Book Reviews

Earth as a Productive System

Primary Productivity of the Biosphere. HELMUT LIETH and ROBERT H. WHITTAKER, Eds. Springer-Verlag, New York, 1975. viii, 340 pp., illus. $29.80. Ecological Studies, vol. 14.

The attempt to estimate the rate of organic production, or primary productivity, of the world's solar-powered natural systems has an interesting history. In 1862 Justus Liebig, the pioneer agricultural chemist and plant nutritionist, well known today for the concept of the law of the minimum, based an estimate of the dry matter production of the global land area on a single sample, a green meadow. Interestingly enough, his estimate of approximately 10^{11} metric tons a year is very close to the estimate of 118×10^9 tons a year for continental areas derived by the editors of this volume (see table 15-1, p. 306) on the basis of measurements in many vegetation types and with the use of models, computer mapping, and other modern techniques. On the other hand, Gordon Riley, in 1944, overestimated ocean productivity by basing his estimate on measurements in fertile inshore waters. It was not until the 1960's, after the introduction of the carbon-14 measurement technique, that the very low productivity of most of the open ocean was recognized. Since the oceans cover more than three times the area of the land, it was natural to assume, as did Riley, that marine ecosystems fixed more total solar energy than terrestrial systems. Actually, land seems to outproduce the sea, perhaps by as much as 2 to 1 according to estimates in this volume (of a total 173×10^9 tons of dry matter a year, 55×10^9 are estimated to be marine and 118×10^9 to be terrestrial).

This book is one of several recent collections of papers on productivity that are outgrowths of the International Biological Program (see also R. H. Whittaker and G. E. Likens, Eds., "The Primary Production of the Biosphere," *Hum. Ecol.* **1**, 301–369 [1973] and D. E. Reichle, J. F. Franklin, and D. W. Goodall, Eds., *Productivity of World Ecosystems*, National Academy of Sciences, Washington, D.C., 1975). It has 15 chapters arranged in four groups: Introduction and History, Methods, Global Patterns, and Utilizing Knowledge of Primary Productivity (the last being mostly about methodology and modeling). The heavy emphasis on methodology is understandable, for no two methods measure exactly the same quantity in the complex, stepwise flow of energy through plant populations. Chapter 3, by A. S. Hall and R. Moll, contains an excellent account and diagram of the total production process; this and the other chapters on methods are especially recommended to students who contemplate attempting field measurements. The disparity between land and water poses special difficulties. The techniques most widely used in the aquatic environment measure gross, or total, production, or some fraction thereof. In contrast, the harvest and similar methods widely used in terrestrial environments measure net community production, which is net primary production minus loss to consumers and decomposers during the period of measurement. Unfortunately, the editors of this volume chose to use net primary productivity as the unit for comparison. A large-biomass forest, where less than a third of the organic production may be "net," and a small-biomass, high-turnover plankton community just cannot be compared on this basis. There is much to be said for assessing productivity on the basis of gross production (that is, total energy flow through the organic system), since harvest and yield to man represent only part of the value of the plant cover. The myriad life-support functions (CO_2 removal, waste assimilation, nutrient retention, and the like) performed by the world's green belts constitute a large part of the "work of nature," and these functions are more directly related to gross than to net productivity.

In summary, this volume is a collection of well-prepared individual papers with little synthesis, except that several articles validate in detail what is already in textbooks, namely that for many ecosystem types primary productivity can be accurately estimated from data on key physical limiting factors, such as precipitation on land and nitrogen-phosphorus fluxes in water. Whittaker and Gene Likens do make a brave attempt at synthesis in the final chapter, entitled "The biosphere and man." These authors conclude that the carrying capacity of the globe for man has already been exceeded, even though man utilizes only a small fraction of the total organic output of the biosphere. Industrial pollution, exhaustion of mineral resources, the shortage of high-quality arable land, and the inherent instability of high-energy agricultural and industrial systems, rather than primary production, are viewed as the major factors limiting further growth of human populations and industrial development. Whittaker and Likens obviously subscribe to the general notion that the optimum or desirable population level for man is substantially less than the maximum human biomass that could be supported by maximum utilization of resources.

I believe we can say that the IBP has been successful in the inventory phases, but it now must be followed by a more direct analysis of the carrying capacity question. For such an analysis interactions between systems become more important than what goes on within systems. Accordingly, one approach would be to focus on the manner of coupling between the three major energy systems of the world, namely, the solar-powered natural systems, the solar-powered but subsidized agricultural food-fiber systems, and the fuel-powered, urban-industrial systems. Models could then be set up to simulate different spatial arrangements and outputs in order to determine optimum mixes of these elements, all of which are required for the survival of man and nature as a symbiotic whole.

EUGENE P. ODUM
Institute of Ecology,
University of Georgia, Athens

Assessing Danger

Of Acceptable Risk. Science and the Determination of Safety. WILLIAM W. LOWRANCE. Kaufmann, Los Altos, Calif., 1976. x, 182 pp. Cloth, $8.95; paper, $4.95.

"One can scarce be in the most humanized society," Sir Richard Steele observed in 1709, "without risking one's life." It is still true. Indeed, the march of civilization has recently brought us chemical pollutants unknown in nature, some of which are carcinogenic, and nuclear referenda and government regulations unknown to history, some of which may be precipitous. Lowrance's study, performed while he held a postdoctoral fellowship at the National Academy of Sciences, provides a summary of the ways in which industrial society may methodically appraise risk. Given the times, it is a useful thing to have. Yet the book is disappointingly unprovocative: safety analysis, it appears, is little more than common sense routinized.

