Natural Pollination Strategies for Agriculture Systems

Like wild plants, many crops require insects for pollination. In fact, over 90% of the crops grown worldwide require pollination services from animals for maximal yields. Currently, honeybees are used almost exclusively for the pollination of crops. The high economic costs of parasite epidemics and high death rates caused by insecticide use have generated a growing interest in the potential use of wild insects as crop pollinators. Using a diversity of pollinators, rather than solely honey bees, may be a cost-effective way of improving both crop yields and insect biodiversity in extensive agricultural landscapes.

In order to understand our pollination options for agriculture, we first must understand the similarities between wild and crop pollination systems and why most wild pollination systems utilize a diversity of pollinators. In this article I discuss these issues, focusing on a variety of agricultural settings in Bolivia, New Zealand, South Africa and India.

Specialization in pollination systems

In natural systems, plants rarely specialize in pollinators. There are a few cases of pollinator specialization such as figs and fig wasps and yucca and yucca moths, but these are the exceptions. One of the reasons specialization is not favored in nature is the huge potential for total loss of reproductive success if something happens to the pollinator. For example, think of a situation where two pollinator species visit a plant. One is a vastly superior pollinator in terms of the amount of pollen transferred from male to female reproductive parts but is a very erratic visitor, visiting only every other year. The other pollinator is not very good at transferring pollen but is a reliable and constant visitor. In this situation, it would not make sense for the plant to prevent the poor pollinator from visiting since this would eliminate its reproductive

Will more knowledge save the environment?

There is no question that new knowledge must play a role in solving humanity’s environmental problems. But in the past few years, there have been repeated suggestions that a knowledge explosion is underway that will more or less automatically solve the human predicament by allowing more economic output with less physical input. A group of three economists and four biologists affiliated with the Center for Conservation Biology set out to address these claims. Specifically, is there a knowledge explosion? And if so, will it help the environment?

Is a knowledge explosion occurring?

It is hard to miss the current information explosion, particularly in industrialized countries. Just consider the case of satellite imagery. Every day satellites record thousands of images of the planet’s surface. Recent increases in data storage technology allow the gathering of this mass of information, and through the Internet, the data may be shared almost instantaneously around the world.

Yet most of these images will never be seen by the human eye, let alone assessed by a human mind. Should this information be counted as an increase in knowledge? In our analysis, we defined knowledge as accurate information that has been organized and evaluated by a human mind. Under this definition, satellite images are not knowledge if they are simply stored on a computer’s hard disk somewhere.

There are many other issues that must be considered when assessing knowledge-growth. Two of these issues are misinformation and potential knowledge. In the environmental arena, much of the information that is put forth is actually disinformation, information that is intended to deceive. Therefore, in judging the extent to which a knowledge explosion is occurring,

see Natural Pollination, p. 2

see More Knowledge, p. 3
Natural Pollination, continued from front page

potential every other year! These are the types of situations that may have led to the high number of generalized pollination systems we see in nature.

Although agricultural systems are much more controlled than natural systems, variation still exists in the visitation rates of each pollinator type and in the ability of pollinator species to pollinate flowers of a given crop. Farmers can compensate for low numbers of pollinators by purchasing more honey bee hives, but this is expensive and increases food prices. For this reason, it is important to identify other ways to stabilize pollination services to crops between years and fields. One solution is to increase pollinator diversity in agricultural landscapes. Increasing pollinator diversity can decrease variability in the number and quality of pollinators visiting a given year or field. This can, in turn, decrease the number of visits needed to ensure maximal yields by improving average pollinator quality.

