The Yale Institute for

Biospheric Studies

YIBS Five Year Report

Introduction

Great universities both empower and constrain the future in the tools they give their students. They are therefore responsible for cultivating graduates who are impassioned yet realistic, and who are attuned to the underlying complexity of environmental challenges. Basic research is no less powerful in shaping society's response to environmental problems, providing the fundamental understandings needed to translate passion into effective action. No other agency has the university's ability to shape both the perceiver and the lens through which a problem is perceived. Through the Institute for Biospheric Studies, Yale University galvanizes its resources to ensure that the observer is acute and the lens is clear.

Leo W. Buss
Professor of Biology and Geology & Geophysics
Director of the Institute for Biospheric Studies, 1991-1996

The search for solutions to the environmental challenges society faces has brought about a re-evaluation of the role of institutions of higher learning. The complex relationships between the earth's ecosystems and the well-being of human and other species require an approach that draws from many academic disciplines in building a new paradigm for solving the most critical environmental challenges through interdisciplinary collaboration.

The Yale Institute for Biospheric Studies was founded in 1991 with an extraordinary gift from Edward P. Bass to build upon the strong foundation of University resources through which Yale would advance understanding of the biosphere and develop relevant approaches to environmental issues of national and global importance. The Institute was established to bring together a community of scholars to capitalize upon the University's strengths in the basic sciences which inform environmental issues; to draw upon the foundation of knowledge embodied in the Faculty of Arts and Sciences and in the graduate and professional schools of the University, particularly the School of Forestry and Environmental Studies; and to encourage the reintegration of the magnificent natural history collections of the Peabody Museum into faculty and student research, thus drawing upon the past to inform the present and enlighten the future.

The Institute is succeeding in cultivating a new standard for university-based environmental research and education and has indeed established itself as a catalyst for interdisciplinary collaboration. To date, 92 faculty members from 18 of the University's Schools, Departments, and Faculties have been involved in environmental research through the Institute's research Centers and/or through its two degree-granting undergraduate programs, Studies in the Environment and the Program in Organismal Biology.

In addition to specific advances in research and education, a principal achievement in the Institute's first five years has been to foster a shared vision among multiple academic units. As a result, Yale's considerable intellectual resources continue to be most effectively brought to bear in solving environmental problems.

Among its most notable achievements, the Institute has:

- **Conceived of the Environmental Sciences Facility and advanced it as a University priority, with groundbreaking planned for 1997.** The facility is planned as a unique space conducive to interdisciplinary interaction; it will house faculty from two Schools and three Departments of the Faculty of Arts and Sciences, laboratories, collections from the Peabody Museum of Natural History, and state-of-the-art teaching facilities. The facility will be the centerpiece of an "Environmental Campus" uniting elements of the School of Forestry and Environmental Studies, the Peabody Museum, the Institute, and

the Departments of Biology and Geology & Geophysics.

- **Conceived of, recruited, and encouraged the active involvement of an External Advisory Board of national and international prominence.** Beginning as an Institute Board only, External Advisory Board members have taken an increasingly active role in addressing larger issues that reach beyond the Institute and encompass the broader concerns that are shared by the Institute, the School of Forestry and Environmental Studies, and the Peabody Museum.
- **Catalyzed an institutional examination of the structure of biological sciences at Yale.** It is anticipated that one outcome of this examination will be to give new institutional emphasis and prominence to fields crucial to the environmental sciences, namely ecology, evolution, and organismal biology.
- **Secured a permanent faculty base and program financing for Studies in the Environment,** one of the oldest undergraduate programs of its kind among US universities offering an environmental studies major. The number of students who had declared Studies in the Environment as a second major climbed from 11 in 1992 to 56 as of January, 1996.
- **Conceived of, funded, and remains a continuing partner in the Yale Environmental Partnership,** a collaborative academic planning and development vehicle that brings together the Institute, the School of Forestry and Environmental Sciences, and the Peabody Museum. Support from corporations, foundations, External Advisory Board members, and Yale alumni and friends of the University has been generated for faculty and student research, graduate and undergraduate course development and enhancement, and equipment purchases or gifts-in-kind.

These accomplishments could only be achieved with the strong commitment to interdisciplinary collaboration that is shared among the participating academic units and fully supported by the University administration. The success of these collaborations and the tangible outcomes described in the following sections serve as the foundation from which the Institute will move forward and upon which it will expand in the next five years.

YIBS Five Year Report

Research and Development: Furthering Knowledge in Specialized Fields

These achievements in strong interdisciplinary collaboration were effected by the Institute's role as an "internal foundation." Through a competitive proposal process, the Institute's Faculty Council established seven synergistic research and teaching Centers focused on three major areas of concern: global change, the evolution and diversity of life, and the engagement of people with their planet and its other forms of life. The first two areas encompass important environmental issues, including changes in the earth's climates, atmosphere, terrestrial ecosystems, and oceans, and the rapid reduction of terrestrial and marine biodiversity at all latitudes. The third area focuses on the ways in which people contribute to and attempt to manage the broad changes underway in their environment.

Over the five year period, $1.733 million was allocated to the Institute's research centers. (More detailed information regarding these allocations is included in the Summary of Resource Allocations beginning on page 23.) These Centers represent those channels of collaboration that have led to the Institute's overall success in advancing its mission:

- Center for Biological Transformation
- Center for Computational Ecology
- Center for Earth Observation
- Center for the Study of Ecology and Systematic Systematics of Animals on the Verge of Extinction (ECOSAVE)
- Center for Global Change
- Center for Human Ecology, Environment, and Infectious Disease
- Center for Molecular Ecology and Systematics (awaiting appropriate laboratory space in the Environmental Sciences Facility

Collectively, these Centers have pushed the frontiers of current scientific knowledge, expanded technological capabilities that will in turn expand the frontiers of what can be discovered, and developed novel applications for existing technology. Each has a unique focus and contributes tangible outcomes to the advancement of our understanding of critical environmental management issues such as how bacteria may be used to remove, or even prevent, pollution; how satellite images can be used to help municipalities plan more effective watershed management strategies; or what effect a doubling of atmospheric carbon dioxide would have on common mammal species in the Continental United States. It is the work of these Centers, more fully discussed on the following pages, that constitutes the heart of the Institute for Biospheric Studies.

