The Yale Institute for

Biospheric Studies

YIBS 1998-1999 Annual Report

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I. PERSONNEL APPOINTMENTS

Karl K. Turekian, Silliman Professor of Geology & Geophysics was appointed Director of the Yale Institute for Biospheric Studies - January 1, 1999 through July 31, 2001.

II. STUDENT PROGRAMS - Supported by the Donnelley Studies in the Environment Endowment Fund

A. Studies in the Environment Program

Chair, Professor Mary Helen Goldsmith
Director of Undergraduate Studies, Assistant Professor Steven Stoll

Studies in the Environment (SE) in Yale College offers a program for students interested in acquiring a more comprehensive understanding of complex environmental processes and issues than afforded by any single major in the natural or social sciences or the humanities. SE, offered only as a second major, provides students with the skills and depth of knowledge required to pursue an environmental career in government or the private sector, to continue their education in graduate and professional programs in business, law, or management of natural resources, and to become effective, informed citizens and stewards of the environment in their communities. SE emphasizes an interdisciplinary approach built on a strong foundation in the natural sciences, especially geology and ecology, subjects that also require a basic background in chemistry, physics, and biology. Essential components of the SE core curriculum are courses in economics, political science and policy analysis in the social sciences, and history and literature in the humanities. Regardless of their primary major, students in the program acquire basic scientific knowledge and practical skills. They become aware, inquiring, and observant, capable of formulating hypotheses, designing experiments, analyzing data, determining its statistical significance, analyzing risk, coming to decisions on the basis of present knowledge, and monitoring and adjusting course in response to unanticipated outcomes. Students in the program who are majoring in one of the humanities or social sciences clearly get a better education in natural sciences than do most of their peers

An Advisory Committee composed of faculty drawn from various participating departments discusses the development of the program and its curriculum. The faculty also provide a resource of information about the program for students with primary majors in their respective departments. The faculty for SE consists of a Director of Undergraduate Studies who is currently a member of the History Department, and a Chair who is currently a member of the Department of Molecular, Cellular and Developmental Biology. To satisfy all requirements of SE, except the new junior seminar and the senior colloquium, SE relies on courses taught by the participating departments which have been designed to satisfy their curricular goals, not the curriculum of SE. In designing their majors and courses, these departments do not consult the SE about the needs of SE students.

B. Support for Undergraduate Summer Internships - Funded by the Bingham Foundation Endowment Fund

Julie Bracken	Studies in the Environment and American Studies Earth System Field School Columbia University Biosphere 2 Center
Isaac Cheng	Studies in the Environment and Economics Agricultural Technology in China

	Technology in China
Elizabeth Cushingham	Department of Ecology and Evolutionary Biology Earth System Field School Session II Columbia University Biosphere 2 Center
Rachel Gruzen	Studies in the Environment and Architecture Consulting and studying with architects in Scandinavia, working on developing environmentally responsible designs.
Henry Kessler	Studies in the Environment and History Internship at Environmental Law Institute
Daniel MacPhee	Studies in the Environment and Department of Geology and Geophysics Yellowstone Big Horn Research Association -summer course in geological field methods.
Sarah McCullough	Studies in the Environment and Department of Ecology and Evolutionary Biology The role of an amphibian, eleutherodactylus copui, in ecosystem functioning in Puerto Rico.
Monique Mendez	Studies in the Environment and Department of Ecology and Evolutionary Biology Research and course participation at the primate behavior and ecology program in Panama.
Shari Rogal	Department of Ecology and Evolutionary Biology Earth System Field School Columbia University Biosphere 2 Center
Katherine Scharf	Studies in the Environment and History Internship with Mountain State Justice
Lauge	Studies in the Environment and
Sokol-Hessner	Department of Ecology and Evolutionary Biology Effects of intraguild predation among three spider species on grasshopper populations in an old-field interaction web.
Geoffrey Suttle	Studies in the Environment and Political Science Response of coyotes to the reintroduction of wolves in Yellowstone National Park.

C. Studies in the Environment Rising Seniors

Julie Brackin
Isaac Cheng
Rachel Gruzen
Henry Kessler
Katherine Scharf
Lauge Hessner Sokol
Geoffrey Suttle

D. G. Evelyn Hutchinson Prize - Graduate Students Support

Department of Ecology and Evolutionary Biology and
Department of Molecular and Cellular Biology

Homayoun Bagheri	*Regulatory Self-Maintenance in Metabolic Pathways and Evolutionary Strategies for Forming Physiological Adaptations*
Luis Cadavid	*Genetic and Molecular Characterization of Hydractinia Symbolongicarpus Allorecognition Locus*
Martin Hanczyc	*Evolving Complexity in and In Vitro Ribozyme System*
Maxim Shpak	*Algebraic and Probabilistic Properties of a Model of Random Unequal Crossing Over*
Michael Slotman	*The Introgression of Nuclear DNA that Occurs Between A. Arabiensis and A. gambiae*

Yale School of Forestry and Environmental Studies

Eva	*Adoption, Management, and Potential of Community Supported*

Cuadrado	*Agriculture*
Timothy Farnham	*The Concept of Biological Diversity*
Carlos Gonzales	*An Examination of Food Safety and International Trade: The Case of Beef Residue Limits in Latin America and Their Effects Worldwide*
Xinzhang Hu	*Numerical Simulation of Canopy Wave and Associated CO2 Flux in Forests*
B.	*Induced Edges in Forest Ecosystems: Tracking the Causes of*
Brooke A. Parry	*Change in Ecosystem Function*
Montira J. Pongsiri	*Risk in Decision Making: Managing Risk Tradeoffs in the Control of Malaria*

Department of Geology and Geophysics

Jessica Maisano	*Patterns and Postnatal Ossification in Squamates: Their Phylogenetic Informativeness and Relationship to Life History Characters and Climate Change*
Cynthia Marshall	*Comparative Analysis of Developmental Anatomy and Growth Patterns in Embryonic Paleognathes; with Comparisons to Embryonic Neognathes, Archosaurs and Non-avian Theorpods*
Steven Petsch	*Weathering of Sedimentary Organic Matter and the Geochemical Cycles of Oxygen and Carbon*

Department of Environmental Engineering

Jeffrey Chen
Eric Vrijenhoek

E. Yale Student Environmental Coalition (YSEC)

YIBS supported speaker Dianne Dumonoski – Our Stolen Future
Presented at the Yale School of Forestry and Environmental Studies in celebration of Earth Day 1999 – sponsored by the Yale Student Environmental Coalition (YSEC)

YIBS supported the Spring Fling Communiversity Day and eco-cabaret – INTOXICating - sponsored by YSEC and Greencorps

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III. GAYLORD DONNELLEY ENVIRONMENTAL FELLOWSHIP

Joseph Kiesecker, PhD.
1997-1999 Gaylord Donnelley Environmental Fellow

Joseph Kiesecker was selected as the first Gaylord Donnelley Environmental Fellow in the spring of 1997. He received his Ph.D. degree in zoology from Oregon State University in May of 1997 and shortly after arrived at the Yale School of Forestry and Environmental Studies (F&ES) to begin his two-year collaboration with David Skelly, assistant professor of ecology forestry at F&ES. While at Yale, his goal was to investigate the influence of fungal pathogens on the distribution of larval amphibians, and dynamics of their communities. The following is a report on his accomplishments while he was at Yale:

Research

During the past two years, Dr. Kiesecker collaborated with several scientists, including graduate students, post-doctoral fellows and professors. Pursuing his interest in disease ecology led him to examine the effects of pathogenic infection on behavioral interactions. He investigated how infection with pathogens may influence social interactions between larval amphibians. In laboratory experiments, tadpoles avoid associating with conspecifics infected with intestinal pathogens. This led to an exciting result and is one of the first demonstrations that animals can recognize and use behavior to avoid pathogenic infection. These results will have important ramifications for the understanding of disease transmission and this work has been accepted for publication in the Proceedings of the National Academy of Sciences, USA.

