

But, in trying to answer the question proposed by the chairman, I was merely pointing out that the International Biological Program does not separate itself from the problem of human welfare.

Mr. BROWN. I think your point is correct. I am merely making the point that you have certain preconceptions about the nature of human welfare which are not necessarily a part of any scientific program.

Dr. RAY. Definitely, I have preconceptions. I quite agree with you. I would like to think they are all right, but I am not sure they are not.

Mr. BROWN. You are getting into the field of politics this time.

Dr. RAY. Well, I think we all are. I just do not see—I will repeat, the International Biological Program as simply biological. It is much more than that. Put it the other way; if we did not have an International Biological Program, how else are we to solve the problems we know we must solve on a world basis, not a regional basis. We have to, in taking this little blue book and put it under the table, come up with a red book or pink book, but some book, that will enable us to have a program by which we can help to guide our own destinies—it is a question of how much destiny we have left.

Mr. BROWN. Well, in the physical sciences in general, we are trying to approach the problem of how man can live better on this earth by figuring out better ways to destroy man.

The point I am trying to make is that I probably agree with your normative biases.

But we have to do something to get these into the equation and get them accepted and not be ashamed of them, or else I don't think our scientific programs per se are necessarily going to do much for man, much as we would like to have them accomplish that.

Dr. RAY. Well, may I add one thing, Mr. Congressman. I think there is always a danger in the pursuit of any scientific endeavor that that scientific endeavor be directed toward use or nonuse. What good is it, is a very frequent question that is put to me particularly. I like to go swimming in the polar seas under ice, to look at seals. What good is that?

We all know the arguments that perhaps a lot of these things are not good or bad. But in the finding out about the total ecology of our environment, this must at least be useful.

Mr. BROWN. Well, you in your statement quoted from Mr. Ogburn's book, which I haven't read but I can imagine what it says. I think it assumes possibly a rather pessimistic outcome for these efforts to solve our problems. In the field of science in general, I think it is a mistake to assume that man is going to solve these problems one way or another, or that there is any good or bad because we don't have any guarantee, as is stated here, the earth will shrug it off in favor of a fresh start. I presume that means it will eliminate man and try some other species or activity or planet, or something.

Dr. RAY. I would not presume that this is guaranteed, but this is the whole area that we are really concerned about. Really, there comes as Fairfield Osborn said, a limit to the earth. Man is a biological organism. He has to live with his environment. So far in the course of human history I think we can fairly easily state that we have always had something else to go to, some other corner to turn to.

I would like to think that the International Biological Program in part, although I can't guarantee this, came about because there is a

realization abroad now that this limit is being reached esthetically spacewise, and as regards production of food.

Mr. DADDARIO. We can't eliminate the fact that the earth might some day just shrug its shoulders and destroy us all. It can do even this if we do the best possible job.

Dr. RAY. It can.

Mr. DADDARIO. But there also is the possibility if we don't recognize what we are doing, that we can create a chain of circumstances which we set about and by ourselves set an irreversible tide in motion which will destroy us. That is what we are talking about here.

Dr. RAY. This is a point. And particularly I like your idea, Mr. Chairman, of tying into our technological programs a fact-finding biological, physical subprogram. I think that we have already set in motion a couple of things which are extremely dangerous, of which the burning of fossil fuels is the most obvious one I can think of; its effect upon the oceans and—the effect of putting carbon dioxide, for instance. I think that these overall considerations are major ones, and again the major consideration of the International Biological Program. The earth is a unit, not politically unfortunately, but it certainly is a unit biologically.

Mr. DADDARIO. If we could understand some of these things better it probably could feed itself into political judgments in a better way than it does now.

One of the witnesses before us as an example told us about one area of our country where the virgin forests have been destroyed for the necessary purpose of getting open fields so we could grow oats and wheat to feed ourselves. But during a period of time when there has been intense heat in that area, it was the wheat and the oats which suffered and it was the natural grasses and trees in the area which were able to adapt themselves to these changes. I think we can read into that the importance of maintaining the natural processes on the surface of the earth. And if we understand it better, maybe we will do things in the right way.

Dr. RAY. Well, I think two points might be mentioned in this very respect, two very fundamental ecological considerations.

In the first place, in man's alteration of his environment, he has usually done two things: (1) he has brought in foreign species or exotics; and (2) he has simplified the environment. Where he had 100 species before, maybe now he has 10.

Now what these two things do usually is first, if a foreign species is brought in, usually the total biomass is reduced. The total productivity of the land may seem to be better in corn than it was in shrubbery and so forth, but it is really not. The biomass is reduced. This means that we are reaping a harvest, but we are not reaping as great a harvest.

Now, what about the variability of the harvest? In planting let's say elm trees all along our streets, rather than having an elm here, an oak here, and something else there, we have opened up a very simple problem in epidemiology. In simplifying the environment, therefore, in two respects, we have damaged it. We have come to know this lately.

But now let's go to the sea. We are starting to talk about fish farming. What are we going to do, wall off a bay and put in just mullet, as some people do, or milkfish, or are we going to maintain the almost

infinite variability of that estuary and possibly get 50 different species with a little more effort? It is not quite as economical. But how much more productivity? We don't know. Here is an ideal area for investigation.

Mr. DADDARIO. Mr. Brown.

Mr. BROWN. Mr. Chairman, I am being somewhat of a devil's advocate.

Mr. DADDARIO. You are doing a good job at it.

Dr. RAY. He sure is.

Mr. BROWN. Because I sense in the witness a nostalgia of the old days in which man and nature are in balance and everything right with the world. By pointing out from the standpoint of science that we could live in a completely artificial environment in which we synthesized our food, our shelter, destroyed all living objects and, as far as man is concerned, we might have a happy life. You could probably argue with that point. To determine that there is some natural balance as you seem to be hinting at is a highly philosophical question.

I am also bothered by the fact that the things you are pointing to as being wrong with our environment today is already exclusively the creation of science. The burning of fossil fuels, as an example, is a result of the tremendous technology created on the basis of the physical sciences.

Now what is science going to do? You are saying, I gather, to go back to some more natural state of mankind. I am asking you to consider what values you are using to set these goals so that we may weigh them in connection with other values in analyzing the situation.

Dr. RAY. I think we have one fundamental difference of opinion, perhaps, and that is science did not create these problems. Technology did. There is a vast difference between science and technology—the personnel who work in it, the training methods, and many other things.

Mr. BROWN. You are trying to do like the nuclear scientists. We created the bomb, but we are not responsible for its use, is that right?

Dr. RAY. No, I wouldn't go so far as to say that. I think all of us are united by the fact that we should have some responsibility as human beings. However, beyond that, as a scientist, the field of science is regulated by somewhat different rules in the field of technology. And I think the confusion between science and technology has been at least one of the stumbling blocks in solving problems. It is another thing we might think of tackling.

You do indeed detect a nostalgia. Not that all was ever right with the world, it seems to have changed too fast for that, but there are several biological things that appear to be pretty basic: variety, change. Human beings like to change things to suit their convenience and need and thence to standardize, to put walls around them, to get the status quo and keep it there. I think that the biology of change and standardization is subject to scientific enquiry; what kind of effect are we dealing with when we change the biota and change people in relationship to it? These are things that can be assessed biologically.

Most of the things that I happen to believe esthetically are my personal opinions. I would like to see the world with lots of trees around. However, I think biologically and scientifically we can actually get down to analyzing what the effect of these things are on the human being, in terms of productivity and in terms of human welfare. I don't see any question but that these biological principles can be investigated and then subsequently we can enlist the aid of the social sciences, the psychological sciences, to determine the effect and the implications of these things on human beings.

Now there have been researches conducted showing what crowding means to human beings, showing what noise means to human beings, showing what lack of trees means. These are in their infancy, but they are going to increase. So I don't think I am entirely dealing in esthetics. I have my preferences, it is true, and I would like to revert to a little more space for all of us, it is true. But I think these things can be backed up by research.

Mr. BROWN. Well, I don't like the way you are trying to weasel out of the responsibility of science for what has happened. In fact, some of the problems in science result from this same need of a human being to bring order out of chaos. The development of science into our vast proliferation of highly compartmentalized boxes is a result of this tendency on the part of human beings. It is this tendency which has resulted in science in general up to now. Maybe this program is going to reverse the not caring what happens to the human being but what happens to their little box.

Dr. RAY. I think you are entirely right in this. I think we actually have more common ground than would at first appear. But I don't want to put the blame on anyone right now. I would like to solve the problems that exist. It is as simple as that. If we can think of a better way to do it, that is fine.

Mr. DADDARIO. Don't programs such as the IGY and the IBP, however, develop a national attitude. They educate the scientific and technical community about its need to go further than it has in the past? It doesn't have the flexibility presently available as it has had as the country was growing and it needs to develop an ability to figure out the social consequences of its activities.

Dr. RAY. I think you are entirely right, on two levels. I believe that a program like this—as happened with the Antarctic program, which started with IGY and with which I have been associated for about 4 years—gets all sorts of scientists all worked up. People seem to push a little harder. And secondly, this has an effect on the general public, I believe. They become aware of the problems more than they would have otherwise. They become aware of what scientists are after, what the problems of applying science are. Overall I think it has a very great psychological impact, quite aside from its practical aspects: that of unification, rather than a series of disjointed happenings which don't get in the papers so well. Whoever heard of the "quiet sun" until the IQSY, International Quiet Sun Year. I personally never heard of a quiet sun or a noisy sun. I knew the sun was there and that was about it. As a scientist, I should have known something about it. Now I know something about it because it was broadcast. This is interesting and I think important.

Mr. DADDARIO. Well, Dr. Ray, I think you have been extremely helpful. I was pleased that we were able to have some of these discussions here this morning. It is going to make a very helpful addition to our testimony.

Mr. BROWN. You will edit them out of the final report, won't you?

Mr. DADDARIO. No.

I feel, Mr. Brown, that we ought to see to it that they remain in there. I think they are extremely important, and I don't look upon them as being argumentative at all. I don't think either you, or Dr. Ray, intended by any of your participation in it that you mean it to be, either.

Dr. RAY. No, sir.

Mr. DADDARIO. Dr. Ray, thanks ever so much.

Dr. RAY. Thank you, sir.

Mr. DADDARIO. We will be in touch with you. You have been very, very helpful to us, both you and Dr. Galler.

This committee will adjourn subject to the call of the Chair.

(Whereupon, at 12:10 p.m., the committee adjourned subject to the call of the Chair.)

APPENDIX A

DRAFT PROGRAM STATEMENT: ATMOSPHERIC DISPERSAL OF BIOLOGICALLY SIGNIFICANT MATERIAL

An *ad hoc* committee¹ has explored the value and feasibility of a national organization for information exchange and the stimulation of national and international cooperation in research involving atmospheric dispersal of spores, pollen, microbes, insects, and non-biological particles and gases that affect organisms. The IBP, especially national programs on spore dispersal associated with it in other countries, provide opportunities for international cooperation and synchronized observations on scales not available previously.

The program within the United States would work to improve information exchange and standardize techniques and records among voluntarily adhering projects. It would arrange cooperation between United States projects and corresponding ones in the IBP programs of other nations. It would stimulate interest by specialists in different disciplines and subject matter areas to cooperate in research having common objectives. Where serious gaps are found in the national or international arrays of investigations, the committee would undertake to help needed projects come into being, and it would serve at least to advise on the establishment of new research stations and data centers on atmospheric dispersal of biologically significant material, if such are needed.

The *ad hoc* committee anticipates the Program will consist of a Task Force having the authority to establish subject matter task groups as required to serve the needs of adherent projects. The Task Force will serve as a connecting link with the U.S. National Committee for the IBP and with counterpart atmospheric dispersal program groups in other nations.

Atmospheric dispersal of spores, pollen, and other biological materials has been studied locally and sporadically for many years. Causes of disease outbreaks in crops and the means by which infections spread, for example, have remained largely unexplained, especially because of lack of precise meteorological information, continued sampling over considerable distances, and exchange of standardization information among investigators. Now the International Biological Program provides means for standardizing observations and for establishing communication between investigators, nationally and internationally. The IBP also furnishes a framework for interdisciplinary cooperation (meteorology, oceanography, ecology, etc.) on scales that did not exist previously. With this aid and new technologies, remarkable opportunities are presented to biologists for investigations under conditions of such urgency that they have become responsibilities in view of human welfare of atmospheric dispersal. Solutions are now within reach for problems of gene flow in populations by pollination, plant disease spread by spores, insect outbreaks, and air pollution effects on organisms, to name a few. This program will undertake to get scientists with existing projects to standardize observations and reporting and to initiate needed projects, so that a sound and comprehensive national effort is established. Then this program will be coordinated with its counterparts in Europe, Australia, Japan, and elsewhere for elucidation of global relationships and general principals of dispersal.

¹ The *ad hoc* committee convened 19 and 20 November 1966 and on 23-24 February 1967 under the auspices of the U.S. National Committee for the International Biological Program (IBP).

JUSTIFICATION

A large segment of the population is allergic to pollen grains, fungus spores, algae, and other airborne allergens. Ragweed pollen causes undue suffering each year. Public health agencies need information on the patterns of distribution of all allergens as affected by meteorological conditions. Because these allergens are so ubiquitous attempts to reduce their number by chemical control measures have met with relatively little success.

Plant pathogens annually cause crop losses in the United States worth several billions of dollars. The spores of many of the most serious of these plant pathogens are widely distributed by air currents. For example, epidemics of wheat rust originate in Mexico and travel northward by means of air currents into the United States and Canada as the season progresses. Research was done in the 1930's by Meier and others to determine spore loads in the upper atmosphere by making collections from aircraft. More recently Pady has reported that smut chlamydospores have been reported over agricultural lands in Canada, the United States, and over the Arctic, the Arctic Ocean, the Atlantic Ocean, and the Mediterranean Sea.

Insects are pests of man, animals, and plants and many species of insects serve as vectors of virus and other diseases. Many of these diseases cause extensive loss of life and human misery. Others affect animals or plants and seriously reduce agricultural productions. Insects are scattered widely by wind currents.

Gene flow in populations, often occurs as a result of air currents dispersing pollen, insects, plant pathogens and other biological material to new areas resulting in the development of new subspecies, races or varieties of pests and allergens as well as hybrid plants.

Although there has been some research on dispersal patterns of pollen grains, spores, plant pathogens and insects, relatively little is known about their distribution patterns as related to air movements (including movements of upper air masses). Information is needed on sources of production of the particulates, the process and factors affecting lofting, the trajectories while airborne, the effects of concentration gradients and diffusion, the factors affecting deposition and viability and phenology or time relations.

It is essential to conduct research on a worldwide basis to learn about the spore loads, their kinds, their viability, their pathogenicity and their distribution patterns in order for man to cope with the increasing demand for food supply and for him to better cope with the health hazards due to allergens.

The report of the first meeting of SCIBP held in Paris in 1964 stated, "It is recommended that SCIBP stress the need for and encourage investigations of the atmosphere as a medium of international dissemination of plant and animal pathogens . . . this would include studies of air currents . . ." The USNC-IBP in their report dated June 1964 stated, "There is a need for a study of atmospheric microflora by simultaneous observations at strategic locations around the world, taken at 'human level' and at designated levels above."

Recent interest of meteorologists in the effects of meteorological factors on wheat rust epidemics led the World Meteorological Organization (WMO) to establish a Working Group on Meteorological Factors Affecting the Epidemiology of Wheat Rusts under its Committee for Agricultural Meteorology. As Zadoks of this Working Group points out there is need to forecast rust epidemics and a thorough knowledge of both wheat and rust phenology is essential to forecasting together with knowledge of aerial spore dispersal. The same information is essential to the forecasting of many other plant disease epidemics.

Hirst has stated, "If plant pathologists knew, or if meteorologists could tell them, the odds against any fungus establishing itself at varying distances from sources of known intensity, it might be possible to decide whether quarantine precautions would be effective, to specify the spectrum of diseases which plant to forecast the times when the disease would be introduced so that control measures could be more effectively timed."

With the advent of the industrial revolution the quantity and kinds of air pollutants has been increasing, but not until recent years has the pace been so accelerated. We have also been experiencing a more intensive agricultural system and the relocation of factories into agricultural areas. Thus, we bring the pollutants into closer proximity with humans, other animals, plants, and material that these pollutants seriously affect.

Major pollution results from combustion of fossile fuels and the production of chemical and natural products. Certain types of naturally formed products can also be considered as pollutants, such as the terpenes formed by certain trees, ice fog in Alaska, etc.

Certain steps must be taken in studying the problems of air pollution:

We must be able to define the pollutants.

We must understand the reactions in the environment—chemical and physical.

We must know the interreaction with or effect of these pollutants on man, other animals, plants, spores, pollen, and other material.

We must try to avoid the adverse effects of pollutants.

In almost every aspect of the problem, meteorology plays an important role. We have to know the diffusion patterns above our land masses and more especially above areas heavily populated. Periods of inversion have prevented the normal movements and dilutions of pollutants and have brought conditions resulting in high levels of deaths and morbidity. Mathematical models could be helpful in predicting what might happen in an area and in attempting to prevent a problem by reducing the load expelled into the atmosphere.

A study of the atmospheric conditions within a small area can help define the chemical reactions occurring there and the effect the pollutants might have on the substrates with which they interact.

All of the above problems are becoming of increasing and critical concern especially to urban areas and are fast taking an important role in urban planning and development so as to avoid the unwarranted spread of the problem. Answers are also needed to try to avoid the problem in the many areas of the world where industrialization is just beginning, but will surely move at a very rapid pace since it can build upon the already known technologies.

Because many of the dispersal patterns are similar much can be gained by bringing interdisciplinary activities to bear on the solution of the problems. Expertise on allergens and infectious diseases, palynology, meteorology including micrometeorology and fluid mechanics, plant pathologists, entomologists, gene ecologists, statisticians, and those concerned with air pollutants is needed. By bringing workers in these disciplines; together under the aegis of an Aero-spore Committee, mutual benefit will result.

OBJECTIVES

The program will endeavor to further investigations of processes and controlling factors in the atmospheric transport of spores, small organisms, and particles and gasses that affect organisms, over distances both great and small. The program will inventory ongoing research and provide information exchange relative to the atmospheric dispersal problems. Uniform methods of making observations and recording data will be worked out through cooperation with counterpart IBP efforts in other countries. Directors of existing projects will be invited to adhere to the uniform system and to contribute to the national and international efforts. Where surveys of accomplished research and research in progress indicate gaps in critical information, the program will define the need and endeavor to recruit personnel to undertake investigations to remedy the deficiency. Some or all of the following information will be sought by each project:

- a. Sources of production of the particulates
- b. Process of lofting
- c. Trajectories while airborne
- d. Concentration gradients and diffusion
- e. Processes of deposition
- f. Factors affecting viability
- g. Phenology or time relations

The objectives of this program, in their basic forms, are regarded as follows:

- (1) Provide an organization within which existing and new investigations of adherent dispersal problems can be integrated into a coherent area program.

- (2) Review and evaluate subjects and areas that would benefit from co-operation, and assist in developing cooperation between adherent ongoing and proposed projects, especially interdisciplinary projects.

(3) Evaluation of proposals submitted to the program for their relevance to the total program and possible significance to developed or anticipated special IBP efforts.

(4) Recommend continuing evaluation of the coverage and effectiveness of the U.S. efforts in this area for the purpose of recommending additional or shifted emphasis in some phases and initiation of entirely new efforts where gaps need to be filled.

(5) Provide for continuous maintenance of records that will assure information retrieval in this subject field, and work for improvement in appropriate information encoding, storage and retrieval systems.

The ultimate objective is to develop from ongoing and newly initiated projects a program of investigations that will best apply available qualified personnel to the more urgent aspects of the total problem of atmospheric dispersal. The program must have sound premises and be as comprehensive as possible. The national program must be considered first, as all other Western Hemisphere efforts in this area will be dependent upon it, and international coordination cannot proceed until the national program has been largely defined.

ORGANIZATION AND PROCEDURES

The Task Force will organize as a permanent group of minimal size, with alternates, representing major area of interest, for example, entomology, mycology and plant pathology, air pollution, algology, pollen transfer, allergens, meteorology, palynology, genecology, etc.

The Task Force will meet as necessary and function to 1) formulate general plans and policy, 2) coordinate activities of subcommittees, 3) assist in the obtaining of research funds, 4) insure the exchange of data and the establishment of liaison with centers of similar research, 5) arrange the publication of reports, 6) plan symposia and workshops, 7) standardize methods, and 8) maintain liaison with the national committee and international counterparts.

A secretariat will be established to provide continuity between meetings of the full Task Force, to provide communications between subcommittees and with consultants and interested groups, to assist in data exchange, to prepare and edit reports and to serve any function necessary to assist in the establishment of a data center to allow systematized storage and retrieval and insure incorporation into unified reports.

Consistent with policies stated earlier, subcommittees will be established in at least the following presently recognized areas:

Transfer of fungal plant pathogens, algae, pollens and aeroallergens

Some fungal plant pathogens, allergens, algae and pollens have the atmosphere as their main avenue of transfer. Although much basic work can be done at single sites, some problems need international cooperation because of the length of the flight path and the origin in one country of material biologically significant in another. The determination of origins, times and lengths of flights and terminal viability are examples of problems which may be attacked by such an effort.

Transfer of non-biologic particulate matter of biological significance

One element of air pollution of biological significance consists of non-biologic particulate matter of considerably smaller size than air-transferred biological matter. The origins, flight paths, time courses, deposition and composition of such matter comprise an area needing further international cooperative effort so that significant interactions with living organisms are better understood.

Transfer of insects including pathogen vectors

For reasons identical to those stated above, insects and other arthropods which cause plant and crop damage, are injurious to man and animals or which transmit the pathogens of plant, animal, and human diseases should be studied through a cooperative international effort.

Transfer of pollens and insects as a method in plant and insect germplasm transfer of evolutionary significance

The mechanisms of geographical migration of genes and gene pool segments are imperfectly understood. Their study forms a major emphasis area in popula-

tion biology and evolutionary studies. Passive atmospheric transfer is of recognized importance in the case of certain pollens and insects. More perfect understanding of this transfer will contribute significantly to the efforts of biologists studying the evolution of populations, geographic barriers and races, physiologic barriers and races, species composition, etc.

Transfer of gases of biological significance

Plant and animal damage is often the result of gases, particularly the by-products of combustion. The diffusion phenomena involved in long-range transfer of such materials form a discrete area of inquiry quite different from the above. Information on levels of gaseous pollutants and their effects (acute and chronic) on organisms, large and small, is needed especially for the major urban and agricultural areas of the world.

Advisory committee on meteorology

The generation, transport, and eventual effects on the environment of biologically significant materials are dependent on a hierarchy of atmospheric variables. It is therefore necessary to determine the relevant meteorological measurements which influence the environmental impact and to insure that these are included in all evaluations. There are areas where the behavior of the atmosphere which affects biologically significant materials is not well understood, e.g., a quantitative understanding of ultraviolet attenuation in polluted atmospheres or the ability to precisely determine the path, dilution and natural removal of spores or pollens over long (>1000 km) distances.

In view of the preceding, the Advisory subcommittee of meteorology will:

- 1) provide guidelines on the scope of meteorological influences on the generation transport, removal and effects of materials. These guidelines should be developed in terms of space or time scales such as <1 km, <1 hour, <1 km, <1 hour (micrometeorology), 1-100 km, 1-12 hours (mesometeorology), 100-3000 km, 1-7 days (synoptic meteorology) and >3000 km and >7 days (global meteorology and climatology);
- 2) Provide guidelines for non-meteorologists on methods of measurement and sources of data relevant to documenting atmospheric variability;
- 3) Provide a referral service to establish communication between meteorological groups, biologists and other scientists; and
- 4) Review the present status of meteorological ability to contribute to IBP and Task Force objectives and identify areas where meteorological research is required. To accomplish these four tasks the subcommittee will convene working groups to prepare problem reviews for submission to the Task Force. Maximum use will be made of existing national and international organizations and their activities to further the international goals of the IBP. The World Meteorological Organization, with its several Commissions and their Working Groups will be an especially important resource for competence and information interchange.

Cooperation

Elements of the proposed research, including some international effort, are already in existence. One guideline to be observed will be the complementation and extension, not the duplication, of extant efforts. Wherever possible, national and international expertise, facilities, manpower and resources will be called into play, such as exist in the FAO, WMO, WHO, UNESCO, etc.

SUMMARY BUDGET

	Fiscal year				
	1968	1969	1970	1971	1972
Task force.....	4,600	4,600	7,000	4,600	7,000
Subcommittee.....	9,600	9,600	2,400	2,400	-----
Symposium.....	5,000	10,000	-----	5,000	10,000
Secretariat.....	120,000	30,000	30,000	30,000	30,000
Total.....	39,200	54,200	39,400	42,000	47,000

* Partial year support to allow for recruitment.

Task force

Assumptions: 10 members
 2 meetings of 2 days each in fiscal year 68
 $\$20 \times 8 \times 4 = \640 per diem
 $\$250 \times 8 \times 2 = 4,000$ travel

Total --- 4,640

Sub-committee meetings

5 meetings in fiscal year 68 of 2 days each
 3 members each plus 5 consultants each
 $8 \times 10 \times 20 = \$1,600$ per diem
 $200 \times 5 \times 8 = 8,000$ travel

Total --- 9,600

Symposium—1

2 days. Held simultaneously with appropriate national society meeting to minimize costs.

Invited personnel: 20
 $20 \times 2 \times 20 = \800 per diem
 $200 \times 20 = 4,000$ travel

Total -- 4,800

Secretariat

Professional	\$16,000
Assistant	8,000
Travel	3,000
Office and other	3,000
Support	30,000

List of Participants

- Dr. William S. Benninghoff, Chairman, The University of Michigan, Department of Botany, Ann Arbor, Michigan 48104.
 Dr. Herbert T. Dalmat, Chief, Research Training Grants Branch, Room 208, Woodmont Bldg., Bethesda, Maryland 20014.
 Dr. A. Linsley Gressitt, Bernice P. Bishop Museum, Honolulu, Hawaii 96819.
 Dr. Howard E. Heggstad, Leader, Plant Air Pollution Laboratory, ARS, USDA, Crops Research Division, Plant Industry Station, Beltsville, Maryland.
 Dr. Wilbur D. McClellan, U.S. Department of Agriculture, Plant Industry Station, Agricultural Research Service, Room 231A, Beltsville, Maryland.
 Dr. Paul W. Oman, Room 107, Agriculture Research Service, U.S. Department of Agriculture, Beltsville, Maryland.
 Mr. Donald H. Pack, Acting Director, Air Resources Laboratory, Environmental Science Services Administration, 8060 Thirteenth Street, Silver Spring, Maryland 20919.
 Dr. Richard D. Schein, Department of Botany and Plant Pathology, Pennsylvania State University, University Park, Pennsylvania.

U.S. NATIONAL COMMITTEE ON THE INTERNATIONAL BIOLOGICAL PROGRAM HAWAIIAN TERRESTRIAL BIOLOGY PROJECT

REPORT OF PLANNING COMMITTEE MEETING, MARCH 20-23, 1967

The purpose of this meeting was to set up a task force, plan out the organization, and prepare background data for a detailed, long term, comprehensive investigation of the endemic and invading biotas of the Hawaiian Islands. This major undertaking is concerned with one of the most critical biotas in the world—critical because of the exceptionally high endemism and the rapidity with which it is disappearing before the onslaught of man and introduced species of animals and plants.

The Planning Committee was concerned with the following primary matters: (1) Criteria for the selection of high priority projects; (2) Plant and animal groups most urgently in need of study; (3) Invasive organisms which are most seriously affecting the native life of the islands; (4) Native communities and habitats which call for prompt investigation; (5) Development of lists and bibliographies and other source materials for efficient research reference; (6) Personnel organization of the projects; (7) Other, related projects pertaining to Hawaiian biology; (8) Facilities already available and still needed for conducting the research; and (9) Budgetary requirements.

The meetings were held at the B. P. Bishop Museum in Honolulu, where Dr. Roland Force, the Director, made excellent facilities available and arranged for a rather large number of invited participants in the discussions. A day was set aside for consultations with authorities at the top administrative levels, visited in their offices by members of the Planning Committee. The following schedule for the conferences was followed:

Monday, March 20:

9:00-12:00. Executive meeting of the Planning Committee.

1:30-5:00. Meeting with small group of selected local biologists.

Tuesday, March 21:

9:00-12:00. Meeting with approximately 15 local biologists concerned with Hawaiian terrestrial biology.

1:30-5:00. Meeting with land managers of state, federal, and private lands.

Wednesday, March 22: Visits by individuals and groups from the Planning Committee to top authorities.

Thursday, March 23: First meeting of proposed task force to discuss the organization of a project proposal.

The members of the Planning Committee present at the meetings were Dr. Sherwin Carlquist (Professor of Botany, Claremont Graduate School, California), Dr. Richard S. Cowan (Director, Museum of Natural History, Smithsonian Institution, U.S. National Museum), Dr. F. R. Fosberg (Special Advisor for Tropical Biology, Smithsonian Institution), Dr. Herman T. Spieth (Professor of Zoology and Chairman, University of California, Davis), Dr. Robert S. Usinger (Department of Entomology, University of California, Berkeley), Dr. Theodore H. Hubbell (Director, Museum of Zoology, University of Michigan, Ann Arbor) was invited, as Chairman of the Subcommittee on Systematics and Biogeography, to serve as Co-Chairman of the Planning Committee meeting together with Dr. W. H. Wagner, Jr. (Director, Botanical Gardens, University of Michigan) who had already been named by the USNC/IBP as Director of the Hawaii Project.

The following persons participated in the conferences: (a) Local biologists—Gladys E. Baker, Andrew J. Berger, George W. Gillett, D. Elmo Hardy, Charles H. Lamoureux, Helmuth Leith, A. C. Smith, J. Linsley Gressitt, Joshio Kondo, Russell Strandtman, Alvin K. Chock, Maxwell Doty, Karl Yoshimoto. (b) Representatives of Land Management agencies—Robert E. Nelson (Forestry Research Center); Gene Kreidler (Bureau of Sport Fisheries and Wildlife); Daniel J. Tobin, Jr. (U.S. National Park, Hawaii); Winstead Banko (U.S. National Park, Hawaii); Michio Takata (Director, Division of Fish and Game);

Dave Woodside (Div. Fish and Game); Max F. Landgraf (State Forester); Karl Korte (Maui District Forester); Ralph Dahler (Kauai District Forester); Leibert Landgraf (Hawaii District Forester); Robert T. Chuck (Water and Land Development); W. W. Goodale Moir (Hawaii Botanical Garden Foundation, Inc.); Paul Ekern (Water Resources Research Center, U. of Hawaii); Leslie D. Swindale (Agronomy and Soil Science, U. of Hawaii); Norman K. Carlson (Bishop Estate); Oswald Stender (Campbell Estate); Fred Carter (Damon Estate). As observers and recorders for most of the meetings, Miss Brenda Bishop and Mr. Edwin H. Bryan were present. Detailed minutes were kept of the meetings, and participants were asked to fill out questionnaires on certain aspects of the project for our records.

The following authorities were visited by members of the Planning Committee: Rear Admiral Henry S. Persons, Col. Burr E. Adams (Deputy for Major General Roy Lassiter, Jr., U.S. Army), Col. Head (Deputy for Colonel Philip A. Sykes, U.S. Air Force), Mr. Herbert K. Keppeler (B. P. Bishop Estate), Hon. John A. Burns (Governor of Hawaii), Hon. John J. Hulten (President of the Senate), Hon. Elmer F. Cravalho (Speaker of the House), Mr. Edward J. Morgan (Board of Water Supply), and Dr. Thomas Hamilton (President, U. of Hawaii). The project was warmly received by all these officials, and specific persons were designated as contacts for arranging access to lands controlled by the state, the U.S. government, and the Armed Forces. Several members of the Planning Committee also attended the brief dedication ceremonies of the new research facilities of the H. L. Lyon Arboretum of the University of Hawaii, where W. H. Wagner, Jr. made a brief address describing the International Biological Program and the Hawaii Project.

PRINCIPAL RESULTS OF THE CONFERENCE

In addition to a large amount of background information which was received during the course of the meetings, as well as a number of important contacts with authorities for the purpose of informing them of the nature of the work contemplated in this project, the Planning Committee made a number of definite decisions regarding the further development of the Hawaii Project. The following outline will summarize these decisions.

1. *Title and Scope of the Project.*—For several reasons it was concluded that the project should be limited to the biology of the land areas, including the leeward islands, and that the "cut-off point" should be the shoreline. The principal basis for this decision was simply that it is the terrestrial biota that is most severely threatened and most likely soon to be destroyed. Furthermore, work on the marine biology of Hawaii is already reasonably well supported. Accordingly, we propose that the title of the project be "The Hawaiian Terrestrial Biology Project."

2. *Criteria for the Selection of High Priority Projects.*—It was concluded that the following considerations should be weighed together in estimating the relative priorities of different studies to be made:

a. To what extent is destruction in the near future likely? This may be judged in terms of such considerations as (1) rarity or narrow geographical extent; (b) narrowness of ecological specialization.

b. To what extent does the group of organisms, the community, or the ecosystem have special biological interest and significance? Is the taxon, community or ecosystem unusually distinctive and different from those most nearly related? Has the taxon undergone unusually vigorous evolution in which important biological principles may be involved? Does the taxon, community or ecosystem show unusual biological adaptation or specialization?

3. *Plant and Animal Groups most Urgently in Need of Study.*—Considerable discussion was directed toward this problem, and specific suggestions were made not only by the members of the Planning Committee but by the local biologists and land managers as well. The following examples illustrate studies which should receive high priority. Among the insects, the longhorned beetles (Cerambycidae) of Hawaii call for detailed investigation. They constitute an outstanding example of evolutionary development in insular isolation, including 110 or more species in six endemic genera, all of which apparently evolved from a single immigrant. Very little is known of their biology, ecology, or immature stages, and a concentrated study would produce results of great interest. Among the mollusks, the Hawaiian members of the genus *Achatinella* have long been cited as classic examples of evolution. In recent times the American Institute of Biological Sciences has requested color slides of *Achatinella* for teaching purposes,

and there has been a resurgence of interest in these snails. This makes it all the more regrettable that we are now witnessing the rapid decline and disappearance of these organisms as a result of disease, dilution of the native forests, rats, and other factors. Detailed biological investigations should be made now, and perhaps ways and means should be formulated to save the most adaptable species for posterity. Of all bird families, the Hawaiian honeycreepers (*Drepaniidae*) provide the most striking examples of adaptive radiation with all its implications for the understanding of evolutionary processes. We know virtually nothing about the ecology and breeding biology of any species of this strictly endemic family. Some of the species are already very rare, and a few may, in fact, be extinct.

Among plant groups the study of which is urgent, attention was called to such genera as *Gouldia* (Rubiaceae), *Euphorbia* (Euphorbiaceae), *Cyanea* (Campanulaceae, subfamily Lobelioideae), *Adenophorus* (Filicineae, Grammitidaceae), and *Metrosideros* (Myrtaceae). The endemic genus *Gouldia*, although considered in the most recent monograph as comprising only three species, has generated an almost unbelievable number of varieties and forms, which all seem to hybridize wherever their ranges overlap. *Gouldia* provides ideal material for studying the evolution of plant groups on volcanic islands, but many of its form have already disappeared or are in present danger of extinction.

4. *Studies of the Spread and Effects of Invasive Species*.—Over the past century one of the most spectacular phenomena in the terrestrial biology of Hawaii has been the more or less explosive invasion by introduced species of environments formerly occupied by native organisms, with resultant change or elimination of the native communities and ecosystems. Among the exotic invaders which were discussed are mites, ants, axis deer, mongoose, pigs, goats, blackberry, lantana, pamekane, Christmasberry, and gorse. Two species of guava have established themselves and taken over great areas of formerly native forest.

The "ilima" (Malvaceae: *Sida fallax* group) is a plant of central Pacific origin which is native to Hawaii and has there undergone great diversification and evolution. Professor St. John has been gathering material toward a revision of the group, which in the Hawaiian Islands has developed variations with weedy tendencies which become abundant where there has been grazing and trampling. Thus invasive organisms, although usually naturalized from other lands, are not necessarily always introductions. In the Planning Committee discussions it was recognized that those few instances of native organisms which have "profited" by the upsets in the biota caused by man should also be considered worthy of study in this project.

5. *Native Communities and Ecosystems Which Should Be Studied*.—During the conferences there was surprising agreement among the participants as to the areas which should be given special attention. In all cases these are localities in which the effects of modern destruction are minimal. The general categories include rainforest, bog, dry forest, and sand dunes, of which the last two are the most threatened. Of the dry forests, those which still remain in the most primitive condition are on the island of Hawaii, and a number of specific localities on that island were recommended for intensive study. Of the rainforests, the Waikamoi Forest area of East Maui stands out for a number of reasons, but especially for its relatively undamaged condition, its altitudinal range, and its great size. In fact, the Planning Committee felt that if it proves desirable to set aside a single area for intensive ecosystem investigations by other subcommittees of the US/IBP, the Waikamoi Forest would be especially suitable. However, the consensus was that because of the urgency of the situation, priority should be given by this project to descriptive ecological studies, and that highly detailed and expensive "in-depth" investigations of one or more selected ecosystems should be the responsibility of other subcommittees of the USNC/IBP. If such an ecosystem study should be approved for Hawaii the Hawaii Terrestrial Biology Project could provide more extensive and complete cooperation on its systematic and geographic aspects than would be available for almost any other site.

6. *Development of Lists, Manuals, and Bibliographies*.—The Planning Committee recognized that most efficient progress on the Hawaii Project will require developing proper source materials. It was discovered, in fact, that a considerable amount of work has already been accomplished in this direction, e.g., by the Pacific Information Center. What is now needed is to collate what has been done and to publish it. As for checklists, various authorities have made lists of particular groups for their own use, which are not known or available to others; it is necessary now to bring these together and revise them (indicating the names of the revisers). Manuals are greatly needed; this is especially true for the local flora, as Hillebrand's great "Flora of Hawaii" is now over eighty

years out of date. The Hawaii Project proposes also to develop an annotated, cross-referenced bibliography on the terrestrial biology of the islands. Out of this work of correlation it should be possible to prepare lists of threatened taxa as well as lists of threatened habitats and communities, including recommendations of sites which might be dedicated as natural area preserves.

7. Personnel Organization of the Project.—The following organization was proposed by the Planning Committee:

Director: W. H. Wagner, Jr.

Associate Director (Zoology): R. S. Usinger

Associate Director (Ecology): F. R. Fosberg

Coordinator: To be named

In charge of Liaison with Marine Biology: Maxwell Doty

Task Force:

Hermann T. Spieth

Sherwin Carlquist

R. S. Cowan

G. W. Gillett

C. H. Lamoureux

D. Elmo Hardy

A. J. Berger

J. Linsley Gressitt

Yoshio Kondo

The task force was selected to represent interests and institutions as fairly as possible. It was deemed desirable not to have too large a task force but at the same time to have a broad enough representation so that it could provide a competent panel for major decisions and for the setting up of research projects. The duties of the task force include the following: (a) Preparing the project proposal; (b) Holding meetings to make important decisions on policies and activities; (c) Judging the relative merits of projects submitted for inclusion in the Hawaii program; and (d) Soliciting investigators and projects, by means of correspondence, visits to other institutions, lectures, and articles calling attention to needed studies of high priority.

It was decided also that an Advisory Board should be named to include persons whose authority and knowledge would make them valuable for consultation and advice. The size of this board need not be specified; it could be fairly large, since a variety of authorities is needed and since it would never be convened as a group.

The most important innovation in our thinking about the organization of the project involves a *Project Coordinator*. This person, who should reside in the Hawaiian Islands and preferably be stationed at the B.P. Bishop Museum, would be in charge of all of the local strategy, including the handling of funds, the coordinating of field work, and the numerous details involved in the actual operation of a project involving perhaps as many as two dozen or more individual researchers at one time for a period of five years.

8. Other Related Projects.—As a result of our conferences we conclude that a number of important research activities are already going on which pertain to our work. Of them, that on the Hawaiian Drosophilidae is perhaps the most significant, for it provides a model of the sort of activity that we deem most important—thorough biological studies of threatened organisms of great evolutionary interest. The research on this group of flies is centered at the University of Hawaii, but it includes researchers from various states, as well as a number of assistants. The Hawaiian state agencies, as well as the Bishop Museum and various departments of the University of Hawaii are currently engaged in numerous projects which will bear upon our project and with which interactions will be sought. We hope also to be able to provide recommendations and aid of IBP subcommittee PT-PF chooses to make an ecosystem study of a selected Hawaiian site.

9. Facilities Required for Conducting the Research.—Already the library and specimen collections of the B. P. Bishop Museum provide a valuable background of information for the development of this project. Other libraries and collections, such as those of University of Hawaii and Hawaiian Sugar Planters' Association, will also be available. Laboratory and research space is currently at a premium, but it is to be expected that some space can be provided with existing facilities at the Bishop Museum, and the new Plant Sciences Building of the University of Hawaii (completion date estimated, 1969) should considerably expand space potentialities there. It is likely that much of the systematic work will be pursued at the Bishop Museum, but that the ecological work will tend to be centered at University of Hawaii.

All members of the Planning Committee agreed that field equipment and facilities are going to be needed. These include small shelters to be constructed at appropriate places selected as study sites, transportation vehicles, as well

as research equipment, including microscopes to be used both in the field as well as the laboratory. Provision must also be made for increased space and collection storage facilities at museums which are major repositories for collections resulting from the project.

10. *Budgetary Needs.*—A preliminary estimate of needs over a five-year period was prepared. Estimates of salaries for researchers were based upon approximately eight established scientists plus twelve graduate-degree students per annum. Local student assistants from University of Hawaii were estimated at eight per year at half-time. In addition, there will be need for secretarial, curatorial, and bibliographical personnel. The total salaries per year were estimated at \$230,500. For laboratory equipment and office expenses we estimate \$31,000 for the first year layout; for field equipment and supplies \$33,100. Transportation and subsistence for some members of the task force and for researchers from other states and countries, as well as those on the local scene (including round-trips to Hawaii, inter-island air transport, jeep operation, helicopter hire, and per diem, about \$73,000) will be needed each year. The grand total of our preliminary estimate for the entire five-year period will be \$1,964,850, including an estimate of \$375,500 for required publication expenses.

THE TERRESTRIAL BIOLOGY OF HAWAII

Revised Outline of Proposal to the National Science Foundation

I. ABSTRACT

II. GOALS IN HAWAII

A. Background:

1. Uniqueness, scientific importance, urgency. Terrestrial and freshwater only.
2. Why relevant to the IBP
3. Body of basic information to build on:
 - a. The Physical Environment (Maps, climatological data, geology, etc.)
 - b. The Biota (Existing checklists, guide books, systematic monographs, ecological studies)

B. Objectives:

1. To determine the most critical studies and establish priorities
 - a. Taxa, sites, communities, ecosystems
 1. Criteria for selection of taxa and communities
 2. Taxa most urgently in need of study
 3. Sites and communities most urgently in need of study
 4. Ecosystems (proposed cooperation with PT-PF in selecting and studying)
 - b. Important invasive species
 1. Exotic
 2. Native species becoming "weeds"
 3. Effects upon native biotas.

C. Activities and Implementation:

1. Taxa
 - a. Biological studies: life cycles, pollination mechanisms, etc.
 - b. Systematic and evolutionary studies
2. Biology of invasive species
 - a. Naturalized
 - b. Native
3. Communities and ecosystems
 - a. Comparative ecological surveys
 - b. In-depth ecological studies of selected sites
 - c. Long-term analysis of a selected Hawaiian ecosystem; desirable if feasible; seek cooperation with PT-PF
4. Development of lists and bibliographies
 - a. Checklists and manuals of Hawaiian taxa, all groups (Need for new flora)
 - b. Annotated bibliography on Hawaiian biology
 - c. Lists of threatened taxa (cf. Red Book)
 - d. Lists of threatened habitats and communities, and areas that should if possible be preserved. (Not an action group; see Shetler, Bishop Museum; Intern. Conservation Association; Conservation Council for Hawaii)

III. ORGANIZATION OF THE PROJECT

A. Project Director (Warren H. Wagner, Jr.) (Botany) Associate Director for Zoology (Robert L. Usinger) Associate Director for Ecology (F. Raymond Fosberg)

B. Project Coordinator. Salaried; to be in Hawaii; managerial and logistic responsibilities only

C. Task Force:

Berger, Gressitt
Carlquist, Hardy

Cowan, Kondo
Fosberg, Lamoreux
Gillett, Spieth
Usinger

One or two ecologists may be added upon recommendation of CE and consultation with PF-PT

Responsibilities:

1. Preparation of proposal(s)
2. Evaluation of projects for inclusion
3. Solicitation of projects and invitation of participants
4. Publicity, including visits to institutions, lectures, seminars
5. *Major responsibility* is to be the policy-determining and idea-generating group in charge of the project

D. Advisory Committee: composition and functions

A body of resource people who have an interest and something to contribute

No definite limitation on size; may include both scientists and non-scientists who can help by reason of their knowledge or position

E. Research Groups and Group Leaders

Interdisciplinary groups may be organized for the study of selected problems under the leadership of some designated member of the group

IV. SCIENTIFIC PERSONNEL: U.S. AND FOREIGN

A. Professional scientists (average of 8/yr.)

B. Predoctoral graduate students (average of 12/yr.)

C. Assistants, non-academic (clerical, technical, preparatory, field)

V. RELATED PROJECTS

A. The Hawaiian *Drosophila* project (a model group-project)

B. State and Government supported research projects

C. Recommended participation by PT-PF in an ecosystem study of a selected Hawaiian site

VI. COOPERATIVE RELATIONS WITH HAWAIIAN INSTITUTIONS AND AGENCIES

A. Roles of the Bishop Museum and the University of Hawaii

B. Facilitation by State and National Agencies in Hawaii

1. State Agencies: information, coordination, access to lands, etc.
2. National Park Service: as above
3. Armed Services: as above

C. Involvement of Private Estates and Individuals controlling study areas

VII. NEEDED FACILITIES

A. Field Facilities

1. Shelters
2. Transportation equipment
3. Research equipment

B. Office space in Hawaii

1. Hawaiian headquarters for project and for systematic work at the Bishop Museum
2. Ecological activities centered at the University of Hawaii

C. Provision for deposition of collections at appropriate museums (Bishop, U.S. National Museum, some others?) with necessary storage space and facilities

VIII. ARRANGEMENTS FOR FUNDING

To be worked out by consultation with NAS, NSF, ICC. Possibilities are: through the Bishop Museum, through AIBS, through incorporation.