Center for Biological Transformation

Most chemicals introduced into the environment are rapidly removed by bacteria. Because the most abundantly produced chemicals are the products of plant metabolism, bacteria's lengthy evolutionary history has provided the genetic "repertoire" needed to effectively metabolize plant products. So through genetic means, it *should* be possible to alter microorganisms so that they convert some of the renewable resources produced by plants to socially beneficial products. In addition, the genes used by bacteria to remove pollutants are variants of the genes used to remove plant products, so genetic

modifications of the genes *should* allow the design of organisms with improved potential for environmental cleanup.

These "shoulds" represent just a few of the questions that inspire and challenge Center for Biological Transformation (CBT) Director, Professor Nicholas Ornston, and co-director, Professor Margaret Riley. In its first five years, the CBT research team has undertaken a comprehensive research program to understand the biological processes underlying the bacterial transformation of chemicals to create useful products as well as those processes underlying successful biological removal of toxic chemicals from the environment. Building upon this basic research, scientists can begin to develop applications for removing and preventing pollution.

The Center's most notable achievement to date is the complete characterization of a segment of bacterial DNA as a basis for understanding how chemicals are degraded in the environment. The segment contains 20,000 nucleotide base pairs and 17 genes; many of the genes encode enzymes with specific catalytic functions. This groundbreaking basic research has been achieved through interdisciplinary efforts combining the insights of biochemistry, physiology, genetics, ecology, and evolutionary biology. The results of CBT studies to date promise generalizations that may permit the design of enzymes with novel catalytic activities. The experimental system also opened mechanisms of genetic variation (mutation and recombination) to analysis. Findings from these studies indicate the steps that will be necessary in establishing and maintaining biodegradative systems in the natural environment.

The Center's work has spawned a successful industrial/academic collaboration with DuPont and has attracted support from the General Reinsurance Corporation, the largest professional property/casualty reinsurer domiciled in the United States. CBT research has also been recognized by the scientific community with the naming of Professor Margaret Riley as a Presidential Young Investigator.

In addition to conducting research, CBT is extremely active in advancing the study of biological transformation beyond the Yale community. In the 1994-95 academic year alone, for example, the Center hosted 11 visitors from seven universities in the US, Korea, Germany, The Netherlands, and France; Center researchers participated in eight invited lectures, seminars, and workshops at universities and professional meetings throughout the US, Spain, and Scotland.

Center for Computational Ecology

What would happen to our country's wildlife populations if atmospheric carbon dioxide were doubled? How do we discover the population genetic processes that enable a species to adapt to environmental disturbances or changes? By using mathematical models, scientists will be able to develop theories about fundamental behavior that will in turn explain the relationships between environmental impacts and ecological patterns.

These seemingly unrelated questions are at the very heart of collaboration among Center for Computational Ecology (CCE) researchers, each of whom contributes the unique perspectives of biology, engineering, geology, wildlife ecology, genetics, and computer science to their common fields of inquiry. Two of the Center's researchers, Professors Leo Buss and Günter Wagner have been recognized as John D. and Catherine T. MacArthur Fellows.

CCE's long-term research goal is to understand how complexity in ecological systems emerges and is sustained, further enabling researchers to:

- understand the dynamics of multi-scale, self-organizing ecological systems;
- predict the effects of perturbations on ecosystem dynamics and organizational structure; and
- gauge the potential to restore perturbed ecological systems.

While CCE researchers represent numerous disciplines, they share underlying conceptual problems that require the solution of structurally similar mathematical challenges. Each research project, therefore, has the potential for producing two types of outcomes: 1) findings specific to the project that advance knowledge in a particular field and contribute to our collective understanding of complexity in ecological systems; and 2) innovations in and applications of computational and mathematical tools, including software, that enhance the knowledge shared by the interdisciplinary community.

CCE research projects are structured around three simulation platforms, which continue to evolve as the related research unfolds; each of these platforms contributes to the computational keys by which researchers have begun to unlock our understanding of complexity:

- *Gecko*, School of Forestry and Environmental Studies Professor Oswald

Schmitz' extension of the Santa Fe Institute's "ECHO" model, simulates behavior such as species competition in highly structured environments. The most immediate applications of this development will be in examining rock intertidal shoreline communities and old field food web structures.

- The *multilocus population genetic simulator* enables scientists to study the dynamics of mutation, selection, recombination and drift. This model, developed by CCE Director Professor of Biology Günter Wagner, Department of Biology, will be applied to the problem of how the adaptive versatility of a population changes under environmental change.
- The *l-grammar model* was designed by Professor Leo Buss, Departments of Biology and Geology, and Walter Fontana, Institute of Theoretical Chemistry, University of Vienna. This model enables scientists to study the emergence of stable, self-maintaining networks of interactions by generating specifications for systems which, if satisfied, will be self-sustaining.

Center for Earth Observation

If you were to dig for archeological treasurers in a part of Syria for which few maps exist, how would you pick the most likely spot? How can pro-active revisions in watershed management in upstate New York help New York City meet the quality standards of the Safe Drinking Water Act? With the remote sensing and geological information systems (GIS) resources of the Center for Earth Observation, researchers are now able to address such questions in innovative ways.

The overall objective of the Center for Earth Observation (CEO) is to enhance and coordinate the use of remote sensing and geographic information system (GIS) technologies for research and academic purposes. The Center is an interdisciplinary research community that brings together researchers from the Departments of Geology & Geophysics and Anthropology, the School of Forestry and Environmental Studies, and the School of Medicine's Department of Epidemiology and Public Health; its resources are used by research teams in at least nine academic areas.

The technology used in the Center can be applied to numerous research topics, many of which have significant economic and environmental implications, such as: mapping mineral deposits, monitoring major storm formation, detecting forest damage, charting atmospheric changes (e.g., holes in the ozone layer), and mapping local cloud patterns and wind circulation to aid in the management of air pollution sources. The Center also enables Yale to join a handful of American universities serving as libraries for satellite images. The Center receives and archives processed satellite images and data sets from NASA, public network sources, and commercial network services. The Center thus acts as a service bureau providing both data and an array of training programs to Yale's entire academic community.

The number of active research projects has grown substantially from four in the spring of 1994 to approximately 20 in the spring of 1995; such growth in project numbers has also expanded the number of disciplines and variety of research questions to which remote sensing can be applied. Most projects involve one to two collaborating researchers and have a duration of approximately six months, while others may evolve over a number of years and engage a number of graduate students whose interests are compatible with the faculty investigator.

