National Center for Ecological Analysis and Synthesis

2005
Report to the National Science Foundation

1. Participants

O.J. Reichman, Director PI

Sandy J. Andelman, Deputy Director Co-PI

Mark Schildhauer, Director of Computing

Partner Organizations
Matching funds have been provided by the University of California ($500,000) and by the University of California, Santa Barbara.

The Andrew W. Mellon Foundation has provided funding to support postdoctoral researchers and the implementation of ecoinformatics tools. During the past year, the Mellon Foundation provided $300,000 to support a scientific programmer and an analytically adept postdoctoral researcher. The Mellon Foundation has made awards to NCEAS totaling approximately $1,450,000 to support informatics research at NCEAS.

The David and Lucille Packard Foundation has provided funding to conduct a distributed graduate seminar focused on a critical review of ecosystem-based management (EBM) efforts relevant to coastal-marine ecosystems and to design a longer-term program of activities to develop the scientific foundations for EBM in coastal marine systems.

Vulcan, Inc. has provided $350,000 to support working groups and to initiate planning for a UCSB Center focused on scientific solutions to important environmental problems.

Other Collaborators
Ben Halpern was a postdoctoral fellow at NCEAS, supported by David Hamilton Smith Fellowships from The Nature Conservancy.

To facilitate informatics research and to support the informatics needs of the ecological community, NCEAS continued a research partnership with three other organizations: San Diego Super Computer Center, University of Kansas and University of New Mexico (LTER Network Office).

2. Activities and Findings

Science Advisory Board
For our July 2004 deadline, we received 33 proposals for 34 activities: 15 postdoctoral fellowships, 3 sabbatical fellowships, and 16 working groups. The Science Advisory Board met September 8-9, 2004 to review these proposals; based on their recommendations, decisions were made to support 4 postdoctoral fellowships, 2 sabbatical fellowships and 7 working groups.

For our January 2005 deadline, we received 46 proposals for 39 activities: 24 postdoctoral fellowships, 6 sabbatical fellowships, and 9 working groups. The Science Advisory Board met

March 2-3, 2005 to review these proposals; based on their recommendations, decisions were made to support 4 postdoctoral fellowships, 6 sabbatical fellowships and 5 working groups.

A list of Science Advisory Board members is available on the NCEAS web site: http://www.nceas.ucsb.edu.

Major Research Activities

During the reporting period, May 1, 2004 through April 30, 2005, NCEAS supported 12 sabbatical visitors and 21 postdoctoral researchers. A list of sabbatical and postdoctoral researchers, including descriptions of their projects is provided below. During the past year, NCEAS postdoctoral scientists have accepted faculty positions at Louisiana State University, Oregon State University, University of British Columbia, University of Guelph and Washington University. Other NCEAS postdoctoral scientists accepted research positions at Australian National University, Instituto Argentino de Investigaciones de las Zonas Áridas, Smithsonian Tropical Research Institute, US Environmental Protection Agency and RMIT University (Australia).

During the reporting period, 684 different scientists participated in activities at NCEAS (944 total visits). NCEAS reported 68 working group meetings, representing the activities of 33 different working groups, and 10 meetings. Twelve of these working groups focus on issues of immediate relevance to resource managers and policy markers, and these are highlighted in a separate section below.

Sabbatical Fellows

Larry Crowder Sabbatical Fellow
01/01/2004-06/30/2004

Marine conservation: Integrating science and policy

Marine conservation requires not only an understanding of the biological, physical, and ecological science, but it also requires a mature understanding of the socio-political process. Poor science can doom the implementation of wise marine conservation practices, but naiveté among scientists regarding the policymaking process also can slow the application of good science. I propose two major goals for my time as a Center Fellow on sabbatical at NCEAS during 2003-2004. First, I will write a book tentatively titled, Marine Conservation: Integrating Science and Policy. This book will follow on the heels of another book on Marine Conservation Biology: The Science of Sustaining the Seas, Island Press, 2003, which I am co-editing with Elliott Norse of MCBI. The new book will be co-authored by Mike Orbach and derives from the Conservation Biology and Policy Course we have taught at the Duke University Marine Laboratory since 1997. Second, I plan to learn more about the science/policy integration process by working with an interdisciplinary group of people who deal with marine conservation from disciplines other than my own including anthropologists, economists, lawyers, journalists, marketing people, governance experts, fishermen, and environmentalists. The current working group on Marine Management (Francis and Kitchell), of which I am a member, is holding its first meeting with people from this broader interdisciplinary group in December 2002. One lesson from previous NCEAS syntheses, like the one on Marine Reserves (Lubchenco et al.), is that even after the science is synthesized, there is much new interdisciplinary work required to implement a marine

reserve. The current working group on Pratical Design of Marine Reserves (Hastings and Botsford) is addressing these issues relative to marine reserves. The purpose of my sabbatical will be to provide a roadmap for ecologists orienteering through the policy landscape.

Ed Hackett Sabbatical Fellow
08/15/2004-08/14/2005
Ecology transformed: Social and intellectual change in ecological research
There are two aspects to this Center Fellow proposal (for support during a sabbatical year): (1) research and writing for a study of NCEAS, its effects, and the recent history of ecology; (2) education about ecology and ecological research practice, which will greatly improve my efforts to integrate ecology with social science in various projects at ASU. The work would have direct and specific benefits for NCEAS and more diffuse benefits for the larger tasks of developing integrative interdisciplinary research and education.

Sharon Harlan Sabbatical Fellow
08/15/2004-08/14/2005
Urban ecology, social inequality, and climate: Building an integrative framework at the neighborhood scale
This is a Center Fellow proposal requesting support for a one-year sabbatical at NCEAS to develop new analytical models concerning human activities, inequality, and climate change in urban communities. My principal activities will be: 1) to develop a framework for understanding how climate and environment influence inequalities in human communities; 2) to analyze, synthesize, and write about how human and ecological communities respond to climatic conditions; and 3) to broaden my knowledge of urban ecology and experience with interdisciplinary research. This project deals with enduring methodological problems in interdisciplinary research and may contribute to public policy interventions to alter the course of climate change on the local scale.

Margaret Kinnaird Sabbatical Fellow
Timothy O'Brien
09/01/2003-08/31/2004
08/31/2004-12/31/2005 (Hosted by NCEAS)
Functional relationships of Asian Hornbills in changing forest landscapes
Birds and mammals are important seed dispersers and pollinators in tropical rainforests and are increasingly threatened by deforestation and hunting. The use of minimum viable populations as targets for conservation may be insufficient to assure the delivery of ecological services such as seed dispersal. Hornbills (Family Bucerotidae) are a distinctive African and Asian bird family, inhabiting savannahs, dry forests and rainforests of Sub-Saharan Africa, and India eastward to the Solomon Islands. In Asia, hornbills are largely frugivorous forest birds and important dispersers of seeds of rainforest trees. Despite more than two decades of research, there has not been an attempt to synthesize and extend knowledge about this family. We propose to collate, analyze and synthesize data that will explore the ecology and behavior of these important birds, demonstrate their functional role in forest ecosystems, highlight keystone interactions with fruit resources, and examine the conservation impact of forest loss and fragmentation for hornbills and their function in the ecosystem.

Vlastimil Krivan Sabbatical Fellow
02/01/2005-01/31/2006
Merging adaptive behavior and population dynamics
Experimental work clearly shows that changes in population numbers influence animal behavior. What is much less clear is, whether animal behavior, in turn, influences population dynamics. If yes, then we get a feedback loop between population dynamics and animal behavior that must be reflected in models of population ecology. If not then we can use the classical, density mediated models of population ecology. I want to study theoretically interplay between direct and indirect interactions in simple food web modules where individuals of one or more population(s) behave adaptively. In particular, I want to focus on a simple bacterial system described by a bacterial population growing on two or more carbon sources.

David Lodge Sabbatical Fellow
08/04/2004-06/30/2005
Biology and policy of invasive species
Species transported by humans from one region to another—nonindigenous species—sometimes become invasive. That is, they spread widely, and some cause enormous environmental and economic damage. Cheat grass, zebra mussels, and West Nile virus are three of hundreds of examples of invasive species in the US. Over at least the last century, increasing global trade and human travel have caused dramatic rises in both intentional and accidental introductions of nonindigenous species. Undoubtedly, this trend will continue, and perhaps accelerate, as global commerce increases. Although ecologists have long recognized the phenomenon of invasive species, only in recent years have they given it concentrated scientific attention. And only in the last decade have the societal costs and natural resource management challenges posed by invasive species received serious policy attention at the US federal and state levels. My project is to write a book entitled Biology and Policy of Invasive Species. The volume will synthesize the current scientific and policy situation of invasive species, and recommend how interdisciplinary research and policy development might move forward.

William Murdoch Sabbatical Fellow
04/04/2005-09/30/2005
International conservation: Expanding the decision framework
Conservation agencies are planning massive expansion of their conservation activities in the largely tropical developing world. Allocating scarce conservation resources among developing nations requires consideration of a broader set of factors than is typically considered in conservation decision-making. Especially important are aspects of political economy that place conservation investments at risk. We will try to develop a support framework for making allocation decisions that should also help guide efforts to ameliorate risks.

W. John O'Brien Sabbatical Fellow
01/01/2004-07/31/2004
Global change and eutrophication: Modeling of arctic lake ecosystems
Two projects involving the examination of complex data sets and the development of integrative models of ecological processes are proposed. Both of the projects address ecological questions of general interest and importance. One has as its primary goal the integration of biological and hydrological information to examine change in Arctic lake chemistry and productivity as it relates

to indicators of global climate change. The second project involves synthesizing data from studies worldwide, including those from the Arctic LTER, in which lake nutrients have been manipulated (either experimentally increased or municipally decreased) to examine the impact of nutrients on zooplankton density and production as phytoplankton densities are altered.

Dianna Padilla Sabbatical Fellow
01/17/2005-01/16/2006
Non-native species introductions in marine reserves and protected areas
This proposal is for sabbatical support as a Center Fellow to conduct two projects. (1.) Aquatic ecosystems have been impacted by a variety of anthropogenic factors, leading to concerns about loss of biodiversity, loss of fisheries stocks, and the introduction and spread of non-native species. In response there has been a dramatic increase in scientific and public attention to the protection of biodiversity and fisheries through marine reserves and protected areas, and the introduction and impacts of non-native species. Although these topics have been the focus of much recent effort, to date there is a lack of attention to the problem of non-native species in marine protected areas and reserves, which will be the focus of my project. For marine systems this problem may be especially important because dispersal and connectedness among marine reserves appears to be a key design features for effective reserve design. These very properties can enhance the likelihood of invasion and spread of non-native species. Marine reserves may also be especially susceptible to aquaculture species, which either escape culture or are deliberately out planted in large abundance to enhance sustainable fisheries and restore ecosystem function that has been lost due to over harvesting. (2) The ecological importance and consequences of phenotypically plastic traits is of great interest to a wide range of scientists. I propose to review the literature on inducible offenses, traits that enhance the ability of consumers or competitors, and contrast this information with what is known about inducible defenses, which have been studied much more extensively. I will explore the similarities and differences between these two types of ecologically important plasticities.

Julia Parrish Sabbatical Fellow
01/01/2004-09/30/2004
Marine Conservation
Marine conservation is a fast emerging multi-discipline responding to the depletion of resources in the marine environment. However, unlike terrestrial conservation, or the more broadly-based conservation biology, marine conservation lacks the written material – especially single volumes which integrate across issues and approaches – to codify itself. This gap is also present in the academic realm, where the vast majority of courses on conservation lack a serious marine component. My proposed work at NCEAS is to write a textbook on marine conservation, incorporating ecology and marine biology; oceanography and physical science; fisheries and natural resource management; and law, economics, and social science.

Moshe Shachak Sabbatical Fellow
07/01/2004-09/30/2004 and 01/28/2005-04/07/2005
The role of plants as landscape modulators in controlling biodiversity
The issue of biodiversity has received increasing attention as a consequence of the unprecedented loss of species and their habitats in response to environmental changes. A central, frontier topic in biodiversity studies concerns the factors controlling the flow of species from regional pools to

local assemblages. My main assumption is that the filtering of species is determined, to a large extent, by a few major species that modify the landscape mosaic, termed Landscape Modulators. I propose to compile ideas and data on the effects of different types of Landscape Modulators, their spatial patterns and their filtering strength on various taxa of plants and animals. The aim of my work at NCEAS is to explore patterns, based on literature review and on long term available data, in order to develop a framework for a theory concerning the effect of organism-induced landscape modulation on landscapes, resources and organisms. My program aims for a synthesis of community and landscape ecology approaches. This study will advance the discipline of biodiversity by developing an approach to integrating species and landscape diversities through the activities of a few dominant modulators that control landscape functioning. This study will contribute to: (1) conservation, restoration and management of landscape and species diversity; (2) predicting responses in terms of species richness to environmental changes (climate and land use) at different landscape scales; and (3) creation of a biodiversity management policy.

Postdoctoral Fellows

Drew Allen Postdoctoral Fellow
03/01/2005-02/28/2006
The role of temperature in the origin and maintenance of biodiversity
The mechanisms responsible for latitudinal gradients in biodiversity are still poorly understood. Mechanistic understanding will require new theory that links short-term species coexistence to long-term speciation-extinction dynamics. My research at NCEAS will involve developing and testing a theoretical framework based on temperature dependence of biological rates and times and the dynamics of speciation and extinction. This framework will involve a synthesis of theory and data that encompasses population genetics, community ecology, and macroevolution. The primary motivations for this work are to better understand and predict changes in biodiversity along temperature gradients, and more generally, to better understand the forces that control the origin and maintenance of species.

Elizabeth Borer Postdoctoral Fellow
09/01/2003-07/16/2004
Synthesizing intraguild predation theory and data
Although intraguild predation (IGP), a form of omnivory, is widespread in natural communities and has received significant attention in the recent theoretical and empirical literature, a gulf exists between theoretical predictions about the role of IGP in food webs and our understanding of its role in real communities. With few exceptions, the IGP literature falls into two categories operating at different time-scales: (1) theory presenting long-term effects of IGP on species persistence and population densities, and (2) short-term studies demonstrating IGP and, from theory, extrapolating the outcome for populations and communities. In addition, IGP models have been formulated for predator-prey (e.g. Holt and Polis 1997), host-parasitoid (Briggs 1993), and host-parasite (or pathogen) (e.g. Hochberg and Holt 1990) systems. Although the broad predictions of all of these model formulations are the same, this commonality is not generally recognized. I propose to synthesize this diffuse body of theory, assess the information available from short-term empirical studies, and test theoretical IGP predictions with empirical data.

Peter Buston Postdoctoral Fellow

10/01/2002-9/31/2005

The ecology of hermaphroditic breeding systems

There is an enormous diversity of hermaphroditic breeding systems distributed throughout the plant and animal kingdoms. To gain a greater understanding of this diversity, I propose to investigate the socio-ecological factors that underlie the evolution of these systems. First, I will develop new game-theoretic models, to generate explicit predictions about how ecological, social, and genetic factors combine to influence the distribution of reproduction within the breeding systems of both sequential and simultaneous hermaphrodites. Second, I will synthesize the extensive, but scattered, empirical literature on plant and animal (vertebrate and invertebrate) hermaphroditic breeding systems, gathering data on the socio-ecological factors that theoretical models indicate might give rise to these systems. Third, I will use this database, in conjunction with the comparative method, to test the alternative models, and determine which factors are indeed the key determinants of the different hermaphroditic breeding systems. The research will provide a comprehensive socio-ecological framework within which the breeding systems of all hermaphrodites can be understood. The work is important because understanding the breeding system of a species can be the key to effectively managing and conserving its populations

Karl Cottenie Postdoctoral Fellow

02/01/2003-06/30/2005

Local versus regional processes: Integrating space and environment

Both local and regional processes can structure local communities, however, their relative roles are poorly understood. The classical methodology used to determine their relative importance is to examine the shape of the relationship between local and regional diversity. However, this approach has been criticized on several conceptual and methodological grounds. This proposal aims to integrate local (biotic and abiotic) and regional (spatial) information, using three novel research methodologies. These will be applied on a range of data sets, starting with zooplankton, but expanding to other aquatic taxa and terrestrial systems. Moreover, I will extend the methodology to genetic data, in order to make a direct comparison between processes working at the interspecific and intraspecific levels. The results will elucidate the processes that generate structure in populations and communities.