IX. PUBLICATION

A. Funds for publication of lists and manuals of Hawaiian groups of terrestrial organisms.

B. Funds for publication of annotated bibliographies of works on Hawaiian biology.

C. Funds for continuation of the monographic series, "Insects of Hawaii."

D. Funds for page costs for publication of research articles up to 40 pages per author, or more if funds permit.

X. PROPOSED BUDGET

	Estimated average, yearly	Estimated 5-year total
A. Salaries:		
1. Professional:		
(a) Coordinator (12 months, including fringe benefits).....	\$15,000	\$75,000
(b) Established scientists (12 months; 8 at \$12,500 per year).....	100,000	500,000
(c) Graduate students (12 months; 12 at \$5,000 per year).....	60,000	300,000
(d) Student assistants (8 at \$2,500 per year).....	20,000	100,000
Subtotal.....	195,000	975,000
2. Nonprofessional:		
(a) Secretaries at \$5,000 per year, 1.5 full-time equivalents.....	7,500	37,500
(b) Curators and preparators at \$5,500, 4 full-time equivalents.....	22,000	110,000
(c) Bibliographers at \$6,000, 1 full-time equivalent.....	6,000	30,000
Total salaries.....	230,500	1,152,500
B.* Office and laboratory equipment and supplies:		
1. Stationery, etc.....	1,000	5,000
2. Office equipment (typewriters, Xerox, etc.).....	2,500	5,000
3. Dissecting microscopes (15 at \$500).....	7,500	7,500
4. Compound microscopes (10 at \$1,200).....	12,000	12,000
5. Furniture for research cubicles.....	4,000	4,000
6. Specimen cases for repository museums.....	4,000	20,000
Total office expenses.....	31,000	53,500
C. Field equipment and supplies:		
1. Shelters (8 at \$3,200).....	25,600	25,600
2. Maintenance of shelters, 5 years.....		2,000
3. Nets, plant pressing equipment, glassware, etc.....	2,000	3,000
4. Shipment of equipment and specimens.....	500	2,500
5. Miscellaneous research equipment (refrigerated boxes, thermometers, hygrothermographs, etc.).....	5,000	10,000
Total field equipment and supplies.....	33,100	43,100
D. Transportation and subsistence:		
1. Round trips to Hawaii, 21 at \$450 average.....	9,450	47,250
(a) 1 meeting per year task force in Hawaii.....	3,000	15,000
2. Interisland air transport, 30 at \$200.....	6,000	30,000
3. Jeep operation, taxis.....	6,000	30,000
4. Helicopter hire.....	4,000	20,000
5. Per diem allowance, at \$15 per day (31 persons, average 3 months in field).....	42,000	210,000
Total transportation and subsistence.....	70,450	352,250
E. Publication:		
1. Publication of lists and manuals.....	500	1,000
2. Publication of annotated bibliographies.....	5,000	7,500
3. Continuation of "Insects of Hawaii" (10 volumes in 5 years at \$30,000 per volume).....	60,000	300,000
4. Page costs for research articles (40 pages per man-year times 35 authors at \$10 per page).....	14,000	70,000
Total publication costs.....	79,500	378,500
Summary of budget:		
1. Salaries.....	230,500	1,152,500
2. Office expenses.....	31,000	53,500
3. Field equipment and supplies.....	33,100	43,100
4. Transportation and subsistence.....	70,450	352,250
5. Publication.....	79,500	378,500
Grand total.....	444,550	1,979,850

ANALYSIS OF DRAINAGE BASINS AND LANDSCAPES

(Submitted by Frederick E. Smith, Department of Wildlife and Fisheries)

SUMMARY

Three years of support are requested for the development and operation of overall research designs and coordination of research effort in a portion of the International Biological Program sponsored by the United States National Committee. The terrestrial (PT) and freshwater (PF) productivity subcommittees have jointly proposed the study of large ecosystems such as whole drainage basins and landscapes. Six major studies are suggested for each of six biomes, together with an unspecified number of contributory studies of smaller scope. The goal is to elucidate the operation of such systems: the dynamics of interchange among all components, the mechanisms of homeostasis, the capacity to change, and the levels of productivity sustained under a variety of natural and disturbed conditions. The major studies will permit the synthesis of information to the system level, while the contributory studies will offer comparative data and broaden the scope of application of the results.

Success depends upon the coordinated efforts of investigators from many disciplines, and upon meaningful collaboration among them. For these reasons, the subcommittees propose a Task Force including a Program Director, a Program Coordinator, a secretary, and the members of the PT and PF subcommittees. This group will work intensively on the design and development of system-level research, including the promotion and coordination of collaborative projects. The assignment is intended to accelerate the development of ecosystem analysis, an approach that is currently developing in several research centers, but too slowly to provide the understanding of ecosystems that is needed today.

The bulk of support for this program will be sought separately by agencies sponsoring sites, and by investigators wishing to participate. The major costs of administration will be included in such requests. This request covers only the efforts of the Task Force. At least three years are needed before an effective evaluation of this approach can be made.

The body of this proposal is a report prepared October, 1966, by the PF and PT subcommittees of the United States National Committee, I.B.P., together with additional invited ecologists. Since other subcommittees were meeting at the same time, attendance varied from day to day. The following is this observer's list of participants:

- *Lawrence Bliss, University of Illinois
- Frederick Bormann, Yale University
- Joseph Connell, University of California at S. B.
- Charles Cooper, University of Michigan
- Rexford Daubenmire, Washington State University
- *Shelby Gerking, Indiana University
- *Charles Goldman, University of California at Davis
- *Arthur Hasler, University of Wisconsin
- *Philip Johnson, Department of the Army
- Gerald Marten, IBP of Canada
- *Eugene Odum, University of Georgia
- *Jerry Olson, Oak Ridge National Laboratory
- Oscar Paris, University of California at Berkeley
- *Frank Pitelka, University of California at Berkeley
- *Ralph Silliman, Fish and Wildlife Service
- *Lawrence Slobodkin, University of Michigan
- *Frederick Smith, University of Michigan
- Forest Stearns, Institute of Forest Genetics
- *George Van Dyne, Colorado State University
- *Richard Whittaker, University of California at Irvine
- John Wolfe, Atomic Energy Commission
- George Woodwell, Brookhaven National Laboratory
- John Wright, Montana State University
- Frederick Wagner, University of Utah

*Indicates members of the subcommittees.

Their report has been revised by correspondence; the December 21, 1966 version is included here.¹ Participation by individuals in the preparation and revision of the report does not imply agreement with or support for the recommendations of the report. It can be said, however, that a large majority support the report as a whole, and that all of the recommendations of the report are supported by a majority of the group.

The proposal is generated from this institution as a host agency for the operations of the Task Force, and as a base of operations for the Program Director, Program Coordinator, and secretary.

JOINT REPORT OF SUBCOMMITTEES PF AND PT, USNC, IBP, DRAFT 3

INTRODUCTION

The gravest problem facing man in a peaceful world is the establishment of a reasonable harmony between a stabilized world population and the environmental resources upon which that population depends. Human population increases at an unprecedented rate, and it has proved difficult to stabilize population in those countries where stability is most desired. Technological power is altering environment at an increasing rate, often in ways which are to man's disadvantage through erosion, atmospheric pollution, and the widespread use of poisons intended for pests, yet an expanding population is forced to make ever-increasing demands on the environment.

American biologists are participating in an intensive international study of man's relation to environment. The American subcommittees on Terrestrial and Freshwater Productivity propose that studies of ecosystems, the size of drainage basins, be central in their contribution to the U.S. program. Such studies will provide a more fundamental understanding of ecosystem dynamics. Present ecological understanding has developed from studies of particular communities and ecosystems, often without assessing the dual role of man as a manipulator of, and a functional component in, these ecosystems. Environmental management is best approached through studies of productivity, cycling of nutrients, and successional processes. Cooperative studies of large-scale ecosystems are needed before existing theory can be applied to their management. The primary purpose of the IBP is to bring about an understanding of ecosystems. Through such understanding, possibilities of wise long-term utilization and conservation may be clarified, and biologists may effectively contribute to the broader policy decisions of man's future.

GENERAL OBJECTIVES

The subcommittees on Productivity of Terrestrial Communities and Productivity of Freshwater Communities jointly propose the study of whole systems, such as drainage basins or landscapes, through team effort by U.S. and foreign scientists. Although intensive studies on the various components of a few selected areas will be emphasized, the scope of the study will be broadened by contributory work from other areas.

Interactions among the components of these ecosystems can then be evaluated on a scale that has not yet been achieved. Our understanding of the ways in which such systems operate, and the extent to which they can be manipulated, will lead to the development of a new level of ecological theory.

Emphasis will be placed on primary productivity and its meaning for man, on trophic structure, energy-flow pathways (food chains), limiting factors, interactions of species, bio-geochemical cycling, species diversity, and other attributes which interact to regulate the structure and function of communities.

The program is not to be restricted to natural areas, but strives to compare ecosystemic processes in environments under various degrees of control by man. Ecological succession should serve as a background against which the general objectives can be pursued, because the principles of succession are at the heart of the growing difficulties in the relation between man and nature. Yet very few of the generally accepted ideas have been tested experimentally or related to whole landscapes as they exist at any one time.

¹ The published version about to be distributed differs in minor ways, and can be substituted if desired.

Collaborative studies are to be undertaken within the major biotic areas in both terrestrial and aquatic environments. Coordinated research will be conducted in entire drainage basins, where environments will be studied simultaneously. Aquatic and terrestrial components of ecosystems must be studied together because they have strong interactions. The program seeks particularly to achieve its objectives through the catalysis of new techniques.

At least three steps lead toward this broad objective:

1. We want to encourage the development of a theory of ecosystems from small-scale laboratory and field studies. The elements of such a theory already exist but require reassessment, refinement, and expansion.

2. Since large-scale natural systems are composed of interacting subsystems, there are problems of scale and of organization which must be solved. Tentative solution of these problems can be tested and further improved only by integrating the ideas inherently concerned with this additional level of complexity with well-organized efforts.

3. To whatever degree this integration proceeds, it will provide perspective for the already extensive experience in landscape management. It may lead to alterations possibilities for management. The results should help man to judge policies for natural resources and ecological zoning to serve diverse human needs.

International efforts to hasten this procedure:

1. Exchange of information at two levels—research design and data analysis.

2. Exchange of mature scientists between laboratories interested in IBP programs.

3. Training in specialized techniques of production biology for IBP programs and related sciences.

PROGRAM

Intensive Drainage Basin Studies

The study of drainage basins as ecosystems offers possibilities for integrated research which have been neglected or viewed too narrowly, despite their relevance to man's use of his environment. We recommend, therefore, that much of the effort of the Subcommittees on Terrestrial and Freshwater Productivity be focused on intensive, multidisciplinary analyses of ecosystems. Study areas will be selected in which the interrelationships of terrestrial and aquatic communities can be investigated. The site should include both undisturbed communities and communities highly modified by human use.

We recommend that concentrated efforts be made in a limited number of sites, representing the following ecosystems: deciduous forests, coniferous forests, grasslands, deserts, tropical forests, and arctic tundra. Scientists with a wide range of interests should collaborate in these centers for intensive study. In addition, contributions can be made through more limited investigations on related communities at other locations. Each study site would be located where there is already a strong university or Federal laboratory.

Limited ecosystem studies are already in progress at a number of locations including several in the eastern deciduous and western coniferous forest in the southwestern desert and in the Arctic. Hydrologic data and other basic information have been gathered at a number of other locations. Any area considered particularly appropriate for comprehensive ecosystem study, either by virtue of the landscape and biological components or by the nature of the background studies completed or in progress there, should be brought to the attention of the Chairman of the PT or PF subcommittees.

Final site selection should be made by a task force composed of at least the following persons: (a) the project coordinator(s), (b) an animal ecologist, (c) a plant ecologist, (d) a limnologist, (e) a geologist, (f) a hydrologist, and (g) a meteorologist. The task force will consider potential cooperation of research centers, training centers, and information centers and non-U.S. collaborators, in addition to considering the inherent ecological interest and management problems of available areas.

CONTRIBUTING STUDIES

The need for understanding of ecosystems is such that any ecological study addressed to IBP objectives is encouraged. Two types of studies are complementary to the intensive investigations under IBP sponsorship at selected loca-

tions or centers: first, those paralleling special parts of center-based programs, to be pursued by collaborators at many locations; and second, separate studies yielding synoptic data for broad geographic comparisons.

Studies that parallel parts of the center-based programs may deal with variants of the ecosystem components found in the intensive study areas, or they may be concerned with the responses of ecosystem components similar to those of the major study areas but existing under different environmental conditions.

The value of certain aspects of ecosystem analysis, particularly seasonal and successional change and productivity, is greatly increased by wide geographic coverage. Studies involving many independent observers must follow rigorous standards to be specified in manuals so that data obtained are strictly comparable. Examples of desirable studies are: (1) timing of appearance and other events in life history for easily observed and identified aquatic and terrestrial animals; (2) date of emergence, coloring, or dropping of leaves for plants with limited genetic variability and widely spread by man, such as ginkgo and metasequoia; (3) counts and/or weights of fruit or seed production made throughout the range of several wide ranging and economically important species, and (4) harvest of peak standing crops of aquatic and terrestrial ecosystems. (Yield values for agricultural crops are abundant but the relationship between economic production and biological productivity is poorly known; thus, correlations of seed yield with peak standing crop in agricultural ecosystems are needed.)

Participation of high-school and college teachers would contribute toward realization of the IBP objective of stirring widespread interest in human-oriented ecology. The teachers' interest would influence the ideas and attitudes of successive groups of students in their classes.

Both the PF and PT subcommittees endorse the general objectives of their international committees and recognize as a relevant part of the American program those contributing studies that relate directly to the specific programs of other countries. The international PF program includes studies relating to eutrophication, primary and secondary production, fish production, the chemical environment, production in man-made lakes and production under environmental extremes. The international PT program includes ecosystem processes of primary and secondary productivity, the dynamics of decomposures, and the interactions of climate, soil, and the impact of man in ecosystems.

METHODS

General

Biologists are sensitive to the need for encouraging advanced and imaginative techniques; yet comparability of results will be enhanced by inter-calibrations, standardization of measurements, and faster communications. Three types of publications will state the possibilities and limitations of techniques:

- (1) published books of general reference value,
- (2) handbooks of the international sections of the IBP,
- (3) supplementary reports of the U.S. National Committee on new techniques and illustrative working results.

For intensive total-system studies, measurements will be made of all major components of the ecosystem. Measurements should include gross production, respiration, net production, secondary and tertiary production, rates of decomposition, exchange of matter with contiguous systems, soil and topographic settings, and microclimatic and macroclimatic variables. Energy flow, nutrient cycling, and production will be investigated on a seasonal basis. Spatial and temporal variation in selected populations should be given special attention.

Examples of techniques for the above measurements include the use of isotopes for tracing food chains and estimating rates of nutrient cycling; remote sensing with such tools as aerial photography, infrared scanning, radar, sonar, and underwater TV; biotelemetry; laboratory microecosystems; and physical and chemical methods, such as chromatographic techniques, nuclear magnetic resonance, activation analysis, atomic absorption, spectrophotometry, calorimetry, nitrogen analyzers, and respiration chambers with automatic gas analyzers.

Systems analysis

In the past two decades a variety of computer-oriented mathematical methods have been developed in industry and government for the analysis of complex systems. Many of these methods and tools have direct applications in analyzing

complex biological systems—especially ecosystems. Systems analysis has already been demonstrated to be a successful adjunct to conventional field and laboratory methods in ecology.

Systems analysis should be applied in at least three major ways in the IBP:

- (1) An early step will involve development of methods to examine existing data on ecosystem processes in a sensitivity analysis aimed to reveal the relative importance of certain factors; this analysis will aid in allocation of resources for research activities in integrated system studies.

- (2) Computer techniques are essential for rapid organization and analysis of data derived in total-system studies, especially those phases involving intensive use of electronic recording equipment.

- (3) Systems methods will be applied in analysis and integration of results from studies in the United States and elsewhere, designed to test and develop ecological theories.

A major task will be to train ecologists in the use of computers and mathematical methods in systems analysis. When possible, systems analysts should be members of each interdisciplinary team. The program should make available systems analysts to consult with investigators working on single processes or components or synoptic data to insure that data obtained can be utilized in composite analyses.

Information centers

The IBP goal of synthesis in man's understanding of ecosystem relations requires one or more information centers to fill several roles:

- (1) To store primary data and derived variables for analyses beyond those to be expected at individual research sites.

- (2) To distribute computer programs and primary data to individuals or other centers.

- (3) To coordinate basic descriptions and groupings of terrestrial and freshwater systems, extending the coding and formats being tested in the data center of the Conservation Section.

- (4) To facilitate comparisons between ecosystems and between parts of the world in a total system context (e.g., summarizing tables expressing rates of transfer of energy, nitrogen, and other elements).

- (5) To aid IBP planning and activities by storing current information on the work of scientists as it is gathered by project directors.

Training

Since there is a shortage of biologists capable of undertaking the type of studies proposed, training is a major need. The objectives of the IBP in general, and the study of terrestrial and aquatic environments in particular, cut across traditional academic boundaries. Outstanding ecologists will be encouraged to apply for funds to develop training programs that educate ecologists who are technically well-trained in a specialty but are also able to deal with the larger problems of man and the landscape.

Three phases of training are acknowledged:

- (1) the university pre- and post-doctoral programs which require close cooperation between the basic biological and natural resource departments and sound basic training in physical, mathematical, and computer sciences;

- (2) special institutes for instruction in modern methods for the practicing ecologists; and

- (3) short courses of symposia for biologists desiring familiarity with recent advances.

Administration

For successful development of the center based programs, and for coordination of contributory studies, some stimulation, assistance, and direction is necessary. We suggest this be accomplished with a Program Director, a Program Coordinator, and an Advisory Committee. Appointment of a Program Director and an Advisory Committee will be through the concurrence of the Freshwater and Terrestrial Productivity Subcommittee on suitable candidates. The Advisory Committee may also include representatives selected from the appropriate federal agencies. Liaison member from other IBP subcommittees should collaborate in the planning.

The Program Director will be a reputable ecologist who will be assisted by a full-time Program Coordinator to handle most of the work of coordinating the

studies once they are underway. The Coordinator will be appointed by the Program Director with the approval of the Advisory Committee. All are subject to approval by the USNC.

The Coordinator and Advisory Committee will assist the Program Director in the organization, initiation, development, and execution of comprehensive ecosystem studies. These duties will include:

- (1) Developing detailed programs and aiding with project proposals.
- (2) Reviewing progress of current programs and identifying areas needing further research.
- (3) Informing the scientific community of progress in the programs, particularly on methods being used.
- (4) Assisting in attracting investigators to the program.
- (5) Assisting in developing training programs.
- (6) Assisting in developing budgets.
- (7) Assisting in obtaining support for the program.
- (8) Maintaining close communications and cooperation with relevant programs in other countries.

At least three working conferences under the sponsorship of the Subcommittees on Terrestrial and Freshwater Productivity will be held during the winter and spring of 1967 to more clearly define the work to be undertaken in analysis of total ecosystems and contributory studies. One conference will consider criteria to be used in selecting sites for the total-systems studies. A second conference will outline procedures to be used in the contributing studies, and a third conference will be held May 18-19 following the Radioecology Symposium at Ann Arbor, Michigan to plan appropriate systems analysis for the total-systems studies and the contributing studies.

Wherever possible the Freshwater and Terrestrial Productivity Subcommittees will encourage interdisciplinary studies that will fit into the proposed programs of the other subcommittees. One or more of the drainage basin studies should be selected in consultation with the Marine Productivity Subcommittee to include the estuarine portion of the system. Close collaboration will be established with the Environmental Physiology Subcommittee, the joint Miometeorological Panel of the U.S. National Committee, and the Committee on Atmospheric Sciences of the National Academy of Sciences. Joint efforts are necessary in the study of microenvironments of animals and plants in relation to their physiology. These efforts will also overlap with the activities of the Production Processes Subcommittee as they relate to studies of nitrogen fixation, photosynthesis and water stress. Collaboration with the Systematics and Biography Subcommittee will be desirable when dealing with aspects of species diversity and the evolutionary significance of environmental selection along gradients.

NOTE.—The following is not the budget of this proposal, but a budget prepared in a second report from the PF-PT subcommittees. It is a request for 1 year of support, and includes an explanation of the moneys needed.

<i>Budget</i>	
Salaries and wages:	
Program Director.....	None
Program coordinator.....	\$15,000
Secretarial services.....	6,000
Staff benefits, 12 percent.....	2,520
Total, salaries and wages.....	23,520
Indirect costs: 45 percent of salaries and wages.....	10,584
Site visits and other travel.....	8,000
Total.....	42,104

BUDGET EXPLANATION

Program Coordinator

The work required to permit collaborative research on ecosystems, and to coordinate the efforts of contributory investigators, is extensive. The fields of Botany, Zoology, Microbiology, Limnology, Soil Science, Hydrology, Geology, and Meteorology are included. Consultation with prospective participants concerning the contributions they can make to the program are imperative. Persuading others to join the program, so as to complete the overall design of ecosystem study,

is another time-consuming but necessary activity. The patience needed to eliminate conflict between related research projects, and to alter each so that the mutual benefit is increased, is difficult to estimate. Assisting in the development of training programs is an additional activity to be undertaken. A Program Coordinator, working with a Program Director, is needed on a full-time basis (12 months) to perform these services.

Initially, however, site selection will occupy most of the time of the Director and Coordinator. There are two sets of information needed concerning selected sites that must accompany intensive studies: (1) comprehensive inventories of the geology, soils, climate, and hydrology of the study areas; and (2) initial characterization of the terrestrial and aquatic plant and animal communities. Precise data on a wide range of weather and hydrologic variables, continuously recorded and reduced to usable form, are necessary in virtually all ecosystem studies. Preparation of the initial inventories and routine environmental monitoring are so expensive that full advantage should be taken of existing installations where technical and logistic support can be provided by the operating agency. There are many field installations in the United States which on the surface appear suitable for expansion. Before any full scale site visits are made, much preliminary screening must be done by correspondence and questionnaires. In some cases advance visits by the Coordinator will prove advantageous. Eventually, visits by the site selection team must be arranged.

Secretarial services

One full-time secretary is required, initially to assist in the correspondence and compilation of information on potential sites, later to handle the routines of program management and data filing. It is expected that the participating project directors will provide for their own needs within their research projects.

Overhead and staff benefits

If the Coordinator is to be affiliated with an institution, such as that of the Director, these items are needed to conform with the hiring policies of the institution, and to provide for space and facilities for the Coordinator.

Site visits and other travel

In the first year, the major activity will be the selection of areas for intensive study. For the reasons given below, the visiting team must comprise six to eight persons. At least five site visits should be made in the first year. The total cost per site visit is estimated to be \$1,200. An additional sum of \$2,000 is needed for other travel by the Coordinator and the Director.

The final evaluation of site suitability requires careful analysis by a team competent to cover all of the research fields listed earlier. Minimally, the team must include terrestrial plant and animal ecologists, a limnologist, a geologist, a meteorologist, and a hydrologist. Competence in soil science and microbiology should also be included. Representatives from other subcommittees, such as CT, SB, and PM will sometimes be needed. At least two members of the group should have had substantial experience in operating complex field operations involving supervision of non-technical labor as well as professional personnel. The team must evaluate the adequacy of existing data, the quality of the environmental monitoring program, the ease with which it can be expanded as necessary, and the adequacy of laboratory facilities and housing accommodations, as well as the ecological suitability of the site for intensive ecosystem studies.

ADDITIONAL INFORMATION

This investigator is attracted to the PF-PT program because the effort is needed, and because ecology is at a stage in development at which such a program can succeed.

The need to know much more than we do about the functional characteristics of whole ecosystems is urgent. Man is increasing his domination of the planet rapidly, and is already embarked upon major programs of environmental alteration. Management programs for whole ecosystems are increasingly being considered. At present we seem to have little more than a trial-and-error approach to such problems, largely because ecosystem analysis as a field of science has just begun to develop.

On the other hand, we know a lot about certain aspects of ecosystems. Over the last 15 years we have accumulated many studies on such features as energy

flow, nutrient cycling, food webs, species diversity, vegetation structure, species associations, stages of succession, etc. It is evident from all of these that ecosystems as wholes are remarkably persistent organizations, even though they may undergo strong fluctuations or permanent changes in species composition. Although these studies document what is going on in ecosystems, they tell us little of how and why ecosystems operate as they do. Furthermore, it is difficult to find any basis for relating energy flow to species diversity, or nutrient cycling to vegetational structure, etc. The different views of ecosystems tend to remain as studies of unrelatable parts of the whole.

These different aspects must be intimately interrelated, since they are but different views of the same whole. The challenge that remains is to discern the whole (especially the how and why of ecosystems). In part this will require putting enough pieces of the same ecosystems together, so that the wholes become evident and the remaining pieces discovered. In part, also, this will require imagination and luck in the development of ecosystem theory that can guide the direction of research. It is this challenge that makes the PF-PT program attractive.

A further description of the work to be done, beyond that given in the PF-PT report, is difficult to make. On February 17-19, the two subcommittees will discuss in detail the criteria to be used for the selection of major sites. Following this, we intend to begin at once on the solicitation of nominations for sites. As soon as any sites are selected, we will begin work on their development. At that point we will be ready to start the major research programs, and help to plan contributory studies.

We plan to have, eventually, several hundred investigators participating in this program. Their projects should, in the aggregate, cost several millions annually. Additionally, such intensive study center, when fully developed, will have cost over one million in development, and several hundred thousands per year for operation. All of this money is to be sought on a normal competitive basis from whatever sources are available. It represents a major diversion of such funds, a shift that will be possible only if many of the most able ecologists wish to participate. For this to happen, the goals of the program must be deemed worthwhile, challenging, and realistic. The advantages of collaborative research, in which data become mutually useful, are a major persuasion for the program.

Perhaps more important, however, will be the hope of reaching new levels of insight, inspiration, or creativity, through the (often turbulent) interaction of minds with different backgrounds wrestling with similar problems.

Vitality of the program depends upon the immediate establishment of the central Task Force as an agency of design and development. This in turn requires the full-time effort of at least one qualified ecologist, which is the Program Coordinator in this program.

FACILITIES

The School of Natural Resources offers adequate space for the work and staff proposed in this proposal. All of the regular services will be supplied. The computer facilities of the University are available on a cost basis. The School now has its own card punch machine, and will soon have a remote entry console (the new computer is in the process of installation).

PERSONNEL

The Principal Investigator of this proposal will be the Program Director of the PF-PT program. In his own work he is intensely involved in ecosystem analysis, beginning with the analysis of models in computers. A progress report attached to this proposal summarizes the first half-year of work with support from NSF Grant GB-5306.

The Research Associate of this proposal will be the Program Coordinator of the PF-PT program. We are fortunate in having a man of exceptional ability and experience for this position, and also one whose training complements that of the Principal Investigator. Not only does a largely terrestrial, botanical training contrast well with an aquatic, zoological one, but experience in agency work contrasts well with that of academe. As can be seen from his publications, the Research Associate also has strong interests in the ecosystem-level of study, and considerable experience with some of the newer techniques of large-scale study.

Since the Program Coordinator will be full-time on this project, while the Director is at best half-time, the qualifications of the Coordinator are probably

the more relevant to the eventual success of the program. Of equal relevance, certainly, is the contribution of the members of the PF and PT subcommittees (listed in the introduction).

Funds for secretarial services are high enough to secure, at Michigan, a person of considerable experience. We anticipate a great deal of correspondence, and a great many routine activities and decisions that can be made by such a person. The position we have in mind is, on this campus, called that of an "Administrative Assistant".

BIOGRAPHICAL DATA—SMITH, FREDERICK E., PROGRAM DIRECTOR AND PROFESSOR OF NATURAL RESOURCES

Education:

B.S. in Entomology, University of Massachusetts, 1941
Ph.D. in Zoology, Yale University, 1950

Experience:

Instructor, University of Michigan, 1950-54
Assistant Professor, University of Michigan, 1954-58
Associate Professor, University of Michigan, 1958-62
Professor of Zoology, University of Michigan, 1962-66
Professor of Natural Resources, University of Michigan, 1965-

Publications:

- 1951: Quantified estimates of feeding specializations in a system of many predator and prey species. *Bull. Ecol. Soc. Amer.* 32:63.
- 1952: Experimental methods in population dynamics, a critique. *Ecology* 33:441-450. The intrinsic rate of natural increase of the human louse, *Pediculus humanus*, L. (with F. C. Evans). *Amer. Nat.* 86:299-310.
- 1954: Quantitative aspects of population growth. In: Dynamics of growth processes, 11th annual growth symposium. Princeton Univ. Press. pp. 277-294.
- 1956: Energetics and natural selection in prey-predator relations. *Bull. Ecol. Soc. Amer.* 37:78.
- 1960: Community structure, population control, and competition (with N. G. Hairston and L. B. Slobodkin). *Amer. Nat.* 44:421-425.
- 1961: Density dependence in the Australian thrips. *Ecology* 42:403-407.
- 1962: Life Table Methods in Population Analysis. *Bull. Ecol. Soc.* 43:6 (paper title).
- 1963: Density-Dependence. *Ecology* 44:220. Population Dynamics in *Daphnia magna* and a New Model for Population Growth. *Ecology* 44:651-663.

JOHNSON, PHILIP L., PROGRAM COORDINATOR AND RESEARCH ASSOCIATE

Education:

B.S. in Agriculture, Purdue University, 1953
M.S. in Conservation, Purdue University, 1955
Ph.D. in Botany, Duke University, 1961

Experience:

Botanist, U.S. Forest Service, Rocky Mt. Station, 1961-62
Ecologist, U.S. Army Cold Regions Research and Engineering Lab., Photographic Interp. Div., 1962-
Assistant Professor, Dartmouth College, 1963
Research Collaborator, Brookhaven Nat'l. Lab., 1963-65
Adjunct Appointment in Biology, Dartmouth College, 1965-

Publications:

- 1961: Frost features and vegetation types in the Wyoming Alpine Zone. Wyoming Range Management Issue 151:4 p. Alpine plant communities in relation to cryopedogenic patterns and processes. *Bull. Ecol. Amer.* 42:142. (Paper presented AAAS symposium on Arctic-Alpine ecology, Dec. 1961)
- 1962: The Alpine vegetation of the Beartooth Plateau in relation to cryopedogenic processes and patterns (with W. D. Billings). *Ecol. Monogr.* 32:105-135. The occurrence of new arctic-alpine species in the Beartooth Mountains, Wyoming, Montana. *Madrono* 16:229-233.

- 1963: Studies in the physiological ecology of *Populus tremuloides* in the Laramie Mountains of Southeastern Wyoming (with B. R. Strain). Ecology 44:581-584. Infrared detection of heat sources obscured by rain forest vegetation (U) (with J. N. Rinker, T. C. Vogel, J. O. Morgan, and D. C. Parker). USA CRREL Res. Rpt. 149 (Confidential).
- 1964: The application of multiband aerial sensing to problems in plant ecology. Tenth Internat. Bot. Congress, Edinburgh, Scotland. Illustrated summary of the geology of the Yukon Flats (with F. P. Heinsohn, and A. O. Poulin). USA CRREL, Tech. Rpt. 154, 27 p.
- 1964: Report on Phase I. Development of photo analysis methods for factor map criteria and first approximation map overlays (with R. D. Leighty, V. H. Anderson, A. O. Poulin and R. E. Frost). USA CRREL (unpublished report, 56 p.). Report on Phase II. Field verification and preparation of revised factor maps (with R. D. Leighty, V. H. Anderson, A. O. Poulin, and R. E. Frost). USA CRREL. (First and second report in a series of three on the Program "Development and Application of Airphoto Methods to Obtain Mobility Information in Thailand," (unpublished report, 700 p.).
- 1965: Pede-ecological investigations, Barrow, Alaska (with J. Brown). USA CRREL, Tech. Rpt. 159, 37 p. Monitoring radioactive contamination to vegetation with aerial photography, Photogrammetric Engr., 31:984-990. Canopy closure index by an optical density method (with T. C. Vogel). USA CRREL, Tech. Note, 16 p. Investigation of sugar cane vigor with aerial photography in Puerto Rico. USA CRREL, Special Rpt. 93, 38 p. Review of vegetation and soils, a world picture by S. R. Eyre. Economic Botany 19:438-439. Evaluation of an economical instrument shelter for microclimatological studies (with T. C. Vogel). For. Sci. 11:434-435.
- 1966: Selected air-photo patterns of terrain features (with R. E. Frost, R. D. Leighty, V. H. Anderson, A. O. Poulin, and J. N. Rinker). In *Mobility environmental research study for describing terrain for ground mobility*. Vol. 6, 327 p. The eye and the photograph, an entropy model. USA CRREL, Tech. Note, 6 p. U.S. Army CRREL Topographic Map, Barrow, Alaska (with J. Brown). USA CRREL Special Report 101 (in press). Vegetation of the Yukon Flats Region, Alaska (with T. C. Vogel). USA CRREL Research Report 209 (in press). A chemically stratified lake in Alaska (with G. E. Likens). Science 153:875-877. Aerial sensing and photographic study of the El Verde Forest, Puerto Rico (with D. A. Atwood). In *A Rain Forest*, (an intensive gamma radiation experiment in a tropical ecosystem) AEC (in press). Educational needs for remote sensing in ecology. Proc. Fourth Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, 719-726. Application of remote sensing of ecological problems. Proc. International Symposium on Ecology of Subarctic Regions, Helsinki, (UNESCO, in press).

PROPOSED BUDGET—3 YEARS

	1st year	2d year	3d year
Salaries and wages.			
Principal investigator (program director)			
Research associate (program coordinator)			
Secretarial services	\$15,000	\$15,750	\$16,540
Staff benefits	6,000	6,000	6,000
	2,520	2,610	2,705
Total salaries and wages			
Indirect costs: 45 percent of salaries and wages.	23,520	24,360	25,245
Site visits and other travel	10,585	10,960	11,360
Computer time	8,000	2,000	2,000
Publication costs		1,000	1,000
	200	200	200
Total amount requested from NSF			
Total, 3 years	42,305	38,520	39,805
		120,630	

INTERNATIONAL BIOLOGICAL PROGRAM

UNIVERSITY CONTRIBUTION

	1st year	2d year	3d year
Salaries and wages:			
Principal Investigator (program director), F. E. Smith, 10-percent time academic year	\$1,700 205	\$1,785 215	\$1,875 225
Staff benefits			
	1,905 855	2,000 900	2,100 945
Total salaries and wages			
Indirect costs: 45 percent of salaries and wages	2,760	2,900	3,045
Total university contribution (per year)		8,705	
Total contribution (3 years)			

BUDGET EXPLANATION

Most of the items are discussed under the second PF-PT report, containing a suggested budget for one year of support. Three years are asked as a minimal period within which the program can develop.

Computer time is requested for the second and third years in anticipation of the need for rapid filing and retrieval of a great deal of information (not the data from projects, but data about projects). The organization of this information will be a major activity of the person to be hired under funds for secretarial services.

Travel during the first year is primarily for visits to sites by the Task Force, as indicated in the PF-PT report. During the second and third years, funds are needed primarily for the Coordinator and Director, who must continue to visit personnel and places involved in the program.

	1st year	2d year
Salaries and wages:		
Principal Investigator (program director)	\$15,000	\$15,750
Research associate (program coordinator)	4,500	4,500
Secretarial services	2,340	2,430
Staff benefits		
	21,840	22,680
Total salaries and wages		
Indirect costs	9,828	10,206
Travel for director and coordinator	4,000	2,000
Communications	250	250
Computer time		300
Total	35,918	35,436
Total		71,354

Note: University contribution: Unchanged.

Proposed research

The director and coordinator propose the organization of research efforts that enact the joint program of the PF-PT subcommittees. We plan first to assemble a cadre of investigators willing to participate in team research, and to select one major site, both early in the first year.

We will develop overall research designs for intensive analysis of ecosystems as rapidly as possible, and seek additional participants where needed. By the end of the first year (spring, 1968) we hope to have some portions of ecosystem study underway, others at the stage of proposals for support, and designs for fully developed programs well worked out.

By the end of the second year the director and coordinator, working intensively at one or two sites, will have the program well under way. By that time the responses of other investigators, and their willingness to participate in such efforts, will be apparent, and the entire program can be evaluated.

From the start we will promote a program that will be integrated into a whole. One way to foster this is to interlock research projects in a system of cross-classification, such as the following:

One classification of projects that is probably the easiest to set up is a series on different *components* of ecosystems: phytoplankton, zooplankton, fish, benthos, insects, small mammals, birds, trees, soil faunas and floras, geology, soils, hydrology, water chemistry, etc. The general format achieved in the Cape Thompson study serves as an example of this classification.

Simultaneously, a cross-classification of studies by *aspects* of ecosystems will be organized: nutrient cycles, energy flow, food webs, species diversity, primary production, secondary production, ecosystem stability, patterns of vegetation, etc.

Since the two sets of studies intersect repeatedly, data-sharing will be beneficial. Since data-sharing is essential to the success of the larger goals of the program, intersecting interests will be promoted whenever possible. A major task will be to preserve a sense of professional security and individuality within a system of data-sharing.

The above organization will be repeated, as rapidly as possible, in a number of contrasting biomes. This will provide a research base upon which the development of ecosystem analysis may proceed.

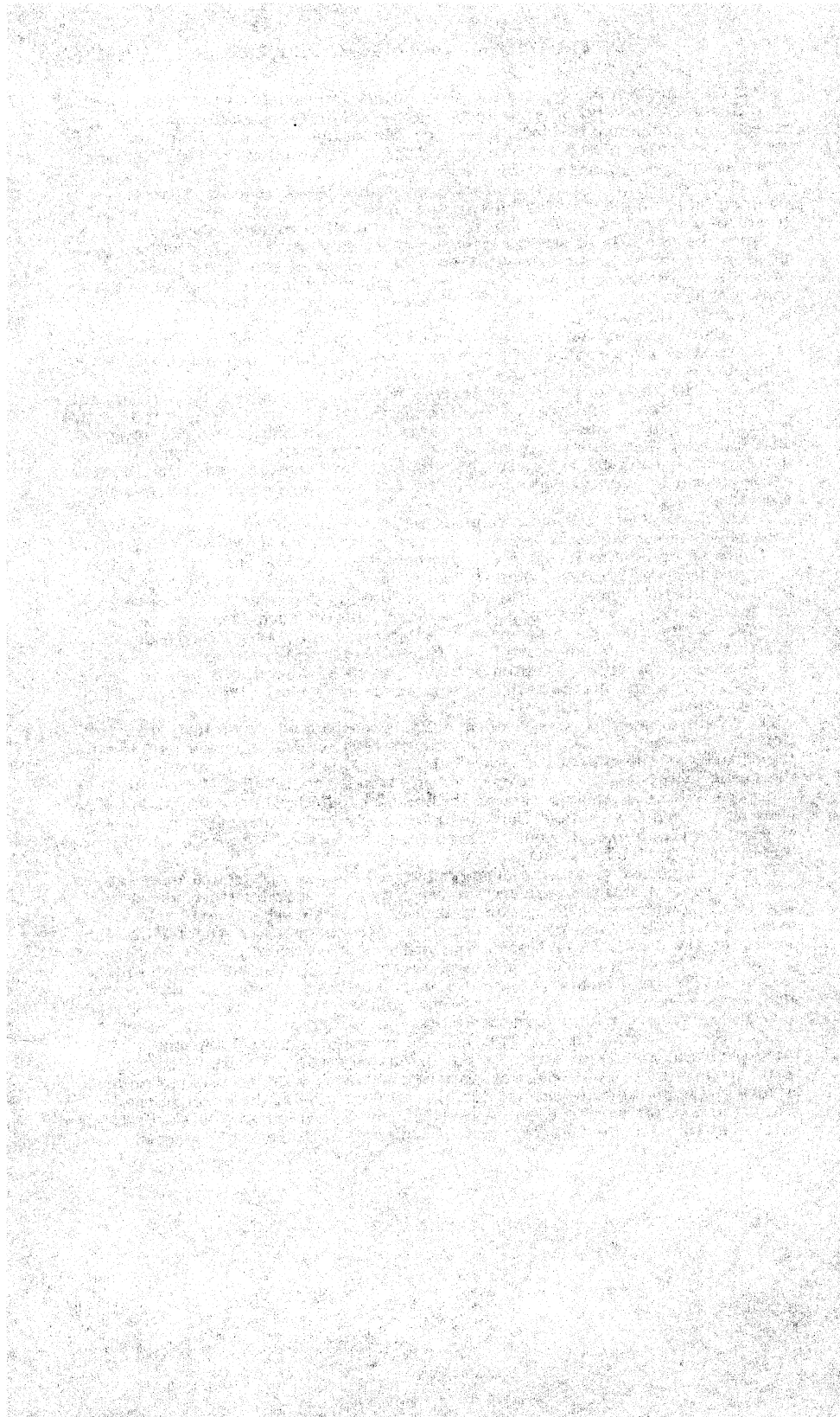
Most of the ideas for ecosystem analysis will be generated by the participants, who will be urged to maintain a continuing analysis of their data as it is gathered. These will guide the further design and modification of the program. The following suggestions are offered as a few examples of problems that require participation by a number of different investigators, and that can be accomplished by careful coordination without the sacrifice of more immediate objectives.

I. Each tree species is most common at some level of moisture or temperature, and is less common at higher or lower levels. An entire range of tree densities may be encountered within one drainage basin. If the capacity for growth of each species is greatest where it is the most common, it follows that some form of environmental resistance (of a density-dependent nature) is also maximal there. It may be possible to detect this in such measures as insect damage, if the studies are designed to sample the full range of tree densities. Possibly, also, a technique such as infra-red photography can show differences in reflectance for trees in optimal compared with sub-optimal habitats, each species showing its own pattern and appearing to be most vigorous where it is most common.

II. Wherever species can be adequately censused and controlled, manipulation of population density upward and downward will be included as a test of the capacity of the system to restore balance. If this is done in various areas of the basin, in various trophic levels, and in various food chains, the results may show the pattern of distribution of stabilizing capability in the ecosystem. The location of "sensitive" spots that regulate poorly may illuminate our concepts of ecosystem stability (I would hazard these to be at the green-leaf-herbivore link of the terrestrial system).

III. Plankton show extreme density fluctuations and strong seasonal succession, yet show a surprising degree of repetitiveness over long periods of time. The ways in which such long-term stabilities are achieved, the extent to which seasonal cycles are incorporated into such mechanisms, and the factors that determine the durations of blooms and order of succession, may be discovered if sufficient detail on enough components are combined. The roles of the higher trophic levels are probably of great importance, and a complete limnological analysis seems essential. A final systems analysis of "unsteady states" that nonetheless remain within extreme limits, will be particularly interesting.

IV. Insect dispersal affects both the food web and nutrient dispersal in both terrestrial and aquatic ecosystems. An extensive record of aerial dispersal by trapping, and of drift in streams, can be combined with intensive population studies in the appropriate habitats. In this way the role of dispersal in the integration and organization of the ecosystem can be evaluated. This will be of particular value in the interrelations of aquatic and terrestrial systems.



APPENDIX B

**U. S.
PARTICIPATION
IN THE
INTERNATIONAL
BIOLOGICAL
PROGRAM**

THIS IS REPORT NO. 2 OF THE U. S. NATIONAL COMMITTEE FOR THE INTERNATIONAL BIOLOGICAL PROGRAM. REPORT NO. 1, ISSUED IN AUGUST 1965, WAS ENTITLED "PRELIMINARY FRAMEWORK OF THE U. S. PROGRAM OF THE IBP".

PREFACE

In this report, the U.S. National Committee for the International Biological Program summarizes some of the key issues in the general question of biological productivity as it relates to human welfare. Much of the material in the report was developed at a conference held at Williamstown, Mass., in October 1966. The conferees were members of the National Committee, its subcommittees, and invited participants. The subcommittees prepared reports that accentuated issues which they considered of vital importance to man's future. (Individual subcommittee reports may be obtained by writing to: IBP Office, Division of Biology and Agriculture, National Research Council, 2101 Constitution Avenue, N.W., Washington, D.C. 20418.)

The National Committee's report has two main parts. In the first, problems highlighted by the subcommittees are described; in the second, a number of suggested actions are brought up for consideration. We hope these problems and suggested actions will encourage U.S. biologists to respond to the challenges of the International Biological Program.

The U.S. part of the International Biological Program will develop from (1) presently established research projects related to the objectives of the International Biological Program that can be expanded, accelerated, or made more significant through international cooperation, and (2) new projects arising out of problems and opportunities described herein. The summaries in this report are presented with the aim of stimulating U.S. biologists to review their current research and to suggest both new and ongoing projects that would contribute to solving the problems with which the IBP is concerned.

Report No. 3 of the National Committee will consist of descriptions of ongoing IBP research projects. Part 1 is near completion. Copies may be obtained by writing to the IBP office (see above).

U.S. National Committee for the
International Biological Program

CONTENTS

INTRODUCTION	232
THE INTERNATIONAL BIOLOGICAL PROGRAM	234
PROBLEM AREAS	237
Population dynamics	237
Dynamics of ecosystems	238
Adaptation to environment	239
Geographic description of the biosphere	242
Preservation of natural ecosystems	242
Limitations of primary production	243
Nutrition	244
Use and management of biological resources	245
Education and manpower	246
PLAN OF ACTION	247
Environmental physiology	247
Production processes	249
Productivity of marine communities	249
Human adaptability	249
Nutrition	250
Productivity of terrestrial and freshwater communities	250
Conservation of ecosystems	252
Systematics and biogeography	253
Human resources	253
APPENDIX	254
Guidelines for participation in the International Biological Program	254
Organization of the IBP in the United States	254
U.S. National Committee	255
IBP subcommittees and Biometeorology Panel	255
Alphabetical list of members of U.S./IBP organization	256
Alphabetical list of countries participating in the International Biological Program ..	257

INTRODUCTION

In our times of unprecedented change, biologists are well aware of the rapidly growing ability of their fellow human beings to alter the face of the earth through technology. But they are equally aware that these alterations can bring about far-spreading and often destructive changes in the web of life that is stretched so thinly over the surface of our planet. Our technology has outpaced our understanding, our cleverness has grown faster than our wisdom.

Technology produces more than physical change. With his new-found powers man has also radically altered part of his own biology: on a worldwide basis, his average length of life has nearly doubled during the last few decades. In many regions of the earth this rise in life expectancy has not increased human happiness; rather it has multiplied human misery. To achieve a decent life for the living generation, further change in our biology may be needed: we may have to reduce fertility as reckoned on a worldwide basis to levels below any previously attained. To meet the needs of human life and human dignity, there must also be a vast increase in productivity, and this will be doubly true for the generation that will be born before the end of this century.

Because of our limited understanding of the relationships among living things, we are limited in our ability to predict the effects of technical change or to help the technologists conserve the values and utilize the abundance of the world of life. Our goal should be not to conquer the natural world but to live in harmony with it. To attain this goal we must learn how to control both the external environment and ourselves. Especially we need to learn how to avoid irreversible change. If we do not, we shall deny to future generations the opportunity to choose the kind of world in which they want to live.

Greater understanding will make it possible for man to respond to opportunity as well as to react to need. To gain such understanding is the underlying purpose of the International Biological Program.

This program has three related objectives: human welfare, scientific advance, and international scientific cooperation. These three objectives cannot be separated. Biologists can

contribute uniquely to human welfare only by advancing scientific understanding, and the basic premise of the International Biological Program is that the growth of understanding will be accelerated by international cooperation among the world's biologists.

To be effective the program should focus on problems whose solution most depends on international cooperation in biological research. Accordingly we are concerned with conserving and expanding the world's biological resources to better serve human needs, with the quality of the natural environment as a realm of human happiness, with nutrition as a basis for human health, and with the biological aspects of the problem of balancing human fertility and natural resources. Our scientific objectives are also limited. Our basic interest is the development of scientific ecology in its broadest sense. We believe we should give special emphasis to the genetics and dynamics of populations, to the factors that control biological productivity, to the ways in which plants, animals, and especially men, adapt to their environment, and to the changing distribution of living things in the sea and in the air and on the land. If scientific opportunities are to be created for the future, scientists of different countries will need to cooperate in preserving natural areas as well as in research.

Because most of the land surface and many of the most interesting problems lie within the territories of less developed countries, international cooperation in the scientific development of these countries is not only desirable in itself but is also essential to attain the scientific objectives of the IBP. These objectives will be achieved only if there is a free exchange of scientists for research and training among different countries, and a broad and rapid flow of scientific information.

New methods must be developed and old ones greatly extended. In the past, ecologists have studied particular limited communities; now, work on a few large-scale systems is needed to test and extend our understanding. New techniques for worldwide biological surveys (perhaps by satellites as well as in other ways) are needed to improve our description of the biosphere. Greater comparability of methods of measurement

and adequate arrangements for data handling are needed for a better appraisal of its productivity.

Field research in appropriate environments by scientists of different biological disciplines will be an essential aspect of the program. This will be most effective if different kinds of research can be undertaken in the same areas; thus a few carefully selected and well-described international research sites would prove highly beneficial. Only a relatively small number of biologists are skilled in the use of modern methods of field research or in studying the interactions among organisms in large ecological systems. The training of young scientists, particularly those from less developed countries, must be a basic component of the entire program.

Each of the subcommittees of the U.S. National Committee will sponsor investigations and other projects within its field of interest. But experience has already shown that each of these subcommittees will interact in many ways with the others. Thus the program as it develops will, we believe, have a growing unity. This will be true also for the relationships between U.S. scientists and the international sections of the Special Committee for the International Biological Program.

The U.S. National Committee and its counterpart within the Federal Government, the Interagency Coordinating Committee, can have only minor roles in this great enterprise. If the United States is to play its part, U.S. biologists, working as individuals or in groups, must assume most of the responsibility. Many U.S. scientists are already engaged in research projects that would be appropriate components of the IBP, especially if the scope and significance of their work could be increased by international cooperation. We hope to stimulate and facilitate such cooperation wherever possible. Other scientists may find opportunities to initiate new research projects that will benefit from or contribute to the IBP. The chief purpose of this report is to outline some of the opportunities and to encourage U.S. biologists to think of others.

