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ABSTRACT

A selection of concepts related to the environment and of particular interest to science teachers are presented in this publication. Statements are brief, for the purpose is more to indicate the major ideas to be considered in relation to the environment than to develop any one of the themes. Those selected are basic to an understanding of the environment and relationships within it. Concepts are offered under headings entitled: Defining the Environment, The Commons and Free Goods, Environmental Problems are Systemic in Nature, The Values of Ecological Diversity, Adaptation and Evolution, Population Growth - Threat to the Future, Matter is Conserved, Energy Cycles, Pollution - Nature Overburdened, New Views of GNP and Economics, and Freedom Thrives in a Varied Environment. (BL)

VITAL VIEWS OF THE ENVIRONMENT

NATIONAL SCIENCE TEACHERS ASSOCIATION
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VITAL VIEWS OF THE ENVIRONMENT

Contents

Foreword

In view of the millions of words that have been written and the hundreds of speeches spoken about the environment in the past year, it seems worthwhile to select and restate a few of the *concepts* that are of particular interest to science teachers. The concepts are presented here as briefly as possible since the purpose of this publication is more to indicate the *major ideas* to be considered in relation to the environment than to develop any one of the themes. From these concepts, education programs can be built, activities can be planned, and an infinite number of subsidiary and related concepts can be developed. The selected concepts are basic to an understanding of the environment and relationships within it. They also seem to be those for which science instruction at all levels can contribute of knowledge as a basis for recognizing alternative courses of action and for taking action. Certainly the involvement of social studies, economics, and engineering must be assumed, and so far as possible interdisciplinary or multidisciplinary thinking should be fostered.

For the most part the statements presented here have been made during the past year in conferences and in the press. The Association is grateful for the generous permission of the original authors and publishers for permission to include these excerpts in this collection of vital views of the environment.

Mary E. Hawkins
Associate Executive Secretary
National Science Teachers Association

Defining the Environment

Environment—Totality of Action and Interaction

FREDERICK E. SMITH
Professor of Resources and Ecology, Harvard University

Environment is a term used many ways with many definitions. Biologically, it is defined only in relation to an organism: it is the sum of everything that influences and interacts with the organism. The environment is imaginary unless it is occupied by an organism, and it is different for each species to the extent that each species differs from others in its activities. These same processes that define environment also bind the organism and the environment together. More than that, through many cause-and-effect processes between them, the two become inverse images of each other.

The human environment is an immense complex of natural elements, man-made structures, institutions, societies, and other people. As with other organisms man is a reflection of his environment, and the human environment is a reflection of man. This leads to the observation that environmental quality and human welfare are not two independent evaluations. They are two views of the same system of interactions. It is not possible for one to remain good while the other is bad. If the entire human environment shows an overall deterioration, human welfare must also deteriorate.

Under this broad definition of environment all of the ills of man emerge as environmental problems. In this country the major problems associated with poverty, prejudice, public education, health services, militarism, inner cities, and pollution all qualify as environmental crises. On a global basis the problems of population, food, and war can be added. These are different kinds of problems involving different disciplines, yet they have strong interactions and many elements in common. Like every other species, man has but one environment.

A large part of this environment is natural: the systems of air, water, land, and life that maintain a habitable planet and provide us many resources. They also produce earthquakes, storms, drought, and pestilence. Man has understandably held conflicting attitudes toward nature, simultaneously aggressive and sentimental. Now that we have conquered most of nature we hear much on the need for peace. It is, however, our persisting sentimental attitudes that may prove our undoing.

Our ancestors lived in a vast, seemingly endless system of nature. No matter what man did, the natural patterns of always changing, always being the same, continued. The clearing of land, building of houses, and dumping of refuse had no apparent effect on nature as a whole. She accepted these disturbances without being changed, and without changing what she offered man. These relationships developed deep-rooted attitudes that are epitomized in our concept of Mother Nature. She is sensitive, efficient, purposeful, and powerful. She takes care of the world, keeping it as it is.

[However] Nature is no longer so vast. . . . The levels of temperature, rainfall, oxygen, and carbon dioxide that emerge from [the large scale systems of the planet] are themselves products of the environment, not [products] of previously determined standards or goals.

This absence of "goal" in the world systems is what makes the concept of Mother Nature dangerous. In the final analysis nothing is guiding the ship. We have already produced effects great enough on a global scale to suggest that we should be prepared to manage the whole earth. Our ability to do so will depend on achievements in the science of natural systems.

Frederick E. Smith, "Scientific Problems and Progress in Solving the Environmental Crisis," speech at a conference: Environment, The Quest for Quality, Washington, D.C., February 19, 1970. Cosponsored by the Public Affairs Council and the International Biological Program, National Academy of Sciences.

The Ecosystem

NATIONAL ACADEMY OF SCIENCES

The environment as a whole includes both biological and nonliving processes. Their interactions in given regions produce complex ecosystems, which in turn may interact in larger systems producing on the largest scale the earth's biosphere, the total system in which organisms participate. The ecosystem is the smallest unit in which environmental management can be applied if problems are to be solved rather than moved.

Man's Survival in a Changing World Number 2, United States Participation in the International Biological Program, National Academy of Sciences, Washington, D.C. 1970.

The Commons and Free Goods

The Tragedy of the Commons

GARRETT HARDIN
Professor of Biology, University of California, Santa Barbara

The tragedy of the commons develops in this way. Picture a pasture open to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons. Such an arrangement may work reasonably satisfactorily for centuries because tribal wars, poaching, and disease keep the numbers of both man and beast well below the carrying capacity of the land. Finally, however, comes the day of reckoning, that is, the day when the long-desired goal of social stability becomes a reality. At this point, the inherent logic of the commons remorselessly generates tragedy.

As a rational being, each herdsman seeks to maximize his gain. Explicitly or implicitly, more or less consciously, he asks, "What is the utility *to me* of adding one more animal to my herd?" This utility has one negative and one positive component.