Dr. Kiesecker also examined the role that disease plays in regulating host populations. Diseases and pathogens are receiving increasing recognition as sources of mortality in animal populations. However, from an ecological standpoint, pathogens have been largely neglected. The work he conducted with digenetic trematode infections in larval amphibians has shown how environmental change can influence disease outbreaks and ultimately host populations. This work is also exciting and is not only one of the few

demonstrations that a pathogen can influence host population regulation, but also shows how environmental change can alter host-pathogen interactions. These results will improve the understanding of disease ecology and the role of disease in conservation issues. This work has resulted in Dr. Kiesecker's submission of two manuscripts that are currently in review.

In addition, Dr. Kiesecker continued to collaborate with researchers at Oregon State University and the University of Maine. This collaborative work allowed him to continue to pursue his interest in amphibian conservation and behavioral ecology. Work from these research projects resulted in eight manuscripts. While at Yale, he began collaborating with Dr. David Skelly (Yale School of Forestry and Environmental Studies and the Department of Ecology and Evolutionary Biology), and this collaboration will continue and will maintain his link with Yale University after he assumes his position as an assistant professor at Pennsylvania State University's Department of Biology. He has also worked with Dr. Skelly on projects that examine the role of food resources and the ecology of larval amphibian communities and how large scale changes in forest canopy cover can alter these associations. This work resulted in two publications that are currently in review.
While in residence at Yale, Dr. Kiesecker submitted sixteen manuscripts, eleven of which have been accepted for publication (see below).

eleven of which have been accepted for publication (see below).

Manuscripts resulting from Donnelley Fellowship support:

Kiesecker, J.M. and A.R. Blaustein.1998. Effects of introduced bullfrogs and small mouth bass on the microhabitat use, growth and survival of native red-legged frogs. Conservation Biology. 12:776-787.

Kiesecker, J.M. 1998. (Book Review): Amphibians in decline: Canadian studies of a global problem. Edited by David M. Green. Copeia 1998:813-815.

Blaustein, A.R., Kiesecker, J.M., Chivers, D.P. and R.G. Anthony. 1997. Ambient UV-B radiation causes deformities in amphibian embryos. Proceedings of the National Academy of Science, USA. 94:13735-13737.

Marco, A., Kiesecker, J.M., Chivers, D.P. and Blaustein, A.R. 1998. Sex recognition and mate choice by male western toads (Bufo boreas). Animal Behaviour, 55:1631-1635.

Wildy, E.L., Chivers, D.P., Kiesecker, J.M. and A.R. Blaustein. 1998. The effects of intraspecific predation on growth in larval long-toed salamanders, Ambystoma macrodactylum. Journal of Herpetology. 32:286-289.

Blaustein, A.R., Kiesecker, J.M. et al. 1999. Using field experiments to examine the effects of ultraviolet radiation on amphibians. American Zoologist. 38:799-812.

Kiesecker, J.M., Chivers, D.P., Marco, A., Quilchano, C., Anderson, M.T and A.R. Blaustein. 1999. Identification of a disturbance signal in larval red-legged frogs (Rana aurora). Animal Behaviour. 57:1295-1300.

Kiesecker, J.M., Skelly, D.K., Beard, K. and E. Pressier. Behavioral Reduction of Infection Risk. In Press Proceedings of the National Academy of Sciences, USA.

Kiesecker, J.M. and A.R. Blaustein. Pathogen reverses competition between larval amphibians. In Press Ecology.

Blaustein, A.R. Hoffman, P., Hayes, J.B., Chivers, D.P., Kiesecker, J.M., et al. The influence of ambient UV-B on embryos of the spotted frog (Rana pretiosa). In Press Ecological Applications.

Blaustein, A.R., Chivers, D.P., Kats, L.B. and J.M. Kiesecker. Effects of Ultraviolet Radiation on Locomotion and Orientation in Roughskin Newts (Taricha granulosa) . In Press Ethology.

Kiesecker, J.M. and D.K. Skelly. Interactions of disease and pond drying on the growth, development and survival of the gray treefrog (Hyla versicolor). Submitted to Ecology. 38 pages.

Kiesecker, J.M. and D.K. Skelly. Choice of oviposition site by gray treefrogs, Hyla versicolor: the role of potential parasitic infection. Submitted to Ecology. 21 pages.

Kiesecker, J.M., Miller, C.L. and A.R. Blaustein. Potential mechanisms underlying the displacement of native red-legged frogs by introduced bullfrogs. Submitted to Ecology. 37 pages.

Skelly, D.K. and J.M. Kiesecker. The importance of larval competition in amphibian assemblages: comparison of experimental venue using a metaanalysis. Submitted to American Naturalist. 31 pages.

Skelly, D.K., Freidenberg, L.K. and J.M. Kiesecker. Forest canopy and the performance of larval amphibians. Submitted to Ecology. 33 pages.

Additional Work:

Dr. Kiesecker was a guest lecturer in the Conservation Biology and Landscape Ecology courses offered by the Yale School of Forestry and Environmental Studies. In September 1997, he was an instructor at the Yale Society for Conservation Biology Weekend Methods Retreat at the Great Mountain Field Station. He also took advantage of the numerous talks and seminars that were presented by the Yale School of Forestry and Environmental Studies and the Department of Ecology and Evolutionary Biology and also was invited to present the results of his research at other universities.

Invited Seminars while at Yale:

University of Connecticut, Department of Ecology and Evolutionary Biology - November 1997

University of Maine, Department of Biological Sciences - December 1997

Hartwick College, Department of Biology - May 1998

Pennsylvania State University, Department of Biology - December 1998

Dr. Kiesecker has shared the results of his research with members of the scientific community and was invited to speak at a symposium, Development in a Volatile World: How Embryos Cope With Environmental Stress, at the American Association for the Advancement of Science 150th Anniversary Meeting in Philadelphia, Pennsylvania in February1998. He also presented the results of research at several professional meetings including the Society for Conservation Biology's annual meeting in Sydney, Australia, July 1998; American Society of Ichthyologists and Herpetologist's annual meeting in University Park, Pennsylvania, June 1999; The annual meeting of the Association for the Study of Animal Behaviour in Harrisburg, Pennsylvania, July 1999.

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IV. RESEARCH CENTERS

A. Center for Biological Transformation
May 1999

L. Nicholas Ornston, Director

The challenge for environmental bacteria is to minimize the toxicity of undesirable chemicals while maximizing opportunities for growth with desirable compounds. Toxic in high concentration, some chemicals may serve as growth substrates in diluted form. Such chemicals present bacteria with adversity that may be turned to advantage. The objective for the bacterium is to present barriers to adversity while fostering potential advantage. Much of this can be achieved at the outer membrane by selective filtration and at the inner membrane by pumping in what is beneficial and pumping out what is detrimental.

Viewed from this perspective, the core of nutritional versatility in bacteria becomes much more than a complex set of metabolic reactions. Physical as well as chemical responses are required to shifting conditions, and bacteria must anticipate both opportunity and hazard in their changing chemical environment. Evolution builds upon precedent, and the small genome size of bacteria makes it inevitable that different sets of responses have evolved in response to similar challenges. So analysis of the nutritional versatility of bacteria leads directly to a study of the origins of evolutionary diversity.

If a single theme emerges from this recent research, it is the fluidity of biological systems. DNA, often heralded as the secure store of genetic information, can undergo programmed loss or change. Enzymes can function despite seemingly major changes in their structure. One transport system can compensate for loss of function in another. Complex metabolic transformations that might be harmful inside the cell can be achieved outside the cell membrane. Emerging from these investigations are strategies that have been successfully applied by bacteria over the ages and that form a repository of knowledge for design of bacteria to meet novel challenges.

Publications:

1. Gerischer, U., A. Segura, and L. N. Ornston. 1998. PcaU, transcriptional activator of genes for protocatechuate utilization in Acinetobacter. J. Bacteriol. 180:1512-1524.

2. Kok, R. G., D. A. D'Argenio, and L. N. Ornston. 1998. Mutation analysis of PobR and PcaU, closely related transcriptional activators in Acinetobacter. J. Bacteriol. 180: 5058-5079.

3. Kok, R. G., D. M. Young, and L. N. Ornston. 1999. Phenotypic expression of PCR-generated random mutations in a Pseudomonas putida gene after its introduction into an Acinetobacter chromosome by natural transformation. Appl. Env. Microbiol. 65: 1675-1680.