Roger Revelle
Chairman

U. S. National Committee for the
International Biological Program

THE INTERNATIONAL BIOLOGICAL PROGRAM

The idea for an international biological program was voiced early in 1959 in discussions between Sir Rudolph Peters, President of the International Council of Scientific Unions, and Professor G. Montalenti, President of the International Union of Biological Sciences. Acting on suggestions by the Union, the Council appointed a planning committee under the chairmanship of Professor Montalenti. In May 1962 the committee outlined a proposed international biological program. In November 1963 the concept and general plan were approved by the Executive Committee of the Union and by the Tenth General Assembly of the International Council. The preamble of the report stated:

"As a consequence of the rapid rate of increase in the numbers and needs of the human populations of the world and their demands on the natural environment, there is an urgent need for greatly increased biological research.

"It is proposed that there shall be an International Biological Program (IBP) entitled The Biological Basis of Productivity and Human Welfare, with the objectives of ensuring a world-wide study of: (1) organic production on the land, in fresh waters, and in the seas, so that adequate estimates may be made of the potential yield of new as well as existing natural resources, and (2) human adaptability to the changing conditions.

"In proposing such a program it is considered essential that it shall be limited to basic biological studies related to productivity and human welfare, which will benefit from international collaboration, and are urgent because of the rapid rate of the changes taking place in all environments throughout the world."

The planning committee further recommended that the program be developed on the basis of seven sections, each dealing with a distinct area of concern, as follows:

- Productivity of Terrestrial Communities (PT)
- Production Processes (PP)
- Conservation of Terrestrial Communities (CT)
- Productivity of Freshwater Communities (PF)
- Productivity of Marine Communities (PM)
- Human Adaptability (HA)
- Use and Management of Biological Resources (UM)

The International Council of Scientific Unions established a Special Committee for the IBP

(SCIBP) and made it responsible for organizing and implementing the Program. SCIBP consists of about 35 scientists—representatives of the International Council and the constituent unions, the convenors of the seven IBP sectional committees, regional representatives, a president, four vice presidents, and a scientific director.

The 2-1/2 years of preparation (phase I) will come to a close in July 1967. At that time the operational phase (phase II) will begin; it is expected to continue for 5 years.

In the United States, the International Biological Program is sponsored by the National Academy of Sciences through a National Committee appointed by President Frederick Seitz. Nine subcommittees have been established. Seven of these correspond to the seven sections of the international organization. (The U.S. subcommittee corresponding to the international section on Conservation of Terrestrial Communities is known as the Subcommittee on Conservation of Ecosystems.) The two additional subcommittees are the Subcommittee on Systematics and Biogeography and the Subcommittee on Environmental Physiology.

Late in 1965 Federal interest in the International Biological Program was formally expressed in a letter from Dr. Donald Hornig, Director of the Office of Science and Technology, to Dr. Leland Haworth, Director of the National Science Foundation. The Foundation was asked to coordinate activity in this area. In response, an Interagency Coordinating Committee was formed with Dr. Harve Carlson of the Division of Biological and Medical Sciences, NSF, as chairman. Representatives from the following agencies make up the Committee:

- Atomic Energy Commission
- Department of Agriculture
 - Cooperative State Research Service
 - Forest Service
 - Agricultural Research Service
- Department of Commerce
- Department of Defense
 - Office of Naval Research
 - Air Force Office of Scientific Research
 - Army Research Office, Life Sciences Division
- Department of Health, Education, and Welfare

National Institutes of Health
 Public Health Service, Office of International Health
 Office of Education, Division of Graduate Programs
 Bureau of State Services, Environmental Health Department of the Interior
 Department of State
 International Sciences and Technological Affairs
 Agency for International Development, Nutrition Branch
 National Aeronautics and Space Administration
 Smithsonian Institution

The U.S. National Committee is a planning and coordinating group supported by funds provided through the Interagency Coordinating Committee—it has no funds for direct support of research.

Following are the subcommittees of the U.S. National Committee and definitions of their programs:

Productivity of Terrestrial Communities (PT) in collaboration with **Productivity of Freshwater Communities (PF)**. This subcommittee will concentrate on ecosystem function, including: (1) productivity and its utilization, with emphasis on primary and secondary energy flow within the framework of the concept that man is both manipulator of and a functional component of his environment; (2) circulation of nutrients, with emphasis on vital processes of decomposition and the nutritive base of production; (3) pollution and other disturbances that affect production in and composition of ecosystems; (4) search for means of integrating data on components within a systems-analysis or other statistical-model framework.

Production Processes (PP). This subcommittee is encouraging studies on recognized specific problems, including: (1) physiology of plants under water stress; (2) frost resistance and the growth limitations imposed by upper or lower temperature thresholds; (3) restricted rooting volume due to low base status, acidity, and aluminum toxicity of the soil, especially in tropical areas, and physiological studies of root growth and root rhizosphere interaction; (4) problems of nitrogen fixation, including (a) assessment of regional bases (types of soils and climates) of the magnitude of nitrogen fixation; (b) factors influencing rate and magnitude of fixation; (c) potential fixation in inadequately studied areas such as the Tropics, the Arctic, and the hydrosphere; (d) distribution of organisms and symbiotic systems that bring about fixation; (e) nitrogen budget and cycle as related to primary production; (f) systematics of nitrogen-fixing organisms; (g) the biochemical mechanisms of fixation and physiological processes associated with the reaction. The subcommittee believes that a study of these specific problems will ultimately lead to a more general treatment of broader problems.

Conservation of Ecosystems (CE). This subcommittee is concerned with freshwater and marine conservation as well as terrestrial, and will help to provide the scientific basis for the preservation of natural and research areas. The program includes: (1) establishment of criteria by which ecosystems can be described and classified; (2) registry of areas now available for research; (3) selection of types of areas still needed to complete a system of research reserves representative of American ecosystems; (4) identification of types of ecosystems and species threatened by destruction; (5) ecological surveys of American sites for concentrated multidisciplinary studies; (6) provision of scientific data in support of the preservation of natural research areas.

Productivity of Freshwater Communities (PF). In collaboration with **Productivity of Terrestrial Communities (PT)**, efforts will be concentrated on a selected stream and a selected lake and their drainage basins. Areas of research will include: (1) detailed analysis of aquatic and terrestrial communities; (2) soil and geological descriptions; (3) transfer of material from air, soil, and bedrock to water and the reverse; (4) nutrient cycling; (5) role of organic substances, as in eutrophication; (6) population dynamics at all trophic levels; (7) role of bacteria in trophic dynamics and decomposition; (8) energetics of the ecosystems; (9) migration of organisms; (10) computer analysis and synthesis of biotic and other variables. Other general objectives include studies of eutrophication, primary and secondary production, fish production, the chemical environment, production in man-made lakes, and production under extreme environmental conditions.

Productivity of Marine Communities (PM). Because studies of the open ocean are already included in other international programs and because man's influence is most marked on estuaries and inshore waters, this program will emphasize the latter. The approach will include: (1) ecosystem analysis as a central problem involving hydrology, solar radiation, nutrients, dissolved and particulate organic matter, phytoplankton pigments, rate of photosynthesis, and the abundance and biogeography of benthos, phytoplankton, zooplankton, and fishes; (2) human food resources; (3) natural and artificial modifications of the environment; (4) distribution and abundance of organisms; (5) development of better understanding of basic ecological mechanisms.

Human Adaptability (HA). The goals of this subcommittee are to measure the distribution and identify the sources of variability of man's adaptive capacity and to elucidate the processes of adaptation. In fulfilling these goals, the subcommittee will undertake studies on a variety of human populations ranging from hunting and gathering groups to industrialized societies which exhibit significant contrasts in genetic background, habitat, and culture. Special attention will be given to the biological adaptation of isolated and migrant groups. The emphasis will be on population dynamics, human genetics, adaptation to stress, and morphology, growth, and aging. In studying adaptations, the subcommittee is especially

concerned with (a) fecundity and fertility, (b) adaptation to undernutrition, and (c) adaptation to disease.

Use and Management of Biological Resources (UM). This subcommittee will emphasize: (1) development of plant gene pools of important groups—especially tropical groups, including rubber, pulses, cocoa, and coffee; (2) use of blood lines as means of identifying and locating potentially useful genetic material for different animal species; (3) biological control; (4) nutrition, with emphasis on protein supply, fatty acids, nutrient-intake levels, establishment of norms, food resources correlated with human needs, means of food preservation, and the incidence of human disease and parasitism as related to nutrition; (5) relation of total biological resources to human nutrition for various countries; (6) growth and ecology of cereals; (7) little exploited sources of protein, both animal and plant; (8) development of microbiological processes for food production.

Systematics and Biogeography (SB). This subcommittee has adopted the following projects and encourages suggestions for additional ones: (1) participation in the ecological surveys of other sections of IBP, especially PT, PF, PM, and HA; (2) salvage operations in natural areas where species and communities are threatened with extinction; (3) comprehensive descriptions of marine ecosystems, particularly where changes may be imminent, as on both sides of the Isthmus of Panama; (4) studies of endemism, extinction, and inventory of local biota.

Environmental Physiology (EP). This subcommittee has construed its terms of reference broadly as (1) physiology of population dynamics with emphasis on (a) understanding of the dynamics of both cosmopolitan and limited populations, (b) factors determining

population equilibria and geographic differentiation, including genotypic and environmentally induced variation in key species of the tropics, estuaries, oceans, deserts, and freshwater; (2) physiological mechanisms of adaptation at individual levels and as bases for community structure, including (a) chemical defense methods and (b) response and survival in extreme environments; (3) description of the biosphere and changes occurring therein because of the impact of the expanding human population and industrialization.

The U.S. National Committee as a whole will be concerned with encouraging multidisciplinary and international cooperation; with the development of instruments and methods; and with the training of personnel to offset shortages in many vital areas of the Program. One of the premises of the International Biological Program is that the work of national committees will not be restricted to their national boundaries; it is expected that they will work elsewhere in coordination with others and may, as appropriate, concentrate attention on selected regions of the globe. Some U.S. scientists have evinced special interest in the American Tropics and in working with Latin American colleagues. The U.S. National Committee looks forward to cooperating in development of research centers in these environments as well as in desert, grassland, deciduous forest, coniferous forest, and arctic environments in the Western Hemisphere and elsewhere in the world.

PROBLEM AREAS

POPULATION DYNAMICS

If man is to stabilize population by means other than starvation and disease, he must learn more about the dynamics of human societies and about regulation of plant and animal populations.

Neither the distribution nor the sources of man's variability in the adaptive process have been rigorously measured. The International Biological Program provides an opportunity to sort out these aspects of variability according to their relative importance and to discover underlying mechanisms through collaborative studies of different groups whose contrasting genetic, social, nutritional, meteorological, and environmental backgrounds are carefully documented.

Genetics and Variability of Human Populations

Mankind possesses great diversity both within and between populations. This diversity has been the basis of the evolutionary success and of many of the present problems of the species.

It is obvious that long-term changes in the human population have occurred and that the environment of man is changing rapidly both physically and culturally. Description and explanation of the underlying processes of change are essential to understanding population dynamics. Whereas individuals succumb to critical changes in environment, populations adapt, genetic selection being the principal process leading to this adaptation.

Of crucial relevance are the processes determining transmission of genetic material from one generation to the next.

A partial listing of forces and processes entering into population genetics follows. Each is a problem for IBP research.

Mating choices and patterns, including inbreeding, outbreeding, and assortative mating

Fertility

Fetal wastage

Age and sex-specific mortality

Postnatal natural selection

Fluctuation and disappearance of populations

Hybridization between populations

Behavior genetics

Genetic drift and founder's principle

The range of human populations available for this type of investigation should make possible a thorough assessment of variability. At one extreme are the relatively few surviving examples of hunting-gathering and incipient agricultural populations. Some of these groups (the South African bushman, the Australian aborigine, the Eskimo, certain tribes of Central and South American Indians) are disappearing so rapidly, culturally if not biologically, that it seems especially appropriate that the International Biological Program should encourage multidisciplinary studies on them without delay—studies that would provide invaluable baselines for subsequent investigation of a variety of other populations.

Special attention should also be paid to biological adaptation of racial isolates from industrialized societies and migrant groups moving from one environment to another. Examination of migrations by different racial groups that have settled in the same or similar environments is desirable. Use of baseline studies from the original environments would be particularly valuable.

Regulation of Plant and Animal Populations

Mechanisms are known, or suspected, which stabilize populations of certain species in ways other than by limitation of nutrients or by predator and disease depredation. While these mechanisms may not be directly applicable to man, knowledge of them would permit biologists to view the human population explosion in fuller perspective.

It would be helpful to know more about factors determining population equilibria. Two approaches hold promise: (1) ecological population analysis, and (2) analysis of physiological mechanisms of variation. The former includes study of reproductive rates and patterns, interorganismic competition, food chains, and predation. The latter deals with biochemical and physiological variation and mechanisms of feedback interaction between organisms and the environment.

DYNAMICS OF ECOSYSTEMS

Man's activities are upsetting natural conditions in many parts of the world. They are changing all of the world's biotic communities and have altered much of the earth's surface. Many of these changes are not well understood, and basic information is needed if natural resources are to be more effectively and efficiently managed.

It is most urgent that studies be undertaken leading to a clear definition of existing conditions, to an understanding of the mechanisms and processes that control the various components of an ecosystem, and to a better comprehension of the interactions among the components of these ecosystems. Emphasis should be placed on primary productivity and its meaning for man, on trophic structure, energy-flow pathways (food chains), limiting factors, interactions of species, biogeochemical cycling, species diversity, and other attributes that interact to regulate and control the structure and function of communities.

Terrestrial and Freshwater Ecosystems

The program will not be restricted to natural areas, but will include comparison of ecosystemic processes in environments under various degrees of control by man. Ecological succession should serve as a background in which the general objectives can be pursued. The principles of succession are central to the growing difficulties in the relation between man and nature; yet very few of the generally accepted ideas concerning succession have been tested experimentally or related to whole landscapes as they exist at any one time.

Solution of the basic problems of productivity requires investigations on a broad front and at various levels of complexity, including laboratory studies of individual species, studies of species and populations in their natural habitat, studies of communities of organisms in a restricted habitat or environment, and multidisciplinary studies of complex ecosystems.

Knowledge of the population structure of the individual species, the ways in which they interact, and the extent to which these communities, aquatic or terrestrial, can be manipulated will lead not only to the development of a new level of ecological theory but also to practical increases in productivity.

Marine Ecosystems

An interdisciplinary study of a representative marine ecosystem seems long overdue. Before we can hope to understand relevant processes and to predict the result of changes in the natural environment, we must assess not only the organisms and their population density but also (1) the relation between one species and another, and (2) the effects of seasonal changes, fluctuations in chemical factors, exchange between the water and bottom sediments, and other variables.

An ecosystem approach is necessary because a number of problems confronting biologists relate not just to individual organisms or a single species but to an entire complex of societies and communities of organisms. In the marine environment, physical, chemical, and geological processes and conditions may affect, even control, the ultimate success of organisms and of populations. A complete ecosystem study requires the cooperative effort of many specialists.

Analyses are most likely to be successful where the life cycles of the dominant organisms are short and the number of trophic levels few, for duration and frequency of field observations are thus reduced. However, since the structure of a biotic community is determined more by the history of environmental conditions than by circumstances at a given time and place, observations must be continued long enough to provide just such a history. For a major ecosystem, this implies a series of observations continuing for some years. Observations will require enlightened insights into causal relationships, insights that can perhaps be best developed through intensive studies of selected processes and mechanisms, in both field and laboratory.

The diversity and multiplicity of observations needed make it clear why the ecosystem approach has been applied to marine communities imperfectly and infrequently. No individual possesses all the abilities and interests required. Only by a coordinated attack can we hope to solve some of our major problems (e.g., marine pollution) or to increase productivity by deliberate modification of the sea.

Modification of the Environment

Eutrophication—an Example of Unplanned Modification. Eutrophication of natural waters is an ex-

ample of man's unplanned and often detrimental modification of the environment. This excessive fertilization, a serious problem in lakes, streams, and estuaries, presents a challenge and an opportunity to the ecologist. Since lack of essential nutrients commonly limits biological productivity, increasing the supply, as by addition of sewage wastes to natural waters, should make it possible to increase productivity in ways useful to man. Generally, however, the community structure is changed and fewer species are able to survive and prosper in the changed environment. Species of plants most likely to survive in highly polluted areas are frequently the ones least suitable for food at the higher trophic levels. Isolated examples of this phenomenon are abundant, but biologists do not understand fully the causal mechanisms. Is it simply the result of the higher concentrations of nutrients, or is it due to changes in the proportions of elements? Would addition of trace elements or essential organic compounds maintain the normal community at a higher level? Can biologists and physiologists achieve the understanding of eutrophication needed to increase the yields of useful organisms and minimize the abundance of the undesirable ones? Planned fertilization of an ecosystem might well lead to this understanding, or at least establish the limits of fertilization above which undesirable effects predominate.

Planned Modifications of the Marine Environment. The study of marine ecology by observation and description has not provided fully adequate understanding of marine ecosystems. We need quantitative analyses of ecological processes—analyses that will require appropriate observations of stressed and unstressed systems. An ecologist can hardly expect to obtain data needed for the identification and understanding of critical mechanisms and processes by finding an ecosystem that has been stressed by chance. The deliberate modification of an ecosystem is an obvious alternative.

Promising manipulations include the selective reduction of competitors and predators of resource organisms, the development of artificial reefs, the modification of temperature with waters from powerplant cooling systems, the addition of nutrients from deeper waters or other sources, and the use of pollutants as fertilizer.

In some instances an ecosystem, or some part of one, may be simulated and then subjected to a

series of experimental changes, but this may be costly and time-consuming because of the size of the needed simulant and the length of time needed for eliciting meaningful responses. Miniaturization of an ecosystem may of course provide preliminary information, but one cannot be certain that a miniature will provide reliable predictive information for dealing with a full-scale system.

ADAPTATION TO ENVIRONMENT

Biological productivity depends not only on the flow of energy, food, and water within the system but also on the adaptability of organisms to the environment and on their interactions. Adaptive physiologic differences fall into two categories:

Resistance, which is related to tolerance of environmental extremes by whole organisms, tissues, or enzymes and must be correlated with the natural limits of the species

Capacity, which permits normal activity in an altered but tolerable environmental range

Both are homeostatic in permitting survival and reproduction in an altered environment and can best be evaluated by stress tests.

Cooperative programs involving physiologists, ecologists, biochemists, and geneticists are essential to an understanding of the physiological basis of adaptation. The goal is to understand organism-environment interaction in terms of the feedback controls that are operative at cellular and organ levels. The principles of metabolic adaptation in respect to enzyme synthesis as regulated by substrate end products have been studied, especially for micro-organisms. The possibilities of applying these principles to regulation with respect to such physical factors as temperature, salinity, and oxygen in the environment are poorly known.

Adaptability of Natural Populations

Studies are needed that will reveal population differentiation and give us a better understanding of adaptability of natural populations. The first step might be to test populations of animals and plants of the same or related species from different regions for their adaptive capacity. Next, behavioral variations of the same or related

species could be identified. Physiological variation may arise genotypically or be environmentally induced, aspects which can be examined in nature or in the laboratory.

In analyses of resistance adaptations and of capacity to adapt (rate functions), comparisons must be based on measurements acceptable to workers in different localities. Data on temperature, salinity, specific ions, photoperiod, available oxygen, and nutrients are, of course, commonly assembled. In comparative studies, the factors selected for attention should be examined at each stage of the life cycle and in each component of a population. For example, if nutrient exploitation is singled out for investigation, it should be studied in young and adult, in male and female, and in various other manageable subdivisions of the population. Of particular importance are physiological, ecological, and genetic analyses of populations of selected species of the following groups of plants and animals:

Species of Expanding Range, Including Those Dispersed by Man. Some of these are cosmopolitan and others are more restricted. Examples of colonizing species include the house mouse, English sparrow, starling, certain cockroaches, toads, cultivated fish (such as *Gambusia*), bracken, and members of the families Compositae and Gramineae. Ecological and physiological convergence under similar environments in different areas of the world deserves analysis.

Polar and Alpine Species. International cooperation could significantly broaden the base for studies of widespread high-latitude and high-altitude species.

Tropical Species. An active research program based on cooperation with stations and organizations in the American Tropics is desirable. An attempt to understand the enormous diversity of species in the Tropics and their often relatively small populations and narrow ranges merits high priority.

Estuarine and Marine Species. Limiting factors, isolating mechanisms, and physiological adaptations of marine species are poorly known. Many estuarine plants and animals occur in salinity gradients, temperature levels, and dissolved oxygen concentrations that may be relatively stable or may vary as the tide shifts. Some marine and estuarine organisms occur, both with

and without species replacement, over geographic ranges where environmental gradients are marked.

Comparison of individual organisms from populations of the same or related species and from different locations should clarify physiological factors involved in abundance, distribution, and speciation. Measurements of adaptive functions should be made in many places.

Organisms in the sea, like those on land, are spottily distributed. Patterns of distribution and behavior vary with age. For example, species that are sessile as adults are frequently pelagic during larval stages, and mobile species that concentrate near shore during juvenile stages move into deeper water and migrate successively longer distances as they grow older. Why and how do marine species concentrate in certain places and avoid others? Finding the answer calls for surveying and mapping entire distributions of species at all life stages, along with significant properties of the environment. This necessitates simultaneous, systematic collections of data and material at frequent intervals to demonstrate the shapes and limits of distribution.

Adaptability of Plants and Animals to Environmental Stress

Extremes of temperature, moisture, radiation, oxygen levels, salinity, pressure, gravity, and other factors have relevance for the International Biological Program in that they limit distribution and activity of organisms, and these organisms vary widely in capacity to respond and to survive under extreme conditions.

Certain aspects of stress physiology have been extensively studied in medical, military, and space science laboratories, but additional studies leading to a broader understanding of additional species, subspecific strains, and life stages are needed. Investigation of acute and chronic exposure at various levels of stress intensity should be included in these studies.

Studies are also needed that will lead to clearer understanding of the roles of intra- and inter-specific chemical defense mechanisms. Susceptibility to naturally occurring antibiotics, growth inhibitors, and toxic exudates appears to vary from species to species and may affect community composition in general; in addition, it may have direct impact on human welfare when it concerns the specific reaction of a crop plant to a given weed species. We should determine the extent to which

intra- and inter-specific toxicities encountered in the laboratory obtain under natural conditions.

Human Adaptability to Environmental Stress

Stresses may be defined as those conditions which impose measurable consequences upon individuals and populations. They may involve both stimulus deficiencies and excesses. They are specific to individuals, and are recognizable by behavioral, physiologic, morphologic, and, ultimately, genetic characteristics. An inventory of stresses significant to historical and current phenotypic adaptations and selection in man includes an array of physical, nutritional, disease, and behavioral factors.

Stresses in Growth and Development. The inadequacy of our knowledge of developmental and environmental factors creates an urgent need for research in the following areas:

Early (prenatal to young child) human development in relation to environmental stress

Physical as related to behavioral development

Adaptive aspects of child development

Formation and chronological development of physiological adjustment to heat, cold, hypoxia, and physical exertion

These studies would be particularly valuable if they compared genetically distinct populations and if longitudinal as well as cross-sectional investigations were included.

Stresses Related to Climate. Among the research areas of importance here, four seem to merit special attention:

Cold tolerance—comparative studies of whole-body cooling, metabolic adjustments to standard cold stresses, and local vascular adjustments to cold

Heat tolerance—comparative studies of body temperature and regulatory responses of limited numbers of subjects under standard work-heat stress (or regulatory responses of larger groups of subjects performing standard work under field conditions in hot climates)

High altitude—examinations of blood, body fluids, metabolism, respiratory function, and circulatory responses of subjects under basal conditions and in standard work tests

Exertion—metabolic, respiratory, and circulatory adjustments of subjects to a standard aerobic work test, and to strenuous exertion designed to determine both aerobic and anaerobic capacity

Nutritional Stresses. Because the effect of nutrition on stress resistance is very poorly understood, specific investigations of the relations between nutrition and disease resistance, and between nutrition and thermal regulating processes, should be undertaken and should emphasize genetically distinct properties. Studies of this kind would be most valuable if directed mostly to young children.

Similarly, adjustments to undernutrition should be examined. By morphological, behavioral, and biochemical changes, human populations and individuals have been able to survive in nutritional circumstances that would be considered inadequate by most criteria—such groups or individuals might almost be said to have adapted to undernutrition. But the consequences of this adaptation are not well known and a critical worldwide determination is essential as a basis for predicting the outcome of particular nutritional regimens. Such a study should consider the norms for sex, age, and related factors, and should be correlated with evaluations of human physiological response in differing situations and locations.

Disease Stresses. Disease acts as an agent of natural selection. Among the maladies that might profitably be studied in this context are tuberculosis, malaria, syphilis, Hanson's disease, Chagas' disease, trypanosomiasis, trichinosis, and schistosomiasis. Emphasis should be placed on intensity of infection and differential epidemiology in selected populations. Related data on genetics, nutrition, and other factors could be advantageously accumulated.

A second concern is with overall morbidity patterns within selected populations. One objective would be to gain information regarding differential susceptibility—e.g., data on exposure to disease as indicated by titers of antibodies and data on reactivity to disease as indicated by development of clinical illness.

Allergic diseases represent a third area to be emphasized. Of particular concern is the extent to which these diseases stem from industrialization, from manipulation of the ecosystem, and even from preventive and therapeutic medical practices. In a sense, allergic diseases are failures of adaptation and thus highly relevant to the question of human adaptability.

Human Activity

Actual cycles of human activity, whether life, circadian, or seasonal, have been seen often to depart markedly from idealized norms. There is in fact virtually no body of observational and quantified data other than that on limited groups within Western society. It would be most valuable, then, to have research in (1) activity cycles in peoples of varying cultures; (2) human energy budgets related to specific activities; and (3) sequences and skills involved in various activities, such as exploitation of the environment, hunting, running, and burden bearing. Obviously, the studies should be designed to provide information on both the individual and the population.

GEOGRAPHIC DESCRIPTION OF THE BIOSPHERE

The International Biological Program will make it possible to assemble data from widely scattered sources to an extent not hitherto feasible. In several sample areas, this seems an especially promising approach.

Diversity of the World's Biota

Ecosystems are composed of many species of animals and plants, each uniquely adapted to its environment and all to a greater or lesser extent dependent upon one another. Each locality, even within a given ecosystem, tends to be composed of a somewhat different assemblage of species. Many of these species are highly localized. Much interest and importance attach to the systematics and biogeography of the diversity of species. Investigations that will contribute data on the vast diversity of the world's biota are to be encouraged.

There is a dearth of knowledge on the biota of islands, particularly small islands, and of caves. To what extent is this also true of localized biota, particularly endemics, on continental areas? What are the distribution patterns of a given species? How many species in a given fauna or flora are widespread, how many are of limited range, and how many are extremely localized? What difference is there between different organisms with respect to localization of species? Answers to these questions are to be had by the often tedious assembly of large masses of information on a wide geographic scale.

The Biology of the Atmosphere

The composition of the atmosphere is influenced by both biologic and nonbiologic factors; hence it is necessary for biologists to work with geochemists and geophysicists. It is important to know what effects pollutants, originating in factories and elsewhere, are having on the earth's atmosphere and on living organisms.

What are the biological effects of increasing atmospheric carbon dioxide, or of possible reduction in oxygen, on the growth of plants and animals? What are the biological effects of increasing atmospheric nitrogen oxides, or other compounds? What are the turnover rates of carbon dioxide, oxygen, water, methane, cyanogen, and other compounds in the natural cycles of carbon, nitrogen, oxygen, hydrogen, and so on? The International Biological Program provides an especially favorable opportunity for making cooperative measurements on a worldwide basis.

The microclimates of plants and animals should be studied in relation to local and seasonal variations in carbon dioxide and other constituents, since these microclimates differ with vegetation type. The macrocomposition of the earth's biosphere needs also to be examined as it relates to oxygen, carbon dioxide, water, nitrogen, and temperature. For these latter studies, all measurements should be made with comparable techniques over the entire globe, and should make possible estimates of changes taking place within a human lifetime rather than over geologic periods.

Airborne Organisms

The composition and distribution of biological material in the atmosphere are not well understood. It should be most rewarding to study the origin, distribution, and effects on other species of these substances.

For example, it would be highly desirable to investigate and learn the origins of plant pathogens, to measure and assess the spore load simultaneously in selected sites around the world, and to determine their significance to world food and crop production.

PRESERVATION OF NATURAL ECOSYSTEMS

Substantial scientific and practical gains can be realized by preserving samples of typical environ-

ments, both those relatively little disturbed by man and those that have been appreciably modified by his activities. These environments provide natural laboratories for the long-term study of ecosystems and their inherent biological productivity. Preserved areas, if available for long-term scientific use, serve as yardsticks for policy decisions on use, protection, and management of comparable areas of land or water. They furnish basic guides to national resource management and land capability evaluations. Relatively undisturbed areas are sources of valuable animals for use in experimental medicine, and they serve as reservoirs of genetic plant material of potential economic value in agriculture and medicine.

There is as yet no fully effective scheme for definition, delimitation, and designation of major ecosystems, but a registry for U.S. and contiguous areas is urgently needed. As for existing reserves, it is safe to say that despite the efforts of the Department of the Interior, the Department of Agriculture, the Nature Conservancy, and other groups, much more information is essential. For example, supplementary data are needed on who owns the areas in question, what use is permitted, and whether there have been earlier studies of a scientific nature.

New reserves are surely needed if the system is to include adequate samples of each major ecosystem, and a system of priorities must be set up for the establishment of these new reserves.

Because natural areas are established for a variety of purposes, techniques adopted for management of a particular unit will depend upon the objectives for which it was set aside. Clearly, an area established to perpetuate a particular ecosystem or special biological entity would require one kind of management and an area intended for research involving manipulation of the components of the system would require another. Again, an area designated for preservation or restoration of a selected successional stage would require one kind of management and an area where natural processes are allowed to continue without hindrance would require another. In most cases, data are presently inadequate to insure that the objectives sought can be successfully attained. It would be most shortsighted to concentrate only on setting aside natural areas and then neglect the studies needed to insure attainment of the established goals.

LIMITATIONS OF PRIMARY PRODUCTION

A major goal is to assess the precise extent of the chief impediments to production processes. It is not precisely known why a rain forest may contain islands of drought or why a desert may contain islands of arable land. Appraising the hemispheric extent of these areas requires comparable maps of rainfall, radiation, soils, and frost. The maps should show the probabilities or frequencies of those quantities needed to insure dependable production. The efforts of organizations, such as the World Meteorological Organization, that are capable of organizing fundamental surveys would be of benefit.

Another goal is to find ways of raising the upper limits of photosynthesis. The assemblage of nationalities, disciplines, and agricultural ecosystems that will exist under the IBP may reveal new ways of removing such limitations as drought, soil fertility, and cold. The prospects of discovery would be enhanced if a number of scientists could be brought together for study of one or more ecosystems unlike the well-known ones characteristic of Temperate Zone agriculture.

There is urgent need for better understanding of drought tolerance of basic crops in the Western Hemisphere. Almost all established crop areas at times receive suboptimal amounts of precipitation. Study of the physiology of plants under water stress is a prerequisite to an understanding of water economy and drought tolerance.

Also needed in the Western Hemisphere is a thorough study of the effects of temperature on the physiology of plants.

A problem particularly relevant to plants growing on soils of the tropical areas of the Western Hemisphere relates to restricted rooting volume due to low base status, soil acidity, and aluminum toxicity. Basic physiological studies of root growth-root rhizosphere interaction are needed.

Nitrogen is often the element limiting primary production, yet the atmosphere contains a vast reservoir of this element. To improve understanding of nitrogen fixation, it is important to—

Assess quantitatively the availability of nitrogen on both a regional and a worldwide basis.

The studies should give attention to great world soil groups and climates and to the Tropics, the Arctic zone, and the hydrosphere.

Standardization of methods and the coordination of studies with those of other national programs are particularly desirable.

Determine the factors that influence fixation and limit its rate and magnitude.

Special attention should be given to the role of nitrogen fixation in limiting primary production.

Determine the distribution of the organisms or symbiotic associations that bring about the fixation of nitrogen.

The studies should pay particular attention to the identity and distribution of as yet unrecognized organisms capable of fixation as well as to the distribution of nitrogen fixers in adequately described habitats.

Investigate the nitrogen budget and nitrogen cycle, with particular emphasis on nitrogen gains and losses, as related to primary production.

Study the systematics of nitrogen-fixing organisms, encouraging the application of modern taxonomic methods to the investigations.

Encourage further work to define the biochemical mechanisms of nitrogen fixation and the physiological processes associated with the reactions.

The following are essential for this research:

Culture collections of the asymbiotic nitrogen fixers and the maintenance of a permanent collection of root-nodule bacteria

Compilation of methods currently in use for the study and evaluation of nitrogen fixation, and a critical analysis of the limitations of those methods

Specialized instruments for routine analytical determinations

NUTRITION

The inability of peoples in many parts of the world to obtain adequate food makes clear that it is necessary (1) to understand nutrition and its relation to other factors, including stress; (2) to identify improvements that may realistically be sought; and (3) to devise methods for increasing food quality and improving preservation.

Nutritional Requirements

Nutritional requirements are subject to modification by a variety of individual characteristics, such as genetic endowment, age, weight, and sex. They are also affected by the physical environment, level of activity, and adaptability to high or low nutrient intake. But the precise role of these factors in determining the nutritional requirements of a given population is poorly understood and an extensive research program in this area is highly desirable.

Thus far efforts have tended to center on increasing food supply as such, but one now sees growing interest in such crucial issues as carbon-nitrogen ratio, protein level, and amino acid content. Broad studies of the fundamental role of fatty acids, both saturated and unsaturated, in the total nutrition of humans living under differing environmental conditions and stresses are needed.

Improvement of Nutrition

The need to match food production to the demands of the world's expanding population is well established. A parallel need is to make more effective use of our capacity to meet established nutritional requirements. The diet of at least half the world's population lacks sufficient high-quality protein. Investigations of protein supply should be undertaken. They should include assessment of protein utilization, amino acid balance, and the potential usefulness of fish and other materials as protein supplements. Studies of naturally occurring nutritional stresses among the world's population, of the source of variability in nutritional requirements, and of human nutritional adaptability would enable us to establish baselines for predicting the consequences of particular nutrient regimens, and would enlarge man's ability to improve nutrition.

Consideration must be given to research promising to open new or hitherto inadequately recognized food sources if the International Biological Program is to be adequately responsive to the challenge of the exploding world population and food needs. Possibilities include conversion of waste materials, exploitation of marine sources, optimum use of various biotas to enhance produc-

tive processes, coordination of production with nutrition needs and with processing procedures, further exploration of methods of preservation, and evaluation of germ plasm banks.

Methodology

Application of the following criteria will aid in developing standardized methods for planning and carrying out nutritional research:

The methods should provide discriminating measures of the effects of nutritional stress.

They should be amenable to field application on representative stratified samples of populations selected for study.

They should yield a maximum of information with minimum disturbance of the groups investigated.

They should be tested and validated in institutions already well equipped and experienced in this work.

They should, whenever human volunteers and experimentation are involved, be consistent with established codes governing the use of human subjects.

USE AND MANAGEMENT OF BIOLOGICAL RESOURCES

Biological Control

The International Biological Program provides an opportunity to promote ecological management as a principal method of pest control, with emphasis on the use of predators, parasites, and pathogens. This method of pest control can succeed only through international cooperation, because the discovery and introduction of useful natural enemies of pests depend on collaborative endeavor. Emphasis on ecological methods will center about maximal use of natural enemies but will include various forms of habitat management or modification, use of resistant hosts, and other genetically based techniques. Proposed research should seek to establish approaches that will be applicable internationally, and should be directed to the solution of specific problems of broad concern.

Plant Gene Pools

By its very nature the process of accumulating a plant gene pool is an international venture and requires intercountry cooperation to be effective.

United States agriculture, with but little reservoir of native germ plasm, already is greatly indebted to outside sources. If effective breeding programs are to continue, the flow of germ plasm must continue. Wild progenitors of major crops, primitive populations, and wild relatives of crop species provide a wealth of genetic material from which to draw new qualities of adaptation to temperature, day length, nutrition, and resistance to pests and diseases. Thus the United States needs continually to procure, assess, and preserve germ plasm for future incorporation into crop varieties. To this end there has been established a National Seed Storage Laboratory at Fort Collins, Colo. The more than 52,000 accessions now held there are largely improved varieties, breeding lines, and plant introductions.

There is additional specific need to locate, describe, and preserve in similar manner (1) important genetic marker collections, (2) lines of particularly high quality that might otherwise be lost in the tendency to emphasize quantity production, and (3) other endangered materials. Biologists are encouraged to make collections available for preservation, and the Agricultural Research Service, in cooperation with other agencies and biological societies, should document these private collections and bring them into the laboratory. A working group on the preservation of genetic stocks, to advise on the merits of individual collections and on techniques of repropagation, would be of benefit.

Animal Gene Pools

In view of the many restrictions to movement of such genetic material as semen and ova from one country to another, and the risks involved, comprehensive study of blood lines is being undertaken as a means of initially fixing the location of valuable stocks and providing a base for future use of these resources. Seventeen countries have expressed an interest and are participating in this study.

Food Handling

Food has traditionally been appraised largely in terms of production and consumption. Less attention has been devoted to what happens in the intervening period. This third dimension of the food question involves primarily the control of deterioration, waste, and other losses. We need a concerted, international effort to collect reliable, adequate data on losses in plant and animal products and to gain an improved understanding of the ecological conditions governing the activities of postharvest pests and diseases.

Food handling can also be construed to include (1) making plant products acceptable to man's digestive processes; (2) removing deleterious components such as antitrypsin factors, anti-thiamins, and saponins; (3) supplementing certain commodities with constituents otherwise missing; and (4) eliminating nonedible portions. Nutritive changes in processing, nutritive improvements through fermentation, and amino acid supplementation are obvious broad areas of great interest.

Special attention should perhaps be directed to fermentation as a means of preservation having marked potential for use in developing countries, where modern techniques are unavailable or

overly expensive. The intricate interplay between a succession of micro-organisms during conversion and preservation of milk curd, bean curd, vegetables, wastes, etc., needs to be studied in the field, possibly by mobile biotechnical laboratories.

Another promising area would be the upgrading of sewage, which would permit its recycling back into food and feed.

EDUCATION AND MANPOWER

The manpower situation in the general area of ecological biology is by no means satisfactory. If the objectives of the International Biological Program are to be achieved, it will be necessary to involve not only experienced scientists but also graduate students who are directing their careers toward human ecology, and high school and college teachers. There will be a heavy demand for biologists trained in the use of computers and in mathematical methods applicable to systems analysis. If we are realistic, we must recognize that the International Biological Program will intensify present shortages. We should take steps to meet the situation promptly.

PLAN OF ACTION

The major problems to which the U.S. International Biological Program addresses itself are stated in the preceding section of this report. This section describes the actions planned by the U.S. Committee and its subcommittees to initiate, encourage, and in some cases to carry out projects to attack these problems. The activities are grouped under separate headings for each subcommittee.

A series of working conferences will be one of the primary methods used by the subcommittees to encourage the development of research projects. Participants will be asked to describe proposed research, specify the data that are to be acquired, and agree on the methodologies that seem most likely to be successful. These conferences and the reports of their proceedings will enable scientists to (1) assess the relevance of their current research to the theme of the International Biological Program, (2) reorient that research if they desire, and (3) propose new essential projects.

ENVIRONMENTAL PHYSIOLOGY

The Environmental Physiology Subcommittee plans a series of working conferences to (1) develop specific, detailed research programs; (2) identify needed improvements in methodology; (3) prepare appropriate proposals and budgets; and (4) stimulate individuals and organizations to participate. As appropriate, these conferences will be sponsored in cooperation with other subcommittees.

Physiological Analysis of Marine and Estuarine Populations

This conference will deal with physiological resistance and performance adaptations of marine and estuarine species to geographical and biotic factors—temperature, light, hydrostatic pressure, streaming velocity, substratum, food supply, and salinity. It is anticipated that a research program centering on the analysis of physiological adaptation in populations from a wide range of

marine environments will be established. The conference will be held at the Duke University Marine Biological Laboratory in Beaufort, N.C. A plan for its organization has been drafted by John Vernberg (Duke) and Carl Schlieper (University of Kiel). The Environmental Physiology Subcommittee representative is C. Ladd Prosser (University of Illinois); the Productivity of Marine Communities representative is V.E. Brock (University of Hawaii). The target date for the conference is the summer of 1967.

Physiology of Colonizing Species

This conference will examine in depth the physiology of species currently expanding into new areas, including some introduced by man. Some are cosmopolitan, others more restricted. As a basis of comparison, the analysis will include several species whose ranges do not appear to be expanding. To some extent, the conference can be considered an outgrowth of the international conference on the Genetics of Colonizing Species held at Asilomar, Calif., in 1964. It will be devoted primarily to selection of species for study and of measurements to be made, and to developing international cooperation in field and laboratory studies. Calvin McMillan (University of Texas) and E. O. Wilson (Harvard University) will be organizers. The Environmental Physiology Subcommittee representatives are Frank Blair and Herbert Baker. The Systematics and Biogeography Subcommittee has indicated its concurrence and support. This conference is tentatively scheduled for 1967.

Environmental Extremes

This conference will deal with the physiological bases for tolerance in plants, animals, and microorganisms of environmental hypoxia, high salinity, aridity, and other factors. Plans for eco-physiological experiments will be developed. It is anticipated that this conference will be cosponsored by the National Aeronautics and Space Administration and that the organizer will be Dale Jenkins, of

that agency. Tentatively, it is planned to hold the conference in Israel, where there is much interest in extreme environments. T. H. Bullock and Knut Schmidt-Nielsen will represent the Environmental Physiology Subcommittee.

Insect Control by Plants

This conference will center on chemical interactions between organisms. It will emphasize control of insects by plants and control of plants by other plants. The fact that terpenoids are implicated in both of these control phenomena suggests that entomologists and botanists might well be brought together to consider mechanisms and applications. The practical worth of international participation in efforts toward insect and weed control for increased agricultural production is clearly worthwhile. Representatives from a number of countries should be involved. Interest has been expressed by representatives of the U.S. Department of Agriculture and by the Subcommittee on Systematics and Biogeography and the Subcommittee on Productivity of Terrestrial Communities. The conference will be organized by E. F. Knippling (USDA) and Cornelius Müller (University of California at Santa Barbara). Carroll Williams, of the Environmental Physiology Subcommittee, will be actively involved in planning.

Biometeorology and Productivity

A conference will be held to consider methods of data collection, to determine what critical measurements are needed, and to plan a data-collecting service. Two distinct approaches are indicated: (1) analysis of the biological significance of long-term trends in the overall balance of carbon dioxide, oxygen, water, and nitrogen levels with atmospheric temperature, and (2) study of microclimates of plants and animals in relation to their physiology. Physical scientists and biologists are expected to pool their knowledge, techniques, and interests in outlining a research plan. Close collaboration will be established between the Environmental Physiology Subcommittee, the Biometeorology Panel of the U.S. National Committee, and the Committee on Atmospheric Sciences of the National Academy of Sciences. The Biometeorology Panel will be encouraged to organize this conference. Wallace

O. Fenn will represent the Environmental Physiology Subcommittee, and Dr. Frederick Sargent, II will provide liaison with the Human Adaptability Subcommittee.

Ecological and Physiological Convergence

A working conference to plan a cooperative program of research on species which occupy similar environments in North and South America is planned. Emphasis will be on the plants and animals of the Chacoan type of community and on those of the creosote bush desert. Both of these environments occupy extensive areas in North and South America. Taxa common to both hemispheres will be considered. Participation of systematists is essential and will be encouraged by the Subcommittee on Systematics and Biogeography. It is proposed that the conference be held in Caracas, Venezuela, in the fall of 1967. It will include biologists from both American continents. The conference will be organized by Dr. Frank Blair (Texas) and Dr. Elio Massola of INTA, Buenos Aires, Argentina, with Professor Osvaldo Reig, University of Caracas, Venezuela, as local representative.

Suggested Additional Conferences

Comparative and Environmental Physiology of Reproduction. This conference would be concerned with broad considerations of human and other species and would use endocrinological, embryological, and other approaches. The Human Adaptability Subcommittee has expressed great interest in cooperating in this venture.

Patterns of Human Fertility. This conference was envisioned initially as a preplanning meeting to define the measurements to be made, select population types of particular value, and identify workers who should be invited to later detailed planning. A second session will be devoted to comparing several human populations of special interest and contrast, and will take into account both overt, statistical fertility and physiological or analytical parameters.

Physiology of Freshwater Species. Details of this conference remain to be worked out.

PRODUCTION PROCESSES

In 1987 the Production Processes Subcommittee will hold two symposia, each of which will be combined with working conferences. The first symposium will deal with physiological limitations on primary production under stresses of water and temperature variations; the second will deal with nitrogen balance.

PRODUCTIVITY OF MARINE COMMUNITIES

The Subcommittee on Productivity of Marine Communities will hold five regional working conferences. Marine biologists who, in replying to questionnaires distributed by the subcommittee, expressed interest in participating in the IBP will be invited to attend. From these sessions will emerge specific plans of action, budgets, and proposals for research. Programs developed at the conferences will be reviewed by the subcommittee and by the U.S. National Committee, and will then constitute the guidelines for the national efforts in this area of the International Biological Program. The proposed regions and suggested convenors are:

New England States and Long Island—Bostwick Ketchum

New York to Palm Beach, Fla.—Lionel A. Walford

Southern Florida, Gulf States, and Puerto Rico—D. E. Wohlschlag

Southern California and Hawaii—F. T. Haxo and V. E. Brock

Northern California, Oregon, Washington, and Alaska—Dixy Lee Ray

Marine biologists have expressed considerable interest in cooperative, interdisciplinary investigation of the marine ecosystem and in planned beneficial modification of the environment aimed at isolating and evaluating the factors and mechanisms that influence and control marine productivity. These studies will include evaluation of hydrography and chemistry and examination of each of the trophic levels. Cooperative efforts of many specialists will be required.

For scientists interested in biogeographical problems it would be helpful to coordinate the vessel programs of the coastal laboratories so that each could concentrate its work in a relatively small sector, thus avoiding overlapping

and gaps in the areas studied and providing nearly synoptic coverage. Concomitant data on temperature and salinity should be recorded to identify water masses and to determine the relation between the distribution and the environmental characteristics.

In their efforts to describe the occurrence and distribution of marine organisms, systematists and biogeographers have been hampered by inadequate support for working up and maintaining collections. These problems have been recognized and steps to correct the deficiencies are being taken.

HUMAN ADAPTABILITY

The program of the Human Adaptability Subcommittee involves complex multidisciplinary investigations. Several working conferences will be devoted to developing details of problem-oriented research projects. Scientists who have indicated willingness and competence to participate in planned research projects will be invited to attend appropriate conferences. Biologists are encouraged to submit additional ideas and projects.

Regional Meetings

Five regional meetings are planned. Each meeting will include two working conferences. The first working conference will define the specific research to be undertaken, decide on methods, select populations to be studied, outline an experimental design, and establish working parties. The working parties will (1) prepare details, proposals, and budgets and (2) prepare draft papers for consideration at the second conference. On the basis of the working parties' drafts, the second conference will prepare an integrated regional program and budget.

The conferences will also give attention to development of instrumentation suitable for use in studies of human populations. They will suggest the size of populations appropriate to the nature of each problem and give attention to details of recording, storing, and processing information. Provision will be made, where possible, for storing human biological materials in central repositories.

Scientists from other countries will be included

in the conferences. Representatives of granting agencies whose missions are significantly related to the topics to be discussed will be invited to participate.

Although many current investigations relate to human adaptability, few are multidisciplinary to the extent here envisioned, and few have adopted standard methodologies. The new studies to be defined will assess the sources of variation in human adaptability and define the adaptive processes by a battery of accepted, standardized procedures.

Multidisciplinary Conferences

Four multidisciplinary working conferences are being planned:

Human adaptability of migrants in Israel. Convenors: J. Magnes (Israel), O. E. Edholm (U.K.), and G. M. Briggs (U.S.). The planning, particularly in relation to nutrition, is being coordinated with the Subcommittee on Use and Management of Biological Resources.

Study of circumpolar peoples. Convenors: J. A. Hildes (Canada) and F. A. Milan (U.S.). W. S. Laughlin will be the representative of the Human Adaptability Subcommittee. An international conference is projected for the summer of 1967.

Ecology of migrant populations in the U.S. Demetri B. Shimkin will be the representative of the Human Adaptability Subcommittee. A. M. Ostfeld has been invited to be convenor. Two working conferences for 1967 were planned at an organizational meeting in November 1966.

