Book Reviews

Ecotoxicology. The Study of Pollutants in Ecosystems. (Second edition)

F. Moriarty
Academic Press, 1988
289 pages
Price: £13,50

The environmental effects of pollutants (substances which occur in the environment at least in part as a result of man's activities, and which have a deleterious effect on living organisms according to this book), is a subject of increasing relevance to us all, but is also a subject about which more nonsense and half sense is written than any other. It was therefore a real pleasure to read a clear, authoritative text which deals objectively with many highly emotional issues. This is a second edition of a book aimed at undergraduate teaching. Details have been changed throughout, some extra examples (e.g. a discussion of melanism) have been added, as has a very informative chapter of case studies explained in some detail.

The book is organized as nine chapters. Chapter one provides some clear definitions, particularly of the difference between toxicology (the effect of toxins on individual organisms), and ecotoxicology, which is the effects of toxins on populations, communities and ecosystems. The author points out one of the basic problems facing those charged with the monitoring and control of pollution — there are some 63 000 chemicals in use world-wide, and 200 to 1000 new ones are introduced each year. Knowing what they are, never mind what complex effects they may have, is an overwhelming difficulty. The following three chapters form a mini-text book of ecology, covering the basic concepts of population dynamics, communities and population genetics. All three are explained in detail, with many examples, but traditional concepts (r/k strategies, energy pyramids, succession, competition, etc.) are dealt with very conventionally, using slightly old-fashioned examples, and without some of the critical insights which have characterized ecology since 1980. These chapters are intended to provide a background for the subsequent discussions of pollution effects on ecosystems, and the author makes the valid point that it is important to understand and examine the interactive nature of organisms and their environments in order to get a holistic view of the effects of pollutants. The inherent plasticity of populations and communities is emphasized in the population genetics chapter, and the author warns that the effects of toxins on restricted laboratory populations cannot reliably be extrapolated even to natural conspecific populations, let alone between species.

Chapter 5 deals with the effects of pollutants on individual organisms, using examples such as trout, a species commonly used for bioassays in freshwater ecosystems. Predicting the tolerance limits of organisms for toxins is a multi-disciplinary field requiring a knowledge of the biochemical effects of a substance, and the ecology of the target organism. Synergistic effects of multiple pollutants in more than one environment make blanket prediction very difficult. The next chapter extends this discussion to the prediction of ecological effects, concluding that our abilities are at present rudimentary, but that there are some generally useful guidelines. Monitoring the release and effects of pollutants is discussed in Chapter 7. The author stresses the need for well-defined aims for any monitoring scheme, which should include measurement of the rate of release of pollutants, the degree and changes of environmental contamination, and their biological effects. He recommends that organisms rather than environments should be monitored, chiefly because organisms integrate a pollutant and its effects.

To me, the most interesting chapter was that on case studies (Chapter 8). This covers four well-known examples: The decline of peregrine falcon populations in Britain during the 1950s; the control of spruce-budworm in Canada; the pollution of the River Thames from 1800 on, and its subsequent recovery during the 1960s and 1970s; and the world-wide effects of oil pollution from marine spills. All these are well-known and often-quoted examples, but it's nice to get concise summaries of the facts laid out like this. The author draws interesting conclusions from each case. For example, the peregrine falcon case shows us that knowledge of pollution often only comes after the event; that if pre-pollution data (in this case from egg collections) is not available, proof of pollution effects may be impossible; that the effects of pollution are often indirect (egg-shell thinning in peregrines was a consequence of food-chain concentration, and was caused, not by the original DDT, but by a metabolite).

The final chapter draws together the author's conclusions from all the previous chapters: biochemical and ecological expertise are necessary for any predictive understanding of the effects of pollution; prediction is very difficult anyway; many environmental pollutants pass unnoticed because their effects are often indirect and subtle, and, even when they are obvious, proof of cause and effect is normally very difficult. Finally, the author draws the excellent conclusion that the polluter (us!) should pay not only for the effects of pollution, but also for research into its causes.

This is an excellent textbook for anyone who wants to know how toxins work in ecosystems, and how we should become more efficient at observing, monitoring and ameliorating their effects. It's not comprehensive (I didn't notice any mention of global warming for example), nor is it a handbook (you can't look up a list of the properties and effects of DDT). It is a very well-organized, clear and interesting introduction to ecotoxicology, and I strongly recommend it as a teaching text and as a good book to read.

