CENTER FOR CONSERVATION BIOLOGY

UPDATE

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Taking the bull by the horns

A two-pronged approach to environmental training in the tropics

A diverse group of professionals and students participated in various field exercises during the CCB's tropical course held in Peru. *Photos by Carlos Galindo-Leal and Carol Boggs.*

The CCB's Tropical Program is now attacking two major obstacles preventing the solution of environmental problems in tropical countries: lack of political will and the absence of reliable information to thoroughly understand and solve those problems. Decision makers often ignore environmental problems because of their lack of understanding. In turn, there are a limited number of professionals with the background to gather reliable information and to make it available to decision makers.

Both of these obstacles are acute in developing countries for several reasons. Environmental awareness by both government and non-government agencies is still in its infancy. There are disproportionally fewer trained professionals in environmental sciences. Further, there is little information on highly complex tropical ecosystems.

For several years we have been engaged in work to reduce the second impediment. We have organized field courses, seminars, and workshops on ecological methodology, landscape ecology, wildlife management, and conservation biology in Guatemala, Ecuador, Mexico, and Peru (See *Ecotono*, Invierno 1996).

Last year, we began a two-pronged approach to address both obstacles mentioned above. Last November, in cooperation with El Colégio de Biólogos del Perú, we organized two courses: one for decision makers and one for environmental professionals.

The first course, "Strategic Basis for Decision Making in Environmental Management", took place in the Auditorium of the Naval Medical Center in Lima from November 1 to 3. The course was aimed at decision makers, professionals, and students interested in environmental economics, impact assessment, and sustainable development. There were approximately a dozen speakers invited from a variety of Peruvian institutions such as El Colégio de Biólogos del Perú, Sociedad Peruana de Derecho Ambiental, Universidad de Piura, Universidad Peruana Cayetano Heredia, and Universidad Ricardo Palma, and from the Center for Conservation Biology, Stanford University. The topics included the international and domestic legal framework for environmental management, environmental education, environment and health, and environmental assessment and industry.

The Stanford team (Paul Ehrlich, Carol Boggs, Gretchen Daily, and myself) closed the course, addressing the issues of population, resources and equity, the role of science in environmental decision making, the economics of ecosystem services, and the need to include environmental economics, landscape ecology, and conservation biology in the modern curricula in environmental sciences studies. These cross-disciplinary issues are usually left outside mainstream education.

The second course "Quantitative Methods for the

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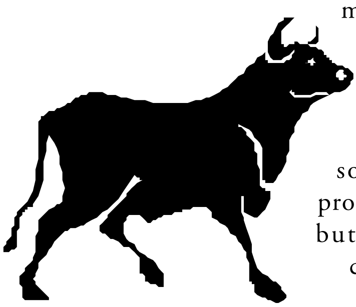
Training, continued from front page

Management of Biological Diversity" took place at the WASAI Lodge in the vicinity of the Tambopata Candamo Reserved Zone, one of the world's biodiversity hot spots. The objective of the course was to provide in-country training opportunities for professional resource managers and scientists to learn quantitative methods for managing biological diversity. The course integrated concepts from conservation biology and landscape ecology. Field exercises on a variety of taxa (butterflies, birds, bats, frogs, palms, etc.) allowed students to apply experimental design, methodology, and statistical analyses. Towards the end of the course, participants designed their own projects, gathered and analyzed information, and communicated their results to the other participants. They also presented projects which they had carried out previously in their own countries in order to get feedback on design, methods, and statistical analyses.

The instructors were all staff from the Center, including Paul Ehrlich, Carol Boggs, Gretchen Daily, Antonio Salas (Peruvian Coordinator), Mauricio Guerrero (Ecuadorian Coordinator), and myself. The field course lasted two weeks from November 4 to 18. It was attended by a diverse group of enthusiastic professionals (biologists, foresters, agronomists, park wardens) from Canada, Costa Rica, Cuba, Colombia, Venezuela, Peru, Chile, and Argentina. For some students this was their first experience in a tropical forest. During the course, participants and instructors were able to enjoy the incredible diversity of species of butterflies, monkeys, frogs, and birds, including the magnificent variety of macaws.

One aspect that was much appreciated by all the students was the effort made by the instructors to deliver the whole course in Spanish. The best indication of the success of the course was the initiative by participants from Colombia, Chile, Cuba, and Argentina to organize similar courses in their countries. The next course will occur in May in Guanahacabibes Biosphere Reserve in Cuba, organized jointly with the Ministry of Science, Technology and Environment of Cuba. We hope that by continuing to create courses that address decision makers as well as environmental professionals, the Tropical Program at Stanford will begin to overcome the obstacles to solving environmental problems that plague all of us, but particularly developing countries.



Dr. Carlos Galindo-Leal is Director of the CCB's Tropical Program. He has been instrumental in the design and carrying out of the CCB's tropical education workshops.

The Center for Conservation Biology

The Center for Conservation Biology was established in 1984 to develop the science of conservation biology, including its application to solutions for critical conservation problems. In particular, the CCB conducts scientific and policy research that is building a sound basis for the conservation, management, and restoration of biotic diversity around the world. The overall goal is to develop ways and means for protecting Earth's life support systems and thus enhancing future human well-being.