Problems of adaptability among human populations residing in high mountains. Convenor: P. T. Baker (U.S.). An organizational meeting will be held in the spring of 1967 to develop details for subsequent working conferences.

Other Conferences

Other working conferences are being considered by the subcommittee. These include conferences on (1) studies of primitive peoples, (2) ecological problems facing migrant racial and hybrid groups, and (3) socio-cultural aspects of health in the Pacific area, with special reference to child development in Southeast Asia.

NUTRITION

The Subcommittee on Use and Management of Biological Resources will hold several working conferences on subjects relating to nutrition. One will be on food production. It will be concerned with the carbon-nitrogen ratio and with amino acid composition.

Another conference, scheduled for Michigan State University in 1967, will emphasize waste and losses in food and feed. The 6-day session will include such topics as nutrition, food science, biochemistry of food changes and preservation, agricultural engineering, soil science in relation to food production, spoilage and preservation, plant diseases, and economic entomology. George Borgstrom, of Michigan State, will be the organizer.

About 25 leaders in the field of biological control will be invited to a symposium workshop scheduled for the University of California at Riverside, in 1967, under the direction of Carl Huffaker. Plans will be developed for research projects designed to establish and clarify fundamental approaches and principles. The formation of a world organization for biological control will also be discussed.

PRODUCTIVITY OF TERRESTRIAL AND FRESH-WATER COMMUNITIES

Much of the efforts of the Terrestrial and Fresh-water Productivity Subcommittees will be focused on intensive, multidisciplinary analyses of ecosystems. Areas selected should be ones in which interrelationships between terrestrial and aquatic communities can be investigated—e.g., drainage basins. Where possible, the areas should include both undisturbed communities and communities importantly modified by human use. We believe that concerted efforts should be made in a limited number of drainage basins representing ecosystems of the following kinds: Deciduous forest, western coniferous forest, grassland, desert, arctic, and tropical. These studies should be supplemented by more restricted investigations on related communities.

The need to understand ecosystems is so vital that any ecological study addressed to IBP objectives is encouraged. Two types of studies are complementary to the intensive investigations under IBP sponsorship at selected locations or

centers: first, those paralleling special parts of center-based programs; second, geographically extensive, independent studies yielding synoptic data for broad geographic comparisons.

Studies which parallel parts of center-based programs will be pursued by collaborators at many locations and can contribute much to the overall objectives. Such studies may deal with variants of the ecosystem components found in the intensive study areas or they may be concerned with the responses of ecosystem components similar to those of the major study areas but existing under different environmental conditions. These studies will be valuable provided that the methods are comparable and that the data can be subjected to systems analysis.

The value of certain aspects of ecosystem analysis, particularly seasonal and successional change and productivity, is greatly increased by a wide geographic coverage that includes international cooperation. Studies of this type will involve many independent observers and must follow standards (to be specified in manuals) so that data obtained are strictly comparable. Examples of desirable studies are:

Timing of appearance and other events in life history of easily observed and identified animals, both aquatic and terrestrial

Seasonal development of plants and animals with limited genetic variability and widely spread by man

Counts or weights of fruit or seed production made throughout the range of several wide-ranging and economically important species

Harvest of peak standing crop of terrestrial and aquatic ecosystems

Correlations of seed yield with peak standing crop in agricultural ecosystems

For the intensive, total system studies, measurements will be made of all major components of the ecosystem(s). Such measurements will include gross production, respiration, net production, secondary and tertiary production, rates of decomposition, exchange of matter with contiguous systems, soil and topographic settings, and microclimatic and macroclimatic variables. Energy flow, nutrient cycling, and production will be investigated on a seasonal basis. Spatial and temporal variation in selected populations will be given special attention.

Examples of techniques to be used in measuring components include the use of isotopes for tracing food chains and estimating rates of nutrient cycling; remote imagery, such as aerial photog-

raphy, radar, sonar, and underwater TV; biotelemetry; laboratory microecosystems; and physical and chemical methods, such as chromatography, nuclear magnetic resonance, atomic absorption, activation analysis, spectrophotometry, calorimetry, and respiration chambers with automatic gas analyzers.

Systems-analysis techniques will supplement more traditional methods of gathering information. The newer approach will be applied in at least three important ways:

Examination of existing data on ecosystem processes by sensitivity analysis of certain factors as an aid in allocation of resources for integrated system studies

Use of computer techniques for rapid organization and analysis of data derived from phases of total system studies that involve electronic recording equipment

Analysis and integration of results obtained from studies designed to develop and test ecological theory

Because of shortages of biologists capable of undertaking the type of studies needed, training is a major concern. Three phases are essential:

University pre- and post-doctoral programs that require close cooperation between the basic biological and natural resources departments and those responsible for training in physics, chemistry, mathematics, and computer science

Special institutes for instruction in modern methods for the practicing ecologists

Short courses or symposia for biologists wishing to become more familiar with recent advances

At least three working conferences under the sponsorship of the Subcommittees on Terrestrial and Freshwater Productivity will be held during the winter and spring of 1967 to define more clearly the work to be undertaken in analyses of total ecosystems and contributory studies. One conference will consider criteria to be used in selecting sites for the total system studies. A second conference will outline procedures to be used (1) in the contributory studies, which will parallel parts of the total system studies but will be carried out in many locations under different environmental conditions, and (2) in accumulating synoptic data on plant and animal development (phenology), fruit and seed yields of wide-ranging and economically important species, and harvest of peak standing crop of aquatic and terrestrial ecosystems. A third conference will be held May 18-19 following the

Radioecology Symposium at Ann Arbor, Mich., to plan appropriate systems analyses for the total system studies and the contributing studies.

CONSERVATION OF ECOSYSTEMS

Far too much of the animal and plant life of the world is threatened with destruction, owing to population expansion, accelerated communication, industrialization of previously underdeveloped countries, and intensification of agriculture, forestry, and other land use. The threat to biotas exists in all parts of the world but is most pronounced in tropical and subtropical areas, where recent changes in land use have been especially drastic. Only the specialist fully realizes how extraordinarily restricted are the ranges of many species.

Registers of Ecosystems

The Conservation of Ecosystems Subcommittee proposes to encourage the establishment of a clearinghouse for collecting, collating, and disseminating existing and new information on the major aquatic and terrestrial ecosystems of the United States. These data will be published in the form of registers, which will include, for each area, a basic description, a statement of the purpose for which the area was established, a summary of policy guiding its management, and a list of facilities available for research. The first of these registers is being prepared by a committee of the U.S. Departments of Agriculture and Interior and will include research data from natu-

ral areas on Federal lands. Since some ecosystems extend beyond U.S. boundaries, Canada and Mexico will be invited to participate in developing and maintaining registers. The subcommittee will encourage and facilitate necessary expeditions and surveys to acquire needed information.

Establishment of Reserves

One of the goals of the Conservation of Ecosystems Subcommittee will be to establish within the U.S. and its possessions a comprehensive system of protected research reserves. The system will include samples of all major aquatic and terrestrial ecosystems that are needed for present and future research. Local specialists will be asked to assist in locating, describing, and justifying the establishment of areas. The subcommittee will provide information on the scientific basis for protection, advise on practical steps toward implementation, and, as appropriate, stimulate action to accomplish it. Not all needed reserves can be established at once. Consequently, a system of priorities, with appropriate criteria, must be set up somewhat as shown at the bottom of this page.

Wherever possible, new areas will be located on lands or waters already in public ownership. In other cases, efforts will be made to persuade appropriate public or private organizations to invoke zoning restrictions, easements, or covenants, or to purchase the area. Efforts will be made to identify public and private sources of acquisition funds. Once an area is designated, plans will be drawn up for its protection and management. The plans will specify the purpose for which it is protected and the uses to which it may best be put.

SYSTEM OF PRIORITIES FOR ESTABLISHING RESERVES

Criteria	Areas Affected
Degree of threat -----	Habitat types imminently threatened by destruction or damage.
Uniqueness -----	Areas representing unique habitat types or containing unique species.
Rarity -----	Areas representing rare habitat types that are unprotected or insufficiently represented in existing reserves.
Completeness -----	Areas representing habitat types not included in the existing reserve system; inclusion needed to insure that the system provides complete coverage.
Research needs -----	Areas required to protect examples of habitat types sufficiently large or numerous to satisfy need for research that involves manipulation and research confined to observation.
Unusual scientific significance -----	Areas having some special value for scientific purposes—for example, areas showing unusual juxtaposition or combination of habitat types, or areas having a long history of sound research, or areas particularly suitable as research facilities because of ease of access or a comparable attribute.
Typicalness -----	Areas that are representative of other widely spread ecosystems.

Use and Management of Preserved Areas

The Conservation of Ecosystems Subcommittee will prepare survey check sheets describing natural areas for use by the Monks Wood data center. Also, the subcommittee will sponsor the preparation and publication of comprehensive ecological surveys of preserved natural areas in the United States. The cooperation of the Subcommittee on Systematics and Biogeography and the Ecological Society of America will be sought to further this program. To insure comparability of data and comprehensive coverage, the subcommittee will prepare appropriate handbooks on the ecological and systematic aspects of the surveys.

Certain conservation groups—e.g., the Nature Conservancy—have already begun to develop information needed in negotiating for ownership of reserves. These groups will be asked to assist in preparing and distributing a compendium of these "legal" guidelines to potential users.

Attention must also be directed to the means by which areas can be most effectively protected against misuse and destruction by private individuals and organized groups. One or more persons experienced in matters of this kind will be commissioned to prepare a list of measures needed to reduce damage to the minimum. The information will be included in a management handbook.

Finally, a program of continuing research will be established to formulate specific management techniques.

SYSTEMATICS AND BIOGEOGRAPHY

It is essential to investigate selected biotas of major systematic and evolutionary significance currently threatened with destruction. Two such studies are summarized here.

Hawaii Project

The Hawaii Project will be a detailed, long-term, comprehensive investigation of the endemic and invading biotas of the Hawaiian Archipelago. This group of islands supports one of the most critical biotas in the world—critical because of an exceptionally high level of endemism and the rapidity with which it is disappearing before the on-

slaught of man and of introduced animal and plant species. Furthermore, these islands are an outstanding natural laboratory for the study of evolutionary processes, on which a considerable background of previous work already exists. The following features make the project highly appropriate to the International Biological Program: (1) The project is feasible; (2) it can provide a model of how to deal with endangered floras and faunas; (3) it is urgently needed; and (4) it will serve to dramatize the scientific basis for preserving ecosystems.

Tropical Latin America

In many areas of Central America and northern South America, highly localized, endemic faunas and floras are being destroyed by man's activities. This is particularly conspicuous in the northern Andes. Colombia appears to offer the most promising site for this study; sites most suitable for comparisons at different altitudes and in the different ranges of the Colombian cordillera will be selected in consultation with Colombian scientists and others with knowledge of the area.

HUMAN RESOURCES

In recognition of critical shortages of trained manpower in this country and of the need to assist developing countries through education and training, the U.S. National Committee will—

Encourage the representatives of Federal agencies on the Interagency Coordinating Committee to collaborate on an undertaking to (a) increase support for pre- and post-doctoral training in this country; (b) identify funds in each agency that can be used in training scientists in developing countries; (c) encourage scientists submitting proposals for research in foreign countries to plan on using students in these areas for training; and (d) support requests for travel funds needed for participation in U.S./IBP activities.

Sponsor interinstitutional cooperation so that faculties and facilities can be pooled and exploited, particularly where specialized resources in statistical techniques, systems analysis, ecological management, etc., are available.

APPENDIX

GUIDELINES FOR PARTICIPATION IN THE INTERNATIONAL BIOLOGICAL PROGRAM

1. Individual scientists, national societies, or other scientific groups who wish to participate in the IBP should—

a. become thoroughly familiar with the nature, objectives, and general scope of the IBP as outlined herein;

b. define precisely the relation between the project they wish to propose and those objectives;

c. establish that the projects will benefit through international cooperation; and

d. submit the proposal to a granting agency and a copy to the Executive Secretary, U.S. National Committee, International Biological Program, Division of Biology and Agriculture, National Research Council, 2101 Constitution Avenue, Washington, D.C. 20418.

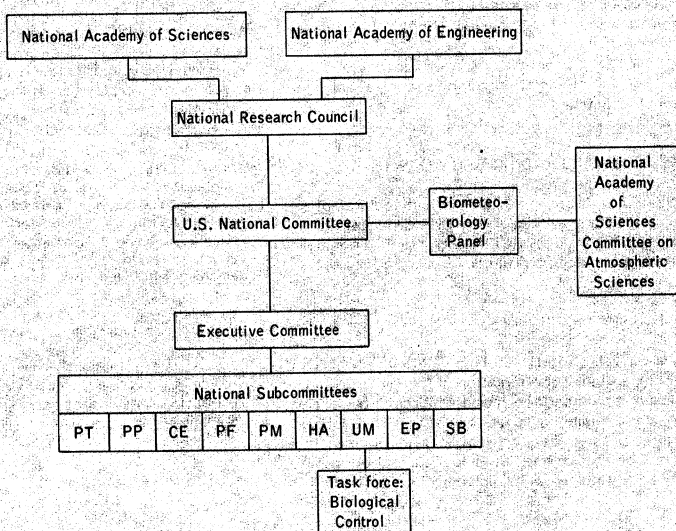
2. U.S. scientists are encouraged to review ongoing research in biology and determine projects that would contribute to and benefit from inclusion in the IBP. Ideas, suggestions, criticisms, and comments on the program should be sent to the IBP office (see 1-d above).

3. The USNC/IBP is not a granting agency; therefore, it can only review and evaluate proposals from the point of view of appropriateness for the IBP.

4. Proposals recommended by the USNC/IBP will compete for funds with other proposals. Final judgment as to provision of funds for a proposal rests with the granting agency.

5. Proposals are to be prepared in accordance with guidelines provided by granting agencies.

ORGANIZATION OF THE IBP IN THE UNITED STATES



U.S. NATIONAL COMMITTEE

Roger Revelle, Chairman
T. C. Byerly, Vice Chairman
Stanley A. Cain, Vice Chairman

Lawrence C. Bliss	William S. Laughlin
John L. Buckley	E. R. Lemon
Theodore H. Bullock	Ernst Mayr
Richard S. Cowan	James V. Neel
George K. Davis	Eugene P. Odum
Arthur D. Hasler	Frederick Sargent, II
Theodore H. Hubbell	Demitri B. Shimkin
Bostwick H. Ketchum	

IBP SUBCOMMITTEES AND BIOMETEOROLOGY PANELPT: Productivity of Terrestrial Communities

Lawrence C. Bliss, Chairman	
Eugene P. Odum	Laurence B. Slobodkin
Jerry S. Olson	George M. Van Dyne
Frank A. Pitelka	R. H. Whittaker

PP: Production Processes

E. R. Lemon, Chairman	
M. Alexander	Norman E. Good
T. C. Byerly	Paul E. Waggoner
C. C. Delwiche	P. W. Wilson
Richard C. Dugdale	

CE: Conservation of Ecosystems

John L. Buckley, Chairman	
Stanley A. Cain	Irwin D. Rasmussen
Richard S. Cowan	Robert S. Sigafos
Reznat M. Darnell	George Sprugel, Jr.
F. R. Fosberg	Donald F. Squires
John Milton	

PF: Productivity of Freshwater Communities

Arthur D. Hasler, Chairman	
Shelby D. Gerking	R. P. Silliman
Charles R. Goldman	Frederick E. Smith, Vice Chairman
Luigi Provasoli	

PM: Productivity of Marine Communities

Bostwick H. Ketchum, Chairman	
Vernon E. Brock	Lionel A. Walford
F. T. Haxo	Donald E. Wohlschlag
Dixy Lee Ray	

HA: Human Adaptability

Frederick Sargent, II, Chairman	
J. R. Audy	Jean Mayer
Paul Baker	James V. Neel
Elsworth R. Buskirk	Sid Robinson
Loren D. Carlson	Demitri B. Shimkin
Oscar Kempthorne	Christopher Tietze
William S. Laughlin	

UM: Use and Management of Biological Resources

George K. Davis, Chairman	
George Borgstrom	Carl B. Huffaker
John L. Creech	David Pimentel
R. E. Hodgson	

UM: Task Force (Biological Control)

Paul De Bach	John D. Paschke
Paul Oman	

SB: Systematics and Biogeography

T. H. Hubbell, Chairman	
Lincoln Constance	Robert R. Miller, Deputy Chairman
John O. Corliss	
Richard S. Cowan	Reed C. Rollins
Herbert Friedmann	Charles G. Sibley
Ernst Mayr	Warren H. Wagner, Jr., Deputy Chairman

EP: Environmental Physiology

Theodore H. Bullock, Chairman	
H. G. Baker	Colin S. Pittendrigh
W. Frank Blair	C. Ladd Prosser, Vice Chairman
Theodosius Dobzhansky	
Wallace O. Fenn	Knut Schmidt-Nielsen
Sidney R. Galler	Carroll M. Williams

Biometeorology Panel

C. B. Tanner, Chairman	
Wayne L. Decker	Lester Macha
David M. Gates	Stuart M. Pady
Glenn R. Hilt	Frederick Sargent, II
E. R. Lemon	

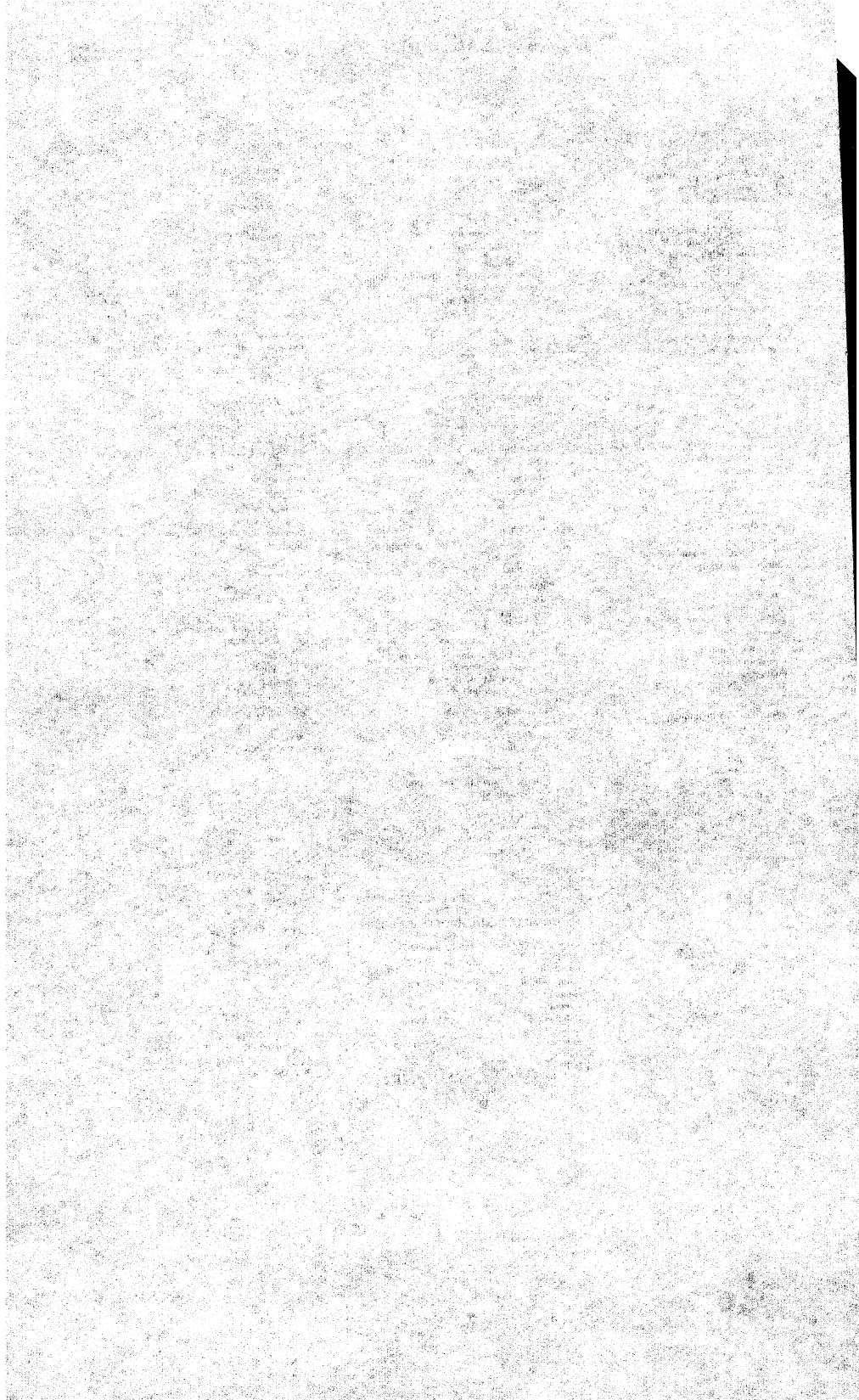
ALPHABETICAL LIST OF MEMBERS OF U.S./IBP ORGANIZATION

- M. Alexander
Department of Soil Microbiology
Cornell University
Ithaca, N.Y. 14850
- Ralph J. Audy
Hooper Foundation
University of California Medical Center
San Francisco, Calif. 94122
- H. G. Baker
Botanical Garden
University of California
Berkeley, Calif. 94720
- Paul Baker
Department of Sociology and Anthropology
Pennsylvania State University
University Park, Pa. 16802
- W. Frank Blair
Department of Zoology
University of Texas
Austin, Tex. 78712
- Lawrence C. Bliss
Department of Botany
University of Illinois
Urbana, Ill. 61801
- George Borgetrom
Department of Food Science
Michigan State University
East Lansing, Mich. 48823
- Vernon E. Brock
Hawaii Institute of Marine Biology
University of Hawaii
Honolulu, Hawaii 96822
- John L. Buckley
Office of Ecology
U.S. Department of the Interior
Washington, D.C. 20240
- Theodore H. Bullock
School of Medicine
University of California
La Jolla, Calif. 92038
- Elsworth R. Buskirk
Laboratory for Human Performance
Research
Pennsylvania State University
University Park, Pa. 16802
- T. C. Byerly
Cooperative State Research Service
U.S. Department of Agriculture
Washington, D.C. 20250
- Stanley A. Cain
Assistant Secretary for Fish and
Wildlife and Parks
U.S. Department of the Interior
Washington, D.C. 20240
- Loren D. Carlson
School of Medicine
University of California
Davis, Calif. 95616
- Lincoln Constance
Department of Botany
University of California
Berkeley, Calif. 94720
- John O. Corliss
Department of Biological Sciences
University of Illinois
Chicago, Ill. 60680
- Richard S. Cowan
Museum of Natural History
Smithsonian Institution
Washington, D.C. 20560
- John L. Creech
Crops Research Division
U.S. Department of Agriculture
Beltsville, Md. 20705
- Kenneth M. Darbell
Department of Biology
Marquette University
Milwaukee, Wis. 53233
- George K. Davis
Division of Biological Sciences
University of Florida
Gainesville, Fla. 32601
- Paul De Bach
Department of Biological Control
University of California
Riverside, Calif. 92507
- Wayne L. Decker
University of Missouri
Columbia, Mo. 65201
- C. C. Delwiche
Department of Soils and Plant Nutrition
University of California
Davis, Calif. 95616
- Theodosius Dobzhansky
Rockefeller University
New York, N.Y. 10021
- Richard C. Dugdale
Douglas Marine Station
P.O. Box 185
Douglas, Alaska 99824
- Wallace O. Fenn
School of Medicine and Dentistry and
Strong Memorial Hospital
University of Rochester
Rochester, N.Y. 14627
- F. R. Fosberg
Pacific Science Board
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418
- Herbert Friedmann
Los Angeles County Museum of
Natural History
Los Angeles, Calif. 90007
- Sidney R. Galler
Assistant Secretary for Science
Smithsonian Institution
Washington, D.C. 20560
- David M. Gates
Missouri Botanical Garden
St. Louis, Mo. 63110
- Shelby D. Gerking
Department of Zoology
Indiana University
Bloomington, Ind. 47401
- Charles R. Goldman
Department of Zoology
University of California
Davis, Calif. 95616
- Norman E. Good
Department of Botany
Michigan State University
East Lansing, Mich. 48823
- Arthur D. Hasler
Laboratory of Limnology
University of Wisconsin
Madison, Wis. 53706
- F. T. Haxo
Scripps Institution of Oceanography
University of California, San Diego
La Jolla, Calif. 92037
- Glenn E. Hilt
61 Glenwood Road
West Hartford, Conn. 06107
- R. E. Hodgson
Animal Husbandry Research Division
Agricultural Research Service, USDA
Beltsville, Md. 20705
- Theodore H. Hubbell
Museum of Zoology
University of Michigan
Ann Arbor, Mich. 48104
- Carl B. Huffaker
Division of Biological Control
University of California
Albany, Calif. 94706
- Oscar Kempthorne
Statistical Laboratory and Department
of Statistics
Iowa State University
Ames, Iowa 50010
- Bostwick H. Ketchum
Woods Hole Oceanographic Institute
Woods Hole, Mass. 02543
- William S. Laughlin
Department of Anthropology
University of Wisconsin
Madison, Wis. 53706
- E. R. Lemon
Soil and Water Conservation Research
Division
Agricultural Research Service, USDA
Ithaca, N.Y. 14850
- Lester Machta
National Center for Atmospheric Research
Boulder, Colo. 80302
- Jean Mayer
School of Public Health
Harvard University
Cambridge, Mass. 02138
- Ernest Mayr
Museum of Comparative Zoology
Harvard University
Cambridge, Mass. 02138
- Robert R. Miller
Museum of Zoology
University of Michigan
Ann Arbor, Mich. 48104

- John Milton
The Conservation Foundation
1250 Connecticut Ave., N.W.
Washington, D.C. 20036
- James V. Neel
Department of Human Genetics
University of Michigan Medical School
Ann Arbor, Mich. 48104
- Eugene P. Odum
Department of Zoology
University of Georgia
Athens, Ga. 30601
- Jerry S. Olson
Radiation Ecology Section
Oak Ridge National Laboratory
Oak Ridge, Tenn. 37830
- Paul Oman
Agricultural Research Service
U.S. Department of Agriculture
Beltsville, Md. 20705
- Stuart M. Pady
Department of Botany and Plant Pathology
Kansas State University
Manhattan, Kans. 66502
- John Donald Paschke
Department of Entomology
Purdue University
Lafayette, Ind. 47907
- David Pimentel
Department of Entomology and Limnology
Cornell University
Ithaca, N.Y. 14850
- Frank A. Pitelka
Department of Zoology
University of California
Berkeley, Calif. 94720
- Colin S. Pittendrigh
Graduate School
Princeton University
Princeton, N.J. 08540
- C. Ladd Prosser
Department of Physiology
University of Illinois
Urbana, Ill. 61801
- Luigi Provasoli
Haskins Laboratories
305 East 43d Street
New York, N.Y. 10017
- Irvin D. Rasmussen
Division of Wildlife Management,
Forest Service
U.S. Department of Agriculture
Washington, D.C. 20250
- Dixy Lee Ray
Pacific Science Center Foundation
Seattle, Wash. 98105
- Roger Revelle
Center for Population Studies
Harvard University
Cambridge, Mass. 02138
- Sid Robinson
Department of Anatomy and Physiology
Indiana University
Bloomington, Ind. 47401
- Reed C. Rollins
Gray Herbarium
Harvard University
Cambridge, Mass. 02138
- Frederick Sargent, II
Center for Human Ecology
University of Illinois
Urbana, Ill. 61801
- Knut Schmidt-Nielsen
Department of Zoology
Duke University
Durham, N.C. 28806
- Demitri B. Shimkin
Department of Anthropology
University of Illinois
Urbana, Ill. 61801
- Charles G. Sibley
Peabody Museum of Natural History
Yale University
New Haven, Conn. 06520
- Robert S. Sigafos
Geological Survey
U.S. Department of the Interior
Washington, D.C. 20240
- Ralph P. Silliman
U.S. Department of the Interior
Bureau of Commercial Fisheries
2725 Montlake Blvd. East
Seattle, Wash. 98102
- Laurence B. Slobodkin
Department of Zoology
University of Michigan
Ann Arbor, Mich. 48104
- George Sprugel, Jr.
Illinois Natural History Survey
Urbana, Ill. 61801
- Donald F. Squires
Museum of Natural History
Smithsonian Institution
Washington, D.C. 20560
- Frederick E. Smith
School of Natural Resources
University of Michigan
Ann Arbor, Mich. 48104
- C. B. Tanner
Department of Soils
University of Wisconsin
Madison, Wis. 53706
- Christopher Tietze
National Committee on Maternal Health, Inc.
Two East 103d Street
New York, N.Y. 10029
- George M. Van Dyne
Department of Forestry and Natural
Resources
Colorado State University
Fort Collins, Colo. 80521
- Paul E. Waggoner
Department of Soil and Climatology
Connecticut Agricultural Experiment Station
New Haven, Conn. 06504
- Warren Wagner, Jr.
Department of Botany
University of Michigan
Ann Arbor, Mich. 48104
- Lionel A. Walford
Sandy Hook Marine Laboratory
Fish and Wildlife Service, USDI
Highlands, N.J. 07732
- R. H. Whittaker
Department of Population Biology
University of California
Irvine, Calif. 92664
- Carroll M. Williams
The Biological Laboratories
Harvard University
Cambridge, Mass. 02138
- P. W. Wilson
University of Wisconsin
Madison, Wis. 53706
- Donald E. Wohlshlag
Marine Institute
University of Texas
Fort Aransas, Tex. 78712

ALPHABETICAL LIST OF COUNTRIES PARTICIPATING
IN THE
INTERNATIONAL BIOLOGICAL PROGRAM

Australia	Germany, Federal	Japan	South Africa, The
Austria	Republic of	Kenya	Republic of
Belgium	Germany, Democratic	Korea, Republic of	Spain
Bulgaria	Republic of	Mexico	Sweden
Canada	Ghana	Netherlands	Thailand
China, The National	Greece	New Zealand	Union of Soviet Socialist
Republic of	Hungary	Nigeria	Republics
Czechoslovakia	India	Norway	United Kingdom
Finland	Indonesia	Philippines, The	United States
France	Israel	Poland	Vietnam, Republic of
	Italy	Rhodesia	Yugoslavia



APPENDIX C

PROGRAM STATEMENT

of the

SUBCOMMITTEE ON CONSERVATION OF ECOSYSTEMS

of the

U.S. National Committee for the International Biological Program

31 October 1966

NATIONAL RESEARCH COUNCIL

National Academy of Sciences

National Academy of Engineering

Division of Biology and Agriculture

PROGRAM STATEMENTOF THESUBCOMMITTEE ON CONSERVATION OF ECOSYSTEMS (CE)

There is high scientific value in preserving samples of typical environments, both those relatively little disturbed by man and those which he has materially modified. There is also decided practical value in applying what is learned from the observation and manipulative study of such environments.

Areas preserved for long-term scientific use provide natural laboratories for the study of ecosystems in all their variety and complexity, including their inherent biological productivity. They can serve as check areas or yardsticks for the use, protection, and management of comparable areas of land and water. They furnish basic data for the development of guides to rational resource management, such as land capability classifications. Many relatively undisturbed areas are the source of animals employed in experimental medicine, especially the large primates. They are reservoirs of genetic materials which may one day prove to be of economic or medicinal value.

It should be emphasized that the Subcommittee on Conservation of Ecosystems is concerned with all types of ecosystems, and that man is considered a component of them. In some ecosystems man is the dominant environmental factor, as in a field of corn or rice. In others he and his influences are relatively less important, as in the management of ecosystems devoted to forestry, fishing, and grazing. In still others he is essentially an intruder and has little influence on the structure and function of the system. It is expected that scientists concerned with agriculture, fishing, and forestry, as well as those dealing with strict nature reserves, will participate in the conservation program.

OBJECTIVES

Objectives of the program are:

1. Establishment within the United States and its possessions of a comprehensive system of protected research reserves. This system will include

examples of intensively managed ecosystems and of all important natural ecosystems (some of which will be available only for observation, others of which may be manipulated). The natural ecosystems will serve also as pools of genetic material.

2. Description of the ecological characteristics of each of these reserved areas.
3. Appropriate management of these reserves.
4. Effective participation internationally of U. S. biologists in accomplishing the IBP goals.

PROGRAM

To achieve the objectives stated above the Subcommittee requires the following activities:

A. Criteria for Definition of Major Ecosystems

There is, as yet, no fully acceptable scheme for definition, delimitation, and designation of major ecosystems, nor is it likely that such a scheme will be devised in time to serve the purpose of the IBP. Hence, for U. S. use, it seems necessary to adapt such existing classifications as are already in use for designation of cover types and other diagnostic features of natural areas.

The terminology used in the list of natural areas on Federal lands, the legend in the Shantz and Zon Atlas of American Agriculture, the system used in Kuchler's vegetation map of the U. S., the scheme used by Project Aqua, and others may serve as a base.

The Subcommittee will adopt and publish for IBP use a provisional scheme including needed definitions. The subcommittee will welcome constructive criticisms and suggestions leading to eventual establishment of a more definitive and scientific scheme.

B. Inventory of Major Ecosystems (Communities and their Habitats) in the United States and Adjoining Areas

The Subcommittee proposes a procedure for collection, collation, and dissemination of existing and new information on the major ecosystems of the United States. Because of similarities of ecosystems in the United States and adjoining countries, the Subcommittee proposes to invite participation of Canada and Mexico in maintaining a joint register.

Where needed to complete knowledge of the array of ecosystem types, the Subcommittee will encourage and facilitate necessary expeditions and surveys.

C. Inventory and Evaluation of Existing Reserves

Many groups have compiled substantial amounts of information about various kinds of reserves in natural and managed ecosystems. For example, information on natural areas on Federal lands is being compiled by a committee of Interior, Agriculture, and Defense; the National Park Service maintains a National Registry of Natural Landmarks; the Nature Conservancy has extensive records of natural areas on private lands; a commission of the AAAS compiled a list of areas known to be used for ecological research; a number of States have listings of areas within their boundaries; the Society of American Foresters has long been concerned with natural areas on forested areas.

Information is needed about ownership (Federal, other public, private) and permitted use (observation or experimental manipulation) of reserved areas for research on natural ecosystems and managed ecosystems in the United States. Information is also needed on areas of importance to science because of previous studies; such areas may be impossible to reserve, but should be awarded some special status by designation as "scientific areas."

The register referred to in B above will include for each area a description, the purpose for establishment, the policy guiding its management, and the facilities available for research.

D. Establishment of Priorities for Needed Action

Establishment of all additional reserves needed cannot be accomplished at one time. Consequently, a system of priorities

must be established, along with criteria for the priorities. The criteria will include the following:

1. Threat. Types of habitat areas imminently threatened by destruction or damage. This factor is of utmost importance when combined with one or more of the criteria that follow.
2. Uniqueness. Areas that represent a unique habitat type or contain unique species.
3. Typicalness. Areas that are representative of the common, widely distributed and therefore important ecosystems.
4. Rarity. Areas representing rare habitat types not protected or insufficiently protected by existing reserves.
5. Completeness. Areas representing a habitat type not included in the existing reserve system, and needed to insure that the system provides complete coverage.
6. Research Requirements. Areas required to provide protection for examples of each habitat type -- sufficiently large or numerous to satisfy needs for manipulatory research as well as research based on observation.
7. Other Unusual Scientific Significance. Areas deserving status of research reserves because of some unusual significance, such as:
 - a. Areas that contain a particular juxtaposition or combination of habitat types.
 - b. Areas with long histories of research.

- c. Areas particularly suitable as research facilities because of accessibility or some other factor.

E. Designation of New Reserves

To complete a reserve system which includes adequate samples of all major ecosystems for present and anticipated future research requirements, the aid of local groups of specialists will be solicited in the location, description, and justification of such areas.

The role of the Conservation of Ecosystems Subcommittee is to provide the scientific and (as appropriate) practical basis for protection; and (as necessary and appropriate) to stimulate action to accomplish it.

Wherever possible new areas will be located on lands already in public ownership. In cases where suitable lands are not available in public ownership, efforts will be made to insure permanent preservation by recommending that appropriate public or private organizations employ zoning restrictions, easements, covenants, or outright purchase. Efforts will be made to identify public and private sources of land acquisition funds. Once an area is designated, the landholder will be encouraged to prepare plans for its protection and management, and to specify the purpose for which it is protected and the uses to which it may be put.

F. Comprehensive Ecological Surveys of Preserved Areas

The Special Committee for the IBP (SCIBP) is sponsoring worldwide preparation of data checksheets on natural areas that provide limited information on composition, structure, and scientific significance of ecosystems. SCIBP has approved Monkwood, England, as a center for automatic data processing on these checksheets.

In addition to preparing checksheets, the Conservation of Ecosystems Subcommittee will support the execution and publication of comprehensive ecological surveys of preserved natural areas in the United States. In order to carry out this program, the Subcommittee will seek cooperation of the Ecological Society of America in organizing and executing the ecological work and,

with the Systematics and Biogeography Subcommittee, the cooperation of the systematic societies in those parts of the program pertaining to faunas and floras.

In order to have comparability and comprehensive coverage, there will be prepared appropriate handbooks on the ecological and systematic aspects of the surveys, including, where useful, preparation of local faunas and floras. In addition, it is expected that the completed surveys will result in a descriptive pamphlet of each area.

G. Reserved Area Protection and Management

To insure a minimum of legal complications, maximum returns for funds expended, and protection against infringement by undesirable interests, it is necessary that acquisition of natural areas be undertaken with full knowledge of appropriate legal procedures.

Certain conservation groups, including the Nature Conservancy, have already initiated the development of information which should be taken into consideration when negotiating for ownership of natural reserves. The Conservation of Ecosystems Subcommittee proposes to ask one or more such groups to assist in preparing and distributing a compendium of "legal guidelines."

Similar attention must be directed to means by which natural areas or reserves can be most suitably protected against misuse and destruction by private individuals and organized groups. The degree of security required will depend, of course, upon the purpose for which the natural unit has been reserved. The Subcommittee expects to commission one or more persons experienced in such matters to prepare a compilation of measures needed to insure a minimum of destructive activities in the various types of natural areas. It is anticipated that the resulting information will be included in a handbook for distribution to persons concerned with establishment and management of reserves.

H. Research on Natural Area Management

Because natural areas or reserves may be established for a variety of special purposes, the management techniques applied to a particular unit will depend upon the purpose for which that unit was established. Management approaches suitable for re-

serves established to perpetuate a particular ecosystem or a special biological entity would be different from those suitable for areas intended to serve as sites for manipulative research on components of an ecosystem. Similarly, procedures suitable for managing areas designated for preservation or restoration of a particular successional stage would be different from those suitable for units wherein natural processes are to proceed without interference from man's influence. In a greater number of instances, however, we do not know the steps needed to insure success. Accordingly, the Conservation of Ecosystems Subcommittee recognizes the necessity of a substantial and continuing program of research to develop the requisite information.

I. Available Manpower--Education and Training

Preoccupation with laboratory biology has led to a decline in training of people interested in descriptive ecology. But the goals of Conservation of Ecosystems -- in fact, the goals of all the IBP -- require just this kind of careful observation and recording. Until the universities change their curricula, we shall be short of these people.

In the meantime, several potential sources of manpower are available:

1. Teachers in small colleges -- even high schools -- who, though overworked, would benefit from being out in the woods in their spare time. With or without their students they could make valuable contributions to the fund of information on natural areas within convenient reach of their schools and homes.
2. Able amateurs also exist. Amateurs have made noteworthy contributions to biological knowledge in the U. S. and Europe.
3. Even the professionals in laboratory sciences may, and often do, find great satisfaction in spare-time outdoor observation, especially if they can see how it fits into a bigger pattern. At present this potential is mostly wasted.

The Subcommittee hopes to find a means to channel this

interest to direct and stimulate such people to do things in such a fashion that their observations fit in an organized pattern of knowledge. Such organized observation would pay off in a valuable flow of information pertinent to our IBP objectives. Equally important, it would enable these volunteers to feel an identity with an important international program.

Short courses, traveling field courses, and individual attention by professional biologists are possible methods of developing existing interest and perhaps attracting new people. This is done very successfully in Western Europe, and would doubtless work here. The first essential is a clear and convincing framework into which such part-time effort would fit.

As an example of a move to bring descriptive ecology back to its proper place in the educational picture, the Conservation of Ecosystems Subcommittee cites the proposed joint Smithsonian-Pan American Union training program in descriptive ecology.

J. International Cooperation

In order to facilitate international efforts in the conservation of ecosystems, the Conservation of Ecosystems Subcommittee proposes to undertake various programs to assist in the creation of a world-wide system of research reserves and provide the scientific basis for their establishment and management. This cooperative work will include:

1. Multidisciplinary expeditions, surveys, and conferences.
2. Inventories of major habitat types and existing reserves.
3. Development of priorities for needed additions to the reserve system.
4. Research on techniques of management.
5. Training in descriptive ecology and reserve management.
6. Assistance in the location and development of multisectional field research

6. stations and other appropriate field stations.
7. Translation of the U. S. National Committee program statement and other documents, and distribution to biologists of other nations.

Conservation of Ecosystems' effort in programs abroad will stress:

1. Cooperative programs with neighboring countries with whom we share common boundaries or conservation problems, and with other countries as appropriate throughout the world. An example is the proposed cooperative inventory of major ecosystems in the United States and adjoining areas.
2. Capability to respond to specific requests from any other country for cooperation with their IBP conservation programs.

K. Cooperation with Other IBP Programs

1. The Conservation of Ecosystems and Systematics and Biogeography Subcommittees are jointly planning a workshop leading to publication of a definitive treatise on endemism and extinction. Planning will start immediately, and the conference will be held in 1968.
2. The Conservation of Ecosystems Subcommittee will participate in the Hawaii project planned by the Systematics and Biogeography Subcommittee.

L. Contributions to Public Education

The Conservation of Ecosystems Subcommittee will stimulate educational and public information work directed at greater understanding of the need for natural areas for research; the means by which they can be established; and the role that professional societies, other groups, and individuals can play in establishing and protecting research areas. The Subcommittee will arrange for preparation of articles, news releases, and other suitable materials, and will help place them for publication in professional journals, society news letters, newspapers, etc.

P R O G R A M S T A T E M E N T
of the
Subcommittee on Use and Management of Biological Resources
of the
U. S. National Committee for the International Biological Program

December 1966

N A T I O N A L R E S E A R C H C O U N C I L
National Academy of Sciences National Academy of Engineering
Division of Biology and Agriculture

269

PROGRAM STATEMENTOF THESUBCOMMITTEE ON USE AND MANAGEMENT OF BIOLOGICAL RESOURCES

The Subcommittee on Use and Management of Biological Resources is cognizant of the tremendously complex tasks confronting mankind. Research in many areas is urgently needed, but it is recognized that only limited areas can be emphasized in the subcommittee's program. Research in the following area is proposed for immediate emphasis:

1. Expansion of programs concerning the preservation and utilization of plant and animal genetic stocks.
2. Optimal use of biota to prevent loss of crops or harvested commodities to pests (insects, weeds, diseases, etc.) and as a means of reducing pollution (for example, pesticides).
3. Optimal use of various types of biota (such as microorganisms) to enhance productive processes.
4. Coordination of production with nutrition needs and with processing procedures.
5. Use of microorganisms to make usable, or render unobjectionable, the pollutants that human civilization adds to the environment.
6. Optimal use of microbiological organisms in the preparation of foodstuffs for human consumption and utilization of waste.

BIOLOGICAL CONTROL

It is proposed that the IBP engage in projects to promote ecological management as a principal method of pest control, with emphasis on the use of predators, parasites, and pathogens.

The field of biological control is essentially one of international cooperation. Such cooperation makes possible the discovery

and introduction of natural enemies of pests.

A principal goal will be the blending together of several avenues of ecological management, centered around optimal use of natural enemies of the pest organisms. Other control methods will be various forms of habitat management or modification, use of resistant hosts and other genetically based techniques, autocidal methods in general, use of lures and repellents, and competitive displacement.

The potentialities for the use of these methods will be evaluated through establishing realistic injury levels.

Thus, in addition to supporting the general proposals of the International Working Group on Biological Control of the IBP, the subcommittee will develop a program of broader scope, although it will adhere to the unifying central core of optimal utilization of biological control agents.

Research proposals should have as their objective the establishment and elucidation of fundamental principles of biological control that will be of international value. The following supporting programs are proposed:

1. The IBP proposes the organizing of an International Symposium on Biological Control to be held at the University of California at Riverside during 1967. About 25 world leaders will be invited to participate.
2. The IBP proposes the establishment of an International Center for Biological Control. The Center would have headquarters at a fixed location and would include participation on a world-wide basis.
3. The IBP will promote the setting up of a training program as a means of developing a body of well-trained scientists in the field of ecological management in pest control.
4. The IBP proposes the addition of a project on the biological control of armored scale insects to the list of five major projects already proposed by the international working group of IBP.

5. The IBP proposes to obtain support for preparation and publication of indexes covering the important families of entomophagous insects of the world.

PLANT GENE POOLS

By its nature, the assembling of plant gene pools is international in scope and requires intercountry cooperation to achieve effective results. The use and preservation of germ plasm may be either international or national, depending on the resources of individual countries.

In the United States, with almost no native crop germ plasm, we need to continually procure, assess, and preserve valuable germ plasm for future incorporation into crop varieties. Wild progenitors of major crops, primitive populations, and wild relatives of crop species form a wealth of genetic diversity from which to draw sources of adaptation or resistance to environmental factors.

The Subcommittee on Use and Management of Biological Resources will work with other subcommittees interested in procurement of germ plasm--namely, the Subcommittees on Productivity of Terrestrial Communities, Conservation of Ecosystems, and Production Processes.

This Subcommittee has participated in the program developed by the IBP international Working Group on Biological Control and will continue to do so. Two projects proposed by the international working group are indicative of the broad framework within which American biologists may develop activities relating to plant gene pools. The projects are "Survey, exploration, assembly, and conservation of genetic stocks" and "Evaluation of plant resources-biology of adaptation." Because of the broad base of genetic variability that would be provided, these activities represent an unusual opportunity for biologists interested in working to preserve genetic stocks.

In the area of preservation of plant germ plasm, there has been established a National Seed Storage Laboratory (NSSL) at Fort Collins, Colorado. Although more than 52,000 accessions have been received and documented, these are largely improved varieties, breeding lines, and plant introductions. There is a specific need to locate, describe, and preserve important genetic marker collections, quality carrying stocks that may be lost in overemphasis on quantity production, and other similar biological tools that are in danger of loss to future biologists.

The Subcommittee believes that biologists should be encouraged to make such collections available for preservation and that the Agricultural Research Service, in cooperation with other agencies and biological societies, should document such collections, and undertake to bring them into the NSSL as a phase of the IBP.

There should likewise be formed a working group on the preservation of genetic stocks. The group would advise on the merits of individual collections and on techniques of repropagation.

ANIMAL GENE POOLS

Because of the many barriers to movement of animal genetic material from one country to another, and the risks involved, an international study of blood is suggested as a means of identifying the location of genetic material and providing a base for future investigations on the use of these resources.

Seventeen countries have expressed an interest and are participating in such a program. The Subcommittee is proposing the development of a training center or centers for scientists of the cooperating countries.

THE THIRD DIMENSION OF FOOD

Food is usually appraised in terms of production and consumption. Less attention is devoted to utilization procedures, the vital intermediary link. This third dimension of food primarily involves the control of deterioration, waste, and losses.

There is in this respect the place for a concerted effort to collect reliable, adequate data on losses in plant and animal products and to gain an understanding of their causes. The subcommittee is proposing and sponsoring a special conference for review of methods to be applied in this area (see below).

This third dimension of food also encompasses the task of making plant products available to man's gastric system; removing deleterious components (ingredients) such as antitrypsin factors, antithiamins, and saponins; supplementing some commodities with key constituents; and eliminating nonedible portions.

Special attention should be directed to fermentation as a means of preservation that is suitable for use in many countries where modern preservation techniques are too expensive or unavailable.

The intricate interplay that takes place between a succession of microorganisms during the process of converting and preserving milk curd, bean curd, vegetables, wastes, etc., needs to be studied in the field, possibly by mobile biotechnical laboratories.

Another essential area would be the upgrading of sewage-allowing its recycling back into food and feed.

PRODUCTIVITY AND QUALITY

Placing of emphasis on coordinating nutrition with biological productivity brings to attention the need of balancing the nutritive criteria with both the quantity and quality of produced organic matter. So far, quantity has largely been given priority over specified nutritional needs. The ratio, protein content, and the aminogram emerge as crucial criteria. After consultation with the Subcommittees on Production Processes and Human Adaptability, we propose the formation of a task force to develop a symposium on food production that would have particular reference to the ratio and the amino acid composition.

