paper of Brooks and Dodson (1965) and the numerous stimulating syntheses of G. E. Hutchinson (1951, 1959 for instance) were consummated without a massive support system. There is probably no better example of the intrinsic merit of studying "potentially instructive mishaps" than W. T. Edmondson's documentation of events in Lake Washington (Edmondson and Litt 1982). There already is a rich tradition of opportunism in lake study. Speaking from my own experience, I have found NSF's generous support of my individual research effort to be totally adequate. I do not think association with a center would have helped me develop the idea of keystone species (Paine 1969) or trophic cascade (Paine 1980), both conspicuous elements of whole-lake thinking, any faster than I did. Perhaps the most telling claim is that the best experimental research on complex interactions and indirect effects was done in aquatic systems by graduate students. The studies by Vandermeer (1969), Wilbur (1972), and Neill (1974) addressed the fundamental focus of this book well over a decade ago; they were all individualistic, low budget efforts. None were cited.

I am not implying that collaborative research is without merit. It obviously can be as, for example, the Hubbard Brook study (Likens and Bormann 1974) illustrates. That collaboration, however, like other effective unions, was built around an intellectual framework based on common scientific interests. The necessary institutional features of all research were secondarily derived.

The question is not one of right or wrong, good vs. evil, but whether the NSF-generated hype about the benefits of collaborative research can be believed, or whether it simply represents an insidious momentum generated by those who believe bigger is better. Such political and economic pressures to rediscover the wheel will not produce the promised enlightenment. Aquatic biology has a grand history of opportunism and innovation; this interesting book fails to convince me that centers will foster creativity.

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References

BROOKS, J. L., AND S. I. DODSON. 1965. Predation, body size, and composition of plankton. Science **150:** 28–35.

EDMONDSON, W. T., AND A. H. LITT. 1982. *Daphnia* in Lake Washington. Limnol. Oceangr. **27:** 272–293.

HURLBERT, S. H. 1984. Pseudoreplication and the design of ecological field experiments. Ecol. Monogr. **54:** 187–211.

HUTCHINSON, G. E. 1951. Copepodology for the ornithologist. Ecology **32:** 571–577.

———. 1959. Homage to Santa Rosalia *or* Why are there so many kinds of animals? Am. Nat. **93:** 145–159.

LIKENS, G. E., AND F. H. BORMANN. 1974. Linkages between terrestrial and aquatic ecosystems. BioScience **24:** 447–456.

LINDEMAN, R. L. 1942. The trophic-dynamic aspect of ecology. Ecology **23:** 399–418.

NEILL, W. E. 1974. The community matrix and interdependence of the competition coefficients. Am. Nat. **108:** 399–408.

PAINE, R. T. 1969. A note on trophic complexity and community stability. Am. Nat. **103:** 91–93.

———. 1980. Food webs: Linkage, interaction strength and community infrastructure. J. Anim. Ecol. **49:** 667–685.

VANDERMEER, J. 1969. The competitive structure of communities: An experimental approach with protozoa. Ecology **50:** 362–371.

WILBUR, H. 1972. Competition, predation and the structure of the *Ambystoma-Rana sylvatica* community. Ecology **53:** 3–21.

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CARPENTER, S. R. [ED.]. 1988. **Complex interactions in lake communities.** Springer-Verlag New York, Inc. 283 p. $64.00.

Definitely provocative, this volume is the product of a planning workshop initiated and sponsored by the General Ecology Program of the U.S. National Science Foundation. The Foreword, authored by two program officers of the NSF, more than hints that the purpose of the report is to influence research directions, and it lays down that charge for the contributors. Evidently, the General Ecology Program of NSF has been sponsoring fewer limnology projects, in proportion to requests, than is true for other disciplines, and the workshop was conceived to brew a more equitable strategy for submissions.

Although the words limnology, lake ecosystems, and biogeochemistry are mentioned throughout the text, the book is actually a circumscribed treatment of community ecology as applied to lake waters. Some of the individual treatments are relatively thoughtful, but they are principally discourse and abstractions of the real scientific results, so readers should consult original sources before swallowing all the interpretations presented. The book does not teach aquatic science, but it does reveal the face of U.S. science administrative policy toward limnology in a way that ought to attract the concern of all limnologists.

The workshop report

The intellectual core or thesis of the document is that "indirect interactions" are the coming thing in lake community ecology. Indirect interaction means that variables (nutrients, population densities) would be expressed as implicit functions of each other in coupled sets of equations describing lake communities. Because most of the individual relations are poorly known or unknown, the implicit links and function derivatives are examined through empirical perturbation and semianalytical analyses.

