INTRODUCTION

Studies in biological oceanography have, with few exceptions, been conducted over limited geographic areas for short periods of time. The result has been a series of snapshots of marine species and their environments in time and space with limited coherence among the observations. Significant progress has been made in describing the more abundant species and communities. Some important groups of organisms, nevertheless, remain poorly understood including fast-moving nekton (e.g., squids, tunas, sharks), soft-bodied gelatinous plankton, and bacteria, particularly with respect to the role they play in the energy flux of the ocean. Large gaps remain in understanding the linkages between primary production and secondary production, and the production of fish and other large predators.

Some important advances have been made in developing quantitative methods for estimating changes in the abundances of marine populations. However, much of the literature describes changes in population levels of single species, often with no consideration of the impact of these changes on other species.

More comprehensive assessments of the impact of changes in population levels on the marine ecosystem will require long-term observations of population-environmental interrelationships at specific sites in the intertidal area, on the continental shelf, and in the deep ocean. As these population studies are developed, at-
attention should be given to sampling design and the use of statistical analyses in determining the appropriate numbers of samples for analyses.

The experimental approach in studying population interactions using large-scale enclosures (e.g., CEPEX, MERL), and in situ "patch-type" studies should be encouraged. Shallow-water field experiments have led to new developments in fundamental ecological theory. Efforts to extend these techniques to the continental shelf and deep sea should be encouraged. In the context of advancing ecological theory, fisheries studies have already provided an opportunity for conducting large-scale field experiments on the effects of the removals of large biomasses of predators and prey on the energy flux of continental shelf ecosystems.

Population processes

Significant problems exist in understanding the growth and mortality processes that occur within populations, among populations, and between populations and the environment. The effects of population density on predator-prey interactions and of physical and chemical factors on age-specific rates of birth, growth, and mortality are largely unknown. For example, testing the effect of a given pollutant at a single stage of an organism's life is almost worthless for predicting the effects that substance will have on a population of that species unless all life stages are considered. Elucidation of the relationships of population processes to physical and biological variables requires controlled experimentation, using either laboratory culture methods or field manipulation. Currently, both approaches are very labor intensive. Also, organisms that are easy to culture generally have certain types of life histories which may not be representative of all, or even the important, species. Improved culture techniques for a variety of fish and invertebrates, particularly automated culture techniques, would greatly facilitate future laboratory population studies. In this regard, the marine analog of the Wistar rat, as a biological indicator of physiological condition in relation to pollution levels is a promising area for further culture research. Rewarding field population experiments on the continental shelf, now utilize benthic species as indicators of environmental health because the problems of motility are much less severe than with free-swimming species. These studies should be encouraged and enlarged to encompass strategic areas of both impacted and relatively "clean" marine environments.

Major Problem

Studies of the interrelationships among ecosystem components can best be approached by posing key questions dealing with the basic processes of recruitment, growth, and mortality of marine populations. To predict the responses of ocean ecosystems to man-made and natural perturbations, we ask how do the individual life-cycles of populations and interrelationships among species relate to patterns of environmental variation.
PLANKTON

The state of knowledge in plankton biology varies by region. Most advances in understanding the processes of reproduction, growth, mortality, and distribution have been attained in accessible, relatively nearshore environments. There, some regions have been intensively described. There is a need to expand descriptive efforts, particularly in the open ocean, especially on scales smaller than ocean-wide. While both long-term and short-term descriptive efforts must continue, insights into processes and rates are best obtained by experimental manipulation of defined systems. In the nearshore environment, various intentional or unintentional perturbations (e.g., formal experimental manipulations, pollution events, fisheries) have given limited insight into ecosystem processes and functioning. No methodology exists for doing such experiments in the open ocean; even selection of appropriate scales is a difficult problem that can only be solved by detailed descriptive efforts. Considerable progress has been made in understanding some ecological processes through laboratory experiments. We need to develop appropriately-scaled experimental techniques tailored to both nearshore and open oceanic environments, so that the laboratory results may be verified in natural systems. Aspects needing such large-scale treatment include very basic processes such as rates of photosynthesis, productivity, second-order and higher level productivities, and reproduction. Other problems needing detailed investigation on realistic scales include questions of competition, predation, and community structure, stability, and evolution.

BENTHOS

Studies of benthic ecosystems have progressed to the extent that the most rapid advances are the result of experimentation involving alteration of single variables in field situations. In shallow water it has been possible to work out the functional role of individual species in maintaining community structure. The role of predators, larval dispersal and recruitment, and networks of competitive relationships between species have all been active areas of investigation. Concepts are being developed that relate the factors influencing survival of individuals to more broadscale patterns of community structure.

The technology is now available to extend these experimental studies into the deep sea. Here the relative uniformity of conditions over substantial areas allows us to generalize from experiments on spatial scales of meters. It is possible now to measure how the basic biological rate processes of individuals and populations influence the major chemical and biochemical fluxes in the benthic boundary layer. Deep-sea experiments of the future will involve detailed studies of the movements, dispersal and mortality of organisms, fluxes and dissolution rates of chemical constituents and movements of particles above and below the sediment-water interface. These processes are so intimately related that one cannot be studied without the other. The deep-sea experiments to study
the benthic-boundary layer processes must be done in areas where the physical regime and influx of particles from the upper layers of the ocean are being studied simultaneously.