John Drake Postdoctoral Fellow

06/01/2004-05/31/2006

Risk analysis for alien species and emerging infectious diseases

Undesirable alien species and emerging infectious diseases (of both wildlife and humans) are urgent environmental concerns. Considerable effort has therefore been invested in understanding the ecology and evolution of invasive species and of infectious diseases. Despite exhibiting similar dynamics that are modeled with the same techniques, these phenomena are commonly studied by separate research communities for the purposes of risk analysis, management, and control. This project will develop techniques for risk analysis of intentional and unintentional introductions of non-indigenous species and will investigate areas of cross-fertilization with epidemiological theory. The products of this study will be tools for decision-making in the presence of uncertainty and specific recommendations for six case studies.

Sergio Floeter Postdoctoral Fellow

09/01/2003-08/31/2006

Diversity, biogeography and macroecological patterns of Atlantic reef fishes
This proposal aim to develop the great potential of reef-fishes as model taxa for biogeographical and macroecological analysis of reef areas in the Atlantic. Detailed large-scale studies of Atlantic reef fishes were always hampered by the lack of reliable geographical distribution of species. Now a multi-institutional international team of researchers is building the most accurate species distribution database possible for the entire tropical and subtropical Atlantic. This extensive new database covering 2404 species from 74 families will be used to 1) synthesize current knowledge of reef fish diversity and endemism in the Atlantic, 2) search for large-scale patterns and affinities among zoogeographical provinces, and 3) advance our understanding of biogeographical and macroecological marine patterns through the test of a series of hypothesis including the operation of biogeographical barriers, dispersal potential, biotic invasions, and the stepping stones concept.

Ben Halpern Postdoctoral Fellow
09/01/2003-12/15/2004
Predicting community-level responses to disturbance: Implications for reserve design (Hosted by NCEAS)
Determining the causes of community stability and productivity remains an elusive goal for ecologists and conservationists alike. A major impediment to filling this gap in our understanding is the lack of ecological data at a scale large enough and over long enough a timeframe to allow differentiation of ephemeral and local changes in biological communities from persistent and general patterns. Using data from the Channel Islands kelp forest monitoring program, which spans hundreds of kilometers and 22 years, I will apply a variety of time-series and multi-factor statistical models to test which factors affect community variables such as stability, trophic and community structure, and productivity (measured as biomass). Results from this work will provide ecologists, conservationists, and resource managers an essential tool for developing more appropriate expectations for long-term responses of biological communities to anthropogenic influences, both negative (e.g., species invasions, species loss, habitat alteration, effects of climate change) and positive (e.g., protection within parks and reserves).

Tiffany Knight Postdoctoral Fellow
01/05/2004-01/03/2005
Beyond hand-pollinations: Linking pollen limitation to plant population biology Pollen sufficiency is an important determinant of plant reproductive success, and thus a major driver in plant ecology and evolution. Despite hundreds of empirical studies addressing the causes and consequences of pollen limitation, we lack a quantitative synthesis. Our working group will bring together evolutionary biologists, pollination ecologists, plant demographers, and theoreticians to produce new insight into the ecological and evolutionary significance of pollen limitation. We will 1) use contemporary theory as a framework for synthesis (via meta-analysis) of published and unpublished empirical data to determine the ecological attributes that are generally associated with pollen limitation, and 2) develop new theory that integrates pollen limitation with plant modularity, resource allocation and perenniality, as well as with plant demography, population growth rates and time to extinction.

Bill Langford Postdoctoral Fellow
02/01/2002-01/31/2005
Evaluation functions for ecological image segmentation

This project examines and enhances various forms of evaluation functions used in the comparison and optimization of image segmentation algorithms. It defines quantitative criteria for definition of the evaluation functions and uses them in the design and selection of these functions. It also investigates the relationship between errors in landscape pattern metrics and segmentation and classification algorithms. Finally, it coordinates the creation of a repository of correct segmentations of aerial and remotely sensed ecological imagery to improve algorithm development by making rigorous comparison of algorithms possible.

Kate Lyons Postdoctoral Fellow
08/01/2003-07/31/2006
Temporal and spatial dimensions of mammalian community structure: Pattern and process
Although progress has been forthcoming concerning macroecological patterns across large spatial scales, relatively little attention has been focused on their temporal dynamics. Moreover, understanding the responses of species to climate change is becoming increasingly important because of the effect humans have on the environment. Predicting how macroecological patterns will change in response to patterns of global warming may allow us to better prepare for the consequences of our actions through informed conservation practices and land use strategies. Comprehensive and spatially explicit data on Pleistocene mammals provide a unique opportunity to perform such spatiotemporal analyses. Community structure was dynamic: many species with historically sympatric ranges are now allopatric. I propose to examine macroecological patterns across the fluid landscape of community structure during the last forty thousand years. As is true in so many instances, the key to predicting the future lies in understanding the past.

Christy McCain Postdoctoral Fellow
01/13/2004-01/12/2006
Elevational trends in biodiversity: Examining theoretical predictions across taxa
Documenting patterns and understanding factors producing and maintaining global biodiversity have been fundamental goals of ecological research since the first expeditions of Darwin and Wallace. After a century and a half of research on biodiversity patterns and processes, Brown asserted that a general explanation for patterns of biodiversity would emerge in the next few years, particularly for elevational and latitudinal patterns. Elevational gradients hold enormous potential for understanding general properties of biodiversity since variable topography is global, and predictable climatic patterns with large concomitant changes in biodiversity occur over small spatial scales. Additionally, biodiversity studies along elevational gradients have been amassed for many taxa on mountain ranges across the globe. Lomolino outlined some testable diversity hypotheses in a research agenda, which would lead to a general explanation for elevational patterns, including climatic hypotheses, species-area effects, community overlap patterns, and historical factors. In the first quantitative synthesis, I tested some of the predictions for elevational diversity patterns of non-volant small mammals (n = 51) with intriguing results. Peak alpha diversity occurred at higher elevations on taller mountains, evidence supporting a combination of climatic factors influencing diversity patterns. In contrast, gamma diversity patterns supported the predictions of the mid-domain effect, displayed a positive, linear trend with latitude, and showed trends consistent with species-area effects. To further examine these preliminary trends, I propose addressing the following questions: (1) Is there a latitudinal trend in elevation of peaks in diversity on mountainsides? (2) Does the species-area relationship inherent

to elevational gradients mask other mechanisms producing and maintaining biodiversity? (3) Is there general support for the community overlap hypothesis on elevational gradients? (4) Are there general mechanisms producing elevational diversity patterns across taxa?

Carlos Melian Postdoctoral Fellow
08/25/2003-06/26/2004
The radiation of seed mass strategies worldwide
Most studies on community ecology have focused on single interaction types (i.e., antagonistic, mutualistic, or competitive). On the other hand, the bulk of behavioral studies have considered interactions among individuals within the same species (i.e., group behavior or group size). To improve our understanding of community structure, I propose to investigate the interdependence between group behavior and the structure of ecological networks integrating multiple interaction types. First, I will introduce behavioral strategies among species within the framework of gametheoretic models. Second, I will complement existing database on food webs by introducing species group size and di_erent interaction types. Third, I will use this enlarged database to test alternative behavioral models of network built up to determine mechanisms generating the structure of ecological networks. This research should provide a first step toward understanding the role of group behavior in the structure of ecological networks with multiple interaction types. The relevance of this work relies on the integration of behavioral and community ecology.

Angela Moles Postdoctoral Fellow
08/25/2003-06/26/2004
The radiation of seed mass strategies worldwide
Recent accumulation of large, multi-species databases of plant traits, combined with major advances in our knowledge of phylogenetic relationships among the angiosperms mean that it is now possible to investigate the role of shifts in seed mass, growth form and dispersal syndrome in the radiation of the angiosperms out of the tropics. Approximately 6500 seed masses are now known for species from all around the world (database accumulated during my PhD). The aim of this proposal is to array these seed masses on to the phylogenetic tree of angiosperms to quantify where and when in the history of the angiosperms the major divergences in seed mass occurred. Then it will become possible to assess how closely divergences in seed mass have been associated with divergences in growth form, dispersal mode or latitude, and to investigate the sequence in which shifts in plant traits and distribution have occurred.

John Orrock Postdoctoral Fellow
06/01/2004-05/31/2006
Interactions between mammalian herbivores and associated plant communities
The grasslands of California represent one of the most dramatic biological invasions in the world: 9.2 million ha (almost 25% of the entire state) are dominated by non-native plants. My work at NCEAS will evaluate whether non-native plants subsidize native consumers, leading to stronger impacts of native consumers on native plants (i.e. apparent competition). I will characterize how differences in consumer behavior among patches change the spatial extent of apparent competition (and thus invasion).

Christopher Pyke Postdoctoral Fellow
12/05/2000-09/07/2004

Climate, ecosystems, and land-use: Understanding environmental variability in human-dominated landscapes (Hosted by NCEAS)

Environmental variation creates both risk and opportunities for conservation. The implications of environmental variation in any particular situation vary depending on climatic processes, ecosystem responses, and land-use patterns. Consequently, it is necessary to understand potential interactions between these factors in order to design conservation strategies that use variation to reduce risk and take advantage of opportunities to increase species persistence. Informed action can offset the natural tendency for risk from environmental variation to increase as the total amount of habitat in a landscape decreases. The proposed research addresses this issue by: (1) simulating how climate, ecosystems, and land-use interact over time to change patterns of environmental variation, and (2) applying this framework to evaluate risks faced by vernal pool ecosystems in the Central Valley of California. The results of this work will help conservationists develop better tools for reserve design, understand processes underlying patterns of environmental variability, and manage local vernal pool landscapes to reduce risks associated with landscape and climate change.

Eric Seabloom Postdoctoral Fellow
06/01/1997-06/30/2004

Effects of plant-community composition on animal movement

The evolution of behavior and plant-community dynamics are two seemingly disparate elements in ecology. However, the movement of animals through a landscape can have strong impacts on the competitive coexistence of various plant life-history strategies, and the distribution of resources can alter animal-movement patterns. Accordingly, animal behavior and plant-community dynamics can be inextricably linked by the influence of animal movement on the composition of plant communities and, in the case of herbivores, the effects of plant-community composition on animal movement. For disturbance-generating herbivores, the link between the animal-movement patterns and plant-community composition is particularly strong, because the animal's foraging success is dependent on the composition of the plant community and the animal's movement generates disturbances that can profoundly alter the competitive balance among plant species.

Disturbance-generating herbivores are of additional interest because of their strong effects on the physical environment. For example, the tunneling behavior of pocket gophers can increase the heterogeneity of soil nitrogen, phosphorous, and carbon at the soil surface, but soil mixing will decrease vertical variability. In addition, the burrowing activity of gophers will lower soil bulk density and increase water infiltration, temperature, and litter decomposition rates. Pocket gopher activity is also a major force determining the rates of soil movement on hillslopes.

In my research, I am using a variety of modeling techniques to examine the interactions between the behavior of disturbance-generating animals, the structure of the associated plant community, and the ecosystem processes that result from this interaction. These models range from spatially-explicit movement models to analytical models of animal energetics and soil erosion.

This modeling work is closely coordinated with a series of field experiments designed to test the predictions in the California grassland system. This system is of particular interest, because of the high density of pocket gophers and their large apparent impacts on plant community composition and soil, nutrient, and water flux. In addition, the outcome of these

studies is of profound conservation interest, because of widespread invasion of California native grasslands by exotic annual species.

Richard Stevens Postdoctoral Fellow
12/15/2002-12/14/2004
Environmental determinants of biodiversity
Understanding the mechanistic bases of patterns in biodiversity has challenged ecologists and evolutionary biologists alike for more than a quarter of a century (Rosenzweig 1995). Although the ubiquity of gradients in species richness is well documented at coarse scales of resolution, it is unclear to what extent patterns are recapitulated at the level of local communities or for any other aspect of biodiversity (Stevens and Willig 2001). Biodiversity represents the totality of variation in living things (Tilman 2000). Thus, it is likely that no one measure such as species richness, or any one perspective, such as that of taxonomic diversity, can provide a comprehensive characterization. Investigations that simultaneously explore fundamental components of biodiversity (i.e., taxonomic, functional, or phylogenetic diversity) will allow for analyses that provide deeper, more comprehensive understanding regarding the distribution of biota across space and time. Although secondary gradients (e.g., latitudinal diversity gradients) have been described ubiquitously, much less is known about the primary environmental gradients or suite of gradients that cause such patterns. Numerous biotic and abiotic characteristics vary spatially in different but correlated ways. Distinguishing the relative contributions of a number of environmental characteristics to gradients in biodiversity will contribute substantially to our understanding of ecology, biogeography, and evolution. Moreover, resolution of the effects of primary gradients on the spatial distribution of biodiversity may also greatly enhance our understanding of the mechanistic basis of secondary gradients such as those described for latitude.

Mark Torchin Postdoctoral Fellow
10/01/2003-08/31/2004
Using biological invasions to test predictions of population control by parasites Introduced species are a major threat to global biodiversity, ranked second only to habitat loss (Vitousek 1990, Wilcove et al. 1998). The damage caused by exotic species results from the high population densities and large body sizes that they attain in their new location (Vitousek 1990, Wilcove et al. 1998, Ruiz et al. 1999, Torchin et al. 2001, 2002). Escape from the effects of natural enemies is a frequent explanation given for the success of introduced species (Keane and Crawley 2002, Shea and Chesson 2002). Recently, Torchin et al. (in press) demonstrated that introduced species are parasitized by half the number of parasite species compared to where they are native and that introduced populations are also less heavily parasitized (% infected) than native populations. However, while parasites are ubiquitous and pervasive, the extent to which parasites mediate invasions and result in increased ecological performance of introduced species has not been evaluated. Further, the extent to which introduced parasites and pathogens are responsible for damage to native species has not been quantified. Using existing data, I propose to extend a database which I developed for a NCEAS working group (Diseases and Conservation Biology) and employ a meta-analysis to test several hypotheses which explore the role of parasites in biological invasions. Further, by using biological invasions as “natural experiments”, I will design this project to investigate a more fundamental question in ecology: How do parasites affect the distribution and abundance of their hosts?

Diego Vázquez Postdoctoral Fellow
10/01/2002-06/30/2005
Null models for specialization and asymmetry in plant-pollinator systems
Pollination biologists have recently suggested that pollination systems may have a greater degree of generalization in plant pollinator interactions than previously thought. However, there have been no attempts to provide null models against which to compare the observed patterns. I propose to conduct research to develop such models, and to use them to test patterns of specialization observed in available datasets of plant-pollinator interactions. My proposed research has the potential to provide important insights about how plants and pollinators interact, and to synthesize ideas on plant-pollinator interactions, species-abundance patterns, and abundance-range size relationships.