4. A. Segura, P. V. Bünz, D. A. D'Argenio, and L. N. Ornston. 1999. Genetic analysis of a chromosomal region containing vanA and -B, genes required for conversion of either ferulate or vanillate to protocatechuate in Acinetobacter. J. Bacteriol. In Press

5. D. A. D'Argenio, A. Segura, W. M. Coco, P. V. Bünz, and L. N. Ornston

J. D. A. D'Argenio, A. Segura, W. M. Coco, P. V. Bunz, and L. N. Ornston. 1999. The physiological contribution of Acinetobacter PcaK, a transport system that acts upon protocatechuate, can be masked by the overlapping specificity of VanK. J. Bacteriol. In Press

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B. Center for Computational Ecology (CCE)
May 1999

Oswald J. Schmitz, Acting Director

During the past year, The Center for Computational Ecology (CCE) maintained its high level of research productivity, producing ten research papers published in, or submitted to top peer-review journals.

Some of the products of the research (e.g., Gecko simulator for complex ecological systems) are available to researchers outside of Yale University to assist in their endeavors to model dynamics in their own specific systems. For example, researchers in the United Kingdom, in conjunction with CCE computer programmer Ginger Booth, have developed Bacsim, a second-generation version of Gecko which they used to do individual-based modeling of bacterial colony growth. More importantly, this research collaboration was done entirely electronically via the World Wide Web.

CCE has also moved vigorously forward to satisfy its teaching mission. It was awarded three separate grants (Howard Hughes, NECUSE and Yale ITS) to develop and implement teaching software to support existing science courses at Yale. The first phase of this initiative required the development of generic software that could be implemented in courses served over the Web. CCE programmer Ginger Booth designed and programmed CourseWare, a generic software platform that facilitates the implementation of simulation programs for specific class assignments. CourseWare not only runs specific simulations, it also produces graphical output to display data from the simulations and can be viewed at http://frog.biology.yale.edu/ginger/java/index.html. The

intent of this software is to allow different science courses to develop assignments that complement material covered in a lecture, and implement those assignments with minimal up-front software development each time a new course is developed. The idea to serve the assignments over the Web is based on the idea that students should have freedom to access the assignments at any time and place. Also, they should have complete freedom to explore and play with assignments outside the strict confines of a protracted weekly lab meeting. This represents a fundamental move toward greater self-directed learning. Funding was also used to implement Community Ecology Lab Assignments in CourseWare. This was completed at the end of December. The web-served lab assignments were implemented this past winter in the School of Forestry and Environmental Studies (F&ES) course number 563/Department of Ecology and Evolutionary Biology (EEB) course number 340, Community Ecology. F&ES/EEB Professor Oswald Schmitz taught Community Ecology with very promising success.

The goals of CCE for the upcoming year are: to continue with research progress on modeling problems of scaling in complex systems; to develop additional laboratory assignments in CourseWare to support Landscape Ecology taught by F&ES/EEB Professor D.K. Skelly; and to begin to offer small grants and fellowships to support graduate student research in CCE.

C. Center for Earth Observation (CEO)
May 1999

Ron Smith, Director

The Yale Center for Earth Observation (CEO) was formed in 1992 as one of the original Yale Institute for Biospheric Studies' (YIBS) Centers. With two full time staff members, CEO supports remote sensing research and mapping activities of Yale students, faculty and staff, as well as assisting regional organizations. The current CEO steering committee members are Ronald Smith, Department of Geology and Geophysics (G&G), Frank Hole, Department of Anthropology, Xuhui Lee, Yale School of Forestry and Environmental Studies (F&ES), and Durland Fish, Department of Epidemiology and Public Health (EPH).

Activities:

1) The summer and fall of 1998 was the transitional period for the new CEO computer system. This system, two SGI servers and eight SGI workstations, were purchased with funds from a NASA Centers of Excellence Grant awarded in the previous year. With new documentation and software added during the fall semester, the capability of CEO's remote sensing analysis system ranks as one of the best in the country.

2) The largest research project at CEO, the South West Asia Project (SWAP), entered its third year in 1999. This NASA-funded project examines the changing landscape and related water resources of the Middle East using a variety of remote sensing methods. Center staff sponsored a Workshop on

Remote Sensing in the Middle East in Aleppo, Syria in November 1998, in cooperation with the International Center for Agricultural Research in Dry Areas. Other active CEO projects include risk factors for Lyme disease, agroforestry in Africa, and coastal wind dynamics.

3) After a year's break, the course Observing the Earth from Space was offered in the spring term (1999). The student enrollment of 35 included about 18 from the F&ES Master's program as well as graduate and undergraduate students from G&G, Anthropology, Economics, Astronomy and Studies in the Environment. Student project topics included ocean productivity, Quinnipiac River watershed, deforestation in Africa, erosion in the Alps, carbon cycle dynamics, Cambodia burial sites, fruit bat ecosystems, Gulf Stream eddies, Malaria in Australia, Suburban sprawl, dust storms, and mangrove changes in Indonesia. Oral reports of the projects were given on April 29, 1999.

CEO faces several challenges in the coming year. It must meet the growing student demand for remote sensing courses and project assistance and prepare for the onslaught of new remote sensing data sets in 1999 and beyond, from the suite of EOS satellites. It must broaden the remote sensing expertise of the Yale faculty so that the innovative teaching and research programs made possible by CEO are more fully explored.

In May of 1999, CEO will move from Bingham Laboratory to Kline Geology Laboratory in rooms 103 and 116. CEO will occupy these quarters until new space in the Environmental Sciences Facility is completed in mid 2001.

Further information about CEO is available from Mr. L. Bonneau at (203) 432-3142, or from its website at http://www.stormy.geology.yale.edu/ceo.html.

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IV. RESEARCH CENTERS

D. Center for Ecology and Systematics of Animals on the Verge of Extinction (ECOSAVE)

May 1999

Elisabeth Vrba, Director
Jeffrey Powell
Jacques Gauthier

A highlight in Elisabeth Vrba's ECOSAVE program was the completion of the volume Deer, Antelopes, Giraffes, and Relatives: Past, Present and Future (eds Vrba, E.S. and Schaller, G.B.) with chapters from 22 international contributors. This volume was sponsored by YIBS and the Wildlife Conservation Society, New York, to which Elisabeth was recently elected as a Fellow. The volume will appear on the spring 2000 booklist of Yale University Press. The following topics on deer, antelopes and relatives were discussed: their fossil record, origins, evolution, diversification, systematics; palaeobiogeography, including major migrations; past tectonic and palaeoclimatic changes associated with ruminant evolution; causes of major speciation and extinction episodes; ecology and behaviour in the past; systematics of living species based on gene sequences, hard and soft anatomy and behaviour; ecology, behaviour and evolution; present biogeography; what the past and present information indicates for conservation : population conservation genetics; which taxonomic level and which taxa and ecosystems merit conservation priority; implications of greenhouse warming; management and role of zoos, national parks, etc.; 'sustainable use' on game ranches and by local peoples; reintroductions.

New systematic analyses of living and extinct antelopes (Bovidae) culminated in the monographic publication 1 (see Vrba publications 1 –7 below) and in the first cladistic analysis of bovids that combines behavior and ecology with soft and hard anatomy (publ. 6). Collaboration with other members of the Middle Awash Research Program on new fossil finds from Late Neogene Ethiopian fossil strata resulted in the recent publication 3 in Science on the

environment and behavior of the new hominid species Australopithecus garhi. A comprehensive new analysis of the all-African fossil record of larger mammals over the past 22 million years was completed and used to test hypotheses of macroevolution (publication 7). A long-standing interest in the relationships between climate, evolution, and organismal growth is represented by an analysis with a new statistical growth model of brain growth data in chimpanzees and humans (publication 2).

Papers (appeared or in press) by Elisabeth Vrba during 1998-1999:

1. Vrba, E.S. 1998. (Monograph.) New fossils of Alcelaphini and Caprinae (Bovidae, Mammalia) from Awash, Ethiopia, and phylogenetic analysis of Alcelaphini. Palaeontologia africana 34: 127- 198.

