C.a. List of Participants

The participants include many tenure-track faculty in the Donald Bren School of Environmental Science and Management, a number of faculty from UCSB’s Department of Economics, and key administrators. The co-PI’s listed are important to the project; only Davis, Dozier, Dunne and Siegel are listed as official co-PI’s on FastLane due to the limit of four co-PI’s.

Prof. Charles D. Kolstad (PI)
Bren School & Department of Economics, UCSB
[Environmental regulation, climate]

Prof. Dennis Aigner
Bren School, UCSB (Acting Dean) and School of Management, UCI
[Econometrics, Env Management]

Prof. Antonio Bento
Bren School & Department of Economics, UCSB
[Transportation, Env & Development]

Prof. Ted Bergstrom
Department of Economics, UCSB
[Public economics, experimental economics]

Prof. Chris Costello (co-PI)
Bren School & Department of Economics, UCSB
[Renewable resources, water]

Prof. Frank Davis (co-PI)
Bren School, UCSB
[Biogeography and Landscape Ecology]

Prof. Robert T. Deacon
Department of Economics, UCSB
[Renewable resources, forestry]

Prof. Magali Delmas
Bren School, UCSB
[Transaction costs, strategy]

Prof. Jeff Dozier (co-PI)
Bren School, UCSB
[Snow hydrology]

Prof. Tom Dunne (co-PI)
Bren School, UCSB
[Hydrology, river systems]

Prof. Catherine Gautier
ICESS and Dept. of Geography, UCSB
[climate]

Dr. Laura Haston
Asst Dean for Academic Programs,
Bren School, UCSB

Prof. Patricia Holden
Bren School, UCSB
[Microbiology, ecotoxicology]

Prof. Arturo Keller
Bren School, UCSB
[hydrology, water chemistry]

Prof. Bruce Kendall (co-PI)
Bren School, UCSB
[Mathematical ecology]

Prof. Natalie Mahowald
Bren School, UCSB
[Atmospheric mineral aerosols]

Prof. Carol McAusland
Department of Economics & Bren School, UCSB
[Trade and Environment]

Prof. John Melack
Bren School & Dept. of Ecology, Evolution and Marine Biology, UCSB
[Limnology]

Prof. Joel Michaelsen
Dept. of Geography, UCSB
[Climate]

Prof. Cathie Ramus
Bren School, UCSB
[Environmental management]

Prof. David Siegel (co-PI)
Bren School & Dept of Geography
[Oceanography, marine science]

Prof. Perry Shapiro
Department of Economics, UCSB
[Environmental federalism, public finance]

Economics of the Environment C - 1 January 26, 2001
The vision of the proposed program is to provide the first truly multidisciplinary Ph.D. program in environmental and resource economics, a program that does not compromise the depth of economics education or the depth of education in a companion natural science discipline.

There are a number of quality Ph.D. programs in environmental economics around the world, nearly all of which involve treating environmental economics as simply another field of economics. These usually reside either in an economics department or in an interdisciplinary environmental program.

The typical economics department Ph.D. curriculum require the same basic core courses of all students plus several courses in each field in which the student chooses to specialize. In the case of environmental economics, students take several courses in that specialty and that is all. Whatever knowledge is needed in non-economics environmental sciences is usually picked up casually or not at all. This model works well for training academic economists. However, it would surprise many environmental scientists to realize how ignorant most environmental economists are of the natural science processes that underlie environmental problems. This model for graduate education hinders progress in the discipline.

The other current model for graduate education in environmental economics may be found in the several interdisciplinary environmental science programs. In these programs the environmental science training is somewhat more rigorous but this is usually attained by sacrificing rigor in training as an economist. It is extraordinarily rare for a graduate of an interdisciplinary environmental program to obtain a good academic job as an environmental economist in a good economics department.

The proposed IGERT program seeks a third path in graduate education in environmental economics, a path not taken at any university, to our knowledge. We seek to produce Ph.D.s who are as well trained in economics as any graduating from a good economics department but who also have Ph.D. level depth in a complementary field of natural science. In fact, if anything, the students in this program must have a stronger than average training in economics to overcome prejudice in the profession regarding multidisciplinary Ph.D. programs.

How is it possible to obtain this multidisciplinary breadth, without stretching a student's Ph.D. program to an unworkable extent? Most Ph.D. students in economics finance their education by serving as teaching assistants, taking a lighter course load while being a TA. Students supported through the IGERT program need not rely on this sort of support and can, instead, take a heavier course load. This allows the attainment of depth in one of the natural sciences without stretching the Ph.D. period very much (no more than one additional year).

The proposed IGERT program requires students to become trained economists but also to specialize in one of four areas of natural science: marine sciences, conservation biology/applied ecology, hydrology/water resources and climate. Students are expected to acquire PhD-level knowledge in one of these four areas. It is true that other appropriate areas in the natural sciences and even in the social sciences are not covered in this IGERT proposal; rather we have focused on a narrower disciplinary agenda, reflecting UCSB’s strengths.

The research component of the proposed IGERT Ph.D. program requires that the dissertation make a contribution to knowledge, either in economics or in the student's companion natural science field, or both. Making a contribution to environmental policy is not usually a sufficient basis for a satisfactory dissertation.

Recruiting students into the program will focus on two groups: those with strong undergraduate degrees in economics or in the natural sciences; and students with undergraduate majors in economics preferably with some natural science coursework.

This program will make a significant impact on the academic community because the graduates will be the first to have a consistent grounding in both economics and the natural sciences. This will increase the likelihood of new advances in understanding of the economics of environmental problems.

Throughout the text we will use the term environmental economics to refer to the field of environmental and natural resource economics.
C.c. MAJOR RESEARCH EFFORTS.

This IGERT has been structured to offer an array of research opportunities for Ph.D. students in environmental economics. Of course, there are fields of the natural and social sciences which are not included in our program but which are entirely appropriate for and complementary to environmental economics research. Rather than be comprehensive, we have carefully chosen four natural science areas on the basis of strength in the faculty here, logical connections and opportunities to integrate natural science and environmental economics, and real interest on the part of participating faculty to foster such integration.

The four natural science areas are (1) climate, (2) conservation biology/applied ecology, (3) hydrology/water resources, and (4) marine science. Each of these four areas is described in considerable more detail in this section. All have specific objectives and the research projects described have a high probability of operating throughout the period of the proposed IGERT program. We expect other investigations to be added to this list as our new assistant professors implement their research programs.

Although most of the projects described here are funded by federal agencies, few if any of these existing investigations has a funded mandate to address both the economics and the natural science dimensions of environmental problems. The IGERT-supported students will weave a common thread through our research by explicitly bridging these disciplinary boundaries. Although the four integrated natural science/economics focus areas described below constitute the research centerpiece of the IGERT-funded multidisciplinary Ph.D. program, it is also important to recognize that there is other research in environmental economics underway at UCSB, research which has no obvious natural science content. Nevertheless, this research, involving a number of the participants in this IGERT is enormously beneficial to the multidisciplinary IGERT program. Because of this, at the end of this section we also describe environmental economics research efforts at UCSB which are not specifically associated with one of the four integrated research efforts.

We have divided this “Major Research Efforts” section of the proposal into five subsections. The first four subsections describe the four main integrated research focus areas. The fifth subsection describes environmental economics research not currently associated with one of the four main focus areas but nevertheless of importance to the proposed IGERT program.

Within each subsection associated with the four main research areas we consider three important questions: (1) what research projects are currently underway with which an IGERT-funded student could readily associate?; (2) more generally, what are the opportunities for developing environmental economics research in the particular research area?; and (3) what might be some possible (though at this point hypothetical) dissertation topics students might pursue.

We have taken it as our charge to convey a sense of how an IGERT-trained student could naturally associate with a research focus. Thus the description of individual research projects has been made as succinct as possible. Most of the short paragraph descriptions described well-funded multi-year projects supported by federal agencies. Furthermore, because of the nature of multidisciplinary undertakings, there is some overlap in research projects between specific research areas. For instance, Dozier and Melack's work in the Sierra Nevada relates to surface effect of climate (the “Climate” focus area) and is also a surface water problem (the “Hydrology” focus area). Mahowald's work on dust relates to climate and marine processes.
Climate

Prof. Jeff Dozier leads the climate focus area, with additional participation of Profs. Deacon, Gautier, Kolstad, Mahowald, and Michaelsen. This faculty composition reflects the fact that climate research in the Bren School and UCSB is very strong and a prime example of multidisciplinary research, within the natural sciences and between the natural and social sciences.

In today’s discussion about climate in the scientific, political, and lay communities, the topic of climate change often dominates. Climate change is the dimension of the climate problem that stimulates cross-disciplinary research between economists and climate scientists; climate variability is as important an issue but receives less attention. The consequences of climate change for human and natural systems are imperfectly known but of great importance to solving the problem. Climate affects all components of the Earth system, particularly the hydrology, ecology, and economy. Our current vulnerability to climate variability shows some possible consequences of long-term trends in the climate. Climate variability and change will increasingly interact with the human pressures that continue to stress our dependence on ecosystems and inland waters. Despite the billions of dollars we spend in flood protection, for example, we still suffer billions of dollars in flood damage.

Profs. Dozier and Melack deal with surface effects of climate; Prof. Mahowald studies mineral aerosols/climate interactions; Prof. Gautier studies Earth’s radiant energy balance; Prof. Michaelsen analyzes climate statistics such as the relation between El Niño and regional precipitation; Prof. Kolstad studies the effect of uncertainty and information on climate damage and regulatory action; Prof. Deacon studies the effect of political structure on deforestation and other precursors of climate change. Agencies funding this work include NSF, DOE and NASA.

The climate area is one in which there is already a great deal of research activity from both the economists and the natural scientists, as is reflected in the project descriptions below. This is a natural and fertile ground for IGERT-supported Ph.D. students.

Current Research in Climate by IGERT Faculty

1. Climate and Desert Dust (Mahowald). Atmospheric desert dust represents a significant source of climate forcing through its interaction with incoming solar radiation and planetary radiation. In addition, desert dust aerosols are likely to change the chemistry of the gas and aerosol phase. Professor Natalie Mahowald’s research investigates multiple dimensions of the desert dust cycle, much of which is poorly understood. This includes sources, transport, deposition and radiative forcing. Factors like climatic conditions, the type of agriculture practices employed, water resource infrastructure investments, global aid programs and the status of the global economy all have a role in dust production (Capone et al., 1997; Falkowski et al., 1998; Mahowald et al., 1999).

