Integrating Tropical Ecology into the Undergraduate Research Experience.

A proposal to the National Science Foundation

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PROJECT ELEMENTS:

- **New REU Site.**
- **Project title:** Integrating Tropical Ecology Research into the Undergraduate Curriculum
- **Principal Investigator:** Donald A. McFarlane
- **Submitting organization:** Claremont McKenna College
- **Other organizations** Pitzer College, Scripps College, Pomona College, Middlebury College, Furman University.
- **Location:** Pitzer College's Firestone Center for Restoration Ecology, Costa Rica.
- **Main field(s)** Biology; Geosciences. **sub-field(s)** Ecology:
- **Number of undergraduate participants per year:** 8
- **Summer REU Site**
- **No. of weeks per year that the students will participate**: 8
- **International ethics component, or RET component?:** International component.
- **Point-of-contact for student applicants:** Donald McFarlane, 909- 607-2564, dmcfarla@jsd.claremont.edu
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Project Summary In the past decade or so, global biodiversity loss has been recognized as one of the preeminent challenges of the 21st century. Since ~ 90% of global biodiversity is likely to be tropical in distribution, the nature and magnitude of these changes are often best addressed in tropical contexts. Through a broad spectrum of study abroad opportunities, undergraduates are often exposed to tropical ecosystems and may be introduced to the basic concepts and problems, but these individuals usually have only limited opportunities to take their education to the next level – hands-on involvement in tropical ecology and biodiversity research. This situation pertains because most tropical field stations are focused on graduate or faculty-level research, and it is often difficult for an inexperienced undergraduate to successfully develop and fund a proposal that is compatible with ongoing 'professional' studies. Pitzer College has recently acquired what we believe to be the nation's only tropical field station and biological reserve run by a liberal arts college specifically to service undergraduate research. In collaboration with 5 other liberal arts colleges, we have developed and present a long-term program of biodiversity assessment and ecological research for undergraduate science majors. The setting is the Firestone Center for Restoration Ecology (FCRE), a 60-hectare recovering lowland pacific rainforest located in southwestern Costa Rica. This initiative is designed to engage students in an integrated, longitudinal program of research in which the undergraduates will take the leading roles. **Intellectual Merit:** Although Costa Rica has been a focus of tropical biological research, remarkably little work has been done on the Pacific lowland forest ecosystem of the southwestern coast which spans the transition between the wet lowland forests of the Osa peninsula to the south and the seasonal dry forest ecosystem to the north. In large part, this is due to the fact that the existing network of biological field stations has not included this area. Moreover, the Firestone reserve and its immediate vicinity incorporates secondary forest, plantation forest, riparian forest and

undisturbed primary forest, but lacks reasonably complete inventories of even common groups such as mammals and butterflies. The area is currently in the throes of a demographic transition which is returning abandoned agricultural land to various grades of recovered habitat, but with very little baseline information to guide the application of best-practice planning. The work of our undergraduates is already contributing to the resolution of these problems. **Broader Impacts:** Undergraduate participation in hands-on research is widely considered to be important in maintaining and channeling student interest in the sciences. The proposed project will extend our current program of ecology research to a wider audience of undergraduates, exposing them to a wider range of faculty and sub-disciplines than any one liberal arts college could provide. By focusing on students between their sophomore-junior and junior-senior years, we encourage our summer researchers to further develop their projects into undergraduate theses. The Firestone Center for Restoration Ecology maintains close contact with the local community, providing educational contributions to local grade schools and through membership and support of ASANA, the local community conservation organization.

PROJECT DESCRIPTION

1. Overview.

This proposal will establish a Research Experiences for Undergraduates (REU) site at Pitzer College's *Firestone Center for Restoration Ecology* (FCRE) at Barú, on the southwestern coast of Costa Rica. This REU program will interface with and extend the existing undergraduate summer research program that the Joint Science Department of the Claremont Colleges (JSD) has operated at the site for the past 3 years. The project will support 8 REU students each summer, working in pairs on four longitudinal ecological investigations. The program will run for 10 weeks, from late May through the beginning of August each year, supervised by a rotating group of 6 faculty from JSD and 3 other liberal arts colleges, together with a GIS specialist.