Pollination systems

Last year I received a Thomas J. Watson Fellowship to travel to Bolivia, New Zealand, South Africa and India. I investigated the use of wild pollinator populations for crop pollination. I selected crops grown by farmers from different economic and cultural backgrounds. From my studies I was able to draw some conclusions about how to effectively utilize pollinator populations in agricultural landscapes. Intensely tilled, monocultural agriculture creates two major problems for wild pollinators. These landscapes lack suitable nesting sites and are often dangerous due to intensive pesticide use. To investigate these issues I observed pollinators visiting a variety of crops in different locations and under different conditions. In rural Bolivia, I found that small coffee, banana, and citrus farms did not have significant pollination problems. Wild insect populations were abundant and played an active role in the pollination of these crops without any attention from farmers. The major factors contributing to the healthy pollination systems in this area of Bolivia were the cultivation techniques being used. Fields were small, separated by wild vegetation, and tilling was rarely used as a method for preparing soils. The landscape provided many nesting sites, and farmers did not utilize pesticides at high levels, thus minimizing unintentional pollinator deaths.

Agriculture in New Zealand is much different from small area farming in Bolivia. Most crops are grown in large monocultures and pesticides are used on a large scale. I used kiwifruit to study the importance of wild areas to pollinator visitation rates in more heavily altered landscapes. I censused pollinators visiting flowers in kiwifruit orchards near and far from native vegetation. As might be expected, I found that in fields surrounded by corridors of native habitat, visitation by non-honey bees was much higher. Twenty-five percent of pollinator visits made in corridor fields were by non-honey bees versus 3% of total visits in isolated fields surrounded by other orchards.

In South Africa, I worked at paprika farms to study an intermediate farming style. Paprika is grown in large monocultures, but fields are generally surrounded by vast tracks of native vegetation. Farmers do utilize pesticides to control pests, primarily fruit flies. Unfortunately, some major pollinators of paprika are also flies, syrphid flies. Pesticide spraying is usually indiscriminate and little effort is made to spray at times when these wild fly pollinators are not foraging. The result is dramatic decreases in syrphid fly numbers following pesticide spraying. Fortunately, efforts are made to avoid the spraying of native bees, thus leaving alternative pollinators in the fields. This study illustrates the impact of pesticides on wild pollinator populations and shows the danger of relying on a single pollinator species. Without the presence of a diversity of pollinators, pesticide use causes fly deaths that could cause serious decreases in yield quality in the future.

India was the only country I visited where farmers actively manage pollinator populations for crop pollination. Cardamon requires visitation by bees for fruit set to occur. Two native honeybee species in Southern India are the major pollinators of this economically important crop. Neither is domesticated, and thus, farmers rely on wild populations. To manage these pollinators, farmers provide nectar sources year round by growing coffee and cardamom in the same fields. These crops flower at different times but utilize the same bees. Shade trees are also selected for their potential as nectar sources when crops are not blooming. Not only does this practice encourage local bee colonies, but it also supports native tree species. Through these efforts most farmers are able to enjoy free and reliable pollination services for their cardamom crops.

Conclusions

The work I have done over the past two years suggests that the use of a single pollinator species is unlikely to be the most effective and economically stable pollination strategy. Use of a variety of pollinators from natural vegetation areas make it possible for Bolivian farmers to ignore the pollination issue altogether. In South Africa, use of diverse pollinators has the potential to save paprika farmers from yield losses. In New Zealand, farmers could benefit from increasing the amount of wild vegetation on their property. Indian farmers enjoyed free pollination services due to pollinator sensitive cultivation techniques. It is unrealistic to think, however, that we will ever be able to increase wild pollinator populations to levels that could completely eliminate our reliance on domestic honey bees in industrialized countries. By adopting thoughtful management practices, however, we may be able to decrease this reliance and stabilize costs associated with pollination problems and perhaps prevent these issues from becoming problems in developing agricultural nations.

Margaret Mayfield is a research assistant at the CCB.
More Knowledge, continued from front page

disinformation must be subtracted from the useful information. Similarly, lost potential knowledge must also be subtracted. Such losses are associated with the decay of biological and cultural diversity. Consequently, once these types of “knowledge” are deducted, we may find that we are being inundated by a flood of information while incurring a net loss of fundamental knowledge.