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Ecology of Sandy Shores

A.C. Brown and A. McLachlan
Elsevier, 1990
328 pages
Price: ±R220,00

There are a number of excellent texts which deal with the ecology of rocky shores. Books on sandy shore ecology, particularly sandy shores subjected to intense wave activity, have not been as forthcoming. This text by Brown and McLachlan is therefore particularly welcome. Both authors are more than qualified to write authoritatively on the subject and it was

therefore no surprise to find the book well written, informative and illustrated with clear diagrams. In addition I found the overall page layout to be good and the authors must be congratulated for this as the book was presented to the publishers camera ready.

The book is divided into 13 chapters, each of which is subdivided. The subdivisions along with a reasonably comprehensive index make it easy to use the text. After a brief introduction (Chapter 1) which includes the rationale behind the book, the text begins (Chapter 2) with a description of the physical environment of sandy beaches. The subject is summarized nicely and the concepts discussed should be grasped easily by most undergraduate biologists. The next five chapters deal with the flora, fauna (macro- and meio-) of sandy beaches. Chapters 3 and 4 explain what flora and fauna (primarily macrofauna) inhabit the sand. In Chapter 4 each animal phylum (multicellular) is considered and family or generic examples are given. Numerous line drawings illustrate many of these animals. Having introduced the plants and animals, the authors go on (Chapter 5) to deal with the morphological, behavioural and physiological adaptations of macrofauna to sandy beach life. Following on from this, macrobenthic communities are examined (Chapter 6), the chapter containing information on how to sample them (brief summary), factors which affect diversity and abundance as well as community distribution and zonation. Chapter 7 then completes this section of the book with a more in depth look at the meiofauna and their role in sandy beaches.

The next section of the book (Chapter 8) deals with an important component of any sandy beach ecosystem, the surf zone and its fauna. Both the zooplankton and fishes which inhabit this dynamic area are examined. By contrast Chapter 9 looks at the role that birds and other terrestrial vertebrates have on sandy beaches. This chapter effectively highlights how little is in fact known.

Chapter 10, entitled 'Sandy beach ecosystems' ties together much of what was previously written with an examination of energy flow and nutrient cycling. The text is accompanied by useful summary flow diagrams which enable the reader to compare sandy beaches from different geographic areas. The topical subject of pollution is covered in Chapter 11, concentrating mainly on organic pollutants and their effects.

Many sandy beaches are associated on their landward side with coastal sand dunes and the authors have not neglected to include a section on dune ecosystems (Chapter 12). The role that wind plays in sand transport is explained as well as the types of dunes to be found and what food chains exist within dune ecosystems. Finally the interaction between dunes and sandy beaches is considered. The final chapter (13) of the book looks at the importance of conservation and management of sandy beach ecosystems, a subject which is of particular relevence to South Africa.

As much of our understanding of the ecology of sandy beaches has come from studies done in South Africa it is not surprising that the authors draw heavily on work done by local scientists. The book has quite a comprehensive reference section and therefore it will be of use to research workers and students. Both postgraduate and undergraduate students should have their attention drawn to it. There is not much upon which to critisize the book, except for the price (not the fault of the authors I might add). At over $90 it will not be an attractive buy, which is a pity as I do feel that it would make an excellent recommended text for any marine biology course. Perhaps the publishers will produce a soft-cover version in the near future. Nevertheless I feel sure that the book will find a place on the shelves of many marine biologists.

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Ecology and Natural History of Tropical Bees.

David W. Roubik
Cambridge University Press, Cambridge, 1989
Price £50,00

Amongst the numerous books about bees and/or the tropics which have appeared over the last two decades, this new work by Roubik is one of exceptional merit and importance. It is a scholarly effort which summarizes and interprets a massive amount of information about all bees (the few honey producers and the tens of thousands of non-honey producers) from all parts of the world. It works by comparison and contrast and really stands out as the first book on the biology of wild bees in general.