2. Surface Climate and Snowmelt Runoff (Dozier and Melack). Jeff Dozier and John Melack lead a group supported by the NASA Earth Observing System to apply satellite- and aircraft-based remote sensing techniques to the study of seasonal snow in Earth’s mountain ranges, concentrating on the Sierra Nevada. They measure the snow’s spatial extent (Rosenthal and Dozier, 1996) and water equivalence (Shi and Dozier, 2000), and then use those measurements to drive spatially distributed models of the energy exchange at the surface (Cline et al., 1998). The research will allow a more detailed monitoring and prediction of subtle changes in the snow resource that result from interannual and secular variations in climate. The incorporation of plausible scenarios for future climate into management of the water supply and the strategy for modifying future plans as science progresses is an excellent illustration of the interesting complexities of integrating science and management.
3. **Learning, Irreversibilities and Climate Regulation** (Kolstad). Uncertainty dominates many dimensions of the climate process, including both physical and human dimensions. Because a great deal is being learned about climate, the amount of uncertainty is changing, though uncertainty will not shrink monotonically, because advances in knowledge sometimes add uncertainty, albeit temporarily. In a series of DOE and NSF grants, Prof. Kolstad has been exploring both the theory and empirical dimensions of learning about the climate and its effect on regulation (Kolstad, 1996, 1997, 2000; Kelly and Kolstad, 2000). In current work, Prof. Kolstad is statistically estimating how agents in the economy might adapt to an unobserved and unanticipated change in climate (Kelly et al, 2000). In other work, Prof. Kolstad is working with Prof. Michael Schlesinger, an atmospheric scientist at the University of Illinois, trying to use the instrumental record to better understand the learning process.

4. **The Political Economy of Deforestation** (Deacon). Some of the most pressing natural resource and environmental policy problems are found in the world’s poorest nations and in countries making the transition away from communism. These countries are often lack the democratic policy-making institutions found in western democracies, and this has been shown to cause deficient provision of environmental protection and other public services (Deacon 2001.) Governmental and legal institutions in the same countries often undergo frequent change. One result of this is that decisions regarding natural resource conservation and general investment discount returns that occur in the distant future too heavily. This has dramatic effects on forest cover and the rates at which nonrenewable resources are used (Deacon, 1994, Deacon 1999, Bohn and Deacon 2000).

5. **Clouds and Aerosols** (Gautier) - Prof. Catherine Gautier is involved in major programs aimed at better understanding climate processes such as cloud and aerosol radiative forcing, and large scale air-sea interactions. With 3-D radiative transfer models she investigates how clouds with complex geometries and cloud droplets distribution absorb solar radiation and develops parameterizations of these in climate models. She has developed unique neural nets satellite techniques to analyze satellite observations of global air-sea exchanges of heat and water and characterize their effects on the major modes of variability of the atmosphere-ocean system (e.g., Madden Julian Oscillation - MJO, El Niño Southern Oscillation - ENSO).

6. **Modeling Spatial Variations in Weather and Climate** (Michaelsen) – This research is directed toward developing reasonable techniques for blending measured data with statistical and physically based models to produce spatially distributed estimates of meteorological and climatological variables. Current projects include: mapping long-term average temperature and precipitation patterns in the Southwest for comparison with maps of species distributions; estimating spatially distributed daily precipitation fields in the Pacific Northwest to provide inputs for hydrologic and biological models; producing maps of spatial patterns of precipitation and drought in southern Africa for the Famine Early Warning System (FEWS).

**Opportunities in Climate for Environmental Economics**

Climate is one of the most fertile areas for collaboration between natural scientists and economists. The problem is so vast and complex that the opportunities are literally unbounded. One of the key unknowns in climate change is the extent of damage wrought by change and variability. This is a well-established area of environmental economics – measuring the demand for environmental goods and services. This is challenging because of the magnitude of structural...
changes that are anticipated from climate change. Variability is also an issue and even harder to measure. Another problem concerns surprises, non-marginal changes in the climate that are sudden and unexpected. Measuring damage is an enormously big area with a large number of fundamental economics questions.

Adaptation is another area of concern. How will individual economics agents (people, farmers, industry) respond to a change in the climate? To what extent can they adapt? How should public infrastructure respond? How will specific sectors respond? All of these questions require an understanding of economic forces as well as the natural science involved in the processes.

Another climate problem concerns how regulatory regimes might work. Will coalitions be effective? Will carbon leakage be a significant issue? How will permit trading work?

**Possible Dissertation Topics**

1. **Measuring Demand for Environmental Goods from Voluntary Provision.** One of the major problems in understanding the consequences of climate change is understanding the damage from that change (whether the change be in the mean temperature/precipitation or in weather variability). Demand estimation for environmental goods is an active area of research. However, revealed preference methods (ie, those methods which rely on observing how people act in real situations of choice) are woefully inadequate for dealing with most of the consequences of climate change. The other popular method for eliciting preferences, contingent valuation (ie, people are asked their value), is controversial and plagued by credibility associated with the hypothetical nature of choices. Nevertheless, it has the very real advantage of being applicable in a wide range of settings. This dissertation would seek to extend revealed preference methods by exploring the theoretical model of voluntary provision of public goods and applying it to instances where people have voluntarily contributed to climate-mitigation activities. The work would extend the economics literature, build understanding of climate policy, and draw heavily on climate science.

2. **Optimal Growth and Climate Dynamics.** One of the major problems of integrating realistic physical representations of the climate and representations of the economy is computational and scale-related. Climate models usually operate at a micro-scale, pushing computational limits. Economic models operate at a more macro scale but because they rely on optimizing behavior, the computational requirements are similarly high. This dissertation seeks to develop parsimonious reduced form representations of the climate process that can be integrated with economic processes. Furthermore, the research seeks to validate these reduced form representations by rigorous comparison with more complex representations of the physical processes in larger models.

3. **Learning About Climate.** Uncertainty is not easy to represent in economic models of climate change. Learning (changes in uncertainty) is even more difficult to represent. Learning can be of the underlying physical parameters (eg, climate sensitivity) or about economic components (eg, the rate of energy efficiency gain). This dissertation seeks to extend previous work by Kelly Kolstad (2000) to learning about other dimensions of the problem. Further, the work seeks to validate the model of learning using the instrument weather record.
Conservation Biology/Applied Ecology

The IGERT focus in conservation biology/applied ecology is led by Prof. Frank Davis, a biogeographer and ecologist. Other faculty include Profs. Bento, Costello, Kendall, McAusland, and Melack.

As population expands and nations become wealthier, the pressure on ecosystems intensifies as does popular demand for species protection and habitat provision. For example, the conflicts between land owners and the endangered species act are becoming more and more acute in many areas of the country. The conflict and then partial resolution of the problem of habitat provision for the coastal California Gnatcatcher is an example of how progress can be made when both the ecology and economic incentives are understood.

Bren School researchers are active in a number of dimensions of applied ecology. Frank Davis leads work on ecosystem management and terrestrial reserve selection and design. Bruce Kendall works on habitat fragmentation and endangered species management. Economists Bento and Costello work in the area of endangered species management and urban habitat fragmentation. Although the Bren School is very strong in this area, UCSB as a whole has even more significant strengths in applied ecology, reflected in the establishment here of the NSF-funded National Center for Ecological Analysis and Synthesis (NCEAS).

Current Research in Ecology by IGERT Faculty.

1. Regional reserve system selection and design (Davis) – This is the problem of identifying alternative sets of new reserve sites to most efficiently achieve ecological goals (such as species viability), while meeting economic constraints. It involves integrating ecological and economic data, information and models, and is solved with numerical algorithms (Davis 1995, Church et al. 1996, Davis et al. 1996, Davis et al. 1999).

2. Population viability analysis and conservation biology (Kendall, Davis) – This is the study of a rare species’ demography and ecology to evaluate whether the species is at risk of extinction, and to identify management activities that might reduce the extinction risk. This work uses demographic data to develop stochastic population models, which are then linked to the landscape of habitat quality.

3. Habitat fragmentation and urbanization (Bento, Kendall) – Given constant total habitat area, many species perform more poorly when the habitat is fragmented, leading to population declines and biodiversity loss. Urbanization is a leading cause of habitat fragmentation in southern California. This project examines the ecological consequences of various land-use planning instruments.

4. Cost effectiveness of endangered species management (Costello, Kendall) – Much conservation policy is implemented without regard to costs (e.g., the Endangered Species Act), yet budgets and political capital are limited. One issue involves identifying the management activities that are likely to have the greatest ecological benefit per dollar spent, using tools such as sensitivity analysis (Caswell 2001). Another examines strategies for efficiently acquiring land that has been identified for a reserve system (Ando, et al. 1998).
5. Adaptive Ecosystem management (Davis) – This is an increasingly popular and controversial approach to regional land planning that is supposed to integrate the best available science with the policy objectives of the various stakeholders; it also often espouses an experimental approach to management (“adaptive management”). Davis and his lab are involved in several ecosystem management initiatives in California (e.g., Davis and Storms 1996).

6. Optimal decisions under uncertainty (Costello, Kendall) – Projections that are used to guide environmental decision making are always uncertain, both because of incomplete knowledge about the important ecological and economic processes (Roughgarden and Smith, 1996) and because many extrinsic factors that affect the ecology and economy fluctuate unpredictably (Clark and Kirwood, 1986; Clarke and Reed, 1994). An important problem is finding a way to quantify that uncertainty in a way that is useful for decision makers (for a study of the value of information, see Costello et al., 1998); another is to find ways to reframe the problem that are less sensitive to the uncertainty.

7. Predicting and Mitigating Exotic Species Introductions (Costello, McAusland) Control of and damage arising from biological invasions by non-native species cost upward of one billion dollars a year in the US; less conservative estimates put the cost at over 130 billion annually (Perrings et al. 2000). Economic research in this area has focused on the cost-effectiveness of different measures for controlling invasions (Shogren et al., 1999). This project focuses instead on prevention, using a simple North-South model of trade in agricultural products. Preliminary results suggest that predictable changes in market structure, arising from advances in agricultural technology, will generate significantly higher rates of biological invasions in the future than have been observed so far.

Campus-wide Research Initiatives

There are several campus-wide research programs that are relevant to this IGERT, and which involve IGERT faculty. The most prominent is the National Center for Ecological Analysis and Synthesis (NCEAS; funded by NSF and State of California). NCEAS hosts postdocs, sabbatical visitors, workshops, and long-term working groups that study a wide variety of ecological issues. Many projects involve conservation biology and reserve design. This is a tremendous resource to IGERT because of the opportunities for students to interact with NCEAS scientists and participate in NCEAS activities. (See www.nceas.ucsb.edu.)