1. The positive component is a function of the increment of one animal. Since the herdsman receives all the proceeds from the sale of the additional animal, the positive utility is nearly +1.

2. The negative component is a function of the additional overgrazing created by one more animal. Since, however, the effects of overgrazing are shared by all the herdsmen, the negative utility for any particular decision-making herdsman is only a fraction of -1.

Adding together the component partial utilities, the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another; and another. . . . But this is the conclusion reached by each and every rational herdsman sharing a commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit—in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all.

Pollution

In a reverse way, the tragedy of the commons reappears in problems of pollution. Here it is not a question of taking something out of the commons, but of putting something in—sewage, or chemical, radioactive, and heat wastes into water; noxious and dangerous fumes into the air; and distracting and unpleasant advertising signs into the line of sight. The calculations of utility are much the same as before. The rational man finds that his share of the cost of the wastes he discharges into the commons is less than the costs of purifying his wastes before releasing them.

The tragedy of the commons as a food basket is averted by private property, or something formally like it. But the air and waters surrounding us cannot readily be fenced, and so the tragedy of the commons as a cesspool must be prevented by different means, by coercive laws or taxing devices that make it cheaper for the polluter to treat his pollutants than to discharge them untreated.

Recognition of Necessity

. . .the commons, if justifiable at all, is justifiable only under conditions of low-population density. As the human population has increased, the commons has had to be abandoned in one aspect after another. . . .The most important aspect of necessity that we must now recognize is the necessity of abandoning the commons in breeding. No technical solution can rescue us from the misery of overpopulation. Freedom to breed will bring ruin to all. . . .

The only way we can preserve and nurture other and more precious freedoms is by relinquishing the freedom to breed, and that very soon.

Garrett Hardin, "The Tragedy of the Commons," *Science*, Volume 162, December 13, 1968, pp. 1243-1248.

Also reprinted in *Population, Evolution, and Birth Control*, Second Edition, 1969, edited by Garrett Hardin, W.H. Freeman & Co., San Francisco.

And in *The Environmental Handbook*, 1970, edited by Garrett DeBell. Ballantine Books, New York.

Environmental Problems Are Systemic in Nature

Systems and Their Functions

MICHAEL F. BREWER
Vice President, Resources for the Future, Washington, D.C.

Environmental problems are systemic in nature—they cannot be adequately described until the boundaries of these systems and their component elements and processes are identified. This suggests that students be sensitized to what systems are—what are their functions, what gives them cohesion, and what are their critical parameters? Exposure to techniques of measurement and empirical analysis are needed if students are to cope effectively with the systemic feature of environmental problems. Energy-balance and materials-balance processes often can be discerned by following energy or material through its conversion and transformation within the system.

Change or improvement in environmental conditions usually requires modification of basic processes within the system rather than one-time remedial measures. However, often these changes in the basic processes of environmental systems involve changing patterns of human behavior through the use of incentives, institutional innovations, and public policies. Sensitivity to differences among behavior patterns and careful observation of their results in terms of the community at large would enable students to critically assess the environmental consequences of contemporary policies, life styles, etc. Analogies with animal behavior would enable this theme to be developed within the life sciences as well as the social sciences.

Michael F. Brewer, "Priorities and Commitments for Environmental Education," speech at a workshop: Environmental Education for Everyone, presented by the National Science Teachers Association, Cincinnati, Ohio, March 12, 1970.

Natural Systems

FREDERICK E. SMITH
Professor of Resources and Ecology, Harvard University

. . .natural systems are scientific nightmares of complexity, redundancy, and loose organization. Any event in nature has the potential of eliciting reaction from a very large number of subsystems. Some of these are regulatory in the sense that they tend to counteract the event, others are not. The number of components involved in a subsystem varies from two to thousands, and these change in time as components come and go. The environmental space involved can be microscopic or global. The response times range from fractions of seconds to centuries. Subsystems overlap broadly with others, and are nested entirely within still others. Finally, at one level of detail or another no two organisms, rocks, streams, mountains, oceans, storms, clouds, or snowflakes are identical.

The hierarchies of subsystems interlock enough so that the whole does hang together. Its vast size and complexity easily produce the impression of varying endlessly within the larger context of never changing at all. The impacts of early man would be very difficult to recognize in the general confusion of activity. We arose, of course, as one more among several million kinds of organisms, each enmeshed weakly but multidimensionally within the web of life. Primitive man had no need to doubt the permanence of his environment, or to be responsible for his actions.

Nature is no longer so vast. We have changed much of the planet's vegetation, reshaped the landscape, altered the course of rivers, and populated the globe. As our power grew, we moved steadily against nature, overpowering one subsystem after another, and replacing natural systems with those of our own design. Much of our environment is man-made, and most of the rest is man-dominated.

Our efforts are still small on a global scale. We have never attempted to change the large-scale systems of the planet. These systems of climate and life that keep the planet habitable seem entirely functional, and remain so without human management. So long as they continue to operate, won't they tend to keep the world the way it is?

These systems are not like the heating system of a house, with a furnace under thermostatic control. The levels of temperature, rainfall, oxygen, and carbon dioxide that emerge are themselves products of the environment, not previously determined standards or goals. Annual rainfall, for example, is determined by a combination of levels of solar energy, air transparency, surface reflection from the earth, free water surface, average residence time of water in the atmosphere, etc. As these levels change, rainfall is regulated to a different level. Furthermore, many of these influencing variables are themselves the summation of many small effects.

In this way, human activity can easily shift the balance of nature if his many small acts add up to be significant in the total. Already, we appear to have increased the average concentration of carbon dioxide in the atmosphere, reduced the transparency of the unclouded sky, and perhaps been responsible for a recent cooling of the earth. We have distributed many materials such as lead and DDT throughout the world. Unfortunately, we know too little about natural systems to predict the further consequences of these changes.