REU participants in this program are not research assistants, but rather will be expected to take primary responsibility for the development and completion of their projects. In addition, all REU participants will take part in field workshops run by individual faculty in their own areas of specialty. Our program differs from the existing Organization for Tropical Studies (OTS) REU program which explicitly targets advanced undergraduates already committed to organismal biology. The Firestone Center REU specifically focuses on recruitment of students into the 'hard' environmental sciences and targets students in their early, formative undergraduate years.

REU participants will receive a stipend at the NSF rate of $450 week, together with room and board at the Firestone Center and basic traveling expenses. Each year, the program will support two students from the JSD consortium (Pitzer, Scripps and Claremont McKenna colleges), three students from our collaborating colleges (Middlebury, Furman, and Pomona colleges), and three from other schools. We expect that this synergistic exchange of faculty and students assembled in an area of outstanding biological diversity will foster a dynamic environment for learning.

2. The Undergraduate Research.

The FCRE reserve and field station is a 60 hectare (150-acre) property located on the southwest coast of Costa Rica, contiguous with the well-known Hacienda Barú National Wildlife Refuge (330 ha), near the coastal town of Dominical. Originally lowland rainforest, the property was progressively cleared for cattle farming in the 1950's and 1960's. Since 1993, the property has been the subject of restoration and sustainable forestry efforts. Ownership of the property was transferred to Pitzer College in 2005, which manages the site through JSD as a biological reserve and logistical base for Claremont-wide undergraduate ecological research and education. August 2007 saw the conclusion of our third undergraduate summer research program, which has now hosted a total of 14 students from CMC, Pitzer and Scripps for two months of full-time ecological research at the FCRE.

The FCRE is a unique resource – we know of no other tropical field station and reserve operated by a liberal arts college. This uniqueness allows us to focus on facilitating faculty-undergraduate research collaborations in a way that simply does not occur at other, graduate student-oriented tropical field stations. However, the complexity of tropical ecosystems places a premium on involving the widest range of faculty. To this end, we funded (through the Andrew W. Mellon Foundation) a May 2007 workshop at

the FCRE for faculty from 5 other liberal arts colleges with an interest in long-term, undergraduate-focused ecology research

The projects chosen for this REU focus on the spatial ecology of soils, water, and species distributions within the reserve and will be integrated through the Firestone Center GIS system. REU students will be provided with a project 'primer' and background reading prepared by their research mentor upon acceptance into the program. During the first week of the program in Costa Rica, students will receive an orientation to the reserve and basic safety protocols conducted by McFarlane and Christenson, who will then work with each student pair on setting up and troubleshooting their projects. Thereafter, research mentors will spend staggered two-week blocks with the students. All the REU students will have the opportunity to participate at some level in all four projects, to provide a diversity of experience, although each student pair will have primary responsibility for the completion of a specific project. Research mentors will also provide additional enrichment experiences based on their own specialties, taking advantage of the resources of the FCRE. These will include activities, such as nocturnal moth trapping, bat netting, and camera-trapping.

2.1. Research Projects:

2.1.1 Project One: Soil Ecology at the Firestone Center

The Firestone Center and adjacent property provides student access to a range of habitat types, including (1) recovering pasture, (2) secondary Forest, ~ 15 years old, (3) abandoned 15 year old hardwood plantation, (4) bamboo plantation, (5) pasture, (6) riparian forest, and (7) primary forest. These habitats occur across a wide range of slopes and aspects, and different geological parent materials. Given that the dominant controls on soil formation are climate, biotic factors, topography, parent material, time and human perturbation, the FCRE provides a rich spectrum of research opportunities that could test the impacts of land management, landform age, slope and geological parent material on soil properties.

