forces in physical oceanography for over 30 years and whose style of inquiry has permeated the subject. As a scientific contribution, the book will be of enduring value to students and practitioners of oceanography.

The book opens with five short essays on Stommel by Arons, Veronis, Montgomery, Deacon, and Fuglister—it takes five essays to give anything like a complete image of this many-faceted, modest, and delightful man. The 18 scientific surveys are contributed by a veritable who's who in oceanography and are grouped into four sections—general ocean circulation, physical processes, techniques of investigation, and ocean and atmosphere. The contributors have taken their task seriously—though the chapters vary considerably in level and depth of technical detail, none is without interest. Papers by Warren, Worthington, and Reid on deep circulations, water mass characteristics, and the mid-depth circulation, respectively, occupy a sixth of the volume and incorporate many new results hitherto scattered. Together they provide a better description of the physical characteristics of the ocean as currently understood than any available hitherto. Fofonoff's account of the Gulf Stream system makes an interesting contrast to Stommel's own book of 20 years ago on the same subject and provides an impressive reminder of the detail achieved in observation during that time. A survey of the dynamics of large-scale ocean circulations by Veronis is more analytical in nature and includes discussion of the interesting recent numerical experiments by Holland and Rhines and others. Leetmaa, McCreary, and Moore survey observation and theory of equatorial currents, and Beardsley and Boicourt give an interesting, though qualitative, overview of estuarine and continental shelf circulations.

The section on physical processes begins at the small scale, with Turner's comprehensive account of small-scale mixing, enlarges to the macro-scale, with Hendershott on long waves and ocean tides and Wunsch on low-frequency (and large-scale) variability, then shrinks again in scale to that of thermal convection. Malkus's contribution on the last topic is both a review and (as is his wont) an original contribution, extending some of his earlier ideas to investigate the amplitude of turbulent convection from stability criteria. In between are a characteristically readable and illuminating discussion of internal waves by Munk and, to remind the physical oceanographer that there are other things in the sea besides water, a short chapter by Steele on some varieties of biological oceanography, emphasizing the variability, both physical and ecological.

Three chapters describe techniques of investigation in physical oceanography. Many of the most striking results in recent years have come as a consequence of ingenious new instruments and careful experimental design; Baker's account in this book can only give a sampling of these. Broecker shows how geochemical tracers have contributed to our appreciation of ocean circulation, and Faller defends the laboratory experiments that have given considerable insight into the dynamics of more complex oceanic systems. Finally, Charnock discusses small-scale air-sea interaction processes with perhaps somewhat less penetration than is found in some other chapters, and Charney and Flierl consider oceanic analogs of large-scale atmospheric motions. There are extensive references and a good index.

In the early '50's, Stommel asked, in a Woods Hole pamphlet, "Why do our ideas about the ocean circulation have such a peculiarly dream-like quality?" This beautifully produced volume is eloquent testimony to the revolution in physical oceanography that has occurred since then, owing in no small part to Stommel's participation, encouragement, imagination, and example. It is a worthy tribute.

OWEN M. PHILLIPS
Department of Earth and Planetary Sciences, Johns Hopkins University, Baltimore, Maryland 21218

An Ecological Reassessment

Primary Productivity in the Sea. Papers from a symposium. PAUL G. FALKOWSKI, Ed. Plenum, New York, 1980. x, 532 pp., illus. $45.90. Environmental Science Research, vol. 19. Brookhaven Symposia in Biology.

This is a most interesting time for those interested in the ecology of phytoplankton. It is a time of reassessment and reflection in which many of the basic ideas and methods that have been generally accepted for years are being reconsidered; our whole understanding of the dynamics of planktonic ecosystems is at stake. This is well illustrated by the proceedings of last summer's Brookhaven symposium on primary productivity in the sea. Despite the distinctly marine bias indicated by the title, the papers in this timely and important volume have general ecological relevance and will be of interest to all those interested in materials processing in ecosystems as well as to oceanographers and limnologists.

The reassessment of ideas in oceanography has been necessitated by the recent suggestion that oceanic productivity measurements are serious underestimates and that, even in oligotrophic oceans, the growth rate of the phytoplankton is close to the maximum rates observed in culture. The presumed high growth rates in the sea can be supported only by recycling of limiting nutrients. All the evidence seems to point to rapid recycling at small spatial and temporal scales: scales at which there is a nonsteady-state relationship between uptake, growth, and recycling processes. The basic questions addressed by the papers in this book include: How good are our productivity measurements? What are the in situ growth rates of phytoplankton? What can we infer from the observed physiology of natural and cultured populations? What is the magnitude and importance of nutrient recycling in planktonic ecosystems? and What can be learned from realistic models of phytoplankton growth and grazing?

The papers are arranged in a logical order beginning with aspects of light absorption and the quantum efficiency of photosynthesis, proceeding through cellular physiology and nutrient kinetics, and ending with such topics as grazing, nutrient regeneration, and the flux of carbon in the sea. Each of the papers is self-contained and forms a good discussion of the latest developments in its field, but the overall flow is more impressive. As Myers points out in the first paper, phytoplankton are not like small higher plants. They are best thought of as microbes in that they show types of overflow metabolism typical of single-celled organisms. This has led to some real problems of interpretation when steady-state continuous-culture data are extrapolated to the (more variable) real world. Yentsch also addresses this problem in a discussion of the fundamental relationship between laboratory data and an understanding of how the oceans work. For the first time, in my opinion, this book successfully fuses the work of physiologists and field oceanographers so that a new synthesis begins to appear.