Frederick E. Smith, "Scientific Problems and Progress in Solving the Environmental Crisis," speech at a conference: Environment, The Quest for Quality, Washington, D.C., February 19, 1970. Cosponsored by the Public Affairs Council and the International Biological Program, National Academy of Sciences.

Disruption of Natural Cycles

PAUL B. SEARS
Professor of Conservation Emeritus, Yale University

Among natural resources there are three—air, water, and food—without which no animal, man included, can survive. As to them there is no choice; but whatever else becomes a resource, e.g. materials for tools, shelter, clothing, energy, amenities and luxuries, is a cultural matter. . . .Cultures may conserve resources or dissipate them. Of all resources air is the most uniformly distributed in quantity and quality. But not even air remains unaffected by human use. So far as the basic physiological resources, air, water, and soil (i.e., food) are concerned the most serious effect of human activity has been to disrupt the great natural cycles that regulate their quality and abundance.

And while the sun paints its energy with a broad brush, shifting its band of all the pigments in obedience to celestial geometry, the picture so created is modified by the irregular distribution of water and land, as well as the varying qualities and forms of the latter.

While stresses within our aging planet continue to reshape its surface, wind and water, powered by the sun, share the task. Yet cushioning the violence of these changes in no small measure is the life that has risen and flourished by virtue of a fraction of the same energy that produces them.

Uncounted forms of life have come and gone, giving rise to highly organized communities in water and on land. By no means changeless themselves, these communities are agents of constructive change, slowing the flux of endless physical forces. Stabilizing the surface, regulating the economy of water, purifying the air, and creating soil, they have not only maintained life but enhanced the capacity of the earth to sustain life.

. . .For most of the more than a million years of man's existence in substantially his present form his power to alter environment grew very slowly. Communities or other forms of life continued to maintain balance and heal the scars of fire and other human tools.

Little more than ten thousand years ago the invention of plant and animal industry so increased human leisure and numbers as to magnify man's impact on his environment. Natural communities with their stabilizing effect became his rival for space as his own numbers increased and became more concentrated. His ways of producing food and fiber, intensifying, more often than not reversed the conserving and constructive processes of nature. The rise and fall of human cultures is witness to the resulting decay in the power of environment to regenerate itself.

. . .Man has tapped vast reserves of energy built up during the geological past. Thus he has created a condition well known in physics—decreased freedom of the individual unit with increased numbers and energy within a finite space.

Paul B. Sears, "The Earth's Natural Resources," pp. 12 and 13. In Huey D. Johnson, Editor, *No Deposit–No Return*, Addision-Wesley, Reading, Massachusetts, 1970. Copyright Addison-Wesley.

Also appeared in the Background Book for U.S. National Commission for UNESCO conference: Man and His Environment. . A View Toward Survival, San Francisco, November 23-25, 1969.

Beyond the Carrying Capacity

JOHN H. THOMAS
Department of Biological Sciences, Stanford University

. . .there is no such thing as a static system.

. . .when we change something in one part of our surroundings, it will affect the environment in some way; the greater the disturbance to a particular part of our surroundings the more widespread those effects are apt to be. If we for instance cut down one tree on a slope, there will be some local rearrangements of plants and animals for a while, but this will not spread much beyond the confines of where that tree was cut. If on the other hand we cut down a whole forest on a hillside, . . .we are going to not only possibly prevent that forest from regenerating, we are undoubtedly going to have increased erosion and runoff, as well as changing the weather pattern slightly, especially in regard to winds.

. . .every system has a buffering capacity or a carrying capacity, but this carrying capacity like the world itself is not infinite. We tend to think that we can dump things into the ocean as though the ocean were infinite but indeed it isn't. The air is finite also. Looking at pollution from this point of view, we see that we are simply exceeding the carrying capacity of some parts of our surroundings. The carrying capacity also applies of course to the population size of any organism. In any particular situation there is a carrying capacity or a buffering capacity for population size.

John H. Thomas, "Ecological Principles As a Part of General Education," speech to Environmental Science Conference for State Supervisors of Science, Portland State University, Portland, Oregon, May 2, 1970. (Conference Report pages 61, 62)

The Values of Ecological Diversity

The Importance of Maintaining Ecological Diversity

RAYMOND F. DASMANN
Director, International Programs
The Conservation Foundation, Washington, D.C.

Perhaps the most valuable quality that remains in the human environment is the quality of diversity, the knowledge that one can leave the place where he happens to be and find some other place that is different.

. . .We still have diversity, in peoples, places and in the natural world. The value of such diversity is immeasurable. The existence of places and people that are different gives to any individual that needs it the opportunity for a new start; it gives to others the chance to see their normal existence in new perspective and allows them to correct some of its inadequacies; it gives an opportunity for recreation, in the sense of re-creation, a chance to renew and reshape one's existence.

. . .The world in which man developed and spent most of his history was a world of incredible biotic diversity developed in response to the existence of geological and climatic diversity. It permitted not only the survival of man, but also the evolution of all the different kinds of people and different ways of life that characterized the world up to the present century. Man's survival depended in turn upon his own cultural diversity. If any particular human group happened to follow a course leading to disaster, as many did, there remained other groups in other places, living in different ways.

Because life in general is favored by climates that are not marked by extremes of temperature or drought . . . The greatest biotic diversity therefore is in the tropics, the least diverse biological communities are in the deserts and the colder areas of the earth.

This diversity has always favored man's survival, but man has progressed by simplifying the complex. . . .By such simplification, mankind channeled the productive forces of nature into pathways of his own choosing.

Initially this process was benign. A cornfield added diversity to the prairie region, a patch of sugar cane subtracted nothing from the diversity of the rainforest. But then human numbers increased, and there were cornfields everywhere and no prairie; sugar cane, coffee or bananas but little rain forest. With the new power of our technology we are eliminating diversity wherever we can. With the new pressures of population we are demanding that more and more of the energy reaching the earth in sunlight and the chemicals of the world's soils be channeled into pathways of our own choosing. We are reaching the end of the line.