CONFERENCES

The Subcommittee is sponsoring the convening of an international Working Conference on the Waste and Losses of Food and Feed to be held at Michigan State University. Emphasis is to be placed on methods of making appraisals. There is a need to understand the causative factors as affected by environmental conditions. Agreement on methods are essential in order to move from ad hoc studies and allow valid comparisons between commodities, climates, and regions. This study would include (1) the relations between the activities of insects and those of microorganisms; (2) the penetration of parasites into man, food-producing animals, and crops; and (3) the conveyance of pathogens from animals and crops to man.

As mentioned above, a symposium to review agricultural production in terms of human food is planned. Focus will be on the quantity and quality of protein. Genetical effects on amino acid com-

position as well as the influence of fertilizers, irrigation, spray materials, and other production factors in this respect will be included. The program of this symposium is to be developed by a task force jointly appointed by Use and Management of Biological Resources and Production Processes Subcommittees.

NUTRITION

The nutrition program of this Subcommittee is envisioned as being closely coordinated with nutrition aspects of the Human Adaptability, Production Processes, and Terrestrial Productivity Subcommittees. The National Committee of the International Union of Nutrition Sciences, cooperating with the Internal Programs Committee of the National Research Council Food and Nutrition Board, is assuming responsibility as a working group of the Use and Management of Biological Resources Subcommittee. Animal and human nutrition are viewed as complimentary in the total program.

- A. The Subcommittee proposes to emphasize investigations of protein supply, including both quantity and quality. This will include amino acid balance and protein utilization studies as well as the use of fish products as protein supplement.
- B. The Subcommittee encourages broad studies of the fundamental role of fatty acids, both saturated and unsaturated, in the total nutrition of humans living under different conditions of environment and stress.
- C. A basic need is for studies of the adaptation of populations to levels of dietary intake different from those considered normal. These studies will be correlated with evaluations of human physiological responses to differing situations in the process of adaptation.
- D. The relationships of nutrition to the incidence of disease and parasitism is a major study area to be included in the nutrition program. A particular area to be included is the influence of factors, such as goitergens, which may influence iodine requirement as it plays a role in thyroid deficiency.

PROJECTS

1. The development of international standards for human biological measurements applicable in a wide spectrum of countries. Sponsored by USNC-IUMS. (Dr. W. A. Krehl, University of Iowa, coordinator)
2. Adaptation of human populations from various geographical areas in Israel (Coop. U. M.)
3. Methodology working conference on the ecology of man's food. (Michigan State University, various departments)
4. An evaluation of N. R. C. animal nutrient requirements in various international situations. (Dr. W. H. Pfander, University of Missouri)
5. International Symposium on Biological Control. (Riverside, California, 1967)
6. International Center for Biological Control.
7. Training center for ecological management in pest control.
8. Preparation and publication of indexes of important families of entomophagous insects of the world. (De Bach cooperating)
9. Development of soy-based foods of high nutrition value. (David Hand, Cornell)
10. Improving nonprotein nitrogen utilization for ruminant animals. (Allen Tillman, Oklahoma State)
11. Genetic control of protein quantity and quality in edible legumes for human consumption. (W. F. Keim and H. F. Hodges, Purdue)

PROGRAM STATEMENT

of the

Subcommittee on Productivity of Freshwater Communities

and

Subcommittee on Productivity of Terrestrial Communities

of the

U.S. National Committee for the International Biological Program

January 1967

2101 CONSTITUTION AVENUE
WASHINGTON, D. C. 20415

CABLE ADDRESS: NARECO
TELEPHONE: EXECUTIVE 3-8100

NATIONAL ACADEMY OF SCIENCES
NATIONAL RESEARCH COUNCIL

DIVISION OF BIOLOGY AND AGRICULTURE

U.S. NATIONAL COMMITTEE FOR THE INTERNATIONAL BIOLOGICAL PROGRAM

March 1967

Dear Colleague:

Recently you received a report, U.S. Participation in the International Biological Program, prepared by the U.S. National Committee for the IBP. Accompanying this letter is a report describing the program of the PF and PT Subcommittees; this program is a part of the proposed U.S. effort. Both reports arise from meetings held in October 1966 at Williamstown, Mass.

At those meetings, a number of invited scientists worked with the members of the U.S. National Committee and its several subcommittees. Those who contributed to the PF-PT program statement, in addition to subcommittee members, include the following:

F. H. Borman
Joseph Connell
C. F. Cooper
R. Daubenmire
Gerald Marten
O. H. Paris

F. W. Stearns
F. H. Wagner
J. N. Wolfe
G. M. Woodwell
J. C. Wright

Enclosed is a supplement to the PF-PT program statement, asking for nominations of IBP study areas. Information is included on the criteria to be used for site selection and on procedures for making nominations. This supplement was prepared at a joint meeting of the subcommittees in Chicago in February 1967.

Following are the guidelines for participation in the International Biological Program. They are from the Appendix to the report mentioned in the first sentence of this letter, and are provided to facilitate your participation in the International Biological Program.

1. Individual scientists, national societies, or other scientific groups who wish to participate in the IBP should -

a. become thoroughly familiar with the nature, objectives, and general scope of the IBP as outlined herein;

b. define precisely the relation between the project they wish to propose and those objectives;

c. establish that the projects will benefit through international cooperation; and

d. submit the proposal to a granting agency and a copy to the Executive Secretary, U.S. National Committee, International Biological Program, Division of Biology and Agriculture, National Research Council, 2101 Constitution Avenue, N.W., Washington, D. C. 20418.

2. U.S. scientists are encouraged to review ongoing research in biology and determine projects that would contribute to and benefit from inclusion in the IBP. Ideas, suggestions, criticisms, and comments on the program should be sent to the IBP office (see 1-d above).

3. The USNC/IBP is not a granting agency; therefore, it can only review and evaluate proposals from the point of view of appropriateness for the IBP.

4. Proposals recommended by the USNC/IBP will compete for funds with other proposals. Final judgment as to provision of funds for a proposal rests with the granting agency.

5. Proposals are to be prepared in accordance with guidelines provided by granting agencies.

PF Subcommittee

- *A. H. Hasler, Chairman
- *F. E. Smith, proposed
Program Chairman
- *S. D. Gerking
- C. R. Goldman
- L. Provasoli
- *R. P. Silliman

PT Subcommittee

- *L. C. Bliss, Chairman
- *P. L. Johnson, proposed
Program Coordinator
- E. P. Odum
- *J. S. Olson
- *F. A. Pitelka
- L. B. Slobodkin
- *G. M. Van Dyne
- R. H. Whittaker

*Present at the February meeting.

SUPPLEMENT TO THE PF-PT PROGRAM STATEMENT

A request for nominations of IBP study areas
for analysis of ecological systems

The Subcommittees on Productivity of Terrestrial Communities and Productivity of Freshwater Communities have proposed the study of whole ecological systems, such as drainage basins and landscapes. Emphasis is to be placed on interrelations among all components of such systems. Wherever possible, the interactions of aquatic and terrestrial systems are to be included. Immediate goals include the analysis of such aspects of ecosystems as energy flow, nutrient cycling, trophic structure, spatial patterns, interspecies relations, and species diversity. Further goals include the understanding of these ecosystem processes, in the sense of analyzing the mechanisms by which observed characteristics of flow, cycling, density, diversity, etc., are achieved and maintained. The ultimate goal is to enable man to more wisely manage his environment. Each intensive analysis will combine research projects from many disciplines, and will require an extensive development of research facilities and monitoring devices.

For these reasons, each area selected for intensive study must have, or must be provided with, services and facilities adequate for a variety of collaborative, concurrent projects. A frank appeal for team effort among ecologists will succeed only if the advantages of participation are both apparent and considerable.

Contributory studies, though smaller in scope, must achieve sufficient quality of investigation to make the results useful in comparison with those of major studies.

Once study areas are selected, the PT and PF Subcommittees will work toward the design and development of research programs in the areas. Later, they will coordinate the programs.

NOMINATING STUDY AREAS

Individuals, institutions, or agencies wishing to sponsor study areas are asked to submit nominations to Professor Frederick E. Smith, School of Natural Resources, University of Michigan, Ann Arbor, Mich. 48104. Each nomination should cover all of the points listed below that are relevant to the proposed study area, and any additional material that is deemed suitable by the sponsor.

Each nomination will be evaluated by a task force consisting of (a) members of the PF and PT Subcommittees, and (b) additional scientists qualified to evaluate proposals concerning a given area. It is not anticipated that any one area will satisfy all the criteria listed below, but a proposed area should satisfy enough criteria to assure the task force that intensive ecosystem studies are feasible.

Persons nominating study areas should consider the following outline in preparing their proposals. If an existing facility is involved, distinction should be made between past accomplishment, present activity, and developments that may result from the proposed project. Include a statement concerning the relevance of any proposed research to the objectives of the International Biological Program.

Informal communication, prior to the formal presentation of a nomination, is encouraged wherever it seems desirable. All members of the PF and PT Subcommittees are available for such consultation.

Outline of Criteria

I. Characteristics

Describe the characteristics of the ecological system and its surroundings which would make the site suitable for intensive ecological study relating land and water. Consider the following:

- A. Size of available study area(s) and surrounding buffer zones; evidence of discrete drainage basin.
- B. Assessment of study area from standpoints of both diversity and homogeneity of the biota.
- C. Geographic relation to widespread or local community-types.
- D. Kind, degree, and duration of man's influences; include historic and prehistoric influences as well as contemporary ones; include favorable and unfavorable aspects of economic and legal setting of the area.
- E. Degree of control, including

1. ability to assess change (weather, human and other disturbances)
2. feasibility of manipulation
3. effectiveness and continuity of administrative control.

II. Attributes favorable for study

Summarize information on the following landscape features:

- A. Meteorology
- B. Hydrology (including ground water)
- C. Geography and topography
- D. Geology and geochemistry
- E. Soils
- F. Physical and chemical limnology
- G. Biotic systems

III. Prior research

Summarize existing knowledge with respect to:

- A. Adequacy of taxonomic coverage
- B. Availability of local specialists on taxonomic groups
- C. Availability of reference collections
- D. Records of paleoecology
- E. Records of population histories
- F. Availability of data on biomass, production rates, and human use.

IV. Physical facilities

Description of laboratories, libraries, computer services, transportation, specialized laboratory and field equipment for both terrestrial and aquatic work, and

living accommodations.

V. Personnel

A. Scientific staff

1. Educational affiliations
2. Research interests
3. Pertinent professional experience
4. Bibliography

B. Supporting staff

1. Technical help
2. Graduate students
3. Administrative structure
4. Editorial and photographic services and graphic arts.

VI. Financial background

A. Current support from granting agencies

B. Other sources of support

C. Administration of research funds

D. Maintenance budget

INSTRUMENTATION

To fulfill the objectives of understanding ecosystems at ecological research sites, instrumentation must be available to monitor a number of variables on a continuing basis. Continuous measurement of some of these variables will be needed, while others will be monitored on an intermittent schedule. Likewise, some measurements will pertain to populations, while others will be needed for studies of individual organisms.

Variables to be monitored can be grouped into physical, chemical and biological. Specific instrumentation for each variable will be dictated by the characteristics of the site and the objectives of the study. The accompanying outline indicates the variables which should be instrumented.

It is important that measurements be suitable for constructing biological budgets or contribute to an understanding of the

structure or functioning of an ecosystem. It is also essential that measurements be compatible with system analysis. A number of methodology handbooks have been sponsored by the IBP and should be consulted for guidance on achieving optimum comparability. These are briefly described in IBP NEWS issues. Seven issues have been prepared to date, and may be obtained by writing to the IBP Central Office, 7 Marylebone Road, London, N.W.1. IBP NEWS Numbers 3, 4 and 7 are particularly relevant.

It is expected that a large instrumentation program will be required at each of the major research centers. Consequently it is desirable that these measurements be recorded on punch or magnetic tape for direct computer analysis. Where possible, instrumentation for the contributory studies should provide data that are comparable with the data obtained by the major research centers.

Outline of Variables

I. Physical measurements

A. Water budget

1. Precipitation
2. Soil moisture gradient
3. Evapotranspiration
4. Surface runoff and ground water

B. Radiation budget

1. Solar and thermal radiation
 - a. Incoming and outgoing: quantity, quality
 - b. Distribution: spatial, organism
2. Ionizing radiation
 - a. Quantity
 - b. Spectra

C. Heat flow and temperatures

1. Spatial distribution (atmospheric, aquatic, substrate)
2. Organism

D. Currents (air, rivers, lakes)

1. Spatial distribution
2. Organism

II. Chemical measurements

A. Inorganic chemical budgets

1. Continual monitoring (conductivity, O₂, CO₂)
2. Intermittent (anions, cations)

B. Organic chemical budgets

Carbon, nitrogen and phosphorus budgets, and compounds of known biological activity for which monitoring techniques exist or can be developed.

III. Biological measurements

A. Spatial changes

1. Populations: remote sensing (e.g., sonar, thermal detection, radar, photography)
2. Individuals: remote sensing (e.g., telemetry, photography)

B. Temporal change

1. Phenology
2. Circadian
3. Succession (photography)

C. Metabolism (individuals and populations)

1. Photosynthesis
2. Respiration
3. Water balance
4. Calorimetry
5. Radioactive isotope tags

D. Standing crop

1. Plants
2. Animals
3. Decomposers

E. Production, consumption, elimination

1. Plants
2. Animals
3. Decomposers

INTRODUCTION

The gravest problem facing man in a peaceful world is the establishment of a reasonable harmony between a stabilized world population and the environmental resources upon which that population depends.

Man, like other organisms, lives in and depends upon environment. That environment, it is increasingly clear, is both limited and vulnerable. Millions of human beings at present exist with inadequate food. Vast quantities of wastes reduce the quality of our environment.

Mankind is engaged in a program of self-defeat. Human population increases at an unprecedented rate, and it has proved difficult to stabilize population in those countries where stability is most needed. Technological power is altering environment at an increasing rate, often in ways which are to man's disadvantage--erosion, occupation of prime farm land by housing, atmospheric pollution, and the widespread use of poisons intended for pests. The product of increase in population and increase in the technological power of that population is an increase in rate of detrimental change in the environment on which man depends.

There is no present reason for confidence that man will succeed in bringing about a harmony between his population and environment. It does not seem that technology alone can produce a long-term solution. Technological progress can increase food production and improve environmental conditions, but such benefits are only palliatives if population meanwhile increases. Technological expedients may also produce unforeseen environmental detriment, as in the case of currently increasingly pollution problems. Solution of the problems of man's relation to his environment is possible only through difficult, long-range decisions on limitation of both population and the technological modification of

environment. Such decisions lie outside the province of an organization of biologists; they are in the realm of national policy. There is much, however, that biologists can offer toward understanding of how man's relation to his environment can be rendered stable, non-destructive, and rewarding.

We propose American participation in an intensive international study of man's relation to environment. The concept of ecosystems should be central to this study. Management of environment is best approached through study of productivity, cycling of nutrients, and successional processes within ecosystems. Pollution results from the processes of transfer, chemical transformation, and biological concentration of materials in ecosystems. Man himself is a part of most ecosystems, and thus exerts a considerable influence upon their dynamics. Present ecological understanding has developed from study of particular, limited communities and ecosystems. Cooperative studies of larger-scale ecosystems are needed before existing theory can be applied to their management.

One purpose of the IBP is to develop a more profound understanding of ecosystems and by this means clarify the possibilities of wise long-term utilization. Thus, biologists may effectively contribute to the broader policy decisions on man's future.

GENERAL OBJECTIVES

The PF and PT subcommittees jointly propose the study and comparison of large systems such as drainage basins and landscapes through team effort. Foreign scientists will be urged to participate in these American studies where possible.

The program will consist chiefly of intensive studies on the various components of a few selected areas but will be broadened by contributory work

from other areas. The program will permit a comparison of data from similar and contrasting climatic regions both here and abroad. Such comparison will make possible an unprecedentedly broad evaluation of the interactions among the components of these ecosystems.

An understanding of the ways in which such large ecosystems operate, and the extent to which they can be manipulated, will lead to the development of a new level of ecological theory. Emphasis will be placed on primary productivity and its meaning for man, on trophic structure, energy-flow pathways (food chains), limiting factors, interactions of species, biogeochemical cycling, species diversity, and other attributes which interact to regulate the structure and function of communities.

The program is not to be restricted to natural areas; it will strive to compare ecosystemic processes in environments under various degrees of control by man. Ecological succession should serve as a background in which the general objectives can be pursued. The principles of succession are central to the growing difficulties in the relation between man and nature; yet very few of the generally accepted ideas concerning succession have been tested experimentally or related to whole landscapes as they exist at any one time.

Coordinated studies are to be undertaken within several of the major biotic areas (or terrestrial ecosystems) of the United States. Entire drainage basins will be used for simultaneous study of terrestrial and aquatic environments. Aquatic and terrestrial components of ecosystems must be studied together because they have strong, mutual interactions.

The program will seek to achieve its objective--better understanding of complete ecosystems--through the catalysis of new concepts. These are needed to make possible an evaluation of man's dual role as a manipulator of, and a functional component in, ecosystems.

Two major steps which lead toward this broad objective are:

1. Development of a theory of ecosystems based on relatively small scale laboratory and field studies. True, the elements of such a theory already exist, but require reassessment, refinement, and exploration.
2. Extension of this ecosystem theory, once developed, to large-scale natural systems. Natural systems are, of course, composed of interacting subsystems, which present problems of scale and of organization. These problems can best be attacked by testing ideas developed relative to this higher level of complexity against the results of well organized field activities.

To the extent that efforts to thus integrate theory and observation are successful, they will provide perspective for the already extensive experience in landscape management and may indeed lead to alternative possibilities for that management. The results should make possible improved policies for natural resource use and ecological zoning.

International efforts to expedite this procedure include:

1. Exchange of information at two levels--research design and data analysis.
2. Exchange of mature scientists between laboratories interested in the IBP.
3. Training in specialized techniques of production biology for the IBP and related sciences.

PROGRAM

Intensive Drainage Basin Studies

The study of drainage basins as ecosystems offers possibilities for integrated research which have been neglected or viewed too narrowly, despite their relevance to man's use of his environment. We have recommended, therefore, that much of the effort of the Terrestrial and Freshwater Productivity Sections of the IBP be focused on intensive, multidisciplinary analyses of ecosystems. Study areas will be selected in which the interrelationships of terrestrial and aquatic communities can be investigated. The site should include both undisturbed communities and communities highly modified by human use.

We recommend that concentrated efforts be made in a limited number of sites representing the following ecosystems: deciduous forests, western coniferous forests, grasslands, deserts, arctic tundra, and tropical forests (in cooperation with Latin American groups). Scientists with a wide range of interests should collaborate in these centers for intensive study. Additional contributions can be made through less comprehensive investigations on related communities at other locations.

Limited ecosystem studies are already in progress at a number of locations, including several in the eastern deciduous and western coniferous forests, in the southwestern desert, and in the Arctic. Hydrologic data and other basic information have been gathered at a number of other locations. Any area considered particularly appropriate for comprehensive ecosystem study, either by virtue of the landscape and biological components or by virtue of the background studies completed or in progress there, should be brought to the attention of the Chairman of the PT or PF subcommittee.

Final selection of major sites should be made by a task force, which

should include the following: The Project Coordinator, an animal ecologist, a plant ecologist, a limnologist, a geologist, a hydrologist, a meteorologist. The task force will consider potential cooperation of research centers, training centers, information centers, and non-U. S. collaborators; the inherent ecological interest of each area; and ownership and management problems of each area.

Contributing Studies

The vital need for understanding of ecosystems is such that any ecological study addressed to IBP objectives is encouraged. Two types of studies are complementary to the intensive investigations under IBP sponsorship at selected locations or centers: first, those paralleling special parts of center-based programs; second, geographically extensive studies yielding synoptic data for broad geographic comparisons.

Studies which parallel parts of center-based programs will be pursued by collaborators at many locations and can contribute much to the overall objectives. Such studies may deal with variants of the ecosystem components found in the intensive study areas or they may be concerned with the responses of ecosystem components similar to those of the major study areas but existing under different environmental conditions. These studies will contribute greatly, provided that methods used are comparable and that the data can be used in systems analysis.

The value of certain aspects of ecosystem analysis, particularly seasonal and successional change and productivity, is greatly increased by a wide geographic coverage that includes international cooperation. Studies of this type will involve many independent observers and must follow standards (to be specified in manuals) so that data obtained are strictly comparable. Examples of desirable studies are:

- (1) timing of appearance and other events in life history of easily observed and identified animals;
- (2) dates of emergence, coloring and dropping of leaves for plants with limited genetic variability and widely spread by man, such as ginkgo and metasequoia;
- (3) counts or weights of fruit or seed production made throughout the range of several wide-ranging and economically important species;
- (4) harvest of peak standing crop of native grassland near existing weather stations; and
- (5) correlations of seed yield with peak standing crop in agricultural ecosystems are needed.

Both the PF and PT subcommittees endorse the general objectives of the international committees and recognize as a relevant part of the American program those contributing studies that relate directly to the specific programs of other countries. The international PF program includes studies relating to eutrophication, primary and secondary production, fish production, the chemical environment, production in man-made lakes, and production under environmental extremes. The international PT program includes ecosystem processes of primary and secondary productivity, the dynamics of decomposers, and the interactions of climate, soil, and the impact of man in ecosystems.

The objectives of IBP in attracting widespread interest to human-oriented ecology can be enhanced by the participation of high-school and college teachers, whose share in IBP would later be reflected in the ideas and attitudes which they engender in their students. This work could be coordinated with the Conservation Section's efforts in describing the properties of interesting communities.

Methods

General

Biologists are sensitive to the need for encouraging advanced and imaginative techniques; yet comparability of results will be enhanced by inter-calibrations, standardization of measurements, and faster communication. Three types of publications will elaborate the possibilities for and limitations of techniques:

- (1) published books of general reference value,
- (2) handbooks of the international sections of IBP, and
- (3) supplementary reports of the U. S. national committee on new techniques.

For intensive total-system studies, measurements will be made to all major components of the ecosystem. Measurements should include gross production, respiration, net production, secondary and tertiary production, rates of decomposition, exchange of matter with contiguous systems, soil and topographic settings, and microclimatic and macroclimatic variables. Energy flow, nutrient cycling, and production will be investigated on a seasonal basis. Spatial and temporal variation in selected populations should be given special attention.

Examples of techniques for the above measurement include the use of isotopes for tracing food chains and estimating rates of nutrient cycling; remote sensing with such tools as aerial photography, infrared scanning, radar, sonar, and underwater TV; biotelemetry; laboratory microecosystems; and physical and chemical methods, such as chromatographic techniques, nuclear magnetic resonance, atomic absorption, activation analysis, spectrophotometry, calorimetry, nitrogen analyzers, and respiration chambers with automatic gas analyzers. Contributing studies could involve one, several, or many of the these techniques at locations other than those chosen for intensive study.

Procurement of synoptic data on an extensive basis will require thoughtful standardization of observations and other simple techniques.

Systems Analysis of Ecosystem Components and Processes

In the past two decades numerous computer-oriented mathematical methods have been developed in industry and government for the analysis of complex systems. Many of these methods and tools have direct applications in analyzing complex biological systems, and especially ecosystems. Systems analysis has already been demonstrated to be a successful adjunct to conventional field and laboratory methods in ecology.

Systems analysis should be applied to IBP studies in at least three major ways:

- (1) An early step will involve development of methods to examine existing data on ecosystem processes in a sensitivity analysis aimed to reveal the relative importance of certain factors; this analysis will aid in allocation of resources for research activities in integrated ecosystem studies.
- (2) Computer techniques will permit rapid organization and analysis of data derived in total-system studies, especially those phases involving intensive use of recording equipment.
- (3) Systems methods will be applied in analysis and integration of results from studies in the United States and elsewhere, designed to test and develop ecological theories.

A major task will be to train ecologists in the use of computers and mathematical methods in systems analysis. When possible, systems analysts should be members of each interdisciplinary team. The IBP should make available systems analysts to consult with investigators working on single processes or components or synoptic data to insure that the data obtained can be utilized in composite analyses.

Information Centers

The IBP goal of synthesis of man's understanding of ecosystem relations requires one or more information centers for these purposes:

1. To store primary data and derived variables, for analyses beyond those to be expected at individual research sites.
2. To distribute computer programs and primary data to individuals or other centers.
3. To coordinate basic descriptions and groupings of terrestrial and freshwater systems.
4. To facilitate comparisons between ecosystems and between parts of the world in a total-system context (e.g. summarizing tables expressing rates of transfer of energy, nitrogen, and other elements).
5. To aid IBP planning and activities by storing current information on the work of scientists as it is gathered by project directors.

Training

Since there is a shortage of biologists capable of undertaking the type of studies proposed, training is a major need. The objectives of IBP in general and the study of terrestrial and aquatic environments in particular, cut across traditional academic boundaries. Outstanding ecologists will be encouraged to apply for funds to develop programs to train ecologists who are well trained in a specialty, but are also able to deal with the larger problems of man and the landscape.

Three phases of training are acknowledged: (1) the university predoctoral and postdoctoral programs which require close cooperation between the basic biological and natural resource departments and sound basic training in physical, mathematical, and computer sciences; (2) special institutes for instruction in modern methods for the practicing ecologists; and (3) short courses or workshops for biologists desiring familiarity with recent advances. Where possible, these training programs should encourage the participation of people from other countries.

ADMINISTRATION

For successful development of the intensive research sites, and for coordination of the contributing studies, some stimulation, assistance, and administrative direction will be necessary. We suggest that this be accomplished with a Program Director, a Program Coordinator, and an Advisory Committee.

1. The Program Director and Advisory Committee will be appointed through the concurrence of the PF and PT subcommittees on suitable candidates. The Advisory Committee may also include representatives selected from the appropriate federal agencies. Liaison members from other IBP subcommittees should collaborate in the planning.

2. The Program Director will be a reputable ecologist who will be assisted by a Program Coordinator in handling most of the work of coordinating the studies once they are underway. The Coordinator will be appointed by the Program Director with the approval of the Advisory Committee.

3. Selection of areas for study has been described in the section on "Intensive Studies."

4. The Program Coordinator and Advisory Committee will assist the Program Director in the organization, initiation, development, and execution of comprehensive ecosystem studies. These duties will include:

- a. Development of detailed programs and aiding with project proposals.
- b. Reviewing progress of current programs and identifying areas needing further research.
- c. Informing the scientific community of progress in the programs, particularly on methods being used.
- d. Assisting in attracting investigators to the program.
- e. Assisting in the development of training programs.
- f. Assisting in developing budgets and in obtaining support for the program.
- g. Maintaining close communication and cooperation with relevant programs in other countries.

PROGRAM STATEMENT
of the
Subcommittee on Production Processes

January 1967

NATIONAL RESEARCH COUNCIL
National Academy of Sciences National Academy of Engineering
Division of Biology and Agriculture

PROGRAM STATEMENTOF THESUBCOMMITTEE ON PRODUCTION PROCESSES

POLICY

The clear necessity of matching food production to the needs of the world's population requires an accurate knowledge of the factors limiting primary production in the various regions and environments of the globe. It is the responsibility of the Subcommittee on Production Processes to help assess those limitations and then encourage studies of how they can be managed by man.

Among the more specific goals of this subcommittee are:

1. To identify the environmental factors that limit production of plant materials, particularly food-stuffs.
2. To encourage and coordinate research on the nature of the physiological responses of plants to the stresses introduced by these limitations.

This should provide a natural basis for manipulation of the environmental and biological factors involved in plant production.

We should conduct our investigations of environmental factors on the sites where they are critical, using an international team approach with local and visiting scientists working together. Concomitantly with field studies, laboratory and model studies are to be encouraged.

OPERATIONAL

Recognizing the limitations of time, funds, and personnel, the subcommittee feels that most can be gained by encouraging immediate studies on problems of a specific nature. Momentum gained in the specific studies will eventually lead to more general and broader treatments.

1. For example, there is an urgent need for better understanding of the drought tolerance of basic crops in the Western Hemisphere. Almost all established crop

areas periodically receive suboptimal amounts of precipitation. Study of physiology of plants under water-stress is a prerequisite to an understanding of water economy and drought tolerance.

2. Also needed in the Western Hemisphere is a study of the effects of temperature on the physiology of plants. Such a study is an understanding of frost resistance and of the growth limitations imposed by temperature thresholds.
3. A third specific problem, particularly relevant to plants growing on soils of the tropical areas of the Western Hemisphere, relates to restricted rooting volume due to low base status, soil acidity, and aluminum toxicity. Basic physiological studies of root growth-root rhizosphere interaction are needed.
4. Nitrogen often is the element that limits primary production, yet the atmosphere contains a vast reservoir of this element in a form utilizable by only certain systems. As part of the IBP program, it is essential to encourage pertinent research bearing on the problems of nitrogen fixation. In particular, it is essential to have these aims:
 - a. To assess quantitatively the magnitude of nitrogen on both a regional and a world-wide basis. The studies should give attention to great world soil groups and climates and to the evaluation of fixation in the hydrosphere. Standardization of methods and the coordination of studies with those of other national programs are particularly desirable.
 - b. To determine the factors that influence fixation and limit its rate and magnitude. Special attention should be given to the role of nitrogen fixation in limiting primary production.
 - c. To evaluate the potential for nitrogen fixation in inadequately investigated areas (e.g., in the Tropics, in the Arctic zone, and in hydrosphere).
 - d. To determine the distribution of the organisms or symbiotic associations which bring about the fixation of nitrogen. The studies

should pay particular attention to the identity and distribution of as yet unrecognized organisms capable of fixation as well as to the distribution of nitrogen fixers in adequately described habitats.

- e. To investigate the nitrogen budget and nitrogen cycle, with particular emphasis on nitrogen gains and losses, as related to primary production.
- f. To study the systematics of nitrogen-fixing organisms, encouraging the introduction of modern taxonomic methods to the investigations.
- g. To encourage further work to define the biochemical mechanism of nitrogen fixation and the physiological processes associated with the reaction.

To accomplish the foregoing aims, certain immediate actions are necessary:

1. Encouraging the development of culture collections of the symbiotic nitrogen fixers and making arrangements for the maintenance of a permanent collection of root-nodule bacteria.
2. Supporting the preparation and publication of
 - a. a compilation of methods currently in use for the study and evaluation of nitrogen fixation, and
 - b. a critical analysis of the limitations of those methods.

Attention will be given to methods for nitrogen analysis and for isotope ratio determination as well as to microbiological procedures and the methods of systematics.

3. Providing means for the use of available specialized instruments (e.g., mass spectrometers) in the accomplishment of routine analytical determinations through support of custom analyses on a modest charge basis.

In focusing on these specific problems, the subcommittee is fully aware of the need to assess the precise extent of the chief impediments to production processes. For example, a rain forest may contain islands of drought; a desert may contain islands of arable land. Appraising the hemispheric extent of these areas requires hemispheric maps of rainfall, radiation, soils, and frost. The maps must show the probabilities or frequencies of quantities needed to appraise the dependability of production. This Subcommittee endorses, therefore, the efforts of those organizations, such as the World Meteorology Organization, that have mission and capability of organizing these fundamental surveys.

The Subcommittee also sees the need for investigations - often by international, interdisciplinary teams - that might reveal ways of removing limitations upon photosynthesis of food. Unquestionably many investigations can contribute to this, but the Subcommittee endorses those that take advantage of this rare opportunity of internationality. New combinations of nationalities, disciplines, and agricultural ecosystems may reveal new ways of removing such limitations as drought, soil fertility, and cold. It seems that the prospects of discovery would be particularly good if several scientists could be brought together for study of an ecosystem unlike the well-known ones of Temperate Zone agriculture. Several months of on-the-spot study would be followed by laboratory research at home bases. Several studies of this kind could be carried out during the life of the IBP.

PROCEDURE

To advance research in the four problems designated the Subcommittee will hold two symposia with working conferences during 1967. The first will deal with physiological limitations on primary production under conditions of water and temperature stress; the second will deal with nitrogen balance.

About thirty scientists will be brought together from throughout the Hemisphere. First the state of knowledge will be presented in the symposia, then the goals and review procedure of proposals will be advanced, and finally, the conferees will be invited to join in research.

Further, the four goals and procedure for review will be announced through publication.

Proposals for training graduate students and others are invited for review. The Subcommittee will examine each proposal for pertinence to the four problems. Each proposal judged to be pertinent and scientifically sound will be forwarded, with the Subcommittee's endorsement, to the funding agency designated by the person making the proposal.

115

116

117

118

119

PROGRAM STATEMENT

of the

Subcommittee on Productivity of Marine Communities

January 1967

NATIONAL RESEARCH COUNCIL

National Academy of Sciences

National Academy of Engineering

Division of Biology and Agriculture

PROGRAM STATEMENT
OF THE
SUBCOMMITTEE ON PRODUCTIVITY OF MARINE COMMUNITIES

INTRODUCTION

The marine program of the International Biological Program has among its objectives the support of studies which will improve our understanding of the ecosystem as a whole, and provide an evaluation of its responses to modifications of the environment. Because of man's increasing interaction with his environment, it is urgent that marine biologists undertake, on a global scale, studies which will produce a clear definition of existing conditions, and an understanding of the mechanisms and processes which control the distribution, survival and development of natural populations.

The rapidly increasing human population and the great technological developments of this century have modified the natural environment in many ways. One of the most injurious of man's activities is the introduction of pollutants into the air and water. In the marine environment man's influence has been greatest in the estuaries and the near-shore coastal waters. Even far from land, however, such pollutants as fallout, radioisotopes, lead and the organic residues of pesticides and detergents have been detected. Increasing pollution is a byproduct of industrial and municipal progress and is perhaps unavoidable in our affluent society. It is necessary to dispose of wastes; but, as practiced today, waste disposal has depleted many natural populations and destroyed the recreational potential of waterways which a few years ago were among the most beautiful in the world. Unfortunately, the marine biologist is unable to predict the specific effects of proposed modifications or developments. There is urgent need to develop this ability.

Another important reason for seeking a better understanding of the marine environment is the growing need to exploit more effectively the protein resources of the sea. There are many questions to be answered: Can local stocks of food organisms be maintained while industrial and commercial activities in

inshore and shallow waters are developed? Can fishing pressures be increased? Can edible but presently not marketed forms take up the slack? Can we turn from being merely a predator to becoming a knowledgeable steward of the riches of our waters?

At least half the world's people lack sufficient animal protein in their diet. The production of carbohydrates on the land has been greatly increased and can be further increased to provide sufficient calories for human needs. The importance of the sea is in providing animal protein. The sea is already supplying a major share of the protein eaten by many people in the world and is an obvious source for additional supplies. Fundamental knowledge of the ocean and its biota is necessary in order to use our marine resources wisely.

The Committee feels that a new approach to the problems of conservation is needed. In general, conservationists have dealt with problems of maintaining productivity of fishery resources with a negative rather than a positive philosophy. The emphasis has been on limiting the sizes or quantities of fish and shellfish harvested, or on limiting fishing to certain seasons, areas or methods. This philosophy assumes that the only influence affecting fishery resources that can be controlled is man, and that a population of marine organisms cannot be increased beyond a point established by natural conditions.

It is time for a positive, active approach: What can we do (not what must we stop doing) to increase production of seafoods? We should cultivate the sea with the same attitude with which we cultivate the land. The massive biological problems associated with such a broad approach are within the purview of the International Biological Program. As information which will be the scientific basis of conservation action becomes available, it is urgent that the practical application should be as immediate as the socio-economic situation will permit.

THE PROGRAM

The solution of these basic marine problems will require investigations on a broad front, at various levels of complexity. These will include laboratory studies of the responses of individual species to controlled variations in their environment, studies of species and populations in their natural habitat, studies of communities of organisms in a restricted habitat or environment and interdisciplinary studies of complex ecosystems. This report emphasizes the more complex problems because the solutions are beyond the resources of a single scientist, or even of existing groups of scientists. Clearly, however, understanding will also require continuing studies of single species, populations, and communities both in the laboratory and in the field. The intent of the proposed program is to offer individual scientists an opportunity to cooperate with others in various ways in order to provide a more comprehensive understanding of the interactions of the multitude of processes which control the productivity of the sea.

Ecosystem Analysis

Nature is too complex for a piecemeal attack, and the time is propitious for an interdisciplinary study of a marine ecosystem so that all parts may be analyzed. The analysis must include evaluation of: (1) The organisms present and their population density, (2) the relation between one species and another, and (3) the effects of currents, seasonal changes, changes in the chemistry of the water, exchanges between the water and the sediments on the bottom, and other variables.

This type of approach is needed because a number of problems confronting biologists deal not with individual organisms or with single species populations but with entire ecological systems. In the marine environment, physical, chemical and geological processes and conditions sometimes affect--and sometimes control--the success of organisms and of populations. A complete study of an ecosystem requires the cooperative effort of many specialists, each contributing his particular insight to the composite description of the system as a whole. The Marine Productivity Subcommittee hopes to bring together interested U. S. scientists and to provide them the opportunity to participate in cooperative and coordinated ecosystem studies.

Ecosystem analysis is most likely to be successful where the life cycles of the dominant organisms are short and the number of trophic levels is small. These determine the required duration and frequency of field observations. In addition, since the structure of a biotic community is determined more by the history of environmental conditions than by the existing conditions at a given time and place, observations must be continued long enough to provide such a history. For a major ecosystem, this implies a continuing series of observations for years. The nature of the observations to be made will require enlightened insights into causal relationships, insights that perhaps can best be developed through intensive studies of selected processes and mechanisms both in the field and in the laboratory.

The variety of necessary observations makes obvious the reasons why the ecosystem approach has been applied imperfectly and on rare occasions to marine communities. Since no individual can encompass all of the abilities, interests and techniques required, a coordinated attack is needed in the effort to solve some of the major marine problems of pollution, fisheries management, and the deliberate modification of the sea to increase marine resources.

Modification of the Environment

The study of marine ecology by observation and description has not provided an adequate understanding of marine ecosystems. To improve our ability to predict the effects of modifications of the environment, we must analyze ecological processes in stressed and unstressed ecosystems. It seems unlikely that an ecosystem would be stressed appropriately by chance. The deliberate modification of an ecosystem as a research tool appears necessary.

In some instances an ecosystem or a portion of one may be simulated and subjected to a series of experimental changes. This may be both costly and time consuming because of the size of the required simulation and the time needed for meaningful responses. Miniaturization of an ecosystem in space or time may provide useful preliminary information, but one cannot be sure that it will provide information on which one may base predictions of the responses of a full-scale system. Deliberate manipulation of an ecosystem is potentially a powerful research

tool and may provide understanding of ways to increase significantly the value of an ecosystem to man. Possible manipulations include the selective reduction of competitors and predators of resource organisms, the development of artificial reefs, the modification of temperature with the cooling waters of power plants, the addition of nutrients from deeper water or other sources, and the fertilization of the environment with pollutants.

Eutrophication of natural waters is an example of man's unplanned and detrimental modification of the environment. This type of overfertilization, a serious problem in many estuaries, presents a challenge and an opportunity to marine ecologists, since lack of essential nutrients commonly limits biological productivity. Increasing the supply of nutrients by adding sewage wastes to natural waters has the potential of increasing biological productivity in ways useful to man. Generally, however, the community structure is changed, with fewer species able to survive and grow in the changed environment. The species of plants which are most likely to survive in highly polluted areas are frequently those which are least suitable as food for the higher trophic levels. Examples of this phenomenon are numerous, but biologists do not understand the causal mechanisms. Is it simply the result of the higher concentrations of the nutrients, or because of changes in the proportions of elements? Would addition of trace elements or essential organic compounds maintain the normal community at a higher level? Can biologists and physiologists achieve the understanding of eutrophication needed to increase the yield of useful organisms and reduce the yield of the undesirable ones? Planned fertilization of an ecosystem might lead to this understanding, or at least establish the limits of fertilization above which undesirable effects predominate.

Distribution and Abundance

Organisms in the sea, like those on land, are spottily distributed in space and time. Patterns of distribution and behavior vary with age. For example, species that are sessile as adults are frequently pelagic during larval stages, and mobile species that concentrate near shore during juvenile stages move into deeper water and migrate successively longer distances as they grow older. Why and how do marine species concentrate in certain places and avoid others? Finding the

answer calls for surveying and mapping, in quantitative terms, entire distributions of species at all life stages, along with significant properties of the environment. This necessitates simultaneous, systematic collections of data and material at frequent intervals to demonstrate the shapes and limits of distribution.

For scientists interested in biogeographical problems, it would be helpful to coordinate the vessel programs of the coastal laboratories so that each could concentrate its work in a relatively small sector, thus avoiding overlapping and gaps in the areas studied and providing nearly synoptic coverage. Concomitant data on temperature and salinity should be recorded to identify water masses and to determine the relationship between the distribution and the environmental characteristics.

In their efforts to describe the distribution and abundance of marine organisms, systematists and biogeographers have been hampered by inadequate support for working up and maintaining collections. Steps to correct the deficiencies are being taken, but there continues to be a need for more precise definition of marine populations by serological and other biochemical and physiological techniques, some of which involve laboratory cultures or experiments.

INTERNATIONAL COOPERATION

One of the IBP's most valuable attributes will be the comparison and synthesis of research results that arise from cooperation throughout the world. Such cooperation should be fostered by joint planning of programs and by interchange of scientific personnel for participation in research or for training. Comparability of observations should be insured by intercalibration of measurements, and by agreeing on uniform analytical and collecting techniques. Projects which by their nature will require cooperative effort will include, for example, comparison between estuaries that are unpolluted and other estuaries in heavily industrialized areas; detailed description of biotic communities on both coasts of Central America in anticipation of a sea-level canal; studies of conditions leading to red tide outbreaks and assessment of the

consequences of these outbreaks in various parts of the world; and the productivity and ecological role of benthic marine algae along different coasts.

IMPLEMENTATION OF PROGRAM

The proposed program, described above, was drafted by this Subcommittee after each member had held extensive discussions with some of his colleagues. The Subcommittee also circulated a questionnaire to a limited number of marine biologists and the proposed program incorporates many of the interests of those who responded. The program will be further developed by holding regional working-group meetings of those scientists who have expressed an interest in participating in the proposed cooperative studies. These meetings are expected to produce specific plans and budgets for the proposed activities and to develop proposals for the initiation of the research. Your best assurance that the final program will accurately reflect the interests of U. S. marine biologists will come from active participation in the final phases of planning during the next few months.

A report of the responses to the questionnaire has been sent to all who received it, and is summarized here.* The questionnaire was mailed to 400 marine scientists, and answers were received from 144. Communications have been received from an additional 50 scientists who have expressed an interest in the program. The specialties of microbiology, phytoplankton, phytobenthos, zoobenthos and fishes are fairly evenly represented in the responses. By type of marine environment in which they are interested, the scientists are grouped as follows: coastal waters (40%); estuaries (25%); open sea (20%); and the intertidal environment (15%). Most of the respondents were interested in participating in cooperative investigations such as interdisciplinary ecosystem studies (40%) and planned modification of the environment (20%). The remainder were interested in laboratory or field studies of processes or mechanisms, or in the distribution of plants and animals in various

*Additional copies of the report and other information about IBP can be obtained from the U. S. National Committee for the IBP, National Academy of Sciences-National Research Council, 2101 Constitution Avenue, Washington, D. C. 20418

parts of the marine environment. The latter subject, which was not included in the questionnaire, has been incorporated into the program proposed in this report. The individual studies of the mechanisms or processes will be vital for the development of insights and of the understanding of the marine ecosystem.

In addition to replying to the questionnaire, many of the scientists wrote very thoughtful letters which have included a number of suggestions for the further development of the International Biological Program. It should be emphasized that the character of the final program will ultimately be determined by the scientists who are participating in it. The objectives of the National Committee are to encourage research and education in the field of marine biology and to provide the opportunity for cooperative effort. Your active collaboration in the further development of the program is earnestly solicited. You are urged to pass on this report and other information about IBP to your colleagues and students who may be interested in the program.

It is apparent that the coastal regions of the United States are so diverse that it would be unrealistic to attempt to develop a single marine program for the entire country. Five regional ad hoc planning committees have been established as follows:

<u>Region</u>	<u>Convener</u>
North Atlantic -----	B. H. Ketchum
Mid-Atlantic -----	L. A. Walford
South Atlantic and Gulf Coast -----	D. E. Wohlschlag
South Pacific and -----	F. T. Haxo
Hawaii -----	V. E. Brock
North Pacific and Alaska -----	D. L. Ray

Regional meetings are to be held to determine how the scientists in the area want to develop the program. As a start, those scientists who, in response to the questionnaire, indicated interest in participating in cooperative, interdisciplinary ecosystem studies or in planned modification of the environment will be invited to cooperate in this planning. These meetings are expected to produce specific plans for the proposed activities, including budgets, and proposals for the initiation of the research.

Individual scientists may participate in the program in a variety of ways. The U. S. National Committee of the IBP has agreed to review and evaluate proposals from the point of view of appropriateness for the IBP. A proposal may be submitted directly to a granting agency by the originator and a copy to the IBP office, Division of Biology & Agriculture, NAS-NRC. A proposal recommended or accepted by the USNC-IBP will compete with other proposals for available funds, and final judgment for support of the proposal rests with the granting agency.

Those scientists desiring to participate in the program should write to the appropriate regional convener. If the intent is to participate in the regional ad hoc planning meetings, this communication should be prompt, since the meetings will be scheduled during January 1967. As indicated above, those who have already expressed their interest in the proposed cooperative studies will be sent announcements of the meeting. Funds will be available to pay travel expenses for some of the participants at these working-group sessions. If you want to attend and will need financial support for your travel, you should write to the convener, even if you have responded previously.

The programs of research developed by the regional ad hoc committees will be reviewed by this Subcommittee and, if approved, will constitute the central theme of the program. Worthy proposals designed to fit into or cooperate with one of the regional programs will be given the highest ratings for appropriateness to the IBP objectives.

Many scientists want to participate in the "Supporting Investigations" of the IBP program. Some of these may be vital to the development of the program, even if they are conducted

independently of any regional program. For inclusion in the IBP, proposals for these studies should also be submitted to the IBP for review. This may be done for research programs which are in progress and already funded, or at the same time the proposal is submitted to the granting agency, or prior to submission to a granting agency, and is especially desirable if the originator would appreciate the comments and advice of the committee members. The proposals should be prepared in accordance with the guidelines provided by the granting agencies. The review will be based both on quality and on the appropriateness to the IBP.

P R O G R A M S T A T E M E N T

of the

Subcommittee on Human Adaptability

of the

U. S. National Committee for the International Biological Program

10 January 1967

N A T I O N A L R E S E A R C H C O U N C I L

National Academy of Sciences

National Academy of Engineering

Division of Biology and Agriculture

317

PROGRAM STATEMENTOF THESUBCOMMITTEE ON HUMAN ADAPTABILITY

The evolutionary success of the human species is based on genetic, morphologic, physiologic, and behavioral variation. The processes and mechanisms of human adaptability are the special concern of this Subcommittee. The term "adaptability" is here used in several senses, including the adaptability of populations and individuals and genetic and phenotypic adaptability.

Human adaptability has multiple bases, with consequences for human survival. However, neither the distribution nor the sources of man's variability have been rigorously measured. The International Biological Program presents a unique opportunity for determining the relative importance of these aspects of variability, and of establishing underlying mechanisms on the basis of closely comparable studies of different groups--groups having contrasting genetic, social, nutritional, and climatic backgrounds.

THE DYNAMICS OF HUMAN POPULATIONS

The range of human populations available for this type of investigation should provide the IBP with possibilities for thoroughly assessing sources of variability. At one extreme are few surviving examples of hunting-gathering and incipient agricultural populations, which represent what were the norms of adaptation until relatively recent times. At the other extreme are diverse industrialized populations.

Some of the primitive groups--e.g., the South African bushman, the Australian aborigines, the Eskimos, certain tribes of Central and South American Indians--are disappearing rapidly, culturally if not biologically. IBP studies of these groups would provide invaluable baselines for investigations of a variety of other populations that exhibit significant contrasts in genetic background, habitat, and culture. Many of the primitive populations have limited resources and have, therefore, been exercising control of population size for centuries. Thus, the study of primitive populations will shed light on processes by which populations control their sizes. The study of such groups is not only extremely timely, but because of their location, may provide unusual opportunities for international cooperation.

