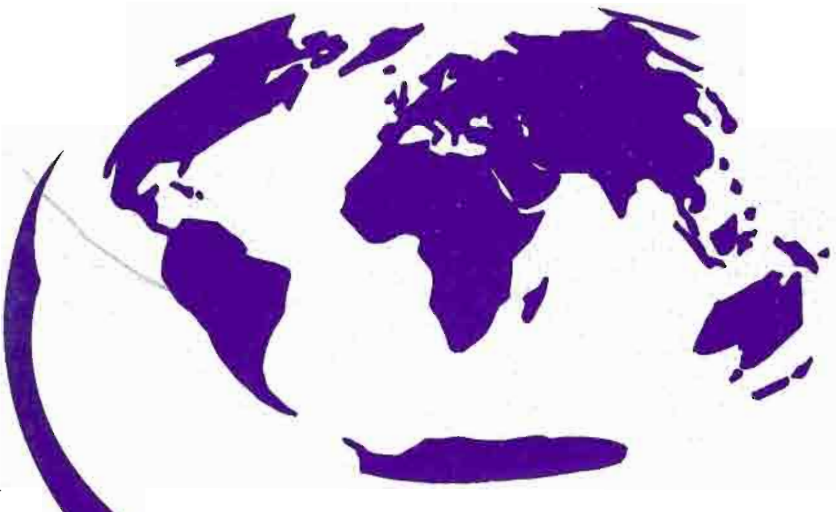
SPECIAL ISSUE - 2

Biology International

The News Magazine of the International Union of Biological Sciences (IUBS)



A DECADE OF THE TROPICS

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Knowledge of a species structure and function, and of its interaction with the physical environment and with other species is the foundation of biological science; such knowledge is also necessary for the rational management of natural and artificial ecosystems. Furthermore, it is equally important to understand how species interact in guilds, in food chains, and in communities and ecosystems. However, our knowledge of these processes and relationships in biological systems is almost entirely derived from temperate and polar species. Our understanding of tropical species and ecosystems is woefully incomplete. Not only are tropical species thought to be more numerous than temperate species (of 4 to 5 million species making up the biosphere, about 3 million exist in the tropics - yet only half a million have been described scientifically NAS/NRC, 1980), but there is good reason to believe that tropical organisms have novel structures and functions, and it is suspected that tropical ecosystems have unique characteristics. The consequence of such insufficient knowledge is the continuation of a limited and fragmentary kind of biology, that constitutes a weak foundation upon which to build management guidelines for biological systems, and almost inevitably will lead to the continuation of the serious problems in applied biology.

Clearly, it is important for biological science in all its aspects that a concentrated effort be made to expand our understanding of biology in the tropics. For this reason, the International Union of Biological Sciences (IUBS) has declared a "Decade of the Tropics", which will concentrate and focus biological research and help overcome some of the handicaps caused by the gaps in biological knowledge of tropical ecosystems.

GENERAL CONSIDERATIONS

The tropics (the area between the Tropic of Cancer and the Tropic of Capricorn) comprises 77,000,000Km^2 compared to 54,000,000Km^2 in the temperate zone; the population of the tropics is 3 1/4 billion inhabitants; as compared to 1.16 billion in the temperate zone. It is estimated that by the end of the century, the population of the world will have increased by nearly two billion additional people, most of whom will be born in the tropics. But although the tropics comprise a majority of the land area of the world, and soon will house two-thirds of its population, most of the countries of the tropics are classified as poor (per capita GNP $100-175), or very poor (GNP under $100), in contrast to the countries of the temperate zone which are classified as either "middle-income" countries (GNP per capita $375-1,000), or "rich" countries (GNP per capita over $1,000) (Kamarck, 1976).

The reasons for this disparity are many, and are not well understood. There are undoubtedly historical, social, cultural, political, as well as physical and biological causes. But whatever the reasons, the discrepancies between the rich temperate zone and the poorer tropics represents probably the largest global problem that mankind faces today, with the possible exception of the specter of nuclear war. In biological term, the problem is that of a fast growing population, living in an area of present low productivity and low income, threatened with famine because of low agricultural productivity and increasing world-wide food demand. A related problem is the destruction of the tropical biota as a direct consequence of the increasing demand for arable land and for forest products. An immediate result of processes of over exploitation of tropical lands and organisms is an increase in the rate of degradation of land to the point where it becomes barren and unproductive. Such processes of desertification have already claimed thousands of km^2 of formerly marginal, but productive land.