What is clearly demonstrated is the critical importance of recycled nutrients. Dugdale, Eppley, and others have stressed the relative importance of "new" versus recycled sources of nutrients in the oceans of the past, but I, as a limnological observer, am impressed by the case that can be made for the magnitude of the recycled flux. Harrison's

review of nutrient recycling clearly indicates that "new" production can account for no more than 10 to 20 percent of total production on a global basis. If these estimates are correct, then nitrogen atoms are recycled 10 to 20 times in the euphotic zone before being lost from surface waters. The importance of recycling is not restricted to marine systems, for phosphorus recycling in fresh waters is just as critical. The relationship between production and consumption in planktonic systems is ill understood, but the data point to a highly coupled set of coevolved mechanisms. Because recycled nitrogen is in the form of ammonia and "new" nitrogen is introduced as nitrate, Malone even goes so far as to suggest that there are size-class differences in the utilization of nitrogen in the oceans. He suggests that nanoplankton are the dominant users of ammonia; in short, the organisms most likely to be recylced are most likely to be the consumers of recycled products.

The problem with the interpretation of productivity measurements is methodological. Confinement of phytoplankton in bottles for a number of hours while carbon-14 uptake takes place has a severe effect on physiological processes, survivorship, and the small-scale grazing and recycling mechanisms. This problem is well reviewed in this book, cropping up in a number of contexts. For example, Eppley attempts to reconcile the productivity estimates from the North Pacific with data from a number of sources and concludes that there is still an order-of-magnitude uncertainty in the data. Many of the papers in this book suggest, sometimes in subtle ways, that we have indeed underestimated the productivity of the oceans, that the phytoplankton in oligotrophic ocean waters are not nutrient-limited and that phytoplankton growth rates in such areas are close to maximal. Such a message should not go unheeded by limnologists.

One other important message comes through clearly. If the algae are to be thought of as microbes and their growth rates and physiology are heavily dependent on small-scale, high-frequency processes, then we must learn much more about the time course of the algal responses at these scales. The physiological and hydrographic data presented in the book indicate that at scales of less than 24 to 48 hours there is considerable interplay between the environment and the cells. It appears that, by knowing what the algal response times are, it may be possible to infer aspects of the physical structure of the environment. Research in the Great Lakes has led to the same conclusion, and we are faced with the interpretation of some complex non–steady-state processes at such scales. The dominant message from this book is that the study of small-scale processes in the oceans, through physiological and hydrographic techniques, will lead to an improved understanding of an important group of organisms and an important global resource. As the last two papers point out, the impact of oceanic productivity on the global fluxes of carbon dioxide is considerable. A better understanding of oceanic productivity and its distribution in time and space is not simply an academic concern.

GRAHAM P. HARRIS
Department of Biology,
McMaster University,
Hamilton, Ontario L8S 4K1, Canada

Managing Wetlands

Wetland Functions and Values. The State of Our Understanding. Proceedings of a symposium, Lake Buena Vista, Fla., Nov. 1978. PHILLIP E. GREESON, JOHN R. CLARK, and JUDITH E. CLARK, Eds. American Water Resources Association, Minneapolis, 1979. x, 674 pp., illus. $49. Technical Publication Series.

Wetland ecosystems currently make up 3 to 4 percent of the landscape of the United States, but the total area is decreasing 0.5 to 1.5 percent annually. Though very productive, wetlands often have unappreciated local and regional influences on organisms, the cycling of elements, the storage and degradation of pollutants, and water budgets. Although wetland fur trapping played a significant role in the European colonial expansion in North America and coastal marsh haying was common, wetlands were once largely considered worthless. George Washington, Thomas Jefferson, and Patrick Henry formed a company to drain the Great Dismal Swamp, for example, and the family of William Bartram, one of America's first naturalists, profited from the grain yields of the wetlands they drained. But over decades the "wetlands are wastelands" philosophy gave way somewhat to a growing interest in wetland conservation, especially with regard to wildlife. This symposium proceedings is a landmark publication in the continuing evolution of an improved and broader understanding of wetland ecosystems and their importance in society. The National Wetlands Technical Council and the Conservation Foundation organized the symposium, which was sponsored by nine federal agencies led by the U.S. Water Resources Council. The emphasis is on management, conservation, and present value.

The book contains good sections on food webs, habitats, and water quality. But the more problematic aspects of wetland management involve the couplings between ecosystems. Organisms, water, and chemicals move through wetlands easily, and there is no clear consensus about where uplands or open waters end and wetlands begin. These couplings, then, are not easily discerned.

Gannon, Bartholic, and Bill ask if wetlands can influence downwind climatic conditions. The answer seems to be "yes" for southern Florida because of the thermal inertia of wet soils to cold fronts and the subsequent slow transfer of the stored heat from land to atmosphere. Wetlands there buffer the type of short-term temperature changes that damage the local citrus crop. The authors then raise the question whether local management agencies can effectively regulate land uses that can cause unintended atmospheric modifications.

Williams and Dodd describe how some large and numerically rare organisms, though consuming a minor portion of the total ecosystem energy flux, fundamentally affect wetlands. Alligator mud wallows, for example, provide a refuge for aquatic organisms during drought, and the elevated edges of the wallows provide a suitable substrate for tree and shrub seedling germination in the otherwise flat prairie. Alligator trails influence the local hydrology, and bay islands form from abandoned alligator nests.

Barber, Kirby-Smith, and Parsley connect the 1972 collapse of the Peruvian anchoveta harvest to an expanded market for alternative protein sources. This circumstance led to wetland clearing for soybean farms in North Carolina and finally to the "inevitable" deleterious effect of the clearing on the coastal estuary, which they document. They conclude by pointing out that needed long-term studies of wetlands are rare and that, since wetland research is often perceived as constraining agricultural devel-