

Mark M. Littler and Frank E. Round

There have been many particularly important contributions to the ecology of benthic marine, planktonic and freshwater algae made during the past decade. Unfortunately, ecological research frequently requires time spans of more than one cycle of seasons so that unusual macro- and micro-climatic fluctuations will not exert a disproportionate influence on the outcome of experimental manipulations, and therefore relatively lengthy papers are the norm. Fortunately, it has been possible to include several such lengthy papers in this section. Many of the works we have selected illustrate diverse aspects of algal ecology and expand our knowledge along specialized lines, e.g., by concentrating on a particular micro-habitat or on interactions between species. Others chosen are examples of more general approaches where the analysis relies on average values. Readers should recognize that this latter approach is equally valuable and the only valid way to begin to understand the biogeochemical cycling of material and its back-reaction into communities.

In benthic algal ecology, a dramatic advance has occurred during the past decade owing largely to the synthesis of traditional empirical (i.e., observational/correlative) approaches and mechanistic or causative (i.e., experimental) studies. The latter have led to much needed theory at the physiological, population and community levels. Many significant advances concerning algal growth, productivity, distribution, succession and especially algal-algal and algal-animal interactions have arisen from laboratory experiments and controlled manipulations performed under natural field conditions. Also, there have been important methodological advances that have resulted in new information, greater standardization and improved consistency. The recognition of the importance of both physiological stress and physical disturbance has led to considerable advances in our ability to understand and predict the effects of natural and anthropogenic factors on seaweed community function, stability and diversity. General ecological theory has become increasingly influenced by studies of benthic algal ecology, and a broader awareness of the amenability and advantages of seaweeds as experimental systems for the elucidation of ecological processes offers exciting prospects for the next decade.

The benthic selections were chosen because they integrate key concepts concerning macroalgal ecology. For example, the five papers on benthic macroalgae begin chronologically with a report (Neushul 1972, this volume), replete with ideas relating morphology to water motion and other factors, that induced other phycologists to examine the question of why there exists such an astounding array of shapes and sizes of seaweeds. The publication of Mann (1973, this volume) was important in revealing the diverse roles and production capacities of seaweeds as well as the importance of disturbance in indirectly affecting algal growth and biomass. Dayton

(1975, this volume) and Vadas (1977, this volume) illustrated the advantages of careful experimental design and their works have led to increases in our knowledge of marine algal competitive interactions and herbivore preferences, respectively. These detailed and comprehensive studies of functionally adaptive features not only led to significant new knowledge, but stimulated similar community research on algal/algal and herbivore/algal interactions. The paper on functional morphology (Littler and Littler 1980, this volume) provides a testable and comprehensive paradigm by contrasting adaptive strategies of opportunistic forms (i.e., ruderals) with long-lived persistent species (e.g., stress-tolerant, physically-resistant, predation-resistant and competitively-competent algae). This paper provides a connective thread with the previous four studies by experimentally showing the interrelated aspects of selective parameters for morphology, growth, productivity, environmental resistance and biological interactions. All of the above papers, while ecological, maintain a clear evolutionary perspective, an approach that is inseparable from modern ecological concepts.

In introducing the important freshwater and planktonic algal papers from the last decade, it should be noted that major ecological advances have arisen from workers interacting with the limnological/oceanographic and biochemical/physiological disciplines. Examples involve the vertical stratification of species and the movement of phytoplankton in the water column. Also, the discovery of an almost universal deep-living population of phytoplankton at sea has opened a fascinating field. The elucidation of these populations, the continual refinement of the ^{14}C technique and improvements in sampling methodology indicate that previous estimates of phytoplankton production have been at least 20% too low. The use of remote sensing for chlorophyll concentration has enabled tracing of phytoplankton along oceanic fronts over long periods without maintaining expensive ships at sea.

There has been increased interest in the interactions between planktonic algae from a symbiotic standpoint and also in terms of growth rate/nutrient kinetics. Furthermore, effects of heavy metals and of differential grazing is also being pursued vigorously. In the past, laboratory studies suffered from unrealistically high nutrient conditions and also from the use of "weed" species. It is of course more difficult to grow many of the species occurring in oceanic situations; however, while growth at ambient nutrient levels may be slow, they are at the appropriate nutrient levels. Into these fields of experimentation, the recognition of diel variation in nutrient uptake, metabolic functioning and growth has refined approaches to production estimations.

