

flow of energy through the food web; patterns of distribution among the dominant species; vegetational structure; and the relation between ecosystem organization and stability. No one ecosystem has ever been studied from all of these points of view.

Within the last decade the quantitative analysis of all aspects of ecosystems has been considered seriously. For the first time in history this has become a realistic goal. We have new and powerful tools in systems analysis and in the availability of high-speed computers. It is only with such tools that the complexity of ecosystems is expected to yield to analysis. The application of these methods has already begun. Since ecosystems are a family of systems distinct from those of economics, or industry, or aeronautics, systems analysis will have to be tailored to fit this new area of application.

Systems analysts often find that systems have properties not easily predicted from the study of components. Some components can be varied greatly without appreciably affecting the performance of the system as a whole, while small changes elsewhere can change the entire pattern of performance. Ecosystems appear to have similar properties. The effect of the total system on the dynamic state of many of its component populations may be far more pervasive than previously thought. Thus, the conviction is growing that ecosystem analysis should be at the forefront of ecology, rather than serving as a background. Although the analysis of the whole may be cumbersome, ecosystem principles may emerge that will simplify our view of ecosystems, and possibly even simplify management programs of biological resources.

At this time, despite some courageous attempts, we have no way to interrelate different aspects of ecosystems, such as energy flow, species diversity, and vegetational structure. Furthermore, although we can describe each of these quantitatively, we have only the haziest of ideas on why some particular set of results is found. In this sense, ecosystem analysis is a discipline that is just being born.

Among the contributions that the International Biological Program will make to ecology, the most significant immediate achievement will result from the establishment of ecology and ecologists in countries that now lack them. These are emerging nations that do not yet have scientific and technical facilities capable of supporting intensive research. They do have formidable problems to be solved. If we estimate the *per capita* value of all natural resources available to each country, we find that these values run at least one hundred times higher in the advanced countries than in many of the emerging nations. It is certainly difficult for the United States, which has resource assets of about \$30,000 per person (U.N. survey, 1963), to visualize how to solve problems of development in countries where the figure is less than \$100 per person. Producing food with poor soil, poor nutrients, and inadequate rainfall is only a small part of the problem. The cost of power for mechanization is prohibitive; the cost of transportation of the food to cities is prohibitive; and the cost of food preservation is prohibitive. Our system of agriculture, which now consumes as much energy in fuel as it produces in food, is applicable only to a few favored regions of the earth. We have achieved high efficiencies of production per acre, and per man-hour, but probably have the lowest efficiency in the world per unit of power. Many of the emerging nations have excesses of land and people, and little or no source of power.

Large areas of Asia, Africa, and South America can reach a good standard of living only if they achieve an efficiency of conservation and re-utilization of natural resources that is at least an order of magnitude greater than ours. With such formidable problems, these nations must explore every possible resource. To do so they must know much more about the characteristics of their environments, their capacities for alteration, and the potential of native species of plants and animals for man's use. The kind of ecology they need has already been developed in other countries, and can readily be applied locally.

The I.B.P. will make major contributions through its programs for the training of foreign scientists and for the international exchange of personnel. We are exploring already the possibility that native game in Africa such as Thompson's Gazelle or the Impala may prove to be more productive than cattle or sheep. Other countries, whose trees are little known to ecology, are asking that their forests be studied. Several nations hope to assess the productivity of estuaries, boundaries between fresh water and marine water that appear to be good sources of fish protein.