Special attention should be paid to biological adaptation of racial isolates of industrialized societies and migrant groups moving from one environment to another. Studies of short-term and long-term migrations by different racial groups to similar environments are desirable. The studies should include baseline studies in the original environments and comparative measurements in the new location; such measurements on the same individuals would be particularly valuable.

Careful descriptions of individual micro-environments and actual behavior need to be included in all population studies. And, before any study is chosen as an IBP project, consideration should be given to whether it would provide opportunity for international cooperation and for making international comparisons. The subcommittee anticipates that studies will focus on three areas--population genetics; adaptation to stress; and morphology, growth, and aging.

POPULATION GENETICS

Mankind possesses great diversity both within and between populations. This diversity has been the basis of both the evolutionary success and many of the present problems of the species.

It is obvious that long-term changes in the human population have occurred and that the environment of man is changing rapidly both physically and culturally. Description and explanation of the underlying processes of change are essential to understanding population dynamics. Whereas individuals succumb to critical changes in environment, populations adapt, natural selection being the principal process leading to this adaptation.

A partial listing of forces and processes entering into population dynamics follows, each of which is a problem for IBP research:

1. Mating choices and patterns, including inbreeding, outbreeding and assortative mating.
2. Fertility.
3. Fetal wastage.
4. Postnatal natural selection.
5. Fluctuation and disappearance of populations.
6. Hybridization between populations.
7. Behavior genetics.
8. Genetic drift and founder's principle.

Of crucial relevance are the processes determining transmission of genetic material from one generation to the next.

ADAPTATION TO STRESS

Stresses may be defined as those conditions which impose measurable consequences upon individuals and populations. Stresses involve both stimulus deficiencies and excesses, are specific to individuals, and are recognizable by behavioral, physiological, morphological, and ultimately, genetic manifestations.

An inventory of stresses significant to historical and current phenotypical adaptation and selection in man includes large numbers of physical, nutritional, disease, and behavioral factors. Studies of interest to the Subcommittee on Human Adaptability encompass virtually all, although in some areas, such as noise, work to date has been initiated only in limited ways. Studies of the following areas are proposed:

1. Environmental Stresses

a. Cold tolerance

Comparative studies of whole body cooling and metabolic adjustments to standard cold stresses, local vascular adjustments to cold, and cold pressor tests.

b. Heat tolerance

Comparative studies of temperature, regulatory responses of limited numbers of subjects under standard work-heat stress, and of larger groups of subjects performing standard work (marching) under field conditions in hot climates, with standardized subjects serving as controls.

c. High altitudes

Comparative studies of hematology, body fluid components, metabolism, respiratory function, and circulatory responses of subjects under basal conditions and in standard work tests.

d. Working capacity

Metabolic, respiratory, and circulatory adjustments of subjects to a standard aerobic work test, and to strenuous work tests designed to determine both aerobic and anaerobic capacities.

2. Nutritional Stresses

Research in human nutrition is critical to any understanding of other aspects of human adaptation and to human welfare generally.

a. Nutritional requirements

These are modified by a variety of individual characteristics, such as genetic endowment, age, weight, and sex; the physical environment; and by activity levels. The role of these factors in determining the nutritional requirements of a particular population is poorly understood, and an extensive research program in this area is highly desirable.

b. Nutrition and stress resistance

The role of nutritional history in determining the stress resistance of a population is very poorly understood. Research should include specific investigations of the relations between nutrition and disease resistance, and between nutrition and thermal regulatory processes. These investigations should take advantage of the breadth of the IBP by emphasizing genetically distinct populations. They would be most valuable when directed toward young children.

c. Adjustments to under-nutrition

By morphological, behavioral, physiological, and biochemical changes, human populations and individuals are able to survive in nutritional circumstances which by most criteria are considered inadequate. Such groups and individuals may be considered adapted to undernutrition. The consequences of the adaptations are not well known and a critical world-wide problem

is their determination in order to understand world population potentials and also to serve as a baseline for predicting the consequences of particular nutritional regimens.

All studies of human nutrition should be developed in collaboration with the Subcommittee on Use and Management of Biological Resources.

3. Disease

Investigations of adaptative processes in relation to disease are relevant to geographical pathology. Three major problems are pertinent to the Human Adaptability program.

First, disease as an agent of natural selection: Among, the diseases that might be studied in this context are tuberculosis, malaria, syphilis, Hansen's disease, Chagas' disease, trypanosomiasis, trichinosis, schistosomiasis, and other helminthiases. Investigations of these diseases, within the framework of the Human Adaptability program, should be multidisciplinary, emphasizing intensity of infection and differential epidemiology in selected populations.

Among the related materials to be accumulated on these intensively studied populations are genetic data and data on nutritional and other stresses experienced by the populations.

Coordination with the Subcommittee on Conservation of Ecosystems is highly desirable.

Second, overall morbidity patterns within selected populations: In these investigations, one objective should be to gain information regarding differential susceptibility--e.g., data on exposure to disease as indicated by titers of antibodies and data on reactivity to disease as indicated by development of clinical illness.

Third, the allergic diseases: These conditions are in many instances consequences of civiliza-

tion, manipulation of the ecosystem, and even preventive and therapeutic practice. In a sense, allergic diseases are due to failures of adaptation. Thus, intensive investigations of these conditions are most relevant to the Human Adaptability program.

4. Biological Consequences of Human Activity

The human activity cycles have been discovered to depart markedly from idealized accounts. We have virtually no observed and quantified information on other than limited groups within western societies. Therefore, the Human Adaptability program will include studies of:

- a. Activity cycles in peoples of different cultures.
- b. Human energy costs of specific activities.
- c. The skills involved in various activities, such as ecological exploitations, hunting, running, and burden bearing.

These studies should be designed to provide information on the consequences of these activities to both the individual and the population.

MORPHOLOGY, GROWTH, AND AGING

Data on morphology, physical growth, and aging will be collected in the context of other studies on human adaptability. However, our knowledge of the relation between developmental and environmental factors is so inadequate that special studies are also recommended. Suitable topics include:

1. Early (perinatal to young child) human development in relation to environmental stress.
2. The relation between physical and behavioral development.
3. The adaptive aspects of child development.
4. Man's physiological adjustments to such stresses as heat, cold, hypoxia and work.

These studies would be particularly valuable if they would compare genetically distinct populations. Longitudinal studies should be favored over cross-sectional ones, although both are necessary.

PROGRAM PLANNING

The elements of program planning are:

1. Statement of specific questions within a hypothetical context.
2. Selection of appropriate technical methodology.
3. Selection of appropriate human populations.
4. Site selection.
5. Construction of experimental design.
6. Development of logistics, instrumentation, and training.

Because the Human Adaptability program envisages undertaking complex multidisciplinary investigations, the Human Adaptability Subcommittee will convene several carefully structured planning conferences to elaborate details of problem-oriented research projects, typologically and regionally. At the same time, the Subcommittee encourages interdisciplinary groups to come forward with additional ideas and program projects consistent with the objectives of the IBP.

REGIONAL PLANNING CENTERS

Planning should be undertaken by interdisciplinary groups composed of individuals who will ultimately engage in the research. Potential groups within the U. S. should be identified and funded. Such groups presumably would be centered at academic institutions having a nucleus of competent biologists and appropriate facilities. The biologists of these centers should bring into the advanced planning the facilities of those institutions located in the vicinity of the centers. The biologists involved in this phase of development of IBP should be selected according to their willingness and competence to contribute and not according to their relation to a particular section of IBP, for the aim would be to develop a program of research consistent with the objectives of the IBP.

CONFERENCES

At a regional center a group will be established which will take the initiative in organizing conferences and in seeing that detailed planning is accomplished. The participants in these regional conferences should be persons who are likely to participate actively in the research under discussion.

At least two conferences will be necessary. The purpose of the first conference will be to state the specific questions that should be studied, decide on methods, select populations for study, outline experimental design, and create working parties to develop details and budgets. These parties will prepare working papers for the large group prior to the second conference. At the second conference the detailed planning will be completed with the development of an integrated program and a comprehensive budget. Selected foreign scientists should be included in these conferences; their presence is necessary for coordination and collaboration. Representatives of granting agencies should be invited to attend as observers.

METHODOLOGY

Although many investigations now in progress relate to the questions raised by the IBP human adaptability program, few have the scope here envisioned and few have adopted a standard methodology for assessing human adaptability. In this program, new multidisciplinary studies will be carried out. They will assess the sources of variation in human adaptability and determine the adaptive processes by a battery of agreed upon standardized procedures.

Several requirements must be applied to selection of methods for conducting the studies.

First, the methods should provide discriminatory measures of the biological and environmental factors relating to human adaptability.

Second, the methods should be capable of field application on representative stratified samples of the populations selected for study.

Third, the methods should yield a maximum of information with a minimum disturbance of the groups investigated.

It is proposed that appropriate methodologies meeting these requirements be carefully tested and validated in institutions already well equipped and experienced in this work. The detailed findings and recommendations of the study groups will be published for the guidance of IBP and other investigators.

Among the methods that must be standardized in this fashion are those concerned with the evaluation of working capacity; physiological

reactions to heat, cold, and altitude; nutritional status; and other relevant demographic, genetic, medical, and behavioral factors.

Early attention must be given to development of instrumentation suitable for use in studies of human populations. It is essential that serious consideration be given to the cost-effectiveness of all instrumentation. Equally important in the planning is the matter of logistics.

It is essential for understanding human adaptability that there be more experimentation on human volunteers. Wherever human experimentation is the method chosen, the projects must be consistent with the ethical codes governing the experimental use of human subjects (e.g., Declaration of Helsinki. Recommendations guiding doctors in clinical research adopted by the World Medical Association in 1964; population genetics in primitive groups. WMO Tech Report No. 32, 1964) and fulfill the conditions stated in PPO #129 (dated July 1, 1966) from the Surgeon General of the U. S. Public Health Service.

RESEARCH DESIGN

The details of each investigation should be designed to sort out the key aspects of interest to the several regional groups. The size of the populations chosen for study should be appropriate to the nature of each problem. Site selection should be made in collaboration with the IBP Subcommittee on Conservation of Ecosystems. Attention must be given to details of recording observations and storing and processing information. Provision should also be made for storing human biological materials in appropriate banks, (e.g., sera and other body fluids) for future immunological or genetic study. Where appropriate, the storage should be coordinated with WHO and with the IBP Subcommittee on Use and Management of Biological Resources.

A broad overriding consideration is that, where feasible, the research design for human adaptability should be integrated with broader planning for the IBP.

TRAINING

In order to accomplish the research proposed in this program, it will be necessary to involve not only seasoned investigators but also graduate students aspiring to become human biologists or human

ecologists. These graduate students will have to be recruited from a group that is under pressure to follow other courses of action. Graduate education and advanced research training under the IBP must, therefore, be integrated into other programs to enlarge the manpower pool of "environmental health scientists." It is urged that inter-institutional cooperation be utilized so that faculties can be pooled in the training. Arrangements should be made for interinstitutional movements of students, for in this way they could take advantage of unique facilities and specialized talents available within the regional centers.

ENDORSEMENT OF THE HUMAN ADAPTABILITY SUBCOMMITTEE

Investigations of human adaptability of the type referred to here are already being considered by various groups in the U. S. and will be developed and submitted to Federal agencies for support whether or not there is an IBP. USNC-IBP will encourage and support these investigations, will provide for appropriate liaison with other national groups, and will seek funds for the planning and conduct of the investigations. The purpose of these efforts is to insure maximum coordination of investigations of human adaptability.

The Human Adaptability subcommittee will review each proposal submitted to it with a view to making two determinations:

1. Relevance of the proposal to IBP, and
2. possession of scientific merit of a high order.

PROGRAM PROGRESS

The Human Adaptability subcommittee has instituted several project-planning conferences:

1. Human Adaptability in Israel. Convenors: J. Magnes (Israel), O. E. Edholm (U. K.), and G. M. Briggs (U. S.). The planning is being coordinated with Use and Management of Biological Resources Subcommittee.
2. A study of circumpolar peoples. Convenors: J. A. Hildes (Canada) and F. A. Milan (U. S.)
3. Ecology of migrant populations in the midwestern U. S.

Convenors: F. Sargent and D. B. Shimkin (U. S.)

4. Problems of adaptability among human populations residing in high mountains. Convenor: P. T. Baker (U. S.)

Two other project-planning conferences have been discussed, but firm plans for meeting have not been formulated. F. Sargent, W. E. Laughlin, and R. H. Osborne (U. S.) and S. Kondo (Japan) have considered a project on study of the ecological problems facing migrant racial and hybrid groups residing in the Western Hemisphere. R. A. Audy (U. S.) has begun to plan studies on the socio-cultural aspects of health in the Pacific area, with special reference to a longitudinal investigation of child maturation in Southeast Asia. Under his direction a working group of the Pacific Science Association is also developing plans for establishing an information exchange center.

Human Adaptability is currently screening several hundred research projects on file with Science Information Exchange with a view to identifying on-going studies that might be relevant to the IBP.

Members of Human Adaptability have also participated in international conferences on methodology and on the identification of major problems of human adaptability. Publications have resulted from these conferences and are important references.

Biology of Human Adaptability, by P. T. Baker (edited by J. S. Weiner), was published by Oxford University Press in 1966.

Conference on Methodology in Human Adaptability (conference held in Kyoto, Japan, in 1965) is to be published by the Japanese Society for the Promotion of Science.

Conference on Human Adaptability (conference held in Warsaw in 1965) is to be published by the Polish Academy of Sciences.

P R O G R A M S T A T E M E N T
of the
SUBCOMMITTEE ON SYSTEMATICS AND BIOGEOGRAPHY
of the
U. S. National Committee for the International Biological Program

January 1967

N A T I O N A L R E S E A R C H C O U N C I L
National Academy of Sciences National Academy of Engineering
Division of Biology and Agriculture

PROGRAM STATEMENTOF THESUBCOMMITTEE ON SYSTEMATICS AND BIOGEOGRAPHY

The diversity and relationships of organisms are important considerations in all programs of the International Biological Program (IBP). The Subcommittee on Systematics and Biogeography (SB) is concerned with the systematics and biogeography of organisms, including their ecological, spatial, and temporal distribution, on land, in fresh water, and in the ocean. The Subcommittee is interested in advancing projects that will contribute to understanding of the evolution and adaptation of the components of the world's biota, as well as of assemblages that are themselves undergoing changes. In addition to developing its own program, the Subcommittee can participate in the programs of other subcommittees in various ways.

The Subcommittee wishes to emphasize its receptivity to ideas for expanding its usefulness, and its willingness to consider a wide variety of proposals for systematic and biogeographic studies within the framework of the IBP.

PROJECTS IN SYSTEMATIC AND EVOLUTIONARY BIOLOGY

An appallingly large part of the animal and plant life of the world is threatened with extinction, owing to the population explosion, improved communication, the commercialization of previously underdeveloped countries, and the intensification of agriculture, forestry, and other types of land use. Threatened biotas exist in all parts of the world but are particularly numerous in tropical and subtropical areas where recent changes in land use have been especially drastic. Only the specialist knows how extraordinarily restricted are the ranges of many species of animals and plants. It is the responsibility of the present generation to carry out detailed research on the endangered biotas and to preserve documented voucher material.

We propose to undertake a few interdisciplinary studies which will require international cooperation. They will deal with selected biotas of major systematic and evolutionary significance, particularly those in imminent danger of destruction.

For the organization and conduct of each such major project the

Subcommittee will select a director, aided if necessary by a full-time coordinator, and will appoint a task force. It will be the duty of the director and the task force, under the continuing general supervision of the Subcommittee to:

- a. Evaluate the suitability of the potential sites for the study and aid in making the final selection.
- b. Find competent experts in the U. S. and other countries.
- c. Prepare the proposal and apply for funds.
- d. Involve graduate trainees in systematic biology and ecology.
- e. Consult and cooperate with groups within and outside of the IBP.
- f. Facilitate the publication of results.

After the program is under way the Subcommittee on Systematics and Biogeography will retain an advisory role.

DESCRIPTION OF TWO PLANNED PROJECTS

Two such projects are being planned at this time.

The Hawaii Project

The Subcommittee has approved this as its first major undertaking. The subcommittee on Conservation of Ecosystems is prepared to participate. The Hawaii Project will be a detailed, long-term, comprehensive investigation of the endemic and invading biotas of Hawaii. This group of islands supports one of the most critical biotas in the world -- critical because of its exceptionally high endemism and the rapidity with which it is disappearing before the

onslaught of man and introduced species of plants and animals. These islands are outstanding as a natural laboratory for the study of evolutionary processes; a considerable background of previous work already exists.

The project has the following features:

- a. It is feasible;
- b. it can provide a model of what can be accomplished in relation to endangered floras and faunas;
- c. the urgency is great; and
- d. it will dramatize the scientific basis for the preservation of ecosystems.

The proposed research will call for participation of the Bernice P. Bishop Museum, the University of Hawaii, the U. S. Armed Forces, and various organizations, universities and museums in the mainland United States and in Europe. Competent experts will be sought from all parts of the world. Federal agencies, including the Department of the Interior and the National Science Foundation, will be asked to cooperate.

Study in Tropical Latin America

The Subcommittee has approved the selection of tropical Latin America for a second major investigation. Many areas in central and northern South America have highly localized and endemic faunas and floras which are currently being destroyed by activities formented by the human population explosion. This is particularly conspicuous in the northern Andes. Colombia has been tentatively agreed upon as the most appropriate country in which to make this study. The actual selection of sites which would be most suitable for comparative studies at different altitudes and in the three different ranges of the Colombian cordillera should be made in consultation with Colombian and other experts.

This project would differ from the Hawaiian one by being even more international in character and depending in large measure upon the cooperation of Colombian scientists and the good will and assistance of the Colombian government. Two special advantages are offered by:

- a. The tradition of cooperation between Colombian and U. S. scientists.
- b. The probable interest of Venezuelan biologists in undertaking coordinated projects.

This project could be instituted by bringing together a working group of botanists, entomologists, and other zoologists who are anxious to undertake this kind of research. This should be an international group which could itself act to encourage investigations and evaluate spontaneously generated proposals. Until a number of individual or cooperative projects are under way, a resident director would probably not be needed.

INDIVIDUAL OR GROUP PROJECTS

The Subcommittee will evaluate proposals submitted by individuals and groups and make recommendations concerning them to the U. S. National Committee. It also will call the attention of biologists, through publication and correspondence, to the need for certain studies, in the expectation that proposals will materialize.

Examples of individually proposed projects which have already been given SB approval for inclusion in the USNC/IBP program are:

1. Preliminary identification manual for African mammals (H. Setzer, Smithsonian Institution, and W. Meester, University of Pretoria, South Africa)
2. A distributional and microevolutionary study of birds of the isolated forests of western Uganda (H. Friedman, Los Angeles County Museum)
3. Studies of aquatic biota and ecology of the endangered Cuatro Ciénegas Basin in Coahuila, Mexico (W. L. Minckley, Arizona State University)
4. Catalog of Neotropical Squamata (J. A. Peters, Smithsonian Institution).

Other proposals are under consideration.

THE TRAINING OF STUDENTS

The shortage of competent systematists is critical and the proposed IBP activities will accentuate this need. Many of the contemplated Subcommittee on Systematics and Biogeography projects seem ideally suited for the advanced training of students in this area, particularly in field work, which is an indispensable part of the training of systematists. The Subcommittee recommends that the funding agencies give sympathetic attention to applications for pre- and post-doctoral support and to requests for travel funds for participation in SB-sponsored studies. We strongly urge the development of mechanisms for the participation of foreign students in such projects.

To accomplish such training, we recommend that use be made of programs such as those of the Organization for Tropical Studies and the proposed Smithsonian-Pan American Union project for training systematists and ecologists.

WORKSHOPS AND CONFERENCES

Planning Conference on the Hawaii Project

This conference will be held in Honolulu on 21 - 23 March, 1967 to plan the project organization and program, in consultation with local authorities and biologists. The personnel involved, arrangements, and proposed budget are being worked out by a joint Systematics and Biogeography - Conservation of Ecosystems Planning Committee and will be submitted shortly.

Workshop on Endemism and Extinction

The Subcommittees on Systematics and Biogeography and Conservation of Ecosystems are jointly planning a workshop leading to the publication of a treatise on endemism and extinction which will serve as a guide to systematists, ecologists, and conservationists in planning scientific investigations and conservation measures. This work will survey the present state of knowledge and theory on these subjects, list information sources, and point out specific problems and situations which need attention. Planning by a joint committee of Systematics and Biogeography and Conservation of Ecosystems is under way, and the workshop will be held in 1968.

PARTICIPATION IN ECOSYSTEM STUDIES

The work of the Subcommittee broadly overlaps that of other subcommittees, particularly Conservation of Ecosystems, Productivity of Terrestrial Communities, Productivity of Freshwater Communities, and Productivity of Marine Communities. Some aspects of the anticipated cooperation with these groups include the following:

1. Systematic Studies and Identification

The reliability of productivity studies and other studies of ecosystems depends on the correct identification of the component animal and plant species. Systematics and Biogeography regards as one of its functions the giving of advice and information concerning persons who may be able to provide identifications or to participate in field studies. Unfortunately, identification is impossible for many groups of organisms in many parts of the world, owing to lack of knowledge and shortage of qualified taxonomists.

Where the biota is poorly known taxonomically, as it is in most areas in the tropics, ecologists should single out key species in the productivity chains and limit their identification demands to these species. Dominant animals and plants can usually be identified.

The interests of ecologists and taxonomists largely coincide in the making of exhaustive inventories, whether of ecological sites or of localities where the biota is doomed to obliteration by human activities.

2. Site Selection

Systematists expect to participate in the selection of sites for major ecosystem studies, to insure involvement of qualified systematists and to effect maximum accuracy in identification.

3. Keys and Manuals

Systematics and Biogeography will encourage the preparation of keys and manuals, and lists of animal and plant species that will be useful to biologists working on various phases of the IBP program. Examples of such manuals are those on African mammals and on tropical American snakes and lizards, mentioned above.

2. The second part outlines the various methods and techniques used to collect and analyze data. It includes a detailed description of the experimental procedures and the statistical tools employed.

3. The third part presents the results of the study, showing the trends and patterns observed in the data. It includes several tables and graphs to illustrate the findings.

4. The fourth part discusses the implications of the results and provides recommendations for future research. It highlights the areas that need further investigation and the potential applications of the findings.

5. The final part of the document is a conclusion that summarizes the main points and reiterates the significance of the study. It also includes a list of references and a bibliography.

PROGRAM STATEMENT
of the
Subcommittee on Environmental Physiology

January 1967

NATIONAL RESEARCH COUNCIL
National Academy of Sciences National Academy of Engineering
Division of Biology and Agriculture

PROGRAM STATEMENTOF THESUBCOMMITTEE ON ENVIRONMENTAL PHYSIOLOGY

The Subcommittee on Environmental Physiology (EP) was created by the U.S. National Committee of the International Biological Program (USNC/IBP) to extend the emphasis on physiological mechanisms relevant to productivity and adaptability to organisms other than man. The program envisioned is directed toward understanding of urgent human problems.

Environmental physiology is construed broadly; it is interdisciplinary in techniques and combines viewpoints of ecology, evolution, and physiology. Indeed, most of the IBP subcommittees deal with environmental physiology. But other subcommittees are likely to overlook certain broad problems when the prime focus is on productivity in specific environments.

Investigations of productivity may legitimately be concerned with production and control of organic diversity as well as with quantities of organic matter. Moreover, human adaptability problems can be considerably illuminated by studies of the reactions to environmental factors by plants and animals. With close liaison and cooperation with other committees, we hope to fill in such gaps and foster inter-area communication.

It is important that a variety of instrumental resources be utilized for implementing the following program, and persons interested in such resources should be a part of the IBP; examples are remote sensing devices, mobile laboratories, and instruments developed for biosatellites. Also, the training of environmental physiologists should receive prominent attention by the IBP.

PHYSIOLOGICAL FACTORS THAT STABILIZE AND MODIFY POPULATIONS

Present work in the physiology of population dynamics is mostly of laboratory nature. This must continue and expand, but it should be supplemented with physiologically oriented field studies in selected situations. Many, if not most, biological populations are subject to abiotic and biotic control, including control by predators and disease. The important question for human welfare is whether man, by wise exercise

of his intelligence, can stabilize his population without undernutrition, starvation, and disease. Mechanisms are known or suspected by which populations of certain species are stabilized in ways other than limitation of nutrients or attrition by predators. Although such limitations may not be applicable to man, a knowledge of them permits biologists to view the human population explosion in better perspective.

Human Populations

It is not certain how soon or how successfully human beings of different races can adjust the birth rate to the food supply and other factors so as to avoid serious undernutrition or starvation. An increase in food supply in an undernourished population may result in an increase in the size of the population, perhaps to an undesirable extent. Unless more food eventually results in a higher level of well-being for the population as a whole, it will have served little useful purpose. A study of different human populations from this point of view, perhaps in collaboration with World Health Organization and the Subcommittee on Human Adaptability (IBP) would be useful. Factors to be considered in such a study include fecundity, fertility, fetal wastage, placental properties, age span of reproduction, intelligence, and cultural level.

Human well-being and behavior as well as quality and size of human populations depend not only on food supply but also on other environmental factors. Research on these factors is needed at physiological, psychological, and sociological levels

Factors Determining Population Equilibria and the Ecogeographic Differentiation of Populations

An understanding of the biological basis for the abundance and distribution of species and hence for productivity requires a fuller knowledge of the identity and history of organisms and the physiological basis of adaptation to habitat within species and of speciation. Other subcommittees are concerned with systematics, biogeography, and ecology, but we need to understand the relation between physiological parameters and mechanisms that separate species, and to understand the causative factors for ecogeographic differentiation of natural populations.

The adaptative characters which form the basis for isolating mechanisms between species may be quite unrelated to those used in systematic descriptions. Many of these char-

acters involve physiological adaptation to the environment; others involve behavior patterns. Understanding of the process of speciation hinges on knowledge of these characters.

Two methodologies need to be applied to an understanding of population equilibria and differentiation. One is ecological population analysis and the other is analysis of physiological mechanisms of variation. The former includes study of reproductive rates and patterns, inter-organismic competition, food chains, and predation. The latter includes biochemical and physiological variations and mechanisms of feedback interaction between organisms and their environment.

There is urgent need to apply tests for both resistance and capacity adaptations to populations of animals and plants of the same or related species from different regions. In addition, behavioral variations of the same or related species must be identified. Such studies may reveal population differentiation and increase our understanding of adaptability of natural populations.

Physiological variation is of two sorts -- genotypic and environmentally induced within genetic limits. The two sorts can be separated by acclimation in nature or in the laboratory. Adaptation in the field is not necessarily the same as that in the laboratory.

Regional comparisons must be based on measurements that are accepted by workers in different locations. Measurements of stresses of temperature, salinity, specific ions, photoperiod, available oxygen, and nutrients are best known. Relevant factors should be studied in each stage of the life cycle and in each component of the population -- e.g., nutrient exploitation in young and adult, male and female, and other subdivisions.

Analyses by physiological, ecological and genetic means of populations of selected species of the following groups of animals and plants from over their entire geographic range are particularly recommended. Agreement on comparable methods should be reached in early working conferences.

1. Species of expanding range. Some of these are cosmopolitan and others are more restricted. Examples of colonizing species include: house mouse, English sparrow, starling, certain cockroaches, toads, culti-

vated fish (such as Gambusia), Pteridium aquilinum (bracken fern), and members of the Compositae and Graminae. A recent international symposium considered many aspects and species (see Genetics of Colonizing Species, published by the Academy Press in 1965; edited by H. G. Baker and G.L. Stebbins). A working conference is recommended to select species for study and to plan investigations of why certain species have spread more widely than others.

2. Polar and alpine species of plants and animals. International cooperation could broaden the base for studies of widespread high-latitude and high-altitude species.
3. Tropical species. An active program conducted in cooperation with stations and organizations in the American tropics is particularly recommended. It should include an effort to understand the enormous diversity of species in the tropics and their often relatively small populations and narrow ranges.
4. Estuarine and marine species. Limiting factors, isolating mechanisms, and physiological adaptations for marine species are poorly known. Many estuarine plants and animals occur in gradients of salinity, temperature, and dissolved oxygen which may be relatively stable or may vary tidally. Some marine and estuarine organisms occur with or without species replacement over geographic ranges where environmental gradients are marked. Comparison of individuals from populations of the same or related species in different locations may elucidate physiological factors in distribution, abundance, and speciation.

Measurements of adaptive functions should be made in many places. They should be made on populations of special advantage which should be chosen after a working conference.

5. Desert species. Much physiological work has been carried out on succulent species from arid regions; more work is needed on nonsucculent plants of the deserts, some of which are of considerable interest to man.
6. Freshwater species. Cooperative projects with the Subcommittee on Productivity of Freshwater Communities (IBP) on jointly selected species would bring together physiological and ecosystem approaches on an international scale. That Subcommittee is planning an intensive ecological survey of selected drainage basins. These studies should provide physical and biological data which will be useful for physiological research on aquatic communities.

PHYSIOLOGICAL MECHANISMS OF ADAPTATION

Productivity in different environments depends not only on the flow of energy, food, and water but also on adaptability of organisms to these environments and on the reactions to one another of different species.

Selected communities and species should be intensively studied. The understanding of communities and of their production of organic matter demands study of the physiological bases of adaptability in relation to the specific ecological niche of each constituent organism. Research on physiological mechanisms of adaptation overlaps with studies of population differentiation, but the approaches are different in that studies of mechanisms of adaptation are concerned with detailed physiology and biochemistry of single species and include cellular and molecular measurements; they need not be comparative and need not include ecology or population dynamics.

Physiological differences which are adaptive can best be identified by stress tests. They are in two categories. Resistance adaptations are related to environmental extremes and their tolerance by whole organisms, tissues, or enzymes, and these must be correlated with the natural limits of species. Capacity adaptations permit normal activity in an altered but tolerable environmental range. Both are homeostatic in permitting survival and reproduction in an altered environment.

Physiological Analysis of Adaptation

This involves cooperative programs between physiologists, ecologists, biochemists, and geneticists. The goal is to understand organism-environment interaction in terms of the feedback controls which are operative at cellular and organ levels. The principles of metabolic adaptation in respect to enzyme synthesis as regulated by substrate and products have been studied, especially for microorganisms. Application of these principles to regulation by physical factors in the environment, such as temperature, salinity, and oxygen, is poorly known.

An example may be taken from phenotypic metabolic compensations to temperature in some plants, microorganisms, and poikilothermic animals. After initial shift from one temperature to another, changes in metabolic rates occur which correspond to the Van't Hoff relations. After some time, many organisms compensate for the temperature alterations by a variety of biochemical changes; these include alterations in lipid composition, in abundance of certain isozymes, and in emphasis on alternate metabolic pathways. In order that the organism can be adapted in its entirety, many different proteins may be involved. Changes can occur only within the limits imposed by the genotype. However, those organisms having genotypes with extensive capacity for synthetic variations may be expected to differ in their ecogeographic limits from organisms with less metabolic adaptability. Some of the environmental control may be directly at the cellular level, some of it indirectly by hormonal or nervous intermediation. The metabolic mechanisms of temperature adaptation are so complex as to require much study.

Other examples of adaptive mechanisms may be taken from osmotic and ionic balance. At the organismic level, these include varied methods for water exclusion or retention, and mechanisms for active uptake or excretion of specific ions. At the cellular level patterns vary from tolerance of a wide osmotic range to functioning only within narrow osmotic and ionic limits. The identification of mechanisms of active transport is essential for an understanding of adaptation of plants and animals to environments which differ in respect to water and ions.

Responses and Survival in Extreme Environments

Extremes of heat, aridity, radiation, oxygen, salinity, pressure, gravity, and other factors have a relevance for the

IBP. They limit distribution and activity, and organisms vary widely in ability to respond and to survive under extreme conditions. Certain kinds of stress physiology have been extensively studied in medical, military, and space science laboratories. However, a broader understanding is needed of the physiological bases in additional species, strains, and stages of life cycle.

Experiments on both acute and chronic exposure with varying rates of application of extreme conditions are needed. Responses to chronic stress may suggest the genetic potential available for the evolution of organisms with higher productivity in extreme environments.

Intraspecific and Interspecific Chemical Defense Mechanisms

Accumulating information about naturally occurring antibiotics in higher as well as lower organisms calls for expanded effort since they may play a significant role in the determination of the structure and composition of biotic communities. Thus, recent evidence has suggested that exudates into the air or the soil from one kind of plant may be selectively toxic to plants of the same species, as in the case of the germination inhibitors of the St. John's wort (*Hypericum perforatum*), which prevent seedlings from appearing in the vicinity of the parent plant as long as that plant is alive for continuation of the infestation. Such regulation of germination has profound implications for weed control.

Another body of literature is developing which documents the effects of toxic exudates from plants of one species on those of another species (allelopathy). Susceptibility to these substances appears to vary from species to species and may, therefore, affect community composition; in addition, it may be of direct importance to human welfare in situations where a crop plant reacts to a weed species. Encouragement should be given to studies which will demonstrate to what extent intra and interspecific toxicities discovered in the laboratory are effective under natural conditions.

Recent studies have called attention to a new method of insect control in which analogues of certain of the insect hormones are used. In particular, the juvenile hormone constitutes a weak spot in the physiological armor of insects which opens them to attack by agents which are nontoxic and physiologically inert for other forms of life. In the evolution of evergreen trees, substances have appeared and have

been retained which protect the trees from insect attack. For example, the balsam fir (Abies balsamiae) has been shown to contain an extremely active analogue of the juvenile hormone of one family of insects -- the Pyrrhocoridae -- and has thereby achieved full and complete protection from all Pyrrhocorid insects. Extracts of this terpenoid material have been found to be fully effective in human control of a number of serious Pyrrhocorid pests, such as the infamous red cotton stainers (Dysdercus sp.).

These findings direct attention to the possibility that analogues of the juvenile hormone of numerous other insect pests are to be found among the tens of thousands of terpenoid materials which a wide range of plants synthesize. Other effects of these substances may include allelopathy (above), formation of atmospheric haze and rain nuclei over coniferous forests and deserts, and alterations in soil structure.

As a first step in this direction, we recommend a conference of experts to outline a practical approach to limited aspects of the problem. This group should include not only entomologists and botanists but also experts on the chemistry of terpenes and other natural products obtained from the gymnosperms. The group could well consider a wide range of other plants and other target species.

CHANGES IN THE BIOSPHERE DUE TO HUMAN ACTIVITY

There was little or no free oxygen in the original atmosphere, and its present existence in large quantities is believed to be due in large part to the development of living organisms. At present the liberation of O_2 by plant photosynthesis tends to be nearly balanced by the removal of O_2 and production of CO_2 by animals. However, CO_2 is increasing in concentration in the atmosphere at a significant rate. This probably results in large part from combustion of fossil fuels but it may result in some degree from oxidation of soil humus or from other biological changes. The biological effects of increasing atmospheric CO_2 are not known, though it presumably stimulates some plant growth. It also affects the radiation balance of the earth and consequently the average temperature of the air and the upper layers of the ocean, but the magnitude of these possible temperature changes is unknown.

The increase of atmospheric CO_2 must be causing a slight decrease in oxygen content. Does this have any effect on the

growth of animals? How can we predict the future energy balance between animals and plants? As the concentration of oxygen has increased during geological ages, animals have developed certain antioxidant defenses. It is important to know whether more or less defense of this sort will be needed for the future. Is the human life span possibly limited even now by the balance between oxygen poisoning and antioxidant defenses? Conversely, what is the relation between physiological adaptations of some organisms to low oxygen pressures and productivity in certain habitats?

Our present oxygen supply presumably came from photosynthetic activity in which the ultimate oxygen source was water. Is the oxygen content of the atmosphere continuing to increase? Is the earth losing more protons than it is gaining from the sun or from cosmic rays? Is the total free water supply in a true steady state or is it increasing from volcanic gases and springs?

The composition of the atmosphere depends on both biological and nonbiological factors, and for this it is necessary for biologists to work with geochemists and geophysicists. What are the effects on the earth's atmosphere of industrialization with its accompanying increase in combustion of coal and oil and production of carbon dioxide? What are the biological effects of increasing nitrogen oxides from internal combustion engines? Is population growth necessarily limited by some environmental factors such as the supply of water, fixed nitrogen, oxygen, or trace minerals? Can we account quantitatively for all the carbon originally present as CH_4 and CN , and now existing as CO_2 or in the form of oil or wood or other organic compounds? What are the turnover rates of all these compounds in the cycles of C, N_2 , O_2 , H_2 , etc?

Two approaches are necessary: (1) The "microclimates" of plants and animals should be studied in respect to local and seasonal variations in CO_2 and other atmospheric constituents. The microclimates are different not only for different kinds of vegetation but also for different parts of a single plant or animal. (2) The macrocomposition of the biosphere of the earth with respect to O_2 , CO_2 , water, temperature, and nitrogen should be studied. Measurements should be made with comparable techniques in many parts of the world. Information is needed to permit estimates of changes within a human generation rather than over geological ages. For atmospheric composition, the measurements made by weather agencies are useful but are limited in numbers and locations of

stations, in kinds of measurement, and in not taking account of biotic variations.

It is recommended that the USNC of IBP establish a working committee to collaborate with the Committee of Atmospheric Sciences in the National Academy of Sciences.

PROPOSED WORKING CONFERENCES

The Subcommittee on Environmental Physiology sees its role in the IBP as primarily one of catalysis of research in certain areas of environmental physiology. A series of working conferences is proposed. It is expected that these will be partly substantive and partly of a planning nature. The planning aspect of each conference will include (1) methodology, (2) research program, and (3) stimulation of individuals and organizations to collaborate. To insure liaison, each conference will have the active participation of at least one member of the Subcommittee. Some of the conferences are intended to be jointly sponsored with other subcommittees. In other cases, other subcommittees have offered encouragement and assistance although they are not cosponsors.

Physiological Analysis of Marine and Estuarine Populations

A working conference is proposed to deal with physiological resistance and performance adaptations of marine and estuarine species to geographical abiotic and biotic environmental factors (temperature, light, hydrostatic pressure, streaming velocity, kind of substratum, food and salinity). It is anticipated that a research program on the analysis of physiological adaptation in populations from a wide range of marine environments will be established. The conference would be international and would be held at Duke Marine Biological Laboratory in Beaufort, N. C. A plan for its organization has been presented by John Vernberg (Duke University) and Carl Schlieper (University of Kiel). The Subcommittee representative is C. L. Prosser; the Subcommittee on Productivity of Marine Communities has designated V. E. Brock as its representative. It is proposed that this conference be held during the summer of 1967.

Physiology of Colonizing Species

It is proposed to examine in depth the physiology of species of expanding range, including some dispersed by man. Some of these are cosmopolitan and others are more restricted.

For purposes of comparison, some species will be chosen whose ranges appear not to be expanding. The proposed conference should be concerned with selection of species for study and of measurements to be made, as well as with international cooperation in making field and laboratory studies. Possibly it could be held in connection with the AIBS meetings at Texas A & M University, in 1967. (This conference can be considered as a successor to a recent international conference on the genetics of colonizing species held at Asilomar, California in 1964.)

Environmental Extremes

A working conference on environmental extremes is proposed. In general, it will be concerned with physiological bases for tolerance of environmental extremes by plants, microorganisms, and animals. Adaptations to extreme temperatures, to hypoxia, high salinity, aridity, and other factors will be considered, and plans for ecophysiological experiments will be suggested. It is anticipated that this conference will be cosponsored by NASA and that the organizer will be Dr. Dale Jenkins. A preliminary conference on this topic was held in San Diego in the autumn of 1965. It is hoped that the proposed conference can be held in Israel, where there is much interest in extreme environments. Subcommittee representatives are T. H. Bullock and Knut Schmidt-Nielsen.

Chemical Interactions Between Organisms, With Emphasis on Control of Insects by Plants and of Plants by Other Plants

The implication of terpenoids in both kinds of control suggests that entomologists and botanists should be brought together for the consideration of mechanisms and applications. These applications may be profound in relation to natural and agricultural productivity and to the organization of biological communities. The practical applications for insect and plant control are clearly international, and representatives from a number of countries should be included. Interest has been expressed by representatives of the United States Department of Agriculture and the Subcommittees on Systematics and Biogeography and Productivity of Terrestrial Communities. It is hoped that the organizers will be E. F. Knipling (USDA) and Cornelius Muller (University of California, Santa Barbara). Dr. Carroll Williams of Environmental Physiology will be actively involved in planning this conference. There is considerable urgency for this proposal, and the meeting should be held as soon as possible.

Biometeorology in Relation To Productivity

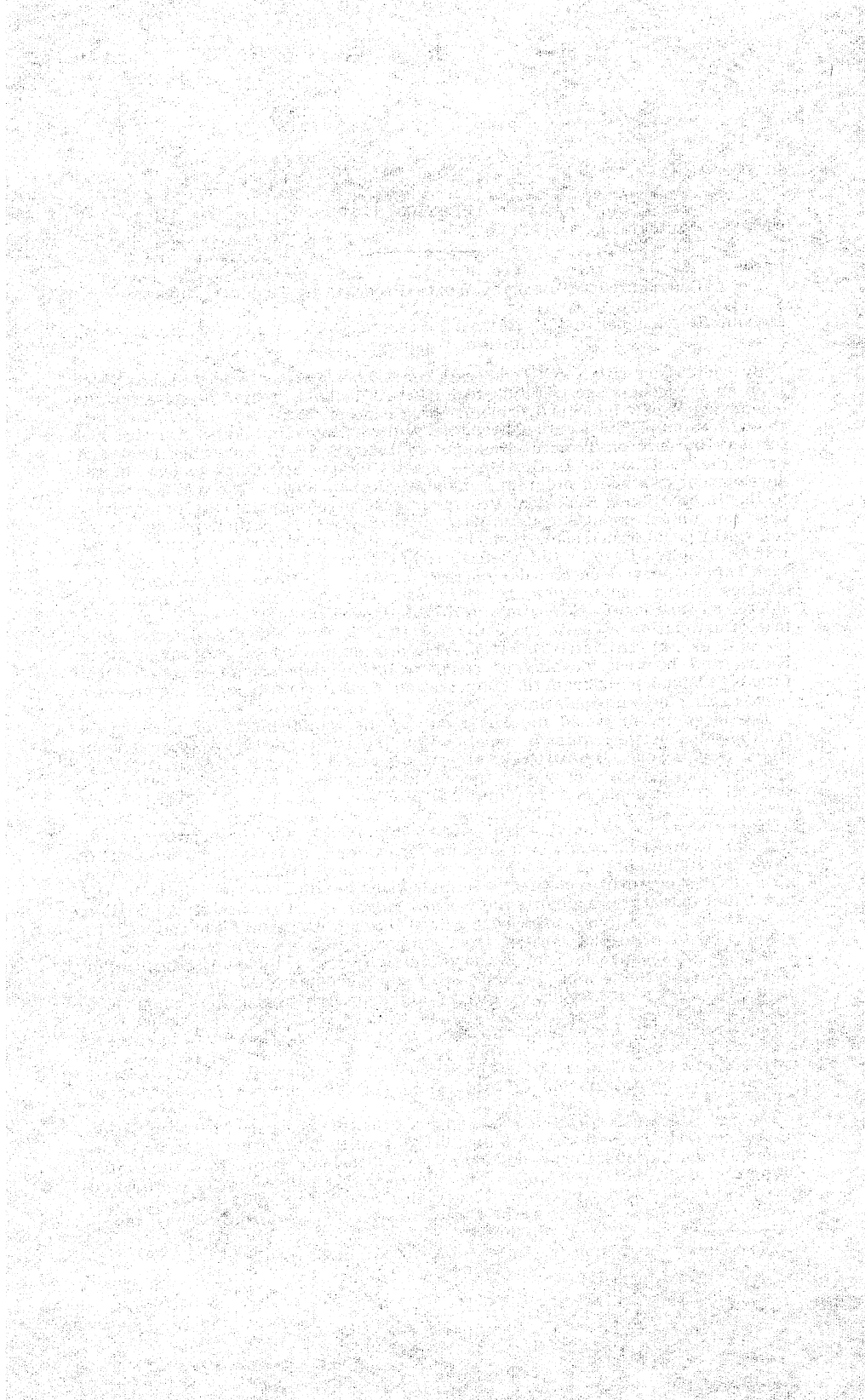
A working conference is proposed to deal with the methods of data collection, the nature of critical measurements, and the planning for data-collecting service. Two approaches are needed: (1) analysis of the over-all balance of CO_2 , O_2 , H_2O , N_2 and temperature of the atmosphere in relation to long-term trends and their biological consequences, and (2) analysis of the microclimates of plants and animals in relation to their physiology. Physical scientists and biologists are expected to pool their techniques and interests in a research plan. It is anticipated that a close collaboration will be established between Environmental Physiology and a joint Biometeorological Panel of the IBP and the Committee on Atmospheric Sciences of the National Academy of Sciences. Liaison will be maintained by Dr. F. Sargent of Human Adaptability. The Subcommittee representative is Dr. Wallace O. Fenn. An appropriate organizer of this conference would be David Gates (Missouri Botanical Garden).

Other Conferences That Are Anticipated But Not Planned in DetailPhysiological factors in human fertility

A conference dealing with the physiology of reproduction as opposed to the demographic aspects of the subject is proposed. Consideration will be given to fecundity, fertility, fetal wastage, placental properties, age span of reproduction, intelligence, cultural level, and related parameters. Programs of research are to be formulated. This conference is to be jointly sponsored with Human Adaptability. The Environmental Physiology representatives are W. O. Fenn and T. Dobzhansky.

Extrapolations from the dynamics of animal populations to human populations.

This conference would examine the biological and physical limitations on the growth and regulation of natural and artificial populations of animals. The question of whether principles derived from such studies can be applied to man will be of prime concern. Plans for observations that might provide critical data will be made. It is proposed that this conference be sponsored jointly by Human Adaptability and Systematics and Biogeography. It is suggested that Thomas Park assist in organizing this conference.



APPENDIX D

A CONTRIBUTION TOWARD A WORLD PROGRAM IN TROPICAL BIOLOGY

Helmut K. Buechner and F. Raymond Fosberg, Office of Ecology, Smithsonian Institution, Washington, D.C.

By comparison with North Temperate Zones, knowledge of biology in the tropics is in an incipient stage, yet this region seems to hold greater promise for the emergence of new biological principles and concepts than any other. With this thought in mind, 60 scientists from the United States and Latin America met for a Conference on Tropical Biology,* in Panama 10-12 November 1966, and urged the Smithsonian Institution to use its unique attributes to lead in the development of a world program in tropical biology. Such a program is relevant to the International Biological Program theme of broadening the productivity base for human populations. In 1965 approximately 1.1 billion people ($\frac{1}{3}$ of the world population) made their homes in about 70 sovereign nations in the world's tropics. Despite the natural richness in variety of species and the high rate of conversion of solar energy to plant and animal life, tropical ecosystems (living communities, including man, and their total environments considered as functional wholes) are readily destroyed through overexploitation by man. Degradation of most tropical ecosystems is now a world concern, since all nations are ultimately affected. Soil erosion on overgrazed savannas in Kenya and bedrock washing of steep mountain slopes denuded of tropical forests in Ecuador illustrate the deterioration of environments under the pressure of expanding human populations.

The most urgent world problem today is the establishment of harmonious relationships between human societies and the environmental resources upon which they depend. Most tropical ecosystems are energy-rich compared to ecosystems elsewhere in the world; therefore, preservation of the productivity of tropical environments is a matter of world concern. In view of the rapidly increasing demands on tropical environments, a world program in tropical biology is urgently needed to provide the scientific foundation for the management of tropical resources. It would be a mistake, for example, to apply our technological power to the building of a sea-level canal in tropical Central America without also attempting to increase our scientific understanding of the effects of the new canal on nature, including the world's human societies. Such a foundation in science depends on new knowledge gained through research in the tropics. The application of principles derived from temperate-zone ecosystems has already contributed to the deterioration in the productivity of the tropics. Management of tropical environments must be approached through studies of the components, structure, energy conversion, cycling of nutrients, and the process underlying temporal changes in ecosystems altered by man within the tropics, rather than through the application of temperate-zone concepts. The foundation of knowledge required for sound decisions on limiting human populations and technological modifications of environments in the tropics, as elsewhere in the world, must emerge from an integration of ideas from both the natural and behavioral sciences.