. . .In simplifying the complex systems of nature we set in motion all of the forces of instability, fragility, and erratic fluctuations that characterize the simple ecological systems of the earth.

. . .As we simplify, reduce, or eliminate natural diversity, we reduce our chances for survival.

We are hurtling through the universe on our little spaceship planet. We know it is a marvelously complex device, but we are not sure how it operates. We nevertheless persist in breaking up its mechanisms and throwing away various, perhaps essential, parts.

Raymond F. Dasmann, "Ecological Diversity," pp. 108-111. In Huey D. Johnson, Editor, *No Deposit—No Return,* Addison-Wesley, Reading, Massachusetts, 1970. Copyright, Addison-Wesley.

Also appeared in the Background Book for the U.S. National Commission for UNESCO conference: Man and His Environment . . A View Toward Survival, San Francisco, November 23-25, 1969.

Also published in *The Science Teacher,* April 1970.

Stability and Diversity

COUNCIL ON ENVIRONMENTAL QUALITY

The stability of a particular ecosystem depends on its diversity. The more interdependencies in an ecosystem, the greater the chances that it will be able to compensate for changes imposed on it. . . .The least stable systems are the single crops—called monocultures—created by man. A cornfield or lawn has little natural stability. If they are not constantly and carefully cultivated, they will not remain cornfields or lawns but will soon be overgrown with a wide variety of hardier plants constituting a more stable ecosystem.

The chemical elements that make up living systems also depend on complex, diverse sources to prevent cyclic shortages or over-supply.

The oxygen cycle, which is crucial to survival, depends upon a vast variety of green plants, notably plankton in the ocean. Similar diversity is essential for the continued functioning of the cycle by which atmospheric nitrogen is made available to allow life to exist. The cycle depends on a wide variety of organisms, including soil bacteria and fungi, which are often destroyed by persistent pesticides in the soil.

Environmental Quality, The First Annual Report of the Council on Environmental Quality, p. 8, transmitted to the Congress, August 1970, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

Man Is a Poor Dominant

ROY A. RAPPAPORT
Associate Professor of Anthropology, The University of Michigan

. . .whatever else he may be, man is an animal. As such he is bound indissolubly to his environment. He has the same needs as other animals, and his populations are limited by similar factors.

Species and societies die of that which made them flourish. The very specializations that at one time have contributed to the survival of many species have led eventually to their extinction. And so it is with civilizations. . .

Man's purposefulness, which has been highly adaptive under certain circumstances, may eventually lead to his downfall. . . .In cultivating, man becomes an ecological dominant; the species which sets the conditions that encourage or discourage the presence of other species in an ecosystem. To cultivate, man replaces stable and mature associations of plants and animals (known as climax communities) with associations of his own devising. Man-dominated ecosystems, anthropocentric ecosystems, are composed of species selected by man for inclusion according to criteria of his own self-interest and are arranged by him into a limited number of short food chains, for all of which man himself is supposed to be the terminus.

Anthropocentric communities are likely to be both less stable and less productive than were the climax communities they replace—and are likely to include fewer species. The relatively degraded nature of these anthropocentric communities is in part a function of their simplicity, in part a function of their constituents. As a rule of thumb, the more species present in a community, the greater its productivity (that is, the greater amount of living tissue produced per unit area per unit time). Moreover, the species present in the climax community are present because they are adapted to their surroundings. In contrast, many of the species included in anthropocentric communities are exotics, introduced by man merely because they yield materials useful to him, and only poorly adapted to the habitats into which they have been introduced. These exotic species need constant protection. Many cannot even reproduce themselves very well without human intervention.

. . . Man's advances have been won at the expense of introducing instability into the systems in which he participates. Moreover, he has taken upon himself the burden of maintaining equilibrium in the unstable systems which he has devised. Far from freeing man from his environment, the assumption of the role of ecological dominant has made man the slave of his own living invention.

Man makes a poor dominant. . . . in nonanthropocentric ecosystems of any extent the dominants are always, or almost always, plants. Oak trees dominate some temperate forests; algae dominate reef-lagoon ecosystems. Plants, because they are nonpurposeful, are well suited to be dominants: Their mere existence fulfills the role, and the conditions which they set for other species therefore tend to be stable. Men, on the other hand, must act to maintain their dominance, and action is less reliable than mere existence. Furthermore, men are capable of making mistakes, and their goals are not always compatible with the requirements of the systems which they dominate. For these reasons, and because even the best laid plans of men are often disrupted, the conditions which they set are unstable.

Roy A. Rappaport, "Purpose, Property, and Environmental Disaster," pp. 5-9. In *Science Looks At Itself,* Charles Scribner's Sons, New York, 1970.

Adaptation and Evolution

Organisms Respond to Their Environment

NATIONAL ACADEMY OF SCIENCES

The scientific basis of environmental management combines a variety of basic and applied areas in several major components:

A. Changes in Plants and Animals
   1. Evolutionary Adaptations
   2. Physiological and Behavioral Adaptations
B. Changes in Relationships of Plants and Animals
   1. Interactions with the nonliving environment
   2. Interactions with other organisms
C. Structure and Function of Ecosystems

A major biological aspect of the environment concerns the changes that occur in plants and animals in response to variations in their surroundings. These areas parallel those in human adaptability. Evolution has produced, for each species, a genetic composition that sets limits to its environmental responses. Within these constraints, physiological and behavioral mechanisms define an array of responses that can be used to cope with environmental change. Both areas, applied to several thousand species in an ecosystem or the several million in the biosphere, will make use of enormous amounts of information already on file, as well as requiring much more research as this information is integrated and the underlying processes become better understood.

A second major biological aspect of the environment concerns changes that occur in relationships between organisms or between organisms and the nonliving environment in response to environmental change. The presence or absence of species in a region is largely determined by such relationships, and for each species present, its many relationships are continually shifting as the composition of the environment changes. The effects of changes imposed by man could be predictable if much more were known about the mechanisms influencing such relationships. Better control of particular species is certain to result. Here the role of the meteorologist, soil scientist and chemist are as significant as those of the ecologist, behaviorist and molecular geneticist.