The NSF has also funded the Santa Barbara Channel Long-Term Ecological Research site (SBC-LTER), a project which examines the effects of natural and anthropogenic nutrient loading and pollution of Central California Coast watersheds on the ecology of nearshore marine communities. The EPA has funded the Western Center for Estuarine Ecosystem Indicator Research, for developing measures of the ecological health of California estuaries, using properties of individual organisms, biological populations and communities, and nutrient flux and storage.

Opportunities in Ecology for Environmental Economics.

Economic activity often has ecological consequences. Ecological change (whether anthropogenic in origin or not) has economic implications. As each discipline increases in sophistication, the danger of proceeding with the status quo (i.e. of non-integration) becomes more apparent. Although economics is defined as the study of the allocation of scarce resources, the field has only recently seen substantial improvements in its realistic application to ecological problems. Although mathematically satisfying, many economic models applied to ecological resources contain
little or no basis in reality. Such models can lead to inaccurate predictions and inefficient allocation of resources – provided the resource manager pays credence to the predictions. Of course, resource managers, whose job is to be grounded in reality, accept results of such exercises with little credibility.

Similarly, ecological models that do not address economic sources of ecological change, or do not address economic feedbacks are not instructive for policy in a human-dominated world. Environmental policy that does not consider economic costs and benefits (as the Endangered Species Act) may lead to policy instruments that are economically inefficient and biologically ineffective. Finally, ecologists have been ineffective at predicting the ways that organisms innovate in response to environmental change, and hence often make unreliable predictions.

Potential gains from integrating a rigorous training in both ecology and economics are substantial. Conceptual and practical formalisms that realistically link social and biological processes are instructive both for applications and development of new theory in each discipline. From the ecologist’s point of view, integrating sound economic reasoning into analyses allows them to move from “descriptive” research to “prescriptive” policy analysis and recommendation of optimal policies. From the economist’s point of view, integration establishes the elusive link between “the real world” and over-simplified, though analytically satisfying models. This facilitates more accurate predictions and, true to the economist’s mission, enhances efficiency.

Perhaps the most striking benefit from integrating these two disciplines in a systematic, meaningful way is the ability for these scientists to appropriately address dynamic feedbacks to/from the ecological/economic system. A thorough understanding of ecological and economic drivers of a system will allow better predictions, more accurate assessment of what is happening, why it is happening, and what can be done about it. Finally, ecology and economics have always benefited from an exchange of theoretical perspectives, and the payoffs from sharing the latest advances in both fields may be high.

From the perspective of policy, an integrated approach, which is certainly more grounded in reality, will be taken more seriously by policy-makers, and therefore has a greater impact. But integration can also be the catalyst for theoretical advances in both fields (and indeed in the emerging cross-disciplinary field. To the extent that ecological-economic systems are, and will always be linked, new theory can be developed with general implications. Economic theory prides itself in its ability to deal with the allocation of scarce resources. Renewable resource models consistently oversimplify biological/ecological environment. Ecology has borrowed extensively from economic theory. But there have been few attempts to link the two “currencies” – reproductive fitness and dollars. Developing this link may lead to innovations in our understanding of the interactions between the human and natural worlds.

**Potential Dissertation Topics.**

**Efficiency in reserve site selection** – Humans care about species viability for both consumptive use (harvest) and passive-use values (ecological services, indicators of ecosystem health, recreation). Importantly, there exist economic pressures to develop land – urbanization, agriculture, forestry – or at the very least, there is some opportunity cost to preserving habitat in its natural state. This suggests that to conserve species, we must protect habitat. The questions of what parcels to protect, how to acquire them, how to link parcel protection with species survival, and how to deal with uncertain ecological and economic values must all be approached from an integrated perspective. Ecological theory has a great deal to say about things like: size, shape, connectivity, and habitat quality. But because land is a scarce resource, there are opportunity costs of development (see above). So, on a simple level, this is a constrained optimization problem which may look like: (1)
choose parcels to minimize cost subject to a given probability of survival; or (2) choose parcels to maximize the probability of survival given a budget. A pragmatic extension is: multiple species – given a fixed budget, how should one trade-off between viability of several species when their habitat needs are different? Some theoretical extensions include: (1) How should ecological uncertainty (i.e. the link between viability and habitat conserved) be accounted for in reserve selection? (2) If reserve sites are purchased sequentially, how should selection proceed?, (3) What is the role of economic uncertainty about future value of the land?

**Regulatory incentives to mitigate adverse consequences of urbanization** Many growing communities in the U.S. face a question of choice of alternative policies to control for the ecological externalities associated with urban sprawl. This project would provide a rigorous analysis (qualitative and empirically quantitative) of the ecological consequences associated with popular anti-sprawl policies.

**An economic approach to managing exotic species introductions** - The ability of exotic species to disrupt, and even derail functioning ecosystems is widely recognized by ecologists. To a large extent the problem of exotic species introductions is driven by economic activity – and international trade in agricultural products is thought to be responsible for most adverse exotic species introductions. Important theoretical and policy questions that can be most accurately answered in a multi-disciplinary framework include: (1) Given current and predicted economic trade patterns, what are the implications for the frequency and severity of exotic species introductions?, (2) How will patterns of trade and corresponding exotic species introductions change with changes in the economic structure (e.g. with changes in production technology) of the agricultural industry?, (3) What will be the effect of liberalized trade on exotic species introductions?, and (4) What economic incentives or trade policies can help mitigate the deleterious consequences of exotic species introductions?

**Hydrology/Water Resources.**

This focus area will be led by Prof. Tom Dunne, a surface hydrologist. Other faculty include Profs. Costello, Dozier, and Melack. The Bren School's excellence in hydrology, aquatic biology, and remote sensing has led to the award of two of NASA's prestigious EOS interdisciplinary science investigations.

Water resources is one of the areas particularly ripe for multidisciplinary integration with economics. In fact, there is a significant tradition in water resource economics. Surface waters are of tremendous importance in arid areas of the world, including California. Understanding how supply and demand are formed and interact with physical process naturally brings natural scientists together with economists. Groundwater is also an important source of water but also an important concern associated with hazardous wastes, such as Superfund sites. All global and national assessments of pressing environmental problems emphasize the significance of secure quantities of clean water to human societies and the rest of the biosphere.

Water resources research in the Bren School incorporates a broad range of concerns, including land-use effects on hydrology and wetland biogeochemistry in the Amazon Basin and erosion and sedimentation in the Andes of Bolivia, as well as the hydrology, water quality, and aquatic ecosystem functioning of the major inhabited lowlands of California. Faculty in this research focus lead interdisciplinary investigations, using a variety of innovative techniques in field investigation, remote sensing, and spatial data handling. Their work covers a wide range of Earth
environments and links strongly to work by other campus scientists who assist with the supervision of students

**Current Research in Hydrology by IGERT Faculty.**

In the paragraphs that follow, we describe four major projects underway in the Bren School. Each of these water resources investigations has significant policy implications for the management of water supply and quality, and the restoration of aquatic and riparian resources. Because of these policy dimensions, there are numerous opportunities for environmental and resource economics dissertations to be developed in association with these research thrusts.

1. **Sierra Nevada.** (Dozier and Melack) A long-running concern of the Bren faculty has been studies of the Sierra Nevada snow pack --- the major water resource in California. The economic significance to California water users will be immense. Jeff Dozier and John Melack use satellite- and aircraft-based remote sensing techniques to study of seasonal snow in Earth’s mountain ranges, concentrating on the Sierra Nevada. They measure the snow’s spatial extent (Rosenthal and Dozier, 1996) and water content (Shi and Dozier, 1997), and then use those measurements to drive spatially distributed hydrologic and hydrochemical models (Cline et al., 1998). The work also involves field and modeling studies of the process by which acidity, concentrated in the snowpack by atmospheric deposition, is flushed into oligotrophic mountain streams during snowmelt (Harrington and Bales, 1998).

2. **Amazon River Basin.** (Dunne, Melack). Prof. Thomas Dunne’s research group studies the routing of water, sediment, and chemicals through landscapes at a variety of scales from hillslopes to large river basins. The work is conducted in the Amazon River basin (funded by NSF and NASA), New Mexico, and the Central Valley of California. In the Amazon, this group collaborates with Melack’s group to use various remote sensing techniques in the study of wetland inundation. Individual components of the study include: analysis of how regional-scale climatic forcing and the routing and storage of water in channel networks and floodplains controls the behavior of large rivers; exchange of sediment between the Amazon River and its floodplain; how hydrogeologic properties of river basins and land use affect the flow and chemistry of rivers in deforested regions; and how deforestation affects water flow paths at the scale of individual hillslopes.

3. **Coastal Contamination from Runoff.** (Melack, Keller, Holden, Dunne). A Bren School group, led by Melack, holds funding from the Long Term Ecological Research initiative at NSF for a study of the loading of nutrients and chemical and bacterial contaminants from urban and rural catchments along the central California coast into the Santa Barbara Channel. This investigation was partly motivated by coast-wide concern about the contamination of beach and marine ecosystems by stormwater from urban and other disturbed environments. Major policy decisions concerning this problem are currently being faced by the State and local governments.

4. **Fluvial Geomorphology in the Western U.S.** (Dunne) Prof. Dunne’s group also studies sediment transport and sedimentation along river valleys. Their investigations include the transport of radioactive materials from the Los Alamos National Laboratory, as a part of broader studies of the exposure of humans to radioactivity in downstream areas. In California, the group studies sedimentation along the Sacramento River. They are examining the response of sediment transport along the channel and into the floodplain to policies proposed by Calfed: manipulation of streamflows; augmentation of sediment supplies; and removal of structural constraints on the channel position. These proposed actions are part of the Calfed plans to improve water quality statewide,
make water deliveries more reliable for farmers and cities, and protect the fragile Sacramento-San Joaquin Delta and San Francisco Bay.

**Opportunities in Hydrology for Environmental Economics**

Each of the water resources investigations described above has significant policy implications for the management of water supply and quality, and the restoration of aquatic and riparian resources, and is associated with some large Statewide initiative. There is ample opportunity for analyses of economics, risk, and other aspects of policy to be connected to ongoing projects, and others that will undoubtedly arise within the Bren School in the near future.

Furthermore, the economics of water resources has been a central issue for environmental economists for decades. Supply and demand for water involve deep economic issues. Furthermore, pricing of water (with significant fixed costs, low marginal costs) is a major economics issue. Market mechanisms for dealing with stochastic supply and interbasin transfers are also of central concern to water resource economists.