Approaches to the biology of tropical bees are varied, but the current one attempts to assess important aspects of these bees in ecological and evolutionary terms. This approach, which most often degenerates into thumb-sucking speculation amongst ecologists, is modified by Roubik into experimentally testable hypotheses based on his own extensive data collections as well as those from literature. This basic philosophy is clearly set out in the introduction and the rest of the book reflects this manner of thinking. The introduction includes a brief account of the natural groups of apoids, and the diversity of tropical bees, and then evaluates this biogeography in terms of current views of geological events. Inevitably, the rate of biological discovery in this century has led to many fundamentally important difficulties in terminology as new and 'intermediate' forms of sociality were uncovered. Thus, it is gratifying to note that Roubik has very clearly redefined terms such as eusocial, parasocial, communal, subsocial, quasisocial etc., which have often precluded both non-specialist and specialist alike in making progress in this area of biology.

The bulk of the book is given over to only three main chapters, each of which could be expanded into a dozen or more full-length chapters had the author written a 2000-page instead of 400-page book. As it is, these are (2) foraging and pollination, (3) nesting and reproductive biology and (4) community ecology. The first of these three chapters begins with a consideration of the resources actually gathered by bees which run the gamut from saps, resins, floral lipids, fragrances, nectar, pollen and waxes to the flesh of dead animals and the salty 'water' of sewerage. The major resources have been studied in detail so that the mechanisms employed by bees to gather these resources are shown and estimates of efficiency considered.

Foraging as a general mechanism (whether it be for nectar, pollen or something else) is examined in terms of physiological ability as well as cost, the problems of navigation and chemical attractants of plants, and the unique aspects of social foraging. There is a general treatment of foraging styles and syndromes and how patterns of optimality are expressed in

solitary and social bees. Loss to predators is mentioned. All of the foregoing is summarized in several unifying essays relating to pollination ecology: the effectiveness of a pollinator, coevolutions between bees and plants and bees as the 'enemies' of plants.

Bees nest in remarkably diverse situations and employ equally varied construction techniques. In this third chapter, appropriately great emphasis is placed on the fundamental dependency of the success of bees on the success of their nests. This boils down to two primary considerations, that of protecting oneself and brood, and mating and the production of offspring. The former gives a fair and balanced account of guard bees, pheromones, colony defence, pathogens and parasites, various commensals and parasitic bees and mites. Brood production begins with mate selection and moves onto larval development and nutrition. The biological peculiarities and difficulties encountered by both solitary and social bees are compared and the section ends with a concise account of what is known of the genetic variation in these contexts.

The final chapter is devoted to community ecology. Here, what data there is, is expertly summarized and developed further into pressing questions. Seasonality, abundance and floral choice are wedded naturally and are explored in long term study data, especially in the long tongue euglossine bees. The composition of varied bee assemblages are contrasted for new world and old world tropics and in turn with non-tropical areas. Evidence is sifted to consider how stable bee populations are and why the tropics seem to enjoy a virtual monopoly on eusocial species. For the first time, the biology of the African honeybee in the new world is interpreted as an interesting experiment. Although this section is excellent, it loses somewhat by the absence of study of this race in its native lands.

There are many species of wild bees. This book goes a long way to help the reader in recognizing them (at generic level) through two important appendices. The first is a fairly complete checklist of higher categories of wild apoids and the second is a formidable collection of photographs of tropical bee genera arranged by family and geographic area. It is just a pity that the photographs are monochrome instead of in the extraordinarily brilliant colours of the real bees. The work concludes with extensive references, and a subject and a taxonomic index.

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The Ants

Bert Hölldobler and Edward O. Wilson

The Belknap Press of Harvard University Press, Cambridge, Massachusetts, 1990
732 pages
Price: $65

On first seeing this book one is immediately impressed by its large size and the spectacular photograph on the cover of a weaver ant in threat posture. The layout inside is extravagant with an abundance of diagrams and large black-and-white photographs as well as 24 beautiful colour plates. I not only enjoyed looking at it but also thoroughly enjoyed reading it, despite the daunting size. By presenting a wealth of detail on ants within a framework of biological principles, the authors have eminently succeeded in preventing this book from becoming a dull compendium of facts.

The chapters are as follows: (1) The importance of ants; (2) Classification and origins; (3) The colony life cycle; (4) Altruism and the origin of the worker caste; (5) Colony odour and kin recognition; (6) Queen numbers and domination; (7) Communication; (8) Caste and division of labor; (9) Social homeostasis and flexibility; (10) Foraging strategies, territory, and population regulation; (11) The organization of species communities; (12) Symbioses among ant species; (13) Symbioses with other arthropods; (14) Symbioses between ants and plants; (15) The specialized predators; (16) The army ants; (17) The fungus growers; (18) The harvesting ants; (19) Weaver ants; and (20) Collecting, culturing, observing. At the back is a comprehensive glossary of terms, a 65-page bibliography, and a detailed index.