Mark Vellend Postdoctoral Fellow
09/01/2004-06/30/2005
Forest plant metapopulations in fragmented and dynamic landscapes: Synthesizing models and data
A central goal of ecology and conservation biology is to understand the responses of populations and communities to spatial and temporal landscape heterogeneity. Many regions of Europe and eastern North America share broadly similar histories of land use over the past several centuries, with varying degrees of forest fragmentation via clearance for agriculture, and varying degrees of forest recovery on abandoned agricultural lands. Organisms in such fragmented and dynamic landscapes exist as metapopulations, but metapopulation theory has only recently begun to incorporate dynamics of the landscape itself (i.e., habitat turnover). The most data-friendly metapopulation model is the "spatially-realistic" Incidence Function Model (IFM) of Hanski. Here I propose to develop modified versions of the IFM to incorporate habitat turnover, and to use these as a theoretical framework in which to synthesize data on forest-plant patch occupancy patterns in landscapes throughout Europe and eastern North America. Data from multiple landscapes will allow models parameterized for one landscape to be tested in others. This integration of models and data will allow metapopulation dynamics and persistence to be projected under a range of scenarios of future land-use change.

Piet Verburg Postdoctoral Fellow
07/16/2004-07/15/2006
Climate forcing of lacustrine energy fluxes
Lakes are warming up globally with the recent climate warming. The effect of the warming on the ecosystems in the lakes depends on the impact on the physics of the lakes. The proposed research investigates the changes since 1980 in energy fluxes leaving and entering lakes in various climatic settings and the relation of these changes with regional meteorology. Implications for aquatic ecosystems will be determined.

Working Groups

Paleobiology Database (Hosted by NCEAS)
John Alroy, Charles Marshall and Arnold Miller – leaders

Aberhan, Martin	Behrensmeyer, Anna K.	Bown, Paul
Alroy, John	Bottjer, David J.	Carrano, Matthew

Clyde, William C.	Ivany, Linda	Plotnick, Roy E.
Danelian, Taniel	Jablonski, David	Raymond, Anne
Davydov, Vladimir	Kidwell, Susan	Rees, P.M. (Allister)
Diver, Patrick	Kiessling, Wolfgang	Rogers, Raymond R.
Fara, Emmanuel	Kosnik, Matthew	Sims, Hallie J.
Finkel, Zoe	Kowalewski, Michal	Stein, William
Foote, Michael	Kucera, Michal	Tiffney, Bruce
Fursich, Franz T.	Lazarus, David	Uhen, Mark D.
Gastaldo, Robert A.	Lees, Jackie	Wagner, Peter J.
Gensel, Patricia G.	Looy, Cindy	Wang, Xiaoming
Head, Jason	Marshall, Charles R.	Whatley, Robin
Hendy, Austin	Miller, Arnold I.	Wise, Sherwood W.
Holland, Steven M.	Olszewski, Tom	Young, Jeremy
Hunter, John P.	Patzkowsky, Mark E.	

Our picture of global diversification and extinction on long time scales is mostly based on generalized data for Phanerozoic marine macroinvertebrates. While every effort was made to guarantee the comprehensiveness of this data set, the community has been aware that sampling artifacts may contribute to the observed trends. Until now, we have been unable to remove these effects. Several robust methods for doing this are now available, but these methods use locality-specific data that are not a part of the existing, more generalized compilations. In order to confirm the reality of the major observed patterns, a collaborative data compilation project needs to be initiated. We wish to form a working group to do this. As a first step, we propose a workshop this August involving workers who have specialized in analyzing paleontological diversity data. This workshop will determine the scope, goals, structure, and time table of a database project. Immediately after the workshop, a post-doc who will serve as project coordinator will begin a two-year residency at NCEAS. Over the following two years, experts specializing on particular parts of the fossil record will meet at NCEAS to guide the data collection process. A final meeting will focus on preparing collaborative publications showing how these data influence our picture of marine diversification and extinction.

Beyond hand-pollinations: Linking pollen limitation to plant population biology

Tia-Lyn Ashman, Tiffany Knight, Susan Mazer, and Martin Morgan – leaders

Ashman, Tia-Lynn	Johnston, Mark O.	Morgan, Martin
Burd, Martin	Knight, Tiffany	Steets, Janette
Campbell, Diane	Mazer, Susan J.	Vamosi, Jana
Dudash, Michele R.	Mitchell, Randall	Wilson, Will G.

Pollen sufficiency is an important determinant of plant reproductive success, and thus a major driver in plant ecology and evolution. Despite hundreds of empirical studies addressing the causes and consequences of pollen limitation, we lack a quantitative synthesis. Our working group will bring together evolutionary biologists, pollination ecologists, plant demographers, and theoreticians to produce new insight into the ecological and evolutionary significance of pollen limitation. We will 1) use contemporary theory as a framework for synthesis (via meta-analysis) of published and unpublished empirical data to determine the ecological attributes that are generally associated with pollen limitation, and 2) develop new theory that integrates pollen limitation with plant modularity, resource allocation and perenniality, as well as with plant demography, population growth rates and time to extinction.

Patterns in microbial biodiversity (Extended)

Brendan Bohannan, Peter Morin, Anna-Louise Reysenbach, and Jennifer Hughes – leaders

Bohannan, Brendan	Hughes, Jennifer B.	Petchey, Owen
Brown, James H.	Kane, Matthew	Smith, Val H.
Colwell, Robert K.	Krumins, Jennifer	Staley, James T.
Fuhrman, Jed	Kuske, Cheryl	Ward, David M.
Green, Jessica	Leibold, Mathew	
Horner-Devine, M. Claire	Ovreas, Lise	

Microorganisms represent the vast majority of Earth's biodiversity and they play a crucial role in nearly every process of environmental importance. However we know very little about how microbial diversity is generated and maintained. Our ignorance is due in part to the isolation of microbial diversity studies from the general study of biodiversity. The proposed working group will bring together microbial biologists who are gathering microbial diversity data and ecologists who study biodiversity, to share tools and approaches, to look for patterns in microbial diversity data, and to propose future directions for microbial biodiversity research.

Integrating the aquatic with the terrestrial component of the global carbon budget

Jonathan Cole, Carlos Duarte and Yves Prairie – leaders

Cole, Jonathan J.	McDowell, William H.	Striegl, Robert
Downing, John	Melack, John M.	Tranvik, Lars
Duarte, Carlos M.	Middelburg, Jack	Verburg, Piet
Kortelainen, Pirkko	Prairie, Yves T.	

The traditional compartmentalized approaches to developing inventories of carbons pools and fluxes in the biosphere have generated gaps in the form of key components. Among these key components, freshwater and wetland ecosystems, have been largely ignored or assumed negligible. Recent literature suggests that freshwater ecosystems contribute significantly to some regional carbon balances. We hypothesize, based on a preliminary assessment of the easily available data, that these key components are critical for a reliable estimation of carbon movements at a global scale as well. While the oceans and terrestrial forests are responsible for the net uptake of atmospheric CO2, freshwater ecosystems process a large amount of terrestrially-derived primary production and alter the balance between C sequestration and net CO2 release. This project aims at synthesizing existing information on the linkage between terrestrial and freshwater ecosystems to yield an improved representation of carbon cycling.

Habitat modification in conservation problems: Modeling invasive ecosystem engineers

Kim Cuddington and Jeb Byers – leaders

Byers, Jeb	Jones, Clive G.	Talley, Theresa
Crooks, Jeff	Lambrinos, John	Wilson, Will G.
Cuddington, Kim	Lenihan, Hunter S.	Yelenik, Stephanie
Hastings, Alan	Levine, Jonathan M.	

We propose a working group to develop models and analyze data for species that substantially modify their environment. We will incorporate such habitat modification in models describing population and community dynamics of invasive species. Therefore, we will simultaneously develop methods of modeling “ecosystem engineers”, and produce generalizations regarding the

effects of invasive habitat modifiers. Finally, we will develop quantitative criteria to determine when it is necessary to consider ecosystem engineering in ecological problems.

Analysis of long-term litter decomposition experiments: Synthesis at the site, regional, and global levels

Mark Harmon – leader

Currie, William S.	Hart, Stephen C.
Harmon, Mark	Parton, William J.

Although numerous short-term experiments have been used to develop conceptual and simulation models of decomposition, very little is known about the later stages of this process. Exclusion of this later stage has led, at best, to incomplete understanding of ecosystem carbon and nitrogen dynamics. We propose a working group to examine the wealth of litter and decomposition data that has been produced by several recent long-term field experiments. Our analysis will initially be based on data from LIDET (Long-term Intersite Decomposition Experiment Team), a 27-site experiment conducted over a 10-year period. We will then incorporate results of other networks in Canada and Europe as well as other long-term results into this synthesis. Data will be used to reexamine fundamental paradigms that have guided ecosystem analysis for over a decade. We will also test the ability of simulation models developed from short-term experiments to predict long-term trends. Results from our working group will then be used to produce global maps of litter decomposition-related variables including litter production, substrate quality, carbon and nitrogen stores, and decomposition rates.

Analyzing pattern and process in human cultural diversity

Michael Hochberg – leader

Choisy, Marc	Hochberg, Michael	Panchanathan, Karthik
Cornell, Howard V.	Lafferty, Kevin	Zak, Paul
Guegan, Jean-Francois	Nettle, Daniel	

A major challenge for ecology is to understand the role of humans in the future of life on Earth. Meeting this challenge is a tremendous and — in many ways — obscure enterprise because our species is extraordinarily complex and rapidly changing, and since assessing many aspects of human biology is fraught with social taboos and political impediments. Answers from the ecological sciences will form a small, but important part of the corpus. If we are willing to accept the analogy that humanity is comprised of an ensemble of communities, then many of the concepts of community ecology should apply to human society. As long as one is very clear about the limitations of this analogy, community ecology can be used as a constructive tool in understanding our species (Diamond 1999), its impact on its environment (Moses & Brown 2003), and the future.

Spatial and temporal community dynamics: Sharing data to answer questions

Jeff Houlahan, C. Scott Findlay and David Currie – leaders

Cottenie, Karl	Houlahan, Jeff	Willis, Theodore
Currie, David	Legendre, Pierre	Woiwod, Ian
Ernest, S. K. Morgan	Muldavin, Esteban	Wondzell, Steve
Fuhlendorf, Samuel D.	Russell, Roly	
Gaedke, Ursula	Stevens, Richard	

General ecological principles can, by definition, only be derived from studies that span multiple taxa, geographic areas, and time periods. Such a broad research agenda implies data-sharing among many researchers from diverse geographic regions. Many of the technological barriers to data-sharing have been and are being addressed but there still exist many sociological obstacles to data-sharing because researchers are often, understandably, reluctant to share hard-won datasets. We propose to identify the key barriers to data-sharing and provide incentives to overcome these barriers. Once an effective data-sharing model is developed we will build a 'pilot' database using multi-species, site and time period datasets contributed by the working group participants. This database will be used to answer fundamental ecological questions such as; Are more diverse communities more stable? Is the diversity-stability relationship scale, taxon or habitat specific? Are natural communities regulated primarily by biotic or abiotic factors? Does the answer to that question depend on the scale, taxa and/or habitats being studies? Do spatial and temporal variability change in some predictable way with scale? This working group is intended to be a pilot project for a large-scale 'consortium' of ecologists sharing multi-species, site, and time period datasets to derive general ecological principles.

Analysis of diversity reduction experiments to address the ecosystem consequences of biodiversity loss

Laura Huenneke, Sandra Diaz, and F. Chapin – leaders

Bret-Harte, Syndonia	Huenneke, Laura F.	Smith, Molly
Diaz, Sandra	Lyons, Kelly	Solan, Martin
Flombaum, Pedro	Pugnaire, Francisco	Suding, Katharine N.
Gurvich, Diego	Seidler, Tristram	Symstad, Amy

A diversity reduction working group will examine the relationship between species diversity and ecosystem functioning in a wide range of natural and managed ecosystems. We will evaluate the results of field experiments in which species diversity and composition of plants, animals, and/or microbes have been reduced and ecosystem processes have been measured. We propose two approaches: (1) a meta-analysis of the species-removal literature and (2) a synthesis of comparative measurements to be made in ongoing species-removal experiments in a diverse array of natural ecosystems.

Science Environment for Ecological Knowledge (SEEK) (Hosted by NCEAS)

Matthew B. Jones, Mark P. Schildhauer, James H. Beach, Bertram Ludaescher, William K. Michener – leaders

Beach, James H.	Graham, Martin	Schildhauer, Mark P.
Berkley, Chad	Higgins, Dan	Spears, Rod
Downey, Laura	Jaeger, Efrat	Stewart, Aimee
Franz, Nico M.	Jones, Matthew B.	Tao, Jing
Gales, Robert	Kennedy, Jessie	Valentich-Scott, Paul
Gauch, Susan	Liu, Xianhua	
Graf, Daniel	Peet, Robert K.	

The goals of the Science Environment for Ecological Knowledge (SEEK) are to make fundamental improvements in how researchers can 1) gain global access to ecological data and information, 2) rapidly locate and utilize distributed computational services, and 3) exercise powerful new methods for capturing, reproducing, and extending the analysis process itself. The project involves a multidisciplinary team of computer scientists, ecologists and technologists from

the Partnership for Biodiversity Informatics (PBI), a consortium comprising the National Center for Ecological Analysis and Synthesis (NCEAS); the San Diego Supercomputer Center (SDSC); the University of Kansas (KU); and the University of New Mexico (UNM) and partnering institutions (Arizona State University, University of North Carolina, University of Vermont, and Napier University in Scotland).

The roles of natural enemies and mutualists in plant invasions

Charles Mitchell and Alison Power – leaders

Bever, James	Kareiva, Peter	Parker, Ingrid M.
Callaway, Ragan	Klironomos, John N.	Power, Alison G.
Gilbert, Gregory S.	Mitchell, Charles	Seabloom, Eric
Hufbauer, Ruth A.	Morris, William	Torchin, Mark E.

Invasive plant species both threaten native biodiversity and are economically costly (OTA 1993, Williamson 1996, Wilcove et al. 1998, Mack et al. 2000, Pimentel 2002). Recent results (Mitchell and Power 2003) suggest that invasive plants become widespread problems, in part, because they are released from attack by pathogens relative to their native range. However, the roles of herbivores and mutualists in plant invasions remain controversial (Maron and Vila 2001, Keane and Crawley 2002, Agrawal and Kotanen 2003), and the potential for interactive effects of natural enemies and mutualists has been little considered. This working group will examine the joint roles of herbivores, pollinators, mycorrhizal fungi, and pathogens in plant invasions. The first goal of this working group will be to more fully quantify the effects of plant introductions on their associations with these enemies and mutualists. We will achieve this by synthesizing existing data on the geographic occurrence and impact of insect herbivores, mycorrhizal fungi, pollinators, and pathogens. We will then examine to what degree changes in naturalized plants' associations with these other organisms can explain major patterns in biological invasions, particularly variation among naturalized species in their ecological impacts.

Seasonality and the population dynamics of infectious diseases

Mercedes Pascual and Andrew Dobson – leaders

Alonso, David	De Leo, Giulio	King, Aaron A.
Altizer, Sonia	Dobson, Andrew P.	Koelle, Katia
Bjornstad, Ottar N.	Hosseini, Parviez R.	Lele, Subhash R.
Cattadori, Isabella	Hudson, Peter	Pascual, Mercedes
Codeco, Claudia	Kendall, Bruce E.	Rohani, Pej

Seasonal variation takes many forms in the natural world. All of us notice the annual cycles in temperature, day length, and rainfall, and these have profound effects on rates of resource production and availability that plants and animals respond to in order to modify their reproduction and maintenance schedules. These regular cycles impose constraints and create opportunities for transmission of infectious diseases. Humans also superimpose seasonal processes onto their lives in a way that creates opportunities for infectious diseases; for example school semesters and annual vacations. This working group will examine the different ways in which seasonal variation in population size, contact rates and the survival of free-living infectious stages modifies the population dynamics of infectious diseases. The working group will bring together biologists, epidemiologists and mathematicians all of who have worked on different aspects of these problems. The workshop is particularly relevant to our understanding of the potential disease problems associated with climate change.