Stockner and Antia (1976, this volume), studying the effects of stress on planktonic algae, collected data based on long-term effects and, while short-term effects may adversely affect many phytoplankters, the possibility that some cells may acclimate and then form resistant inocula had been previously neglected. Many algae have evolved in habitats which are naturally

stressed, e.g., where anaerobic growth is the only possibility. In this regard Cohen et al. (1975, this volume) examine the photoassimilation of carbon dioxide by a blue-green alga and found that sodium sulphide rather than water was the electron-donor. Heterotrophic tendencies in photosynthetic algae are generally thought to be uncommon. However, under conditions of anoxia, in genera (such as *Scenedesmus*) which have the ability to induce the necessary enzymes, such metabolism is possible, as indirectly shown by Vincent (1980, this volume). Algae seem to have colonized every suitable available niche and oceanographers have been aware that more carbon fixation was proceeding in the sea than appeared possible when only the euplankton biomass was considered. Johnson and Sieburth (1979, this volume) have shown conclusively that small blue-green algae are important components of minute-celled communities. In the future greater attention will have to be paid to such organisms of bacterial size (termed pico-plankton).

Schindler (1977, this volume) has again emphasized the key role of phosphorus in lake eutrophication and also illustrated that unexpected alterations in the phytoplankton community composition can occur when the level of this single nutrient is altered. Goldman et al. (1979, this volume) combined data on algal growth under various laboratory conditions with information from nature and demonstrated that when conditions are suitable for the occurrence of a given species an optimal growth rate is achieved. We suspect that in nature each species in turn realizes its full potential before declining. Factors such as sinking, loss of particulate organic matter, upwelling and the production of a new matter, as opposed to regenerated organic matter, i.e., that which has formed from recycled nutrients, are discussed by Eppley and Peterson (1979, this volume). This last paper sets the scene for a consideration of the physical habitat in relation to cell form which has never been adequately explored. Hence, the value of the paper by Margalef (1978, this volume) lies in the new viewpoint emphasizing the role of external energy in the form of wind-induced turbulence and its relationship to morphological adaptations of phytoplankton. The neustonic habitat sampled by Parker and Hatcher (1974, this volume) has been neglected--that organisms are specifically adapted to and accumulate at this air-water interface is undisputed and the way is now open for studies of metabolic activity in this micro-layer.

The simple concept of reduction of phytoplankton biomass by zooplankton grazing was shown by Porter (1976, this volume) to be a very complex matter, with differential symbiotic effects; it has not been generally appreciated that some algal

populations actually benefit from being grazed and even survive and increase their nutrient uptake as they pass through the guts of zooplankton. Simultaneously, other algae are destroyed by this passage. The necessity for experimental studies combined with detailed knowledge of the organisms in the water column is an important contribution of this study. A fascinating contribution to the "paradox of the plankton" is provided by Titman (1975, this volume) who shows how the ratio of two essential nutrients can affect the growth of two diatom species and determine either co-existence or dominance.

Few workers have studied the interactions between parasitic fungi and algae common in freshwater, yet in the plankton almost every alga has associated parasites; the benthic algae are also prone to attack but almost nothing is known of this interaction. The longstanding problem of dual-clonal cultures now seems to have been overcome by Canter and Jaworski (1978, this volume) for some species. Of great significance is their finding of rather extreme fungal/host specificity and the need for a living substrate to complete the fungal life history. Antagonistic effects of one alga on another have often been cited in seasonal cycles, but rarely has any concrete evidence been forthcoming. Commonly, researchers have suggested that excreted metabolic products suppress growth of other species; it is interesting to find an example (Murphy et al. 1976, this volume) where iron is removed by a blue-green alga to the possible detriment of its competitors (i.e., exploitive competition). Of course such effects require very lengthy detailed seasonal studies to determine possible overall effects on community structure.

Even though 18 works could be reprinted, many equally deserving contributions are mentioned in the following chapters in this volume (E.2 freshwater, E.3 benthic marine, E.4 planktonic marine), and we refer the interested reader to these. In addition, an excellent manual of ecological methods for phytoplankton research has been produced by Sournia (1978, this volume). Also, the fourth in the series of the Phycological Society of America's Handbooks "Ecological Field Methods: Macroalgae" is currently being compiled and edited by Littler and is scheduled for publication in 1984. Readers seeking further information on algal ecology now have at their disposal the recently published text "The Ecology of Algae" authored by Round (1981, The Ecology of Algae, Cambridge Univ. Press).

A new series containing exhaustive essays on phycological topics, "Progress in Phycological Research," edited by Round and Chapman, will appear as an annual volume and the first contains articles of ecological interest.