The Smithsonian Institution is in a key position to encourage the coordination of the interests and efforts of universities, private foundations, corporations, national scientific laboratories, and governmental agencies, both within the United States and abroad, in developing an effective cooperative program of research and education in the biology of the world's tropics. Such an interinstitutional, multidisciplinary effort is basic to a world program aimed at achieving rational use of

*Supported by a grant from the Air Force Office of Scientific Research.

tropical natural resources. The Smithsonian's role would be principally to catalyze the program and help coordinate worldwide activities. It was noted that by virtue of its vast collections the Smithsonian Institution already has the potential capacity for identification of plants and animals that form the components of tropical ecosystems, but a realistic increase in the staff of scientists and supporting help would be required for an expanded world program in tropical biology. Extensive educational programs in cooperation with universities are needed to train young scientists in the systematics of tropical organisms at the Smithsonian. In addition to the systematic base that already exists, the Smithsonian Institution is currently evolving a comprehensive program in ecology. However, this program is at its inception, having started 1 July 1965. The capability for sophisticated research is the ecology of tropical ecosystems will require additional staff and financial resources. It was recommended that the Smithsonian serve as a focal point for the many different organizations that must cooperate effectively if a world program in tropical biology is to succeed in achieving harmony between human societies and their tropical environments.

The Conference was held in Panama because this is one of the most exciting tropical areas of the world and because the Smithsonian Tropical Research Institute (STRI) is located there. Formerly known as the Canal Zone Biological Area, STRI is responsible for maintaining Barro Colorado Island in Gatun Lake as a biological preserve. The research program is concerned with principles of evolution, behavior, and ecology in tropical ecosystems. Recent emphasis, under the directorship of Martin H. Moynihan, has been on comparative behavior of primates, the evolution of interspecific relations, the significance of social signal systems, social organization and behavior of tropical birds, and isolating mechanisms in marine fishes. STRI provides a strategically located base from which to develop programs of biological research in the New World tropics.

Panama is of special significance to marine biology because nowhere else in the world can one compare ecosystems of the world's two largest oceans within a distance of 40 miles. The simultaneous role of the isthmus as a bridge and a barrier to distribution of organisms makes Panama a significant area in which to study evolutionary processes. The planned construction of a sea-level interoceanic canal somewhere on the isthmus increases the potentialities for an effective program in marine and terrestrial tropical biology in the region of Panama. The opportunities provided by this major environmental manipulation can contribute substantially to the advancement of biological knowledge in the tropics, particularly if a long-term program of investigation is broadly planned to include all levels of biological integration from the molecular level through the organismal level to the total human ecosystem.

The general chairman of the Conference was Sidney R. Galler, Assistant Secretary (Science) at the Smithsonian Institution. The first day of the meeting was devoted to discussions of existing projects and programs including: tropical biology and oceanography at the University of Panama (Octavio Sousa and Luis Howell-Rivero, respectively), the interoceanic canal studies of the U.S. Army Corps of Engineers (Brigadier General H. G. Woodbury), the Atomic Energy Commission interests in the tropics (Richard Hamburger), bioenvironmental and radiological safety studies of Battelle Memorial Institute (Richard S. Davidson), the Army Tropic Test Center programs (Robert Hutton), Middle America Research Unit programs in tropical disease ecology (Merle L. Kuns), tropical biology at Gorgas Memorial Laboratory (Graham B. Fairchild), anthropology in Panama (Reina Torres de Arauz), the program of the Guama Ecological Research Area at Belém, Brazil (Philip S. Humphrey), the Organization of Tropical Studies (Emmett T. Hooper), research programs at the Smithsonian Tropical Research Institute (Martin H. Moynihan), tropical oceanography (Giles W. Mead), and proposed Smithsonian activities in the tropics in connection with the International Biological Program (F. Raymond Fosberg). Preceding these discussions S. Dillon Ripley, Secretary of the Smithsonian Institution, gave the keynote speech that appears in the following article. On the morning of the second day, participants visited various biological facilities, such as the Army Research Tower, the University of Panama, Gorgas Memorial Laboratory, Barro Colorado Island, the Navy Pipeline Area, and the marine facilities at Galeta Point and Fort Amador. Panel discussions on ecology, oceanography and limnology, anthropology, tropical botany, mammalogy and ornithology, reptiles and fishes, and entomology held during the afternoon and evening of the second day resulted in reports given the following day. Resolutions and recommendations were presented at a final plenary session.

PANEL REPORTS

Résumés of the panel reports are presented here in the belief that they represent digests of important thoughts that emerged at the Conference.

Ecology (moderated by H. K. Beuchner)

Under the impact of exploding human populations, tropical ecosystems are rapidly disappearing. From a theoretical point of view we are in a position of needing to discover biological principles and concepts that can emerge only from studying existing tropical ecosystems before they disappear. From a practical viewpoint there are compelling economic and social reasons for studying tropical ecosystems to achieve harmonious adjustments between human societies and the tropical systems in which they live. This is of importance not only to the tropical countries involved, but also to temperate-zone countries whose economies will suffer from increased demands of growing populations in tropical nations. As the high-energy tropical ecosystems deteriorate, more and more economic assistance will be required from countries with the more limited resources of the comparatively low-energy temperate ecosystems.

Although the panel recommended a concentration of effort in Panama, it recognized the importance of an extensive world program involving selected sites of a wide variety to advance knowledge through comparisons of tropical ecosystems. The panel recommended Barro Colorado Island, the Navy Pipeline Area, and the Darien Area as sites in Panama for a concentration of activity designed to understand the structure and functioning of humid, lowland tropical ecosystems. Moving out from these centers of concentrated effort, additional studies of a specific, but less comprehensive, nature were recommended for other parts of Panama and neighboring countries. These recommendations were predicated on the assumption that Panama and neighboring countries would welcome the proposed studies and cooperate actively in the program.

The panel discussed the need for a foundation in systematics for ecological studies. It was suggested that consideration be given to developing a Terrestrial Sorting Center, comparable to that of the existing Smithsonian Oceanographic Sorting Center. It was also suggested that task forces be developed with teams of professional and subprofessional personnel to carry out expeditions to selected sites to develop the necessary knowledge of the systematics of the flora and fauna as a basis for ecological studies.

The panel recommended that the Cape Thompson study in Alaska, which was carried out by the U.S. Atomic Energy Commission in preparation for the proposed harbor development using atomic explosives, become a model for studies required in connection with the sea-level canal. This study demonstrated a basic approach to the study of whole ecosystems, starting with geology, hydrology, soils, and climatology on the physical side of the system and extending through flora and vegetation, fauna and animal population studies, and anthropology. Sophisticated ecosystem ecology studies involving mineral cycling and energy conversion extend well beyond the baseline studies illustrated by the Cape Thompson report.

Interinstitutional cooperation between universities in the United States and in tropical countries, national laboratories, government agencies, and corporations was considered by the panel to be essential to obtain sufficient talent for the study.

Oceanography and Limnology (moderated by I. E. Wallen)

The panel concluded that a long-term study of marine organisms on both sides of the isthmus is necessary and of urgent priority. The most desirable geographic extent of the study was not established, but the initial studies should extend from the bulges of South America to the Yucatan Peninsula on the east and to the Mexican coast on the west and for about 800 miles to sea.

The following were advanced as reasons for the study:

1. This would be an ideal experiment, consisting of the mixing of two mature ecosystems with the jolt of introduction of exotic elements.
2. Recombining of many biotic species that have not been mixed since the Pliocene offers a 1 in 5 million chance to learn about evolution. This would be a chance to see evolution and to participate in it.
3. The study of the effects of major construction on marine organisms would assist in the development of a prediction capability, useful in future planning. The experiment would permit hypotheses to be tested and refinement of study techniques to be developed.

4. The advancement in learning probably would be as great as that coming from landing a man on the moon with at least equally valuable technical fallout. The study could contribute to the harvesting of food from the sea.

5. The study would be a demonstration of ecosystem studies which are needed to understand the general biology of the ocean. Carefully designed projects would be developed to provide test series of various shallow to deep-water ecosystems.

6. There is an imbalance in world knowledge, tilted towards temperate zones. These studies would move toward a better equilibrium of effort. A paucity of information about marine tropical species exists. We can only move toward the understanding of their significance for world application by such studies as are proposed.

7. The study would lead to an understanding of many marine processes peculiar to the tropics. Highly complex marine ecosystems could be identified for the pursuit of studies in biological principles, as well as for management.

8. The study would make a useful contribution to the International Biological Program. Concentrated study in the area proposed and its application to marine productivity are of a nature that is already a part of the International Biological Program.

9. A special by-product should be contributions to fish culture in the shallow mid-American ocean. Marine fish culture is still in a primitive stage.

10. An obligation exists to our scientific posterity to assemble baseline information for future evaluation of the biogeographic, biotic, and ecological consequences of the canal construction. We collected material before the Bikini nuclear experiments and this has been valuable as a baseline to note changes. It is urgent that samples be collected from the waters that would be affected by the transisthmian canal.

11. A possibility exists of modifying the present situation with regard to seasonal upwelling and its accompanying biological productivity. This must be studied. Upwelling areas are anticipated to have high fish production. If flow continued through the canal, rather than receding after reaching the shore, major effects could appear.

Tropical Botany (moderated by F. R. Fosberg)

Tropical botany comprises those aspects of botany that are regionally relevant in the tropics, as contrasted with those which are generally significant regardless of the climatic zone of the earth. Omitted from this context were those parts of botany that may be investigated without reference to the geographical area or are strictly nontropical in their regional interest.

The broad fields of investigation that seem to make up the more interesting and urgent part of tropical botany are as follows:

1. Monographic investigations in tropical systematic botany, leading to usable classification, as well as understanding of the evolution of tropical plant groups (both phanerogamic and cryptogamic); and their geographical distribution.

2. Systematic anatomy and palynology of tropical plant taxa.

3. Tropical paleobotany and paleopalynology.

4. Tropical floristic work, leading to the preparation of floras and contributions to plant geography.

5. Autecology and phenology of tropical plants.

6. Studies of adaptive features, ecological anatomy, and the origins and significance of growth forms of tropical plants.

7. Description and analysis of tropical vegetation, and its chorology.

8. Relation of tropical plant communities to environment factors and patterns.

9. Dynamics, utilization of resources, productivity, and other functional aspects of tropical plant communities.

10. Cytoecology of tropical plants (relation of chromosome number and configuration, as well as other cytological features, to environment).

11. Tropical ethnobotany and archeological botany.

Proposed activities in tropical botany regarded as of special or immediate importance or urgency (some of which are already initiated and in progress):

1. Monographic studies of tropical plant groups, both those which form parts of the Flora Neotropica and some of neglected groups in other parts of the tropics.

2. Floristic investigations, resulting in the preparation of regional floras and local ecological floras.

3. Ecological studies to provide the botanical information required for the description and understanding of important tropical ecosystems.

4. Development of means of exploring the canopy of tropical forests, and pursuit of such explorations.

5. Intensive emergency botanical exploration and collection of material and data on threatened tropical areas.

6. General botanical exploration of little-known tropical areas to fill gaps in knowledge and material.

7. Botanical aspects of IBP site development. This involves the following types of specific activities.

a. Physiognomic, or structural-functional, description of vegetation in general areas.

b. Detailed sampling and analyses of vegetation of preserved areas, establishment of permanent plots and photo-points, and marking of specific trees.

c. Phenological studies.

d. Annotated check-lists of ecological floras, with keys to genera and species.

e. Special keys to identify fruits, seedlings, and other items of ecological interest.

8. Small field conferences. It was suggested that small field-trip type conferences of 5-10 carefully selected participants interested in a particular problem, ecosystem, or methodology, would be productive. These would be conducted in the field, in the areas where the subjects of the conferences were well illustrated. The objectives would be mutual stimulation and generation of new ideas, approaches, and methods. An example of such a conference might be one on methods of exploring the canopy of the tropical forest.

9. Of special pertinence to Panama and the proposed sea-level canal investigation, the panel recommended giving every support and encouragement to the carrying to a successful conclusion the "Missouri Botanical Garden's Flora of Panama," now estimated to be about 55% finished. Five volumes and 3,000 pages have already appeared. Activities ancillary to this, and to the work of the Smithsonian Tropical Research Institute (STRI), would be the preparation of a new ecological flora of Barro Colorado Island and adjacent mainland areas under STRI control.

For this, cooperation between the Smithsonian, Missouri Botanical Garden, University of Panama, Army Tropic Test Center, and as many other organizations as could be interested in participation, should be encouraged and supported.

With great satisfaction, the panel received the information that a bilateral cooperative arrangement is being set up for botanical work in Panama between the University of Panama and the Missouri Botanical Garden. This is in line with a recommendation made by the UNESCO visiting committee for Tropical Herbaria, and will certainly be a matter of great satisfaction to that committee and its parent organization, too.

Of the proposed activities listed, the panel found it difficult to select any to which priorities could be assigned. Because the selection and development of IBP sites necessarily must be done in time for their use by the IBP, this activity should be initiated promptly. The exploration of threatened tropical areas also must be viewed with more than casual urgency, as the areas are likely to be changed and vital information lost. Likewise, the exploration of little-known regions is more than ordinarily urgent, as it may well yield data essential to other aspects of the program.

The panel concluded its report by pointing out that the urgent problems and needs in tropical botany are so great and widespread that they will require the participation and earnest efforts of all institutions with interests or capabilities in this field. It is suggested that the Smithsonian Institution, in addition to such efforts in tropical botany as its present and anticipated staff are able to make, use its prestige and experience to help secure support for the efforts and participation of any other qualified institution that needs such support to engage in the above listed activities in tropical botany.

Ornithology and Mammalogy (moderated by P. S. Humphrey)

In certain tropical areas of the world a critical need exists for general collections of birds and mammals to clarify important details of distribution and classification. Some of this work is already underway in relation to epidemiologi-

cal surveys in Southeast Asia, the lower Amazon, Venezuela, Africa, and elsewhere. For various tropical regions identification manuals for field ecologists and epidemiologists are required to facilitate field work, encourage collections, and promote solutions to taxonomic and zoogeographic problems.

In Panama, largely through the field work of Alexander Wetmore and Charles O. Handley, Jr., the classification of birds and mammals has been nearly completed. Handley's book on the mammals of Panama, which includes keys, chorology, and ecological information, is expected to be published in 1968. Similar works are not available for most countries in the tropics. Wetmore's first volume on the birds of Panama has been published and two more volumes are forthcoming. A field guide as a supplement to Wetmore's important work is needed to facilitate field identification.

In the last decade increased emphasis has been placed on ecological studies of tropical birds and mammals in relation to problems of public health. Most of this interest has concerned birds and mammals as reservoirs for arthropod-borne viruses and other diseases, and as hosts for various ectoparasite vectors of disease. There is a paucity of knowledge concerning population dynamics, reproductive cycles, predator-prey relationships, food chains, and life histories.

A critical shortage of trained mammalogists and ornithologists exists in the tropical areas of the world. Ultimately, basic work in these fields must be undertaken by citizens of the countries involved, not by visiting scientists. Development of scientific manpower resources in tropical countries of the New World can be encouraged through collaborative programs involving the Organization of American States, the Smithsonian Institution, the Organization of Tropical Studies, and various regional educational institutions.

Future ecological surveys in tropical regions should be planned, at least in part, to include site developments, interdisciplinary collaboration, reasonable standardization of techniques for collecting field data, improved processing of specimens and automatic data processing.

Reptiles and Fishes (moderated by J. A. Peters)

A world program in tropical biology should be based on the following statements of organization.

1. There should be a continuous, thorough assessment of the composition of the biota of the tropics, upon which further accumulation of knowledge must be based.

2. There should be a continuous focus on those problems in biology that are most likely to be solved by carrying on their investigation in the tropics.

3. There should be an increase in the encouragement of the talents of actual and incipient scholars originating in the countries within the tropics, through training grants, scholarships, fellowships, and grants-in-aid for research.

The panel recommended the development and maintenance of natural areas in the tropics to perpetuate and preserve habitats and species. Such reserves would facilitate comparative investigations throughout South and Central America.

Considerations should be given to the establishment of supported chairs in Latin American universities to encourage the development of scholars with the time, opportunity, and finances to carry on research and graduate instruction in tropical biology. The determination of the occupant of the chair should be under complete control of the university concerned, and it was recommended that the occupant be preferably a citizen of that country.

Entomology (moderated by W. D. Duckworth)

The enormous diversity of insects is such that entomologists have a severe problem in systematics, thus making it difficult to coordinate with and to collaborate with more diverse and advanced studies in the tropics all over the world. Programs involving specific type-site studies in various ecological habitats of the tropics seem to be the most desirable way to develop cooperative programs. Large numbers of entomologists are already at work in the tropics, many of whom are located in mission-oriented operations related to health and agriculture, yet the manpower resources in entomology are seriously inadequate for the task ahead. Insufficient effort has been made to identify entomologists, their places of activity, and their research work as a basis for coordinating programs and collecting information into a useful whole for all persons interested in tropical habitats.

With respect to Panama the panel regarded the program and facilities of the Smithsonian Tropical Research Institute, and the sites available to it, as adequate in meeting requirements for entomological studies in depth in the lowland humid tropics of Central America. A concentration of effort should be placed where data can be accumulated in an orderly fashion over long periods of time, such as Barro Colorado Island, and where short-range mission-oriented projects can be introduced as opportunities present themselves.

There is a manpower potential in almost every country in the tropics, and any effort to develop studies in the tropics should be coordinated with local people and local institutions.

Currently, the Smithsonian Institution is cooperating with the U.S. Army in a project on mosquitos in Southeast Asia. Systematists working in Washington are directly coordinated with a series of biological laboratories in Southeast Asia where ecological studies on mosquitos and other insects are underway. Similar cooperative arrangements could be established in other tropical areas of the world.

Anthropology (moderated by R. B. Woodbury)

Since anthropology is the study of patterned human behavior both in its widest variations and in its central tendencies, and since the living groups of mankind are anthropology's laboratory, therefore every human group is of potential scientific importance as showing particular cultural adaptations to a specific physical and biotic environment.

From the fact of man's worldwide present-day ecological dominance, it follows that the study of tropical biology must take human activities into consideration. This is especially true where man is manipulating the environment by means of major engineering projects. Such projects present to the scientific community great opportunities and heavy responsibilities. Because these projects so greatly accelerate rates of change, they give the opportunity to make extensive baseline studies followed immediately by analysis of subsequent drastic modifications on a scale previously rarely available. Such studies will make fundamental contributions to knowledge, and therefore deserve the application of our best intellectual resources. Observation and analysis of changes, however, are insufficient without accepting the responsibility to apply scientific insights to the task of selecting among alternative courses of action in view of their expectable total impact on the environment in which we live.

Anthropology's role within such interdisciplinary studies is not only to record and analyze the changes that occur, but to assist the responsible agencies in formulating, executing, and evaluating programs for the human occupants of the areas affected. These programs often involve relocation of large numbers of people and their adaptation to new habitats and new socioeconomic patterns. For example, in Africa the Kariba Dam project required the relocation of 50,000 people, the Aswan High Dam project of over 100,000 people, and the Volta scheme of some 75,000. In such projects the potential contributions of social science and indeed of all the sciences to the immense human problems created have not always been used to full advantage.

In eastern Panama there now exists an opportunity to greatly improve the effective application of anthropological techniques to situations of enforced drastic change. Three engineering programs have been initiated which will drastically alter the lives of nearly 30,000 people of the region. These are first the Pan-American Highway, second the Bayano Dam, and third the examination of possible routes for a sea-level canal. Rates of cultural change among the local population are increased as soon as surveys for engineering studies begin, and long before actual construction. This area contains two quite separate Indian groups, a large and rapidly growing Negro or mestizo group, and a smaller number of recent white settlers. All of these ethnic segments live in small and widely dispersed communities. Anthropological studies have already been successfully begun as reported at this Conference by Reina Torres de Arauz. The study of the four cultural groups in this area should serve as a model for such investigations everywhere, thus it should include the collection during baseline and subsequent studies of the following topics for each cultural group and in each major geographic subdivision of the area.

1. Demography and demographic trends.

2. Systems or resource exploitation, both current and past. This would include archeological surveys and studies, nutritional and medical studies, and also the usual land-use analyses.

3. Social and political systems and patterns of leadership and authority.

4. Expectation, attitudes and value orientations, with special attention to the reactions to past governmental attempts to induce change.

The baseline study along the lines just mentioned must be sufficiently comprehensive to enable those making subsequent studies to understand the nature of the changes occurring in all sectors of the different cultures. Relocation and rapid social change can be expected to increase stress within the societies involved. For example, relocation usually brings major dietary changes and temporarily increased mortality. It widens social contacts with other groups and increases the number of cultural alternatives among which choices must be made.

The very complexity of changes arising from major engineering projects requires a long-term, interdisciplinary approach. The anthropological aspects of these studies can be appropriately incorporated in biological programs, national resource surveys, and other similar projects. The shortage of qualified personnel makes cooperation among national and international agencies essential. It is especially important that every investigation effectively involve educational and research institutions in the host country and that it bear in mind the development goal of the country involved.

Man has been changing the face of the earth from his earliest beginnings, but the immensity and the rapidity of the changes being made at the present provide both an unparalleled opportunity for large-scale research during the course of these changes and a new major responsibility to apply our best scientific insights and understanding to the direction of these changes.

RESOLUTIONS

The full text of all resolutions is presented here as a summary of significant conclusions of the Conference. The conferees resolved:

1. That the participants in the Smithsonian Conference on Tropical Biology urge the development of a worldwide tropical biology program, including initially inventories and surveys such as those required in connection with the construction of a sea-level canal and the Bayano Dam.

2. That the Smithsonian Institution, with appropriate advice from a body of recognized scientists from various countries, should:

a. Seek funds immediately for a marine program in the Caribbean and in the Pacific Ocean adjacent to the Isthmus of Panama.

b. Seek funding for world-wide surveys of terrestrial and fresh-water environments.

c. Seek funding for intensive ecological studies in the tropics, initially in Panama.

3. That the Smithsonian Institution seek the advice of foundations and federal granting agencies, such as the National Science Foundation and the National Institutes of Health, in establishing policies governing the distribution of financial support.

4. That administrators of museums, and other institutions which maintain systematic collections, anticipate the large increases of such collections that will result from any successful tropical biology program, that they accept the responsibility of storing and protecting them adequately, and that they provide space not only for their own staff but for other scientists who need to consult and study these collections.

5. That the Smithsonian Institution consider the establishment of supported chairs of tropical biology at universities in the tropics to encourage the development of scholars with the time, opportunity, and finances to carry on research and graduate instruction in areas of interest to the Smithsonian Institution, the filling of the chairs to be under control of the universities concerned; it is recommended that the chairs be occupied by a citizen of the country in which the university is located as often as possible and practical.

6. That investigators obtaining grants and contracts for research in tropical biology and anthropology include, where appropriate, requests for funds to provide advanced training of students to increase the number of qualified scientists concerned with science in the tropics.

7. That collaboration between scientists of the U.S. and those of host countries include:

- a. Joint planning of research programs from their inception.
- b. Development of research programs through government scientific bodies as well as directly with research organizations in the host countries.
- c. Publication of at least preliminary research results in the host country's scientific journals, in the host country's language, when appropriate and feasible.
- d. Deposition of representative data and specimens in host country institutions.

CONCLUSION

As a result of the Panama Conference on Tropical Biology, the Smithsonian Institution is revising and expanding its Task Force Report as a statement of need, opportunities, and reasons for a world program in the biology of the tropics, together with suggestions for implementing such a program. This report will be made available to the scientific community, government officials, and other relevant persons.

Although the Smithsonian Institution will design a program that reflects a world outlook for the study of tropical ecosystems, the results of the Panama Conference clearly indicate the priority that should be given to the Central American tropics because of the unique research opportunity offered by the planned construction of the sea-level canal. There is a high probability that the knowledge acquired from a tropical biology program will buttress the precanal surveys currently underway by the U.S. Army Corps of Engineers which are focused on the engineering feasibility, including from the biological point of view studies relevant to radiological safety in the event that nuclear explosions are used to excavate the canal. Under present world conditions of exploding human populations and the limitations of the resources that support them, it is essential that proposed environmental manipulations as significant as the proposed Atlanti-Pacific sea-level canal be based on a comprehensive background of fundamental information.

It is clear that major sums of money can be made available for imaginative programs of scientific investigation if prestige in international circles is involved—witness the vast and well-funded programs in the Antarctic and space research. Great sums are also provided where major economic benefits are promised—witness the attention being given to oceanography. The profound importance of tropical regions, and the biological studies necessary to understand them, may actually be more critical than the Antarctic. Space, and Oceanography with respect to our future tenure as dominant inhabitants of the earth. Unfortunately, most of the required work is outside the experience of most of those in control of large disburseable funds. Biologists, at least, should have no difficulty in grasping the urgency of making an effort comparable with the big programs mentioned above. It is hoped that their influence in favor of adequate financial resources for tropical biology will be felt strongly at the levels where decisions are made.

PERSPECTIVES IN TROPICAL BIOLOGY*

S. Dillon Ripley, Secretary, Smithsonian Institution, Washington, D.C.

We, in the United States, are inevitably a temperate-zone oriented people. We have always lived and have evolved our culture in the temperate regions; this includes our science as well. Thus, it is not surprising that a disproportionate amount of the scientific information we have gathered concerns the phenomena immediately about us in cooler, strongly seasonal climates. As a result, in the case of biology, a major part of the accumulated biological knowledge is concerned with a rather minor part of the world's fauna and flora, because of the chance development of biology in the temperate zones.

There has always been a contrast between two tendencies in research on the marvelous diversity of organisms that share the world with us. There are scientists who are infinitely fascinated by the wealth of detail to be seen and studied immediately around them and who bring out and develop our awareness of the complicated patterns and processes to be seen right at home. Perhaps the

*An address given at the Panama Conference on Tropical Biology, Panama City, 9-12 November, 1966.

current fads of molecular biology and numerical taxonomy may be instances of this preoccupation. On the other hand, there are those to whom the far-away places, the unexplored or little known parts of the world and the different, and sometimes fearsome, creatures that live there are like magnets. These opposing tendencies are epitomized in a story told some years ago of two prominent botanists from the same well-known institution. One of them remarked that he could not understand the other's going all the way to South America to collect and study plants when there were many new varieties still to be discovered right around him at home in New England. The other replied that he could not see why the first wasted his time on these trivial varieties, when in the tropics there were new species still to be discovered. These two tendencies, of course, even sometimes coexist in the same individual.

For some time, in the United States, the intensive, home-centered or laboratory-centered aspects of research have had the lion's share of attention. Concern about military threats has brought good support to far-away research in the Arctic and considerations of international prestige have resulted in more-than-ample backing for work in Antarctica. Research in the tropics, in spite of the fascination of the myriads of new and strange creatures there, has been the poorly supported stepchild. Only a few institutions, prominent among them the Smithsonian, have answered the call of the far-away warm parts of the globe. These efforts, though very productive, have been on a small scale and poorly supported, even during a spurt of activity just after World War II when costly campaigns drew our attention to certain tropical places, many of them previously quite unknown to 99% of our people.

Science is, or should be, completely international in its aims and scope. To the biogeographer, for example, it is just as interesting and important that there are species of *Draba*, a small cress-like plant, in the Andes as that others exist in the Southern California mountains. The honey ratel of Africa is just as interesting to him as the North American badger and wolverine. In fact, the existence of all three is a more significant fact than that of any one of them considered separately. From a scientific, as opposed to a practical viewpoint, it is equally important to have information from one part of the world as from another, and the relative scarcity of knowledge and lack of understanding of the rich tropical biotas is a serious deficiency and gap in our body of scientific data. Few major biological problems can be solved finally without understanding their tropical aspects.

You are here this morning to consider what should be done about this state of affairs. Presumably, most of you are here because you belong to the second category described above, those who are attracted by the far-away and less-known aspects of biology. You may not need any explanation from me as to why tropical biology is important enough to be a major preoccupation in one of the world's most distinguished and important scientific institutions. However, most of you, also, are here because you are much more than usually competent in some special field. You each are probably better qualified than I to speak on your own particular aspect of our subject. You may not have had much time, however, to devote to a swath in world science as broad as tropical biology. If so, it may be interesting to some of you to see how someone else views this field and perhaps even your own particular significance in it.

Let us first take a look at the propriety of the Smithsonian's more than casual interest in the tropics. Might it not be asked why a U.S. institution should go so far afield when its own country is not yet adequately known, scientifically. There are, indeed, those who ask this, and who are critical of our efforts to know the world outside of our own borders. A U.S. Congressman recently criticized Smithsonian support of a botanist working on the high mountain vegetation of Mexico—a subject “that could only be of concern to a Mexican sheep herder.”

Although the Congressman could be and, indeed, was answered on his own practical terms, that was not the real answer. We stress the fact that we have had a long-standing interest here in Panama because we have our biological station on Barro Colorado Island. Even this, though, is not the real reason. The reason is essentially that given by the mountain climber for his efforts to scale Everest or some other difficult peak—“It is there.” In the tropics a great unconquered mountain of fascinating biological information *is there*. The scientist who has in some way been given even a short exposure to tropics will, if he is the second sort mentioned above, not likely be satisfied until he has had a chance to go back for more—to look longer at these incredible forests with their innumerable kinds of plants and animals, to collect and compare, to know and understand.

The tropics are where the rich harvests are, and science is not conscious of national boundaries. Because the Smithsonian has a backlog of tropical experience it may be well enough qualified to help stimulate the growth of indigenous science in tropical areas and to guide and assist other temperate institutions and individuals to take their first steps, or to develop their research interest in the tropics, as well as to broaden and intensify its own work there.

By bringing together the conclusions of paleontology, especially paleoecology and paleobotany, and the data of present-day biogeography, we are reasonably certain that at least before the mid-Tertiary Period tropical conditions extended over the larger part of the earth. The differentiation of the main groups—families and even genera—of organisms took place under these conditions. Something at least resembling the great tropical vegetation formations, the rain forest, the monsoon forest, and perhaps even the savanna, must have been much more widespread over what is now the temperate zone during those earlier epochs. Many of our best biogeographers consider the lowland rain forest, or Urwald, of the tropics to be the oldest of all existing vegetation formations and to have been the great reservoir from which emerged, or were differentiated, the faunas and floras of the present temperate and montane regions of the world. The present richness and diversity of tropical biotas, as well as the fossil record, lend good support to this theory.

Some of the most fascinating problems of biology are those of the evolution and spread of the groups of plants and animals, and the communities they make up, over the earth. This applies equally to those of land and sea. Although we know much about the evolution of subspecific entities and can even experiment on it, this is not true of the larger groups of plants and animals. These must be studied by observation and comparison of the plants and animals in their natural habitats and in our museums. Since the cradle of the phenomena we are interested in is in the tropics, or in areas that were once tropical, it seems clear that a great amount of work must center in the tropics, if we are to arrive at any adequate understanding.

The enormous diversity of organisms in the tropics has been known for a long time. Some biologists have speculated on why this diversity exists, but so far their suggestions are only guesses. Recent findings and deductions are giving leads, and the whole subject of availability of resources and diversity of riches, as well as the enormous amounts of time available in the history of a tropical biota, are fertile fields for investigation.

To the ecologist, this great diversity of faunas and floras is the basis of the richest and most complex ecosystems in the world, as well as those which are least known. In at least the wet tropical ecosystems conditions are extremely favorable to life. Hence, the usual and obvious adaptations to severe physical environment and less common, but the more subtle, adaptations to living with other organisms are outstanding. Competition is rigorous and takes multitudinous forms. The struggle here is most intense among the components of the biota rather than between them and their nonliving environment. Incidentally, under modern, civilized circumstances, this is, in a way, the situation in which human beings find themselves; the adverse physical aspects of their environments have largely been ameliorated. The struggle is now between human beings rather than against a hostile environment. Even more is this so in the tropics than in cooler zones.

Both as a matter of intense scientific interest and as one of practical concern, it seems essential that we develop some understanding of such ecosystems. As scientists, we are not able to ignore the fascination of these problems. As practical people, concerned with the continued existence of man as a part of these ecosystems, we cannot afford to neglect them.

In the past, resources have been so abundant, human communities have been scattered and relatively few and isolated, that mistakes were not too likely to result in disasters. This period is passing rapidly. Man is so filling up the world that errors are too likely to produce chain reactions. We now must know what we are doing before we do it. A thorough understanding of the tropics, as well as the rest of the world, is a necessity.

The final and, to me, the most urgent consideration is one that follows from our filling up the world. Most of the fascinating things that draw us to the tropics are vanishing with a rapidity never before even imagined. The tropical forest is falling before the combination of superior tools and too many people more rapidly and more finally than before any forest fire or other natural

calamity. Already, many plants and animal species have vanished before they were even discovered. Far more are doomed in spite of anything we can do. Even such loss is an impoverishment of the world. Most people in the tropics, as in other parts of the world, do not realize that this is happening and would not grasp its significance anyhow. As scientists, we are in a position to appreciate this in a way that will be generally grasped by humanity when it is too late, and the world will have lost much of its savor and interest. Our presumably more enlightened descendants will look back with bitterness at generations who allowed this to happen.

Knowledge and understanding such as we possess in these fields carry with them serious responsibilities. Because of our interest and willingness to learn, society has given us more than ordinary opportunities and privileges, and we have enjoyed far richer lives than most men. I feel that we owe to humanity, to our descendants, our best efforts to bequeath to them a still interesting and varied world. A world with the full range of fascinating phenomena that we are privileged to see now, rather than a dreary waste of landscape from which all diversity has been subordinated to the devastating influence of the agriculturist or the engineer.

I commend to you the task and the challenge of finding out what there is in these fascinating tropics and at the same time of working out means of saving enough of it for the future so that tropical biology, to our descendants, will not be largely a matter of paleontology.

As a closing remark, I should point out that the success of long-range research on tropical ecosystems depends on accomplishments by local scientists here at home in the tropics. Scientists from abroad cannot carry out alone the fundamental research essential for the management of tropical resources. There must be effective collaboration with colleagues in various tropical countries. Well-trained endemic scientists are already at work in the tropics. They need encouragement and support from their temperate-zone colleagues. In particular, they need help through foreign-aid programs in creating opportunities for careers in research and management of tropical ecosystems. Without opportunities for local scientists and resource managers within a given tropical country, the world program in tropical biology that we envision cannot advance effectively. The most important thought I can leave with you is that in the evolution of a tropical ecosystem science we must emphasize the development of local competence in research, education, and public service within each tropical country.

CONSERVATION AND UNDERSTANDING

David M. Gates, Director, Missouri Botanical Garden

The tempests and tempests of conservation have surged across the matter of saving the landscape from the pressures of an exploding population. It is self-evident that certain representative large tracts of native habitat must be preserved and protected against encroachment and exploitation by man. Much less self-evident are the reasons for setting aside large reserves. Many people of the Christian world operate with the doctrine that nature serves man; that nature and native habitats are for man's use; and they do not look on man as a part of nature. This immediately forces the issue concerning the reasons for setting aside natural reserves; it is a reason of use. The matter of use means different things to different people. To many, a piece of native landscape, is for floating, or camping; motor boating or hiking; sailing or horseback riding; swimming or picnicking. To some it is a place where rare birds, animals or plants are found, or a remarkable geological or topographical feature of the earth's surface.

Conservation, the idea of having plants and animals, of pieces of the landscape, is a tangible and emotional experience in which the consequences of our action are seen before us and are walked upon and touched as we reach out. Less tangible but enormously essential to all of mankind is the use of the landscape for understanding the natural history of the planet earth. How many of us realize that unless something is done soon, future generations may be denied forever the opportunity to understand the evolutionary and ecological genesis of the planet on which we live? We have been denied by our own actions and by the actions of those who preceded us, the opportunity to understand many things concerning our natural environment, of our changing environment, or of the immediate past history of the earth's surface. Without history and without an understanding of the physical and biological evolution of the world around us mankind is susceptible to the catastrophic impact of his actions on its own habitat.

Man is an intimate part of nature, not one who is above or removed from nature nor designed to exploit and use nature, but man and nature are one and the same thing. Who among us would advise that we build a bridge across the Mississippi without employing the engineer who understands the principles of bridge construction? Someone did just this many years ago at Tacoma, Washington, and the bridge collapsed in a high wind. Who among us would deny that we must understand and give attention to every last detail in the construction of a jet aircraft for safe passage? Yet someone made just this mistake a decade ago when the British Comets (pioneering jet passenger travel) exploded in flight. Then why must we persist, as a civilized, modern nation, to live and expand and to involve ourselves more and more critically with our environment without a strong program to understand the world in which we live? By understanding I do not mean simply to describe the physical and living world around us, but describing it is the first step in the process of understanding. We are currently collecting and recording the organisms from the world's habitats at a reasonable rate; but the rate must increase, particularly for tropical regions. However, our efforts to understand the intricacies of the natural habitats of the world are shocking little at a time when man's need for this understanding is becoming desperate.

It is a fine thing to conserve natural habitats—the Grand Canyon, the Redwoods, the native prairie, the Great Smokies and many others—but in addition we must marshal our forces for understanding them. The collecting of knowledge and the pursuit of understanding is not as tangible as redwoods, rivers, mountains and canyons, but it is every bit as essential. All the saving of natural habitats will be to little avail if we do not strive for a vigorous program in the

pursuit of knowledge. If we do not understand the natural history of the earth, mankind will be threatened with a running down of the environmental mainspring—a life of ever increasing degeneracy; of an overcrowded, polluted and plundered planet containing only small remnants of its former natural beauties, and these badly disturbed. While we are vastly improving our technology, our communications, our bridge building, our transportation, our ability to explore space, the planetary system, and the galaxies, we are letting slip through our grasp the single most critical opportunity mankind will ever have—the opportunity to understand the natural history of the earth. We will be starry eyed and impressed with our own technological achievements in the vastness of space and the intimacies of the atomic nucleus while we lose forever the opportunity to consciously and intelligently plan the future of mankind as an intimate, dynamic part of nature. Mankind cannot afford to continue its attitude toward natural history, of understanding too little and too late.

As a nation we are strong in scientific research and in becoming strong we have made conscious decisions at high government levels concerning research programs. We have decided repeatedly to emphasize nuclear physics and in so doing we are building great nuclear research centers such as the new commitment for a \$350 million nuclear accelerator at Weston, Illinois. We build the world's finest astronomical observatories, solar telescopes and radio telescopes costing hundreds of millions of dollars. We launch great oceanographic ships to explore the oceans of the world. We put dozens of satellites into orbit to measure and probe the geophysical environment of the earth or to look down at the global weather. These things should be done and in so doing will pay handsome dividends to mankind from the knowledge they accrue. Yet it will be possible to study the atomic nucleus, the sun, the planets or the galaxy a hundred or five hundred years from now. But not so the natural history of the earth, especially the natural habitats of the land masses, the terrestrial ecosystems. The woods, prairies, deserts, chaparral, streams, bogs, swamps, estuaries, and lakes of the land are susceptible to rapid and almost instant change. They are abruptly wiped out by the blade of the bulldozer; they are poisoned by pollution; they are destroyed by man-made changes of climate; they are sprayed with insecticides and herbicides; and they are invaded by weedy plants, by pernicious animals, and by man himself. Every terrestrial ecosystem we know is undergoing rapid change or is under the threat of rapid change by the hand of man. With the change goes forever the irretrievable opportunity of understanding the natural history of the earth.

We do not understand the detailed relationships of plants, animals, and environment within any single ecosystem. An ecosystem is a single community of plants and animals such as a forest, a grassland or a bog, where the boundaries can be more or less specified. Scientists have described the plants and animals and the climate of many ecosystems and have achieved some understanding of food chains, population relationships, and climatic effects. Yet we understand very little of how the simplest ecosystem works; the complexity of the simplest of natural communities is enormous. Modern science has the capacity to work out the causal relationships within an ecosystem for a basic understanding. There is not a subject in science more diverse and difficult than the complexity of an ecosystem. Its understanding involves meteorology, climatology, geology, soils physics and chemistry, physiology, plant and animal anatomy, morphology, taxonomy and systematics, biochemistry, genetics, population dynamics, sociology, behavioral science, mathematics, and others. This is the basis of the difficulty which exists within ecology as an intellectual discipline.

Why must we persist in doing those things that are easiest; of putting our national resources and manpower, our intellects and cleverness, to work on those things which are tangible engineering achievements without buckling down to understanding the world in which we live? While we *save* a redwood forest let us also marshal our forces to *understand* it. Why do the redwoods grow where they do; to the immense size they assume; what is the secret of their longevity of 4000 years; how do they transport water 300 feet straight up? When we save the sand dunes of Indiana let us understand the unique quality of the ammophila grass which clothes them and protects them against blowing away in the wind. Why were the great plains of Kansas so productive of bison and antelope and less so of cultivated plants and animals? Why and how do salmon navigate to return to their breeding grounds up the great rivers of the Pacific northwest after foraging for a thousand miles at sea?

We do not understand with any precision how it is when the rains fall on the land the water is taken up by the plants, breathed back into the atmosphere allowing only a fraction to run into the rivers. Yet water is our most essential resource and our very survival depends upon knowing how plants use it and pass it on. Why do sycamores and cottonwoods grow in the Meramec flood plain and oaks and cedars on the bluffs above? We do not really know. Must we know? Indeed to live among the oaks and sycamores, cedars and cottonwoods, to walk amidst them, to breathe the same air they breathe, to drink the same water, to depend upon them in every intimate way and upon the millions of plant relations, we must understand them.

In some way we must get across to the leaders of this great country of ours the absolute necessity for greatly increased attention towards understanding the living complexities of the habitat in which we live—a crash program to train young people in ecology, in the dynamics of the living landscape, with a capacity to make rational decisions concerning man's welfare. We urgently need the establishment of great centers of learning devoted to understanding the single most important thing ever given to mankind, the heritage of living things. The natural world around us is as much a part of ourselves as are our own children, or our own parents. Many people believe we are studying these things. We are; barely. Yet we need to do so with the passion and dedication with which we race for the moon. It is our lives and our children's lives and the lives of their progeny with which we are playing roulette; a game one cannot possibly win when played too long. We can only safeguard the future of mankind through understanding the natural history of the only planet upon which most of us will ever live. Help us to understand this magnificent green earth before it is too late.

ECOLOGY OF MAN: HIS ARTS AND SCIENCE

Dr. Stanley A. Cain, Assistant Secretary for Fish and Wildlife and Parks, Department of the Interior, at the Seminar for Environmental Arts and Sciences Sponsored by the Thorne Ecological Foundation, Aspen, Colorado, July 23-29, 1967

This symposium seeks to deal with two exceedingly complex areas of contemporary interest: one called ecology in the area of science; the other called conservation in the area of societal action.

Scientists do many different things under the rubric of ecology and many scientists carry on ecological research that they wouldn't dream of calling ecology. Physicists, chemists, and astronomers usually don't have this uncertainty about labels, nor do many biologists such as cytogeneticists, physiologists, and morphologists.

The hesitance of some scientists to call themselves ecologists goes back in part to natural history approaches based largely on observation and unsophisticated instrumentation. And it is true, to a degree at least, that many ecological problems are so complicated that they are not even now amenable to refined mathematical treatment. Also, many of the measurements and past attempts at quantification seem not to have led to solutions of the problems posed. Many ecological studies have piled up data on climate, geomorphology, soils, the composition and structure of vegetation, and the relations between one species and another, or a species and selected environmental conditions, without putting the data to work by revealing a convincing causal relationship between them. Many things and conditions that vary together have not been shown to be coordinated in a cause-and-effect relationship, or not to be so coordinated.

One distinguished physiologist, after associating with ecologists for several days under pleasant circumstances, announced to the group his discovery that "Ecology is the physiology of togetherness." Another scientist on a different occasion said wryly and with a touch of arrogance, "Ecology is what I do and others think they are doing."

Perhaps the most widely accepted simple definition is that ecology is the science of life and environment. Following this thought, that ecology is concerned with interrelations—interrelations among things and conditions and processes—one can see that there is inevitably an unlimited scope for ecology.

It runs the circuit from intra- and inter-molecular phenomena, as particles interact under different physical conditions, to global phenomena and impingements on our world from space. In between there are the interrelations between life and environment at the intracellular level, the intra-organismal level of tissues and systems, the species population level, and that of multi-species communities of plants and animals together. Having reached the community level of organization, one finds identifiable and describable communities that range from those of relatively simple composition and structure, occupying small space, to global formations.

Examples of small and, as you will see, intimate communities I would mention are termite colonies and their associated species that have evolved together over millennia, and man, I mean one man, and his collection of ectoparasites and the fauna and flora of his gut. At a larger scale are small ponds, the communities of restricted rock outcrops, or patches of peculiar soil. At the large end of the scale are the pantropic rain forests, temperate grasslands, and circumboreal tundra.

As one passes along this continuum of the organization of life, its internal complexity increases as does the variety of interrelations of it with the external environment, both physical and biological. Also in passing along this continuum, scientists find it increasingly difficult to qualify their data, to express it mathematically, and to perform controlled experiments. Nevertheless, in a general way, there is predictability, always cherished by scientists, even for the largest life units. For example, in Brazil where high tropical rain forest often meets grass and brush savanna with a sharply demarcated boundary, the disturbance

of one by lumbering and the other by fire does not diminish their integrity. Each, if given a chance, renews itself. Neither invades the other, as I have seen in Minas Geraise and Para.

More recently, ecologists have found ways of simplifying even complex communities to express the fundamental basis of their existence and their relationships with the physical world. This has been said facetiously as a matter of "who eats whom." Like many a jest, it has a penetrating core of truth.

It all starts with the elementary fact that to be alive requires a supply of energy, and that the ultimate source of energy for living organisms is the sun. This energy, as every schoolboy learns, is made available by a photochemical process involving green plants principally. In the process, organic carbon compounds are formed from which energy can be released and used by the living substance to maintain a multitude of life activities, including maintenance, growth, and reproduction of the living substance and the organisms it composes.

The resulting situation is simplified by considering those carbon compounds that are assimilable as food. Green plants and a very limited number of other photosynthetic organisms are autotrophic, which means that they can start from scratch with carbon dioxide and water and sunlight and manufacture simple carbohydrates, granted the pre-existence of chlorophyll and certain catalyzing enzymes and the living matrix itself. (This is no place to go into the question of the origin of life on the world or for that matter whether on another world it might be based on iron rather than carbon).

Starting from this base, all animals and all non-photosynthetic plants, such as parasites and saprophytes, are heterotrophic and cannot start from scratch. They must eat something. I use the word eat rather loosely to include all methods of acquiring organic carbon and its associated energy supply. This does not refer to acquisition in solution of essential mineral nutrients such as nitrogen, phosphorus, sulfur, magnesium, iron, calcium, and certain trace elements, although these are parts of many foods.

This situation can now be seen to be truly a matter of who eats whom. Green plants are called primary producers. Organisms eating such plants are first order consumers. Rabbits eat pea plants and carrots when they get a chance. But foxes eat rabbits when they get a chance, and they are second order consumers. There may be other identifiable levels in the food chains until one comes to the top predators of any ecological system which are in this gross sense without enemies because none of their consorts is capable of successfully attacking them. Still, even the top predators die because they, like the lowliest green plant, are subject to the ravages of parasites, to starvation, and to accidental death.

The sequence described in this general and non-scientific language is one of transfer of energy-bearing carbon compounds from one level to another with each trophic-dynamic level having fewer numbers of organisms and less biomass. (Now I have used some technical language, but the meanings are now implicit.) On this basis, the biological system of a community can be described quantitatively if one samples adequately, aggregates data, and simplifies everything about who eats whom.

This concept of a pyramid of numbers of organisms and the amount of substance contained in each level is upset, however, by the degraders and decomposers. I have already referred to the fact that the top predators die for one reason or another other than themselves being gross food for somebody else. It is now seen that this isn't really true. Nearly every organism, perhaps all of them if we knew enough, is subject to parasitism. And not every part of every organism is alive. Many structures of both plants and animals are composed at least partly of substances produced by the living organism, perhaps once alive but certainly not now alive. For example, a large healthy tree may be more than 90 percent dead. All such organic material, whether a dead organism or part of a still living one, is subject to decomposition and degradation by saprophytes. These organisms, as distinct from parasites that live on living substance, usually killing it, live on dead substances. They are mostly but not entirely bacteria, fungi, microscopic animals, and small worms.

So the cycle is completed, because the degraders and decomposers reverse the build-up process and return complicated compounds to simple forms such as mineral nutrients that are again available to green plants. As has been known for many centuries, and as we are reminded at every funeral, man is mortal. "Dust thou art, to dust returnest."