In pursuit of this mission, the Center for Conservation Biology

- designs experiments to address specific and general questions in conservation biology;
- conducts research on broad-scale policy issues, including human population growth, resource use, and environmental deterioration, and the interactions among them;
- applies and communicates the results of this scientific and policy research broadly, to conservation biologists, reserve managers, planners, decision-makers and the public; and
- educates students and professionals through participation in research and conferences, and by collaboration with other scientists and conservation groups around the world.

The Center for Conservation Biology is part of the Stanford University Department of Biological Sciences. It is supported by donations and grants from individuals, private foundations, and corporations.

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UPDATE Editors • Sylvia Fallon, Carol Boggs; Layout • Deborah Levoy

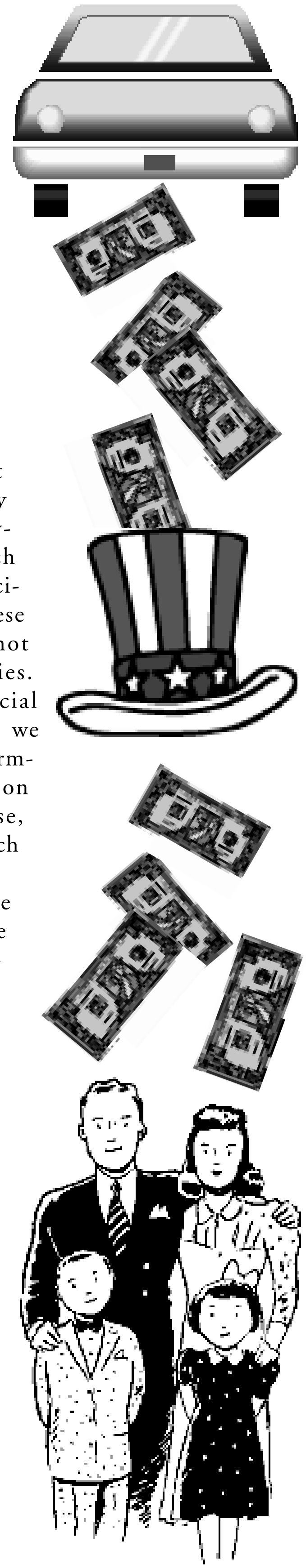
Can environmental policy be good for the economy?

We buy and use environmentally damaging products everyday, but who pays for the damage they inflict? For example, the current price of fossil fuels does not include the social cost of global warming that results from their use. Several factors must be considered when trying to compensate for this missing cost. First, how do we scientifically quantify environmental damage (such as the effect of global warming)? Second, how do we assign that damage a price? And most importantly, where will the money to pay that price come from?

In 1918, economist A.C. Pigou introduced the idea of 'corrective taxes' to compensate for social costs that are not included in market prices. Since then, an extensive body of theory has been developed for corrective taxes. However not many countries have adopted such taxes. This is in part because the data and scientific understanding required to calculate these costs have not been available, and still are not for many environmentally damaging activities. Furthermore, even our best estimates of social costs are subjective to some extent. How can we agree on 'the right price' to control global warming, for example, when many people disagree on the seriousness of global warming? Likewise, how do we convince opponents to support such a tax policy?

CCB researcher Gary Wolff is analyzing the possibility of corrective taxes that benefit the environment and yet have 'no costs'. For example, suppose we were to introduce a gasoline tax in order to reduce gasoline consumption, thus benefiting the environment. We could then route the tax revenues into the social security trust fund and lower the social security tax. The trust fund balance is not changed, but workers might have higher take home pay. This might eliminate opposition to the proposed tax policy. If a policy doesn't decrease taxpayers' personal income and it happens to benefit the environment, why would they oppose it?

Here is another example of how a tax policy might benefit the environment at no cost to the economy: We could introduce a differentiated sales tax, where disposable goods (paper plates, plastic silverware) are taxed highly while reusable goods (ceramic plates and cups, metal silverware) are taxed less highly, but revenue from sales taxation is kept constant. Before implementing this particular policy, however, we would need to determine whether reusable metal silverware really is less damaging to the environment than plastic silverware. This information is not currently available.



Nonetheless, these sorts of tax policies provide incentive for consumers to be environmentally friendly. For example, if these hypothetical policies were to be implemented, individuals would likely decrease their gasoline consumption and buy the (cheaper) reusable goods. In addition, these policies might increase the real incomes of consumers.

This concept of improving the environment and improving the economy is often referred to as creating 'double dividends.' Previous research on this topic has been largely theoretical. Wolff is reevaluating these theories empirically - via analysis of extensive historical data from the US economy. He is developing a procedure that would allow him to evaluate whether particular policy proposals would yield double dividends. He has created an estimation process for analyzing the qualitative effects of tax reform on society. This process examines the market economy and the social costs that are not included in the market prices. If a specific tax reform is beneficial to both the economy and the environment, he says, "we do not need to quantify the benefits of environmental improvements. They have no costs, so even if the benefits are small, policies to capture those benefits should be adopted." This eliminates the disagreement over finding 'the right price' that originates from subjectivity and limited scientific information.

If we can identify the proper tax policies (as Gary Wolff's project seeks to do), we would not need to quantify environmental damage (as long as we can determine which products are damaging). Nor would we need to assign that damage a price. And most importantly, we wouldn't have to worry about where the money comes from because in essence, the policy would be free.

Sylvia Fallon is a research assistant for the CCB and co-editor of UPDATE.