When, and how much, does fear matter? Quantitatively assessing the impact of predator intimidation of prey on community dynamics

Evan Preisser and Daniel Bolnick – leaders

Abrams, Peter A.	Luttbeg, Barney	Preisser, Evan L.
Bolnick, Daniel I.	Orrock, John L.	Schmitz, Oswald J.
Diehl, Sebastian	Pantel, Jelena	Sih, Andrew
Dill, Lawrence M.	Peacor, Scott	Trussell, Geoffrey
Grabowski, Jonathan	Peckarsky, Barbara	Werner, Earl E.

Interactions between predators and their prey are the cornerstone of food-web ecology. Ecologists have traditionally thought of such interactions in terms of the number of prey consumed by predators. A mounting array of evidence suggests that prey are far from helpless victims, however, and that they employ a wide array of defensive strategies. The costs of these strategies can include reduced energy income, lower mating success, or increased vulnerability to other predators. Predators can thus reduce prey density both through direct consumption (density-mediated interactions, 'DMIs') and through the costs arising from anti-predator strategies (trait-mediated interactions, 'TMIs'). The presence of TMIs can introduce nonlinearities into species interactions that profoundly affect both short-term interactions and longterm population dynamics. We will use meta-analysis to evaluate patterns of TMIs across a range of ecosystems, taxa, and as a function of predator, prey, and resource density, and to determine the relative importance of different forms of TMIs (reductions in feeding, mating opportunities, reproductive allocation, etc) in shaping predator-prey interactions. Our empirical results will be used to help develop models of predator-prey interactions incorporating both density-mediated and a range of trait-mediated effects, in turn allowing us to generate new hypotheses testable by meta-analysis. We will produce: 1) a series of articles, including one which proposes TMIappropriate experimental methodologies; 2) an article for the general public; and 3) a comprehensive database of TMI research.

Testing alternative methodologies for modeling species' ecological niches and predicting geographic distributions

A. Townsend Peterson and Craig Moritz – leaders

Anderson, Robert P.	Hijmans, Robert	Nakamura, Miguel
Elith, Jane	Huettmann, Falk	Peterson, A. Townsend
Ferrier, Simon	Lehmann, Anthony	Phillips, Steven
Graham, Catherine	Li, Jin	Scachetti Pereira, Ricardo
Guisan, Antoine	Moritz, Craig	Wisz, Mary

Knowledge of world biodiversity remains sparse, with millions of species left to be described, most species' geographic distributions poorly understood and the ecological and evolutionary processes that underpin geographic patterns of diversity still far from resolved. Many large-scale conservation projects, however, depend critically on more complete descriptions of species' distributions and there is increasing interest in incorporating process as well as pattern into biodiversity evaluation. The inferential step that leads from incomplete present knowledge to a explicit prediction of geographic distribution is presently made via diverse methods which have not been tested against each other to establish which would provide the greatest predictive ability for different types of questions and data. We propose a NCEAS working group that will review

and compare diverse predictive modeling approaches with the goal of producing an ideal strategy for modeling parameters related to ecological niches and predicting geographic distributions.

Ecological and evolutionary models for homeland security strategy

Rafe Sagarin – leader

Atran, Scott	Johnson, Dominic	Tooby, John
Blumstein, Daniel	Madin, Elizabeth M.P.	Vermeij, Geerat
Buston, Peter	Sagarin, Rafe	
Hochberg, Michael	Taylor, Terence	

Biological organisms have developed a remarkable number of strategies to mitigate conflict with a broad range of adversaries in their environment. The diversity and success of these strategies, as illustrated by the millions of extant species on the Earth today, suggests that biological evolution may be a field rich with lessons for guiding societal conflict resolution and security strategy. The working group will bring leading security policy analysts together with evolutionary biologists, anthropologists and ecologists to draw on their expertise and identify evolutionary strategies that are applicable to security challenges faced by people, institutions and nations in the 21st century. These biological analogies will be developed into models of decision-making and behavior to explore alternative hypotheses related to strategies for security planning. The combination of biological and policy-oriented perspectives will allow both a rich theoretical discussion and a realistic assessment of the barriers to practical applications of theory.

Exotic species: A source of insight into ecology, evolution, and biogeography

Dov Sax, Steven Gaines and Jay Stachowicz – leaders

Blackburn, Tim M.	Grosberg, Richard K.	O'Connor, Mary I.
Brown, James H.	Hastings, Alan	Rice, William
Bruno, John	Holt, Robert D.	Sax, Dov F.
Cassey, Phillip	Hughes, Randall	Stachowicz, Jay
D'Antonio, Carla	Lafferty, Kevin	Tilman, David
Gaines, Steven D.	Lockwood, Julie	

Exotic species pose a serious threat to the structure and function of native ecosystems and cause significant economic damage. In spite of these costs, exotic species present unique opportunities to advance our conceptual understanding of ecological patterns and processes. By using exotic species as a vast array of natural experiments we can address questions at scales that would otherwise be non-experimental, and we can observe processes that have occurred repeatedly in the past, but that have previously gone unrecorded. Indeed exotic species may present one of the best inroads available to understanding ecology, evolution and biogeography. The goals of this working group are three-fold. First, to explore the insights that exotic species provide to fundamental conceptual issues in ecology, evolution and biogeography. Second, to provide a model for the budding field of invasion biology, which currently is focused strongly on applied issues, but which could be redirected to simultaneously study both applied and conceptual issues. Third, to use the insights we gain to ecology, evolution and biogeography to in turn improve our ability to manage and mitigate the damage caused by exotic species. To accomplish these goals, we propose a novel model that includes the delegation of work prior to the first meeting of the working group; we have identified a motivated body of scientists who are ready to initiate this work. This approach should allow us to produce a great number of conceptual insights, as well as

a great number of important publications, that will advance the study of ecological systems and our ability to effectively manage them.

Can we now determine if, when, and how microbial community composition impacts ecosystem processes? Will that understanding yield critical new information about ecosystem function and response to change?

Josh Schimel – leader

Allen, Michael F.	Lawrence, Corey	Schimel, Josh
Bohannan, Brendan	Moorhead, Daryl	Sinsabaugh, Robert
Firestone, Mary	Neff, Jason	Treseder, Kathleen

Linking populations and process dynamics has been a major thrust in ecology for the last decade or more. This issue has been a concern in microbial ecology, but linking microbial community dynamics with ecosystem scale processes has been a major challenge. There remains debate as to whether any such linkages really exist, though there are theories about which processes should be sensitive to community composition and there have been a number of individual studies that support these theories. There has not, however, been any broad and effective synthesis to test theories or critically assess how best to establish microbe-ecosystem linkages. We propose a working group that will identify the most successful current approaches for establishing linkages, work with available data sets and existing ecosystem models to determine how to best incorporate appropriate microbial community dynamics into larger-scale models, and work with the models to evaluate the effects of incorporating microbial dynamics into them.

Macro-Ecology and biogeography: Hierarchical (Bayesian) model development using data from South Africa

John Silander – leader

Banard, Dawn	Holsinger, Kent	Rebelo, Anthony G.
Gelfand, Alan E.	Latimer, Andrew	Silander, John
Hegerl, Gabriele	Midgley, Guy F.	
Hewitson, Bruce	Prunier, Rachel	

We propose a Working Group that will focus on developing hierarchical (Bayesian) statistical models to explain joint spatial patterns in plant species distributions (and thus diversity), using unique datasets from South Africa.

The statistical models will: be individual species-based, be spatially explicit, utilize individual species attributes (including phylogenetic information), and include various explicit sources of environmental heterogeneity. The models will be hierarchical in attempting to explain joint patterns of species distributions, thus getting at diversity directly from a mechanistic perspective. We know of no other studies which have taken this approach. In building, validating and comparing the models, we have access to unique data sets from South Africa: 1) the Protea Atlas species inventory; 2) A set of explanatory GIS data layers for the Cape Floristic Region (CFR); 3) cladistic/phylogenetic data on taxa in the Proteaceae; 4) a database of up to 4000 releves from the CFR; and 5) potentially, access to a database of the distribution (at ¼ degree grid cells) of all 23,000 flowering plant species in Southern Africa. The CFR is one of the world's hottest hotspots of plant diversity, and the Protea Atlas dataset may be the most complete presence-absence data set for any taxonomic group across any region.

The fate of nitrogen inputs to terrestrial ecosystems

Pamela Templer, Michelle Mack and Knute Nadelhoffer – leaders

Christenson, Lynn	Hobbie, Sarah	Schimel, Josh
Compton, Jana	Holland, Keri	Schleppi, Patrick
Currie, William S.	Hungate, Bruce	Sommerkorn, Martin
D'Antonio, Carla	Kappel Schmidt, Inger	Spoelstra, John
Dail, Bryan	Mack, Michelle	Templer, Pamela
Emmett, Bridgett	Nadelhoffer, Knute	Tietema, Albert
Epstein, Howie	Osenberg, Craig W.	Zak, Donald R.
Gundersen, Per	Perakis, Steve	

Recent technical innovations in the use of 15N stable isotopic tracers at the ecosystem scale have produced a wealth of data on the fate of N inputs to terrestrial ecosystems. Although this analytically intensive technique has been used at over 20 sites world wide, there have been few attempts at cross-site synthesis. Here we propose a series of working group activities to synthesize ecosystem-scale 15N tracer experiments across a wide geographic range of ecosystem types. While at NCEAS, we propose to develop three products: (1) a standardized protocol for application and analysis of 15N tracer studies, (2) a meta-analysis of the fate and redistribution of N across sites and ecosystem types, and (3) an inter-site comparison with the TRACE model, a simulation model that predicts the fate of N inputs over long time scales. Through these activities, we will address questions about controls over the fate of N inputs in terrestrial ecosystems and the consequences of increased N deposition.

Global change and infectious disease

Mark L. Wilson and Leslie A. Real – leaders

Ahumada, Jorge	Pascual, Mercedes	Smith, David L.
Bouma, Menno J.	Real, Leslie A.	Smith, Katherine F.
Dobson, Andrew P.	Recker, Mario	Wilson, Mark L.
Hay, Simon	Rodo, Xavier	

A major element underlying many emerging and reemerging infectious diseases is environmental change. This may be manifested through direct and intentional landscape changes(e.g. hydroelectric dams, agricultural development projects, irrigation, urban expansion, mining, deforestation), indirect habitat changes that favor transmission (e.g. increased vector breeding sites, evolution of virulence, or enhanced contact with infectious agents), and the possibility that other indirect abiotic effects including climate change might alter the intensity or distribution of various diseases. A better understanding of these processes is needed for risk is to be understood and reduced, and for outbreak forecasts are to be made accurate and credible. The goal of this sub-group is to explore various associations between environmental change and specific infectious diseases that have strong environmental links by analyzing data sets with extensive and well-documented temporal and/or spatial variation.

Specifically, we propose to begin by analyzing two categories of infectious disease. The first is vectorborne disease. Within this category we focus on a mosquito-borne anthroponosis, human malaria, which will be analyzed using data from various sites and sources throughout the world. Time-series analysis and study of spatial patterns among cases and environmental variables will be undertaken using standard time-series and GIS-based statistical models. An attempt will be made to test hypotheses that are based in the biology of vectors, human ecological relations with the environment and each other, and climatic factors that influence transmission.

Diarrheal diseases comprise the second category. Evolutionary theory and empirical studies indicate that diarrheal diseases evolve increased or decreased virulence in response to environmental changes. Specifically, this work suggests that when waterborne routes of transmission are available natural selection will favor highly exploitative pathogen variants because in such environments the costs of exploitation are low. Even ill, immobilized hosts can act as sources of infection because fecal material is removed and washed in water that can contaminate supplies of drinking water. Conversely, if safe water supplies are provisioned, we predict pathogens to evolve toward benignity. There exists a great amount of data in the literature and in unpublished records (e.g., located in ministry of health archives) that we propose to analyze to test this prediction. Our focus in this second category will be on the bacterial agents of dysentery, because the inherent virulence of these agents varies at the species level, and the frequencies of these species in human populations spans the length of time over which water supplies have been improved (i.e., over the past century).

Working Groups With Near Term Relevance for Resource Managers and Policy Makers

Knowledge and capacity-building to support ecosystem-based management for sustainable coastal-marine systems (Hosted by NCEAS)

Sandy Andelman – leaders

Abelson, Avigdor	Green, David	Parrish, Julia K.
Abramson, Sarah	Halpern, Ben	Paton, Peter
Adams, Vanessa	Hershner, Carl	Perevolotsky, Avi
Altman, Irit	Hoffmann, Gretchen	Pyke, Chris
Andelman, Sandy J.	Holsman, Kirstin	Rehmus, Scott
Arkema, Katie	Huang, Mary	Rosenberg, Andrew A.
Baron, Nancy	Iwaniec, David	Ruesink, Jennifer
Blanchette, Carol	Jagtap, Tanaji	Ruttenberg, Benjamin
Bode, Michael	Jenkins, Aaron	Segoli, Moran
Byers, Jeb	Kinnaird, Margaret F.	Selkoe, Kimberly
Childers, Dan L.	Lafferty, Kevin	Shachak, Moshe
Chou, Loke Ming	Langford, Bill T.	Sheffer, Efrat
Costello, Christopher	Lenihan, Hunter S.	Stanaway, Kathryn
Dewsbury, Bryan	Lester, Sarah	Strickler, Matt
Dingerson, Lindy	Lorda, Julio	Teck, Sarah J.
Dugan, Jenifer E.	Madin, Elizabeth M.P.	Vigness-Raposa, Kathy
Evans, Kirsten	McClanahan, Tim	Walbridge, Shaun
Floeter, Sergio R.	Metz, Josh	Wieters, Evie
Gaines, Steven D.	Meyer, John	Wilson, Kerrie
Gibson, Patrick	Morlock, Summer	Wozniak, Jeff
Goss, Chuck	Navarrete, Sergio A.	Young, Thomas
Grebmeier, Jacqueline M.	O'Brien, Timothy G.	Zollett, Erika

The recent U.S. Commission for Ocean Policy Report (2004) calls for a new national ocean policy that balances use with sustainability, and moves towards ecosystem-based management (EBM) founded on sound science. But, as yet, there is no scientific consensus on (1) the basic elements or processes involved in ecosystem-based management; (2) the scientific understanding

of coastal-marine systems that it will require; or (3) how best to integrate that scientific understanding into decision-making processes. The David and Lucile Packard Foundation has developed a strategic vision to fill this urgent need – a carefully designed science program to help create and ensure the use of the knowledge, tools, and skills needed for EBM of sustainable coastal-marine systems.

In June 2004, the Packard Foundation awarded $2,060,292 to the National Center for Ecological Analysis and Synthesis (NCEAS), at the University of California, Santa Barbara for a three year program of activities, involving the analysis and synthesis of existing data and development of new tools to address gaps in knowledge that are critical to successful implementation of ecosystem-based management. The NCEAS activities will include support for working groups, postdoctoral fellowships, graduate student support, and a distributed graduate seminar.

In this program, NCEAS will go beyond publishing academic papers to devise specific strategies to make the scientific knowledge developed through the project directly useful for practitioners and policy makers. Previous attempts to implement ecosystem-based management have been hindered by the failure to effectively incorporate scientific understanding into the decision-making process, and by neglecting to include the stakeholders whose support will be essential to action. We expect that this set of NCEAS activities will lead to the development of a coherent body of knowledge that will change the conceptual foundations for managing coastal-marine ecosystems and help develop the necessary capacity among individuals and institutions to catalyze this sea-change.