2. Vrba, E.S. 1998. Multiphasic growth models and the evolution of prolonged growth exemplified by human brain evolution. Journal of Theoretical Biology 190: 227-239.

3. de Heinzelin, J., Clark, J.D., White, T., Hart, W., Renne, P., WoldeGabriel, G., Beyene, Y. and Vrba, E.S. 1999. Environment and behavior of 2.5-million-year-old Bouri hominids. Science 284: 625-629.

4. Vrba, E.S. and Schaller, G.B. (eds. of book) In press. Deer, Antelopes, Giraffes, and Relatives: Past, Present and Future. Yale University Press, New Haven, Connecticut.

5. Vrba, E.S. and Schaller, G. B. In press. Introduction. In Vrba, E.S. and Schaller, G.B. (eds.) Deer, Antelopes, Giraffes, and Relatives: Past, Present and Future. Yale University Press, New Haven, Connecticut.

6. Vrba, E.S. and Schaller, G. B. In press. Phylogeny of Bovidae (Mammalia) based on behavior, glands and skull morphology. In Vrba, E.S. and Schaller, G.B. (eds.) Deer, Antelopes, Giraffes, and Relatives: Past, Present and Future. Yale University Press, New Haven, Connecticut.

7. Vrba, E.S. In press. Major features of Neogene Mammalian Evolution in Africa. In T.C. Partridge and R. Maud (eds.), Cenozoic Geology of Southern Africa. Oxford University Press, Oxford, United Kingdom.

8. Vrba, E.S. In press. Habitat theory in relation to the evolution in African Neogene biota and hominids. In T.G. Bromage and F. Schrenk (eds.), African Biogeography, Climate Change, and Early Hominid Evolution. Part of New Series on Human Evolution (Series Eds Wood, B. and Ciochon, R.). Oxford University Press, Oxford, United Kingdom.

The Center for the Study of the Ecology and Systematics of Animals on the Verge of Extinction (ECOSAVE) focuses on understanding the biodiversity crisis on two time-scales. A long-term view is provided by analyses of evidence for ecosystem changes in the fossil record and the reconstruction of phylogenetic relationship of extinct and extant taxa. A more contemporary view is provided by genetic analyses of extant species. Understanding the historical and contemporary patterns of biodiversity provides the scientific basis for developing effective strategies for maximizing biodiversity. One major

initiative this past year was the establishment of the Molecular Systematics and Conservation Genetics Laboratory directed by Gisella Caccone. This facility has both a research and training mission.

Research:

Two research projects have focused on tortoises. One study was on endemic Madagascar tortoises, two of which are considered rare and endangered. The results showed that contrary to accepted classifications, Madagascar tortoises form a monophyletic clade consistent with a single founding of tortoises on Madagascar. This work is "in press" and was done in collaboration with workers from the Wildlife Conservation Society and a Yale undergraduate. The second tortoise project concerns the conservation genetics and phylogenetics of giant Galápagos tortoises. To date over 2,000 blood samples have been collected from several subspecies of these tortoises. These samples will be analyzed using modern DNA technology. This past year the phylogenetic relationships of the subspecies were determined as well as identifying the likely closest living relative of the Galápagos tortoises (manuscript submitted); surprisingly, this was the smallest mainland South American tortoise, the Chaco tortoise. Also, from these results we are confident that we will be able to determine the island origin of Galápagos tortoises based on DNA data. This will be useful in determining the origin of captive animals of unknown origin that then might be placed back into the wild if the subspecies is threatened.

Another project, with graduate student Kristin Saltonstall, concerns an invasive plant, Phragmites, that has recently undergone a large range expansion in both freshwater and brackish wetlands. It is threatening native biodiversity. Why this species is suddenly spreading is not clear; one hypothesis is that a new genotype has colonized the United States. Genetic studies of modern populations compared to herbarium specimens and old core samples will determine if there has been a genetic shift. The data that is being collected is a combination of DNA sequences, microsatellites, and karyotypes.

In collaboration with Dr. Caccone, Geology and Geophysics Professor Jacques Gauthier, has been studying zantusiid lizards native to the Southwest United States. Based on mitochondrial DNA sequences, it appears that a new species has been identified, Xantusia arizonae. Like all other xantusiids, it is essentially a troglodyte living its entire life in a confined space from which it seldom emerges. All aspects of its biology, its low metabolism, slow growth

and reproductive rates, dark-adapted eyes, suit it to the challenges of its preferred microhabitat. The newly recognized Xantusia arizonae represents the earliest and least modified derivative of the rock-morph line. Recognition of a new rock-morph species will have important implications for conservation efforts in Arizona. Xantusia vigilis - the Yucca dweller to which Xantusia arizonae is currently allied as a subspecies - is widespread, locally abundant and lives in a readily renewable habitat, so it enjoys no special protection in Arizona. That poses a potential problem for the Xantusia arizonae rock-morph, however, as it lives primarily beneath exfoliating granite, a habitat that replaces only very slowly. Habitat modification has always been a prime

factor in extinction. To ensure robust local populations of Xantusia arizonae, the state of Arizona should consider modifying current practices, for example, by outlawing crowbar use and other destructive collecting practices in rocky habitats.

Teaching and training:

Part of the mission of the Molecular Systematics and Conservation Genetics Laboratory is teaching and training both graduate and undergraduate students. This past year, Dr. Caccone offered one formal course: Molecular Approaches to Systematics, Conservation Genetics and Behavioral Ecology. A new course has been planned for the fall: Laboratory in Molecular Systematics. In addition, four graduate students and two undergraduates received training directly in the laboratory. Six more students received training on use of our computer facilities for analysis of molecular data.

Major accomplishments in Jacques Gauthier's laboratory included reorganization of the Divisions of Vertebrate Zoology and Vertebrate Paleontology in the Peabody Museum to better meet research and teaching needs of the Departments of Ecology and Evolutionary Biology, Geology and Geophysics, and Anthropology, as well as the Environmental Sciences Facility, Yale Institute for Biospherics and the Yale School of Forestry and Environmental Studies. Jacques organized the Ostrom Symposium: New Perspectives on the Origin and Early Evolution of Birds. A group of 24 scientists from around the world came to New Haven over the weekend of February 13 -14 to address an audience of 500 honoring Yale Emeritus Professor John Ostrom's contributions to dinosaur paleontology and evolution. Jacques is currently editing the 35 invited papers submitted to the Ostrom Symposium Volume, which should appear in 2000. He also produced, directed and wrote an exhibit entitled China's Feathered Dinosaurs' that opened on the weekend of the Ostrom Symposium and remained on display in the Yale Peabody Museum of Natural History for three months in the spring of 1999. A research highlight was the developmental and evolutionary analysis of the avian hand (publications 2 – 4 below) 1998-1999.

Papers (appeared or in press) by Jacques Gauthier during 1998-1999:

1. Britt, B., P. Makovicky, J. Gauthier. 1998. Postcranial pneumaticity in Archaeopteryx . Nature 395:374-376.

2. Gauthier, J. and G. Wagner. 1998. I,II,III or II,III,IV or both?: A solution to the problem or avian digit homology. Abstract In: Journal of Vertebrate Paleontology 18(3):45A-46A.

3. Wagner, G.P. and J.A. Gauthier. 1999. 1,2,3 = 2,3,4: A solution to the problem of the homology of the digits in the avian hand. Proceedings of the National Academy of Sciences 96:5111-5116.

4. Gauthier, J. and G. Wagner. 1999. 1-2-3 or 2-3-4 or both?: A solution to the problem of avian digit homology. Abstract In: American Society of

Ichthyologists and Herpetologists (79th). Penn. State Univ., State College.

E. Center for the Study of Global Change (CEO)
May 1999

Karl K. Turekian, Director

The Center for the Study of Global Change accomplishes its goals through various ways:

- Through a series of weekly seminars on Global Change topics

- Through a series of weekly seminars on Global Change topics.
- By providing an environment for visiting scientists such as Dr. Ellen Thomas, a former Global Change scholar still active in this Center.
- By participation of its Director in the planning and execution of a Global Change program at Schlumberger-Doll Research Center in Ridgefield, Connecticut, in honor of their 50th anniversary. Several Yale alumni and faculty were involved.