Will more knowledge help the environment?

Because of the difficulty involved in the assessment of knowledge growth, we agreed to remain agnostic about whether a knowledge explosion was occurring. We then turned to the question of whether more knowledge would help the environment.

One empirically testable claim for a positive relationship between increasing knowledge and environmental quality is that knowledge is replacing some elements of natural and human-made capital, such as land and machines, as factors of production. With historical data we can observe the connections between economic output and the use of material inputs. We focused on changes in materials inputs on the assumption that it correlates with environmental damage. In many instances this correlation is quite strong: global warming is a function of total emissions of greenhouse gases, and loss of habitat for biodiversity is a function of total area of natural ecosystems converted for human purposes.

We gathered material input data from the US, Germany, the Netherlands, and Japan since 1975. Material inputs are decreasing per unit of GDP in all the countries, suggesting that physical inputs are indeed becoming less important per unit of economic output. At the same time, population growth and increased resource consumption per person offset these gains. The total amount of materials used by the four countries has either remained the same (in the Netherlands and Japan) or increased (in the US and Germany). These data demonstrate an essential point. While knowledge may increase and allow a decrease in the physical inputs per unit of economic output, this trend by itself does not guarantee that environmental quality improves.

How can knowledge benefit the environment?

Although knowledge does not inevitably lead to environmentally beneficial outcomes, additional knowledge of environmental systems, the assaults upon them, and the human behavior and institutions behind these assaults is imperative for solving the human predicament. Thus, one path to improving environmental quality is to encourage the production and use of environmentally relevant knowledge. There are a number of ways to achieve this objective. One strategy is to provide economic incentives for the generation of environmentally relevant knowledge. Much knowledge that is environmentally relevant is not excludable. In other words, once this knowledge is generated, everyone has access to it and the knowledge-generators are not rewarded for their contribution. As a result, investment in research and development in this type of knowledge is discouraged. Consider the management of vector-borne diseases like malaria. Malaria can often be controlled by environmental management at least as cost effectively as through patentable biotechnological solutions such as vaccines, high tech pesticides, and so forth.

More Knowledge, continued from page 9
Understanding The Consequences: Mitten Crab Invasion Of The San Francisco Bay Area

As humans have developed means of traveling faster and farther, we have sometimes purposefully and sometimes inadvertently taken plant and animal hitchhikers with us. Human travel has dramatically increased the opportunities for these globetrotting stowaways to colonize new areas, resulting in epidemics of invasive species in much-traveled areas.

Not every “hitchhiker” establishes a population outside of its native range. Disturbed, previously invaded, and/or aquatic ecosystems tend to be more susceptible to invasion. An example is the San Francisco Bay- Delta ecosystem: it supports heavy national and international shipping traffic, and is home to more than 230 non-indigenous species. Species that tend to be successful invaders also have attributes in common: short generation time, high reproductive capability, and tolerance of varied environmental conditions. One successful invader with these traits is the Chinese mitten crab (Eriocheir sinensis).

Mitten Crabs In The San Francisco Bay

The mitten crab is native to China and Korea. It was introduced to Germany in the first decade of the twentieth century and rapidly invaded the waterways of Europe, eventually spreading to Czechoslovakia, Spain, and Portugal. Isolated Chinese mitten crabs were recorded several times in North American waters before the 1990’s but no populations were established. In recognition of potential dangers from an invasion, California outlawed live imports of mitten crabs in 1987. Stricter laws were implemented by the U.S. Fish and Wildlife Service when E. sinensis was officially labeled an “injurious species” in 1989. However, illegal live imports continued due to the high price commanded by fresh crab as a food item -- especially egg-bearing females.