Man's Survival in a Changing World Number 2, United States Participation in the International Biological Program, National Academy of Sciences, Washington, D.C. 1970, pp. 14-15.

Man and Biotic Communities

FRANK FRASER DARLING AND RAYMOND F. DASMANN
Vice President and Director of International Programs, respectively
The Conservation Foundation, Washington, D.C.

Man has been a part of ecosystems throughout his time on earth, functioning originally as one of many consumer organisms. During human evolution, however, man has moved from being a simple component of an ecosystem to becoming a dominant force in the system. Today, with his new technology and his massive urban concentrations, he has assumed a new role on the planet, tying all ecosystems together in a higher level of organization comprising the entire biosphere itself. To understand this new global organization it is worth while to consider comparisons between human societies and biotic communities and the roles which they play within the broader natural systems of which both form a part.

Frank Fraser Darling and Raymond F. Dasmann, "The Ecosystem View of Human Society," *Impact of Science on Society*, Volume XIX, Number 2, April-June 1969, p. 110. Copyright, UNESCO.

Population Growth – Threat to the Future

The Price of Expansion

PHILIP HANDLER
President, National Academy of Sciences, Washington, D.C.

The greatest threat to the future of the human race is man's own procreation. Hunger, pollution, crime, despoliation of the natural beauty of the planet, irreversible extermination of countless species of plants and animals, overlarge, dirty, overcrowded cities with their paradoxical loneliness, threatened exhaustion of our limited natural resources, and the social unrest which leads to internal upheaval and international conflict—all these and more, derive from the unbridled growth of human population.

It is a presumably unalterable fact that in thirty years, barring worldwide catastrophe, our Earth will be required to support six to seven billion humans. . . . The impact of this adjustment on the quality of our way of life is not pleasant to contemplate.

. . . much attention is focused on the extraordinary rates of population growth in some of the less developed nations. But, for us, the important concept is that the price of population expansion in our developed nation is far greater than it is in more primitive societies. Instead of a loincloth and a hut, each of us acquires, by birth, the privilege of about 800 sq. ft. of private space, a school desk, a hospital bed, 20 ft. of steel on the highway, parking space wherever we go and all the steak we can eat.

. . . Man is the most adaptable of animals, and perhaps he can even adjust biologically to some of the damaging consequences of this experience. But certainly the comforts, conveniences and high culture of contemporary civilization will be denied to our posterity unless the classic bases of economic growth are altered.

Whereas modern technology finds itself the scapegoat for the declining quality of our environment, the basic problems are overpopulation and increasing human congestion. The artifacts of man are instruments of environmental destruction only where they are utilized carelessly and in massive proportions. Thus, the ecological consequences of man's procreation become the major issue before us.

Philip Handler, "Opening Remarks," at a conference: Environment—The Quest for Quality, Washington, D.C., February 18, 1970. Cosponsored by the Public Affairs Council and the International Biological Program of the National Academy of Sciences.

Goal for a Stabilized Population

PAUL R. EHRLICH
Professor of Biology, Stanford University

The facts of human population growth are simple. The people of the earth make up a closed population, one to which there is no immigration and from which there is no emigration. It can be readily shown that the earth's human population will remain essentially closed—that no substantial movement of people to other planets is likely and that no substantial movement of people to other planets is likely and that no substantial movement to other solar systems is possible. Now, a closed population will grow if the birth rate exceeds the death rate, and will shrink in size if the death rate is greater than the birth rate. Over the past half-century or so a massive increase in man's understanding and utilization of death control has resulted in a rapid rise in the rate of growth of the human population. . . .Sooner or later the growth of the human population must stop.

I think that 50 million people might be an optimum number to live comfortably in the United States. Such a number is probably enough to maintain our highly technological society. It is also a small enough number that, when properly distributed and accommodated, it should be possible for individuals to find as much solitude and breathing space as they desire. With a population stabilized at such a level we could concentrate on improving the quality of human life at home and abroad.

Paul R. Ehrlich, "Population, Food, and Environment: Is the Battle Lost?" In *The Texas Quarterly*, Volume XI, Number Two, Summer 1968, pp. 43-54. Reprinted with permission of Paul R. Ehrlich and the Editors of *The Texas Quarterly*.

Matter Is Conserved

Change, not Creation

JOHN H. THOMAS
Department of Biological Science, Stanford University

We cannot create anything and we cannot destroy anything. All we can do is change things. . . .In the days when we burned things, we weren't really getting rid of anything. We were simply changing it to carbon dioxide, water, ash and so forth. . . .we cannot create anything and we cannot destroy anything. There is nothing that we can flush down the sewer as it were. The oceans, lakes, streams and rivers are not infinite sumps into which we can put things, whether pesticides, fertilizers or heat.

John H. Thomas, "Ecological Principles As a Part of General Education," speech to Environmental Science Conference for State Supervisors of Science, Portland State University, Portland, Oregon, May 2, 1970. (Conference Report, page 61)

Energy Cycles

Food Production

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Food production depends on the process of photosynthesis in green plants. Basically, it is concerned with the conversion of the sun's energy into chemical energy, forming sugars, starches and cellulose. The land with growing green plants plus sunlight constitutes the greatest chemical manufacturing plant in the world. The process involves CO_2 and water plus sunlight and chlorophyll of the plant, producing carbohydrates and releasing oxygen to the atmosphere. The process uses carbon dioxide from the atmosphere. When the carbohydrates are used by man or other living animals, oxygen is used and the vast products of water and CO_2 are returned to the environment. A complete cycle: CO_2 and water with the driving force of the sun's energy, carbohydrates are formed and O_2 released to the atmosphere; the carbohydrates are digested and metabolized by using O_2, giving encrgy, and producing CO_2 and water. This simple photosynthetic process plus nitrogen is the source of all of our food. It takes green plants, green fields and sunlight to produce.