BACTERIA

Marine bacteria are ubiquitous in the ocean environment, distributed as free-living planktonic species, associated with particulates, or in commensal or symbiotic relationships with other life forms. A major role of marine bacteria in the sea is the regeneration of nutrients and mineralization of allochthonous materials, a critical role in nutrient cycles. Techniques for determining rates of activity and degradative potential of free-living microbial populations have been applied to the water column, but still require considerable effort and increased field application. Deep-sea microbiology, still in the developmental stage, has the technology available to measure in situ metabolic rates of deep-sea microbial populations that exist under extreme conditions of low temperature and nutrient levels and elevated hydrostatic pressure. Initial studies indicate that metabolic rates for free-living bacteria in the deep-sea trenches and basins are markedly reduced relative to activity under atmospheric pressure and temperature. Recent studies of bacteria associated with intestinal tracts of deep-sea amphipods suggest the nutrient-rich guts of macroorganisms are sites of considerable microbial activity even under deep-sea conditions. Studies of the importance of physical associations of bacteria with particulates and with other organisms should be expanded in order to understand periphytic and commensal or symbiotic activities of microorganisms and their role in food webs of the sea.

It is increasingly evident that rapid evaluation of man-made and natural perturbations in the ocean can best be accomplished by examining impact at the microbial level. Bacterial community structure will reflect the environment from which the organisms are isolated. In the open ocean, where the nutrient supply is limited, functional oligotrophs predominate. Studies of deep-sea sediment, water, and intestinal gut flora have shown that taxonomically distinct groups of bacterial types are associated with a specific habitat. Environmental changes will be accompanied by changes in community structure and/or microbial biomass. Although the last decade has seen rapid advances in assessment of microbial biomass, the various methods, including epifluorescence microscopy, ATP and/or GTP analysis, heterotrophic uptake, and Limulus lysate assay, remain to be standardized, inter-calibrated and automated for large-scale studies of marine bacteria. In addition to further development and application of these techniques to marine studies, sampling problems, in particular, equipment interference in the integrity of samples collected for microbiological analyses must be overcome. To date, the microbiologist does not have available equipment or technology for aseptic collection of deep sea sediments. Future studies in marine microbiology should stress a comprehensive approach, including taxonomy, ecology, and physiology, for improving the definition of autochthonous bacterial populations, as well as
providing a basis for quantitating the sensitivity of the microbial communities to impingements of man and his activities on the ocean environment.

FISH

Studies of fish are moving rapidly from the more traditional assessments of single species populations to investigations of fish as principal predators in complex marine ecosystems. The newly emerging fisheries ecology studies focus on the importance of primary production, secondary production, and predation on the growth, recruitment, and mortality of fish stocks. Considerable effort is directed to the partitioning of mortality into natural mortality, mortality due to fishing, and mortality that may be related to increasing ocean pollution.

One of the major problems in fisheries studies is the present lack of understanding of the relationship between the size of the parent stock and the numbers of larvae and juveniles they produce as new recruits to the fishery. A better understanding of the stock-recruitment relationship is required if predictions of future levels of abundance are to be improved. Programs have been developed and are now underway to deal with this problem using a combination of laboratory experimentation on the growth and survival of eggs and larvae and large-scale systematic assessments of changing levels of larval, juvenile, and adult fish abundance. These studies should be expanded to sample adequately the newly established fisheries management zone of the U. S. Present survey methods could be improved with the refinement and application of acoustic systems for estimating population biomass.

Technology Needs

In the laboratory, two time-consuming procedures could be improved with the application of image scanning systems: ageing of scales and otoliths, and the sorting, sizing, and counting of phytoplankton, zooplankton, fish eggs, and larvae. Development of hydroacoustic and other pertinent advanced technology for increasing the efficiency of present trawling methods used to monitor changes in the abundance of fish stocks should be accelerated.

Expanding Fishery Ecosystem Studies

Time-series measurement of changes in the abundance levels of fish stocks and their prey over space and time should be expanded to include all of the area now under the jurisdiction of the U. S. as described in the recently enacted Fisheries Conservation and Management Act of 1977.

Fisheries studies provide a unique opportunity to view the changing abundance levels of fish as large-scale field experiments in ecosystem dynamics. For example, off the northeast coast during the past decade there has been a decrease of about 50% in the biomass of fish. Much of the decline is attributed to heavy fishing
mortality. Local environmental conditions and longer-term climatic changes may also have contributed to the decline. Significant questions remain unanswered. Does the reduction of principal species (e.g., herring, cod, haddock, yellowtail flounder) release secondary production to be consumed by short-lived, fast growing, smaller, less desirable species? What are the probabilities associated with the return of over-exploited species to former abundance levels? Present studies focus on the critical linkages among the principal sources of the food of fish and the recruitment, survival, and productivity of the fish stocks from the Gulf of Maine to Cape Hatteras. The availability of these stocks to U. S. fishermen is the end product of a complex series of interactions among the fish stocks, benthos, plankton, and hydrography of the region. Studies of single species have not provided the kind of scientific information required for effective management of multispecies fisheries operating at different trophic levels. While it is important to continue these studies, they must be conducted within a broader matrix that measures changing abundances of key species in the ecosystem. Fisheries ecosystem studies will lead to improved understanding of the factors controlling fish production, and this information in turn will allow for greatly improved forecasts of abundance levels of fish stocks.