The needs of tropical populations are staggering. FAO has calculated that food production would have to increase at a rate of 4% a year just to maintain present levels of nutrition; actual growth during the 1970-1980 decade however, was 3% (FAO Yearbook). Energy needs are equally staggering. UNIDO has set a goal of 50% increase in energy production by the end of the century, most of it to be obtained from vegetable biomass. This figure represents most of the world's standing biomass! It is easy to dismiss these figures as totally unrealistic. But although they are unrealistic in the sense that there is little hope to achieve either the food production or the biomass energy goals by the end of this century, they truly represent the needs of the inhabitants of the tropics. Failure to approach them could have social and biological consequences of global proportions.

Why are these goals so difficult to reach? Why have we not been able to reach the same levels of productivity in the tropics that we obtain in the temperate zones? Why are all the poor nations located in the tropics, and all the rich nations in the temperate zone? No precise answer can be given to these questions, but it is fair to assume that it is related in some measure to the differences in climate, soils, and biology, which exist between temperate and tropical areas. Some of these differences are well-documented. Others are not yet known. But even among those factors known to be important such as soils and nutrients, much more research is required before the system is sufficiently understood to manage it more effectively.

Soil is the direct mineral substrate for terrestrial plants. All nutrients required by plants with the exception of carbon, are drawn by them primarily from the soil. Of the required nutrients, only water, nitrogen, sulfur, and chlorine cycle through the atmosphere so as to become widely available to organisms capable of assimilating them. The other vital elements such as phosphorous, potassium, sodium, calcium, and the many so-called "minor" elements must be available in the soil solution in the vicinity of the roots of the plant if they are to be absorbed.

The soil solution is the immediate source of nutrients for absorption by roots. The model of mineral nutrition in temperate zone soils, contemplates a constant replenishment of the solutes in the soil solution from the release of mineral elements from the solid phase of the soil (Epstein, 1972). For the tropics, it has been hypothesized that nutrient cycling, at least in the humid forest, differs radically from this process in temperate areas. The soil supporting tropical rainforests and the water draining from them is frequently singularly deficient in nutrients (Jordan, 1971; Hardy, 1958; Odum & Pigeon, 1970; Stark, 1971), and therefore, the forests have evolved mechanisms to recycle essential elements efficiently. Disregard of these recycling mechanisms is probably the single most important factor for some of the spectacular failures of tropical agricultural projects.

As another example, it is widely acknowledged that microorganisms play an important role in plant nutrition (Barber, 1968; 1969), but their precise function is still not adequately understood. For nitrogen and other elements, the mycorrhizal fungi ("root-fungi") appear to be among the most important. They either penetrate the roots of plants, or form a tight sheet around them, thereby creating a more intimate relation between roots and soil that would otherwise obtain. This association apparently facilitates the supply of inorganic phosphorous and other nutrients that are passed from the soil to the root through the mycorrhiza (Harley, 1969). These associations, which are as yet only incompletely known for temperate soils, are just now being investigated in tropical areas. As could have been surmised, they not only play an important role in the tropics, but they appear to be more complex than in temperate areas, and entirely novel mechanisms are being discovered. So for example, Herrera and collaborators (1978) have found tight associations between decomposing litter, fungi, and plant roots in the San Carlos de Rio Negro area of Venezuela, which demonstrate that at least some plants are obtaining a significant part of their mineral nutrition directly from decomposing litter, bypassing the soil solution!

Inhabitants of the tropical forest have developed effective technology to deal with the low nutrient value of the soil. For example, the slash and burn method of shifting agriculture is universally practiced in all tropical areas (Bartlett, 1956). In the undisturbed forest, the more easily-cut trees are felled, and later burned. This burning kills most of the remaining trees, removing the foliage, vines, and smaller branches, which are deposited as soluble ash on the surface of the soil. On this substrate, a first crop is planted, which usually is plentiful. As the nutrients in the ash are absorbed by the crop; or by fast-growing weeds, or is washed away by rainfall, productivity is sharply reduced in the second planting, and seldom is a third or fourth crop worth planting or harvesting. At this point the agriculturist moves on to another plot of forest, where he repeats the process. Slowly the small abandoned plot is re-invaded by the forest, and is eventually restored to its original state. Provided that the patches are not too large (it has been calculated in very nutrient-poor Amazonian soils that the plot cannot exceed one Ha., (Herrera et al, 1981), and that the rotation is long enough (in the order of 12 to 100 years or more), slash and burn shifting agriculture is a sustainable method compatible with the rainforest ecosystem. However, it is unlikely that is can maintain more than 10 inhabitants per Km^2, and then only at a subsistence level (Nye & Greenland, 1960; Richards, 1967). With the increase in density of the human population in the tropics, and with increasing material demands of that population, the rate of forest clearing through slash and burn agriculture has increased, resulting in an increase in the size of the plots, and a shortening of the needed fallow period, to the point that today it is the principal cause of tropical forest destruction (FAO, 1981).