Because of the breadth of economics issues associated with water and the importance of hydrologic (physical) dimensions of the problem, this is a natural and fertile area for specialization within the IGERT-funded Ph.D. program.

**Possible Dissertation Topics**

**Salmon Habitat Management with Stochastic Sediment Transport.** A significant issue for many concerns the management of anadromous fish (e.g. salmon and steelhead trout) in waterways significantly interrupted by dams. The economics of these fisheries is complicated not only by the presence of dams, interrupting spawning and migration of juveniles, but by the changed nature of sedimentation and sediment transport, brought on by dams and altered land-use patterns. Developing ecologically realistic but economically tractable models of these fisheries is the subject of this dissertation.

**Natural Monopoly in Deregulating Water Supply in California.** Electricity receives the most attention these days, in the context of deregulation. Yet it is important to remember that electricity deregulation in the US was spurred by deregulation in the U.K. The U.K. has also vigorously pursued deregulation of local water supply. There are many dimensions of this issue that have yet to be explored in other contexts. For instance, what aspects of water supply are natural monopolies and what aspects might be deregulated? How will deregulation deal with the stochastic nature of snowfall and thus water supply, other than letting prices clear the market in a politically unworkable manner?

**Marine Science**

The Marine Science focus area is led by Prof. David Siegel, a physical oceanographer in the Bren School. Other associated faculty include Profs. Costello, Kendall and Mahowald.

From fisheries to coastal zone management to sequestration strategies for the global carbon cycle, marine issues are vitally important to the nation and the world. Furthermore, as these topics suggest, marine policy usually involves substantial economic and natural science dimensions.

Marine Science is a broad subject including both oceanography and marine biology. Marine Science is an extremely strong campus-wide program at UCSB as exemplified by the UCSB interdepartmental PhD program in marine science (with nearly 40 active faculty members). It is a natural focus area for this IGERT program in environmental economics.
Current Marine Research by IGERT Faculty

1. The role of climate uncertainty in fishery management (Costello) – Climate variations affect the growth of fish stocks (Barber and Chavez, 1983; Johnson, 1988). Examples include the collapse of the Peruvian anchovetta fishery in 1972 and the collapse of the coho salmon fishery in the Pacific Northwest – both attributed, in part, to El Nino. This raises many important ecological questions about the susceptibility of various fish stocks at different points in their life-history, as well as the obvious economic implications for management. The implementation and value of climate forecasts can be assessed in a bioeconomic framework (Costello, Adams, Polasky, 1998; Costello, Polasky, Solow, 2001).

2. The effect of industry influence on fishery regulators (Costello) – Fishery regulation is seen as a possible remedy to the externality of entry, which eventually leads to zero profits and depressed fish stocks (Homans and Wilen, 1997). However, many regulated fisheries have collapsed. It has been suggested that industry participants can exert significant influence over fishery regulators (Karpoff, 1987, Johnson and Libecap, 1982). This research explores, in a political economy framework, the likely management tools utilized, and resulting bio-economic impacts of industry influence over fishery managers.

3. Watershed-Ocean Coupling in the Kelp Forests (Siegel, Kendall and others) – Researching the roles of watershed and ocean processes on the kelp forest ecosystem and its trophic dynamics in the Santa Barbara Channel. There is little knowledge of the interaction of watershed processes in semi-arid biomes with coastal ocean resources. This project is an interdisciplinary collaboration of 21 UCSB faculty and is part of the NSF sponsored Long Term Ecological Research (LTER) program. It is in the first year of at least 6 years of NSF support.

4. Design and Monitoring of Marine Reserves (Siegel and Kendall) – A federal-state process is underway to design a system of no-take marine reserves within the Channel Islands National Marine Sanctuary. Marine reserves are becoming a popular way of regulating fisheries. For example, the Ocean Studies Board of the National Academy has just completed an analysis of marine reserves (NRC, 2001) and President Clinton recently ordered their consideration for resource management in the National Marine Sanctuary system (Executive Order 13158, May 26, 2000). Bren faculty are working in support of this activity. In addition, Siegel and Kendall are working on understanding the role of temporal change in the marine environment on the designation of a marine reserve.

5. Iron Deposition and Ocean Biogeochemistry (Siegel and Mahowald) – It is thought that productivity for large regions of the ocean are limited by the supply of iron from the atmosphere and that may have a role in climate change on centennial to paleo time scales. For example, John Martin said in 1989 “if you give me a tanker of iron ore, I’ll give you an ice age” (Martin, 1990). Investigators at the Bren School are studying the role of atmospheric iron deposition on ocean biogeochemistry and specifically its controls on global rates of nitrogen fixation and implications for the carbon budget. This work is supported by the NSF Biocomplexity initiative and is in its first year of five years of support. The results of this work has an important bearing on mitigation strategies for anthropogenic carbon emissions by ocean fertilization.

Campus-wide Research Initiatives

UCSB is the ideal place to establish meaningful connections between marine science and environmental and resource economics. A huge variety of local projects ranging from the Santa
Barbara Channel LTER project, fishery recruitment studies performed by the Packard Foundation supported PISCO program, coastal ocean remote sensing projects (Plumes and Blooms) to the oil spill mitigation work supported by the Mineral Management Services. Hence, UCSB is a rich and highly interdisciplinary marine science research environment.

IGERT-participants also have significant ties and access to important global resources which will enhance the success and impact of this cross-disciplinary endeavor. Noteworthy global resources including the the U.S. ocean carbon program (JGOFS), joint appointments at several institutions (WHOI and the Bermuda Biological station, etc.). Finally, interdepartmental collaboration is expected to be highly productive. One likely collaborator is the Marine Sciences Program at UCSB, one of the most highly active interdisciplinary marine science programs in the country.

**Opportunities in Marine Science for Environmental Economics:**

From fisheries to coastal zone management to sequestration strategies for the global carbon cycle, a wide variety of contemporary marine resource issues have economic ramifications. However, multidisciplinary marine problems are often narrowly approached from the perspective of the investigator’s field of expertise, omitting a serious consideration of the effect of (or on) economics. Because it is difficult to generalize the deficiencies of this typical narrow approach, we illustrate the importance of approaching such marine resource issues from a perspective of expertise in both fields with the following example.

The design of marine reserves provides an example that is typically approached in two dramatically different ways by marine scientists and environmental economists. From a marine science perspective, marine reserves are set to achieve several objectives including maintenance of biodiversity and the sustainability of a fishery. The factors taken into consideration include ecological data such as primary production, dispersal of juveniles and adults, growth rates and age-structure of the species of interest and its interaction with the rest of the community. Although human harvest is considered by the marine scientist, it is typically assumed to be an exogenous factor. Thus, the marine scientist ignores the endogeneity of the economic agent’s activity.

Similarly, the environmental economist approaches the problem of optimal marine reserve design from the perspective of maximizing net gains to society. Focused on economic efficiency, the economist acknowledges ecological constraints, but is likely unaware of important biological and physical realities. Therefore, he conducts a clean analysis of optimal reserve design, mistakenly believing he has captured the essential features of the marine environment in a simple model.

Our goal for the IGERT program is to train and equip the next generation of marine and resource scientists and marine economists – both of which have garnered expertise in both the marine sciences and marine economics. The necessary linkages and endogeneities between marine science and marine economics will not only be recognized by these individuals, but they will have the tools required to engage complex and important problems in marine resource management.

**Possible Dissertation Topics**

The research activities in marine economics to be conducted within the IGERT may be best explained using a few example thesis topics. These are meant to show the breadth required of students and the importance of the questions that students could work on.

**Fisheries, Climate and Choice** The object here would be to understand the interactions among ecological, economic, social and regulatory processes in a multi-species regional fishery. For
example, fishermen choose their target species based upon a variety of factors. These factors include (but are surely not limited to) availability of the fish, prior knowledge of where/how to fish for a given species, the market, the need for specialized equipment, distance from port, price of fuel, the regulatory framework and the notion that the fisherman is known to his peers and clients as a "halibut" (or whatever) fisherman. Hence, choice is not only an industry-wide decision, but one made by individual fishermen. The problem is spatial as different species may be found in different habitats and temporal in that climate strongly influences the fecundity and recruitment of many marine fish species. Bringing this together is the need for an accounting of uncertainty on the choices made by individual fisherman. This uncertainty arises from the assessment of the fish stock on the management employed, the recruitment of juveniles to adults, and the role of climate and the market on all of this.

**Marine Reserves as a Conservation Tool.** No-take marine reserves are increasingly becoming popular conservation tools for protecting coastal ecosystems and sustaining fisheries. President Clinton ordered their consideration for resources in the National Marine Sanctuary system. Simple ecological models show equivalence between the fractional set aside for a marine reserve and overall reduced levels of overall fishing mortality. However, these models do not even attempt to deal with the factors of economic endogeneity. That is, closing one area may restrict supply locally, raise prices, and make it more profitable for fishermen to expand to other areas. One key point is that the designation of a marine reserve in one area may essentially (given political economy) give free reign to increased fishing mortality outside of the reserve. Further, marine reserves may account for some species (particularly sessile one), but will be nearly useless for fish with pelagic life histories. This is especially true as many economically valued species have long stages where juveniles are in the plankton and are dispersed at the whim of ocean processes. The analysis of marine reserves as a management requires information, data, and models from fishery ecology, economics and oceanography.

**Iron Fertilization and Ocean Carbon Sequestration Strategies.** Marine scientists have long debated the efficiency and ethics of ocean carbon sequestration by means of iron fertilization. There are large regions of the ocean that have been identified as iron stressed and the increased production and carbon assimilation due to a fertilization program is thought (by some) to be a reasonable approach to mitigating anthropogenic carbon emissions. In fact, several start-up companies are posed to implement ocean fertilization as a carbon mitigation strategy and plan to provide their investors credits against their emissions. There is a huge degree of uncertainty to what degree ocean fertilization will actually mitigate the atmospheric CO$_2$ burden. In particular, practically nothing is known about the long-term impact to marine ecosystems and the biogeochemical cycling of other nutrients. Further as atmospheric transport is the natural source of dust to much of the oceans, it is unclear how land use change (the development of marginal agriculture in the Sahel and Gobi). The marine economic issue deals in the use of the commons and an accounting of uncertainty. Research can also be conducted to develop economic instruments that limit the degree to which ocean fertilization as a carbon mitigation strategy.