In much of the tropics, the dominant control on soil properties is the age of the soil—with prolonged exposure to the intense chemical weathering and leaching associated with humid tropical environments, soils become depleted in soluble nutrients like Ca, K and Mg and enriched in toxic Al. At the same time, Fe concentrations also increase (like Al, it is relatively insoluble and thus remains in the soil), resulting in the formation of iron oxides and hydroxides that produce orange and red colors. Chemical weathering also results in destruction of coarse grains (often rock-derived grains of feldspar, pyroxene and other primary minerals that are unstable in the tropical weathering environment) and production of clays like kaolinite that are relatively stable in this environment. Loss of primary minerals and associated base cations (Ca, Mg, Na, K) ends up resulting in acidic soil. So, the natural trend of soils in a Firestone-like environment is toward an acidic, clay-rich, nutrient-depleted, Al-rich state. Old-growth tropical forests tend to store most plant-available nutrients in the biomass, recycling nutrients before the heavy rains are able to leach the soluble nutrients out of the soil and into ground water, while forestry and agriculture tend to remove this nutrient pool. At the FCRE, preliminary investigations in May 2007 indicate that parent materials are a mixture of

fluvial sediments and igneous and sedimentary bedrock. In some places, parent material is obvious—for example, young, rocky brownish soils on the terrace above Quebrada Cacao have clearly formed from fluvial parent materials. This soil is comprised of river-deposited clasts that once were part of riverbed and floodplain (and stand in stark contrast to older, clayey, red soils at higher elevations). Similarly, the soils on the broad plain along the Dominical – San Isidro road (below the Program House and Ecology Center) are on a Rio Baru terrace. Subduction and thrusting associated with convergence of the Cocos oceanic plate beneath the Central American plate is causing uplift to the extent that the Pacific coast of Costa Rica is rising at rates ranging from 0.1 to 4 m per thousand years (Sak et al. 2004; Fisher and Ryan 2006). This means that river floodplains are bound to be uplifted while rivers erode down into the landscape, and former floodplains become terraces that progressively get uplifted well above river bottoms. Farther to the northwest along the Pacific coast, uplifted terraces are clearly visible within 15 km north and south of the town of Parrita. Soil erosion on the steep slopes of the FCRE has obliterated much of the topographic evidence of uplifted terraces, but reconnaissance work in May 2007 reveals numerous ~flat , terrace-like features within the FCRE that might be remnants of uplifted terraces (of Q Cacao or R Baru or both). These flat features are generally on the order of 100s of square meters. The other source of soil parent material at the FCRE is the underlying bedrock. Reconnaissance mapping in May 2007 documents two main bedrock types in the area—Oligocene-Miocene shale (with some interbeds of sandstone and conglomerate) and younger diorite that probably intruded into the shale during late Pliocene or Pleistocene time. The shale is exposed in outcrops in Quebrada Cacao and in the creeks that flow into Q. Cacao, but it does not appear to be appreciably affected by chemical weathering. However, cobbles and boulders of diorite, which are prevalent as corestones (in soils at the higher elevations at the FCRE), have thick weathering rinds and clearly are contributing to soil material.

Accordingly, we will address the following issues, and for many of the potential projects we provide brief summaries of methods to illustrate that they are feasible projects for a research center such as the FCRE:

Soil bulk density: This property can be affected by a few factors, one of which is the proportion of low-density clay to higher-density primary minerals. In general, older soils are richer in clay and thus are less dense. However, land-clearing and grazing increase bulk density due to compaction, which can then result in limited infiltration and greater run-off. Students will test soil bulk density in areas of similar elevation and topography at FCRE that have been managed differently, thus limiting controlling variables—one such spot is the uppermost reaches of the reserve where old-growth forest, pasture and bamboo are adjacent on the same terrace-like landform. Preliminary analysis in May 2007 suggests that old growth forests have much greater ant populations than adjacent bamboo or pasture, and this results in much greater secondary porosity, which can be quantified by measuring bulk density given that tunneling activities of organisms are also important players in soil bulk density.