Center for ECOSAVE

In our desire to preserve the broadest possible segments of earth's vast biodiversity, scientists must constantly ask themselves and one another which ecosystems should be conserved, and where? Which are the endangered species? Which species require priority attention? What sort of habitat does a species require? How do habitats relate to species' life cycles and behaviors?

The Center for the Study of Ecology and Systematics of Animals on the Verge of Extinction (ECOSAVE) is designed to make Yale one of the few research institutions that focuses specifically on providing the vital scientific basis for conservation strategies to help diminish the loss of threatened species. ECOSAVE concentrates research efforts in two major areas: studying evidence of ecosystem changes found in fossil records and understanding a species' "family tree" by combining the traditional method of analyzing physical form and function with new techniques to analyze underlying genetic similarities. Information of this type will be essential for creating animal and plant reserves and for developing effective management strategies in the future.

Under the leadership of Yale paleontologist Elisabeth Vrba, ECOSAVE has entered into collaborations with scientists from the New York Zoological Society and the

American Museum of Natural History. These collaborations currently focus on deer and antelope species, specifically the new genus and species Pseudoryx nghetinhensis found in Vietnam, as reported in the June, 1993 issue of Nature. The study of this newly identified species includes mitochondrial DNA studies, skeletal studies of fossil and recent related taxa, and ecological and behavioral studies in the field. In a related endeavor, researchers are studying the biology, including morphology, behavior, ecology and conservation status of other new species of antelope and deer recently found in Laos and Vietnam.

Dr. Vrba also continues to collaborate in the Middle Awash Research Program (MARP), which involves annual field trips to find new fossil sites in the eastern African Rift in Ethiopia and to excavate and study the stratigraphy and fossil contents of the most promising strata. This effort not only advances scientists' understanding of the evolutionary process, it brings Yale researchers into direct interaction with students and scientists in developing countries, furthering the transfer of intellectual resources among scholars and potentially attracting graduate students from Third World research institutions.

The Center's efforts have also resulted in the publication of Paleoclimate and Evolution, with Emphasis on Human Origins, to be released by the Yale University Press in early 1996. The book is edited by Dr. Vrba and colleagues from the University of Maine; the University of Witwatersrand, Johannesburg, South Africa; and the Lamont-Doherty Earth Observatory, Palisades, New York. The collection of writings focuses on how climatic change during the last 15 million years-especially the last three million-has affected human evolution and other evolutionary events.

Center for Global Change

> For most people, "global change" is equated with future global warming and an accompanying increase in "greenhouse" gases; for geologists, however, global change is the very essence of their discipline. One of the most provocative assignments in the study of global change is that of determining changes in the environment over millions of years. As "the child is the father of the man," so also is the past environment the commentator on the future.

The Center for Global Change (CGC) was established to encourage the interdisciplinary study of changes occurring on the plant's surface over time scales ranging from tens to millions of years. The only way to evaluate global climate change over such long periods is to examine the geological record; isotope geochemistry is the principal technique used for such analysis. Research in isotope geochemistry is therefore the means by which CGC researchers work to fulfill the Center's mission of providing a richer scientific base on which to build the environmental policies that are critical to protect and manage our biosphere and atmosphere.

In collaboration with Woods Hole Oceanographic Institution, Karl Turekian, CGC Director, Professor of Geology & Geophysics, and member of the National Academy of Science, is developing and refining research techniques that enable researchers to better distinguish long-term global climate changes from natural fluctuations in climate occurring over long periods. In the course of his distinguished research career, Professor Turekian has introduced many of the modern techniques for examining geological indicators of global climate change; his current research focuses on measurements of the isotope ratios of osmium in dated deep sea cores.

The radioactive decay of an isotope of rhenium enhances one of the isotopes of the platinum group element osmium (os-187). The higher the rhenium concentration of a geologic deposit and the older it is, the higher the Os-187 will be relative to the other isotopes of osmium. Black shales, a common source rock type for petroleum, are enriched in rhenium, uranium, and phosphorous. The weathering of old black shales or similar deposits burdens the oceans with Os-187 enriched osmium. This burdening changes with the rate of weathering, which in turn depends on the extent of mountain building and land exposure above sea level. By following the changing osmium isotope complexion of sea water over time, we can determine the changing intensity of mountain erosion. This information, combined with profiles of uranium and phosphorus found by studying ancient corals, reveals the history of atmospheric carbon dioxide, the control of which lies at the heart of the climate change question.

In addition to pursuing a world-renowned research agenda, Professor Turekian has recently published Global Environmental Change: Past, Present, and Future as an outgrowth of the undergraduate "Global Change" course (which is itself an outgrowth of two smaller Berkeley College seminars entitled "The Earth and Human History" and "The Human View of Earth"). The book addresses issues of natural and human induced or accelerated environmental change on a global scale at a level appropriate

to a general audience. Each of the book's 11 chapters examines a topic in global change from an interdisciplinary perspective that at various points incorporates aspects of geology, atmospheric science, oceanography, biology, astronomy, chemistry, physics, geography, political science, history, archaeology, and economics.

Center for Human Ecology, Environment and Infectious Disease

> As long as tropical forests are under the pressure of human incursion and development, there must be the ability to define the options for achieving sustainable use in terms of biological mechanisms and social costs and benefits, particularly those related to human health.

Tropical rainforest destruction has caused not only drastic economic, social, and environmental changes in many countries in recent years, but has also exacted a heavy toll through an increase in infectious diseases such as malaria. The Center for Human Ecology, Environment and Infectious Disease (CHEEID) is charting the impact of social and economic factors and of environmental change, such as deforestation, on infectious diseases. This fundamental research will provide the basis for scientifically sound health and environmental policies.

Initial research activities have focused on the Amazon River Basin of Brazil and on three insect-transmitted diseases-malaria, leishmaniasis, and yellow fever. The project Land Use and Health in the Amazon is the first intensive study to integrate health and environmental factors in an effort to guide settlement in the Amazon basin. Developed as a collaborative effort among Yale scientists and colleagues from Brazilian institutions, this project focuses on the relationship between insect transmitted diseases and deforestation, and on sustainable land-use for socioeconomic development. The multidisciplinary project is set in the frontier settlements of the state of Rondonia and in the floodplain communities of the Amazon estuary in Pará, Brazil. Two research projects are currently in progress through CHEEID: A soil and vegetation characterization of the tidal floodplains, and a socio-economic study in the Amazon estuary of Pará, Brazil. However, with the 1994 departure of Professor Burt Singer, CHEEID Director and Dean of Epidemiology and Public Health, the Center is now re-assessing the direction that new research will take.