Both goals and approaches for EBM vary, depending on geographic location, social values, institutional settings, economic constraints, etc. Nonetheless, it is clear that EBM entails some level of understanding of the scale, complexity and dynamic nature of both ecological and human systems

Understanding, valuing, and managing dynamic ecosystem services under stress: Synthesizing across the LTER Network

Stephen Farber and Robert Costanza – leaders

Childers, Dan L.	Gross, Katherine L.	Pincetl, Stephanie
Costanza, Robert	Grove, Morgan	Troy, Austin
Erickson, Jon D.	Hopkinson, Chuck	Warren, Paige S.
Farber, Stephen	Kahn, James R.	Wilson, Matthew A.

This project utilizes the LTER site network to develop understanding of the biogeophysical dynamics in stressed ecosystems and the implications of those dynamics for the valuation and management of ecosystem services and underlying ecological support systems. It uses a variety of LTER sites, in different ecological and economic contexts but all subject to existing or potential human stressors. It addresses the appropriateness of valuation methods, how valuations can be transferred among different contexts, and how databases can be developed consistently across sites to assist in ecological management. It also addresses the special management needs demanded of complex, dynamic systems.

Models of alternative management policies for marine ecosystems

Robert Francis and James Kitchell – leaders

Aydin, Kerim	Dalton, Michael	Francis, Robert C.
Christensen, Villy	Field, John	Gaichas, Sarah

Hinke, Jefferson	Little, Jodie	Walters, Carl
Kaplan, Isaac	Martell, Steve J.	Watters, George
Kitchell, James F.	Olson, Robert J.	

We are employing comparative approaches based on a common modeling framework developed for each of five large marine ecosystems in the North Pacific Ocean. Each of these ecosystems has served as the focus of controversy over the ecological consequences of fishery management practices, protection for threatened or endangered species, and the relative importance of large-scale environmental variability. Each of these ecosystems has been the focus of model development effort using the common framework of an Ecopath/Ecosim approach. We are using these five models as the basis for evaluating policy effects on ecosystem structure, clarifying the tradeoffs in fishery and conservation goals, and designing robust management strategies. We have also created novel ways of visualizing complex ecosystem models, as a way to make them more accessible to policy makers. Our efforts are supported by the National Center for Ecological Analysis and Synthesis.

Putting ocean wilderness on the map: Building a global GIS atlas of pristine marine environments

Ben Halpern, Kimberly Selkoe, Fiorenza Micheli and Hunter Lenihan – leaders

Benison, Sean	Heinemann, Dennis	Selkoe, Kimberly
D'Agrosa, Caterina	Lenihan, Hunter S.	Smith, Mike
Fox, Helen	Micheli, Fiorenza	Steneck, Robert S.
Fujita, Rod	Myers, Ransom A.	
Halpern, Ben	Sanderson, Eric W.	

Terrestrial conservation has long recognized the need for setting global priorities, and a common strategy for such efforts has been to focus on wilderness, or pristine, areas. Only recently have conservation groups begun to consider marine ecosystems, and efforts to take a global approach remain nascent at best. In order to move forward, conservation groups need global-scale data on which to base their priority models, but such data are currently highly dispersed and poorly synthesized. We propose a working group to address two questions that should greatly help close this gap: first, what is a pristine marine ecosystem, and second, where are the remaining pristine areas of the world's oceans? The definition of pristine will be based on an ecologically rigorous assessment of anthropogenic influences on marine ecosystems, and will guide us in identifying existing global-scale datasets that we will use to map the distribution of pristine areas across all marine environments. Our final product will be a GIS-based, interactive atlas of the pristine and impacted areas of the ocean that can be used as a practical tool by conservation groups in developing marine conservation priority models, by academic scientists in future ecological and biogeographic research, and by educators in efforts to increase awareness of ocean conservation needs.

Development of tools for the practical design of marine reserves

Alan Hastings and Louis Botsford – leaders

Baskett, Marissa	Fluharty, Dave	Kinlan, Brian
Baskett, Marissa	Gaines, Steven D.	Largier, John L.
Botsford, Louis W.	Gaylord, Brian P.	Leff, Jamie
Brumbaugh, Dan	Halpern, Ben	Micheli, Fiorenza
Carr, Mark H.	Hastings, Alan	Rosenberg, Andrew A.

Warner, Robert R.
We propose a working group to examine the general question of moving from theory to policy, specifically looking at the design of marine reserves, building on the quantitative results obtained under a previous NCEAS working group, "A Theory of Marine Reserves", by J. Lubchenco, S. Gaines and S. Palumbi. Whereas the modeling in that working group was a development of a general theory of marine reserves, the focus of the working group proposed here will be an application of that theory to specific problems. Rather than consider ideal optimal reserve configurations, we will study implementing actual marine reserves, given a specific situation and constraints (i.e., current fishing rate, current state of the ecosystem, limited area under consideration, uncertainty in larval dispersal, fisher behavior). The goal will be to develop scientifically sound design tools that can be used in ongoing and future implementation efforts for reserve systems, considering reserves designed both to improve fisheries and to conserve natural marine ecosystems. This effort can be viewed as a paradigm for the problem of translating ecological theory into practical policy applications.

Narrowing the gap between theory and practice in mycorrhizal management
Jason Hoeksema, Nancy Johnson and James Umbanhowar – leaders

Bever, James	Klironomos, John N.	Simard, Suzanne
Chaudhary, Bala	Miller, Michael R	Swenson, William
Gehring , Catherine	Moore, John C.	Umbanhowar, James A.
Hoeksema, Jason D.	Moutoglis, Peter	Wilson, Gail W.
Johnson, Nancy C.	Schwartz, Mark	Zabinski, Catherine

Research on interactions between plants and their symbiotic mycorrhizal fungi has increased dramatically during the last decade, generating a confusing body of theoretical and empirical results. Simultaneously, there has been an explosion in commercial applications of mycorrhizal fungi in agriculture, horticulture, forestry and ecosystem restoration. Considering the unexpected consequences of many human introductions of non-native plants and animals, and our current lack of understanding of the factors controlling mutualistic performance of mycorrhizas, it is alarming that so little caution is being used in commercial applications of mycorrhizal fungi. Our proposed working group will: 1) perform meta-analyses to synthesize the currently disparate body of empirical and theoretical work on mycorrhizal function within communities and ecosystems, 2) develop models of mycorrhizal performance with environmental conditions and plant and fungal phenotypes as variables, 3) generate recommendations and precautions regarding the commercial use of mycorrhizal inoculum, 4) establish an online database that documents inoculation trials and tracks their outcome over time, and 5) organize a symposium at an international conference. In addition to contributing to the development of principles to guide mycorrhizal management, our efforts will help generate better theories for understanding the roles of mutualisms in population and community dynamics.

Stochastic demography for an increasingly variable world
William Morris, Catherine Pfister and Shripad Tuljapurkar – leaders

Boggs, Carol	Doak, Daniel	Kendall, Bruce E.
Boggs, Carol	Gaillard, Jean-Michel	Knight, Tiffany
Boyce, Mark	Haridas, Chirakkal V.	Lee, Charlotte
Bruna, Emilio M.	Horvitz, Carol C.	Mastrandrea, Michael Dechen
Coulson, Tim	Kalisz, Susan	

Menges, Eric	Pfister, Catherine A.
Morris, William	Tuljapurkar, Shripad

Both the means and the variances of such important environmental variables as growing-season temperature and rainfall are projected to increase in many regions over the 21st century. While effects on organisms of changes in mean conditions have often been anticipated, the potential effects of increasing variability have been relatively neglected. We propose a Stochastic Demography Working Group to assess how increasing environmental variability is likely to impact populations of plants and animals. Using unpublished demographic data for a diverse set of taxa and new theoretical tools developed by group members, we will compare the effects of changes in the means vs. the variances of environmental variables, as well as the pattern of sensitivity to environmental variability across species, life histories, and habitats. In addition, we will ask whether the demographic processes that most influence population growth are the least sensitive to environmental variation, a pattern that has been observed in the relatively small number of species previously tested and that would serve to buffer populations against increasing environmental variability. Our ultimate goal is to improve the ability of ecologists to forecast the consequences for the long-term viability of populations of not only overall trends in environmental conditions but also expected changes in year-to-year variability.

Ecosystem-based management for the oceans: The role of zoning

Gail Osherenko, Elliott Norse, Larry Crowder, Oran Young and Satie Airame – leaders

Abramson, Sarah	Halpern, Ben	Osherenko, Gail
Airame, Satie	Langdon, Stephen J.	Peach, Robbin
Cairns, Christina	McLeod, Karen	Rosenberg, Andrew A.
Crowder, Larry B.	Norse, Elliott	Wilson, James
Day, Jon	Ogden, John C.	Young, Oran R.

The proposed working group on Ocean Ecosystem Management will explore the role of place-based systems in achieving ecosystem-based ocean management. The U.S. Commission on Ocean Policy (2004) and the Pew Oceans Commission (2003) both recommend ecosystem-based management of the 4.4 million square miles of ocean within the jurisdiction of the United States. The Pew Oceans Commission Report, as well as numerous scientists, managers, and advocacy organizations, has called for development of ocean zoning as a key component of ecosystem-based management. Ocean zoning is the authoritative regulation and allocation of access and use to specific marine geographic areas. Zoning systems aim to separate competing uses, reduce conflict, increase certainty among users, and protect sensitive marine resources. Fisheries management has increasingly used spatial regulation to determine access, protect nursing and spawning areas, reduce gear impacts, etc. More recently, place-based marine management is growing through the establishment of marine protected areas (MPAs), including fully protected no-take reserves and areas offering protection from a limited set of uses. This working group will bring together ecologists and social scientists to explore the concept, practice, and opportunities for ocean zoning in a unique political and social climate primed for change. We will focus particularly on the question of whether or not and how zoning systems can be used to implement ecosystem-based management of oceans within the jurisdiction of the United States. The working group goals are to: (1) compile and synthesize information on existing systems of ocean zoning and their ecological and social impacts, (2) compile and synthesize available ecological and social data necessary to design and develop effective zoning systems, (3) develop the concept of ocean zoning within the context of ecosystem based management, and (4) design a set of principles and

policies for creation of sustainable and resilient ecosystem-based ocean zoning systems. We have identified a group of leading thinkers engaged in developing an understanding of the complex ecological and social dynamics of ocean systems. The resources of NCEAS will enable us to bring these experts together to advance our understanding of marine ecosystems and our ability to implement scientifically based and effective ecosystem management.

A synthetic analysis of the scientific basis of ecological restoration of stream ecosystems
Margaret Palmer and J. David Allan – leaders

Alexander, Gretchen	Follstad-Shah, Jennifer	Meyer, Judy
Allan, J. David	Galat, David L.	O'Donnell, T. Kevin
Bernhardt, Emily	Gloss, Steven P.	Pagano, Laura
Bowman, Margaret	Hassett, Brooke	Palmer, Margaret A.
Brooks, Shane	Jenkinson, Robin	Powell, Bruce
Carr, Jamie	Kondolf, G. Mathias	Srivastava, Puneet
Clayton, Steve	Lake, P. S.	Sudduth, Elizabeth
Dahm, Cliff	Lave, Rebecca	Wright, Justin

We will assess the quality of the science underlying ecological restoration activities using stream ecosystems as model restoration systems. We will assemble a unique data set that spans multiple ecoregions and many different types of restoration activities performed by diverse groups with various stakeholder interests. Specifically, our data set will address: what kinds of restoration activities, at what scale, and by what means, are taking place; how goals were set and success measured in these restoration efforts; the extent to which scientific criteria were used; the extent to which adaptive management was an explicit component of the restoration activity; and the extent to which scientists are forming partnerships with restorationists in order to use restoration projects as opportunities for scientific experimentation. Our synthesis will facilitate the linkage between the practice of ecological restoration and the science of restoration ecology and will attempt to establish standards for data gathering to scientifically assess restoration methods and success.

A Knowledge Network for Biocomplexity: Building and evaluating a metadata-based framework for integrating heterogeneous scientific data (Hosted by NCEAS)
Jim Reichman, James Brunt, John Helly, Matthew Jones and Michael Willig – leaders

Altintas, Ilkay	Colunga, Manuel	Higgins, Dan
Ancheta, Johnoel	Costa, Duane	Huang, Jr-Chuan
Anderson, John	Czarnoms, Nicole	Hutchison, Vivian
Attenberger, Stan	Downey, Laura	Jenkins, Keith
Baker, Debbie	Drake, John	Johnston, Karla
Ball, William	Endrulat, Erik	Jones, Chris
Bauer, Steven	Fiala, Anne	Jones, Matthew B.
Berkley, Chad	Franz, Nico M.	Jones, Owen
Best, Ben	Fredericks, Tom	Kling, Louise
Brenner, Jorge	Gardner, Christopher	Laundre, James
Browne, Kevin	Garg, Saurabh	Levatich, Tim
Chen, Chien-Wen	Garrit, Robert	Lienkaemper, George
Chen, Jin-Song	Gartner, Kevin	Lin, Chau Chin
Collins, Scott L.	Hale, Stephen	Melendez, Eda

Milojevic, Stasa	Romanello, Samantha J.	Valentine, Theresa
Moreno Baez, Marcia	Rundall, Jill	Vanderbilt, Kristin
Pedroso, Moacir	Schenck, Donald	Walsh, Jonathan
Pennington, Deana D.	Schildhauer, Mark P.	Wang, Xiaoping
Philippi, Tom	Servilla, Mark	Williams, Rich
Quiros, Sandra	Shaw, M. Rebecca	Wimbrow, Mike
Rewerts, Chris	Stevenson, Robert	Yiu, Wen Ting
Rhyne, Tim	Swemmer, Anthony	
Riordan, Brian	Tonsor, Stephen	

Complexity is an inherent property of living systems that arises from direct and indirect interactions among the earth's physical, chemical, and biological components. Biocomplexity includes the structural and functional attributes of dynamic systems that arise at all levels of biological organization, including individuals, populations, and communities. Importantly, ecological components of biocomplexity (e.g., biodiversity, ecosystem services) are in crisis, and are undergoing potentially irreversible changes in the face of rapid human population growth and economic development. Wise stewardship, based on all available scientific knowledge concerning these natural systems, is essential. Data Catalyzed by these societal concerns, and facilitated by technology advances, scientists focused on complex ecological systems have generated an explosion of ecological and environmental data. When integrated with data from other disciplines (e.g., meteorology), these data have the potential to greatly enhance understanding of biocomplexity. However, broad-scale and synthetic research is stymied because these data are largely inaccessible due to their spatial dispersion, extreme structural and semantic heterogeneity, and complexity.

Lianas and tropical forest dynamics: Synthesis of Pan-tropical patterns from regional data sets

Stefan Schnitzer and Robyn Burnham – leaders

Bongers, Frans	Foster, Robin	Pérez Salicrup, Diego
Burnham, Robyn J.	Gerwing, Jeff	Schnitzer, Stefan A.
Chave, Jérôme	Martinez-Ramos, Miguel	Thomas, Duncan
DeWalt, Saara J.	Muller-Landau, Helene C.	
Ewango, Corneille E.N.	Parren, Marc	

Lianas (woody vines) are an important component in tropical forest dynamics, altering forest regeneration, species diversity and ecosystem-level processes such as carbon sequestration. Recently, the study of liana ecology has increased substantially throughout the tropics; however, methods for collecting liana data are only rarely consistent and there is little comparability in liana abundance, biomass, diversity, composition, or community dynamics across large areas of the tropics. Until these data sets are combined and synthesized, many large-scale questions on the ecology of lianas will remain unanswered. We propose an NCEAS Working Group to standardize, combine, and synthesize the many liana data sets from research groups around the world. In doing so, we will compile a pan-tropical data set with which we can answer specific questions about the contribution of lianas to forest diversity and biomass worldwide, as well as the pan-tropical distribution of many important liana taxa. Four main goals will be addressed during two Working Group Meetings and the intervening year. (1) Establish logical and useable guidelines for censuses of lianas, given different research goals. (2) Assemble and synthesize preexisting data sets on liana stem diameter, abundance, and diversity using empirically derived

correction factors to generate a uniform, pan-tropical data set on lianas. (3) Estimate liana biomass at the whole-forest and regional levels using new and substantially more robust stem diameter-to-biomass equations. (4) Create standard systematic databases and maps of the geographic distribution of liana taxa and maps of liana hotspots to identify conservation priorities.