Soil organisms: Preliminary analysis of soils in old-growth forest, bamboo plantation and pasture suggests that old-growth soils have large populations of ants, which create secondary porosity and presumably have a trickle-down effect on other soil properties such as nutrient cycling, aeration and water infiltration. If this is true in the northwestern corner of the reserve, it raises questions about ant populations in other parts

of the reserve—have ants re-inhabited secondary forests? How do ant populations correlate to nutrient availability, pH, soil bulk density and soil moisture? Furthermore, it might be interesting to examine A-horizon thickness across soil age and vegetation, with the assumption that old-growth forest would preserve organic matter in the uppermost part of the soil profile to a greater extent than would pasture, and this is crucial because humus in A-horizons has tremendously high nutrient retention capabilities. By virtue of their different compositions and weathering rates, parent materials can also influence soil organisms.

Soil color: Munsell books can be used to key out soil colors according to a systematic approach that is used throughout soil sciences—given that soil color is largely controlled by age and the formation of iron oxides with time, soil color serves as a great proxy for soil age. In a tectonically active landscape like the Pacific coast of Central America, the oldest soils tend to occur at higher elevations, and younger soils are lower elevations (especially floodplains and young terraces). The FCRE has a high relief, from alluvial terraces at ~ 20 m asl to the ridge top at ~ 320 m asl.

Soil pH: In general, soils with pH < 5 or 6 tend to have problems with elevated Al availability and limited Ca availability. We predict that soil pH will decrease with increasing soil age (which presumably is correlated to elevation).

Soil nutrients: Potential projects include analysis of variation in soil nutrients as a function of parameters such as vegetation classification (e.g. bamboo vs. pasture vs. old growth vs. secondary growth) and soil age. Soil nutrients are typically extracted by shaking dried, sieved <2 mm soil in a salt solution, where the salt cation displaces nutrient cations (Ca+2, K+, Mg+2) from exchange sites into solution and the salt anion displaces nutrient anions (NO3-, e.g.) into solution. Non-nutrients such as Al and Na are also extracted into solution by this process. There are numerous choices of salt extractants— NH_4NO_3 and NH_4OAc (ammonium acetate) are good choices for cations, and this type of analysis can be performed with glassware and spectrometers available on-site at FCRE.

2.1.2. Project Two: Hydrology and Nutrient Export.

The FCRE lies within the Rio Baru watershed, which supports the expanding human population along the San Isidro-Dominical corridor. The property is bounded by the Quebrada Cacao and two additional un-named streams. A fourth stream, "Terciopelo Creek" is entirely contained within the reserve, and we have been actively involved in the study of the major drainage of the neighboring Hacienda Baru reserve. Together, these stream courses traverse a wide range of slopes and habitats from actively grazed cattle pasture to primary forest, carrying the runoff from ~ 3500 mm of rainfall per year. Large differences in sediment transport are apparent to the naked eye, and seemingly derive from differences in watershed habitat and land management practices.

This project extends work begun in 2005. Detailed topographic mapping of the FCRE by student teams has enabled us to delineate local, small scale watersheds within the Reserve, and begin to quantify slope and aspect. This work needs to be extended into the Hacienda Baru reserve (our neighbor to the west) and over privately owned agricultural property (our neighbor to the east). We currently own 60cm resolution true color satellite

imagery for the reserve and surrounding area, and will use GIS-based habitat classification to quantify slope and habitat feeding each stream.

The climate of the FCRE is highly seasonal, with a 4-month dry season and heavy rainfall in the remaining 8 months. Stream flow can vary by a factor of 10 or more over short time scales during rain events, which coupled with the high relief of the stream channels, has made continuous flow monitoring a challenge. Undergraduate work in 2006 demonstrated an increase in flow on 'Terciopelo Creek' from 1.0 to 4.5 m^3/min over 40 minutes. To continue and extend this work, we will install weirs with stilling wells at the bottom of each of our reserve streams, and instrument them with high-precision level-loggers, giving us a 365 day record of stream flow. Two automated rain gauges are already in place at the FCRE, but we will install 3 additional units to monitor local variations due to hillside aspect.