When Native and Introduced Species Meet

"What harm does it do to have introduced *Eucalyptus* trees in central California? They're rather pretty." My father asked me this on a recent visit to Stanford. His question reflects the more general issue of the impacts of introduced species on their new communities. Answers to that question are becoming more urgent as humans continue to aid species' movements into new areas, both by accident and design.

An introduced mustard, *Thlaspi arvense,* dominates the foreground in this picture of a new road cut in a housing development in Mt. Cresed Butte, Colorado. *Photo by Carol Boggs.*

Some effects of introduced species are straightforward. Asian clams introduced into the San Francisco Bay are reducing the populations of three native copepod species through direct predation on the young. A North American crayfish introduced into the British river Great Ouse outcompetes two native benthic fishes for shelter. Invading star thistles in California bloom during seasons when nectar is scarce, providing a food resource for native insects. Other effects are more complex, affecting communities over a longer time scale. The invasive plant *Myrica faya*, introduced to Hawaii, thrives on new volcanic soils. Peter Vitousek and colleagues at Stanford have shown that the nitrogen-fixing plant enriches the soil at an earlier point in succession than would otherwise be the case. Combined with the observation that seedlings of the native dominant tree do not germinate under the invasive plant, this introduced plant surely affects the identity of the plant species that will invade the area as the soil develops.

What happens when an introduced species intrudes into a tightly coevolved interaction between sets of other species? Coevolved interactions are relatively common. Flower corolla tube lengths match the tongue lengths of their insect pollinators in some cases. One species of insect may feed on one or a few species of plant, with the choice based on plant secondary chemistry. Ants tend larvae of some lycaenid butterfly species, and so on.

The green-veined white butterfly, *Pieris napi*, has a strong coevolved relationship with its larval host plants in its native habitat. At my study site near Rocky Mountain Biological Laboratory in central Colorado, *P. napi* larvae will eat any of six native plant species in the mustard family. While larval developmental rates differ among the different host species, and females prefer to lay eggs on some hosts as compared to others, the butterfly is nonetheless able to utilize them all.

A European mustard, *Thlaspi arvense*, was introduced to the area, most likely arriving in the early 1880's with an influx of miners. The plant thrives in newly disturbed soil that is well drained, but not too rocky. Road cuts, new paths, house construction areas, pipeline burial sites, and cow and bear wallows all provide excellent habitat for the plant. This plant has a congener living in the area, *T. alpestre*, which is utilized by the butterfly. We therefore might expect that *T. arvense* would simply be one more species for the butterfly to eat. However, Dr. Francie Chew of Tufts University discovered about 25 years ago that, while females happily lay eggs on the introduced plant, it kills the larvae when they try to eat it. The plant thus meets some of the conditions of the coevolved system, in that females recognize it, but not others, in that it cannot support larval development.

How does the presence of *T. arvense* affect the native butterfly? There are three possible predictions. First, the larvae might evolve to be able to develop on the plant. Second, the females might evolve to discriminate against the plant, no longer laying eggs on it. Third, such evolution may not be possible for any of a variety of reasons. In this case, the introduced plant will reduce the population size of the butterfly through reduced larval survival. Working with several undergraduate students, I have been examining these questions over the past several summers.

Our work shows that, over the past 25 years, the newly hatched larvae have not evolved the ability to develop on the introduced plant. The first possible outcome thus has not yet happened.

The second alternative, that females evolve to discriminate against the plant, requires (1) individual variation among females in willingness to lay eggs on the plant, and (2) that the variation be heritable. The first criterion is met. When females are presented with both *T. arvense* and other host plants, the percentage of eggs laid on the introduced plants varies among females from 0 to 100%. However, work done with Stanford undergraduate Becky Niell shows that the variation in preference is not heritable. Evolutionary adaptation to "ignore" the introduced plant is thus not possible at this time.

The next step will be to assess the impact of the plant on the butterfly's population size. The different species tend to be distributed patchily throughout the environment, rather than inter-mixed. The introduced plant thus forms patches in the habitat where the butterfly's fitness is zero, similar to the sink area of a source-sink habitat network. Working with Yale undergraduate Julia Bowsher, I am asking how geometry and extent of the patches of introduced plant affect the butterfly's population density in a given area.

The *P. napi* / *T. arvense* interaction is a specialized example of a general phenomenon. Native organisms can be unable to adapt to introduced organisms rapidly enough to avoid impacts on the natives' population sizes. In most known cases, such adaptation is to effects of predation or competition, and there is no *a priori* reason to expect that adaptation would or could occur. However, in this particular case, we would expect that rapid evolution would be possible, since the native butterfly interacts with the introduced plant in the same manner as with native plants with which it is closely coevolved. The fact that adaptation is apparently not possible raises a strong cautionary flag concerning the breadth of the disruptive influence of introduced species.

The native green-veined white butterfly, *Pieris napi. Photo by Carol Boggs.*

Dr. Carol Boggs is Director of the CCB.

Center Notes

• Congratulations to Anne & Paul Ehrlich, joint recipients of the prestigious 1998 Tyler Prize for Environmental Achievement. Announced on March 18, the prize was awarded on April 17 in Los Angeles.

• The Masoala National Park in Madagascar became a reality on October 20, 1997, with publication of the official degree. Congratulations to all who labored to bring the park into existence! Center researcher Claire Kremen and our GIS laboratory continue to work to ensure that this "integrated conservation and development project" is successful in the long run. See *UPDATE* vol. 10 upof earlier work.