In 1992 a shrimp trawler in South San Francisco Bay recorded the first mitten crab on the West Coast. Since then, the crab has established itself throughout the San Francisco Bay as well as in many of the estuaries and streams which feed into the Bay. It is likely that the crabs were introduced by the release of ballast water bearing larvae or adults from a transoceanic vessel, or the accidental or purposeful release of live crabs imported for food. It is possible that there have been multiple introduction events.

Economic and ecological problems associated with the mitten crab have already been reported from around the Bay Area. Crayfishermen are concerned about competition between the increasingly plentiful mitten crabs and the commercially important crayfish and anglers have complained about stolen bait. Water managers also fear that dense mitten crab burrows may weaken banks and levees, causing disastrous floods. At the Tracy Fish Collection Facility, designed to divert fish around an industrial pumping area, fish screens clogged with as many as 18,000 crabs per day at the height of the 1998 downstream migration, damaging fish and overwhelming the facility.

Mitten Crabs At Stanford

Each summer, Center researcher Alan Launer and a crew of CCB research assistants monitor the populations of riparian species in San Francisquito and other creeks on Stanford property. Some of these species are steelhead, catfish, Sacramento suckers, roach, stickleback, red-legged frogs, signal crayfish, and Louisiana red crayfish. In 1996, in the course of routine summer fieldwork, we unexpectedly found a mitten crab near the Stanford Golf Course stretch of San Francisquito. Again in 1997 a single crab was recorded in San Francisquito Creek near the Golf Course. The following year no crabs were found. Between June and October of 1999, it became clear that mitten crabs were going to have a serious impact on the ecology of San Francisquito. We recorded hundreds of live crabs, dead crabs, and molts along a ten kilometer stretch of the creek. The furthest upstream were inside Jasper Ridge Biological Preserve and within the range of federally listed endangered red-legged frogs and steelhead.

Studies in China, Korea and Europe have identified the crabs as phenotypically and behaviorally plastic. These results suggest that the Bay Area crab populations, such as those in the San Francisquito, will be ecologically distinct from populations in China or Germany. Since
little local work has been formally designed or completed on this species, many questions are still unanswered. What will eventually limit the mitten crab’s distribution and abundance in the San Francisco Bay and its watersheds? How can we control the economic and ecologic damage from the invasion? How can we predict which year classes are going to be overwhelmingly large? The San Franciscuito is a good location to find the answers to some of these questions. At a recent meeting of mitten crab researchers from the Department of Fish and Game, Department of Water Resources, Bureau of Reclamation, U.S. Geological Survey, San Francisco Estuary Institute, UC Berkeley, and Stanford, we worked on establishing standard research protocols to make it possible to effectively share data and to begin to answer some of our questions.

Next summer, Launer and CCB research assistants will try to answer questions about the ecology of our local populations. How does the presence of mitten crabs impact populations of California red-legged frogs and steelhead? What kind of interactions occur between the crabs and other native and non-native species in the creek? Why are there no mitten crabs in Los Trancos Creek, a San Franciscuito tributary within the crabs’ range? What will eventually limit the crabs’ distribution on Stanford property?

1999 was a boom year for mitten crabs in the South Bay. At this point, it isn’t clear if there will be further increases in the numbers of crabs inhabiting Stanford creeks in the next few years or if 1999 was unique. However, it is certain that mitten crab monitoring and control will be part of Stanford’s long term conservation planning.

Darcy Gordon is a research assistant working with Dr. Alan Launer at the CCB.
As the human population expands to more than 6 billion individuals, human-dominated landscapes comprise an increasing portion of land area. Although it remains important to preserve pristine ecosystems and the biodiversity therein, we must also investigate the potential for human-altered landscapes to support biodiversity. We must think less about remnant habitat patches as islands in a matrix of human-dominated landscapes and more about the countryside as a functioning mosaic of natural and human-dominated patches.