Nutrient export is a key aspect of ecosystem function, particularly in disturbed and recovering habitats. REU students will collect stream water samples around the clock during storm events, and analyze them for sediment load and major nutrient export (nitrate, nitrite, potassium, phosphate), which we will then attempt to correlate to watershed soils, aspect, slope, vegetation cover and land use. By integrating the data into the FCRE GIS system, we hope to be able to use GIS predictive tools to extend our data to the larger Barú watershed community.

Confluence of the Rio Guabo (foreground) and Rio Baru (upper left), illustrating extreme differences in sediment load due to differing land use in their respective watersheds.

2.1.3: Project Three: Spatial Ecology of Anurans

Frogs and toads are a diverse and spectacular group, well represented at the FCRE and immediate surroundings with some 30 taxa present. Summer student research 2005-2007 has established some interesting differences between habitats. Our experience has been that anurans are very popular subjects with our summer research students, in part because of the considerable publicity that the global amphibian crisis has generated. Since the REU 'season' corresponds with wet weather at the FCRE, anurans are plentiful and active.

Call analysis. In the past two summers, our summer student researchers have deployed a digital froglogger at the FCRE, and our 2007 summer student is working on the beginnings of a call library for her senior thesis. We propose to extend this work through the REU program; students will collect digital call recordings in the field, across the wide variety of available aquatic habitats. Calls will be correlated with individuals by direct capture, identification, and release. Call recordings are initially processed through the open-source software program *Audacity*. More detailed sonogram analysis is performed with the software *Sonobat*, developed for the analysis of bat calls. Photographs of the species and their identifying characters will be integrated with the call library through the biological-key program LucidID, and made available on the internet via our existing FCRE website.

Habitat analysis: Previous summer student research in 2006 and 2007 has identified differences in the small-scale distribution of anuran species on the FCRE, even between superficially similar ponds located a few hundred meters apart. We will use automated 'froglogging' to make quantitative determinations of species compositions and relative densities at the four major ponds and in the four stream courses on the FCRE which we will then attempt to correlate with vegetation, soil characteristics, water quality and the presence/absence of other aquatic organisms.

Habitat fragmentation analysis: The regional environment surrounding the FCRE is one of a patchwork of protected natural forest, plantation forest of various types and grades, secondary forest, cattle pasture, and developed land. Preliminary observations suggest that the diversity of anuran species in a particular habitat may be influenced by habitat patch size over the range of scales seen in the Barú area. Using satellite imagery and our GIS system, we propose to identify, delineate and quantify appropriate habitat patches across a range of sizes (with replicates) and, through digital froglogging, assay their anuran diversities. We hope that this will lead to the identification of minimum critical habitat sizes for sensitive species.

2.1.4. Project Four: Microecology of *Cecropia*.

Trees of the genus *Cecropia* are the dominant pioneer species in heavily disturbed and recovering habitats in the area of the Firestone reserve. A notable feature of *Cecropia* trunks is the circular leaf scars; each scar representing a single leaf. Particularly noticeable is how variable the distance between adjacent scars can be: at some point in the tree's history, growth was rapid and the interval between scars is wide (the tree grew rapidly between successive leaves), at other points, the leaf scars are more closely spaced, implying that the growth rate was slower at those times. Examining the number and spacing of these scars allows one to infer information about the growth rate of individual trees. It is likely that vertical growth in *Cecropia* is affected by water availability (trees grow faster during the rainy season than during the dry season), by availability of sunlight (trees exposed to higher light availability grow faster than trees growing in shade), and herbivory (plants with high levels of herbivory grow more slowly than those that experience little herbivory). This project will investigate the causes of variable leaf scar intervals of *Cecropia* in different habitats. We anticipate that these studies may allow us to use *Cecropia* leaf scar arrangement to infer land use and microclimatic conditions over the preceding few decades.