Linking marine biodiversity to ecosystem functions and services

Boris Worm and Enric Sala – leaders

Baron, Nancy	Lotze, Heike K.	Stachowicz, Jay
Beaumont, Nicola	Micheli, Fiorenza	Watson, Reg
Duffy, Emmett	Palumbi, Stephen R.	Worm, Boris
Halpern, Ben	Sala, Enric	
Jackson, Jeremy	Selkoe, Kimberly	

Biodiversity, or biological diversity, is the variation of life at all levels of organization, from the level of genetic variation within and among species to the level of variation within and among communities, ecosystems and biomes. It is well-documented how human impacts are changing biodiversity in terrestrial (Wilson 1999) and marine ecosystems (NRC 1995). Historical studies in marine systems have further shown that long-term impacts often lead to the simplification of food webs, as species and species groups are driven to such low abundances that they become functionally extinct (Jackson et al. 2001, Lotze and Milewski 2002). The general consequences of these trends and changes for ecosystem functions, such as primary and secondary productivity, carbon and nutrient cycling, food and habitat provision are little understood in marine systems. The recent research focus on biodiversity, however, has generated a significant, albeit diffuse body of theory and empirical studies. Without synthesis, it is difficult to communicate to the public and to environmental managers why marine biodiversity matters, what the ecological and economic consequences of species loss and changes in biodiversity are, and how dramatic consequences can be prevented. The proposed working group aims to fill this gap. In addition to quantifying the link between marine biodiversity and ecosystem functioning, we will analyze the potential for the disruption of marine ecosystem services, which are those functions that are vital to our food supply, economies, and human health (see Fig. 1). Finally, we will use the results from our analyses to evaluate the costs and benefits of maintaining the status quo versus implementing significant global conservation measures. In three consecutive workshops we will (1) collate experimental and observational evidence on how marine biodiversity and ecosystem functions are linked in a web-accessible database, (2) conduct and publish a series of meta-analyses to derive generalizations about the effects of species loss, ecological simplification and changes in marine biodiversity on ecosystem functions and services, (3) write a policy paper that translates our results into management strategies.

Meetings Hosted by NCEAS

Name	Sponsor and Project Title
Frank Davis	Coastal Reserves
Ed Hackett	Environmental Hazards, Transportation and Equity
Peter Kareiva	The Nature Conservancy, Data Management Meeting

David Lodge	Integrated Systems for Invasive Species
Deborah McCullough	Pathways of non-indigenous plant pest introductions: How exotic insects, pathogens and weeds arrive in the United States
Bob Peet	VegBank Desktop Client Workshop
Diana Rhoten	Integrative, interdisciplinary graduate education: New concepts and approaches for assessment
Rebecca Shaw	USFWS Island Fox Recovery
Ali Whitmer	LTER Planning Grant Committee and Advisory Committee

Scientific Visitors

Name	Project Title
Jannicke Moe	University of Oslo
Felisa Smith	University of New Mexico
Diane Srivastava	University of British Columbia
Jim Regetz	Princeton University
Kris Verheyen	Katholieke Universiteit Leuven

Center Associates Hosted by NCEAS

Name	Project Title
John Alroy	Paleobiology Database
Nancy Baron	SeaWeb

Research Training Activities

Seven graduate student interns and seven undergraduate interns were involved with research activities at NCEAS during the reporting period. They are listed below, along with the titles of the projects they worked on.

Graduate Student Interns

Intern	Sponsor and Project Title
Sarah Abramson	Jim Reichman Kids Do Ecology
Sean Benison	Ben Halpern Putting ocean wilderness on the map: Building a global GIS atlas of pristine marine environments
Andrea Chadden	Jim Reichman Mellon Informatics (Hosted by NCEAS)
David Lamb	John Alroy Paleobiology Database
Erin Leckey	John Alroy Paleobiology Database
Josh Metz	Sandy Andelman Knowledge and capacity-building to support ecosystem-based management for sustainable coastal-marine systems (Hosted by NCEAS)
Kim Selkoe	Boris Worm and Enric Sala Linking marine biodiversity to ecosystem functions and services
Jill Wertheim	John Alroy Paleobiology Database (Hosted by NCEAS)
Robin Whatley	John Alroy Paleobiology Database (Hosted by NCEAS)

Undergraduate Student Interns

Intern	Sponsor and Project Title
Helen Claudio	John Gamon SpecNet

Education and Outreach Activities

NCEAS' Kids Do Ecology (KDE) program continues as our primary means of outreach to the K-12 Santa Barbara schools. Sarah Abramson, a graduate student intern, coordinates KDE activities. Visits by NCEAS and UCSB-associated scientists to 5th-grade classrooms remain the core of our

local outreach activities. During these visits, scientists help students formulate and execute an ecological experiment, including data analysis and presentation.

Six Santa Barbara classes and 7 scientists participated in the “Scientist in the Classroom” program during the past year. A total of 300 students participated, including 240 minority students (80%). Examples of this year’s projects include: Examining the attraction of intertidal invertebrates to red and blue light, Observing wind effects on seed dispersal, Analyzing worm decomposition of polluted and unpolluted leaves, Examining pollinator preference according to flower color, Looking at seed growth in dry and wet conditions, and Investigating pill bug preference for shade or sunlight. The students will present their projects at a poster session at NCEAS on May 25, 2005 to share what they learned with each other and NCEAS residents.

Five additional classrooms participated in smaller outreach activities. Two Santa Barbara classes and one Huntsville, Alabama class participated in the Common Ground in Conservation program. Two 6th grade classes in Santa Barbara participated in an ecology lesson presented by 2 scientists – one lesson focused on predator-prey interactions and the other on energy use.

Over the past year, three publications have featured the Kids Do Ecology program. In the May-June 2005 edition of Audubon magazine, staff writer Jessica Ebert wrote a dispatch piece entitled "Junior Ecologists". This short column highlighted Annemari Goldsmith's class experiment on the feeding habits of sea stars. Sarah Abramson wrote an article, "Science Policy and the K-12 Classroom" for the Society for Advancement of Chicanos and Native Americans in Science (SACNAS) Fall 2004 Newsletter. The article identifies the National Science Education Standards met by Kids Do Ecology and features the Common Ground in Conservation program as a useful means of teaching students about science policy through the Endangered Species Act. She also wrote a letter of correspondence to Nature published on September 9, 2004 (volume 431) publicizing the Kids Do Ecology program as a unique method of involving professional scientists in elementary education.

In response to the 2004 site review, we have updated the Kids Do Ecology web site to include a Spanish language version.

Publications

Below we list publications for the reporting period 1 May 2004 - 31 April 2005. Note that this list includes publications that have been reported to us by participants in NCEAS activities during this period, and actual publication dates may precede this period. * Previously reported as in press.

NCEAS Publications
Reported May 1, 2004 - April 30, 2005
** Previously reported as in press*

Abrams, Peter A.. 2004. When does periodic variation in resource growth allow robust coexistence of competing consumer species?. Ecology. Vol: 85. Pages 372-382.

Abrams, Peter A.; Chen, Xin. 2002. The evolution of traits affecting resource acquisition and predator vulnerability: Character displacement under real and apparent competition. American Naturalist. Vol: 160. Pages 692-704.

Altizer, Sonia; Harvell, Drew; Friedle, Elizabeth. 2003. Rapid evolutionary dynamics and disease threats to biodiversity. Trends in Ecology and Evolution. Vol: 18(11). Pages 589-596.

Amarasekare, Priyanga. 2000. Coexistence of competing parasitoids on a patchily distributed host: Local vs. spatial mechanisms. Ecology. Vol: 81. Pages 1286-1296.

Andelman, Sandy J.; Willig, Michael R.. 2004. Networks by design: A revolution in ecology. Science. Vol: 305. Pages 1563-1564.

*Agapow, Paul-Michael; Bininda-Emonds, Olaf R.P.; Crandall, Keith A.; Gittleman, John L.; Mace, Georgina; Marshall, Jonathon G.; Purvis, Andy. 2004. The impact of species concept on biodiversity studies. Quarterly Review of Biology. Vol: 79(2). Pages 161-179.

Ashman, Tia-Lynn; Knight, Tiffany; Steets, Janette; Amarasekare, Priyanga; Burd, Martin; Campbell, Diane; Dudash, Michele R.; Johnston, Mark O.; Mazer, Susan J.; Mitchell, Randall; Morgan, Martin; Wilson, Will G.. 2004. Pollen limitation of plant reproduction: Ecological and evolutionary causes and consequences. Ecology. Vol: 85(9). Pages 2408-2421.

Ashman, Tia-Lynn; Morgan, Martin. 2004. Explaining phenotypic selection on plant attractive characters: Male function, gender balance or ecological context?. Proceedings of The Royal Society: Biological Sciences. Vol: 271(1539). Pages 553-559.

Becerra, Judith. 2003. Evolution of Mexican Bursera (Burseraceae) inferred from ITS, ETS, and 5S nuclear ribosomal DNA sequences. Molecular Phylogenetics and Evolution. Vol: 26. Pages 300-309.

Becerra, Judith. 2003. Synchronous coadaptation in an ancient case of herbivory. Proceedings of the National Academy of Sciences. Vol: 100(22). Pages 12804-12807.

Becerra, Judith. 2004. Molecular systematics of Blepharida beetles (Chrysomelidae: Alticinae) and relatives. Molecular Phylogenetics and Evolution. Vol: 30(1). Pages 107-117.

Bernhardt, Emily; Palmer, Margaret A.; Allan, J. David; Alexander, Gretchen; Barnas, K.; Brooks, Shane; Carr, Jamie; Clayton, Steve; Dahm, Cliff; Follstad-Shah, Jennifer; Galat, David L.; Gloss, Steven P.; Goodwin, Peter; Hart, David; Hassett, Brooke; Jenkinson, Robin; Katz, S.; Kondolf, G. Mathias; Lake, P. S.; Lave, Rebecca; Meyer, Judy; O'Donnell, T. Kevin; Pagano, Laura; Powell, Bruce; Sudduth, Elizabeth. 2005. Synthesizing U.S. River Restoration Efforts. Science. Vol: 308. Pages 636-637.

*Borer, Elizabeth T.; Seabloom, Eric; Shurin, Jonathan B.; Anderson, Kurt E.; Blanchette, C A; Broitman, Bernardo R.; Cooper, S D; Halpern, Ben. 2005. What determines the strength of a trophic cascade?. Ecology. Vol: 86. Pages 528-537.

Botsford, Louis W.; Kaplan, David; Hastings, Alan. 2004. Sustainability and yield in marine reserve policy. American Fisheries Society Symposium. Vol: 42. Pages 75-86.

Brock, William; Xepapadeas, A.. 2004. Management of interacting species: Regulation under nonlinearities and hysteresis. Resource and Energy Economics (Special issue on the economics of biodiversity). Vol: 26(2). Pages 137-156.

Bronstein, Judith L.; Wilson, Will G.; Morris, William. 2003. Ecological dynamics of mutualist/antagonist communities. American Naturalist. Vol: 162. Pages S24-S39.

Brooker, Robin; Kikvidze, Zaal; Pugnaire, Francisco; Callaway, Ragan; Choler, Philippe; Lortie, Christopher J.; Michalet, Richard. 2005. The importance of importance. Oikos. Vol: 109. Pages 63-70.

Burgman, Mark. 2004. Evaluating methods for assessing extinction risk. Acta Oecologica. Vol: 26. Pages 65-66.

Burgman, Mark; Regan, Helen; Ben-Haim, Yakov. 2004. Population viability analysis and robust decisions for management: Combining population models with decision theory.. Sustainable use and conservation of biological diversity, Proceedings of the International Symposium, Berlin, 1-4 December 2003. Federal Ministry of Education and Research. Bonn, Germany. Pages 64-65.

Bush, Andrew M.; Bambach, Richard K.. 2004. Did alpha diversity increase through the Phanerozoic? Lifting the veils of taphonomic, latitudinal, and environmental biases. Journal of Geology. Vol: 112. Pages 625-642.

Bush, Andrew M.; Markey, M. J.; Marshall, Charles R.. 2004. Removing bias from diversity curves: The effects of spatially organized biodiversity on sampling-standardization. Paleobiology. Vol: 30. Pages 666-686.

Buston, Peter. 2004. Does the presence of non-breeders enhance the fitness of breeders? An experimental analysis in the clown anemonefish Amphiprion percula. Behavioral Ecology and Sociobiology. Vol: 57. Pages 23-31.

Buston, Peter. 2004. Territory inheritance in the clown anemonefish. Proceedings of the Royal Society of London, Series B. Vol: 271. Pages S252-S254.

Callaway, Ragan; Kikodze, David; Chiboshvili, M.; Khetsuriani, L.. In press. Unpalatable plants protect neighbors from grazing and increase plant community diversity. Ecology.

Cassey, Phillip; Blackburn, Tim M.; Jones, Kate; Lockwood, Julie. 2004. Mistakes in the analysis of exotic species establishment: Source pool designation and correlates of introduction success among parrots (Aves: Psittaciformes) of the world. Journal of Biogeography. Vol: 31(2). Pages 277-284.

Caswell, Hal; Lensink, Rob; Neubert, Michael G.. 2003. Demography and dispersal: Life table response experiments for invasion speed. Ecology. Vol: 84. Pages 1968-1978.

Cavender-Bares, Jeannine; Ackerly, David D.; Baum, D. A.; Bazzaz, Fakhri A.. 2004. Phylogenetic overdispersion of floridian oak communities. American Naturalist. Vol: 163. Pages 606-615.

Cavender-Bares, Jeannine; Wilczek, Amity. 2003. Integrating micro- and macroevolutionary processes in community ecology. Ecology. Vol: 84. Pages 592-597.

Chalcraft, David R.; Williams, John W.; Smith, Melinda; Willig, Michael R.. 2004. Scale dependence in the species-richness–productivity relationship: The role of species turnover. Ecology. Vol: 85(10). Pages 2701-2708.

Chapin, F. Stuart; Sala, Osvaldo E.; Huber-Sannwald, Elisabeth. 2001. Future Scenarios of Climate Change: Scenarios for the 21st Century. Springer-Verlag. New York, NY.

Christensen, Villy; Walters, Carl. 2004. Ecopath with Ecosim: Methods, capabilities and limitations. Ecological Modelling (Special Issue: Placing Fisheries in their Ecosystem Context). Vol: 172(2-4). Pages 109-139.

Christensen, Villy; Walters, Carl. 2004. Trade-offs in ecosystem-scale optimization of fisheries management policies. Bulletin of Marine Science. Vol: 74. Pages 549-562.

Cleland, Elsa; Smith, Melinda; Andelman, Sandy J.; Bowles, Christy; Carney, Karen; Horner-Devine, M. Claire; Drake, John; Emery, Sarah; Gramling, Joel; Vandermast, David. 2004. Invasion in space and time: Non-native species richness and relative abundance respond to interannual variation in productivity and diversity. Ecology Letters. Vol: 7. Pages 947-957.