Traditional agriculturalists have also devised more intensive management systems to deal with the tropical production problems. These include the chinanpa system of tropical America, the home garden of Indonesia, and the paddy rice complex of southeast Asia. All of these indigenous systems concentrate human ingenuity and labor on relatively small plots, and manipulate complex assemblages of plants, animals and soils, which mimic the natural tropical systems.

Tropical shifting and more intensive agricultural systems differ in significant ways from temperate agriculture, but also are disturbed significantly by further intensification or by direct application of temperate agricultural practices to them. Destruction of forest cover and tilling of soil hastens the oxidation of organic matter, leaches whatever nutrients are present, substantially reduces the flora and fauna of microorganisms, and destroys soil structure, often turning plots into quagmires during the rainy season, and rendering them useless for agriculture. Fertilizer applied under these conditions is wasted and harms soil structure: it is rapidly leached because the soils have few colloids to retain the fertilizer. Furthermore, in many lateritic soils, any remaining fertilizer is made unavailable to plants as it is sequestered by the high levels of aluminum and iron in such soils (Goodland & Irwin, 1975). Thus, the methods of improving agricultural productivity in temperate conditions can create exactly the opposite effect under certain tropical conditions.

Of course not all tropical soils are unfit for agriculture; great extensions, especially those covered by younger alluvial soils, are highly productive. However, this only underscores the need for more information. Rigorous studies on tropical soils, and soil microorganisms are badly needed. An important component of the IUBS Decade of the Tropics will be research in soil biology, and plant-nutrient flow in tropical ecosystems.

Other serious problems of tropical agriculture are created by insect pests, and by plant and animal diseases. The magnitude of these problems is not always sufficiently appreciated. In the temperate zone, a harsh and inhospitable winter sets an upper limit to the size of the overwintering insect population. From this low number of survivors the population expands every year according to available food supply, predator density, and climatic conditions. With the aid of appropriate agronomic practices, resistant varieties, and judicious use of insecticides, the temperate-zone farmer can keep the crop losses to insects to a reasonable amount, in spite of the fact that he is in principle offering the potential pest an almost limitless source of food? In the tropics no climatic constraints on population growth exist comparable to the harsh temperate winter, excepting perhaps long periods of drought in semidesert areas. Instead, the populations of most insect and parasitic microorganisms are regulated by a combination of toxic, repellent or undigestable substances produced by potential food plants; by insufficient food as a result of the low density and wide scattering of plant species in the wet tropics; and by the controlling effect of the insect-eating trophic guild (formed primarily by birds, carnivorous insects, spiders, and even mammals). Consequently, when the tropical farmer increases the herbivore's food supply through the planting of a dense monoculture, he removes one of the principal factors that limits pest populations. The use of pesticides in such conditions is inefficient, as the frequent rains wash them from the foliage, and since the insect populations persist throughout the year, they quickly acquire tolerance to the insecticide, requiring increasingly higher and more frequent applications. The more slowly breeding predators; however, accumulate and concentrate the toxic substances, with deleterious effects. The reduction of the predator populations, requires even greater application of pesticides, increasing the costs of production. It is estimated that the cost of insect control is around 20% of the value of the cotton crop in Colombia, and about 45% in Nicaragua (Leurquin, 1966; McPherson & Johnston, 1967). In CentralAmerica (Georghiou, 1972) as many as 30 applications of pesticides during a six-month growing season are needed to grow cotton. This can render cotton production uneconomical, and can lead to abandonment of cultivation as was done in the Cañete Valley of Peru.

Studies of plant-animal interactions in the tropics have demonstrated a large set of relationships between taxa, resulting in complex interactions, which may be one of the reasons for the high species diversity of the tropics, and the intricate structure of tropical populations, guilds, and ecosystems. This is another area badly in need of more basic research, and one we hope the Decade of the Tropics will address. Questions that need to be addressed and for which answers cannot be obtained by studying structurally simpler, and species poor temperate systems are: the behavior and physiology of plants and animals under alternation of wet and dry periods, mechanisms of physiological triggering in environments with low photo- and thermal amplitude, primary and secondary chemistry of plant defenses against herbivores, and plant-animal; and animal-animal interactions.