**Coastal Contamination.** For most coastal environments, it is becoming clear that stormwater runoff is a major source of anthropogenic inputs into the coastal ocean. This includes pollutants (ranging from pesticides to plastic grocery bags), sediments from improperly controlled land development and viral and bacterial contamination from both natural and human sources. In Southern California region, bacterial contamination has become a major issue in terms of coastal water quality. Insofar as economic activity is driving the availability of such contaminants to the ecosystem, the source of the
problem, and indeed potential policies aimed at mitigating this important problem, are economic in nature. However, without a sound understanding of the biological and physical marine processes governing damages to marine resources, economics can provide little guidance to policy-makers. Another dimension of the problem is the direct economic loss – mostly in lost recreation benefits – from coastal contamination.

**Environmental Economics**

UCSB is recognized as one of the world's leading universities in the field of environmental and resource economics and, as a result, attracts numerous students and visiting scholars from around the world. The leading journal in the field (*Journal of Environmental Economics and Management*) has been edited here (by Prof. Deacon) for the last five years. One of the other leading field journals, *Resource and Energy Economics* is also edited here (by Prof. Kolstad). Furthermore, the PI is currently president of the leading international professional association of environmental and resource economists (AERE).

A number of faculty are involved in environmental economics research at UCSB, including Profs. Bento, Costello, Deacon, Kolstad, McAusland and Shapiro. Other closely related faculty include Profs. Aigner (econometrics) and Bergstrom (public economics). Other faculty have closely related interests but have not been included in this proposal; they would nevertheless be a significant resource for IGERT students.

Most of the environmental and resource economics research done at UCSB is described in one of the four applications-oriented parts of this section (above). However, other work is cross-cutting and warrants emphasis. Some existing research projects are described below.

1. **Eco-Labeling** (McAusland, Delmas) Eco-labels are hailed as a means for consumers to differentiate between goods produced using clean and dirty methods of production (Mattoo and Singh, 1994; Rege 2000), and they have been used to settle controversial issues brought before the WTO such as the Mexico, US Dolphin-Tuna dispute. However several countries have complained to the WTO that application of labeling criteria may be discriminatory and unfairly bias consumers. This research examines the incentives for third party labeling organizations—-which may care exclusively for the quality of the global environment—-to nonetheless discriminate against certain producers even though their environmental performance is no worse; this discrimination may take the form either of differential labeling costs or outright exclusion from the market.

2. **Political Economy as a Basis for Trade** (McAusland) Traditional economic theory proposes that countries trade with one another either to gain indirect access to surplus supplies of land and labor, or to capture profits from less than fully competitive overseas markets. This work focuses on variation across countries in their political and institutional structures that form a third basis for trade. For example, when proportional representation is used in the election of governments, supporters of green industrial policy have a stronger voice than they would in a winner-takes-all political system. Other things equal, a country with proportional representation would then choose stricter environmental policy and import instead of export pollution intensive goods. This paper examines institutional differences that are likely to generate such "institution based" trade and the types of trade disputes that will arise concerning it.

3. **Land Use, Transportation and the Spatial Configuration of Metropolitan Areas** (Bento) - The main focus of this research program is to develop discrete choice models with instrumental variables that accommodate geographical information systems data. This methodology is being applied to...
study the impact of the spatial configuration of metropolitan areas on auto dependence. This methodology will also be applied to study: (a) the patterns of land use development; and (b) the competition among local governments in setting policies to regulate land use externalities.

4. The Value of Visibility in Coordination Games (McAusland, Shapiro) Numerous resource and environmental problems are transboundary in nature and compliance with international agreements regarding their management is often difficult to monitor. This difficulty in monitoring raises the expected payoffs to contracting parties who cheat on their obligations, reducing the likelihood that agreements will be reached in the first place (Shapiro and Pechey 1997). This work investigates the value of substituting more visible, but less cost efficient, means of compliance in a two stage game when there is a stochastic component to the environmental outcome and when players have imperfect information on the payoff functions of their opponents.

5. Trade and the Laxity of Environmental Regulations (Kolstad) This work confronts the concern that free trade will lead to a “race to the bottom” – a tendency for polluting industry to flee to countries with weaker environmental regulations. If this occurs that removing trade barriers, through free-trade zones or GATT-type agreements, will have the effect of exacerbating environmental degradation. Somewhat surprisingly however, the empirical literature has been unable to measure this effect. The work by Kolstad seeks to use more sensitive measures, focusing on foreign direct investment, to measure such effects. Preliminary results suggest that the effect exists though it is weak. (Xing and Kolstad, 2000).

6. Environmental Federalism (Shapiro). As the European Union moves to a federal system, as the US seeks to strengthen its environmental protection, a fundamental issue is at what level should environmental regulation apply: local, state or federal? The focus of the research is the ability of autonomous, sovereign states to manage policies that involve significant interjurisdictional externalities (Hoel and Shapiro, 2000). When there is an overarching central benevolent fully informed central government, there is no problem; but sovereign states do not necessarily adhere to the pronouncements of a central government. Recognizing this, we ask what policies and political mechanisms are best in a world in which each state is seeking its own interest (Dasgupta et al, 1997; Hoel, 1999; Barrett, 1994).

7. Cost Effectiveness of Environmental Regulatory Policies (Bento) - The main focus of this research program is the development of analytical and numerically solved general equilibrium models to analyze the welfare effects of new policy interventions in the presence of pre-existing distorted markets. This methodology has been applied to study the cost-effectiveness of alternative environmental policy instruments and the cost effectiveness of alternative transportation policies. The same methodology will be applied to analyze the efficiency of environmental policies in the context of developing countries and study the efficiency of alternative policies to reduce externalities associated with Urban Sprawl.
C.d. EDUCATION AND TRAINING

The IGERT PhD program is unique in its requirements. The goal is to build strength in economics and a complementary natural science area so that dissertation research can be truly innovative and multidisciplinary. In addition to the standard coursework and research normally expected in Ph.D. programs, the IGERT program is designed to provide an appreciation and understanding of real-world research problems, to infuse an understanding of ethical dimensions of scientific research and practice, and to position students to take on leadership roles when they leave the program. Requirements are greater than in a standard disciplinary department; however IGERT support relieves students of relying on teaching assistantship support, allowing them to take a heavier load.

We expect to admit two types of students: those with a natural science undergraduate degree and little economics preparation and those with significant economics preparation but weak natural science preparation. We expect the majority to be in the first category, primarily based on our experience with our professional Masters degree. We expect that most students will matriculate in the Bren School of Environmental Science and Management. A few students, those with undergraduate preparation in economics, may choose to enter the Economics Department Ph.D. program. In either case, the requirements for IGERT-supported students will be the same.

The IGERT-supported doctoral degree will involve the normal Bren School requirements for the Ph.D. plus some special elements. The IGERT program will include required curriculum that exposes all participating students to multiple perspectives on environmental issues. The student will receive strong course-oriented preparation in both economics and a chosen complementary area of natural science. Internships and group project mentorship will help build leadership and research management skills. Workshops in environmental policy, economics and natural science will connect students to the world of environmental policy and the research community in environmental science and management. The dissertation will position the student as one of a new generation of environmental economists: highly trained research economists who are equally at home in environmental natural science.

Requirements Summary

The basic requirements for the IGERT-supported PhD are coursework (in economics, natural science and research ethics), several seminar series, an optional internship, a leadership role in a Masters group project, an empirical research paper and the dissertation.

The coursework requirements for the IGERT-supported PhD are almost exactly the requirements of UCSB’s Economics Department Ph.D., plus a set of core courses in the student’s chosen complementary field of natural science and a course in research ethics. There may also be preparation deficiencies to cure. Coursework should occupy students full time during the first two years of the program. In the third year, students will register for an additional three elective courses, probably in the natural sciences, but not necessarily. During the first summer, students are encouraged to pursue an internship outside of academia. Incentives are structured to make an internship very attractive to students.

Starting in the spring of their second year, students will be required to associate with one of the Bren School Masters program group projects. Each PhD student will be expected to take a leadership role in the group project, as well as carving out a smaller research topic to develop into a research paper.
During the third year of the program, students will be expected to complete a research paper, preferably empirical, to demonstrate ability in research. This would likely emerge from the group project experience but need not.

Starting the second year, students will be expected to enroll in a seminar in environmental policy. Starting in their third year, students will be expected to begin two workshops, one in environmental economics and one in their chosen natural science complementary field. These seminars and workshops will involve only modest time commitments; thus three concurrent seminars/workshops should not be a burden. The seminars are a vital part of the research portion of the IGERT program. They are important in helping students identify research problems and to learn where their interests fit into a broader context.

Student performance will be monitored through several channels. At the end of their first year, students must pass a preliminary examination in microeconomics and econometrics. During their third year, students must successfully develop a research paper. By the end of their third year, students must develop and defend a research proposal. By the end of their fifth year, the nominal time for completion, students must defend their dissertation. Additionally each student will be assigned a faculty advisory committee and that committee will review progress on an annual basis and make recommendations to the Bren School faculty who will have ultimate say on whether the student should continue in the program.

The schedule of activities is summarized in Table I. Nominal time is indicated as five years though we would expect to see a number of students take six years, the nominal time for completion of a Ph.D. in the Bren School. The Bren School and the Economics Department have teaching assistantships available to assist IGERT students in a sixth year.

**Coursework in Economics**

Coursework in the first year will be devoted almost entirely to a rigorous graduate sequence in economics. This will include the two-quarter masters sequence in applied microeconomics (205AB). The course is an advanced intermediate microeconomics course, emphasizing policy applications. This is not normally required of Economics Ph.D. students but is an excellent introduction to economic intuition that will be most valuable for students with weak undergraduate preparation in the area, which is expected to be the case for most IGERT students. Students with strong economics preparation will choose to substitute two electives for this sequence, probably to cure deficiencies in natural science preparation. All students will take four quarters of Ph.D.-level microeconomic theory (at the level of Mas-Colell et al), two quarters of macroeconomic theory and three quarters of econometrics. This is eleven courses which at a load of four courses a quarter leaves one opening for an elective.

Coursework in the second year shifts to more of a balance between economics and natural science. Students will be expected to take six quarters of coursework in their chosen cognate natural science field plus three quarters of environmental and resource economics, constituting the field (externality and public goods theory; renewable/nonrenewable resources; pollution regulation and environmental valuation).