Center for Molecular Ecology and Systematics

The Center for Molecular Ecology and Systematics (CMES) will further develop and utilize the latest advances in molecular biology to rapidly survey the genetic status of natural populations. In addition to providing a focus for the development of new technology, the Center will serve the increasingly important demands of the community of ecologists, conservation biologists, and evolutionists for access to such tools. In carrying out their work, Center researchers intend to ultimately build a molecular collection destined to become a new division of the Peabody Museum of Natural History. This Center's programs await the construction of the new Environmental Sciences Facility.

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Advancing Graduate and Undergraduate Education

The Institute for Biospheric Studies not only serves as a catalyst for interdisciplinary research collaborations, but also provides active financial and conceptual support for the interdisciplinary study of the environment at the graduate and undergraduate levels. The over-arching goal of this aspect of the Institute's mission is to help create a new type of environmental scientist who is prepared to address complex, multi-disciplinary challenges.

During its first five years, the Institute began to address this goal by supporting the development of new courses for graduate and undergraduate students; by strengthening the Studies in the Environment major and assisting with the establishment of the Program in Organismal Biology; by engaging in targeted development strategies to attract student support from corporations, foundations, and individual donors; and by funding new faculty positions. Over the five year period, $1.387 million was allocated for these purposes. (See Summary of Resource Allocation, pages 23-24.)

Course Development, Graduate Seminars and Fellowships

The **Center for Earth Observation** makes a significant impact on education through its relevance to a wide range of academic disciplines and by enabling advanced undergraduate and beginning graduate students to learn the fundamentals of remote sensing and apply these techniques to their study of the earth's environment and man's relationship to it. A number of graduate students indicate that the opportunity to draw upon CEO resources was a determining factor in their decision to pursue graduate study at Yale.

Students in the tremendously successful "Observing Earth from Space" course offered through the Center for Earth Observation not only gain knowledge that can be applied in their own research, but they acquire a valuable technical skill that is applicable in a range of scientific and information-industry careers. These students also assist the Center in expanding the applications of remote sensing and geological information systems into areas of research that had not previously benefited from such techniques. One graduate student, for example, contributed the knowledge he had acquired through this course to his collaboration with a faculty member in Geology & Geophysics who is not himself affiliated with the Center for Earth Observation. The student's contribution of newly acquired knowledge not only enhanced the project's design, it contributed to the group's findings to such a degree that the student is listed as a co-author of the resulting publication.

This course is regularly oversubscribed, as enrollment must be capped at 40 students due to the limited availability of work stations in the electronic laboratory. In the Fall 1995 term, 40 students from nine academic disciplines were enrolled.

Both undergraduate and graduate students also benefit from the **Courses in Population Studies** developed and enhanced with funding to support invited speakers provided by a Yale alumnus through the Institute's development effort. Students enrolled in the course may receive credit in either Biology, Forestry and Environmental Studies, Economics, or Epidemiology and Public Health; in addition to students from these areas, the course also attracts majors in International Studies, Political Science, Divinity, Anthropology, and others. In this course, students learn the principles of global demography, with an emphasis on the influences of population growth on environmental problems in ecosystems, health, economies, the atmosphere, water, soil, and energy; discussion also focuses on the history of population size changes, patterns of migration, family planning in more and less developed countries, and prospects for population stability and low-growth economics.

A new course addressing population issues is currently being developed by Biology Professor Robert Wyman; this course will be offered through the Department of International Studies in fall 1996. In addition to these specific courses, population

issues are integrated into other course offerings in basic biology and ecology, as well as in economics, public health, and sociology.

The **Center for Global Change** sponsors an interdisciplinary course entitled "Topics in Global Change" which engages students in discussions with Yale faculty and visiting scholars dealing with the present workings of the environment, measurable changes in recent times, and changes recorded over longer periods in rocks, sediments, ice cores, pre-historic and historic archaeological remains, and written records. This seminar has brought Yale students into direct dialogue with the leading scholars in the field of climate change on a weekly basis over the past five years.

To provide direct financial support to graduate students in Anthropology, Biology, Geology & Geophysics, and in the School of Forestry and Environmental Studies, the **Hutchinson Prize** was established in memory of Professor Evelyn Hutchinson, a founder of the modern science of ecology. To date 84 students have received stipends and/or research support for up to four years of graduate study in areas relevant to the Institute's mission.

Looking to the future of enhanced post-graduate education, an endowment has been established for the **Gaylord Donnelley Environmental Fellows Fund** to support post-doctoral associates whose research interests are in the area of biodiversity. Based on projected growth, the first post-doctoral Donnelley Fellow will be appointed in 1997.

Undergraduate Education

The Institute provides support for two undergraduate degree-granting programs: Studies in the Environment and the Program in Organismal Biology. Both are offered as second majors only, thus they enhance the interdisciplinary nature of environmental studies at Yale by encouraging students to formally consider the relationships linking environmental topics with their primary course of study. These programs draw students from disciplines as diverse as Yale College itself, and prepare them for graduate study and careers in professions such as law, medicine, theology, and organic farming, among numerous others.

Studies in the Environment, established in 1984, is a second major designed to engage Yale College students in the interdisciplinary study of environmental issues and to encourage students to integrate a broad range of economic, political, ethical, and scientific approaches to environmental problem-solving. Studies in the Environment is the only one of Yale College's four environmental majors that operates independently of any single academic Department.

While Studies in the Environment was established well before the Institute, its subsequent affiliation with the Institute enabled students, faculty, and program administrators to become a more integral part of the University's broader efforts to enhance the environmental sciences. Furthermore, this affiliation provided the program with the stability needed to attract internal and external support, both financial and conceptual, and to benefit from a targeted development effort. In 1991-92, for example, the program faced a "Catch 22" that often proves fatal to many innovative academic programs-the University was putting pressure on program administrators to demonstrate their ability to attract external funding, while external funding sources were reluctant to support an initiative that had not secured a long-term commitment from the University. Working through the Institute and its development team, the program was successful in attracting a total of $750,000 in endowment from the William Bingham Foundation, the Gaylord and Dorothy Donnelley Foundation, and friends of the University, including an External Advisory Board member; this success proved to be a turning point in the program's growth and stability.