• This fall has been marked by farewells and welcomes to the Center staff. Jamie Reaser and Steve Rottenborn received their PhDs and have moved on, with Jamie taking a position at the Smithsonian Institution and Steve working for a Bay Area environmental consulting group. Gerardo Ceballos, who was visiting the Center for a year while on sabbatical from the Universidad Nacional Autónoma de México, returned to Mexico City. Andy Weiss, who has run our GIS lab for several years, has moved to Thailand to brush up on his Thai language skills and work with archeologists there. Dennis Murphy, Center President, accepted a faculty position at the University of Nevada, Reno as of September 1997. We wish all five of them the best of luck.

• We extend a warm welcome to several new personnel. Gary Wolff has joined the CCB as a post-doctoral fellow. Gary is trained as an environmental engineer and economist, with an interest in the economic aspects of environmental policy. Erica Fleishman is also a new post-doctoral fellow, working with the Nevada Biodiversity Initiative. Erica's interests include the utility of butterflies as indicator species for management purposes by public agencies and metapopulation dynamics. The Center also welcomed John Fay to our GIS lab, and Wendy Fox and Sylvia Fallon as research assistants.

• The Center is delighted to host José Sarukhan for his sabbatical year from the Universidad Nacional Autonoma de México (UNAM). He has just finished an 8 year term as President of UNAM, and is developing several projects related to restoration and conservation biology and graduate education while at Stanford.

• The CCB also welcomed Antoine Guisan from Switzerland for a 6-month post-doctoral fellowship this fall. Antoine's interests are in use of GIS to explore patterns of biological diversity in montane regions, and he was involved in collaborative work with the CCB's GIS lab and Stu Weiss on diversity of the Spring Mountains in Nevada.

• Congratulations to the Center's Anne Ehrlich, who has been named by the Sierra Club Board as Vice President for Science. As this is a newly created position, Anne will be shaping it. She plans to focus on keeping the Club up-to-date on relevant science, screening releases for scientific accuracy and fostering interaction between scientists and the Sierra Club.

Center Notes con't on page 7

Conservation in Suburbia

Fishes, Frogs, and Landuse Issues at Stanford University

As the world's landscapes become increasingly impacted by human activities, successful conservation of biotic diversity becomes more dependent on our ability to maintain species and biotic communities in altered ecosystems. One of the CCB's ongoing projects dealing with modified landscapes is conservation planning at Stanford and vicinity. With more than 8,100 acres, Stanford is one of the largest landholders in the region. This acreage, coupled with its location near several large open space preserves, makes conservation planning at Stanford key to regional conservation efforts. The University has a longstanding commitment to preserve natural resources. However, the University also has a mandate to provide resources for its primary mission, namely education and research. To meet the demands of its role as a large private university with extensive land holdings, Stanford is a major developer, building student, faculty and staff housing, teaching and research facilities, recreational facilities, and transportation linkages. Stanford is also in the utility business, operating an extensive water system with three reservoirs and an electrical generation plant. In short, Stanford does everything necessary to operate a small town.

Buzzy Spain at Jasper Ridge conducting diurnal surveys for bull frogs. *Photo by Alan Launer.*

In such a multiple-use setting, conservation is a complex mixture of science, prioritization, and compromise. Stanford's recent work in the San Francisquito Creek drainage is a case in point. San Francisquito Creek and its tributaries drain a large area of the eastern Santa Cruz Mountains, and flow through many of Stanford's holdings. The University originally constructed Searsville dam in the upper watershed to supply university land with irrigation water. Searsville Reservoir, now a focal point of Jasper Ridge Biological Preserve, is still an integral part of Stanford's water supply system. The reservoir is also filling in with sediment at a rapid rate — some studies estimate that the reservoir will be completely full of sediment in fewer than 20 years.

Recently, the University commissioned several studies to determine the fate of the reservoir. One of the biological questions was whether non-native species originating from Searsville Reservoir are impacting native species present in the San Francisquito Creek system. In spite of many alterations to the system, the drainage still supports a regionally important number of native plant and animal species, including steelhead, red-legged frogs, western pond turtles and saltmarsh common yellowthroat. Unfortunately, Searsville Reservoir is also the home of many non-native species, including largemouth bass, sunfish, bullhead catfish, and bullfrogs. Biologists have been concerned for some time that individuals of non-native species originating from the reservoir might pose a severe problem for native species downstream. This concern became more pressing when a number of modifications to the dam slightly altered the outflow from the reservoir. These modifications may have exacerbated the problem of non-native species entering the downstream portions of the drainage and damaging regional conservation efforts.

To address these biological issues, the University enlisted the Center's help. A team of undergraduate field assistants and local biologists led by Center scientist Alan Launer conducted field work in the Searsville Reservoir and the San Francisquito Creek drainage. During the summer and autumn of 1997, they mapped the distribution and abundance of native and non-native species in the system using a wide range of techniques, including electrofishing, night surveys, and trapping. They also investigated the feasibility of controlling non-native species in the system.

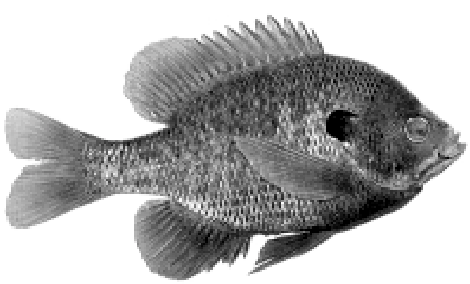
Fortunately, they found that the native species in the drainage are still present in moderate to high numbers. Red-legged frogs and steelhead, the two species in the system with federal protection, are doing quite well:

young steelhead are scattered throughout system and red-legged frogs reproduce along at least two stretches of creek. Non-native species in the creek are essentially limited to areas near the dam and are not generally reproducing in the downstream portions of the drainage.