Global Change Seminar Series

Light Stable Isotopes in Biogenic Systems as Environmental Signatures

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Fall, 1998

September 14, 1998 - D. Rye, Department of Geology and Geophysics, Yale University: *Principles of light stable isotope fractionation*

September 21, 1998 - R. Blake, Deparment of Geology and Geophysics, Yale University: *Oxygen isotope systematics of microbially mediated reactions phosphate*

September 28, 1998 - Y. Kolodny, Hebrew University: *Paleoreconstructions with phosphatic deposits*

October 5, 1998 – J. Kingston, Department of Geology and Geophysics, Yale University: *___C_____S and _18O and diet reconstruction*

October 12, 1998 - M. Bender, Princeton University: *The elemental and isotopic chemistry of atmospheric oxygen*

October 19, 1998 – T. Cerling, University of Utah: *CO2 starvation, development of C4 ecosystems and mammalian evolution*

November 9, 1998 – K. Miler, Rutgers University: *Global sea level change during the past 90 million years: _18O and the New Jersey Margin record*

November 16, 1998 - D. Shrag, *Harvard University: _13C in deep sea deposits and pore waters*

December 4, 1998 - G. Farquhar, Australian National University, Canberra: *Global change: a plant perspective*

Spring, 1999

January 18, 1999 – Ellen Thomas, Yale University: *Deep-sea methane hydrates and their influence on climate and the carbon isotope record*

January 5, 1999 – Karl K. Turekian, Yale University: *The effects of climate, sea level change and tectonics on the Os isotope record in marine sediments*

February 8, 1999 – Kristina Beuning, Wesleyan University: *Paleohydrology of Lake Victoria, East Africa inferred from 18O/16O in sediment cellulose*

February 15, 1999 - Ronald Smith, Yale University: *Large scale aspects of middle east hydrology as seen from space*

March 1, 1999 – Edward A. Boyle, Massachusetts Institute of Technology: *Is there a relationship between abrupt stadial/interstadial climate changes and deep ocean circulation?*

March 22, 1999 – Donald T. Rodbell, Union College: *Continuous records of late Quaternary climate change and El Nino activity from high elevation lakes in the tropical Andes*

March 29, 1999 – D. James Baker, Administrator, NOAA (Zucker Fellow): *Sustainability - a Luce Hall paradigm for the future*

April 5, 1999 – H. Thomas Rossby, University of Rhode Island: *Current switching as a mechanism for rapid climate change*

April 12, 1999 - Barry Saltzman, Yale University: *Heinrich surge events as an internal property of ice sheets*

April 19, 1999 - Ariel Anbar, University of Rochester: *New approaches to the early Earth*

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V. SPONSORED PROGRAMS AND SEMINARS

A. Society for Conservation Biology Seminar Series

February 25, 1999 – Dr. Chris Raxworthy, Professor of Ecology, University of Kansas – Herpetological diversity and conservation in Madagascar

April 2, 1999 – Drs. Peter and Rosemary Grant, Professors of Ecology and Evolutionary Biology, Princeton University – Biological Conservation in the Galapagos

April 15, 1999 – Dr. Daniel Simberloff, Professor of Ecology, University of Tennessee at Knoxille – Charactger release in the small Indian mongoose, and ecological villain

April 22, 1999 – Dr. David Ehrenfeld, Professor of Ecology and Natural Resources, Cook College, Rutgers University – War and Peace and Conservation Biology

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B. Invasive Species Conference

February 27, 1999 – Greater New England Symposium on the Ecology of Invasive Species - at the Yale School of Forestry and Environmental Studies.

Presentations, posters, and discussion of current scientific research on invasive animals and plants of the New England region.

C: Global Change Policy Project

Support of the following list of activities and publications for the Global Change Policy Project, Yale Center for Environmental Law and Policy:

Meyerson, F.A.B., Population and Climate Change Policy, book chapter in Schneider, S., A. Rosencranz, edsl, A Climate Policy Primer

Meyerson, F.A.B., Global Population Growth and the Future: Why the U.S. Should Care, Congressional Briefing, 2200 Rayburn House Office Building,

Washington, D.C., March 9, 1999. (with John Haaga, Ph.D., Population Reference Bureau, sponsored by the office of Congressman Tom Campbell)

Meyerson, F.A.B., Population and Global Warming Policy Options, Population-Environment Forum, American Association for the Advancement of Science (AAAS), Washington, D.C., January 25, 1999. (with Stuart Gaffin, Ph.D., Environmental Defense Fund, and Robert Engelman, Population Action International)

On May 19-23, 1999, Fredrick Meyerson represented the Project and Center at the Brazil-US Aspen Global Forum on Carbon Emission Reductions, the third in a series of meetings of representatives of 40 key United States and Brazilian governmental, NGO and academic entities, including the United States State Department, EPA, UNDP, WRI, EDF, Enron, General Motors, Toyota, Champion, and parallel Brazilian organizations.

VI. COURSES

Studies in the Environment 199a/F&ES 199a, Introduction to Environmental Studies

Studies in the Environment 205bg/EEB 155b/MCDB 150bg, Global Problems of Population Growth

Studies in the Environment 286b/MCDB 255b, Functioning of Plants in Agriculture and Ecosystems

Studies in the Environment 466b, Multidisciplinary Approaches to Managing Earth and Its Resources

Studies in the Environment 469a, Senior Research Project and Colloquium

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VII. MEMBERS OF THE FACULTY COUNCIL

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Professor, Department of Geology and Geophysics

Günter Wagner
Chair, Department of Ecology and Evolutionary Biology
Professor, Department of Ecology and Evolutionary Biology

Robert Wyman
Professor, Department of Molecular, Cellular and Developmental Biology

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VIII. MEMBERS OF THE EXTERNAL ADVISORY BOARD

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1998 - 1999 G. Evelyn Hutchinson Prize Graduate Student Abstracts

Index

Regulatory Self Maintenance in Metabolic Pathways and Evolutionary Strategies for Forming Physiological Adaptations

Homayoun Bagheri
Department of Ecology and Evolutionary Biology

In previous stages of my research it had been concluded that in order to address the evolution of metabolic pathways, a model is required which includes a causal understanding of enzyme kinetics at the single enzyme level. Subsequently this understanding has to be incorporated into a multi-enzyme pathway. I have successfully implemented the afore mentioned steps and have developed a model which captures metabolic pathways at the physiological level. In doing so I have also encountered and addressed several serious problems associated with metabolic control theory that relates to both physiology and evolution. Metabolic control theory has been used in its present format since 1973. Addressing these problems has opened the possibility for me to address metabolic evolution at a much deeper level

than has been possible so far.

The above mentioned model of metabolic physiology has to be now introduced into an evolutionary context so that we may study different physiological architectures in terms of three evolutionary properties: 1) physiological performance (fitness), 2) adaptability (fitness in different environments) and 3) evolvability (mutational properties of particular architectures). Physiological architecture refers to differences in terms of a) pathway structure, b) kinetic properties of the enzymes and c) regulatory relations within the pathway.

Genetic and Molecular Characterization of Hydractinia Symbiolongicarpus Allorecognition Locus

Luis F. Cadavid
Department of Ecology and Evolutionary Biology

Colonial invertebrates typically discern between self-tissues and those from unrelated individuals of the same species. These allorecognition phenomena have played a significant role in several biological questions such as the origin and maintenance of genetic variation, the problem of units of selection in evolutionary theory, and the evolution of the vertebrate immune system. Despite the ubiquity of invertebrate allorecognition events and its prominence in biological thought, the responsible molecules and the encoding genes remain unknown.

Hydractinia symbiolongicarpus (Cnidaria: Hydrozoa) displays an unequivocal allorecognition response involving either fusion or rejection of conspecific tissues. The latter outcome involves an effector response characterized by site-specific differentiation, transport, and triggering of nematocysts, the stinging organelles. The allorecognition response in H. symbiolongicarpus segregates as a single co-

dominant Mendelian trait. Colonies sharing one or both alleles fuse and those lacking shared alleles reject.