The first chapter argues for the importance of ants in the terrestrial world and includes facts that myrmecologists like to mention when they are feeling insecure or insignificant. We all know that in most terrestrial habitats ants are among the leading predators of insects and other invertebrates, but did you know that ants are important in moving soil, to the extent that in tropical forests they have been found to surpass the soil-moving activities of earthworms? There are approximately 8 800 known species of ants in the world and many more that are undescribed. This chapter also highlights the economic importance of ants and the advantages of using them for research in behavioural ecology and sociobiology.

The taxonomy of ants is dealt with in Chapter 2 and includes: a synonymic list of ant subfamilies and genera (including references to species-level revisions); comprehensive morphological diagrams; a glossary of terms used in ant taxonomy; keys to the ant genera for each of the zoogeographical regions; and illustrative examples of each of the 297 ant genera. The authors wisely drew on the expertise of the available ant taxonomists, especially Barry Bolton, for compiling the keys and for general taxonomic advice. I have mixed feelings about this chapter. Without doubt it makes genus-level ant identification much easier than it used to be. For example, Barry Bolton's out-of-date 1973 paper on the ant genera of West Africa was previously the best available source for identifying southern African ants to genus level. The keys could have been improved, however, if reference had been made to diagrams of the features that are mentioned. For example a beginner to ant taxonomy would have difficulty in understanding couplet 2 of the subfamily key which uses the acidopore to identify the Formicinae. Chapter 2 contains no labelled diagrams of the acidopore and the best one can do is find a definition of this structure in the glossary at the back of the book. There are a number of diagrams in the rest of the book that show the acidopore but these are not mentioned in the key or the glossary.

The illustrations of the ant genera, reprinted from a large number of different sources, are useful to refer to while reading the book but their artistic quality varies greatly. There is also no indication of scale in these figures. For instance, on page 93 there is a small line drawing of the huge 20 mm long ponerine ant *Streblognathus aethiopicus* while on the opposite page is a much larger drawing of the tiny 3 mm long *Probolomyrmex filiformis*. I had to look up these lengths in a separate source; they are not mentioned in the captions.

Chapter 2 also contains a most interesting discussion of the evolution of ants and their social behaviour. However, other than a short section on island biogeography in Chapter 11,

very little is said about speciation in ants.

Throughout the book the authors have used tables to summarize large bodies of information. Besides being useful to the reader, these also save the text from being drowned in facts and references. Some of the more useful tables include: degrees of genetic relatedness in various ant species; records of worker reproduction in ants; a number of tables of the different types of pheromones in ants and their glandular sources; studies that have been done of caste and division of labour; the known parasitic ants and their characteristics (eight pages long); arthopods that are symbiotic with ants (14 pages long); plants with structures specialized to house ant colonies; and records of ants that harvest seeds.

From a theoretical point of view, Hölldobler and Wilson centre their text mainly round kin selection and optimization. On page 334 there is a discussion on the application of optimization theory in evolutionary biology. They state that 'In biology, as in engineering, optimization implies an optimum, a goal with reference to which the system may or may not have been ideally designed'. While the authors are clearly aware that not everything in nature is optimal, the text sometimes gives this impression or gives the impression that animals are always evolving in the direction of an optimum. An explicit example of this tendency is given at the end of the chapter on weaver ants in which the authors discuss the reasons why there are so many species of ant that, in comparison to *Oecophylla* weaver ants, employ silk in nest construction so imperfectly. They provide two hypotheses, but do not suggest the obvious reason which is that there is no selection for better silk weaving capabilities because the way these species use silk is already adequate for their purposes.