The economics coursework requirement for IGERT-funded students is fulfilled by the completion of the two or three courses required to qualify in one additional field of economics, most likely public economics, industrial organization or experimental economics. Other possible fields include macroeconomics, game theory, computational economics, mathematical economics, money...
and finance, econometrics, dynamic optimization, labor and international trade. This is a total of 5-6 electives in economics, almost the same requirements as for a Ph.D. in economics at UCSB.²

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<th>Table I: Typical IGERT Student Schedule</th>
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Note: Courses are typically 3-4 units of credit; workshops are typically 1 unit of credit. A full load for fellowship students is 15-20 units; for students with other obligations such as teaching or research assistantships, a full load is 12-15 units.

**Coursework in Natural Science.**

Students are admitted with a focus in one of four natural science cognate areas: hydrology/water resources, climate, conservation biology/applied ecology and marine science. Students are expected to acquire a deep level of knowledge of their chosen cognate area. Specific course requirements will depend on the undergraduate training of the individual student. Generally speaking, students would be expected to have a preparation at least at the level of the three Bren Masters level courses in Earth System Science (ESM 201), Biogeochemistry (ESM 202) and Applied Ecology (ESM 203). It is likely most students would have this preparation but some may have to remedy deficiencies. Which of these courses would be considered necessary preparation depends on which focus area is chosen. This will be determined individually, in consultation with the student's advisory committee. Coursework in each of the four natural science focus areas is described below.

² The UCSB Economics Department Ph.D. requirements are for the same core classes as in the IGERT program plus completion of two fields in economics, also a requirement of the IGERT program. However, the Economics Department requires 8 elective courses, including those taken as part of the fields; the IGERT program requires 5-6 electives, taken as part of the two required fields.
**Marine Science.** In marine science, students would be expected to have a preparation at least at the level of the the three Bren Masters level courses in Earth System Science (ESM 203), Biogeochemistry (ESM 202) and Ecological Principles (ESM 201). Assuming that to be the case, students would take a total of seven courses in the field, five of which would be core courses: Biological Oceanography (EEMB 243), Geological Oceanography (Geol 276), Chemical Oceanography (Geol 266), Introduction to Physical Oceanography (Geog 263), and Marine Processes & Resources (ESM 258). Students would then choose to focus on one dimension of marine science, taking three electives from the following list: Applied Population Ecology (ESM 211), Environmental Microbiology (ESM 219), Fate and Transport of Pollutants in the Environment (ESM 222), Introduction to Atmospheric Science (ESM 229), Remote sensing of Environment (ESM 266), Phycology (EEMB 234), Biological Oceanography (EEMB 243), Marine Microbiology (EEMB 244), Photosynthesis and Primary Production (EEMB 250), Ocean Optics (Geog 261), Upper Ocean Physical Processes (Geog 262), Tropical Meteorology (Geog 233), El Niño: Atmosphere Ocean Interactions (Geog 237), Nearshore Processes (MEE 286).

**Conservation Biology/Applied Ecology.** In conservation biology/applied ecology, students should understand processes affecting individuals, populations, communities, landscapes and ecosystems, and how the interactions of these processes depend on spatial and temporal scale. Students without an ecology background should start with Ecological Principles, a graduate-level introduction to applied ecology in the Bren School (ESM 201). Following this, students will take a three-course sequence of graduate courses in Applied Population Ecology (ESM 211), Landscape Ecology (ESM 215), and Ecosystem Processes (EEMB 271). Students will then select 2-4 electives to develop a further expertise in an area of conservation biology/applied ecology, such as Conservation Biology (ESM 216), Restoration Ecology (ESM 217), Conservation Planning (ESM 270), Environmental Microbiology (ESM 219), Ecology of Running Waters (EEMB 248), Ecological Modeling (EEMB 279), or Biodiversity Inventory and Ecological Assessment (ESM 212).

**Hydrology/Water Resources.** In hydrology/water resources, students should know basic hydrology of surface and ground waters. A set of 6-8 courses should establish a good grounding in the area. Students in this specialization would be expected to take four courses: Watershed Analysis (ESM 235), River Systems (ESM 234), Groundwater Hydrology (Geog 116) and Advanced Hydrologic Modelling (Geog 246). Students should further choose 2-4 elective courses: Water Pollution (Geog 162), The Mountain Snowpack (ESM 236), Dynamic Meteorology (Geog 262), and Water Resource Systems Planning (Geog 208).

**Climate.** In climate, students should understand the climate processes from the short time scales of meteorology to longer-term climate change. Students should have taken the equivalent of Earth System Science (ESM 203); if not, that deficiency should first be remedies. Students would then be expected to take seven courses, including a core three quarter sequence: Environmental Modeling (ESM 205), Atmospheric Science (ESM 229) and Global Climate and Climate Change (ESM 231). An additional four elective courses would be selected from Dynamic Meteorology (Geog 269), Atmospheric Chemistry (ESM 230), Energy and Radiation (Geog 248), Physical Oceanography (Geog 263), The Mountain Snowpack (ESM 236), Time Series Analysis (Geog 276B), Seminar in Climatology (Geog 268), and Management of Scientific Data (ESM 261).
Coursework in Ethics and Research Practice

An important component of a Ph.D. program, unfortunately missing from most, is training in ethical dimensions of the conduct and application of research. Responsible conduct of research relies in large part on the honesty and ethical strength of the researcher. In the area of environmental economics, where many of the graduates will be applying their knowledge in litigation or regulatory contexts, it is also important to indicate why one should stick to principles and not be seduced to generate justifications for the positions taken by superiors.

In the third year of the program, IGERT-funded students will be required to take a one-quarter course in “Ethics of Research Practice.” This will consist of a series of speakers from the outside world, practicing natural scientists and economists, who will discuss the opportunities for unethical behavior and the advantages of taking the high road. This will be a new course.

Teamwork, Leadership and Management

It is important that students gain an appreciation for the real-world practical uses for their research, as well as the real-world problems that motivate research. This is all too often lacking from conventional Ph.D. programs. It is also important that students understand how to manage and take leadership roles in research projects. Fortunately, the Bren School has aspects of its professional Masters program that can dovetail nicely with the proposed IGERT-funded Ph.D. program: the short course in Project Management, the group project and the internship.

Project Management Course. The Bren School offers all Masters students a short, intensive course in project management. This is offered over two weekends during the year. It is intended to prepare Masters students for managing real-world research projects, including their group project. We propose to require that all IGERT-funded Ph.D. students take this course during their second year.

Group Project. A central aspect of the Masters program is a one year group project, commencing in the Spring of the first year for the Masters students. This is in lieu of the Masters thesis. Every year nearly a dozen projects are initiated.

The Bren School developed the group project in direct response to prospective employer requests that graduates possess “real world” skills. Employers have expressed interest in the ability of graduates to work successfully and communicate as part of a team and manage a professional project. Typically, the group projects are sponsored by an external agency with an environmental “problem” - some management or policy decision is needed. Students work in groups of 3-6 as a team, with 1-2 faculty advisors, initially generating a statement of work, a work plan, project objectives and then executing the project, delivering a final report and final oral presentation. Some recent group project titles:

- Assessing the effectiveness of ISO 14000

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3 The Bren School offers a Masters of Environmental Science and Management (MESM). This is a two-year professional degree with many components designed to turn out employable, practical, problem-solving environmental professionals. Approximately 50 students per year enter the program. During the first year, the students take core courses in earth systems science, biogeochemistry, conservation ecology, law & policy, economics, organizational behavior, finance & accounting, corporate strategy and statistics. During the second year, they take elective courses in one of six “specializations.” Beginning in the Spring quarter of their first year, they undertake a client-driven group project which calls for deliverables one year later. There is an active colloquium program as well as professionally-oriented workshops in such subjects as grant writing, presentation skills, project management and communications.

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Students collaborate with outside sponsors (industry, government and non-governmental organizations) to produce final projects that are useful and applicable to “real clients.” The dual use of the Group Project (academic and professional) enhances the students’ experience at the Bren School by allowing them not only an opportunity to participate in an applied project, but to gain valuable experience interacting with professionals and the community.

This is well illustrated by the recent Santa Clara River oil spill project. As a result of a settlement from an oil spill caused by the Northridge Earthquake, the US Fish and Wildlife Service (USFWS) had $8 million in a trust fund with the stipulation that it be used to enhance ecosystem services in the Santa Clara River, which was damaged by the oil spill. This money is not to clean up the oil spill (that was done quickly) but to enhance the river to make up for the temporary ecological damage associated with the oil spill. The USFWS was at a loss to figure out how to optimally and justifiably spend the money for ecosystem enhancement. They asked the Bren School for help and the problem became a group project. The five students struggled successfully the first quarter to determine the scope of the project and to narrow it so that it could be successfully executed. Also during that first quarter, they designed a work plan for the remaining two quarters. The project involved determining the relative value of different ecosystem services, ranging from endangered species habitat protection to elimination of invasive plant species. Furthermore the cost of acquiring land or conservation easements needed to be considered. Ultimately, tradeoffs were needed because of the $8 million budget. The ultimate recommendation was a set of specific land acquisitions.

We propose that the IGERT-supported doctoral students help guide, mentor and manage a group project to hone their managerial, team building, and leadership skills. Our plan is to assign each of the PhD students to one of the group projects, probably in the Spring of their second year. The PhD student would be responsible for assisting and advising the Masters students in identifying the real problem in what often begins as a vague client-specified problem statement, interacting with the outside sponsor, scoping out a realistic work plan for the project and helping the Masters students undertake the practical research. The PhD student would not be a replacement for the faculty advisor(s) but rather a complement, working between the faculty and the Masters students.

An additional task for the PhD student will be to identify some aspect of the project that is appropriate for original research. The PhD student would undertake that research during the summer quarter and would be assigned one of the Master’s students as a paid assistant (with support from the IGERT program). For instance in the case of the USFWS Group Project described above, a Ph.D. student might have examined the tradeoffs at the margin between investing in habitat for the Least Bell’s Vireo (an endangered bird) and habitat for the also endangered red-legged frog.

Quite frankly, the Bren School faculty who have supervised group projects have learned a great deal from that supervision. The big challenge is how to translate a real-world environmental problem into a researchable project, and one that can be successfully completed with a limited budget, in a limited period of time, and executed by staff (ie, students) with diverse skills. We feel that this leadership experience can be extraordinarily beneficial for IGERT-funded Ph.D. students. The students will learn how to lead a research project, how to define a research project from vaguely defined goals, how to interact with outside sponsors and how to manage people.
**Internship.** The summer after the first year of study is a summer with light responsibilities. The research program of the student has yet to become very active and coursework is not usually undertaken in summer. This is an ideal time for an internship. We propose to encourage (almost require) that students undertake an internship during the summer following their first year—an internship from 1-3 months in duration. In fact, to drive home the importance of the internship, the Bren School will pay a bonus of $2000 (from its own funds) to any IGERT student taking an appropriate internship during the student's first summer. This should assure that most students take the internship.