This study proposes a genetic and molecular characterization of the allorecognition locus (arl) in Hydractinia symbiolongicarpus, employing chromosome-landing strategies. The approach involves the use of Amplified Fragment Length Polymorphisms (AFLPs) to generate large numbers of markers linked to arl. We are using near-isogeneic lines, previously established in our laboratory, to generate offspring pools of homozygotes for arl; AFLP markers that are linked to the locus of interest are identified by presence in one pool and absence in the other. Using the correct number of offspring in each pool, we will identify markers lying in a 1 cM arl-spanning interval. After a high-resolution mapping of the AFLP markers using a large F2 mapping population, the markers of the most tightly linked flanking arl will be detected. These markers, in turn, will serve to screen a BAC library, generating thus a small collection of contiguous positive BAC clones. The arl-containing clones will be used as probes to screen a ectodermal-enriched cDNA library and candidate genes showing appropriate expression patterns and polymorphic domains that cosegregate with fusibility, will be selected for further functional analysis.

At this point, we have generated the homozygous pools and are actively searching for cosegregating markers.

Evolving Complexity in an In Vitro Ribozyme System

Martin Hanczyc
Department of Genetics

Using an in vitro mimic of the Darwinian process, a population of molecules can be mutated, amplified and selected for multiple generations, giving rise to a descended population of evolved molecules with enhanced, selected activity. While selecting the group I ribozyme (an RNA enzyme) from Tetrahymena thermophila for improved DNA cleavage activity, I observe an unexpected bifurcation resulting in active ribozymes that effect DNA cleavage and inactive ribozyme variants that act as trans substrates for the active ribozymes in the population. This intermolecular interaction ensures the propagation of both the active and inactive molecular species in the population. I show the specific nucleotide changes that have evolved to promote this intermolecular reaction and explore the mechanism of the interaction revealing the source of the nucleophile and the electrophile.

Kinetic analyses suggest that these inactive ribozymes are not parasites since there is no detrimental effect of the inactive variants on the action of the evolving ribozymes. I conclude from these studies that complex molecular roles have evolved in a few generations in a system that was initially designed to produce a singular, selected outcome.

Algebraic and Probabilistic Properties of a Model of Random Unequal Crossing Over

Maxim Shpak
Department of Ecology and Evolutionary Biology

In collaboration with Günter P. Wagner and Kevin Atteson, I have investigated the algebraic and probabilistic properties of a model of random unequal crossing over. The research was motivated by the idea of gene duplication by unequal recombination being a source of evolutionary innovation, i.e. a process which generates new dimensions of evolutionary space rather than simply changing frequencies within fixed state spaces. The evolutionary implications of this model, along with a formal algebraic treatment of the structure of the configuration spaces induced by unequal crossover are treated in a paper in preparation with G. P. Wagner, while the treatment of the special type of reversible stochastic process representing this recombination scheme is to appear in a work in progress with Kevin Atteson. I hope to include some of this material in my doctoral thesis, in which I hope to treat the question of how symmetric recombination and hence well defined "alleles" and "loci" evolved from more primitive and less controlled genetic systems.

I spent the summer of 1998 collaborating with N. H. Barton at the University of Edinburgh on several problems in theoretical quantitative genetics. Principally, we investigated two problems: the accuracy of linkage-equilibrium models of cline shape represented by diffusion approximations and the stability of concordant solutions to multilocus clines (i.e. solutions to selection/migration regimes, which give equal allele frequencies across all loci).

The Introgression of Nuclear DNA that Occurs Between A. arabiensis and A. gambiae

Michel Slotman
Department of Ecology and Evolutionary Biology

The Anopheles gambiae complex consists of six closely related species that were only fairly recently found out as being distinct species. Several of these, especially A. gambiae and A. arabiensis, are among the most important vectors of malaria in Africa, where about 90% of the world's yearly 200 to 300 million cases of malaria occur. In trying to resolve the phylogenetic relationships among these taxa using mitochondrial, as well as different nuclear genes, several incongruencies have been observed. The most parsimonious explanation for the current data is that introgression of nuclear DNA is occurring between A. arabiensis and A. gambiae.

In order to investigate to what extent different regions of the genome can actually introgress between these two species, we are analyzing the genetic structure of backcrosses between A. gambiae and A. arabiensis. At this point these crosses are provided by a collaborator in Rome. These crosses were (or will be) made according to the following scheme: A. arabiensis is crossed with A. gambiae, which yields the F1 generation. F1 males are sterile, whereas the females are fertile. The F1 females are backcrossed with both A. gambiae and A. arabiensis males. This results in the F2 generation. The F2 generation is then analyzed with respect to fertility by dissection of the reproductive organs.

This F2 generation is subsequently analyzed genetically, i.e. we are using microsatellite markers to analyze the genetic make-up of these specimens. About 130 microsatellite loci, mapped on the A. gambiae genome, have been published by L. Zheng. We are using a large number of these loci to distinguish which parental strain a particular portion of the genome comes from. This should not only provide us with information as to what extent introgression is actually possible, but also if introgression of some chromosomal regions is easier than others and if introgression can go in both directions. However, it will also shed some light on some of the underlying genetic processes of speciation in these mosquitoes. That is, it will allow us to say something about the number as well as the location of genes that are

involved in causing sterility.

**Application of an Ecosystem Approach to Agricultural Systems:
A Comparison of Conventional, Certified Organic and Community Supported Agricultural Farm Models**

Eva Cuadrado
Yale School of Forestry and Environmental Studies

Farming requires adaptability and innovation. In recent years, many farmers have significantly modified their production practices in order to accommodate demands of researchers, regulators and the general public for a "sustainable agriculture".

Proponents of agriculture sustainability suggest that it is crucial for agricultural systems to holistically incorporate environmental and socioeconomic factors without sacrificing yields. This is problematic to farmers, because as yet, no viable agricultural system model has been shown to fully exemplify an integration of social and natural system components.

Ecosystem approaches have been used successfully in other natural resource management fields to directly address both socioeconomic and natural system components, and may be appropriate for use with agricultural systems. This research proposed to apply an ecosystem approach to assess the abilities of different farm models to minimize the negative impacts of agriculture and achieve the necessary balance between ecosystem health and agriculture and achieve the necessary balance between ecosystem health and agricultural productivity.

Methods, Expected Results and Applications
Community Supported Agriculture (CSA) is a new farm model wherein consumers directly affect farm management. This is unique in that it appears to embody an ecosystem approach, through direct links and feedback between natural and socioeconomic components of the system. This research will use the CSA model as a case study that will be contrasted with the more established models of direct market conventional and certified organic farms.

In CSA, non-farming consumers subscribe to a farm on a seasonal basis for a weekly share of the harvest. Farmers are paid in advance by CSA consumers who assume the risk of crop failure by accepting their portion of whatever the farm produces. This eliminates farmers' income uncertainties and reduces their need to use pesticides, which are used in other farm models as tools to minimize risks of crop failure and ensure income.

Biodiversity, pesticide use, and productivity are powerful indicators of ecosystem health and are relevant to agricultural system inputs and outputs. These variables will be assessed, along with several social variables such as primary influences on farmers' decisions to adopt and implement the CSA model. I have chosen variables that appear to be significant based on my preliminary research. I anticipate that this research will show that ecosystem health outcomes will differ between the three farm models of conventional, certified organic and CSA dependant upon the selected variables.

My research will promote a better balance between the needs for ecosystem health and sustainable food production. If my hypotheses are confirmed, the CSA model could be promoted as a viable, inexpensive private sector method to reduce farmers' reliance on pesticides and ensure their economic security without continual regulation and support from government programs.

Further, CSA could serve as a reference model for the development of other farm systems that balance ecosystem health with sustained agricultural productivity through strong links between farmers and consumers.

**The Concept of Biological Diversity:
A Recent History of the Evolution of Concern for the Diversity of Life**

Timothy Farnham
Yale School of Forestry and Environmental Studies

Biological diversity, a term whose predominance in the vocabulary of conservation is now largely taken for granted, only recently gained its broad popularity. Its presence in both academic and popular journals has grown dramatically since the early 1980's.