For present purposes, I do not need to say much more about ecology as a biological science. Life activities are supported by energy originally from the sun. Green plants collectively seem able to capture only about two percent of that reaching the surface of the earth. This is the low average efficiency. Since keeping themselves alive uses up some of the food of green plants, and since the herbivores—that is, the plant eaters or vegetarians—do not harvest completely the annual production of the primary producers, and cannot use what they eat with perfect efficiency, the biomass of the first order consumers may be about 10 percent of that of the plants. Moving up a trophic level, not all rabbits get caught by predators and the predators themselves have a relatively low efficiency in converting rabbit flesh to fox flesh, so they and other associated predators of that level may make up only 10 percent of what is theoretically potential. The idea of ecological pyramid has become clear.

Let us suppose for a moment that we are interested in the welfare of animals that are not so choosy—ones that are omnivorous. Man is a good example. If something is eatable, he will eat it. Not any one man, but man collectively, for we each have psychosomatic hungers and distastes. Some of us will eat snails, whole fish, if they are small enough, dairy products rotted by fungi, which we call cheese, and blood sausage. But we find distasteful the idea of eating grasshoppers, termites, and grubs. Hungry rice eaters have to force themselves to eat wheat and on today's world grain market you could exchange one ton of rice for two tons of wheat without asking the nutritional value of either.

There is a lesson in the ecological pyramid of biomass made up of the different trophic levels. If man is looking for food, assuming that he can digest it, he will find more of it available at lower than at higher trophic levels. This is the moral of the human population/food dilemma. People of populous poor countries must subsist mainly on grains. Meat, poultry, and milk are too scarce and costly for common consumption. And if starving, man turns to grass itself, bark of trees, and as did Moses and the children of Israel during their sojourn in the desert, to manna, which the dictionary says was food miraculously supplied, and which botanists speculate must have been lichens called rocktripe blown by desert winds from rocky summits.

It is an interesting fact that most human foods comes from a relatively small number of kinds of domesticated animals and agricultural crops. Over time the varieties and strains of these few species have been increased, but scarcely a new species has been put to use for human food during historic time.

This problem is being faced by the International Biological Program that has been in its planning phase for the past few years and is just now starting on the research phase. The theme of the IBP is the biological basis of productivity and human welfare. Some 60 nations are embarking on more or less elaborate programs of study of organic production on land, in fresh waters, and in the seas, so that more adequate estimates may be made of the potential yield of new as well as existing natural resources. Another, related part of the IBP is a group of studies of human adaptability to changing conditions, while yet other sections of the program are looking at the scientific basis for the use and management of biological resources and the conservation of natural areas for comparison with managed ecological systems.

The plain facts of the matter are that burgeoning human population, especially during the past two decades, and the rate at which man is deteriorating his environment by thoughtless and ill-advised practices and constructions that reduce the productivity of ecological systems, has caused biological scientists to recognize an urgent need for greatly increased ecological research. *The United States' part of the IBP promises to cost millions of dollars and the sympathetic House Science and Astronautics Committee's Subcommittee on Science, Research and Development, chaired by Congressman Emilio Q. Daddario, of Connecticut, is currently holding a series of hearings on it.*

This massive, worldwide, planned effort will produce a much better understanding of how biological systems work. For the various landscapes, and especially those upon which most people depend for sustenance, there will be better knowledge of natural production at the different trophic levels, of their interrelationships, and of the principal effective species of each level. From such knowledge there will stem guidelines for the selection of new species to be used for human benefits, for the modification of agricultural practices to higher levels of sustainable efficiency, and for the planned allocation of land to its highest uses.

This line of comment leads me to conservation which, as I implied in the beginning, is at least as complex as ecology. One of the purposes of this symposium is to discuss whether conservation is compliance to ecological principles and consists of working in conformity to constructive ecological processes. I believe that this is so as long as we do not assume that it implies a return to nature by turning our backs on what can be gained by management techniques based on scientific facts.

It is commonly said that conservation is the wise use of natural resources. This is all right, too, if wisdom means the use of all pertinent knowledge.

I know that this audience is familiar with the population explosion, with hunger and unrest in the world, and with the rate at which man is changing the face of the world and not practicing conservation. Not all is bad and none of us would return to the innocent stability of certain primitive societies which, in fine ecological adjustment, survived for many centuries as did many Indian tribes of North and South America. Yet neither can we ignore that early civilizations ended up by destroying the fertility of the eastern Mediterranean crescent and that Rome's breadbasket was once northern Africa. But not many of us really realize how close catastrophe is for many nations and hundreds of millions of people.

In writing a paper for the April Alma College American Assembly on the Population Dilemma, which I entitled "Population Ecology," I said:

"It is implicit in the reproductive potential of our species, as it is of all other species, that growth and reproduction will continue until the population has reached a size at which resistances begin to check growth. We are back to the sigmoid growth curve. It is inescapable. Man, however, has abilities that no other species shares. We do not have to endure the Apocalyptic reduction by the Four Horsemen: War, Conquest, Famine, and Death."

I went on to say that after two decades of technical and other assistance "the statistics show a worsened, not an improved condition for the vast majority of the two billion people of the poor countries. To make the situation even more dismal, I look for a reversal in several countries of the recent history of falling death rates."

It was in unhappy confirmation of that prediction that I read in the *New York Times* for April 19, 1967, that "The Bihar state government said . . . that two districts and several regions affected by drought had become famine areas . . . Bihar's government thus became the first in India to declare famine conditions since the country became independent 20 years ago. The famine areas cover more than 23,400 square miles involving 12,730,000 people." (Incidentally, these figures average the population density at 544 persons per square mile." There are, of course, other parts of India in difficulty, such as the eastern part of Uttar Pradesh, and the headline of the *Times* article read: "Drought, Disease and Famine Sweep Bihar State in India, Affecting 40 Million."

I would like to turn now to another paper on the American Assembly program, given by Lester R. Brown, Administrator, International Agricultural Development Service. He subtitled his paper, "Chronology of a Crisis." Here are some highlights.

In country after country throughout the less developed world, the fertility of the people is outrunning the fertility of the soil.

A few years ago the world was plagued with burdensome surpluses of wheat, rice, and feedgrains. Today there are no surpluses of any major food commodity in the United States or anywhere else in the world.

The three largest countries of the world—China, India, and the Soviet Union—are now net food importers.

Sharply higher prices for rice even in the last few months are reducing the levels of intake, particularly in the low income countries where income and diets were already pitifully low.

The per capita availability of grain in India has dropped nearly 5 percent over the past two years as contrasted with the early 60's, and this has occurred even though the United States is now shipping the equivalent of nearly one-fourth its wheat crop to India each year.

This movement of wheat from the U.S. to India in 1966 required 600 ships. India needs an additional 10 million tons of wheat in 1967, but even this vast movement of food is not achieving any improvement in diets. It is not even maintaining consumption levels of the early 1960's. Sunday *New York Times* business section, July 16, 1967, says Suez closing will require 18 months to ship one year's food supplies to India.

President Johnson has recognized that balance between food and people cannot be achieved by focusing our attention on food alone, for he said in San Francisco on the occasion of the 20th Anniversary of the United Nations: "Let us act on the fact that less than five dollars invested in population control is worth \$100 invested in economic growth."

Lester Brown had a chart that I would like to put into words. It brings me down to the last part of my remarks some words about human ecology. This chart plots total grain and grain consumed directly as human food on a per capita basis against per capita income in U.S. dollars.

For many countries, such as India, Mexico, and Japan, the per capita use of grain is between 300 and 500 pounds a year, averaging about 400 pounds. Such countries range from less than \$100 to less than \$400 income per capita. Because of the low income, nearly all the grain is used directly for human food. Middle income countries, around \$1,000 to \$1,200 per capita a year, such as the United Kingdom, France, West Germany, and the USSR, consume about 800 to 1,000 pounds of grain per capita a year, but only one-third to one-half is direct human food. At the upper end of the scale, the United States and Canada consume around 1,600 to 1,900 pounds of grain per capita a year, but less than 10 percent is direct human food.

When comparing countries in this way, we have a continuum from the poorest and most populous where about 90 percent of the grain consumption is direct human food to the richest countries where it is only about 10 percent. The richer and less populous countries convert grain to meat, milk, poultry and eggs, achieving a protein-rich diet.

What has happened during the lifetime of most of us here is shown by the following dramatic and startling comparison. If we look at the world trade in grain, we find that shortly before World War II (data for 1934-38) North America had a net export of about 5 million metric tons of grain, and for the same period Asia exported about 2 million metric tons. In 1960, North America exported 39 million metric tons and Asia imported 16 million metric tons of grain. For 1966 the estimates are 60 million metric tons export for North America and 30 million metric tons import for Asia.

I have developed these remarks so that they suggest, so far at least, that human ecology is largely a matter of food. Food is fundamental, but I now want my stress to be otherwise.

There is a human ecology that is exactly like that of other organisms for which food sustains life, permits growth and reproduction and all the rest of the characteristic activities of a species. Man is sensitive to many conditions of his environment such as temperature and humidity; he has innate rhythms of several kinds that are partly related to external phenomena and he has varying responses to stimuli of many kinds that depend upon his genetic endowment, his physiological state and his conditioning by experience. Even in all of this man is animal-like. He has his bouts with other organisms including food that upsets him, parasites that attack him, and less occasionally in modern life predators that would kill him in self-defense or for food.

But these are the aspects of human ecology that are of interest to nutritionists, pathologists, physiologists, and medical specialists, who might, if they wished, study another species in the same way.

There is another human ecology that is based upon man's social characteristics, his organized togetherness, and, possibly derivative from his social features, one that is based on his manipulation of the environment.

I cannot dwell upon any of the details of what I refer to, so it will be sufficient to suggest the areas of humanness that I have in mind.

In appraisal of the environment, man is more observant and analytic than other creatures. Despite that no one of his senses may be as acute as that of certain other animals, he has a collective appraisal that results from efficient communication by language and the long accumulation and transmission of experiences. As time has passed, he has acquired a great storehouse of information and put it to work with more or less beneficial results. Somewhere along the line trial and error gave way to prognostication based on assumption from past experience and actual experimentation—testing—developed as a tool of analysis and appraisal of the environment in relation to man's well-being. Much, much later there developed the scientific method that allowed the repetition of foreseeable results that would flow from described procedures—procedures that could be codified, recorded, transmitted, and duplicated by others.

This is the sort of process that destroys the traditional explanations of the mysteries of life and the world about us, that enables man to bend nature to his will—within limits, that is—and leads to the nearly innumerable extensions of his physical capacities by the development of what we now lump together as technology. I use the term broadly to include the technologies growing out of biological knowledge, such as those related to medicine and nutrition; the technologies growing out of knowledge of the physical world, such as those related to chemistry, mechanics, and external non-physiological forms of energy; the technologies growing out of increasing knowledge of man's social organization and the psychological and empirical bases for it.

This line of reasoning emphasizes that man has created a variety of tools, including many complicated machines, that enhance his otherwise rather meager physical capacities so that he can speak around the world, travel faster than sound, and see into the atom or the universe.

On the other side, man has created all of the societal factors that impinge upon him, aiding or retarding his individual actions. Here one must place all of the organizations that institutionalize his daily activities and permit collective action. We tend to lump them into the categories of the social sciences, such as politics, economics and sociology.

Having done this, we see that man's productivity is not that of other creatures of nature. Outstanding is his ability to harness and use external forms of energy to do his physical, and more lately, his mental work. His ever-growing knowledge of himself is applied to survival, health, and population growth. His knowledge of plants and animals and of the conditions they require have enhanced his food supply and taken him from the Garden of Eden into thousand-acre fields of corn and hundred-thousand-acre cattle ranches. At a different scale, he is exploring the more efficient micro-organisms as sources of food, the algae and yeasts, and looking toward the conversion of petrochemicals to comestibles.

All this and much more is very, very recent in man's history. Science has caused him to focus his attention closely on a small number of things, conditions, and processes. The resulting successes have kept his attention riveted on pieces of the real world. The technological developments that have been made possible have not encouraged a broad view of the world. On the contrary, engineering is singularly direct and single-minded in most of its solutions to problems. The problems themselves are narrowly defined.

We have only lately, and with something of a shock, come to realize that the way we have approached the world has produced benefits, certainly, but also very unfavorable consequences which we still think of as side effects. What technology for some time has been doing that we now find we don't like is not the cause of our problems but a symptom of them. The problem is that we have viewed the world mechanically. We have isolated partial problems one at a time. This is a failure of society, not of science and technology. Take autos, for example. They seem to have become an end in themselves, for the great companies and for the individual man. That as a result of autos the air is polluted and roads are often in the wrong places is what we have permitted, not an inevitable consequence of autos *per se*.

It is ironic to call the pollution of air and water by industrial waste "side effects." The way we have done things, thinking only of the economic products for which the process was designed, proves our narrow outlook. The pollutants are just as much a product of the functioning of an automobile as its ability to move a certain mass a certain distance in a certain time at a determinable cost of energy expended.

It is ironic that we have with great humanistic intent carried medicine, public health, and sanitation to people with little and certainly inadequate thought about the needs of the living people who would otherwise be peacefully dead. We have woefully, with inexcusable ignorance or thoughtlessness, unbalanced the population/food ratio by working on the death rate and leaving the birth rate unchallenged, and by affecting population growth so that it became explosive. (We can expect at least a billion more people in the world during the next 15 years), without a corresponding effort to assure them of adequate sustenance and a reasonably human existence.

I will end these remarks by saying that there are two human ecologies. One is that of the individual, and collectively all of us. The other is that of society, of culture in all its manifestations.

The work of the International Biological Program that I mentioned earlier is fundamental, necessary, and long overdue. But all of the knowledge that can be accumulated by this kind of ecology is of little moment unless we strive equally hard to learn how to put it to work.

I will leave you with one illustration. During this century, and especially during the last two decades, there have been many efforts at land reform. The idea was simple. Divide the land up among those who would work it. Where there are large holdings by private individuals or institutions that are not fully worked, divide them up and pass them out to farmers. This idea had a converse. Because primogeniture was not practiced in many countries, as generations passed and populations grew, inheritances resulted in minute, often scattered, inefficient land holdings. By one means or another, especially exchange, consolidated and efficient farms were to result.

Land reform with few exceptions has been a failure. In some countries, because of the population and the land-man ratio, there simply isn't enough agricultural land to alleviate the land hunger. One result of this was too small, uneconomic farms.

It is slowly being learned that effective land reform is revolutionary. Ways must be found to increase efficiency and agricultural productivity. Ways must be found to increase the capitalization of the farmer so that he can afford fertilizer, for example. He must have credit. He must have a market. He must make a reasonable profit. He must have security. He must have knowledge.

This sort of thing doesn't flow automatically from dividing up the land. It doesn't flow from a political upset or a revolution. It doesn't follow as an inevitable consequence of building a dam for power or irrigation. It certainly doesn't flow from gifts or soft loans of money by one country to another.

The changing of traditional ways of doing things is slow. The adoption and adaptation of technology are slow. Education is slow. The change of cultures is evolutionary, not revolutionary. We speak of the Agricultural Revolution, but we are speaking of six centuries and the acceleration of the past hundred years, and that only for a very small part of the world. We think of the Industrial Revolution, and some persons would date it from the close of the 18th century, or perhaps longer from the start of science-based technology, and that, too, has not yet affected much of the world's population despite transistor radios in hungry villages.

Having been negligent about the population/food equation that Malthus sensed nearly two centuries ago, we cannot now expect a quick solution. Having allowed our environment to deteriorate for decades, we cannot expect to repair it overnight. There are difficult times ahead. We have only one recourse that I see: To double and redouble every effort; to make up our minds to afford the cost, as Evelyn Hutchinson said, of repairing the biosphere.

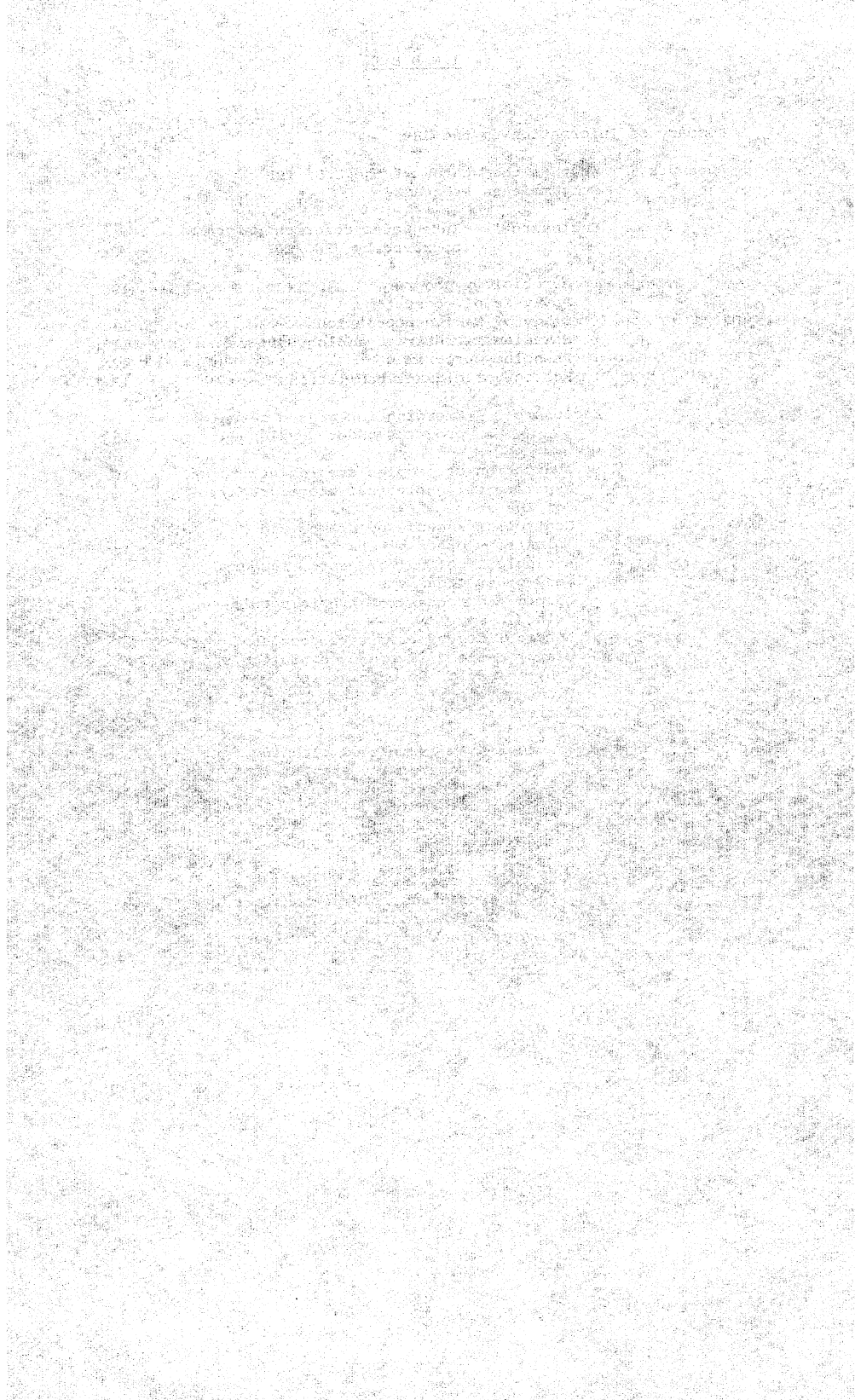
Brock Chisholm once said, "If now we all revert to our little private concerns, if we all tell ourselves 'it is someone else's responsibility,' there will one day be none of us left, not even any to bury the dead."

An important ingredient, an indispensable and even optimistic one in my opinion, is that we stop looking at the world as though it were some sort of haphazard conglomeration of independent things. We live in a pluralistic world and we ignore it at great risk. We have found, if we examine our situation, that there are systems of interacting phenomena that characterize the world. We must work with the systems. This is the usefulness of ecology. Although not all persons can or should be ecologists, we should all endeavor to use ecological thinking. That is, we should think in terms of interrelations. Famine is not a side effect of public health programs and inadequate attention to food production. It is *the* effect. That some people are alive to face an existence of misery is the side effect. When enough of us can think in this radical way, then there is hope for the future.

APPENDIX E

INFORMATION ON THE INTERNATIONAL BIOLOGICAL PROGRAM

Prepared for the Subcommittee on Science, Research, and Development of the Committee on Science and Astronautics of the U.S. House of Representatives, from the Staff of the U.S. National Committee for the International Biological Program, Division of Biology and Agriculture, National Academy of Sciences



I N D E X

	<u>Page</u>
Summary of Information on the IBP	1
Appendix I What is the status of the U.S. IBP Subcommittee Programs?	8
Enclosure 1 - Integrated research programs approved by USNC/IBP	10
Aerobiology program	10
Analysis of ecosystems	10
Study of Eskimo populations	11
Hawaiian terrestrial biology program	11
Phenology program	12
Ecology of migrant populations	13
Enclosure 2 - Emerging integrated research programs under development	15
Adaptation of peoples at high altitudes	15
Experimental analytical biogeography of the sea	15
Control of insects by plants and of plants by other plants	16
Biological control of pests, insects and other organisms	16
Adaptive processes of hybrid popula- tions	16
Adaptability of primitive peoples	17
Convergent and divergent evolution and physiology of colonizing species	17
Plant gene pools	17
Nutrition	18
Enclosure 3 - An example of planning for an emerging program (con- vergent and divergent evolution)	20
Appendix II	
A. Concerning the present and future U. S. program funding needs, please consider (a) is the US/IBP program in danger of faltering for lack of funds or for any other reason?	24
	375

	<u>Page</u>
B. Concerning the present and future U.S. program funding needs please consider (b) what effect would any lapse of funds have on the international program as a whole and upon the prestige of American science and the U.S. in general?	25
Appendix III What is the estimate of the National Committee as to the amount of money needed for the U.S. in the IBP program for the next fiscal year?	27
a. "New" money for support of integrated research programs	28
b. "New" money for support of recently submitted proposals	29
c. "New" money needs for on-going research	29
d. "New" money needs for IBP training	30
e. Summary of "new" money needed for the US/IBP	31
Appendix IV What is the view of the Interagency Co-ordinating Committee concerning the probability of being able to raise the necessary funds in the manner proposed?	32
APPENDIX V Concerning program models, in what respects, structurally, will the management of the IBP be similar to or different from the IGY?	34
Appendix VI Has any other international program been managed in the manner which is proposed for the IBP?	36
Appendix VII What nations are formally participating in the IBP?	43
Appendix VIII What is, and will be, the role of the USSR and Communist block nations in Phase I and in Phase II?	51
Enclosure 1 - The International Biological Program - Bykhovskiy & Rodin	54

	<u>Page</u>
Appendix IX	
A. Describe manpower and facilities in international training centers, collections and holding facilities, and field stations	60
B. Describe logistics (ships, aircraft, trucks, specialized vehicles, etc.)	65

SUMMARY OF INFORMATION
ON THE IBP
FOR
THE SUBCOMMITTEE ON SCIENCE, RESEARCH & DEVELOPMENT

This paper summarizes the response to the 10 questions asked by the Counsel, Committee on Science and Astronautics concerning the International Biological Program (IBP). Answers to the questions are in the following order: the status of the U.S. program, funds, comparisons of the IBP with other international programs, international participation, manpower, logistics and reviews. Discussions elaborating on this summary are attached as appendices.

Catagories of research included in the US/IBP may be grouped into (1) major research programs having their origins from the U.S. National Committee (Integrated Research Programs), (2) individual research proposals submitted in response to, or because of, the USNC/IBP and (3) IBP related research included in other major research programs of the Federal or private agencies. Approval of a major research program reflects action by the U.S. National Committee toward initiating a major, centrally coordinated research program responsive to IBP needs. The National Committee's approval of individual projects submitted because of the IBP, reflects the same judgment by the National Committee. The USNC's approval of related research included in other major research programs of the Federal or private agencies reflects the USNC's evaluation for IBP relevance. The USNC/IBP was established by the National Academy of Sciences for the purpose of sponsoring U.S. participation in this international program. Evaluations of on-going projects now in primary programs of Federal agencies for IBP relevance is only partially complete. Similarly, IBP evaluations of new proposals submitted primarily in response to agency programs are continuous and will last for the life of the IBP. Thus, many hundreds of projects independently funded within other primary programs will be included in the U.S. program as contributing to or supporting the IBP.

The information provided herein was developed with the assistance of members of the U.S. National Committee for the IBP including the Chairman and the two Vice Chairmen, members of the Interagency Coordinating Committee (ICC) for the US/IBP and the Executive Secretary of the Central Office for the IBP in London, England. Opinions of members of the ICC are given by them as individuals and do not necessarily reflect the official position

of their agencies. No advice from the Bureau of the Budget has been sought by the ICC.

QUESTIONS AND ANSWER ABSTRACTS

1. What is the status of the U.S. IBP Subcommittee Programs (Schedule of readiness for Phase II operations)?

Answer: Discussion in Appendix I.

Abstract:

a. One hundred and thirty-two funded projects are now included in the U.S. program. This number will increase as additional projects are reviewed and accepted in the US/IBP.

b. Six major integrated research programs have been approved by the U.S. National Committee for implementation when adequately funded.

c. Nine additional major integrated research programs are being developed for the consideration of the U.S. National Committee.

2. Concerning the present and future U.S. program funding needs; (a) is the US/IBP program in danger of faltering for lack of funds or for any other reason?

Answer: Discussion in Appendix II-A.

Abstract: The U.S. National Committee states that the U.S. program urgently needs substantially increased funds. Lack of funds would cause major integrated research programs to be delayed or abandoned.

(b) What effect would any lapse of funds have on the international program as a whole and upon the prestige of American (US) science and the United States in general?

Answer: Discussion in Appendix II-B.

Abstract:

a. Inadequate U.S. support would adversely affect this international research program.

b. Inadequate U.S. support and participation would delay urgently needed world wide ecosystem research.

c. Would not greatly affect the overall prestige of U.S. science since the total U.S. effort in science is so great. Reduction or elimination of any one U.S. program would not seriously alter our prestigious position.

3. What is the estimate of the National Committee as to the amount of money needed for the U.S. in the IBP program for the next fiscal year?

Ans^r or: Discussion in Appendix III.

Abstract: Additional funds needed for support of the U.S. program are:

	<u>1st Year in \$</u> <u>Millions</u>	<u>5 Years in \$</u> <u>Millions</u>
Approved integrated research programs	2.40	77.00
Developing integrated research programs	0	77.00
Individual Proposals	4.46	22.30
Training	4.20	21.00
NAS Contract Support	<u>.40</u>	<u>2.00</u>
Total	11.46	199.30

4. What is the view of the Interagency Coordinating Committee (ICC) concerning the probability of being able to raise the necessary funds in the manner proposed?

Answer: Discussion in Appendix IV.

Abstract: Members of the Interagency Coordinating Committee have stated that presently budgeted funds are not adequate to support the major integrated research programs of the US/IBP.

5. Concerning program models, in what respects, structurally, will the management of the IBP be similar to or different from the IGY?

Answer: Discussion in Appendix V.

Abstract: The IBP and the IGY are similar in that U.S. participation in each was established through the National Academy of Sciences (NAS). Several Federal agencies participated in and contributed to support of the IGY, and are doing so for the IBP. The NAS established a National Committee for each program. Functionally, the technical panels of the US/IGY are comparable to the US/IBP subcommittees, panels and integrated research programs. U.S. program management and funds control were more centralized for the IGY than for the IBP according to present plans.

6. Has any other international program been managed in the manner which is proposed for the IBP?

Answer: Discussion in Appendix VI.

Abstract: U.S. participation through the National Academy of Sciences in international programs is well tested. Eleven such programs are described in enclosure 1 to Appendix VI. In principle, they are comparable. Differences in detail are attributed to differences in the problems addressed and to the development of the most effective methods for addressing those problems.

7. What nations are formally participating in the IBP? What is the extent of this participation in terms of leadership, manpower and funds?

Answer: Discussion in Appendix VII.

Abstract: By continents and regions the following are the members of participating nations:

<u>Country</u>	<u>Number of Nations</u>
North America	3
South America	5
Europe	21
Asia	12
Africa	7
Australia	1
New Zealand	1
Total	50

Number of above having national committees - 46, number of above having national programs - 30. Twenty-six countries contribute to the financial support of the Special Committee for the

International Biological Program (SCIBP). Costs of the national programs are not available. The names and institutions of scientists participating in the international structure of the IBP are listed in Appendix VII.

8. a. What is, and will be, the role of the USSR and Communist bloc nations in Phase I?

Answer: Discussion in Appendix VIII.

Abstract:

a. The USSR has an established national committee and a description of its national position in enclosure 1 to Appendix VIII indicates that it is well developed along advanced scientific principles.

b. Representatives from the USSR, Poland and Czechoslovakia are on the international structure of the IBP.

c. Bulgaria, Czechoslovakia, Yugoslavia, the German Democratic Republic, Hungary, Poland and the USSR have organized their National Committees, and, with exception of Hungary, completed their subcommittee organizations with IBP plans.

b. What is, and will be, the role of the developing nations in Phase I?

Answer: Discussion in Appendix VIII.

Abstract: Several developing countries in Asia and Africa are participating in the IBP. Mutual hemispheric interests in the IBP enhance the importance of participation of all nations of the Americas. Argentina, Brazil, Chile and Mexico have established national committees. Scientists from Peru and Venezuela have participated in IBP working groups. The U.S. National Committee has particularly fostered participation on a basis of equal respect by all nations of the Americas. All countries including those developing will benefit through accelerated development and application of biological information sponsored in this program.

9. a. Describe manpower and facilities in International Training Centers, collections and holding facilities and field stations.

Answer: Discussion in Appendix IX-A.

Abstract: SCIBP has endorsed a series of national facilities, centers and stations as appropriate to the IBP activities. These endorsements are continuing as the formal activities of SCIBP proceed. Eight endorsements are described in Appendix IX-A.

b. Describe logistics (ships, aircraft, trucks, specialized vehicles, etc.).

Answer: Discussion in Appendix IX-B.

Abstract: Logistic planning and support will be decentralized to that specified in each IBP integrated research program and project. Facilities available in or under the control of colleges, universities, oceanographic institutions, Federal agencies, and others will be arranged for. Examples are given in Appendix IX-B.

c. Describe manpower and facilities for recruitment.

Answer: Recruitment for US/IBP support has proceeded in a stepwise fashion. Starting with meetings of the U.S. National Committee, leading to meetings of subcommittees, and to workshops for design of programs and projects, recruitment has been carried out at each stage. The most critical stage of recruitment will be that involved in project and program proposals. Recruitment for the research phase of the integrated research programs of the US/IBP is just now being fully confronted.

Recruitment for memberships on committees, subcommittees and panels of the US/IBP structure has been very effective. The purposes of this structure include planning, review and evaluation. These purposes are specific for Phase I of the IBP, but more general for Phase II. Additional specific personnel requirements for Phase II are for researchers working on accepted and funded research proposals and research directors and administrators who will coordinate proposals within integrated research programs.

10. What is the machinery for review of the program progress and problems?

Answer: Internationally, SCIBP plans to hold annual review symposia, with the first to be in 1970. These will be held on a regional basis. Nationally, the U.S. National Committee, the 9 subcommittees and 2 panels will continue to meet approximately once each 6 months. At these meetings, reviews of progress, new plans, and actions needed toward program development have been and will be on all agendas. Within integrated research programs, the

directors, coordinators and principal investigators will accomplish continuous reviews. The review panels of the granting agencies will review projects supported by these agencies.

APPENDIX I

What is the status of the US/IBP Subcommittee Programs (Schedule of readiness for Phase II operations)?

The state of readiness for Phase II operations may be assessed by considering (1) the number of funded projects approved by each subcommittee for inclusion in the IBP (2) the number and scope of integrated research programs being developed and (3) the number of workshops conducted or planned for the purpose of proposal development.

Funded Approved Projects

These are on-going research projects (and a few new proposals) that have been identified with the US/IBP. They contribute to and support the IBP, but were not initiated because of the IBP. By subcommittee the numbers are:

Freshwater Productivity)	21
Terrestrial Productivity)	
Marine Productivity	35
Production Processes	18
Conservation of Ecosystems	3
Human Adaptability	8
Use and Management of Biological	
Resources	36
Environmental Physiology	2
Systematics & Biogeography	<u>9</u>
*Total	132

*Part 1 of Report Number 3 of the U.S. National Committee (report now being printed) will list 104 projects. Part 2 and succeeding parts will list projects as they are added. The cumulative total to date is 132. Report Number 3 with all its parts, as each is published, will list all IBP projects and integrated research programs. Thus, the total series will identify the total U.S. program.

Integrated Research Programs

These programs forming the central portion of the U.S. program are just now developing. Six have been approved by the National Committee and nine additional are being formulated. The concept of integrated research programs is discussed under Appendix IIa and descriptions of both those approved by the National Committee and those developing for later consideration are given at enclosures 1 and 2, Appendix I.

Concerning the six programs approved by the USNC/IBP:

Five program directors have accepted appointments and the sixth is now being invited to serve in that capacity.

One management proposal has been accepted and funded by a granting agency.

One management proposal is nearing completion and will be submitted in the near future.

Preliminary estimates for total funding of each approved integrated research program have been made and are shown under Appendix III. No research proposal for work under these integrated research programs has been submitted. Such proposals are in various stages of preparation.

Workshops Conducted and Planned

As described later, 27 IBP workshops have been conducted and 9 are planned for the near future. The pattern for these conferences, usually requiring 2 to 4 days, has been:

- Review the research underway on the subject.
- Describe research that should be undertaken.
- Identify investigators and facilities that should undertake the proposed work.
- Prepare outline proposals.
- Request appropriate participants in the workshop to complete proposals.

In the case of the integrated research programs, the latter two steps have required extensive coordination between principal investigators, internationally and nationally, and have involved large geographic areas. Therefore, the organizational effort has been extensive.

The integrated research programs developing for later consideration of the National Committee are of comparable scope. The development of these programs is contingent upon the willingness of scientists who participate in the workshops to enter into the coordinated efforts necessary in each program. Preplanning in each case, and increased awareness that this coordination is needed, cause most convenors to predict development of the additional integrated research programs.

ENCLOSURE 1 TO APPENDIX IIntegrated Research Programs Approved by USNC/IBP1. Aerobiology Program

Objective: To conduct and correlate on a world wide basis research on dispersal of air-borne biological material, including pollen grains, fungus spores, algae, pathogens, and insects that affect health of both animals and plants.

Program: There are firm requirements for better predictive techniques concerning the spread of crop disease and pests and other bacterial, viral and fungal diseases affecting man. Identification of more vulnerable periods in the life cycles of pests and microorganisms will lead to improved methods of control.

The IBP will afford means of standardizing observations and for establishing communication between investigators internationally. It will also provide a framework of interdisciplinary cooperation in many fields, including phytopathology, entomology, meteorology, oceanography and ecology. Scientists with existing projects will reconcile differences in methods of observation and reporting, and identify gaps in current efforts to solve these problems.

Funding: First year support required: \$250,000
Five year support required: \$16,000,000

Program Director: Dr. William S. Benninghoff, Department of Botany, University of Michigan.

2. Analysis of Ecosystems

Objective: To clarify by means of integrated research and multidisciplinary analyses the operation of ecosystems; that is, the interaction of all organisms with a defined environment including the atmosphere and soil.

Program: Research in ecosystem operations will probably prove to be the ultimate understanding of the environment and how man-made changes will affect it. Major studies will be done on the following types of regions: eastern forest, western coniferous forest, Arctic or Antarctic, western grassland and cultivated ecosystems, desert, and tropical forest. The study of tropical forests will be in cooperation with Latin American groups. Final site selections will be made by a special committee. Maximum use will be made of computer-oriented mathematical methods. Information

centers will be required and a training program will be prepared.

Funding: Pilot management and research by grant to University of Michigan, 2 years, \$71,354 by NSF.

First year support required: \$1,250,000

Five year support required: \$45,000,000

Program Director: Frederick E. Smith, School of Natural Resources, University of Michigan.

3. Study of Eskimo Populations

Objective: To carry out intensive, multidisciplinary studies on at least three centers of Eskimo populations, a joint United States-Canadian program which will be coordinated with IBP efforts in Japan, the USSR, and Scandinavian scientists in Denmark, Greenland and Lapland. These studies will provide improved understanding of the productivity of the community and its utilization of its environment, and to reveal similarities and differences that exist despite different environments.

Program: Eskimo populations along the Arctic coastline from the Bering Strait to Greenland are appropriate for comparative studies as they all stem from the same origin but are increasingly more isolated from one another. The specific studies planned within the joint US/Canadian program on Eskimo populations (1) at Wainwright, Alaska; (2) a Canadian arctic community, and (3) Upernavik, Greenland are: genealogy and demography; genetic markers; anthropometry-growth and development; epidemiology; nutrition; physiology; behavior; ecology and micro-climatology; and population history.

Funding: First year support required: \$100,000
Five year support required: \$2,000,000

Program Director: Frederick A. Milan, Aeromedical Laboratory, Fairbanks, Alaska.

4. Hawaiian Terrestrial Biology Program

Objective: To study intensively the endemic and invading biotas of the Hawaiian Islands.

Program: This will be a detailed, long-term, comprehensive investigation of the plant and animal species of the Hawaiian Islands. It will be limited to the land areas because the terrestrial biotas are the ones most severely threatened. Already, more Hawaiian plants

and animals have become extinct than the total lost for the entire North American continent. However, most of the species still remain, and many of them can be saved with scientific understanding of the interactions between the plants and animals and their changing environments, especially those environments which are influenced by man. The whole of the rich Hawaiian flora and fauna evolved from about 700 immigrant ancestral species, under conditions of extreme isolation, in the course of a few million years. What happened might be called an evolutionary explosion, and Hawaii constitutes an unsurpassed natural laboratory for the study of evolutionary and ecological phenomena. Because of the rapidity with which native species and communities are disappearing, it is urgent that an intensive study of the Hawaiian biota be carried out while there is still time.

The planners of this program have selected key species of plants and animals and have established priorities within their selections so that the extent of destruction in the near future may be assessed by considering (a) rarity, or narrow geographical extent, and (b) narrowness of ecological specialization. In addition, multidisciplinary studies will determine (1) the extent that the group of organisms, the community, or the ecosystem have special biological interest and significance; (2) the interrelationships of the taxon, community, or ecosystem; (3) any evidence of unusual biological adaptations of the taxon, community, or ecosystem. The native ecosystems, including rainforest, dry forest, bogs, and sand dunes will be studied.

Funding: First year support required: \$400,000
Five year support required: \$2,000,000

Program Director: Warren H. Wagner, Jr., Department of Botany, University of Michigan.

5. Phenology Program

Objective: To conduct detailed studies on plant and animal species, both aquatic and terrestrial at a number of sites within the United States in order to prepare phenological maps, obtain clues to the physiologic limitations that determine climatic limits of species, explain the biological basis for phenological timing, test the hypothesis that such studies will aid in understanding evolutionary mechanisms, and contribute to understanding the role of phenologic phenomena in the structure and productivity of ecosystems.

Program: Results of this program will more explicitly describe the seasonal development of organisms and from these

descriptions will provide better understanding, interpretation and prediction of biological events. Broad studies will be conducted with the aid of a large network of stations and observers. Species have been selected as the first step toward standardized methodology. These contributory studies can be conducted at several levels of sophistication, and many people with divergent interests and all levels of scientific training can participate. Several special sites will be selected and intensive multidisciplinary studies of measurements of environmental parameters and population structure, breeding behavior, and physiology of organisms and other detailed phenologic observations will be made. One of the chief aims of the program is the development of phenologic maps that would predict planting and harvesting dates for crops and outbreaks of plant and animal-borne diseases as well as many other biological events.

Funding: First year support required: \$100,000
Five year support required: \$2,000,000

Program Director: Dr. Byron O. Blair, Professor of Agronomy,
Purdue University

6. Ecology of Migrant Populations

Objective: To conduct comprehensive bio-social assessments of migrant populations with emphasis on movements of people from rural to urban areas.

Program: Bio-social assessments constitute quantitative ecological descriptions of a group's size and composition, biological (including genetic) and sociopsychological characteristics, habitat, and major behavior patterns so designed as to (a) identify the group's constituent biological populations, and (b) the levels of fitness, adaptive mechanisms and selective pressures characterizing such populations.

The rapid technological, socioeconomic and demographic changes of the recent past have profoundly altered the nature of physical and psychological stresses operating upon many human populations. Some stresses, such as bacterial diseases, have diminished in importance; others, such as noise, mechanical injury and air pollution, have intensified. Medical intervention is saving and repairing an increasing number of persons with serious congenital defects. Dietary changes and decreases in physical activity have introduced new stresses; industrialization and mass communications have caused unparalleled demands upon symbolic learning, memory and fine psychomotor coordination. The tolerances of man to these changes and the

degrees of hazard, on one hand, and of potential, on the other, that they may present to development, physiology, behavior, longevity and genetics in man are still poorly understood. Their evaluation consequently represents a key task in understanding human adaptability.

Specific sites will be located in rural Mississippi among Negroes and whites and in receiving areas, such as Chicago. Other studies will encompass statistically adequate components of Spanish American and American Indian populations. Adaptation to a sub-arctic city, such as Fairbanks, Alaska, will aid in understanding similarities and differences in white, Eskimo, and Indian adaptations to that special environment. Correlation with similar work in Canada, and in Israel will be undertaken. The program will be in several phases based on a series of comparable studies by field and visiting specialist teams under individual institutions coordinated by the Program Director.

Funding: First year support required: \$300,000
Five year support required: \$10,000,000

Program Director: Dr. Adrian Ostfeld, Department of Preventive Medicine and Community Health, University of Illinois College of Medicine.

ENCLOSURE 2 TO APPENDIX IEmerging Integrated Research Programs Under Development

The following programs are being formulated by the various Subcommittees of the U.S. National Committee. When finally approved, there will be a requirement for funding support. No estimates of needed funds are currently available.

1. Adaptation of Peoples at High Altitudes

Objectives: To study the distribution and the nature of the variabilities in man's adaptive capacity at high terrestrial altitudes, and to define the processes of adaptation.

Program: Dr. P. T. Baker, of Pennsylvania State University, is the project convenor. A working group will meet at Lima, Peru in November 1967, to develop a basis for a firm program and for coordinated proposals involving both South and North American countries. The aims of this program are the investigation of fertility; postnatal growth; development and psychological maturation; aging; and diseases at high altitude.

The World Health Organization has expressed an interest in the project. It is anticipated that scientists from the Institute of Andean Man, Lima, Peru, and from the high altitude station at La Paz, Bolivia will participate in the planning.

2. Experimental Analytical Biogeography of the Sea

Objective: To engage in coherent, cooperative research on a broad geographical basis to study the physio-ecological resistance and performance adaptations of marine and estuarine species to geographical, abiotic, and biotic environmental factors, such as temperature, light, hydrostatic pressure, streaming velocity, nature of substratum, food, and salinity.

Program: Dr. F. John Vernberg, Duke Marine Laboratory, Beaufort, North Carolina is the coordinator of this program. A workshop will be held on 23-26 October at the Duke Marine Laboratory to define the specific research to be undertaken, the methodologies, and the scientists to participate. A proposed budget will be prepared. Dr. Carl Schlieper, University of Kiel, is actively cooperating in this working group. Dr. C. Ladd Prosser represents the Subcommittee on Environmental Physiology, and Dr. V. E. Brock

represents the Subcommittee on Productivity of Marine Communities and will cooperate on this project.

3. Control of Insects by Plants and of Plants by Other Plants

Objective: To study the mechanisms of chemical interactions between organisms, emphasizing the control of insects by plants, and of plants by other plants.

Program: Implication of terpenoids in both kinds of control requires that entomologists and botanists work together to identify mechanisms and to develop methods of biological control of pests. Dr. E. F. Knipling (USDA) and Dr. Cornelius Muller, University of California, Santa Barbara, will organize a working conference to be held at the University of California in 1968. The Subcommittees on Systematics and Biogeography, and Productivity of Terrestrial Communities will be involved.

4. Biological Control of Pest, Insects and other Organisms

Objective: To promote ecological management as a principal method of pest control, with emphasis on the use of predators, parasites, and pathogens.

Program: While somewhat related to the developing program above on control of insects by plants, this investigation will emphasize the optimal use of other natural enemies of pest organisms. Control methods studied will include the various forms of habitat management or modification, use of resistant hosts, autocidal methods, use of lures and repellents, and competitive displacement. Establishment of a training center for Biological Control at the University of California has been proposed for purposes of the IBP and would be an important supporting element of both programs. A number of active proposals supporting the above objective have been approved by the IBP.

5. Adaptive Processes of Hybrid Populations

Objective: To undertake with Japan a joint study of the ecology of hybrid populations.

Program: This program has been defined in preliminary terms. Professor S. Kondo (HA/Japan) will visit Madison, Wisconsin in the Spring of 1968. At that time a meeting will be called by Dr. W. S. Laughlin, University of Wisconsin, to discuss the feasibility of a program on US/Japanese population groups

in both Japan and the United States.

6. Adaptability of Primitive Peoples

Objective: To study the adaptability of primitive peoples to their environment.

Program: This program will develop from a Conference on Primitive Peoples held by WHO in July, 1967, of which J. V. Neel (HA/US) was the principal organizer. In 1968, there will be a second conference in Latin America. It is anticipated that a definite program will be developed by the Subcommittee as a result of these conferences.

7. Convergent and Divergent Evolution and Physiology of Colonizing Species (probably two programs)

Objective: To attain a greater degree of cooperation between biologists of North and South America in fundamental studies on the evolution of species and the physiology of species of expanding range in order to furnish needed advice for planning man's future relations with the ecosystems of which he is a part.

Program: A research planning conference will be held in Caracas, Venezuela, on November 22-24, 1967, on each of these two problems concurrently. It is expected that a high degree of inter-American cooperation in these fields will result. A program on convergent and divergent evolutions in amphibians should result from this meeting, with an estimate of funds required. This group will be chaired by Dr. Frank Blair, University of Texas. A copy of his preliminary plan is attached as enclosure 3 to Appendix I. It is included as an example of a program under development.

As many species of plants and animals expand their range, they become weeds. This expansion causes great loss to man, such as the destruction of material (rats and mice), spoilage of landscapes (mesquite), and in nuisance factors (starlings). It is necessary to study the basic physiological mechanisms that promote expansion in order to manage the problems that may develop. This working group will be chaired by Dr. Calvin McMillan, University of Texas. An integrated research program is expected to result.

8. Plant Gene Pools

Objective: To continually procure, assess, and preserve valuable germ plasm for future incorporation into crop varieties.

Wild progenitors of major crops, primitive populations, and wild relatives of crop species form a wealth of genetic diversity from which to draw sources of adaptation or resistance to environmental factors.

Program: In the United States, with almost no native crop germ plasm, cooperation with other countries for this purpose has been on-going. It is now necessary to examine our total national effort for adequacy in connection with the rapidly increasing scope of the international work and to determine any additional support that is required.

The Use and Management Subcommittee of the US/IBP has participated in the program developed by the IBP international Working Group on Biological Control and will continue to do so. Two projects proposed by the international working group are indicative of the broad framework within which American biologists may develop activities relating to plant gene pools. The projects are "Survey, exploration, assembly, and conservation of genetic stocks" and "Evaluation of plant resources-biology of adaptation." Because of the broad base of genetic variability that would be provided, these activities represent an unusual opportunity for biologists interested in working to preserve genetic stocks.

There has been established, a National Seed Storage Laboratory (NSSL) at Fort Collins, Colorado. While this collection is extensive, there is a need to preserve important genetic marker collections, quality carrying stocks that may be lost in over-emphasis on quantity production, and other biological tools that are in danger of being lost. A program will be developed by the subcommittee by means of a working group on the preservation of genetic stocks.

9. Nutrition

Objective: To accomplish the following:

- a. Emphasize investigations of protein supply, to include amino acid balance and protein utilization studies, as well as use of fish products as protein supplement.
- b. Encourage broad studies of the role of fatty acids in the nutrition of humans living under different conditions of environment and stress.
- c. Study the adaptation of populations to levels of dietary intake different from those considered normal.

d. Study the relationships of nutrition to the incidence of disease and parasitism. A particular area is the influence of factors, such as goitrogens, which may influence iodine requirement and their role in thyroid deficiency.

Program: This program will require close coordination with related programs of the Subcommittees on Human Adaptability, Production Processes, and Terrestrial Productivity. The National Committee of the International Union of Nutrition Sciences, cooperating with the Internal Programs Committee of the National Research Council Food and Nutrition Board, is assuming responsibility as a working group of the Use and Management of Biological Resources Subcommittee. The total program will encompass both animal and human nutrition.