In addition to plant pests, numerous specialized tropical weeds compete with the crop for the limited supply of nutrients. These species are frequently better adapted than the crop to tolerate drought, wide temperature fluctuations, high insolation, as well as torrential rains. As weed communities are commonly composed of many species, nutritional competition is reduced among weed species. Finally, while not all weeds have chemical defenses against insect pests; they usually are less palatable than the crops with which they are competing.

The task of weed eradication results in higher labor and/or capital inputs. Clayton (1960) reports that it takes 155 manhours/acre for weed control in maize production in Kenya, and 171 manhours/acre for cassava. There is little quantitative knowledge regarding the effect that levels of weed control, and different methods, have on yield. Weed killers are being used quite extensively in tropical countries, but usually without the benefit of comparative studies to show whether such measures are economic. However, it is known that clean cultivation, as practiced in temperate areas, is not the most economical system in the tropics (Wickizer, 1960). Development of methods of controlled vegetative cover to control weeds are badly needed (McPherson & Johnston, 1967), and will figure among the priorities of the subjects to be investigated by the Decade of the Tropics.

To this list of negative factors about the tropics, a number of positive ones must now be added. Plants in a figurative sense eat light, and nowhere is light more plentiful throughout the year, and more predictable, than in the tropics. Secondly, the rate of plant growth, like any physicochemical process, is temperature dependant, and again, nowhere on earth are temperatures better suited for growth than in the tropics. Where soil fertility and water do not limit plant growth, productivity in the tropics potentially is about twice as high as in comparable temperate regions (Cooper, 1975). Consequently, if the problems that have held back development of the tropics can be identified, and if once identified they prove to be solvable, then tropical agriculture, forestry, and livestock-raising have a great potential. But first, the reasons for the lack of development of the tropics must be identified, a non-trivial task, and one where much disagreement exists.

PRESENT VIEWS AND ATTITUDES TOWARDS

USE OF RENEWABLE TROPICAL RESOURCES

There are almost as many theories, opinions, and explanations for the lack of development of the tropics, as there are authors that have written on the subject. There are single factor hypothesis, that blame the problems of the tropics on factors such as weather (Karmarck, 1976), soil (Holdridge, 1967), insect pests (Janzen, 1973), history, education, lack of appropriate institutions, market forces (Rozensweig, 1965), skewed income distribution (Barraclough & Domike, 1966), colonization by European countries, and exploitation by multinational corporations. And then there are more complex theories combining one or more of these factors. It is almost impossible to compare, and much less evaluate, all the available biological, historical, sociological, and economical information. However, a cursory study of the relevant literature reveal that the views on tropical development can be grouped into two broad categories: 1) those of the optimists that believe that development of tropical areas is not only possible, but that it will solve a large number of problems of tropical countries; and 2) those of the pessimists, that only see disaster ahead, in the form of a run-away population inexorably destroying the environment, and eventually producing an ecological catastrophe.

In contrast to these extreme, and to some extent simplistic views, stand our great ignorance of what is likely to happen. Certain facts are undeniable: the fragility of many tropical soils, the low level of nutrients in most of these same soils, the potentially very high density of insect pests, the tremendous demographic growth of human populations in the tropics, their low level of income and education, the potential for famine (as evidenced by the drought in the Sahel, or the problems of northeastern Brazil or Banglădesh), the shortage of developmental capital, the disastrous effects of uncontrolled exploitation.

At present it is more a question of opinion than of fact, whether these represent solvable problems of a first "exploitative" phase, similar to what happened in Europe in the 16th and 17th centuries, and in temperate North America in the 19th and 20th; or whether they are the harbingers of worse things to come. The truth is that for almost every failure in the tropics, there is a success story to be told: so advanced agronomic techniques have increased yields over much of the tropics; smallpox has been eradicated; meat production is on the rise. At the same time new problems have arisen, such as the depletion of genetic variability in the stock of our cultivated plants, and the problems of income distribution associated with the green revolution, and the increase in malaria after the tremendous strides towards its control in the fifties and sixties. But we should not be willing to be swayed by very incomplete knowledge into accepting either the idea of salvation in unlimited development, or ultimate doom. Instead, we would like to advocate a rational and systematic application of basic biological knowledge to the problem at hand, in close collaboration with economists, developmentalists, planners, ecologists, and environmentalists. But first, a more complete and integrated knowledge of tropical ecosystems is required.