Costello, Christopher; Polasky, Stephen. 2004. Dynamic reserve site selection. Resource and Energy Economics (Special issue on the economics of biodiversity). Vol: 26(2). Pages 157-174.

Cottingham, Kathryn L.; Schindler, Daniel. 2000. Effects of grazer community structure on phytoplankton response to nutrient pulses. Ecology. Vol: 81. Pages 183-200.

Crowley, Philip H.. 2000. Sexual dimorphism with female demographic dominance: Age, size, and sex ratio at maturation. Ecology. Vol: 81. Pages 2592-2605.

Currie, David; Mittelbach, Gary; Cornell, Howard V.; Field, Richard; Guegan, Jean-Francois; Hawkins, Bradford A.; Kaufman, Dawn; Kerr, Jeremy T.; Oberdorff, Thierry; O'Brien, Eileen

M.; Turner, John. 2004. Predictions and tests of climate-based hypotheses of broad-scale variation in taxonomic richness. Ecology Letters. Vol: 7. Pages 1121–1134.

Denno, Robert F.; Fagan, William F.. 2003. Might nitrogen limitation promote omnivory among carnivorous arthropods?. Ecology. Vol: 84. Pages 2522-2531.

Diehl, Sebastian. 2003. The evolution and maintenance of omnivory: Dynamic constraints and the role of food quality. Ecology. Vol: 84. Pages 2557-2567.

Dodson, Stanley I.; Arnott, Shelley E.; Cottingham, Kathryn L.. 2000. The relationship in lake communities between primary productivity and species richness. Ecology. Vol: 81. Pages 2662-2679.

Dorn, N. J.; Mittelbach, Gary. 2005. Effects of native crayfish on the reproductive success and nesting behavior of freshwater sunfish (Lepomis spp.). Canadian Journal Fisheries and Aquatic Sciences. Vol: 61. Pages 2135-2143.

Easterling, David; Meehl, Gerald A.; Parmesan, Camille; Changnon, Stanley A.; Karl, Thomas R.; Mearns, Linda. 2000. Climate extremes: Observations, modeling, and impacts. Science. Vol: 289. Pages 2068-2074.

Ellner, Stephen P.; Seifu, Yodit; Smith, Robert H.. 2002. Fitting population dynamic models to time-series data by gradient matching. Ecology. Vol: 83. Pages 2256-2270.

Fara, Emmanuel. 2004. Estimating minimum global species diversity for groups with a poor fossil record: A case study of Late Jurassic-Eocene lissamphibians. Palaeogeography, Palaeoclimatology, Palaeoecology. Vol: 207. Pages 59-82.

Ferreira, C. E. L.; Floeter, Sergio R.; Gasparini, J. L.; Ferreira, B. P.; Joyeux, J. C.. 2004. Trophic structure patterns of Brazilian reef fishes: A latitudinal comparison. Journal of Biogeography. Vol: 31. Pages 1093-1106.

Ferreira, C. E. L.; Gasparini, J. L.; Carvalho-Filho, A.; Floeter, Sergio R.. In press. A recently extinct parrotfish species from Brazil. Coral Reefs.

Fidler, Fiona; Cumming, G.; Burgman, Mark; Thomason, N.. 2004. Statistical reform in medicine, psychology and ecology. Journal of Socioeconomics. Vol: 33. Pages 615-630.

Floeter, Sergio R.; Ferreira, C. E. L.; Dominici-Arosemena, A.; Zalmon, I. R.. 2004. Latitudinal gradients in Atlantic reef fish communities: Trophic structure and spatial use patterns. Journal of Fish Biology. Vol: 64. Pages 1680–1699.

Floeter, Sergio R.; Soares-Gomes, A.; Hajdu, E.. In press. Marine Biogeography. Edited by Pereira, R.C.; Soares-Gomes, A. Biologia Marinha. Vol: 2nd edition. Editora Interciência. Brazil.

Fryxell, John M.; Wilmshurst, John F.; Sinclair, Anthony R.E.. 2004. Predictive models of movement by Serengeti grazers. Ecology. Vol: 85(9). Pages 2429-2435.

Gasparini, J. L.; Floeter, Sergio R.; Ferreira, C. E. L.; Sazima, I.. In press. Marine ornamental trade in Brazil. Biodiversity and Conservation.

Gaylord, Brian P.; Gaines, Steven D.. 2000. Temperature or transport?: Range limits in marine species mediated solely by flow. American Naturalist. Vol: 155. Pages 769-789.

Gelfand, Alan E.; Silander, John; Wu, Shanshan; Latimer, Andrew; Lewis, Paul; Rebelo, Anthony G.; Holder, Mark. 2005. Explaining species distribution patterns through hierarchical modeling. Bayesian Analysis. Vol: 54(1). Pages 1-20.

Gillespie, Rosemary. 2004. Community assembly through adaptive radiation in hawaiian spiders. Science. Vol: 303. Pages 356-359.

Gordon, Wendy; Jackson, Robert B.. 2000. Nutrient concentrations in fine roots. Ecology. Vol: 81. Pages 275-280.

Gotelli, Nicholas J.; Rohde, Klaus. 2002. Co-occurrence of ectoparasites of marine fishes: A null model analysis. Ecology Letters. Vol: 5(1). Pages 86-94.

Graham, Catherine ; Ferrier, Simon; Huettmann, Falk; Moritz, Craig; Peterson, A. Townsend. 2004. New developments in museum-based informatics and applications in biodiversity analysis. Trends in Ecology and Evolution. Vol: 19(9). Pages 499-503.

Graham, Michael H.; Halpern, Ben. In press. Diversity and dynamics of California subtidal kelp forests: Disentangling trophic interactions from habitat associations. Edited by T. McClanahan Marine Sublittoral Food Webs. Oxford University.

Greene, Charles H.; Pershing, Andrew J.. 2004. Climate and the conservation biology of North Atlantic right whales: The right whale at the wrong time?. Frontiers in Ecology and the Environment. Vol: 2. Pages 29-34.

Grover, James P.. 2003. The impact of variable stoichiometry on predator-prey interactions: A multinutrient approach. American Naturalist. Vol: 162. Pages 29-43.

Guernier, Vanina; Hochberg, Michael; Guegan, Jean-Francois. 2004. Ecology drives the worldwide distribution of human diseases. Public Library of Science Biology. Vol: 2(6). Pages 1-7.

Halpern, Ben; Borer, Elizabeth T.; Seabloom, Eric; Shurin, Jonathan B.. 2004. Predator effects on herbivore and plant stability. Ecology Letters. Vol: 8. Pages 189-194.

Halpern, Ben; Gaines, Steven D.; Warner, Robert R.. 2004. Confounding effects of the export of production and the displacement of fishing effort from marine reserves. Ecological Applications. Vol: 14(4). Pages 1248-1256.

Halpern, Ben; Pyke, Chris; Haney, C.; Zaradic, P.; Fox, Helen; Schlapfer, M.. In press. Gaps and mismatches between global conservation priorities and spending. Conservation Biology.

Harvell, Drew; Aronson, Richard B.; Baron, Nancy; Connell, Joseph H.; Dobson, Andrew P.; Ellner, Stephen P.; Gerber, Leah; Kim, Kiho; Kuris, Armand; McCallum, Hamish; Lafferty, Kevin; McKay, Bruce; Porter, James W.; Pascual, Mercedes; Smith, Garriet; Sutherland, Kathryn; Ward, Jessica. 2004. The rising tide of ocean diseases: unsolved problems and research priorities. Frontiers in Ecology and the Environment. Vol: 7(2). Pages 375-382.

Heal, Geoffrey. 2004. Economics of biodiversity: An introduction. Resource and Energy Economics (Special issue on the economics of biodiversity). Vol: 26(2). Pages 105-114.

Heal, Geoffrey; Walker, Brian; Levin, Simon A.; Arrow, Kenneth; Dasgupta, Partha; Daily, Gretchen; Ehrlich, Paul; Maler, Karl-Goran; Kautsky, Nils; Lubchenco, Jane; Schneider, Steve; Starrett, David. 2004. Genetic diversity and interdependent crop choices in agriculture. Resource and Energy Economics (Special issue on the economics of biodiversity). Vol: 26(2). Pages 175-184.

Hilderbrand, Robert; Watts, Adam; Randle, April. In press. The myths of restoration ecology. Ecology and Society.

Holl, Karen; Crone, Elizabeth E.. 2004. Local vs. landscape factors affecting restoration of riparian understorey plants. Journal of Applied Ecology. Vol: 41. Pages 922-933.

Holland, Steven M.; Patzkowsky, Mark E.. 2004. Ecosystem structure and stability: Middle Upper Ordovician of central Kentucky. USA, Palaios. Vol: 19. Pages 316-331.

Holyoak, Marcel; Lawler, Sharon; Crowley, Philip H.. 2000. Predicting extinction: Progress with an individual-based model of protozoan predators and prey. Ecology. Vol: 81. Pages 3312-3329.

Holyoak, Marcel; Leibold, Mathew; Holt, Robert D.. In press. Metacommunities: Spatial dynamics and ecological communities. University of Chicago Press. Chicago, IL.

Hurlbert, Allen; Haskell, John P.. 2003. The effect of energy and seasonality on avian species richness and community composition. American Naturalist. Vol: 161. Pages 83-97.

Kaplan, David; Botsford, Louis W.. 2005. Effects of variability in spacing of coastal marine reserves on fisheries yield and sustainability. Canadian Journal of Fisheries and Aquatic Sciences. Vol: 62. Pages 905-912.

Kaplan, Isaac. In press. A risk assessment for Pacific leatherback turtles (Dermochelys coriacea). Canadian Journal of Fisheries and Aquatic Sciences.

Kawecki, Tadeusz; Holt, Robert D.. 2002. Evolutionary consequences of asymmetric dispersal rates. American Naturalist. Vol: 16. Pages 333-347.

Keith, David A.; McCarthy, Mick; Regan, Helen; Regan, Tracey; Bowles, Christy; Drill, Claire; Craig, Cory; Pellow, Belinda; Burgman, Mark; Master, Larry; Ruckelshaus, Mary; Mackenzie, Berin; Andelman, Sandy J.; Wade, Paul. 2004. Protocols for listing threatened species can forecast extinction. Ecology Letters. Vol: 7. Pages 1101-1108.

Keitt, Timothy H.; Lewis, Mark A.; Holt, Robert D.. 2001. Allee effects, invasion pinning, and Species' Borders. American Naturalist. Vol: 157. Pages 203-216.

Kendall, Bruce E.; Ellner, Stephen P.; McCauley, Edward; Wood, Simon; Briggs, Cherie J.; Murdoch, William W.; Turchin, Peter. 2005. Population cycles in the pine looper moth: Dynamical tests of mechanistic hypotheses. Ecological Monographs. Vol: 75(2). Pages 259-276.

Kiessling, Wolfgang. 2005. Long-term relationships between ecological stability and biodiversity in Phanerozoic reefs. Nature. Vol: 433. Pages 410-413.

Kiessling, Wolfgang; Baron-Szabo, R.. 2004. Extinction and recovery patterns of scleractinian corals at the Cretaceous-Tertiary boundary. Palaeogeography. Vol: 214. Pages 195-223.

Kikvidze, Zaal; Pugnaire, Francisco; Brooker, Robin; Choler, Philippe; Lortie, Christopher J.; Michalet, Richard; Callaway, Ragan. 2005. Linking patterns and processes in alpine plant communities: A global study. Ecology. Vol: 86(6). Pages 1395-1400.

Kim, Kiho; Harvell, Drew. 2004. The rise and fall of a six-year coral-fungal epizootis. The American Naturalist. Vol: 164. Pages S52-S63.

Kitchell, James F.; Kaplan, Isaac; Cox, Sean; Martell, Steve J.; Essington, Timothy; Boggs, Chris; Walters, Carl. 2004. Ecological and economic components of alternative fishing methods to reduce bycatch of marlin in a tropical pelagic ecosystem. Bulletin of Marine Science. Vol: 73(3). Pages 607-619.

Klug, Jen; Cottingham, Kathryn L.. 2001. Interactions among environmental drivers: Community responses to changing nutrients and dissolved organic carbon. Ecology. Vol: 82. Pages 3390-3403.

Klug, Jen; Fischer, Janet; Ives, Anthony R.; Dennis, Brian. 2000. Compensatory dynamics in planktonic community responses to pH perturbations. Ecology. Vol: 81. Pages 387-398.

Knapp, Alan K.; Smith, M. D.; Collins, Scott L.; Zambatis, Nick; Peel, Mike; Emery, Sarah; Wodjak, J.; Horner-Devine, M. Claire; Biggs, Harry; Kruger, Judith; Andelman, Sandy J.. 2004. Generality in ecology: Testing North American grassland rules in South African savannas. Frontiers in Ecology and the Environment. Vol: 2(9). Pages 483-491.

Koelle, Katia; Pascual, Mercedes. 2004. Disentangling extrinsic from intrinsic factors in disease dynamics: A nonlinear time series approach with an application to cholera. American Naturalist. Vol: 163. Pages 901-913.

Krivan, Vlastimil. 2000. Optimal intraguild foraging and population stability. Theoretical Population Biology. Vol: 58. Pages 79-94.

Krug, A. Z.; Patzkowsky, Mark E.. 2004. Rapid recovery from the Late Ordovician mass extinction. Proceedings of the national Academy of Sciences. Vol: 101. Pages 17605-17610.

Kunz, Thomas H.. 2003. Censusing bats: Challenges, solutions, and sampling biases. Edited by T.J. O'Shea and M.A. Bogan Monitoring trends in bat populations of the United States and territories: Problems and Prospects. USGS/BRD/ITR-0003. Pages 9-20.

Kunz, Thomas H.. 2004. Foraging habits of North American bats. Edited by R.M. Brigham, E.K.V. Kalko, G. Jones, S. Parsons, and H.J.H.A. Limpens Bat echolocation research: Tools, techiques and analysis. Bat Conservation International. Austin, Texas. Pages 13-25.

Lafferty, Kevin; Porter, James W.; Ford, Susan E.. 2004. Are diseases increasing in the ocean?. Annual Review of Ecology, Evolution, and Systematics. Vol: 35. Pages 31–54.

Latimer, Andrew; Wu, Shanshan; Gelfand, Alan E.; Silander, John. In press. Building statistical models to analyze species distributions. Ecological Applications.

Lee, Y. F.; McCracken, Gary F.. In press. Predation by Brazilian free-tailed bats on migratory populations of pest insects. Journal of Mammalogy.

Leibold, Mathew; Holyoak, Marcel; Mouquet, Nicolas; Amarasekare, Priyanga; Chase, Jonathan; Hoopes, Martha F.; Holt, Robert D.; Shurin, Jonathan B.; Law, Richard; Tilman, David; Loreau, Michel; Gonzalez, Andy. 2004. The metacommunity concept: A framework for multi-scale community ecology. Ecology Letters. Vol: 7. Pages 601-613.

Levine, Jonathan M.; D'Antonio, Carla. 2003. Forecasting biological invasions with increasing international trade. Conservation Biology. Vol: 17(1). Pages 332-326.
Liebhold, Andrew S.; Koenig, Walter; Bjornstad, Ottar N.. 2004. Spatial synchrony in population dynamics. Annual Review of Ecology, Evolution, and Systematics. Vol: 35. Pages 467–490.

Loreau, Michel; Holt, Robert D.. 2004. Spatial flows and the regulation of ecosystems. American Naturalist. Vol: 163. Pages 606-615.

Lortie, Christopher J.; Brooker, Robin; Choler, Philippe; Kikvidze, Zaal; Michalet, Richard; Pugnaire, Francisco; Callaway, Ragan. 2004. Rethinking plant community theory. Oikos. Vol: 107. Pages 433-438.