It is most commonly defined as the variety of life on earth examined at three levels: genetic; species; and ecosystem. In this context, the representation of biological diversity as a 'concept' assumes that there is significance in the different ways that humans may conceive of the natural world. By seeing the world as biologically diverse, we choose to focus on the variety of life and life processes. This conception differs from ones that focuses on, for example, 'resources' or 'wilderness.' It is my position that "biological diversity" is a term that has gained recent popularity because, for certain segments of the scientific and professional communities and for a significant constituency in the general public, it succeeds in expressing a range of values which suggest a particular relationship between humans and the rest of nature. The question that I wish to pursue: Why has "biological diversity"—as an object of study, as a framework for pursuing knowledge and making management decisions about the natural world—arisen in the past two decades as a leading concern in conservation circles? What is the history of the events, the values, and the thoughts that have led to the popularity of the concept? As earlier stated, the reason we choose to characterize nature in a particular way is because it allows us to study and be concerned with what we find valuable about the natural world. What do we find valuable about biological diversity? Why do we find it valuable? What makes it different from the other ways we conceived of (and still conceive of) the natural world? To answer these questions, several stages of research are proposed, including a review of contemporary literature on environmental values and biological

diversity; interviews with influential scientists and thinkers who contributed to the popularity of the concept; and research of historical texts and articles. Congressional records and government documents will help to identify significant events and case studies illustrating changes in our conception of the natural world.

An Examination of Food Safety and International Trade:
The Case of Beef Residue Limits in Latin America and their Effects Worldwide

Carlos A. González
Yale School of Forestry and Environmental Studies

The United States is a leader among nations with respect to food safety standards and their enforcement, but even we have had problems with contaminated foods entering our markets. Situations such as this one have occurred throughout the world even though standards exist worldwide for controlling the amount of allowable contaminants in food products. This issue raises many interesting questions about the safety of Third World markets (and in this case, specifically Latin American markets). One that I have found of particular interest is: How do countries set Maximum Residue Limits (MRLs) and why do they differ amongst themselves and with Codex?

Before completely addressing the question, the issue of what MRLs are and what they measure should be discussed. Maximum Residue Limits are the legal concentration limits for pesticides, hormones, antibiotics, food additives, and other potentially harmful residues. Furthermore, while the United Nations Food and Agriculture Organization established some MRL guidelines known as Codex, each individual country establishes its own limits to protect their citizens.

The issue of country specific residue limits means that exporting countries must meet the residue standards set by every importing country for each specific product. Such a complex system can therefore lead to ineffective enforcement. In fact, some countries do not have residue limits established for many products, and do not have the resources to ensure enforcement for the residue limits they do set. Therefore, we must ask ourselves how safe the food purchased and consumed in the developing world truly is. And we should ask ourselves how safe the food exported from those countries is.

The driving force behind this research has been my desire to understand how (Latin American) countries set and enforce their MRLs and, more importantly, why they differ amongst themselves and with Codex. These differences have forced me to question whether the international beef supply (and food supply in general) is safe. This has also led me to ask two main questions. First of all, what is the logic behind the selection of specific MRLs? Second, are these commodities adequately tested, or are these limits unenforced?

I believe that the setting and enforcement of residue limits is not science-based but, rather, based on considerations of wealth, production status (of the specific commodity tested), and history of political stability. This research seeks to answer

these questions using the commodity of beef and the countries of Argentina and

Nicaragua as examples. The research plan involves on-site interviews and archival research. The overriding goal of this research is to highlight the importance of effective food safety standards worldwide and suggest improvements to the current system in Latin America.

Numerical Simulation of Canopy Wave and Associated CO2 Flux in Forests

Xinhang Hu
Yale School of Forestry and Environmental Studies

Canopy waves are wave-like motions near treetops at clear nights. The salient wave features have been observed in the time series of wind speed, temperature, water vapor, CO2 and other scalars measured within and above forest canopies. During wave events, the measured fluxes of heat, water vapor and CO2 are found to be enhanced. However, the erratic behaviors of the measured nocturnal fluxes raise the concern of the uncertainty of the estimation of long-term net ecosystem exchange of CO2. The objectives of this project are 1) to investigate the characteristics and dynamics of the canopy wave; 2) to investigate the transport process of CO2 associated with wave events.

A numerical wave model is being developed to simulate the canopy waves. The model starts from the basic governing equations and takes into account the exchanges of momentum and heat between canopies and the atmosphere. With th support oEvelyn Hutchinson prize, a Pentium-II 266MHZ system with 64MB memory has been purchased to perform the calculations. The softwares, including C++ compiler, FORTRAN compiler and Matlab have been upgraded. The tools for analyzing field observation data have been developed with Matlab. Some preliminary results have been achieved and will be presented in the 23rd Conference on Agriculture and Forest Meteorology, 2-7 November 1998, Albuquerque, New Mexico. The backbone code for the numerical wave model has been developed by collaborating with David E. Stevens at Lawrence Berkeley National Laboratory. The debugging and revision of the code is underway. Once the code passes the test, several widely used parameterization schemes will be examined. If the wave model can adequately reproduce the wave features, a random walk dispersion model will be linked to the numerical wave model to investigate the nocturnal transport processes in forests, specifically the possibility of the escape of CO2 out of forests during the wave events.

The expected results from this project are 1) the detailed mechanism of canopy waves and their parameterization; 2) the effects of canopy waves on vertical transport diffusion in forests and their implications on the CO2 flux measurement.

Induced Edges in Forest Ecosystem:
Tracking the Cause of Change in Ecosystem Function

B. Brooke A. Parry
Yale School of Forestry and Environmental Studies

Current recognition of the extensive loss and degradation of forest ecosystems has intensified concern about the sustainability of our world's forests. Although objections to forest clearing have concentrated in habitat loss, we have recently come to understand that creation of forest edges presents an additional, and serious, challenge to forest sustainability. The edge of a forest adjacent to recently cleared land is exposed to new forces, "edge effects," which are thought to change the forest ecosystem they influence.

As a result of land clearing, edges are becoming increasingly common, and our understanding of how they function in the landscape is far from complete. Our knowledge of edge ecosystems is based on studies that approach edges simplistically, by looking at either abiotic or biotic gradients as an edge. The proposed study seeks to expand our understanding of the implications edge creation can have for forest sustainability. I will investigate the effects of edge creation on forest function by testing resistance of forest edges to weed invasion and disease and by evaluating ecosystem legacies that may be responsible for the observed resistance or susceptibility. My central questions are: (1) Does edge creation change ecosystem function? And (2) What are the causes of the observed changes in

ecosystem function? My general hypotheses are: (1) Changes in ecosystem function at an edge depend on the ecosystem legacies present and the degree of resistance and resilience of an ecosystem edge-induced disturbance and (2) The newly created edge ecosystem can become the spatial zone of influence in the landscape, expressed as control over the function of edges in a landscape, it is important to move beyond gradient analyses of edge effects by identifying ecosystem legacies that can be a source of susceptibility or strength in an ecosystem's response to disturbance. Tracking and elucidation the causes of change in ecosystem function at edges should allow us to evaluate the risks involved in creating edges in different kinds of landscapes.

Risk in Decision-Making Risk Tradeoffs in the Control of Malaria

Montira Pongsiri
Yale School of Forestry and Environmental Studies

Persistent organic pollutants (POPS) such as DDT are long-lasting and tend to bioaccumulate in many different media such as soil, air, water, and living tissues. Because of these properties, they can cause adverse effects on human health and the environment at both short and long range distances from their actual sources. Although DDT is banned in almost all countries for use in agriculture, it is still authorized for use primarily against malaria. The overwhelming effectiveness of DDT in the first decades of its use lead to an overconfidence that malaria could be eradicated at one time, but it has since been realized that reliance on DDT as a primary control strategy is not sustainable. An international call for action was initiated in 1995 to eliminate the emissions of the "dirty dozen" POPs and where appropriate, ban their remaining production and use. However, an across-the-board ban may be difficult because of the case of DDT. Moreover, the World Health Organization (WHO) still considers DDT as one of the most important elements in vector control programs. While malaria continues to assert itself all over the world, there is mounting evidence of DDT's enduring legacy in the form of irreversible

adverse impacts on human health and the natural environment. There is debate over the risks of exposure to DDT compared with the risks to health of those currently suffering from or vulnerable to malaria.