Countryside biogeography is the study of species diversity, abundance, restoration and conservation in human-dominated landscapes (Update, Winter 1999). Two goals of this approach are to determine the characteristics of species that allow them to persist in human-dominated landscapes and the capacity of these landscapes to support native biodiversity. Few studies have investigated these topics in the Latin American tropics, where conversion from pristine to agricultural systems is currently taking place. The tropics provide an excellent opportunity to study the process of conversion from native to countryside habitats and resulting shifts in community structure and species compositions.

I am currently studying why some species are able to persist in these modified tropical landscapes while others are not. Specifically, I am investigating the relationship between land-use type and neotropical lepidopteran diversity. The ecological importance of butterflies as pollinators and herbivores, their close association with their host plants, and their potential as indicators of native plant and insect diversity renders them an important taxon for conservation and biogeographical research.

During the rainy season of the summer of 1999, I surveyed butterflies in southern Costa Rica and characterized the distribution of species in both native forest and agricultural areas. Because coffee farms comprise a major proportion of the Costa Rican landscape, I chose them to represent the human-dominated habitat in my study. I sampled butterfly species richness in the forest and coffee fields to address the following questions:

1. Do butterfly diversity, abundance and composition differ among agricultural and forest habitat types?
2. Are butterfly diversity, abundance and composition in human-dominated habitats related to the proximity and size of primary forest patches?
3. Do butterflies at different distances from forest patches share particular morphological or life history traits?

I sampled butterfly fauna at 15 representative sites in and surrounding the Las Cruces forest using fruit-baited traps and hand nets. Three sites were located in the large primary forest reserve (227 ha) and 12 sites in coffee fields. The Las Cruces forest is the only large forest patch in the area in a landscape composed primarily of coffee fields and cattle pasture. I examined the effects of forest proximity on butterfly distribution in two manners. First, half of the coffee sites have small adjacent forest patches (<5 ha.) while the other half are isolated from forest by other coffee fields (hereafter referred to as pure coffee). Second, half of the coffee sites are near (<5 km) and half are far (>10 km) from the large forest reserve. The two scales of forest proximity might lend insight into whether the size of nearby forest patches and distance to large tracts of forest determine the species composition of agricultural areas.

Preliminary analysis suggests that proximity to forest patches does have a significant effect on the number of species found in a given patch. Coffee sites with adjacent forest patches contain more species than do forest or pure coffee sites. This suggests that the edge between forest and coffee fields supports a large number of species. Distance from the large forest reserve, however, does not have an effect on the species richness of the agricultural sites. Other data suggest that roadside tangles and hedgerows support a high abundance and diversity of butterflies.

To further characterize patterns of species richness, I designated each species as restricted or shared. Restricted species...
Predicting current and future biodiversity in agricultural landscapes

The rapid rate of conversion of pristine habitat to agricultural land in the Americas is a key issue in conservation biology. In contrast, a more insidious reduction of biodiversity has occurred in Northern Europe. Conversion to agricultural landscapes began over six thousand years ago and continued, albeit sporadically, until the present day. In the UK, the final coup de grace occurred as a result of the post World War II drive towards agricultural intensification. Increased fragmentation of remaining habitats (termed ‘semi-natural’ as they have undergone some form of management) was intensified by removal of habitat patches and modification of surrounding landscape.

The end result of habitat reduction over any time scale is generally the same: biodiversity decreases. Worldwide, research in conservation biology over the last few decades has documented this loss and has provided models with which the mechanisms that underlie the loss can be better understood, firstly through island biogeography, then metapopulation theory and landscape ecology. However, a duality in the development of landscape ecological theories between Europe and North America has occurred. This duality reflects the temporal differences in landscape modification across the continents. The partial replacement of pristine communities with countryside communities has lead to a focus in European landscape ecology and conservation biology on the preservation of biodiversity within cultural landscapes. In North America, links with traditional ecology are more evident and the science more conceptual.