The fundamental distinction in this subject is between risk and safety, Lowrance says. Risk is here taken to mean the (objectively ascertainable) probability of harm. "Safety" denotes the social and legal judgment that that probability is appropriately low; "a thing is safe if its risks are judged to be acceptable" (p. 8). The statement has a peculiar ring to it.

What is peculiar is its flatness. Lowrance omits a crucial signpost that would help to orient the reader in the conceptual marshes of hazard assessment. The long-running dispute over the interpretation of probability measures is of central, if unacknowledged, importance for the definition of risk. One school holds that probabilities are primarily reflections of the actual frequency of occurrence of events; probabilities are therefore objective, as Lowrance postulates. Another school holds that the assignment of probabilities primarily reflects the assigner's belief or confidence that the events in question will occur. This subjectivist view would, if adopted, blur the difference between risk and safety that Lowrance seeks to discern: probability and judgment are intertwined, not separate. Significantly, most disputes about safety concern situations, as in the case of carcinogenic pollutants or nuclear waste, where the frequency of mishap is low but the potential damage high. Here public policy is based upon probabilities *subjectively* estimated. Lowrance's easy distinction between risk and safety turns out to be unavailable in practice. Probabilities, in the hard cases, must be estimated under poor conditions, where neutral objectivity is out of reach.

This is not cause for despair, however. Lowrance provides two clearly written inventories of the elements of safety analysis: a list of the types of data that bear upon probability estimates, and a discussion of factors that affect judgments about the acceptability of risks. The data are often haphazard—"most test methods 'just grow' " (p. 54). The criteria of acceptability are similarly disjointed. The controversial Delaney amendment to the Food and Drug Act erects an absolute barrier against food additives found to cause cancer, but air and water pollution pose larger dangers, which are imperfectly recognized and unevenly regulated.

What the inevitable subjectivity of safety assessments does do is to place an uncomfortable burden upon scientists and public officials. For technical experts must, in their judgments, exceed the authority that properly belongs to them. A finding of adequately low probabilities is inextricably tied both to one's technical intuitions and to one's idea of what is adequate. Public officials, complementarily, must rule on safety with some arbitrariness when the experts disagree. There is no objective means by which to choose among experts when their judgments are partly subjective.

How to steer between the Scylla of scientific arrogance and the Charybdis of uninformed governmental ukase? Lowrance proposes a professional *contrat social*: society subsidizes the education of professionals and in turn becomes a partner in "a trust that the professions will watch over the well-being of society" (p. 122). The idea of a social contract linking scientists and those affected by their expert judgments is surely partly correct. The criticisms of nuclear power would have been poorer by far without the voluntary contributions of many academic scientists, and their statements of motive have often included references to the stewardship implicit in their training.

But the trust is, one should note, a blind one: the technological adjustments that can minimize risk are often obscure, Lowrance notes, and "only technical people can envision the possibilities" (p. 121). For some professions, notably medicine, a legal conception of malpractice has developed. (Interestingly, the training of physicians has also been less visibly subsidized by government—though one hardly imagines that aid to medical education could be rationalized as a way to strengthen doctors' social responsibility.) For other professions such as engineering, malpractice is a concept with so few worked out cases that it remains quite elusive. And none of the sciences have any standards of social performance at all—only the tender mercies of the refereed journal.

The trend is plain: the more the contribution of the technical expert is confined to providing information and counsel, the less is the trust relationship with society enforceable, the less it is realizable. In the hard cases, where judgment must substitute for empirical action, the accountability of the technical adviser is elusive indeed.

Of Acceptable Risk could have pointed toward the hard questions and the promising lines of inquiry. Psychological studies of individual perceptions of danger, for example, still do not add up to a coherent account of how social customs emerge to cope with new hazards. The puzzle of how to reconcile legal forms and procedures with the processes of technical analysis points to a conspicuously problematic boundary between two kinds of social custom. More broadly, the systematic interpretation of technological possibilities in terms of their social implications languishes, as does the establishment of criteria for evaluating these implications. Between hard technical possibility and formalized regulation lies the often murky middle ground of the social criterion. It is murky for new technologies because scientific conceptions are forced to substitute for a social experience that has yet to occur. That is, as the late Hannah Arendt noted, an unrevealing, unsatisfying alternative so far as social policy is concerned.

These problems lie beyond the complacent pale of Lowrance's account. His is nonetheless a useful survey for the scientist or engineer who is interested in, but has never thought about, the rational approach to peril.

KAI N. LEE
Institute for Environmental Studies and
Department of Political Science,
University of Washington, Seattle

The Endocrine System

Trends in Comparative Endocrinology. Papers from a symposium, Kenya, June 1974. E. J. W. BARRINGTON, Ed. American Society of Zoologists, Thousand Oaks, Calif., 1975. vi, 270 pp., illus. $12. *American Zoologist* Supplement 1975.

Endocrinology is innately an integrative branch of science, and this collection of papers deals with a wide variety of functions in a wide variety of organisms. There are few zoologists who will not find information pertinent to their specialties in these papers, and comparative endocrinologists will find recent information on a generous number of the subjects that constitute their discipline. The few areas that have been neglected, such as the hormonal control of hydromineral functions and calcium metabo-