Increased interest in the environment among both the students and the faculty has generated substantial growth in the Studies in the Environment program. Formal enrollment has risen dramatically, from 11 students in 1992 to 56 in the current academic year, making it the 23rd largest among Yale College's 72 undergraduate majors. In addition, as many as 250 students per term took introductory courses in spring 1994 and in the 1994-95 academic year.

In recognition of this stability and growth, Yale College recently granted one "faculty line" to the program; an international search for an environmental historian has resulted in the appointment of Dr. Steven Stoll, who will also serve as the program's Director of Undergraduate Studies. In addition, Studies in the Environment has for the first time in the 1995-96 academic year begun to offer courses under its own sponsorship: *The Country and* the City in America, 1750 to 1950; and *Functioning of Plants in Agriculture and Ecosystems*.

Students wishing to augment their studies with research projects that would not be feasible within an academic year are eligible to apply for grants of $500-$2,000 funded by Hitachi America and by one of the Institute's External Advisory Board members to defray summer research expenses; such grants are referred to as "student internships." Discussions with program alumni suggest that the internship is

a source of insight, experience, and network contacts that influence subsequent academic and career decisions. For example, one student is currently completing research entitled "Investigating Fertility Decline in Kenya" for which she spent the summer of 1995 in the outskirts of Nairobi, conducting focus group discussions and other field studies to gather data on the role of locally held myths and misconceptions as a barrier to contraceptive use. As a result of this experience, she now plans to continue field research in population planning at the graduate level.

The **Program in Organismal Biology** was created in 1991 to serve as a vehicle for students pursuing careers in environmental sciences, particularly in the evolutionary and ecological sciences, enabling them to earn a second major in conjunction with a degree in Anthropology, Biology, Geology & Geophysics, or Molecular Biophysics and Biochemistry. The focus of this major is to prepare students as natural scientists who can work in such fields as conservation biology.

Although this is a relatively new major, enrollment continues to increase each year; as of January, 1996, 35 students had formally declared a second major in Organismal Biology. At this time the majority of the program's graduates are engaged in graduate-level study. One graduate is working with fisheries in southeast Asia as a Peace Corp volunteer, while another is studying at Oxford University on a Marshall Scholarship. The latter was the first undergraduate in Yale history to be simultaneously awarded Exceptional Distinction in two undergraduate degrees, Anthropology and the Program in Organismal Biology.

As with Studies in the Environment, Organismal Biology offers students the opportunity to apply for Hitachi America Summer Internship funds to undertake research challenges beyond those typically presented as part of the undergraduate experience. One student, for example, used a research grant funded by Hitachi America to develop a study of the web decorating behavior of *Argiope argentat*a in Panama. Her internship support enabled her to spend the summer months of 1995 in Panama conducting field research to explore the relationships between web form and function and prey capture. The initial field work was so successful that the student was invited to remain in Panama to continue her research through the 1995-96 academic year. She is currently on leave from Yale College and will return to graduate in the Fall 1996 term; the current research will serve as the foundation for her senior project and thesis. Other examples of internship research conducted in 1995 include studies of captive breeding programs in conservation biology, behavioral ecology of cliff swallow colonies, and nesting ecology of a neotropical warbler. Proposed studies for summer 1996 include an effort to reintroduce desert tortoises to an area in Nevada where they formerly existed and a study of a fossil Mesozoic flora.

The Program is also for the first time offering courses under its own sponsorship in the 1995-96 academic year: *The Biology of Fishe*s , which attracted over 100 students in Fall 1995; and *Herpetolog*y, offered in Spring 1996. A new course in Marine Biology is proposed for spring 1997. All other Organismal Biology courses are cross-listed with and taught by faculty from the Departments of Anthropology, Biology, Geology & Geophysics, Psychology and from the School of Forestry and Environmental Studies.

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YIBS as a Communication Forum

In addition to its academic research and education activities, the Institute serves as a convener of academic and public audiences around environmental and scientific issues of common concern. While the Institute has focused primarily on building internal collaborations in its first five years, it has taken some initial steps in developing a public role beyond that already played by individual faculty by:

- Sponsoring the Yale in the Environment conference, February 9-10, 1993. This two-day conference brought Yale faculty together with environmental leaders to discuss current environmental issues and explore Yale's role in addressing them. A total of 96 faculty, students, External Advisory Board members, and invited guests attended the two-day sessions.
- Providing financial support for conferences sponsored by affiliated or germane organizations within the Yale community.

    - Ecorealism: Toward the Next Generation of Environmental Policy was sponsored by the Yale Student Environmental Coalition and the Yale Center for Environmental Law and Policy with support from the Institute.
    - The decadal UN conference on demographic policy, most recently held in Cairo in September 1994, is typically followed by local conferences aimed at national implementation. One such follow-up conference was held at Yale under the joint sponsorship of the Institute and a variety of other Yale and non-Yale groups.

- Producing written communications to keep the university community, Institute supporters from multiple sectors, and prospective students in participating academic Departments apprised of the Institute's mission, activities, and achievements of participating faculty and students.

    - The Yale Environmental News was launched in summer 1995 to provide timely news of environmental research, programs, and events. The second issue of what will become a quarterly publication has recently been released; circulation is currently 1000.
    - The Institute's annual publications "Molecular Evolution at Yale" and "Theoretical Biology at Yale" are distributed to all applicants for graduate study through the Department of Biology.

- Maintaining sites on the World Wide Web from which interested parties can retrieve information concerning research, findings, articles, and published and internally reviewed unpublished manuscripts.

    - Center for Computational Ecology: http://peaplant.biology.yale.edu:8001/
    - Center for Earth Observation: http://stormy.geology.yale.edu/ceo.html

Informing the scientific community of its research outcomes through published articles in refereed journals; these publications are listed by Center. Access this list here.