Lortie, Christopher J.; Brooker, Robin; Kikvidze, Zaal; Callaway, Ragan. 2004. The value of stress and limitation in an imperfect world: A reply to Körner. Journal of Vegetation Science. Vol: 15. Pages 577-580.

Lyons, Kate. In press. A quantitative model assessing the community dynamics of Pleistocene mammals. American Naturalist.

Lyons, Kate; Smith, Felisa A.; Wagner, Peter J.; White, P. J.; Brown, James H.. 2004. Was a hyperdisease responsible for the late Pleistocene megafaunal extinction?. Ecology Letters. Vol: 7. Pages 859-868.

Lyons, Kate; Willig, Michael R.. 2002. Species richness, latitude, and scale-sensitivity. Ecology. Vol: 83. Pages 47-58.

MERCINA. 2004. Supply-side ecology and the response of zooplankton to climate-driven changes in North Atlantic Ocean circulation. Oceanography. Vol: 17(3). Pages 10-21.

Mangel, Marc; Munch, S.; Snover, M.; Watters, George. In press. A unified treatment of top down and bottom up control of reproduction in populations. Ecology Letters.

McCallum, Hamish; Kuris, Armand; Harvell, Drew; Lafferty, Kevin; Smith, Garriet; Porter, James W.. 2004. Does terrestrial epidemiology apply to marine systems?. Trends in Ecology and Evolution. Vol: 19(11). Pages 585-591.

McCracken, Gary F.. 2003. Estimates of population sizes in summer colonies in Brazilian free-tailed bats (Tadarida brasiliensis). Edited by T.J. O'Shea and M.A.Bogan Monitoring trends in bat populations of the Unitedc States and territories: Problems and prospects. USGA/BRD/ITR-0003. Pages 21-30.

Meir, Eli; Andelman, Sandy J.; Possingham, Hugh P.. 2004. Does conservation planning matter in a dynamic and uncertain world?. Ecology Letters. Vol: 7(8). Pages 615-622.

Meiri, Shai; Dayan, Tamar; Simberloff, Daniel S.. 2004. Body size of insular carnivores: Little support for the island rule. American Naturalist. Vol: 163. Pages 469-479.

Micheli, Fiorenza; Halpern, Ben. 2005. Low functional redundancy in coastal marine assemblages. Ecology Letters. Vol: 8. Pages 391-400.

Micheli, Fiorenza; Halpern, Ben; Botsford, Louis W.; Warner, Robert R.. 2004. Trajectories and correlates of community change in no-take marine reserves. Ecological Applications. Vol: 14(6). Pages 1709-1723.

Mitchell, Charles; Power, Alison G.. 2003. Release of invasive plants from fungal and viral pathogens. Nature. Vol: 421. Pages 625-627.

Moe, Jannicke; Stelzer, R. S.; Forum, M. R.; Harpole, W. Stanley; Daufresne, T.; Yoshida, T.. 2005. Recent advances in ecological stoichiometry: Insights for population and community ecology. Oikos. Vol: 109. Pages 29-39.

Moles, Angela; Ackerly, David D.; Webb, Campbell O.; Tweddle, John C.; Dickie, John B.; Westoby, Mark. 2005. A brief history of seed size. Science. Vol: 307. Pages 576-580.

Moles, Angela; Warton, David I.; Stevens, Richard; Westoby, Mark. 2004. Does a latitudinal gradient in seedling survival favour larger seeds in the tropics?. Ecology Letters. Vol: 7. Pages 911-914.

Moore, John C.; Berlow, Eric; Coleman, David C.; de Ruiter, Peter C.; Dong, Quan; Hastings, Alan; Johnson, Nancy C.; McCann, Kevin; Melville, Kim; Morin, Peter J.; Nadelhoffer, Knute; Rosemond, Amy; Post, David M.; Sabo, John; Scow, Kate; Vanni, Michael J.; Wall, Diana H.. 2004. Detritus, trophic dynamics and biodiversity. Ecology Letters. Vol: 7. Pages 584-600.

Moore, John C.; McCann, Kevin; Setala, Heikki; de Ruiter, Peter C.. 2003. Top-down is bottom-up: Does predation in the rhizosphere regulate above ground dynamics?. Ecology. Vol: 84. Pages 846-857.

Muller, Jeffrey; Albers, Heidi J.. 2004. Enforcement, payments, and development projects near protected areas: How the market setting determines what works where. Resource and Energy Economics (Special issue on the economics of biodiversity). Vol: 26(2). Pages 185-204.

Nehring, Klaus; Puppe, Clemens. 2004. Modelling phylogenetic diversity. Resource and Energy Economics (Special issue on the economics of biodiversity). Vol: 26(2). Pages 205-235.

O'Grady, J. J.; Burgman, Mark; Keith, David A.; Master, Larry; Andelman, Sandy J.; Brook, Barry W.; Hammerson, Geoffrey A.; Regan, Tracey; Frankham, R.. 2004. Correlations among extinction risks assessed by different systems of threatened species categorization. Conservation Biology. Vol: 18. Pages 1624-1635.

Owen-Smith, Norman; Mason, D. M.; Ogutu, Joseph O.. In press. Correlates of survival rates for ten African ungulate populations: Density, rainfall and predation. Journal of Animal Ecology.

Packer, Craig; Hilborn, Ray; Mosser, Anna; Kissui, Bernard; Borner, Markus; Hopcraft, Grant; Wilmshurst, John F.; Mduma, Simon A. R.; Sinclair, Anthony R.E.. 2005. Ecological change, group territoriality, and population dynamics in Serengeti lions. Science. Vol: 307. Pages 390-393.

Palmer, Margaret A.; Bernhardt, Emily; Chornesky, Liz; Collins, Scott L.; Dobson, Andrew P.; Duke, Cliff; Gold, Barry D.; Jacobson, Robb; Kingsland, Sharon; Kranz, Rhonda; Mappin, Mike; Martinez, M. Luisa; Micheli, Fiorenza; Morse, Jen; Pace, Michael; Pascual, Mercedes; Palumbi, Stephen R.; Reichman, O. J.; Townsend, Alan R.; Turner, Monica G.. 2005. Ecological science and sustainability for the 21st century. Frontiers in Ecology and the Environment. Vol: 3(1). Pages 4-11.

Pfaff, Alexander; Sanchez-Azofeifa, G.A.. 2004. Deforestation pressure and biological reserve planning: A conceptual approach and an illustrative application for Costa Rica. Resource and Energy Economics (Special issue on the economics of biodiversity). Vol: 26(2). Pages 237-254.

Pyke, Chris; Andelman, Sandy J.; Midgley, Guy F.. In press. Identifying priority areas for bioclimatic representation under climate change: A case study for Proteaceae in the Cape Floristic Region, South Africa. Biological Conservation.

Ranta, Esa; Kaitala, Veijo. 2005. A leap for lion populations. Science. Vol: 307. Pages 365-366.

Raymond, Anne; Metz, C.. 2004. Ice and its consequences: Glaciation in the Ordovician, Late Devonian, Pennsylvania-Permian and Cenozoic compared. Journal of Geology. Vol: 112. Pages 655-670.

Regan, Helen; Auld, T. D.. 2004. Australian shrub Grevillea caleyi: Recovery through management of fire and predation. Edited by H.R. Akcakaya, M.A. Burgman, O. Kindvall, C.C. Wood, P. Sjogren-Gulve, J. Hatfield, and M. McCarthy Species Conservation and Management: Case Studies. Oxford University Press. Pages 23-35.

Regan, Helen; Ben-Haim, Yakov; Langford, Bill T.; Wilson, Will G.; Lundberg, Per; Andelman, Sandy J.; Burgman, Mark. In press. Robust decision making under severe uncertainty for conservation management. Ecological Applications.

Regan, Tracey; Master, Larry; Hammerson, Geoffrey A.. 2004. Capturing expert knowledge for threatened species assessments: A case study using NatureServe conservation status ranks. Acta Oecologica. Vol: 26. Pages 95-107.

Reiners, William A; Driese, Kenneth L.. 2004. Transport Processes in Nature: Propagation of Ecological Influences through Environmental Space. Cambridge University Press. Cambridge. Pages 314.

Romanch, S. S.; Reichman, O. J.; Seabloom, Eric. In press. Seasonal influences on burrowing activity of a subterranean rodent, Thomomys bottae. Journal of Zoology.

Romanch, S. S.; Reichman, O. J.; Seabloom, Eric; Rogers, W. E.; Cameron, G. N.. In press. Effects of species, gender, age, and habitat on pocket gopher foraging tunnel geometry. Journal of Mammalogy.

Sabo, John; Power, Mary E.. 2002. Numerical response of lizards to aquatic insects and short-term consequences for terrestrial prey. Ecology. Vol: 83(11). Pages 3023-3036.

Sabo, John; Power, M. E.. 2002. River-watershed exchange: Effects of riverine subsidies on riparian lizards and their terrestrial prey. Ecology. Vol: 83(7). Pages 1860-1869.

Sabo, John; Holmes, Elizabeth E.; Kareiva, Peter. 2004. Efficacy of simple viability models in ecological risk assessment: Does density dependence matter?. Ecology. Vol: 85(2). Pages 328-341.

Sala, Osvaldo E.; Chapin, F. Stuart; Armesto, Juan; Berlow, Eric; Bloomfield, Janine; Dirzo, Rodolfo; Huber-Sannwald, Elisabeth; Huenneke, Laura F.; Jackson, Robert B.; Kinzig, Ann P.; Leemans, Rik; Lodge, David M.; Mooney, Harold A.; Oesterheld, Martin; Poff, N. LeRoy; Sykes, Martin; Walker, Brian; Walker, Marilyn D.; Wall, Diana H.. 2000. Global biodiversity scenarios for the year 2100. Science. Vol: 287. Pages 1770-1774.

Sanchez, Juan A.; Lasker, Howard R.; Nepomuceno, Erivelton G.; Sanchez, J. Dario; Woldenberg, Michael J.. 2004. Branching and self-organization in marine modular colonial organisms: A model. American Naturalist. Vol: 163. Pages E24-E39.

Seabloom, Eric; Bjornstad, Ottar N.; Bolker, Ben; Reichman, O. J.. In press. The spatial signature of dispersal and competitition in successional grasslands. Ecological Monographs.

Settle, Chad; Shogren, Jason. 2004. Hyperbolic discounting and time inconsistency in a native-exotic species conflict. Resource and Energy Economics (Special issue on the economics of biodiversity). Vol: 26(2). Pages 255-274.

Shannon, L. J.; Christensen, Villy; Walters, Carl. 2004. Modelling stock dynamics in the southern Benguela ecosystem over the last twenty five years. African Journal of Marine Science. Vol: 26. Pages 179-196.

Shea, Katriona; Amarasekare, Priyanga; Mangel, Marc; Moore, Joslin L.; Murdoch, William W.; Noonburg, Erik; Parma, Ana Maria; Pascual, Mercedes; Possingham, Hugh P.; Wilcox, Chris; Yu, Douglas W.. 1999. Management of populations in conservation, harvesting and control. Trends in Ecology and Evolution. Vol: 13. Pages 371-375.

Shurin, Jonathan B.; Seabloom, Eric. In press. The strength of trophic cascades across ecosystems: Predictions from allometry and energetics. Journal of Animal Ecology.

Smith, Katherine F.; Dobson, Andrew P.; McKenzie, Ellis; Real, Leslie A.; Smith, David L.; Wilson, Mark L.. 2005. Ecological theory to enhance infectious disease control and public health policy. Frontiers in Ecology and the Environment. Vol: 3(1). Pages 29-37.

Steiner, Christopher F.; Leibold, Mathew. 2004. Cyclic assembly trajectories and scale-dependent productivity-diversity relationships. Ecology. Vol: 85. Pages 107-113.

Stevens, Richard; Willig, Michael R.. 2002. Geographical ecology at the community level: Perspectives on the diversity of new world bats. Ecology. Vol: 83. Pages 545-560.

Turchin, Peter; Ellner, Stephen P.. 2000. Living on the edge of chaos: Population dynamics of fennoscandian voles. Ecology. Vol: 81. Pages 3099-3116.

Urban, Dean; Keitt, Timothy. 2001. Landscape connectivity: A graph-theoretic perspective**.** Ecology. Vol: 82(5). Pages 1205-1218.

Vazquez, Diego; Stevens, Richard. 2004. The latitudinal gradient in niche breadth: Concepts and evidence. American Naturalist. Vol: 164. Pages E1-E19.

Vellend, Mark. In press. Species diversity and genetic diversity: Parallel processes and correlated patterns. American Naturalist.

Vellend, Mark; Geber, M. A.. In press. Connection between species diversity and genetic diversity. Ecology Letters.

Vellend, Mark; Hughes, A. R.; Grosberg, Richard K.; Holt, Robert D.. In press. Introduction: Insights into evolutionfrom species invasion. Edited by D.F. Sax, S.D. Gaines, and J.J. Stachowicz Species invasions: Insights to ecology, evolution and biogeography. Sinauer Associates. Sunderland, MA.

Villier, L.; Korn, Dieter. 2004. Morphological disparity of ammonoids and the mark of Permian mass extinctions. Science. Vol: 306. Pages 264-266.

Walters, Carl. 2003. Folly and fantasy in the analysis of spatial catch rate data. Canadian Journal of Fisheries and Aquatic Sciences. Vol: 60(12). Pages 1433-1436.

Walters, Carl. 2004. Simple representation of the dynamics of biomass error propagation for stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences. Vol: 61(7). Pages 1061-1065.

Walters, Carl; Christensen, Villy; Martell, Steve J.; Kitchell, James F.. 2005. Possible ecosystem impacts of applying MSY policies from single-species assessment. ICES Journal of Marine Science. Vol: 62(3). Pages 558-568.

Walters, Carl; Hilborn, Ray. In press. Exploratory analysis of recruitment trends using relative abundance and catch data. Canadian Journal of Fisheries and Aquatic Sciences.

Walters, Carl; Martell, Steve J.. 2004. Fisheries Ecology and Management. Princeton University Press. Princeton, NJ. Pages 448.

Walters, Carl; Pauly, D. M.; Christensen, Villy; Kitchell, James F.. 2000. Representing density dependent consequences of life history strategies in aquatic ecosystems: EcoSim II. Ecosystems. Vol: 3. Pages 70-83.

Weltzin, Jake F.; Loik, Michael E.; Schwinning, Susan; Williams, David G.; Fay, Phil; Haddad, Brent; Harte, John; Huxman, Travis E.; Knapp, Alan K.; Lin, Guanghui; Pockman, William T.; Shaw, M. Rebecca; Small, Eric E.; Smith, Melinda; Smith, Stanley D.; Tissue, David T.; Zak, John C.. 2003. Assessing the response of terrestrial ecosystems to potential changes in precipitation. BioScience. Vol: 53(10). Pages 941-952.

*Werner, Earl E.; Peacor, S. D.. 2003. A review of trait-mediated indirect interactions in ecological communities. Ecology. Vol: 84(5). Pages 1083-1100.

Wilcox, Chris; Possingham, Hugh P.. 2002. Do life history traits affect the accuracy of diffusion approximations for mean time to extinction?. Ecological Applications. Vol: 12(4). Pages 1163-1179.

Williams, Jack; Seabloom, Eric; Slayback, Dan; Stoms, David; Viers, Joshua H.. 2004. Anthropogenic impacts upon plant species richness and net primary productivity in California. Ecology Letters. Vol: 8. Pages 127-137.

Wilson, Will G.; Harder, L. D.. 2003. Reproductive uncertainty and the relative competitiveness of simultaneous hermaphroditism versus dioecy. American Naturalist. Vol: 162. Pages 220-241.