Mitigating biodiversity loss through understanding landscape structure

In the UK, I studied species movement across countryside separating patches of semi-natural habitat. Using satellite imagery, I classified these landscapes according to their potential for increasing biodiversity following a reduction in fragmentation. When these images were combined with details about species’ dispersal abilities, it was possible to quantify the landscape structure. Specific mitigation prescriptions were then produced according to the nature of fragmentation represented by the quantified classification. The nationwide satellite and digital information provided by this research have provided valuable information for determining funding priorities in conservation policy throughout the country.

Countryside biogeography: beyond the local scale

Dr. Gretchen Daily and others at the CCB have been examining the conservation of species in tropical rural landscapes through the development of “countryside biogeography.” Countryside biogeography emphasizes the importance of understanding the role of new cultural landscapes in “the diversity, abundance, conservation and restoration of species in rural [...] landscapes” (Update, Winter 1999). In Costa Rica, Daily is investigating the relationship between bird diversity and agricultural intensity in four distinct biogeographic and agricultural regions. I am investigating the extent to which patterns of bird diversity can be predicted from satellite images. Published examples of the classification of land cover from satellite images to assess biodiversity in semi-natural landscapes are few. Projects in Uganda and India have combined field surveys of plants and animals with classified images to describe biodiversity. Our work is taking this process a step further. We are using information on the landscape context of land covers in order to enhance land cover classification to reflect land use intensity. The classification will then be combined with the bird diversity survey to enable predictions of bird diversity to be extended across large areas. Our next goal is to extrapolate to the national scale to assess biodiversity change across Costa Rica. This research could lead to the prediction of biodiversity patterns through satellite imagery of agricultural landscapes in tropical climes and ultimately across the globe.

Addressing biodiversity loss in the British countryside

Along with the Costa Rica project, I am collaborating on a Habitat Restoration Project (HRP) with English Nature, the British Government’s statutory conservation advisor. The goal of the HRP is to evolve procedures and

**Predicting Biodiversity**, continued on page 8
practices to mitigate the reduction of biodiversity in the British countryside. Thus far, species have been identified in four 100 km² trial areas, for which opportunities exist to restore or recreate habitat. Via the HRP, landowners, farmers and other custodians of the landscape have been encouraged to reverse biodiversity loss by participating in Environmental Land Management Schemes (ELMS). Each of the trial areas will be monitored for 10 years following habitat restoration and creation. The criteria for judging ‘successful’ habitat restoration in the HRP, for the purpose of this investigation, is the increased presence of target species within the trial areas.

I am developing predictive models to provide an indication of the success of restoration programs and guidance on the type and location of the most important habitats to restore. Application of the technique to the HRP offers a chance to refine methods I have developed by modeling the probability of species recolonization following habitat restoration/creation and to test these predictions with the findings of future monitoring programs. For selected species that are currently present in low numbers in the trial areas (pipistrelle bat, barn owl, gatekeeper, small and Essex skippers), GIS will be used to define which landscape features they require for persistence. The probability of their distribution once habitat restoration or creation has occurred will then be modelled using the future landscape data. Using selected species, I will suggest where future restoration efforts should be located to maximise habitat/landscape quality. These techniques should be of value to policy makers and conservation agencies embarking on similar restoration projects in the agricultural landscapes of the US and Europe.

*Morpho pleides* is one of 185 species captured in the Las Cruces landscape. Photograph by Claire Devine.

Claire Devine is a doctoral student at the CCB.

*Dr. Sallie Bailey is Director of the CCB’s GIS lab.*
One such management technique is to manipulate the timing of flood irrigation of rice paddies to reduce mosquito populations. In fact, studies indicate that this type of knowledge-intensive irrigation management also increases rice production in nations like Japan with good water control. Because these techniques are not patentable, however, there is less private incentive for such knowledge than is socially desirable. In these cases, it is socially beneficial to subsidize research in non-patentable areas.