We are reminded that big perturbations yield big responses, and a pitch is made for small perturbations which may reveal subtleties. In one of the best sections, W. E. Neill discusses his results from graded manip-

ulations of nutrient levels in oligotrophic lakes. He discovered that nonlinear, threshold responses are characteristic when nonlinear processes (gains and losses) are combined by difference and integrated over time. In the long run, communities are dominated only by taxa with sustained positive net growth, and taxa with negative growth rates are absent. When environmental conditions, or experimental design, cause values to cross from positive to negative for particular key species, wholesale community changes can result. The phenomenon is very general and is relevant to investigations of differences between lakes and across frontal regions in large lakes.

One treatment seemingly at odds with the overall theme of community ecology involves the pelagic microbial assemblage. Microbial food webs are ably described, but not a lot could be inferred about the community ecology of bacteria, flagellates, and ciliates, although everyone seems to agree that microbes are important elements of the report. The importance is defended in terms of potential mass flux, energy transfers, and nutrient cycling, rather than in terms of how one community of bacteria might give way to another. It may be that the approach taken is the best and most relevant one possible now, but hopefully the future will include efforts to draw the field of microbial ecology into the realm of community ecology. Quite a lot is known about nitrification, denitrification, sulfate reduction, methanogenesis, metal oxidations, and so forth, and the bugs that run the reactions must have interesting, interactive ecologies. The same is true for the photosynthetic bacteria other than cyanobacteria that occur in many productive lakes.

In general, the report adequately chronicles the current state of lake community studies and some of the prevailing wisdom. It fails, however, to tackle many scientifically new and challenging areas for limnology, which I believe owes more to the lack of breadth of perspective of the science administration than to failings by participants.

Limnology and science administration

Because the workshop report conforms to the administrative limits of the NSF Ecology Program, it inadvertently does great disservice to aquatic sciences as a discipline and to limnology in particular. Emphasis is limited to the intersection of limnology with community ecology, rather than focused on how community studies may be integrated with other pursuits to advance our understanding of important, natural features of the earth. For instance, current limnology texts were roundly criticized for underrepresenting fish ecology. Total numbers of pages which treated fish in each text were counted, figured as a percentage of total text pages, and offered as proof of de facto bias against finny forms. If such bias does exist, however, it was swiftly countered with other biases and omissions.

Considering the premise and fanfare of the Foreword, it seems fair to examine some of the more glaring omissions of the report. I think the need for a critical commentary is especially great because the report was touted by NSF officials as a guidepost for future research directions and practically as the salvation of aquatic ecology. Nonetheless, the insights emerging from use of stable isotopes and natural radiotracers for food web studies were ignored. No heed was given to one of the high priorities of practicing limnologists—that of obtaining and analyzing long cores from relict lakes. The new inquiries possible now with molecular tools were barely mentioned, even though such advances could revolutionize aquatic ecology.

The report illustrated for me the failing of U.S. science to provide a coherent framework for the study of aquatic ecosystems. The administrative structure has been "scoping-down" limnology to fit the programmatic constraints of NSF Divisions. The participants missed their opportunity to become a voice for change and, even more, an example. Instead, their recommendations ended with pleas for a committee approach to multi-disciplinarity. Readers of the report were asked to join with others who had presumably read other books about physical processes, chemistry, etc., and somehow they would develop insights and forge breakthroughs. The recommendations conjured in my mind the crude paraphrase "We need more blind men (or at least myopic ones) to help solve this elephant problem."

It may be that many ecological issues were ignored because they were not the province of the NSF Ecology Program (the "it's not my department" problem). Molecular approaches may help population studies, but that, I suppose, is the business of Population Biology. Similarly, biogeochemistry and stable isotope geochemistry must belong to Ecosystem Ecology. There must be a more rational way to confront the challenges of lake studies. Despite railings of some authors, limnology texts make the breadth of the field evident. Unfortunately, the science administration seems unequipped to handle it. Limnology is sprinkled across a diverse range of programs and even across major NSF Directorates. Limnologists studying the Great Lakes, for instance, are assigned to Ocean Sciences, because the U.S. Congress has decreed these lakes to be oceans. In the past such ad hoc arrangements were largely irrelevant because the field was smaller and most academic limnologists knew one another's work. Increasingly, U.S. limnologists and oceanographers, too, tailor their grasp and scope to the dimensions of their funding source. Administrative structure has come to define the science. In their Foreword, Redfield and Flanagan report that their advisory panels find "a paucity of innovative lake ecology at the community level," which seems to be the judgment of nonlimnologists about the value of lake studies to general community ecology. That is a very different business from the challenge faced by limnologists to integrate community ecology with all aquatic studies.

The report also raises the matter of distributing financial resources for limnological work. The competing allocation plans were not identified explicitly, but they involve independent investigators, directed programs, and national or regional research centers. What is the equitable distribution of funds among these to maximize knowledge gained per unit effort? The meeting organizers clearly favor the national center approach. However, in limnology the subject has never been subjected to open debate. There exist many na-

tional labs under the aegis of EPA, NOAA, USGS, and the Fish and Wildlife Service, all charged with responsibilities for aquatic systems. There is no full accounting of the total national resources directed to regional labs and centers versus to directed programs (consortia of investigators pursuing similar project goals of finite duration) or to individual, independent investigators, but my impression is that the former dominates present resource distributions. The distribution of creativity and innovation is probably significantly different.