Despite the wealth of references used in this book (covered till about the end of 1988), I noticed some serious omissions with regard to papers on African ants. On page 567, the authors comment on the biology of the termite-eating genus *Carebara* and remark that 'The unsolved mysteries of *Carebara* are symptomatic of our general ignorance of the myrmicine ants associated with termites'. However, they were unaware of Lepage and Darlington's 1984 paper in *Journal of Natural History* on the biology of *Carebara vidua* which clears up many of these mysteries. None of Barbara Curtis's papers on the Namib Desert dune ant *Camponotus detritus* is mentioned even though they were published in prominent journals (such as *Insectes Sociaux* and *Journal of Insect Physiology*) and contained information that should at least have been listed in some of the tables such as Table 3-2 on colony sizes and Table 10-1 on preferred foraging temperatures. Crewe and Fletcher's 1974 paper on the mandibular secretion of *Paltothyreus tarsatus* could have been mentioned in Table 7-4. Presumably there are other references that have been omitted so that one should be careful in assuming that the information in the tables is complete. However, the tables remain excellent general summaries of most of the available information on certain subjects.

In reading *The Ants* one is struck by the remarkable amount of research that has been done on this group since the publication in 1971 of Wilson's classic *The Insect Societies*. To a large extent this can be attributed to the publication of the earlier book which excited people's imaginations and stimulated some really high quality research on social insects, particularly ants. Hölldobler and Wilson dedicate their book to the next generation of myrmecologists and state in the introduction that one of their aims in writing it was to make ants more accessible for future study by others. They have undoubtedly succeeded in their aim and have taken ant research a quantum leap forward, not only by providing an easily understood synthesis of the group, but also by providing useful suggestions for future research.

The Ants, like *The Insect Societies*, will become a classic and is an essential purchase for not only university libraries but also city libraries and even good school libraries. Besides being required reading for myrmecologists and behavioural biologists, it is a book that can be enjoyed by anyone who likes being excited by the intricacies and dynamics of life on earth.

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Social Insects: an evolutionary approach to castes and reproduction

Edited by W. Engels
Springer Verlag, Berlin 1990
265 pages
Price: DM89,00

Although knowledge of the social insects, especially honeybees, stretches back over two millenia to Aristotle, it is only since Edward Wilson popularized socio-biology two decades ago that science has energetically applied its growing technology to the biology of social insects. The result has been a tripling of the number of journals specializing in articles about animal sociality, and a shelf-full of books reviewing facts and hypotheses of social organization.

As in other areas of science, it is practically a truism that no insight into sociality can develop without an understanding of the mechanisms generating social phenomena. Similarly, the origins of these mechanisms must be understood in the context of the phylogeny and natural history of the organisms displaying them. *Social Insects: an evolutionary approach to castes and reproduction* braids together these three themes in an extensive review of one of the central characteristics of insect sociality: the division of reproductive activity amongst members of a colony. In doing so, it touches on most aspects of social differentiation in these insects.

The nine chapters of this book take a usefully broad view of reproduction, by discussing the production of both new individuals and new colonies, and by recounting both natural history and experimental work. The first three essays deal with termites, ants, and social wasps respectively, while bumblebees, sweat bees, carpenter bees and various other bees occupy the rest. This taxonomic diversity is paralleled by the diversity of the topics that have been explored. The preface serves not only as an introduction, but also provides definitions of the terms *differentiation* and *pheromone*, in order to unify the body of the volume. The difficulty of defining *caste* is a recurrent theme in several of the subsequent chapters.

The implications of hemimetaboly for termite caste, and of diploidy in both sexes for termite reproduction, are well laid out by Noirot, and form a neat counterpoint to the rest of the volume by emphasizing the contextual importance of holometaboly and haplodiploidy in the remaining societies.

The amazing social flexibility of species where the social differentiation of individuals arises primarily from behavioural

interactions between adults, is the nub of Michener's discussion of social halictine bees. He also highlights the role of nest architecture and colony size in giving societies structure, and the effects of varying seasonal conditions during larval development on the body size of adults. All of this information is integrated with a discussion of the evolutionary origins of sociality of these insects.

In other groups of bees, a less flexible form of social organization results from the physical differentiation of colony members during larval development. Reproductive differentiation of the adults is mediated by pheromones characteristic of the reproductive caste. The long article by Engels and Imperatriz-Fonseca examines such a state in the honeybees and stingless bees, and concludes that the problems created by the evolution of increasingly specialized reproductive individuals has led, by separate paths, to a convergence of the social organization of these two groups.

In certain races of honeybee, the disadvantages of the more rigid form of social organization have apparently been met by the evolution of laying workers, an apparent reversal of the evolutionary trend towards differential specialization in the honeybees. Velthuis, Ruttner and Crewe explore this phenomenon, giving details of the associated modifications to the expression of pheromonal regulation that is otherwise characteristic of honeybees.