What is the rate of leaf production of Cecropia growing in different habitats (low and high light, early succession and late succession, in grassland and in bamboo thickets)? This will involve marking small trees in different habitats (with replicates in each habitat), measuring their height at each census, marking leaves (with rings on petioles; most important will be to mark the youngest leaf at each census period), revisiting trees often enough to be able to count the number of new leaves produced (before the last marked leaf falls off the tree), and measuring interleaf distances for each tree. This monitoring will take place over a period of at least three years, to encompass different growing seasons in the census. We will enlist the participation of Pitzer College's semester abroad students, who use the FCRE during both fall and spring semesters, to ensure that monitoring is not simply limited to the summer REU season. REU students will then address: Does leaf production rate vary within and among habitats? Does leaf production rate vary with height of tree? Is leaf production rate constant across seasons within a year? Is leaf production arte different between female and male trees? Do trees that are occupied by ants have the same growth rate/leaf production rate as trees that have no ants living within them? (Schupp 1986 has shown that saplings with ant occupation have faster growth rates, but does this advantage persist in older trees?)

Does inter-scar distance vary across habitats? *Cecropia* are relatively small trees, measuring some 10 m or so at maturity; hence, their trunks are easily and safely accessed using a conventional painter's extendable ladder with appropriate guy lines. The position of each leaf scar will be fixed using a relatively inexpensive Leica laser rangefinder that reads to +/- 3mm over the desired range. By comparing current growth to the earlier growth, REU students will be able to determine if the pattern of leaf-scar interval changes at the same time in all trees within a habitat. This data will be integrated into the reserve GIS system, and correlated with slope, aspect, and soil characteristics.

2.1.5. Project Five: Spatial Ecology of Odonates

Odonates - dragonflies and damselflies - provide outstanding opportunities for undergraduate research. The adults are active, colorful, diurnal "charismatic" insects that are easy to observe and handle. The larvae exhibit a wide range of environmental tolerances, making the group excellent monitors of habitat quality. Unlike beetles or butterflies, odonate diversity in Costa Rica is manageable (a few hundred species) by non-specialists and there are several taxonomic keys available in print and on the web.

Adult odonate species survey: The distribution of odonates in Costa Rica is imperfectly known, and almost no specific information is available for the Pacific lowland moist habitat in which the FCRE is situated. REU students will focus on adult odonate capture, photography, identification, and habitat associations. Using digital macro-photography equipment, students will be able to obtain high-quality images of whole animals, wing venation patterns, terminal appendages, and genitalia suitable for species identification. Identification will employ field guides (e.g. Esquivel, 2006) and formal keys (e.g. Forster, 1999) following training by a faculty odonate specialist. Digital imagery will be entered into the LucidID software package (Centre for Biological Information Technology, The University of Queensland) for the production of region-specific visual keys.

Microhabitat selection by larvae and adults: The Firestone reserve runs from ridge-top to flood-plain, so stream substrates change from bedrock to cobbles to gravel to sand or mud. There are also several man-made ponds at FCRE, and the Hacienda Barú reserve has peat swamps and drainage canals subject to occasional salt-water intrusion. The diversity of habitats and the variation in substrates provide an excellent opportunity to describe microhabitat associations of larvae and adults. Studies on larvae will focus on associations with substrate characteristics. Studies on adults will focus on characteristics of perch sites, defended territories, and oviposition sites. Because identifying larvae is difficult (and often unresolved), this project will interface with efforts to rear larvae to metamorphosis.

Larval taxonomy: Little information is available on the identification of odonate larvae in Costa Rica. REU students will collect larvae from different aquatic habitats (ponds, muddy streams, sandy streams, rocky streams), document them by careful macro-photography, and then attempt to rear late instar larvae to metamorphosis in aquaria at the FCRE so that the adult can be identified . REU students will also conduct pre-dawn searches for eclosing metamorphs. The exuvia shed by the metamorph will be used to describe larval characteristics. The newly emerged adult will be caged for a few hours until metamorphosis is complete (wings expanded and pigment deposited) and they can be identified.