Synthetic foods are also carbon-carbon and carbon-nitrogen compounds which are primarily made by living plants or derived from fossil fuels, such as oil deposits. These are limited and when consumed, use O_2 and produce CO_2.

Karl Dittmer, "Environmental Studies As a Basis for Science Education," speech to Environmental Science Conference for State Supervisors of Science, Portland State University, Portland, Oregon, May 2, 1970.

Energy in the Ecosystem

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To obtain a full picture of the nature of an ecosystem it is necessary to consider how it functions. Energy enters it in the form of solar radiation, the sun's energy being captured by the *producer organisms* of the system, usually the green plants, which store it as chemical (or food) energy. This food energy is then available to the *consumer organisms* including the animals that feed on the green plants. Food energy may pass in turn through more than one level of consumers, through herbivores that eat plants, through carnivores that eat herbivores, through larger carnivores that eat smaller carnivores along a series known as a "food chain." Eventually, because energy cannot be transferred from one body to another without loss in the form of heat, all energy is lost to the system. The ecosystem, however, acts as a storehouse of energy, held in animal and plant bodies, and acts to arrest the process of degradation of energy (increase in entropy) that otherwise would go unchecked in a system that was devoid of life.

Energy stored by ecosystems powers most of our human activity today, since it is used by man not only in the form of food for himself and his domestic animals, but also in the form of fossil fuels which power most of his industrial activities. Only the relatively small percentage of energy in the human economy represented by hydroelectric power, solar power and nuclear power is derived from non-organic sources.

Chemical raw materials are present in the soil, air, and water components of the ecosystem. These enter first the producers of green plants, and like energy move in food chains through various levels of consumers. Unlike energy, however, they are not lost to the system. When a producer or consumer dies it is broken down by the organisms of decay, the *reducer organisms*. These return chemicals to soil, water, or air, from which they become available once more to circulate through other food chains. Chemicals in an ecosystem thus move continually through circular pathways—cycles—whereas energy follows a one-way route into and out of the system.

Frank Fraser Darling and Raymond F. Dasmann, "The Ecosystem View of Human Society," *Impact of Science on Society*, Volume XIX, Number 2, April-June 1969, p. 110. Copyright, UNESCO.

Pollution – Nature Overburdened

Natural Processes

COUNCIL ON ENVIRONMENTAL QUALITY

Pollution . . . is only one facet of the many-sided environmental problem. It is a highly visible, sometimes dangerous sign of environmental deterioration. Pollution occurs when materials accumulate where they are not wanted. Overburdened natural processes cannot quickly adjust to the heavy load of materials which man, or sometimes nature, adds to them. Pollution threatens natural systems, human health, and esthetic sensibilities.

Historically, man has assumed that the land, water, and air around him would absorb his waste products. The ocean, the atmosphere, and even the earth were viewed as receptacles of infinite capacity. It is clear now that man may be exceeding nature's capacity to assimilate his wastes.

Most pollutants eventually decompose and diffuse throughout the environment. When organic substances are discarded, they are attacked by bacteria and decompose through oxidation. They simply rot. However, some synthetic products of our advanced technology resist natural decomposition. Plastics, some cans and bottles, and various persistent pesticides fall into this category. Many of these materials are toxic, posing a serious health danger.

Some pollutants, which may be thinly spread throughout the environment, tend to reconcentrate in natural food chains.

Environmental Quality, The First Annual Report of the Council on Environmental Quality, transmitted to the Congress August 1970, pp. 8 and 9. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

The Atmosphere

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At this point, it is convenient to summarize the principal air pollutants and their effects. No more succinct summary is available than that prepared by the United States Department of Health, Education, and Welfare Publication 1555. That summary follows:

"At levels frequently found in heavy traffic, carbon monoxide produces headache, loss of visual acuity, and decreased muscular coordination.

"Sulfur oxides, found wherever coal and oil are the common fuels, corrode metal and stone, and at concentrations frequently found in our larger cities reduce visibility, injure vegetation, and contribute to the incidence of respiratory disease and premature death.

"Beside their contribution to photochemical smog, described below, nitrogen oxides are responsible for the whiskey brown haze that not only destroys the view in some of our cities, but endangers the takeoff and landing of planes. At concentrations higher than those usually experienced, these oxides can interfere with respiratory function and, it is suspected, contribute to respiratory disease. They are formed in the combustion of all types of fuels.

"Hydrocarbons are a very large class of chemicals some of which, in particle form, have produced cancer in laboratory animals, and others of which, discharged chiefly by the automobile, play a major role in the formation of photochemical smog.

"Photochemical smog is a complex mixture of gases and particles manufactured by sunlight out of the raw materials—nitrogen oxides and hydrocarbons—discharged to the atmosphere chiefly by the automobile. Smog, whose effects have been observed in every region of the United States, can severely damage crops and trees, deteriorate rubber and other materials, reduce visibility, cause the eyes to smart and the throat to sting, and, it is thought, reduce resistance to respiratory disease.

"Particulate matter not only soils our clothes, shows up on our window sills, and scatters light to blur the image of what we see, it acts as a catalyst in the formation of other pollutants, it contributes to the corrosion of metals, and in proper particle size can carry into our lungs irritant gases which might otherwise have been harmlessly dissipated in the upper respiratory tract. Some particulates contain poisons whose effects on man are gradual, often the result of the accumulation of years."

Thomas F. Malone, "The Atmosphere," pp. 166-167. In Huey D. Johnson, Editor, *No Deposit—No Return*, 1970, Addison-Wesley, Reading, Massachusetts. Copyright, Addison-Wesley.

Also appeared in the Background Book, for U.S. National Commission for UNESCO conference: Man and His Environment . . A View Toward Survival, San Francisco, November 23-25, 1969.