The Intergovernmental Negotiating Committee (INC) will begin to address this policy problem at the first round of negotiations on POPs this summer, with the goal of developing a resolution on DDT. However, there is no systematic, conceptual framework for characterizing and comparing the risks and tradeoffs of this issue. Elucidating the processes by which the complexities of risks and tradeoffs are managed by the key decision-makers will be meaningful for developing a framework for the design of more protective and sustainable environmental health policies.

Patterns of Postnatal Ossification in Squamates:
Their Phylogenetic Informativeness and Relationship to Life History Characters

Jessica A. Maisano
Department of Geology and Geophysics

This is the first systematic survey of postnatal ossification patterns throughout any major vertebrate group, and the first to attempt to discern the relationship between these patterns and life history characters. The group of interest is the Squamata, the clade comprised of lizards (including snakes). This project focuses on the development of the skeleton from birth or hatching to maximum size, and the relationship of that development to life history characters such as growth rate and sexual maturity. This approach will help to elucidate the degree of complexity of developmental processes and thus the number of discrete developmental units upon which evolution can act. It will also reveal the amount of phylogenetic information contained in these patterns, at least for the squamate clade. Finally, the documentation of the timing and sequence of these ossification events will greatly aid in the interpretation of the fossil record in terms of the biological age of individual specimens. This should help alleviate the general problem of taxonomic oversplitting due to the naming of different stages of the same ontogeny as different species. That, in turn, will provide a more accurate picture of vertebrate diversity through time, so that its relationship to changing environmental factors can be better ascertained.

This project includes 27 species representing 12 major squamate clades. Its basic

This project includes 27 species representing 12 major squamate clades. Its basic framework consists of the detailed description of postnatal skeletal ossification in each of these species. From these descriptions will follow the comparative component. First, the ossification patterns will be coded as characters and mapped onto a phylogenetic hypothesis independently derived from morphological and molecular data. The degree of congruence between the ossification character set and the other character sets will indicate the quality of phylogenetic information in the ossification data. This component of the project has the potential not only to improve hypotheses of squamate relationships, but also to provide all systematists working on vertebrates with an additional line of evidence: ossification sequences.

The second set of comparisons will consider ossification patterns in light of life history characters such as size at birth, size at sexual maturity, maximum size,

growth rate, and age at sexual maturity. A wide variety of questions will be addressed, including the following: Do ossification patterns support the theory that the skeleton, from an evolutionary standpoint, is compartmentalized into major integrated regions? How closely do patterns of ossification recapitulate patterns of morphogenesis? What fusions, if any, are consistently reliable indicators of sexual maturity? Are terminal fusions really terminal, that is, do they truly mark the cessation of further significant growth? What is the relationship between ossification rate and growth rate?

In lizards, because they are ectotherms, changes in life history strategies are logically attributable to changes in climate. For example, climatic cooling is considered causal to a longer retention of eggs by the female, which is generally considered to be how viviparity evolves. The shift from oviparity to viviparity has occurred many times in squamate history, yet we currently have no concept of how this affects ossification patterns and, by extension, morphology. This project will provide an important first step toward understanding this link between climate, life history strategy, and morphology.

In summary, the postnatal ossification of the skeleton is an area ripe for inquiry. Not only is it relatively untouched territory, but it also holds much potential for elucidating answers to the some of the most pressing questions in paleobiology today, namely, how does the vertebrate skeleton evolve and how is this evolution related to environmental changes in the earth's history? Squamates are an ideal group for the first systematic investigation of these patterns because they have a rich fossil history, a large number of extant representatives, and their phylogenetic relationships are reasonably well established. It is expected that this study will prove rewarding enough to spur similar investigations in other vertebrate groups.

Comparative Analysis of Developmental Anatomy and Growth Patterns In Embryonic Paleognathes; With Comparisons to Embryonic Neognathes, Archosaurs and Non-avian Theropods

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The question of ratite affinities is of classic and enduring interest, but little is known about their growth. Comparative patterns of ratite growth and development are poorly documented. The purpose of this study is to describe and quantify general skeletal growth patterns within ratites focusing on the comparative developmental anatomy of the embryonic skeleton. Using established vertebrate clearing and staining techniques, a pre-hatching, skeletal developmental series is being analyzed. The growth and shape information will be of interest to those studying comparative evolutionary patterns and processes such as heterochrony, as well as those investigating development and growth in either modern or extinct taxa. This information can subsequently be applied to larger questions such as those involving exploration of how these growth patterns may possibly correlate to the ecological adaptive strategies of these birds, or of evolution as it relates to heterochrony, biogeography, and continental movements.

Various Research Projects Dealing With Degradation of Organic Matter within Rocks and Sediments

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I would like to take this opportunity to thank the awardees of the G. Evelyn

Hutchinson Award for the financial support I have received towards completing my dissertation research. This year has been a very busy one for me, and the support of the Institute for Biospheric Studies has played no small part in making this busyness possible. For example, I am just returned from the International Meeting on Organic Geochemistry held in Istanbul, Turkey, where I presented much results and conclusions from a study of the chemical weathering black shales.

I think it appropriate to summarize in chronological order the research activities I have been involved with during the past year. Publications and presentation resulting from YIBS support are included at the end of this summary. My academic advisor (Robert Berner) and I were asked last fall to write a Perspectives piece for Science magazine, specifically commenting on work to be published in the same issue on sulfur isotopes and the geochemical sulfur cycle1.

Shortly after this piece was submitted, I began preparing a manuscript for submission to the journal Organic Geochemistry. In this paper, co-authored by Robert Berner and our collaborator at Woods Hole Oceanographic Institution, Timothy Eglinton, I described the work we had to date completed that examines the chemical weathering of black shales2. The manuscript was accepted this spring and should be published by year's end.

In January, I began a short study examining the effect of mineral surface area on degradation of organic matter within rocks and sediments, using analytical facilities in the Yale Department of Geology and Geophysics. Although not conclusive, this study strongly suggests a relation between organic matter preservation and association with mineral surfaces.

In March, I spent two weeks working in the laboratory of Malcolm Oades, Department of Soil Science, University of Adelaide, South Australia. Dr. Oades is a world-renowned expert on organic matter in soils with an excellently equipped nuclear magnetic resonance spectroscopy laboratory. We had met at a geochemistry meeting last summer, and he invited me to his lab to apply his NMR techniques to my organic matter samples. At Adelaide, I worked closely with Dr. Oades's post-doctoral research assistant, Ronald Smernik, using the tool of NMR to describe bulk chemical structure variations in organic matter during weathering. Upon return to Yale, I spent several weeks examining our results and preparing a first draft of a manuscript. This manuscript is now nearly completed and only awaits one last revision from the laboratory in Adelaide3.

This past summer, I began a mathematical modeling study of black shale weathering based on estimates of fluid flow and chemical reaction rates. The goal of this study is to recreate as accurately as possible in a model the chemical features I observed in my samples. Results to date have been very satisfying, and I will be preparing a manuscript describing this study in the next few weeks4.

I also presented my work at two meetings this summer: the 5th Geochemistry of the Earth's Surface meeting in Reykjavik, Iceland5, and the 19th International Meeting on Organic Geochemistry in Istanbul, Turkey6. The poster and talk were very well received, and the opportunity to travel and meet with the greater geochemistry community allowed me to make contacts with and plan potential collaboration with a variety of researchers with similar interests as mine.

And lastly, I am beginning a new study in collaboration with Robert Berner and Carmela Cuomo, a research associate in the Yale Department of Geology and Geophysics on the influence of atmospheric O2 concentration on carbon isotope discrimination in plants and algae. We began by analyzing the isotopic composition of plants grown at various pO2, and found that there was a significant and consistent isotope variation7. We are now building the apparatus that will allow us to culture several species of algae that are dominant contributors to organic matter in marine sediments at various and controlled pCO2 and pO2. Although it is unlikely that I will be at Yale long enough to see this project to completion, I intend to participate in this study by including compound-specific isotope analysis of algae samples in the post-doctoral research I will begin in a few months at Woods Hole Oceanographic Institution.

Again, I am deeply indebted to the Yale Institute for Biospheric Studies for the financial support I have received. It is because of programs such as these that excellent and important research can result from a graduate student's dissertation.

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