Launer's team determined that control of non-native fishes and bullfrogs could be accomplished in the creek, but fairly drastic measures would be required to control non-native species in Searsville Reservoir itself at the moment. However, the dynamic nature of the drainage and the rapid sedimentation of the reservoir will likely eliminate many of the non-native species within the next decade. The current suite of non-native species apparently do not reproduce well under San Francisquito Creeks' alternating flooding and drying periods. They must be replenished from Searsville Reservoir to maintain their populations. However, as Searsville Reservoir silts in, the source populations of non-natives will go extinct. As a result, the number of non-native species in the drainage should decrease over time. This would make many regional conservation efforts easier and ultimately more successful.

These data suggest that the impacts of non-native species on the native fauna will decrease with time, under Stanford's current management regime for Searsville Reservoir. Continued monitoring of native and non-native species in San Francisquito Creek and Searsville Reservoir is critical both to determine whether this expectation indeed is fulfilled and to allow changes in the reservoir management should the need arise.

Studies such as this one on the San Francisquito Creek drainage demonstrate that conservation problems can sometimes be self-alleviating, with the proper management. In this case, however, there is a trade-off: allowing Searsville Reservoir to silt in will also destroy its value as a reservoir, including flood control, water provision, and bird habitat services. The final management decision by Stanford University will include consideration of all the costs and benefits associated with the Reservoir. Such a decision is ultimately based not just on biology, but also social and political priorities.



Dr. Alan Launer is a research associate with the Center for Conservation Biology. His research focuses on Bay Area conservation problems.

Center Notes continued...

- A record five books with CCB authors have appeared within the past six months:

· CCB doctoral student Taylor Ricketts is senior author of A Conservation Assessment of the Terrestrial Ecoregions of North America: Volume I, published by the World Wildlife Fund. The book analyzes patterns of diversity of birds, butterflies, vascular plants, amphibians, land snails, tiger beetles, reptiles and mammals by ecoregion in North America, north of Mexico. Hotspots of diversity are pin-pointed for future conservation efforts. Ricketts has continued working with the database, exploring factors determining the distribution of hotspots.

· Dennis Murphy is an editor of The Science of Conservation Planning, published this fall by Island Press. This important work examines habitat-based conservation under the Endangered Species Act.

· Paul Ehrlich has written World of Wounds, published by The Ecology Institute in association with The Ecology Institute Prize awarded to him. In a personal account, Ehrlich outlines the most important issues facing ecologists, and argues for greater involvement in solving the world's pressing environmental problems.

· José Sarukhan co-authored a book on the Weeds of the Valley of Mexico (Malezas del Valle de Mexico) with F. Espinoza.

· Carlos Galindo-Leal and Manuel Weber have co-authored El Venado de la Sierra Madre Occidental: Ecología, Manejo, y Conservación. [The western Sierra Madre White-tailed Deer: Ecology, Conservation and Management.]

- The first issue of a new occasional Center publication, *Ecofables/Ecoscience* has appeared, and the second is well on its way to press. This publication examines myths promulgated as environmental science, and presents the actual science. If you would like to be on the mailing list for this publication, please contact the CCB at the address on our masthead, or by e-mailing ecofable@bing.stanford.edu

- Center personnel have participated in a number of conferences recently. Jennifer Hughes and Gretchen Daily presented papers at the Conference on Biodiversity at the National Academy of Sciences this fall, and Paul Ehrlich moderated a panel at the same meeting. Anne Ehrlich was co-rapporteur of a working group on natural resources and the environment at the Pugwash meeting in Norway this summer. Two workshops on global warming are expected to be held during the coming year as a result of those efforts. Claire Kremen spoke at the 10th Annual Bodega Marine Lab Colloquium on "The Use of Model Systems in Ecological and Evolutionary Research." She was also interviewed on a local radio station, KQED, regarding her work in Madagascar. Erica Fleishman was invited by the Swedish EPA to participate in the symposium "The Use of Population Viability Analysis (PVAs) in Conservation Planning." She discussed the use of indicator and umbrella species in conservation planning. Stu Weiss presented papers at several conferences this year including the Society for Conservation Biology in Victoria, BC and the Ecological Society of America meeting in Albequerque, NM.

Population Diversity and Extinction

Today *biodiversity* and *extinction* are almost household words. They invoke images of imperiled species such as the tiger, black rhino, and condor, and lost species such as the passenger pigeon, dodo, and ivory-billed woodpecker. But biodiversity is much more than species. Ultimately, most of the benefits biodiversity confers on humanity are delivered through *populations* of species, rather than the species themselves.

Every species is made up of one or more populations, groups of individuals of the same species which are genetically different from other groups. Most benefits that humans derive from biodiversity are provided not by one population of a species that exists somewhere in the world (perhaps in a zoo), but by multiple populations that occur in natural ecosystems.

populations of species often confer more benefits than the species themselves.

One of the most obvious benefits of population diversity is the aesthetic enjoyment of wild populations. Natural habitats are made up of populations of trees, birds, wildflowers, and so on. When such areas are destroyed, people's enjoyment of their ambiance is diminished.

