all the work was for. By way of contrast, when MacArthur and Wilson discuss stochastic effects on population growth in their book on island biogeography, they attempt to derive qualitatively interesting conclusions, such as a classification of alternative colonization strategies.

Another example of technical methods veering hopelessly away from reality is chapter 6, which treats diversity and stability in ecological systems. Here results from almost periodic function theory take command, and we are led to compute the mean frequency of oscillations in population size about equilibrium as a measure of ecological stability (thus continuing the work of Leigh and others). Results are invoked from a previous chapter, and it is possible to read along without realizing that the whole method is contingent on the fluctuations' not taking the system too far from equilibrium; specifically, not far enough for *linearization* about the equilibrium to be invalid. In other words, we are analyzing the frequency of small oscillations around equilibrium. There is no attempt to consider the global stability and large oscillation frequency problems which should be our true interest for noisy ecological data.

Equally cavalier is the treatment of asymptotic assumptions concerning the number of competing species. Casual references (p. 74) to the truth of results "because the number of species is perhaps several million or more" will perplex empirical ecologists who have been laboring under the impression that competing species in their ecosystems number at most in the hundreds. The problem here is that Goel *et al.* are attempting to follow in the footsteps of Kerner's "statistical mechanics" for Volterra systems; treatment of models along these lines occupies most of chapters 2 and 5. In this regard, it should be pointed out that the only substantive prediction of Kerner's theory is a certain distribution of Maxwell-Boltzmann type which contains the empirical Fisher-Corbet-Williams (1943) species frequency distribution as a special case. This last distribution has since been largely replaced, both in ecological theory and in applications. Thus Goel *et al.* take as a major task the investigation of the logical niceties of a formalism with literally no proven empirical content.

From a technical standpoint, this monograph is essentially a loosely connected series of topical essays. It occasionally tends to degenerate into a short list of known results stated in purely mathematical terms (for example, chapter 9). Also, the authors have an annoying habit of referring to chapter 5 as section 4. Notation is occasionally confusing, as when G_0 means two unrelated things in (1.9b) and in the text immediately preceding (1.30). These are not serious criticisms.

Joel Cohen has commented (*Science* **172**, 675 [1971]) that "physics-envy is the curse of biology." He was criticizing the clumsy use of imitative models that often characterizes poor biological theory. There is a converse moral well illustrated by the monograph under review: physicists who wish to do useful biology should not try it on their own. The real future of systems like the Volterra one lies in painstaking, time-consuming, and sometimes dull attacks on the problem of independent estimation of the parameters, with the aim of eventually being able to synthesize ecological processes out of the physiology, behavior, and other performance characteristics of individual species members. The resulting body of theory should be free of the "knife-edge" instabilities which plague results in the specific Volterra formalism. Moreover, the theory should de-emphasize random contributions from unknown forces, which probably do more to highlight the poverty of our theories than the final state of our knowledge. In their introduction, the present authors express the hope that a Volterra model "might play the same role that the harmonic oscillator or the Ising model plays in theoretical physics." They apparently do not realize that the harmonic oscillator's importance derives from fundamental physical principles which have no connection with its formalism. The corresponding biology remains to be done.

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Applied Microbial Ecology

Water Pollution Microbiology. RALPH MITCHELL, Ed. Wiley-Interscience, New York, 1972. xii, 416 pp., illus. $19.50.

Biochemical Ecology of Water Pollution. PATRICK R. DUGAN. Plenum, New York, 1972. x, 160 pp., illus. $14.50.

Ralph Mitchell's primary goal in *Water Pollution Microbiology* was to produce a text for advanced students that would show how modern microbiological concepts have been applied to the analysis of water pollution problems. In accomplishing his objective he has assembled an impressive group of environmental microbiologists, chemists, and engineers who have, for the most part, carefully and critically summarized the current state of our knowledge of many topics in this field.

Following an introductory chapter in which the editor attempts to tie together the disparate subject material contained in the volume, he presents the chapters grouped into several parts. The first part contains three chapters on inorganic pollutant materials, namely phosphorus, nitrogen, and acid mine drainage. The second part contains four chapters on the degradation of organic substances. A single chapter on water-borne pathogens constitutes the third part, and this is followed by a consideration of the effect of pollution on the structure of microbial communities in the fourth part. In the fifth part various procedures used in assaying biomass and activity as well as techniques employed for the enumeration of viruses and coliform bacteria are compared and discussed. The final part includes one article that critically and musingly reviews waste-water treatment processes and another that discusses the practice of destratification of impoundments. Altogether there are 17 chapters and 24 authors.

As might be expected, the treatment of the subject material is somewhat discipline-oriented. Perhaps the most notable example of this is the chapter on acid mine drainage by Lundgren, Vestal, and Tabita. Though this is an excellent article on the biology of the thiobacilli that cause the perplexing problem of acid mine waters, it would have been appropriate to discusss, in addition, the substantial, albeit inconclusive, research undertaken to control this problem. All in all, however, the authors have done a commendable job in bridging the interdisciplinary gap.

The book is to be especially recommended to prospective applied microbial ecologists. They will surely heed the "call" when they read some of the enticing comments of la Rivière, such as "microorganisms promise to be excellent tools for model laboratory studies in ecology, just as they are already in biochemistry and genetics."

Bravo for Mitchell! This book has been needed.

P. R. Dugan's book is aimed at a much wider audience including "engineers, economists, biologists, public servants, and others." Assuming that the nonbiologist reader is not intimidated by the title, he will find the first portion of the book highly readable and informative. It presents an overview of the significance, types, and causes of water pollution. In this section Dugan coins the terms "first-order pollution," which refers to the biological excreta of humanity, and "second-order pollution," as nonbiological human excrement, that is, technological pollution (it would not be fair to consider the book as an example of this!).

The second part of biochemistry begins benignly enough, but the chapter on the chemistry and biochemistry of water and those on degradation are, as the author himself suspected, too technical for most of the audience.

This book also has a chapter on acid mine drainage. Unquestionably it is, for the biologist, the best chapter in the book.

The appearance of these books is further evidence that the recently emerging interest of microbiologists in ecology is gaining momentum that will remain sustained for some time to come.

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Faunal Remains

The Study of Animal Bones from Archaeological Sites. RAYMOND E. CHAPLIN. Seminar, New York, 1971. x, 170 pp., illus. $5.75. International Series of Monographs on Science in Archaeology, No. 1.

Clearly the age of the specialist is in full swing in archeology. No expedition worthy of the name will take to the field without having available the expertise of those from a wide variety of disciplines. In many of these fields the degree of sophistication in techniques and analysis has increased remarkably in the years since World War II, and such is the case in the study of animal bones. This book, the first of a forthcoming series by specialists in disciplines pertaining to archeology, is a comprehensive study of most of the current aspects of faunal analysis, and should be read not only by the zoologist studying archeological material but by the archeologist as well. It includes valuable information on the collection, study, and treatment of bones and discusses the three most common methods of quantifying animal remains. There is an important chapter on bone measurements in which Chaplin rightly points out that they should be used with caution: "A dimension should be measured only when it is hoped or known that it will provide information relevant to the problem in hand such as size, weight or sex of the animal." I heartily agree, and wish that all our colleages in faunal studies would take this advice to heart.

I cannot find fault with Chaplin's presentation of field methods and study techniques, which is exemplary if