The importance of regulatory pheromones and the quality of larval nutrition in reproductive differentiation in each group of social insects are mentioned in varying detail in the respective chapters. Hartfelder fills in a few gaps in earlier chapters by concluding the collection of papers with a detailed review of the roles of juvenile hormone and the ecdysteroids, including prothoracicotropic hormone, in the physiological differentiation and regulation of reproductives in bees and ants. Valuable comparisons are made with the hormonal regulation of growth and diapause in other insect orders, pointing to the origins of the mechanisms underlying the other manifestations of reproductive differentiation in social insects.

The essays are clearly and concisely written. The scope of each is partly a product of the amount of research that has been done in each field, and certain theoretical issues, such as the place of kin selection in social evolution or the evolution of reproductive differentiation in ants, are given only implicit treatment. The general result of this compendium of reviews is to give an introduction to the literature dealing directly with reproduction in social insects, and to point out where future research would be fruitful; this must constitute a mark of its value. Each chapter is illustrated and well referenced. An index is absent, but because a list of sub-headings leads each chapter, and because of the well defined taxonomic scope of each contribution, it is unnecessary. Apart from a thin scattering of typographical errors and editorial lapses, this book is a satisfying and useful review that meets the general standards of its publisher. It would benefit an entomological research library.

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Mathematical Biology

J.D. Murray
Springer-Verlag, New York, 1989
767 pages
Volume 19 in the Biomathematics series
Price: DM98,00

The author, who is director of the Centre for Mathematical Biology at Oxford, has produced a book covering a wide spectrum of problems that are amenable to mathematical analysis. Among the topics covered are population growth models, predator-prey models, biological oscillators, nerve conduction, animal coat patterns and the spread of epidemics from the ancient (the Black Death) to the modern (AIDS).

Ecologists will be interested in the chapters on population growth and the discussions dealing with the management of fish harvesting and assumptions which underlie the International Whaling Commission's model of the baleen whale. The phenomenon of synchronized insect emergence every 13 or 17 years is explained in terms of a predator-prey model.

One of the most interesting sections of the book deals with spot production in animals such as leopards and giraffes. The basic model postulates that the patterning is governed by reaction-diffusion mechanisms. Such systems (the Belushov-Zhabotinskii reaction being an example) can give rise to areas in which the concentrations of the chemicals form steady-state spatial patterns. Applying such a model to the diffusion of morphogens (one for light hair and the other for dark) gives rise to the spot pattern. Different patterns depend upon the size of the animal, the time of activation of the morphogens and their rate of diffusion. A later chapter which deals with more complex patterns such as the distribution of microvilli on the cellular surface, shows that interaction between mechanical forces generated by the interaction of a cell with its environment and chemical concentrations could also explain spatial patterning.

The last chapters deal with the spread of epidemics. An amusing aside is given in a short history of the Black Death, describing a 15th century cure for the plague which contained (among other things) saffron, dill, a crane's beak and mustard. As Murray remarks — 'There is no record of how effective this cure was!' Of great interest to us in Africa is the section on the spread of AIDS. The curves, generated with data obtained from the homosexual community in San Francisco, paint a bleak picture and show clearly the effects of promiscuity on the spread of the disease. What is particularly disturbing is that the curves are based on the assumption that not all HIV seropositives will develop AIDS. If this is not so, the model predicts a catastrophic spread of the disease.

As the author points out in his introduction, these models represent possible descriptions of the process — a working hypothesis as it were, and it requires experiments to further refine the models and to determine which ones should be discarded. The author has succeeded in giving a 'Cook's tour' of many of the interesting areas of mathematical biology. I would have preferred a greater use of experimental data to give actual solutions to the equations. Of course, in many cases these values are simply not available. In a sense this represents both the strength and weakness of mathematical biology today — with a few simple assumptions some very sophisticated behaviours can be modelled, but without some input from an

experimenter, they remain but an interesting speculation.

This book requires a knowledge of calculus, differential equations and matrix algebra of at least 2nd year university standard. Some sections (17 out of 119) require graduate skills. The book is aimed more toward the mathematician or applied mathematician who wants to apply his skills to biology rather than the biologist or zoologist who wants to learn about biomathematics.

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