A DECADE OF THE TROPICS

There is a unanimous agreement that much more research is needed in order to understand the functioning of tropical species and tropical ecosystems. It is also generally acknowledged that without this knowledge no satisfactory solutions to the many applied biological problems are likely to be found. Experts in all fields, also agree that with concentrated effort we may expect advances in tropical biology comparable to those made in temperate biology. We anticipate fruitful research opportunities in molecular biology, plant and animal physiology, taxonomy, plant-animal interactions, ecosystem nutrient cycling, and plant, animal, and human diseases. Progress in these subject areas should advance our ability to deal with problems in conservation of tropical organisms, management of pest and weed populations, agricultural productivity, and improvement of the life of man.

But while it is true that much is to be learned, it is also true that a great deal of knowledge already exists, and that although still inadequate, a great deal of applied research is being conducted, especially in agriculture, by a variety of international govermental agencies, such as FAO, CGIAR, and private foundations, as well as by regional and national agencies. Although there is general agreement that the research effort, and the total investment in research is inadequate in terms of the needs, these efforts are still several times greater than anything IUBS can undertake.

What then can IUBS offer that other institutions involved in tropical research are not offering? Is there any sense in embarking on such an ambitious program given the magnitude of the problems, and the meagerness of present resources?

The answer is yes, because the Union hopefully can provide ingredients that are either missing or are in short supply in present programs, namely a perspective on the problems from the point of view of basic science, an ability to apply this insight to the modelling of the system and the aggregate imagination of the best scientific minds in the field. Potentially, if the will exists, and enough interest can be marshalled, the Union could make a significant contribution to the advancement of biology? An example of how the application of biological knowledge can help in the development of rational basis of management is found in the work of Sir Otto Frankel and Michael Soule (1981) entitled "Conservation and Evolution". By applying the principles of genetics and evolution to the problem of conservation of the diversity of wild and domestic plant and animal species, these authors come up with a set of scientifically-based, rational conservation guidelines.

What we need then is imagination, scientific insight, common sense, and goodwill, something that we are confident can be provided. In closing, we would like to present a scientific rationale and the general principles to be followed by the Decade of the Tropics, which were approved by the IUBS General Assembly at its recent meeting in Ottawa, Canada, August, 1982.

SCIENTIFIC RATIONALE FOR A DECADE OF THE TROPICS

The IUBS Decade of the Tropics program would have the objective of increasing our knowledge and understanding of the biology of the tropics fromthe point of view of the various biological subdisciplines. The Decade would build upon the IUBS sections and constituent national and international associations, which represent the international biological community. The objective of the IUBS Decade of the Tropics is to facilitate the work of interested scientists, the communication between biologists, and the publication of their work.

Within the tropics are terrestrial and aquatic ecosystems, including forests, savanna, freshwater lakes and rivers, and coastal benthic systems of unequalled species richness. We suggest that a greatly increased study of the following aspects of these systems is urgently required:

1° The means by which exceptional species richness is maintained, and the capacity for simplification of species-rich systems without detriment to their sustainability. The relative roles of deterministic and stochastic events in the maintenance of species richness is still the subject of more speculation than rational analysis. Yet the potential utilitarian, as well as biological, significance of the coexistance of numerous lines of related species, in many different orders, in the same habitat, and of plant and animal prey and their predators and pathogens, is obvious. Knowledge of the breeding systems, social behavior, population structure and genetics of tropical organisms is, with very few exceptions, rudimentary;

The means by which energy and minerals are trapped, transferred, and stored within systems which, despite their tremendous species and biomass richness, exist in physical habitats frequently exceptionally poor in nutrients. Free mineral ions are often found in such low concentrations in forest soils and tropical waters as to defy measurement with adequate precision; yet such substrates in nature support some of the world's greatest biomasses. We do not yet know the strategies of adaptation of organisms living in these environments, or the rules which govern potential, sustainable net productivity of such systems under modification;

The relationship of water, temperature, and carbon dioxide of tropical terrestrial ecosystems must be defined. There has been much speculation concerning the potential effects that the change in the heat and water balance of tropical land surfaces, as a result of deforestation, may have on worldwide climate. The methodology now exists to describe the relevant physical characteristics of the forest canopy surface, consequently, testable predictions regarding the effect of deforestation on the heat and water balance are possible;

An understanding of human societies as intrinsic components of tropical ecosystems in dynamic equilibrium is badly needed. There have been few collaborative studies between biologists and social scientists in which the economic, social, ethical, and cosmological systems of human society are analyzed in relation to the environmental -- and more particulary biological -- constraints and potentialities which surround it. It is the lack of sensitivity to precisely this interaction which in our opinion, has slowed attempts by technologists to ameliorate human conditions in the tropics. We feel it is urgent that such studies be undertaken.