The lake community workshop calls attention to the pressing need for organization and planning for aquatic science at a much higher level in U.S. science administration. Curiously, one of the themes pursued in the text is a need for hierarchical thinking in research ventures. This means that one must tailor observational programs and theory to the scope of the problem under investigation. Following such logic, we cannot pursue thorough and revealing studies of nature armed only with the viewpoints, concepts, and tools of community ecology. When it comes to lakes, we must blend geochemistry, hydrology, and limnology into a unified conceptual front. Then come the breakthroughs.

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POSTMA, H., AND J. J. ZIJLSTRA [EDS.]. 1988. **Continental shelves.** Ecosystems of the World. V. 27. Elsevier Sci. Publ., Amsterdam. 421 p. $189.50.

The satellite's view of Earth has become a cliché, but such views still show us some simple truths with surprising clarity. False-color chlorophyll images, for example, show us that nearly all of the regions of high plant biomass in the oceans are around the margins, on, or adjacent to the continental shelves. So the shelves, after decades of neglect by oceanographers with a blue-water fetish, have begun to receive deserved attention. Postma and Zijlstra have brought together chapters by authorities on the world's continental shelves. The book as a whole though suffers from a lack of synthesis. Most readers of this review will know that there has been a significant revolution in our paradigm of food web structure and function over the last decade or so. Nowhere in the book is this explicitly stated, and the various authors take views of their subjects that are variously dated in this regard—from perhaps 1950 to 1988. The naive reader, for whom this work presumably is intended, might well add all these chapters together and get a zero sum. Although dated material is always a potential hazard of encyclopedic works, it could have been clarified in this instance in a brief introduction.

The volume begins with an excellent, up-to-date exposition of the major features of shelf circulation and nutrient chemistry by Postma. It is largely descriptive and emphasizes what biologists need to know about shelf circulation rather than issues that will excite physical and chemical oceanographers. Eisma follows with a good summary of the geological history and development of continental shelves worldwide. He also gives an extensive exposition of sedimentation, flawed for this reader only by its meagre treatment of biological impacts on marine sediments. For example, he gives a geologist's view of sediment aggregates: there is organic matter sticking them together. However, he does not mention the microbial processes that produce the organic matter and mediate its role in aggregate formation. Smetacek does this in the following chapter, however, without reference to its significance to sedimentology. Smetacek's chapter on the plankton includes a detailed account of current food web concepts, the significance of nano- and picoplankton, the microbial food web, and detailed variations on the theme of phytoplankton production around the world and especially on polar shelves. In a chapter on benthic fauna, McLusky and McIntyre attempt to integrate work on benthic bioenergetics with that in the overlying water on which most of the continental shelf benthos must depend for falling foodstuffs. While this is appropriate in theory, they approach it through a review of pelagic ecosystem models as a measure of what the benthos receive—a misuse of heueristic models that are not sufficiently predictive even to yield a reliable energy budget. McLusky and McIntyre are more successful with descriptive generalizations about food webs and their variations with latitude.

After reading through chapters which lead us consecutively through physics, chemistry, geology, and biology, we come upon a sort of homunculus chapter by G. D. Sharp. Leaving nothing to chance—or to the editors—Sharp begins at the beginning again, with rivers flowing into the sea, physical mixing in the coastal sea, and so on, but from the point of view of fisheries. Some of this is repetitive of previous chapters, much of it is idiosyncratic and opinionated, and little of it is quantitative, but it is by far the most interesting and readable part of the book. Sharp attempts a bold synthesis of evolution, population and community ecology, ecosystem ecology, and physical and chemical oceanography. Although it is hardly surprising that the result is not wholly credible, Sharp produces a stimulating synthesis.

Though Sharp would have seemed to have covered everything, his chapter is followed by one by D. H. Cushing on the flow of energy in the marine ecosystems. In this chapter everything becomes clear and simple. There are three or five trophic levels in the sea, depending on your location. The only bacteria are cyanobacteria, and the only protozoa are tintinnids (an additional trophic level). The first half of Cushing's chapter is devoted to a detailed discussion of the methods of measuring primary production. One might conclude from this discussion that the subject is in disarray, but Cushing proceeds to give estimates for primary production for the continental shelves of the world. The remainder of the chapter is concerned with the other two trophic levels—grazing zooplankton and fishes. Inconsistencies between Cushing's ocean and Smetacek's are, to say the least, significant.

The volume ends with four chapters describing specific shelf regions: the North Sea, the mid-Atlantic shelf