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External Advisory Board (EAB)

Edward P. Bass, EAB Chairman, 1992-Present

Edward A. Adelberg, Yale University, 1993-Present

Frances Beineke, Natural Resources Defense Council, 1992-Present

Coleman P. Burke, Waterfront New York, 1994-Present

William Cronon, University of Wisconsin, 1993-Present

Robert E. Dickinson, University of Arizona, 1992-1993

Duane Dickson, Mercer Mgt Consulting, 1993-Present

Strachan Donnelley, The Hastings Center, 1993-Present

Michael J. Donoghue, The Harvard University Herbaria, 1993-Present

John R. Hall, Ashland Oil, Inc., 1994-Present

Teresa Heinz, Heinz Family Philanthropies, 1993-1994

Danny Hillis, MIT Media Lab, 1993-Present

F. Donald Hudson, Venture Capitalist, 1993-Present

Thomas E. Lovejoy, Smithsonian Institution, 1992-Present

Adrienne B. Mars, 1993

George G. Montgomery, Jr., Hambrecht & Quist, Inc., 1993-Present

Michael Novacek, American Museum of Natural History, 1993-Present

Nicholas Pappas, Rollins Environmental Services, 1993-Present

Peter Raven, Missouri Botanical Garden, 1992-1993

William K. Reilly, World Wildlife Fund, 1994-Present

Ralph C. Schmidt, United Nations Development Programme, 1993-Present

Nelson (Bud) S. Talbott, Sawyer Research Products, Inc., 1993-Present

Faculty Council Members

The Institute is governed by a Director acting on the advice of a Faculty Council comprised of Deans, Directors, and Faculty from across the University. The Council meets twice each year to discuss administrative issues and matters pertaining to the scholarly research sponsored by the Institute. Faculty Council members for the 1991-1996 period include

Professor Richard Burger
Director, Peabody Museum of Natural History; Dept of Anthropology, 1994-Present

Professor Leo W. Buss
Director, Institute for Biospheric Studies; Depts of Biology and
Geology & Geophysics, 1991-1996

Professor D. Allan Bromley
Dean, Faculty of Engineering, 1995-Present

Professor Jared L. Cohon
Dean, School of Forestry & Environmental Studies, 1991-Present

Professor William J. Cronon
Dept of History (1991-1992)

Professor Gary L. Haller
Chairman, Council of Engineering, 1991-1992

Professor Douglas R. Kankel
Chairman, Dept of Biology, 1991-Present

Professor Michael Merson
Dean, Epidemiology and Public Health, 1995-Present

Professor Jeffery Powell
Chairman Program in Organismal Biology; Department of Biology, 1991-Present

Professor Alison F. Richard
Director, Peabody Museum of Natural History, 1991-1994

Professor Frank H. Ruddle
Chairman, Dept of Biology, 1991

Professor Burton H. Singer
Chairman, Dept of Epidemiology and Public Health, 1991-1994

Professor Gaddis Smith
Director, Center for International & Area Studies;
Dept of History, 1991-1996

Professor Ronald B. Smith
Chairman, Dept of Geology & Geophysics, 1991-Present

Professor Karl K. Turekian
Dept of Geology & Geophysics, 1991-Present

Professor J. Rimas Vaisnys
Depts of Electrical Engineering
and Geology & Geophysics, 1991-Present

Professor Robin Winks
Chairman, Studies in the Environment; Dept of History, 1991-Present

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Contributors

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The William Bingham Foundation

Consulting Environmental Engineers

The Gaylord & Dorothy Donnelley Foundation

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YIBS Five Year Report

Publications Resulting from YIBS Center Research: 1991-1995

Books

Center for Global Change
CGC 8: Turekian, K.K. (1995). *Global Environmental Change: Past Present and Future*. Prentice Hall, Upper Saddle River, NJ.

Center for ECOSAVE
CE 5: Vrba, E. S., Denton, G. H., Partridge, T. C. & L. H. Burckle (1994). *Paleoclimate* and evolution with emphasis on human origins. Yale University Press, New Haven, CT. in press.

Articles

Center For Biological Transformation
CBT a: DiMarco, A. A., Averhoff, B., & L. N. Ornston (1993). Identification of the transcriptional activator pobR, and characterization of its role in the expression of pobA, the structural gene for p-hydroxybenzoate hydroxylase in Acinetobacter calcoaceticus. *J. Bacteriol*. 175: 4499-4506.

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CBT 4: DiMarco, A. A. & L. N. Ornston (1994). Regulation of p-hydroxybenzoate hydroxylase synthesis by pobR bound to an operator in Acinetobacter calcoaceticus. *J.* Bacteriol. 176: 4277-4284.

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CBT 9: Houghton, J. E., Brown,T. M., Appel, A. J., Hughes, E. J. & L. N. Ornston (1994). Discontinuities in the evolution of Pseudomonas putida cat genes. *J. Bacteriol*. 177: 401-412.

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CBT 11: Elsemore, D. A. & L. N. Ornston (1995). Unusual ancestry of dehydratases associated with quinate catabolism in Acinetobacter calocaceticus. *J. Bacteri*ol. 177 (20): 5971-5978.

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CBT 14: Sun, L., Jiang, R-Z., Steinbach, S., Holmes, A., Campanelli, C., Forstner, J., Sajjan, U., Tan, Y., Riley, M. A. & R. Goldstein(1995). The emergence of a highly transmissible lineage of cbl+ Pseudoomonas (Burkholderia) cepacia causing CF centre epidemics in North America and Britain. *Nature Medici*ne v. 1 (7): 661-666.

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Center For Computational Ecology

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CCE 3: Fontana, W. & L. W. Buss (1993). "The arrival of the fittest: Toward a theory of biological organization." *Bull. of Math. Biol.* 56 (1): 1-64.

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CCE 5: Fontana, W. & L. W. Buss (1993). What would be conserved if the "tape were run twice?" *PNAS, US*A, 91: 757-761.

CCE 6: Wagner, G. P. & P. Krall (1993). What is the difference between models of error thresholds and Muller's ratchet? *J. Math. Biol.* 32: 33-44.

CCE 7: Wagner, A., Wagner, G. P. & P. Similion (1993). Epistasis facilitates the evolution of reproductive isolation by peak shifts: A two locus two-allele mode*l. Genet*ics 138: 533-545.

CCE 8: Wagner, A. & N. Blackstone (1994). Surveys of gene families using polymerase chain reaction: PCR selection and PCR drift. *System Bi*ol. 43: 250-261.

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CCE 10: Fontana, W., Wagner, G. P. & L. W. Buss (1994). Beyond digital naturalism. *Artificial L*ife 1: 211-227.

CCE 11: Fontana, W. & L. W. Buss (1994). Toward a theory of biological organizatio*n.* Bull. Math. Biol. 56: 1-64.

CCE 12: Dudgeon, S. R. & L. W. Buss (1994). Growing with the flow: On the maintenance and malleability of colony form in the hydroid hydractini*a. Amer. Naturali*st submitted.

CCE 13: Schmitz, O. J. (1994). Resource edibility and trophic exploitation in an old-field web. *PNAS,* USA, 91: 5364-6367.