METHOD AND PROJECT EMPHASIS

: guiding methodological principle for the Decade of the Tropics must be laboration. Increased funding will of course be essential, but it cannot elf ensure success. A first step will be to identify ongoing projects in the pics in order to establish contacts leading to joint IUBS programs. The mate responsability however, must lie with the scientific community resident in the tropics. The principal objective must therefore be to fortify that community to enable scientists, both local and visiting, to carry out the work required. Visiting scientists must become aware of the need to incorporate themselves into the local scientific communities, especially in order to contribute to training of new personnel. There is already a general awareness among our colleagues and governments in tropical countries of the urgency and gravity of the problems presented, but success will only be achieved if projects are defined in such a way that the resident scientists see themselves as the principal beneficiaries. Two suggestions are given:

1) Joint projects should first aim to ensure that resident scientists can collaborate as equals with visiting scientists from other nations, scientifically as well as administratively. In this connection, graduate training programs must be given highest priority;

2) The success of such collaboration rests on the mutual trust and respect of the participants. Projects which have the best chance of success are those initiated through friendly negotiation between scientific colleagues who are themselves committed to carry out the work. The participants can each facilitate formal ratification through official channels within their governments

IUBS, through its permanent secretariat, will oversee the network and communications requirements of the program, but the majority of resources will be applied directly to research work. Present channels and organizations will be utilized, and **possibly expanded, rather than created anew. Special** involvement by sections and IUBS affiliated organizations will be required. In this way the program will increase the links between biologists and avoids creating an unnecessary bureaucracy. It is anticipated that the secretariat will be especially helpful in overcoming problems of movement, import of equipment and specimens, provisions of bibliographic information, etc. We also anticipate that the program will provide a basis for cooperative interactions between biologists of different countries. Besides building the program upon the research efforts of active biologists in its constituent sections and associations, the IUBS Decade of the Tropics should cooperate with the activities of other non-governmental and governmental organizations. For example, a logical interaction is with the UNESCO Man and Biosphere (MAB) Program, providing that effort with a biological basis for solving land management problems which is their primary objective. Concentration of IUBS on biological research could free MAB to concentrate its efforts on man/land problems, while providing us with a ready user group for some of the results of the program. We might also wish to collaborate closely with programs of our sister scientific unions, or call on them to collaborate with us, especially in the area of human biology. The intent of the IUBS Decade of the Tropics is to concentrate and focus the best and most productive biological research in order that our theoretical and empirical understanding of tropical biology be increased, thereby providing an improved scientific basis upon which to develop applied programs of research and management.

Two principal types of projects are envisaged. First, there are integrative programs, involving human societies where possible, and which should be concentrated at a few representative sites throughout the tropics. Facilities for research and training can be built and maintained on a continuing basis; costs will be minimized, collaboration and comparability of results facilitated and -- a major priority -- permanent plots set up for long term surveillance of selected phenomena.

At the same time, the need is recognized for a greatly increased effort into the inventory of tropical organisms, giving particular priority to general collecting, to the collection of materials by means which minimize damage to their tissues, and to collection of live organisms for ex-situ conservation; attention should be concentrated on areas currently undergoing irreversible conversion.

The importance of new techniques and approaches is recognized. Whenever possible, molecular and cellular biologists, as well as physiologists, taxonomists, and ecologists, should be encouraged to participate and use their unique knowledge and insight. The ultimate objective of the Decade of the Tropics is a thorough understanding of the functioning of tropical ecosystems; from their genetics to their ecology. In closing we can do no better than quote from a statement by Golley and Medina (1975):

> *"The kaleidoscope of interest in tropical biology |ecology| ..... is truly impressive. The biologist's |ecologist's| challenge in this context is to develop mechanisms for working together, for exchanging information, and for developing concepts with high predictive value that will be useful to society. This kind of statement is usually introductory to a call for team research. However, we do not call for massive international teams of research workers focused on learning everything that can be known about one spot, although that method of research can be very useful. Rather, we need more effective communication, better publication opportunities, wider exchange of journals, and more opportunities to participate in international meetings. We require more penetrating questions, more critical thought directed at the theory that confines the way we think about the tropical world. We need more visits between institutions where the visitor can assist national research efforts, and less exploitation of research opportunities solely for private purposes."*

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