Another benefit is that the genetic material which populations contain is crucial for the discovery and improvement of pharmaceuticals. The successful development of penicillin as a therapeutic drug did not occur until 15 years after Alexander Fleming's discovery of the compound in common bread mold. One reason for this delay was a worldwide search to find a strain (a population) of the mold which produced greater quantities of penicillin than the original.

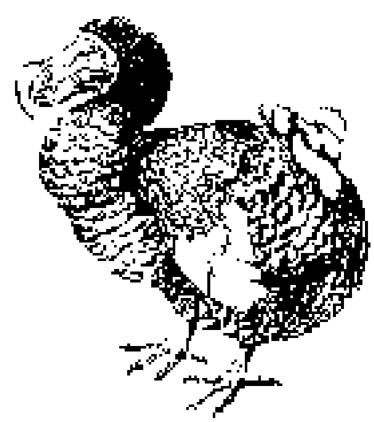
Population diversity also supplies critical genetic material to crops. Genetically uniform strains of the world's three major crops (rice, wheat, and maize) are widely planted. This makes them susceptible to a new disease or pest. Large fractions of the harvest could be threatened at one time. Thousands of strains, or populations, of wild crop relatives may have to be tested until one is found that carries the desired genetic resistance which can be used to protect the crop. When the grassy stunt virus emerged as a serious threat to the rice crop in southeast Asia in the late 1960s and 1970s, for example, an extensive search for resistant rice varieties was conducted at the gene bank of the International Rice Research Institute. Populations from all over the world were screened, and only one population of wild rice collected in India was found to resist the virus.

But perhaps the most important benefits that populations bestow on humanity are in the form of ecosystem services. Ecosystem services include natural processes such as purification of air and water, detoxification and decomposition of waste, generation and maintenance of soil fertility, pollination of crops and natural vegetation, and pest control.

Consider the flood control service that forest populations provide. Regardless of the continued existence of the Douglas fir elsewhere, populations of the trees which have been logged in the northwestern US no longer protect downstream areas from floods. Much of the damage from the heavy rains in 1997 might have been avoided if these populations were still in place.

New York City provides another example of the value of population diversity. The city was famed for its pure water, which came from the Catskill Mountains, 100 miles to the north. For most of the city's history, natural purification processes, performed by populations of plants and soil organisms, were sufficient to cleanse the water, but in recent years land development and associated human activities reduced the efficacy of these processes. In 1996, city water officials floated an environmental bond issue to purchase land, freeze development on other lands, and subsidize the improvement of septic tanks. It is hoped that these actions will restore and safeguard the local populations of the organisms that filter and purify the water. If so, an investment of $1 billion in natural purification services will have saved city tax payers $6-8 billion, the additional avoided cost (over 10 years) of building a water treatment plant.

Recently, Paul Ehrlich, Gretchen Daily and I estimated that more than 1800 populations per hour are going extinct from human-driven habitat destruction. This is three times faster than species extinction. The main message from this astounding number is one that ecologists have long recognized: habitat preservation is crucial for the preservation of biodiversity and the life-support systems which maintain human civilization. Unfortunately, the present legislative focus on species conservation neglects crucial dimensions of biodiversity such as population diversity. To protect the benefits that humanity derives from all levels of biodiversity, an Endangered Biodiversity Act would be more appropriate than an Endangered Species Act.



Jennifer B. Hughes is a graduate student and part of the research staff at the CCB. Her work on population extinction was published recently in Science. *(Hughes, J.B., G.C. Daily, and P.R. Ehrlich. 1997. Population Diversity: Its extent and extinction.* Science *278:689-692.)*

Butterflies and Land Management in the Great Basin

Resource agencies in the United States currently operate under ecosystem management mandates. The objective of ecosystem management is to protect ecosystem integrity over time by integrating scientific knowledge about ecological relationships with social and political values. An understanding of interactions between organisms and their environment is vital to effective ecosystem management. Because time and money inevitably are scarce, ecosystem managers also seek scientifically valid short cuts to guide their planning efforts. As part of ongoing research supported by NBI, the Nevada Biodiversity Research and Conservation Initiative, former CCB president Dennis Murphy and I are examining how butterflies can be used to inform ecosystem management in the Great Basin. Roughly 75% of this high desert region, which extends from the east slope of the Sierra Nevada in California to the west slope of the Wasatch Range in Utah, is administered by federal agencies. The management orientations of these agencies are shifting rapidly from commodity production to maintenance of ecosystem function and biotic diversity.


Speyeria nokomis apacheana in central Nevada. This subspecies is restricted to mesic habitats, which are sensitive to human activities. *Photo by Erica Fleishman.*

Our work has demonstrated that surveys of butterflies at the level of individual canyons within mountain ranges can help evaluate how human activities might perturb current species distributions in the Great Basin. For example, butterfly communities in the Great Basin tend to be nested—species present in comparatively depauperate locations generally are subsets of those present in locations that are richer in species (see *UPDATE* Vol. 9, No. 2). Nested distributional patterns usually are produced by habitat fragmentation, such as isolation of Great Basin mountain ranges by lower-elevation desert scrub following the Pleistocene. The order of species extirpations in nested faunas is fairly predictable. This allows managers to identify and plan appropriately for species that may be most sensitive to further natural and anthropogenic habitat fragmentation.