CCE 14: Schmitz, O. J. (1994). Optimal foraging and consumer-resource dynamics. *Proceedings of the 6th International Theriological Cong*ress. Sydney, Australia, in press.

CCE 15: Belovsky, G. E. & O. J. Schmitz (1994). Herbivore optimal foraging and plant defenses. *Proceedings of the 6th International Theriological Cong*ress, Sydney, Australia, in press.

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CCE 17: Wagner, A. (1995). Can nonlinear epigenetic interactions obscure relations

between genotype and phenotype*? Nonlinear*ity submitted.

CCE 18: Schmitz, O. J., Cohon, J. L., Rothley, K. D. & A. P. Berckerman (1995). Adaptive behavior in complex environments: A multiobjective programming approa*ch. Am.* Naturalist submitted.

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CCE 24: Schmitz, O. J. & G. Booth (1995). Modeling food web complexity: the consequence of individual-based spatially explicit behavioral ecology on trophic interactions. *Evolutionary Ecolo*gy submitted.

CCE 25: Wagner, G. P. (1995). Adaptation and the modular design of organisms.8 In F. Morán, A. Morán, J. J. Merelo and P. Chacón (ed.*). Advances in Artificial L*ife. Berlin, Springer pp. 317-32.

CCE 27: Wagner, G. P. & L. Altenberg (1995). Complex Adaptations and the Evolution of Evolvability. *Evolutio*n in press.

CCE 30: Wagner, G. P. (1995). Apparent stabilizing selection and the maintenance of neutral genetic variatio*n. Gene*tics submitted.

CCE 31: Laubichler, M. D. (1995). The semiotics of biological functions. I. Rauch (e*d.) Proceedings of the Fifth Congress of the International Association for Semiotic Stu*dies, Berkeley, Mouton de Gryter, Berlin, in press.

CCE 32: Dudgeon, S., Wagner, A., Vaisnys, J. R. & L. W. Buss (1995). Dynamics of gastrovascula circulation in the colonial hydroid, Podocoryne carnea. The one-polyp c*ase*. J. Exp. Biol. submitted.

CCE 34: Schmitz, O. J., Beckerman, A. P. & S. Litman (1995). The trophic dynamic consequences of adaptive foraging by herbivore*s. Evolutionary Eco*logy submitted.

CCE 35: Johnston, K. M. & O. J. Schmitz (1995). Influence of climate change on the distribution of selected wildlife species within the continental US*A. Ecological Applicat*ions submitted.

CCE 36: Beckerman, A. P. (1995). Body size dependent patterns in functional responses: the evolutionary ecological basis for pattern in dynamics of ecological system*s. Evolution*ary Ecology submitted.

CCE 37: Freund, H. (1995). Self-maintaining lambda-organized and analysis via rewrite system*s. Evolutionary Ecolo*gy submitted.

CCE 39: Laubichler, M. D. (1995). Wittgensteinian Biology. I. Rauch (e*d.) Proceedings* of the fifth Congress of the International Association for Semiotic Studies, Berkeley, Mouton de Gryter, Berlin, in press.

CCE 40: Rannala, B., Brown, C.R., & M.B. Brown (1996). Spatio-temporal refugia and parasitic avoidance in the Cliff Swallo*w. Eco*logy in press.

CCE 41: Fontana, W. and L.W. Buss (1996). The barrier of objects: From Dynamical Systems to bounded organizations. In J. Gasti and A. Karlquist, e*ds. Boundaries and Barr*iers. Addison-Wesley, Reading, Massachusetts.

Center For ECOSAVE

CE 1: Vrba, E. S. (1993). Turnover-pulses, the Red Queen, and related topics. *American* J. of Science 293A: 418-452.

CE 2: Clark, J. D., deHeinzelin, J., Schick, K., Hart, W. K., White, T. D., WoldeGabriel, G., Walter, R. C., Suwa, G., Asfaw, B., Vrba, E. S. & Y. H. Selassie (1994). Ages and young Oldowan asemblages in the Middle Awash Valley, Ethiop*ia. Sci*ence 264: 1907-1910.

CE 3: Vrba, E. S. (1994). An hypothesis of heterochrony in response to climatic cooling and its relevance to early hominid evolution. In R. Ciochon & R. Corruccini (e*d.) Integrative pa*ths to the past: Paleoanthropological advances in honor of F. Clark Howell. Prentice Hall, Englewood Cliffs, New Jersey. 345-376.

CE 4: Vrba, E. S. (1994). Possible turnover-pulses in antelope and hominid evolution. In E. S. Vrba, G. H. Denton, T. C. Partridge, & L. H. Burckle (e*d.) Paleoclimate and evolut*ion with emphasis on human origins. Yale University Press, New Haven, CT. in press.

CE 6: Vrba, E. S. & J. E. Gatesy (1994). New fossils of hippotragine antelopes from the Middle Awash deposits, Ethiopia, in the context of a phylogenetic analysis of

hippotragini (Bovidae, Mammal*ia). Palaeontologia Afri*cana in press.

CE 7: Gatesy, J., Hayachi, S., Vrba, E. S. & R. DeSalle (1994). Correlated character change and rate estimations for rRNA stem regions. In preparation.

CE 8: Vrba, E. S., Vaisnys, J. R., Gatesy, J. E., DeSalle, R., & K. Y. Wei (1994). Analysis of paedomorphosis using allometric characters: The example of reduncici antelopes (Bovidae, Mammal*ia). Syst.* Biol. 43 (1): 92-116.

CE 9: Vrba, E. S. & J. Gatesy (1994). New Antelope Fossils from Awash, Ethiopia, and Phylocenetic analysis of Hippotragini (Bovidae, Mammal*ia). Palaeontological Africa*n 31 (0): 55-72.

CE 10: Vrba, E. S. (1994). An hypothesis of early hominid heterochrony in response to climatic cooling. In R. Ciochon and R. Corruccini (e*ds), Integrative Paths to the P*ast: Paleoanthro-pological Advances in Honour of F. Clark Howell, pp. 345-376. Prentice Hall, New York.

CE 11: Gatesy, J., Hayachi, S., DeSalle, R. & E. S.Vrba (1994). Rate limits for mispairing and compensatory change: the mitochrondrial ribosomal DNA of antelop*es. Evolut*ion 48 (1): 188-196.