**Essential resources and the limits of knowledge**

Even with increases in knowledge that directly benefit the environment, there are limits to what knowledge can do. It cannot eliminate humanity’s need for essential resources. These are resources that are crucial for economic production and for which there are no conceivable substitutes. Their stocks (both renewable and nonrenewable) are finite in supply and largely given by nature, rather than augmented by human beings.

Let’s briefly examine the case of fresh water. Water is indisputably an essential resource. It is necessary for consumption, cooking, bathing, and crop production. But the current and projected rates of water use are unsustainable. On a global scale, humanity is already using about half of the accessible fresh water for personal, industrial, and (primarily) agricultural purposes. Improvements in irrigation technology and genetic engineering may reduce the per-capita requirement of water, but these improvements are subject to biological and energetic constraints. For instance, strains of high-yielding wheat have lower water use efficiency than lower yielding varieties, suggesting that the window may be narrow for improving yields and water use efficiency at the same time. In sum, the rate of innovation seems far below that required to keep up with demand, which under optimistic assumptions suggest humanity will use more than 70% of accessible fresh water by 2025.

**Conclusions**

It is not a straightforward task to determine if a knowledge explosion is actually occurring and if so, whether or not knowledge will have a positive net impact on the environment. Our investigation emphasizes the crucial role of public policy in helping generate knowledge that can benefit the environment and channel that knowledge to good effect. However, the ability to shift economic activities from goods toward services only partly eliminates the need for fundamental natural resources. Knowledge can never be a sole antidote to the increasing pressures on the environment posed by increasing population and per-capita consumption. These constraints are largely unacknowledged in the policy arena.


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**Center Notes**

- We welcomed several new members to the CCB this fall. Dr. Jacintha Ellers is from Leiden University, Netherlands. She is studying variation in resource allocation and its consequences for population differentiation in the butterfly *Colias p. eriphyle*. Dr. Patty Balvanera is from the National Autonomous University of Mexico (UNAM). She is working on beta species diversity and its link to ecosystem services. Dr. Salit Kark, from Israel, is interested in ecosystem services and the effects of stress at the edges of species’ ranges. Dr. Caitlin O’Connell is examining the Chinese trade in old ivory. Lisa Bohannan, a doctoral student at Michigan State University studying rural and environmental sociology, has also recently joined the CCB. Margaret Mayfield is a new research assistant at the Center.

- We recently hosted several visiting scholars from around the world. Dr. Ralph Mac Nally, from Monash University, Australia, spent 6 weeks with Erica Fleishman, analyzing diversity patterns of butterflies from the mountain ranges in the Great Basin, Esteban Martinez from UNAM, Mexico and Rogelio Cedeno from El Colegio de la Frontera Sur - Quintana Roo, Mexico came for two weeks to work with Carlos Galindo-Leal on diversity patterns in Calakmul, Mexico. Yvo Weidmann, from Switzerland and Mexico, visited the Center’s GIS lab briefly to work on a Calakmul vegetation map.

- Carlos Galindo-Leal directed a course on tropical biodiversity this October in Bacunayagua, Cuba. The CCB, UNAM and the Ministry of Science, Technology, and Environment of Cuba sponsored the course. The 35 participants from 9 countries came from academic institutions, NGOs and government agencies. A course was also held at the Universidad de Concepción in Chile, January 4th - 20th, 2000.

- In mid-December, the CCB hosted a meeting, at Stanford, of the Marbled Murrelet Advisory Committee, part of the Headwaters Habitat Conservation Plan. The meeting was facilitated by the Sustainable Ecosystems Institute from Portland, Oregon.

- Erica Fleishman organized this year’s San Francisco Bay Area Conservation Biology Symposium, sponsored by the Center. Many members of the CCB presented talks and posters at the Symposium in late January.


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*Dr. Jennifer B. Hughes is a former doctoral student at the CCB. She currently works on problems of bacterial diversity and continues to collaborate with center personnel.*
Thank you!

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