NBI researchers have found that across the Great Basin, elevational gradients have significant effects on the species richness and elevational distributions of butterflies. These data are enabling us to examine not only how regional warming may modify contemporary patterns of butterfly species richness, but also which butterfly species are at greatest risk of being lost from individual mountain ranges. A key management recommendation that already has emerged is that to maintain native biotic diversity and maximize the potential of Great Basin butterflies to adapt to rapid climate change, habitat protection and restoration efforts should target not only high elevation wilderness areas, but also intermediate elevations.

Research conducted to date suggests that quantification of relationships between butterfly distributions and fundamental environmental parameters facilitates predictions about species and community-level effects of ecological change. The ability to anticipate such scenarios is of considerable value to land managers. A logical next step is to test empirically whether studies of butterflies also can convey important messages about the health of habitats or ecosystem processes—in other words, whether butterflies can serve as short-cuts for ecosystem management.

To address this issue, Murphy and I are pursuing several related areas of inquiry. First, we are evaluating the effects on butterflies of variation in the spatial and temporal scales at which specific management alternatives are implemented. For example, under a cooperative agreement with the U.S. Forest Service, we are assessing how butterfly populations respond to prescribed burns of different sizes that were ignited at different times of the year. Second, we are measuring the extent to which the distribution and abundance of butterflies vary in space and time, even when human impacts are minimal or held at a constant level. Third, we are testing whether human activities in sensitive habitats are influencing the viability of certain butterfly taxa. Understanding the mechanisms by which these activities affect native species may enable ecosystem managers to mitigate human impacts without excluding human uses. Finally, in partnership with CCB collaborator George Austin (Nevada State Museum and Historical Society), NBI and CCB researchers will attempt to determine whether butterfly species with extreme susceptibility to human activities already have been lost from the Great Basin. Collectively, these investigations will provide agency personnel with clear guidance as to situations in which butterflies may meet their needs for management short cuts.

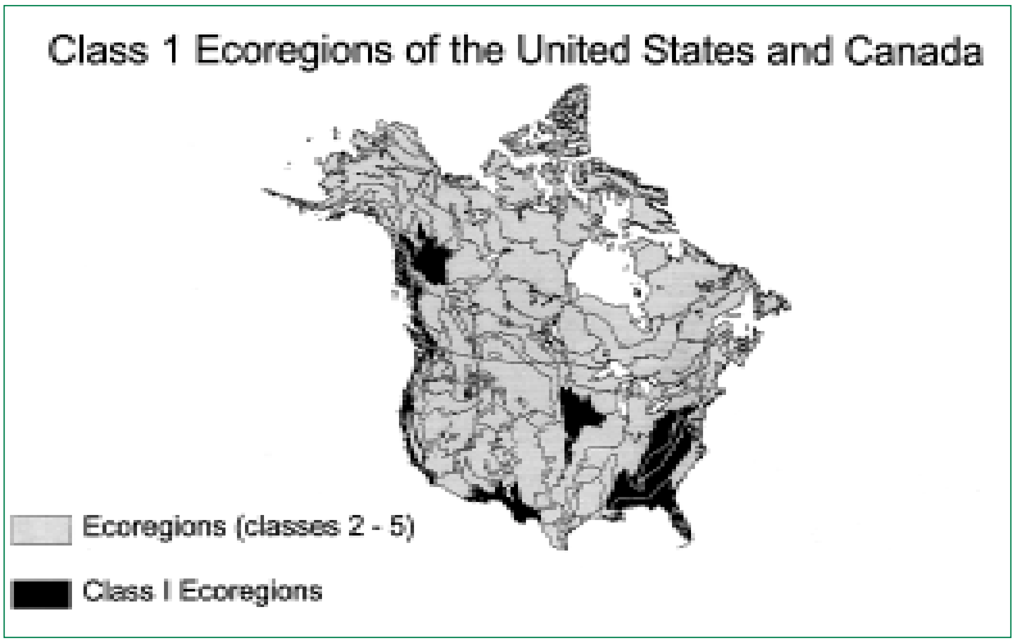
Ecosystem management is based on the long-term goal of ecological sustainability. Testing the hypothesis that any group of species can serve as a reliable surrogate measure of management efficacy or ecological integrity likewise requires long-term commitments to funding and field study. It is increasingly apparent, however, that research on butterflies in the Great Basin may be of substantial value to comprehensive conservation planning and ecosystem management.

Dr. Erica Fleishman is a post-doctoral researcher at the CCB. She has spent the past several years studying patterns of butterfly diversity in the Great Basin.

Ecoregions to Watch in North America

In the most comprehensive study to date on the status of biodiversity in North America, Taylor Ricketts of the CCB, in collaboration with World Wildlife Fund, has produced a report identifying areas in the United States and Canada in need of most immediate conservation efforts. The study, entitled "A Conservation Assessment of the Terrestrial Ecoregions of North America," focused on the big picture, taking a broad and inclusive look at entire ecosystems. Ricketts and his colleagues hope that this will result in informed, strategic allocation of scarce conservation resources at more local levels, by placing the biodiversity and conservation status of these areas in a global context.

The study is the first at this scale in North America to employ ecologically meaningful units in a conservation assessment. Instead of arbitrary political boundaries such as states or provinces, Ricketts and his colleagues mapped 116 ecoregions, or regions that harbor a characteristic set of species, communities, and environmental conditions. With the help of over 35 American and Canadian ecologists, they analyzed patterns of diversity of birds, butterflies, vascular plants, amphibians, land snails, tiger beetles, reptiles and mammals. Ricketts and his colleagues used this and other information to assess the ecoregion's biological distinctiveness and conservation status. The combination of these two measurements indicates the extent to which the ecoregion needs conservation efforts.