The purpose of the internship is to give students an appreciation for the real-world of environmental problem solving, whether it be firms trying to comply with regulations, agencies trying to efficiently manage natural resources, governments constructing regulatory policies, or UN agencies trying to fashion treaties. By an internship, we do not usually mean a summer research assistantship with a faculty member.

Once again, the existing Bren School Masters program can be very helpful in placing students in internships. The Masters students are strongly encouraged to undertake internships during the summer and many of them do so. These range from local companies to the USEPA (Office of Policy) in Washington.

In support of this, the Bren School Career Office has developed a structured program for placing Masters students in internships. All students receive internship announcements on a weekly basis through the Bren School internship listserv. Students are able to access internship listings through a number of internship books and newsletters located in the Bren School Career Development Library and through the University Counseling and Career Services Center. Students can find additional internship listings through the Bren School Career Development Website. Furthermore, the Director of Career Development works closely with each student, assessing their interests and then pursuing internship opportunities related to their interests. The students are also encouraged to pursue opportunities on their own in organizations where they might enjoy working. Through the internship program, over 90% of the Masters students complete summer internships while many others complete internships throughout the year.

This is a natural resource for the IGERT-supported students to draw upon in finding an internship for their first summer. Effort will be made to expand the list of participating internship hosts to include international organizations and foreign-government agencies.

**Empirical Paper Requirement.**

One of the unique features of this proposed IGERT program is the production by the student of an empirical research paper of publishable quality. This is expected to be finalized in the middle of the third year of study. It is likely this will emerge from the student’s group project experience but need not. The important thing is that students understand the nature of research prior to embarking on a much greater research project, their dissertation.

The empirical research paper will be subject to very much the same review process as at a scholarly journal. Two faculty will anonymously write reviews of the paper, recommending “publish” or not. If the recommendation is negative, an indication of the reasons and what can be done to remedy the situation will be included. Students will be expected to revise their paper until it is ultimately acceptable to the referees. Standards will not be quite as high as at a first-rate journal but at the end of this process students will be encouraged to send the paper out to an actual journal for publication. This requirement and process are used in the Ph.D. program in the Economics Department at Yale where they appear to work very well.

Possible topics include:
Of course it may be the case that this turns out to be a difficult hurdle for some students. If research does not come easily, it is better to know that in the third year rather than in the fifth, sixth or even seventh year of graduate school.

**Seminars/Workshops**

As students move out of the coursework-dominated first two years of the curriculum, towards the research-dominated fourth and fifth years, they are faced with two fundamental problems in developing and completing their dissertation: what topic to work on and how to conduct the research. Students are always surprised at how difficult it is to generate a dissertation topic. Consequently, the IGERT-funded program has a number of elements with the specific purpose of facilitating this transition to the dissertation. In particular, a set of three workshops are phased in during the second and third year of the Ph.D. program. These workshops are designed to help students appreciate the research of others, understand research methods and help to identify promising research directions.

**Environmental Policy Workshop.** One of the important dimensions of environmental economics is understanding the context for the economics – understanding the policy environment where problems arise and within which solutions must be found. It is not easy to appreciate the breadth and practicalities of environmental problems. In an effort to make students more aware of the nature and complexities of environmental problems, IGERT-supported PhD students will attend an environmental policy workshop, starting in their second year.

The Environmental Policy Workshop is currently being introduced into the Bren School Masters program and should serve both Masters students and IGERT-supported PhD students. The Workshop meets 3 times per quarter with an outside environmental practitioner as guest speaker/presenter. The speaker is someone with authority to manage or solve some sort of environmental problem. The speaker will convey to the students two things: the nature of the environmental problem and an aspect of the problem that he or she (the speaker) is having difficulty solving, for one reason or another. The workshop is conducted in a seminar fashion with open discussion among the speaker, students and faculty.

One of the unique aspects of this workshop is that it will be conducted, in part, in conjunction with the Goldman School of Public Policy at UC Berkeley – in particular, Prof. Michael Hanemann’s Environmental Policy Program within the School. Through a video link, students at both campuses will be able to benefit from outside speakers at one of the two campuses. This is important because many people involved in managing environmental problems have difficulty travelling large distances, taking significant time out of their schedule. Having the UC Berkeley connection allows us to cover California quite effectively.

We are also pursuing similar arrangements with universities in Washington, DC and Brussels, to allow us to more effectively cover national and international environmental policy. We have an informal agreement with the University of Leuven in Belgium to experiment with hosting policy speakers associated with the European Commission. This coordination would be achieved via video conferencing, in much the same way as the UC Berkeley interaction. We are also discussing a
similar arrangement with Johns Hopkins’ School of Advanced International Studies in Washington, DC. To facilitate this distance learning, funds are included to equip one of our seminar rooms with video equipment so that effective multi-location seminars can take place.

**Environmental Economics Workshop.** There is an ongoing and active PhD-level workshop in the UCSB Economics Department in the area of Environmental and Resource Economics. IGERT-supported PhD students will be required to register for this workshop starting in their third year. The workshop meets weekly for an hour during the academic year.

The purpose of the workshop is to develop research skills in environmental economics. This is accomplished by a combination of outside speakers presenting research, students presenting research, students monitoring journals and reporting on that effort, and the reading of promising new papers. Each year, each student will be required to develop a research proposal over the course of the year, which will be presented in June at the end of the academic year. This proposal need not lead to research; its purpose is to help develop skills in identifying research problems and designing research programs.

**Natural Science Workshops.** Each of the four complementary natural science focus areas (marine science, conservation biology/applied ecology, climate and hydrology/water resources) currently has an informal regular meeting of graduate students and faculty in the area. These workshops serve to review progress on dissertations, discuss recent research, listen to outside speakers and generally keep abreast of the field. These workshops will be of vital importance to the IGERT-funded Ph.D. students, for whom one of these workshops will be required, starting in the third year.

The natural science workshop will be important because it will be an opportunity for the environmental economist specializing in the particular area of natural science to interact with non-economics Ph.D. students also focusing on that particular area of natural science. For the IGERT-funded program to be successful, the Ph.D. student must feel like a colleague within the complementary natural science field, not just an outsider with some understanding.

**International Dimensions of the IGERT Program**

Environmental management is a global problem. It is very important that IGERT-funded students appreciate the global nature of many problems. We have structured several elements of the IGERT program to accomplish this.

The Environmental Policy Workshop will actively seek to include an international policy perspective. We plan to experiment with the University of Leuven in Belgium in hosting speakers associated with environmental management in the European Union. The logistics of a video seminar with a 9-hour time difference are not to be underestimated; however, if successful, this should expose our students to a much broader international perspective.

The Bren School group projects have had some international dimensions and we expect that to continue. One of the first Group Projects involved Mexico-US water quality issues in the vicinity of El Paso-Juarez. A project is being developed for the coming year to look at how to optimally design Monarch butterfly habitat in central Mexico. Because we plan to involve IGERT-funded Ph.D. students in the group projects, this also adds an international dimension to the program.

We will also seek to identify additional internship opportunities overseas. This should not be a problem and should greatly enhance the exposure of the IGERT-funded students to international perspectives on environmental problems.
Several of the research thrusts in this proposal have very significant overseas components. The Hydrology/Water Resources program conducts much of its field work in the Amazon in Brazil. The climate program is by its very nature international. One of the Bren School environmental economics faculty specializes in the environment in developing countries.

**Existing Bren School PhD Program**

Ph.D. students supported by the IGERT grant will be admitted to the Bren School Ph.D. program or the Economics Department Ph.D. program. The vast majority are expected to be admitted to the Bren School, because of the orientation of the program and the expectation that many applicants will come from a non-economics undergraduate major. The Bren School’s requirements are fully compatible with those of the IGERT program. The Economics Department’s requirements are also compatible, though a few extra courses may need to be taken to satisfy the Economics Ph.D. requirements.

The Bren School’s Ph.D. program is highly individualized, reflecting the multidisciplinary nature of the school. Students entering the Ph.D program establish an Advisory Committee consisting of at least two faculty members from within the School. This small group designs a program of study for the first year that meets the student’s specific interests and needs and satisfies the mission of the School. By the end of the first year of study or the beginning of the second, each Ph.D. student forms a Ph.D. committee consisting of at least 3 members of the Bren School ladder faculty. Additional external members are highly recommended. This committee works with the student to design the student’s program of study.

Since a guiding principle of the School is that analysis of environmental problems requires quantitative and highly analytical training in more than one discipline and an awareness of the physical, biological, social, political, and economic consequences of scientific or technological decisions, Ph.D. students are generally required to undertake some coursework or independent study that provides cross-disciplinary perspective to their area of specialization.

Bren Ph.D. students normally complete the bulk of their coursework during the first two years. At the end of their second year or no later than the end of their third year, a Ph.D. student must pass a written examination prepared by his/her Ph.D. committee that tests the student’s knowledge of his/her specialization in the context of the field of Environmental Science and Management. A few months following successful completion of the written examination, the student ordinarily prepares a dissertation proposal and applies to the faculty for admission to Ph.D. candidacy. Under supervision of the Ph.D. committee, the faculty conduct an oral examination on the dissertation proposal, the student’s readiness to do the required research, and the student’s preparation and aptitude for completion of the Ph.D. On completion of the doctoral dissertation to the satisfaction of the student’s Ph.D. committee, the student gives a public lecture on and in defense of the dissertation.

The requirements outlined here for the IGERT-supported Ph.D. students are greater than those of the normal Bren student, though completely compatible. The IGERT requirements are also easily compatible with the Economics Department requirements.
**C.e. RECRUITMENT AND RETENTION**

**Bren School Recruitment.**

The Bren School has an active recruitment effort, primarily associated with its professional Masters degree. This effort includes posters, distributed to institutions around the country, printed brochures, a web page, and person-to-person recruitment.

One of the most effective parts of our recruiting effort involve on-campus open houses, several of which we organize every year. These day-long events include activities to introduce prospective students to the Bren School’s programs and faculty. These have proved most effective in recruiting students; in fact, in the past more than 40% of our incoming Masters students have attended one of our open houses.

In 2000, the Bren School hired a recruitment staff person to travel to various California colleges and universities to make informative presentations about the program.

It is clear that one component of recruitment is an effective web presence. The Bren School has invested significant resources to make our web page attractive and informative. A separate presence on the web page will be devoted to the IGERT program.