The Waste Problem

SANFORD ROSE
Fortune Magazine

Those who imagine that pollution can be totally eliminated fail to grasp the dimensions of the waste problem. As some economists have recently suggested, it might be well to dispose of the expression "final consumption." People and businesses do not consume goods; they extract utilities from goods before discarding them. Such things as gems, works of art, heirlooms, and monuments might be thought of as being in some sense, finally consumed. But all other goods—durables, nondurables, and byproducts—are eventually either discharged to the environment or cycled back into the production process. About 10 to 15 percent of total output, however, is temporarily accumulated in the form of personal possessions, capital goods, additions to inventory, etc. If society were to stop accumulating for a while, observes economist Allen V. Kneese of Resources for the Future, the weight of residuals discharged into the natural environment would equal the weight of raw materials used plus the weight of the oxygen absorbed during production. In other words, waste disposal would be an even larger operation than basic material production.

Though waste and pollution problems are too big to be eliminated, they can be ameliorated by producing fewer goods (or a different mix of goods), by recycling more of what has been produced, or by changing the form of wastes or the manner of their disposal. These alternatives are subject to economic evaluation. In principle, pollution is at an optimal level when the cost of additional amelioration would exceed the benefits. If by spending a dollar an upstream mill can save downstream water users at least a dollar, it should do so—from society's point of view.

Sanford Rose, "The Economics of Environmental Quality," *Fortune*, Volume 81, Number 2, February 1970, p. 120. Copyright, *Fortune*.

Managing Residuals

RESOURCES FOR THE FUTURE

Pollution of water, air, and land are not separate problems but rather aspects of an overall problem of managing residuals. . . . all, or nearly all, forms of environmental pollution are parts of one large problem: how to manage the residuals generated by the production and consumption activities of the U.S. population.

The overall problem is something like an almost-filled toy balloon: if you punch it at one point, it fills our somewhere else.

. . .if the people of an area want to maintain, or if possible improve, the quality of their entire physical environment, they will have to consider all kinds of residuals together and develop the processes and procedures that will result in the smallest overall damage at costs that can be borne.

What the country faces, then, is a tremendously broad problem of how to deal simultaneously with the waste products of industry, commerce, agriculture, and domestic living.

. . .The engendering of wastes is the reverse side of the medal of economic growth.

Full understanding of the size of the residuals problem is often obscured by the wide use of the term "final consumption." In standard economic theory, which is concerned with services that yield certain utilities and not with physical substances, the phrase has a clear meaning. In broader context it can be very misleading. Yet many people, including some economists, persist in referring to the final consumption of goods as if such objects as fuels, materials for fabrication, and all kinds of finished products simply disappear into the void when they have served their buyer's purpose. They do not. Even treatment of wastes does not reduce the amount of residuals; it merely changes their form and may even add to the total quantity of residuals. As long as air, water, and unused landscape were almost literally "free goods" for receiving wastes without noticeable bad effects, total discharge of wastes, and the persistence of many of them, made little difference to most people. Today it does make a difference.

The exact size and composition of the residuals load under current practices is one of the many facts still to be determined. To get some idea of its outside limits one only need recall the law of the conservation of matter. Sooner or later the amount of residuals thrown back upon the natural environment must equal the amount of fuels, food, and other raw materials that enter the processing and production system—more than equal, in fact, for oxygen is often picked up from the atmosphere in the making of many finished products.

A part of these totals—perhaps 10 to 15 per cent in recent years—is added to stocks or capital equipment and thus cannot yet be counted as residuals. Much of the remaining load can be assimilated without human intervention and with little or no difficulty or damage to the environment. In terms of weight, nearly half of the materials entering into production are discharged into the atmosphere as carbon and hydrogen, which for the most part end up as carbon dioxide or water after combining with the oxygen of the atmosphere. About 10 per cent of the carbon unites with oxygen to form carbon monoxide.

The formation of water, resulting mostly from the combustion of fossil fuels and animal respiration, is largely harmless, although in vaporizing it can have some bad effects. Carbon dioxide, at least in the short run, is also harmless. Most of it is absorbed by vegetation and by the oceans and other large bodies of water. In the long run, however, the effects may not be altogether innocuous.

With due allowance for the capacity of the environment to absorb the hydrogen and much of the carbon residues, there is a direct relationship between what goes into the modern economic machine and what comes out as the kind of waste that creates difficulties. The root problem, therefore, is how to cut down on materials imputs without reducing the human satisfactions that are the desired end products. One obvious course is to make production processes more efficient—more useful energy from a unit of oil, more metals from the same quantities of ore, more finished products from raw timber, more cans of tomatoes from a ton of raw tomatoes. A second is to recycle as many of the wastes as possible, substituting them for fresh materials that otherwise would have to be drawn upon. A third course is to make cars, building, machinery, and other durable goods last longer: to the extent this can be done the fewer new materials will be required to compensate for depreciation and sustain a desired rate of capital accumulation.

"Wastes Management and Environmental Quality." In Annual Report 1969, Resources for the Future, Washington, D.C., pp. 25, 27, 28, 29. (Chapter based on reports of work in progress by Allen V. Kneese, Blair T. Bower, and other RFF staff members)

New Views of GNP and Economics

Philosophical Readjustment

PHILIP HANDLER
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. . .it may well be that the social and economic philosophies of our industrial society, upon which the current affluence of Western civilization is based, may require substantial adjustment. The remarkable prosperity shared by Western civilization since World War II has been in no small measure the consequence of an economy of waste and inordinate resource exploitation.

Clearly, international prosperity cannot be based upon an untrammeled exploitation of our remaining scarce resources. Our small fraction of the world's population generates a huge share of the world's major environmental problems. Were the lesser developed countries even to begin to approach our living standards all of us would be in for a very bad time.

Philip Handler, "Opening Remarks," at a conference: Environment—The Quest for Quality, Washington, D.C., February 18, 1970. Cosponsored by the Public Affairs Council and the International Biological Program of the National Academy of Sciences.

The No-Growth Concept

JERRY MANDER
Freeman, Mander and Gossage, San Francisco, California

. . .there is only so much getting bigger possible.