To determine the first measurement, biological distinctiveness, the team catalogued the species richness and endemism (number of highly localized species) in each ecoregion, as well as any "globally outstanding phenomena." This last category included regions with rare ecological or evolutionary phenomena, or globally rare habitat.

The second measurement, conservation status, was based on large-scale variables including percent remaining habitat, degree of fragmentation, and level of existing protection. These variables were combined to form a measure of each ecoregion's ability to maintain viable species, populations and communities, sustain ecological processes and respond effectively to short and long-term environmental change

By integrating the biological distinctiveness of an ecoregion with its conservation status, Ricketts and his colleagues were able to combine the biological importance of an area with a measure of human impacts on ecological integrity and species diversity. This allowed them to prioritize ecoregions by their need for conservation actions. Their study identified 21 "Class I" ecoregions, or "globally outstanding ecoregions requiring immediate protection of remaining habitat and extensive restoration" (see map).

The researchers themselves were surprised to find the study revealing more biological diversity than was previously acknowledged for North America. Ricketts and his colleagues report that North America holds some of the richest ecosystems outside of the tropics. The Appalachian-Blue Ridge forests, for example, are among the richest temperate forests in the world. Much of the world's conservation efforts have focused on the tropics due to their high levels of species richness. This study reveals that in terms of temperate biodiversity, North America is exceptional, but in serious conservation trouble.

Some critics have argued that this new study is so broad that the results are overwhelming and do not provide a starting point on which to focus conservation efforts. In fact, comments Ricketts, the study provides exactly such a starting point. It takes a large and diverse continent, made up of 116 ecoregions, analyses them in a continental and global context, and identifies a subset of 21 that require immediate and intense attention. With their global importance established, these ecoregions, suggest the authors, should be the targets of finer scale analyses, management plans, and, most importantly, concrete action. The team hopes that they have sounded a wake up call to North Americans: that we harbor extraordinary biodiversity in our own backyards, but in many cases, we are doing a worse job of protecting it than many developing countries without nearly the resources available. With the publication of this broad, timely study, perhaps conservationists are now better equipped to reverse this trend.

Sylvia Fallon is research assistant for the CCB and co-editor of UPDATE.

Readings from the Center...

Following is a list of some of the recent conservation publications by Center staff, ranging from magazine and scientific journal articles to books. Single copies of the shorter publications are available from the Center.

Butterfly diversity and human land use: species assemblages along an urban gradient. Blair, R.B. and A.E. Launer. 1997. Biological Conservation 80:113-125.

Community composition in mountain ecosystems: climatic determinants of montane butterfly distributions. Boggs, C.L. and D.D. Murphy. 1997. Global Ecology & Biogeography Letters 6:39-48.

Nature's Services: Societal Dependence on Natural Ecosystems. Daily, G.C., Ed. Island Press, Washington, D.C. 1997.

Ecosystem services: benefits supplied to human societies by natural ecosystems. Daily, G.C., S.E. Alexander, P.R. Ehrlich, L.H. Goulder, J. Lubchenco, P.A. Matson, H.A. Mooney, S. Postel, S.H. Schneider, D. Tilman, and G.M. Woodwell. 1997. Issues in Ecology 2:1-18.

Worldwide interdependence in ecological matters. Ehrlich, A.H. In J. Rotblat, F.R.S., Ed. World Citizenship: Allegiance to Humanity. St. Martin's Press, New York. 1997. Pp. 38-53.

A World of Wounds: Ecologists and the Human Dilemma. Ehrlich, P.R. In O. Kinne, Ed. Excellence in Ecology, Ecology Institute, Germany. 1997.

Natural history and biogeography of the butterflies of the Toiyabe Range, Nevada (Lepidoptera: Papilionoidea). Fleishman, E., G.T. Austin, and D.D. Murphy. 1997. Holarctic Lepidoptera 4:1-18.

The Western Sierra Madre White-tailed Deer: Ecology, Conservation, and Management. Galindo-Leal, C. and J.M. Weber. CONABIO, Edicusa, S.A. Mexico. 1997. 250 pp.

The distribution, habitat and conservation status of the Pacific Water Shrew, *Sorex bendirii*, in British Columbia. Galindo-Leal, C. and G. Zuleta. 1997. Canadian Field Naturalist 111:422-428.

Population diversity: its extent and extinction. Hughes, J.B., G.C. Daily, and P.R. Ehrlich. 1997. Science 278:689-692.

The Science of Conservation Planning: Habitat-based Conservation Under the Endangered Species Act. Noss, F., M.A. O'Connell, and D.D. Murphy. Island Press, Washington, D.C. 1997.

Caudata: *Batrachoseps attenuatus* (California slender salamander). Predation. Reaser, J.K. 1997. Herpetological Review 28:81.

A Conservation Assessment of the Terrestrial Ecoregions of North America: Volume I, the United States and Canada. Ricketts, T.H., E. Dinerstein, D.M. Olson, C.J. Loucks, W. Eichbaum, K. Kavanagh, P. Hedao, P. Hurley, K.M. Carney, R. Abell, and S. Walters. 1997. World Wildlife Fund, Conservation Science Program, Washington, D.C.

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