**UCSB Institutional Recruitment**

The University of California, Santa Barbara is committed to the recruitment, admission, and retention of a high quality, diverse graduate student body. UCSB has developed a variety of diversity programs designed to encourage and support both prospective and current graduate students who have overcome economic and social disadvantage in pursuing academic objectives and those who bring perspectives, research topics, or career interests that advance the University’s goals of excellence and diversity.

UCSB participates in such recruitment programs as the Western Name Exchange, GRE Student Locator Service, Project 1000 (whose goal is to enroll 1,000 more Hispanic graduate students), California State University Pre-Doctoral Program, and the National Consortium for Graduate Degrees for Minorities in Engineering and Science (GEM) program.

UCSB provides outreach and recruitment materials to hundreds of colleges and universities throughout the US, with special attention to UC and CSU campuses, historically Black Colleges and Universities, the Society for the Advancement of Chicanos and Native Americans in Science, the American Indian Science and Education Society, and campuses with high concentrations of Hispanic students. UCSB’s connection to a diverse pool of prospective students is enhanced by participation in a wide variety of grad fairs during the year.

UCSB’s Summer Academic Research Internship (SARI) program is a full-time eight-week program designed to increase the pool of highly qualified and diverse students eligible for graduate training. We propose to exploit this program fully in our IGERT efforts.

**Direct Recruiting of Underrepresented Students**

The Bren School has a cooperative relationship with California State University, Los Angeles (CSLA). CSLA ranks first among all California universities in the number of Latino students who subsequently earned PhD. Degrees between 1980 and 1990. In 1994 NSF ranked CSLA among the top 200 four-year institutions nationwide whose students went on to Ph.D. programs in science and engineering.
We have developed a “Bridges-to-the PhD” program that will train promising undergraduate and master’s level students in environmental science research at CSLA and then place the most qualified of these students in the Bren School’s Ph.D. program.

Recognizing the importance of minority participation in environmental education, CSLA faculty and administrators have created the Center for Environmental Analysis (CEA). Underrepresented minorities account for 51% of the departments participating in CEA and 60% are women. Our recruitment efforts for IGERT will include the following elements:

- Hold workshops every fall at CSLA to acquaint prospective students with our program.
- Prospective students will visit UCSB in the winter quarter of their junior year.
- Because mentorship is important, IGERT program faculty will interact with outstanding undergraduate and masters students with interests in environmental science and management.

Our “Bridges to the PhD” program provides an effective mechanism for increasing the numbers of underrepresented groups enrolling in the Bren School’s PhD programs.

**IGERT-Specific Recruitment**

Most students will be admitted to begin study in the first three years of the program. Because this is an unusual program, significant resources will be devoted to recruitment in the first two years. The usual recruiting material (web site, brochure, posters) will be prepared. But we also expect to place a significant number of advertisements in college newspapers, trade journals (to attract students in the workforce), and in diverse other effective outlets. Further, we will place ads on the web (for instance, in the New York Times on the web) in order to reach out to the nonconventional student.

In addition, staff will conduct information sessions at major colleges and universities in the US. The Bren School already does this in California but the effort will be expanded significantly. Faculty will assist in this process whenever their travel schedule permits.

Our target audience is current undergraduates, students receiving Masters degrees and practicing professionals who may wish to return to school.

**Retention**

We are committed to maintaining this interdisciplinary training program over the long-term, beyond the five-year NSF funding period. Five years of funding and collaboration between economics and the natural sciences should generate new links to continued funding sources.

Our plan is to offer IGERT students four years of fellowship support. This is viewed as an adequate resource injection; students should be able to attach themselves to a faculty research program in their fifth year or undertake a teaching assistantship, a number of which are available. However, as an incentive for the entering class, five years of support will be offered to those students starting in the program's first year.

One of the issues in retention applies to students who do not enter in the first or second year. NSF funds will not be available to offer those students the full four years of IGERT support first and second year students are promised. This might be expected to be a serious retention issue. However, UCSB is willing to support IGERT students who enter in the third and fourth year of the program so that they receive a full four years of support. Furthermore, UCSB will make those commitments to students as they enter, during the term of the IGERT grant. This is a very substantial resource commitment, which should greatly facilitate retention. For those students who are unable to finish the program in the allotted five years, teaching assistantships are available from the Bren School and the Economics Department for a sixth year, though students must compete for these. We would expect IGERT students to be successful in this competition.
The primary administrative requirements for the IGERT project involve student recruitment and admission. Some additional effort is needed to monitor student progress, place students in internships, and coordinate the workshop series. The recruiting and admissions process will dominate the early years of the program and the other activities will dominate the later years. This will be accomplished using a full-time administrative assistant (in conjunction with the PI) and a faculty IGERT steering committee, chaired by the PI and operating out of the Bren School of Environmental Science and Management.

Procedure to Select Students.

We will form an 8-member IGERT Steering Committee (ISC), chaired by the PI and composed additionally of one representative from each of the four natural science focus areas, one representative from the Economics Department and one member of the environmental economics faculty in the Bren School. In addition, the Bren School Assistant Dean for Academic Programs (Dr. Laura Haston) will be a *de facto* and full voting member of the ISC. All representatives, except for the PI and Assistant Dean, will serve for two-year terms, with rotation in different years to assure continuity. The ISC will recommend the applications of qualified students and fellows, decide on allocation of resources, review student progress, and resolve any conflicts. The committee will also prepare an annual report of the IGERT program.

Twice a year, all faculty participants will meet to ensure their active involvement in the IGERT program. Annually, the faculty of the Bren School will review the program, consider the quality of applicants, review student progress reports, and evaluate student placement after graduation. The faculty will recommend any changes needed to serve students’ needs more effectively.

Following standard practice at UCSB, the IGERT program will be reviewed every five years. The campus administration appoints a small external panel of experts from leading US universities with related academic programs, who report on scope, content, and effectiveness to an internal panel, which then recommend changes and future directions to the Dean of the Bren School and the UCSB Chancellor.

Given the multidisciplinary nature of the Bren School, students enter from various undergraduate majors. The same applies to the IGERT-funded Ph.D. students. We would expect that candidates for the program would have majored either in economics or in one of the natural sciences or engineering. However, other majors would be considered, provided the undergraduate preparation is rigorous and relevant. An important requirement for admission is strong preparation in mathematics, including at minimum, a year of calculus.

All IGERT applicants must unconditionally meet the admission requirements of the department to which they are applying (Bren School or Economics) as well as UCSB’s Graduate Division and University requirements as stated in the *UCSB General Catalog*.

Each student applicant for IGERT support must be supported by at least two faculty members, one an economist and one a natural scientist from one of the four focus areas in IGERT. The ISC will review all IGERT applications and make recommendations for awards.

An active recruitment policy will be put into place and a special effort will be made to reinforce the visibility of the program for students from the natural sciences, students who may not be as aware of environmental economics as a field of study and research. We are also very anxious to make our recruitment effort national in scope (even international, reaching out to US citizens who
may be overseas). Furthermore, we hope to attract students just finishing their undergraduate programs as well as students currently working. Our recruitment efforts will be very extensive in the first two years of IGERT (until the reputation of the program is established), and will involve faculty as well as staff.

**Ph.D. Advisory Committees**

During their first year, and no later than the beginning of their second year, all IGERT-funded Ph.D. students will establish an advisory committee consisting of at least three members. The committee shall include one faculty member from the Department of Economics and one faculty member from the student’s chosen complementary area of natural science. At least two members of the committee should be faculty from the student's department. The student’s research advisor will chair the student’s advisory committee. Students are encouraged to take advantage of resources in other UC departments or schools by inviting a faculty member from outside the UCSB to serve on the student’s advisory committee.

**Progress Check Points.**

Although each student is subject to an annual review by the ISC and the Bren School faculty, there are several examination points. At the end of the first year, the student must pass a preliminary examination in microeconomic theory and econometrics (two exams). Should the student fail to pass either of these, one retake will be permitted at the end of the first summer. Failure at that point will result in termination from the program.

Students must also successfully prepare a written empirical paper in the third year that is acceptable to the faculty, using the criteria described in section d. Students must also pass a qualifying exam in their third year and successfully prepare a dissertation proposal. Failure to fulfill these obligations in a timely manner may be grounds for termination from the IGERT program. Such cases will be reviewed by the ISC.

**Resources for Students.**

All IGERT-funded students will have access to the Bren School resources, including the Student Computing Facility and the School’s Infrastructure Laboratory, which has analytical laboratory equipment for chemical and microbiological analysis. Library purchases in excess of $100,000 per year support both the Master’s and Ph.D. programs. As a member of the California Digital Library, UCSB faculty and students have on-line access to thousands of journals, including nearly all of those relevant to the IGERT program.

The Bren School logically integrates with several Organized Research Units (ORU’s), several NSF centers, and other interdisciplinary research efforts on the Santa Barbara campus. The formal institutions include the Institute for Social, Behavioral and Economic Research, the Institute for Computational Earth System Science, the National Center for Ecological Analysis and Synthesis, the Marine Science Institute, the Institute for Crustal Studies and centers in the College of Engineering.
C.g. PERFORMANCE ASSESSMENT

To assure we meet the goals set forth in this proposal to prepare Ph.D. graduates in Environmental Economics with a multidisciplinary approach to problem-solving who can communicate effectively across fields and be successful in both academic and non-academic careers, our performance assessment strategy will be three-pronged:

(1) Each June all participating faculty and students will prepare a written performance evaluation. This form will rate the students’ progress and performance using a simple scale, ranging from Excellent to Poor. The evaluation will be followed by a review in which the students and their advisors set goals for the next year. Performance factors will include research knowledge, quality of work, planning and organizing, productivity, initiative, and teamwork. Supervisory skills will also be assessed during the year the students are managing a group project, by evaluating their leadership, delegation, and development of group project participants.

(2) At the end of the second and fourth year we will conduct a formal review with a specially appointed committee, composed of two to three senior reviewers who are not participants, from on- and off-campus. Comments and suggestions from this analysis will be readily incorporated into our program.

(3) We will establish a database that tracks program applicants, follows the progress of students through their course work and dissertation, and monitors their subsequent success in the workplace. Each quarter faculty members who advise or teach IGERT students will submit short evaluations of students’ performance in seminars and workshops to the steering committee, and the results will be tabulated in the database. The database will permit us to target members of underrepresented groups and to build on the relationship we are establishing with California State University, Los Angeles.

We will also conduct quarterly peer and faculty evaluations in the master’s group project where our IGERT students will act as mentors and managers. These evaluations will permit the IGERT group project managers the opportunity to evaluate and respond to information received on their performance in this context.