That should have been evident, of course, the moment our astronauts flashed us pictures of the Earth and we noted it was round. The idea of an infinitely expanding Gross National Product on an isolated sphere, a finite system, an island in space, is complete nonsense, to put it as lightly as possible, or, to put it the way I personally perceive it, may be, together with population growth, the most dangerous tendency in the world today.

You simply may not have a continually expanding economy within a finite system: Earth. At least not if the economy is based upon anything approaching technological exploitation and production as we now know it. On a round ball, there is only so much of anything. Minerals. Food. Air. Water. Space. . .and things *they* need to stay in balance. An economy which feeds on itself can't keep on eating forever.

. . .I am not saying we should tear down factories, or that there should be no technology. Naturally. But I am saying there should probably be a lot less of it, and less people to be served by it of course, but most important, *less emphasis on increase, starting now.* Less emphasis on acquisition and material wealth as any measure of anything good.

Beginning now, national preparations toward a no-growth economy.

Jerry Mander, "Advertising: Affording the Message," pp. 208, 210. In Huey D. Johnson, Editor, *No Deposit–No Return*, 1970, Addison-Wesley, Reading, Massachusetts. Copyright, Addison-Wesley.

Also appeared in the Background Book for the U.S. National Commission for UNESCO conference: Man and His Environment . . A View Toward Survival, San Francisco, November 23-25, 1969.

Environmental Trade-offs, Taxes, Incentives

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Restoration of the environment will not occur in a crescendo of attention on "Earth Day," April 22. Nor will action, however concerted, bring it in a quantum jump on any other day we can foresee. It will happen bit by bit, reversing the gradual process of accretion by which the present state of deterioration came about. April 22 will have real meaning only if it begins transforming our laws and their enforcement, our system of taxes and incentives, and our whole educational process. Environmental concern must become an integral part of the ongoing functions of production and consumption. For so long as this concern remains only an adjunct to business as usual, whether by producers or consumers, industry or government, we will not get the result we seek.

Setting conditions for technology to do the most effective, efficient job possible in upgrading the environment involves two fundamental issues. First is a recognition by all concerned of the necessity for environmental trade-offs. Second, is a reasoned approach to the question, "how clean is clean?"

We need better information on long-term ecological effects of various environmental trade-offs. This, so we may assess risks and benefits of alternate technologies. Regulatory agencies share this need. Industry and government must provide sufficient funds to finance relevant scientific research. The public must be informed of at least the basic facts and their implications.

We need better information on what an informed public demands of, and for, the natural environment. . . . Not simply "how clean is clean" in terms of costs and benefits, but in terms of the benefits alone. Are standards set to make a given river's water drinkable? Or simply suited for recreation? Let us be sure that those who set standards know the answers to such questions, and act accordingly, and in unison, in dealing with industry.

Louis H. Roddis, Jr., "The Responsibility of Industry Toward the Environment," speech at a conference: Environment—The Quest for Quality, Washington, D.C., February 19, 1970. Cosponsored by the Public Affairs Council and the International Biological Program of the National Academy of Sciences.

Science of Social Design

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Many persons mistakenly assume that constraints on population and technological growth will lead the world into a period of stagnation and, eventually, of decadence. But I believe that a closed system is compatible with a continuous process of creative changes, and that changes within a closed system will offer intellectual challenges far more interesting than those associated with the kind of rampant economic growth that has characterized the nineteenth and twentieth centuries. We cannot have a scientific and technological renaissance, however, until we develop new conceptual ideas about design on a grand scale. A science of social design will certainly emerge if we abandon quantitative growth as a value for its own sake, and learn instead to use ecological constraints as creative stimuli for the management of human life on the spaceship Earth.

René Dubos, Introduction to *Science Looks At Itself*, 1970, Charles Scribner's Sons, New York, xvi.

Freedom Thrives in a Varied Environment

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The concept of freedom subsumes the idea that each man shall have freedom of choice: in diet, in dress, in faith, and *in habitat*. From this ideal follows the desirability of a spectrum of habitats from metropolitan complexes through isolated villages to wilderness.

[From this concept we formulate a new definition of conservation:]

Conservation is the maintenance of a varied environment offering maximum freedom of choice to mankind and to its individual members, in perpetuity.

Probably few students would deny the desirability of a maximally varied environment, once they comprehend its inseparability from the idea of freedom. . . .the pleas of conservationists and preservationists may often fall on deaf ears because of two major fallacies in their argument.

First, appeal is frequently made to the obvious desirability and inherent beauty of wild species, wild places, and pastoral-agricultural settings. [The populace may be unresponsive to this appeal, or it may be low on their list of priorities.] . . .Second, is the frequent opposition by the conservationist-preservationist to dams, highways, and tracts, *per se* and *in toto*. In the face of the steady one-way homogenizing of the environment, one can certainly sympathize with this view. A more widely acceptable argument, however, might be that development decisions should be based upon the principle of varied environment. For example, in California, a hundred carbon-copy canyons cut through the chaparral of the coastal ranges . . . In such a habitat, a few dammed canyons serve to increase the variety of the environment and thus extend the freedom of choice. Then, the water-ski crowd are not deprived of their rights any more than are the naturalists. . .

. . .students should come to appreciate the distinction between a few dammed canyons (which maximize choice) and a hundred dammed canyons (which eradicate choice). They should be able to distinguish also between the damming of a carbon-copy canyon and a unique one . . . the soundest principle which they can use to judge the worth of new projects is the principle of an optimally varied environment.

. . .from this point in time onward, freedom of choice will vary inversely with population. . . .population growth combined with material wealth brings a steady homogenizing of the environment, a reduction in the choices available, a limiting of human freedom.

. . .optimum freedom of choice will be possible only when we have a stabilized population.

R. Thomas Tanner, "Freedom and a Varied Environment", *The Science Teacher*, Volume 36, Number 4, April 1969, pp. 32-33.