CE 12: Vrba, E. S. (1995). Species as habitat specific, complex systems. In J. C. Masters, D. M. Lambert and H. G. Spencer (ed.) The Recognition of Species: Speciation and the Recognition concept, pp. 3-44. Johns Hopkins University Press. Washington, DC.

CE 13: Lieberman, B. & E. S. Vrba (1994). Levels of select*ion. Bios*cience. 45 (6) 394-399.

CE 14: Clark, J.D., De Heinzelin, J., Schick, K., Hart, W., White, T., WoldeGabriel, R. W., Suwa, G., Asfaw, B., Vrba, E.S. & Y. Haile-Selassie (1994). Middle Pleistocene discoveries in the Middle Awash Valley Ethiop*ia. S*cience 264:1907-10.

Center For Earth Observation

CEO 1: Fraser, R., Warrent, M. & P. Barten (1995). Comparative evaluation of land cover data sources for erosion predict*ion. Water Resources Bulle*tin in pre**ss.**

Center For Global Change

CGC 1: Pegram, W. J., Krishnaswami, D., Ravizza, G. E. & K. K. Turekian (1992). The record of sea water 187Os/186Os variation through the cenozo*ic. Earth and Planetary Sci*ence Letters 113: 569-576.

CGC 2: Turekian, K. K. & N. Tanaka (1992). The use of atmospheric cosmogenic 35S and 7Be in determining depositional fluxes of *SO2. Geophysical Res. L*etters 19 (17): 1767-1770.

CGC 3: Tanaka, N. & K. K. Turekian (1995). The determination of the dry deposition flux of SO2 using cosmogenic 35S and 7Be measurem*ents. J. Geophys.* Res. 100: 2841-2848.

CGC 4: Pegram, W. J., Esser, B. K., Krishnaswami, S., & K. K. Turekian (1994). The isotopic composition of leachable osmium from river sedimen*ts. Earth and Planetary* Let. in press.

CGC 5: Turekian, K. K., Tanaka, N., Turekian, V. C., Torgersen, T. & E. C. DeAngelo (1995). Transfer rates of dissolved tracers through estuaries based on 228 Ra: A study of Long Island S*ound. Cont. She*lf Res. in press.

CGC 6: Prospero, J. M., Schmitt, R., Cuevas, E., Savoie, D., Graustein, W. C., Turekian, K. K., Volz-Thomas, A. A., Diaz, A., Oltmans, S. & H. Levy (1995). Temporal variability of summer-time ozone and aerosols in the free troposphere over the eastern North Atlan*tic. Geophys. Re*s. Let. in press.

CGC 7: Turekian, K. K., Krishnaswami, S., Ribe, N. M. & I. M. Reinitz (1995). Radioactive disequilibrium among 238U series nuclides in recent volcanic rocks: a mode*l for chronology and mechanism of fo*rmation. (Vinogradov Jubilee Volume) Nauka Publishing House, Moscow, in pr**ess.**

Center For Human Ecology, Environmental and Infectious Disease

CHD a: Montagnini, F., Singer, B., Auer, B. & N. Muñiz-Miret (Spring 1993). TRI Initiative-Human health and effective utilization of tropical for*ests. TRI News-Journ*al of Tropical Resource Institute, Yale University School of Forestry and Environmental Studies 12(1): 1-2.

CHD 1: Land Use and Health in the Amazon: An Update of the Project's Second *Year*. TRI News, Spring 1995.

CHD 2: Montagnini, F. & N. Muñiz-Miret (August 3, 1995). Vegetation and soils of tidal floodplains of the Amazon estuary: A comparison of várzea andterra firme forest in Pará, Braz*il*. *Journal of Tropical E*cology submitted.

CHD 3: Muñiz-Miret, N., Vamos, R., Hiraoka, M., Montagnini, F. & R. Mendelsohn (1995). The Economic Value of Managing Açaí (Euterpe oleracea Maart) in the floodplains of the Amazon Estuary, Pará, Braz*il*. *Journal Ecological Econ*omics submitted.

The Yale Institute for

Biospheric Studies

YIBS Five Year Report

SUMMARY OF YIBS RESOURCE ALLOCATION FOR FIRST FIVE YEARS (For years 1991 through 1995/6)

PROGRAM AREAS	FUNDING LEVEL
1. Research Centers	$1,733,170

Center for Biological Transformation - support for 6 graduate students; 6 postdoctoral fellows; 1 lab assistant; equipment; symposia; travel; and supplies.

Center for Computational Ecology - support for 1 Program Analyst; 2 postdoctoral fellows; 2 graduate students; 1 undergraduate; 1 research assistant; partial salary for a laboratory manager; Hewlett Packard workstations, and a silicon graphics workstation.

Center for Earth Observation - support for 14 Silicon Graphics workstations; 1 Research Support Specialist; 9 undergraduate student assistants for summer work; computer software; development of course materials and publications.

Center for ECOSAVE - support for 1 undergraduate student assistant for summer work; computer hardware; travel; and supplies.

Center for Human Ecology, Environment and Infectious Disease - support for 7 graduate students; 1 Program Manager; 1 summer internship; international conference; and travel.

Center for Global Change - support for seminar series.

Center for Molecular Ecology and Systematics - training in molecular techniques.

2. Education	$616,253

Hitachi Internship Program - summer research support for 33 undergraduate students in Organismal Biology and 23 undergraduate students in Studies in the Environment.

Studies in the Environment Summer Internship Grant for Rising Seniors - support for 5 undergraduate summer thesis research projects for Studies in the Environment.

Hutchinson Prize - stipend support for 84 graduate students from the Departments of Biology, Anthropology, Geology & Geophysics, and the School of Forestry and Environmental Studies.

Administrative Assistance - support for 50% effort.

3. Program Supplement (non-recurring	$80,000

Funding utilized to set up laboratory for the new faculty member in the Department of Geology and Geophysics.

4. Faculty (includes salary and fringe benefits)	**$770,932**
Director of Undergraduate Studies for Studies in the Environment Oceanographer in the Department of Geology and Geophysics Director of the Peabody Museum	
5. Administrative Costs	
A. Staff (includes salary and fringe benefits)	**$747,015**
Development Director Assistant Development Director Administrator Administrative Assistant (50% effort)	
B. Operations	**$246,328**
Support includes funds for computer equipment, Yale in the Environment Forum, EcoRealism Conference, EAB meetings; travel; and publications (Newsletter, Theoretical Biology Brochure, Molecular Evolution Brochure).	
Total	$4,193,698