2.2. Project Coordination, Integration, and the Importance of GIS

A project of this nature faces challenges of coordination and integration across multiple campuses within the US and between these campuses and the Costa Rican field station. Our principal tool for integrating research is the FCRE Geographic Information System (ArcGIS), supported (training, conventions, metadata) and hosted (Internet Mapping) by the Libraries of the Claremont Colleges. All of our research has a significant spatial component - fine scale species distributions, soil characteristics, and watershed evaluations – and has and will continue to be linked to our continuing small-scale topographic mapping and high resolution (60 cms true color) satellite imagery through the GIS system. By January 2008, we expect the FCRE-GIS to have open access, (downloading past project layers for incorporation into new projects), on-line via ArcIMS (Internet Map Server).

A guiding principle behind our selection of research projects is that students should have an opportunity to develop an understanding and basic skills in spatial data collection and analysis[1], which we achieve by requiring all our undergraduate researchers to participate in continued "traditional" topographic surveying and data processing, in addition to providing them with sub-meter GPS hardware and human support where practical (i.e. areas without dense canopy cover). The FCRE-GIS system has and is expected to continue to provide students with the data and tools for more sophisticated

[1] Learning to Think Spatially: GIS as a Support System in the K-12 Curriculum http://books.nap.edu/catalog/11019.html; http://www.doleta.gov/BRG/Indprof/Geospatial.cfm

spatial ecology and geographic analysis after their summer research experience, through our Senior Thesis program (at Claremont) and equivalent programs at our sister schools.

With appropriate instruction and commensurate levels of low- and high-tech support from Claremont Colleges Library GIS Services, REU students will learn to use GIS as a tool beyond data collection to perform spatial analysis, model processes, formulate decisions, and create innovative presentations.

2.3 The FCRE Digital Library

REU students in the field will have internet connectivity to our FCRE digital library of open-access scientific papers (PDF format), reports and unpublished research results from former students. They will also have access to the FCRE GIS system via ArcIMS, hosted by the Claremont Colleges Library server, and full access to the Claremont Colleges Digital Library (CCDL) with its electronic journal subscriptions. A major goal of student and faculty research at the FCRE is to generate FCRE-specific keys and guides to the identification of groups of organisms that, because of their numbers of constituent taxa, are challenging for students to identify using existing technical country or region-wide monographs and texts. We will use the software package LucidID (Center for biological Information Technology, University of Queensland) as a framework for the development of sophisticated by ultimately visually-based keys. LucidID keys will then be made openly available via our website, and can be used with freely-available LucidID viewer software.

2.4. Local Collaborations

Although the REU projects will be focused on the FCRE, we expect that the projects will extend into adjacent properties with which we have strong collaborative arrangements, most notably the privately-owned Hacienda Barú National Wildlife Refuge, which is contiguous with our property. Our previous undergraduate researchers have developed a good working relationship with the neighboring Barú Elementary school and Platanillo High School. We will further this by inviting top science students and their teachers from Platanillo High School to participate in a seminar on the REU projects at the FCRE and later 'shadow' our student researchers for a day. All student research at the FCRE concludes with a presentation in English and Spanish to members of the local community.

Mapping the community provides valuable resources to local educators for use in classrooms on a variety of applications, including conservation, social studies, biological sciences and technology. Data collected by FCRE projects along with freely available data from the web and public agencies can be downloaded through an online clearinghouse. A full-day GIS workshop for local educators will be scheduled for community educators at the FCRE, focusing on an introduction to GIS, conventions for field data and GPS collection, and information on acquiring GIS resources.

3. The Research Environment

3.1. Past Involvement of Undergraduate Students

The Joint Science Department administers an institutional program of undergraduate research serving students in biology, chemistry, physics, and environmental studies. All JSD majors complete a senior thesis in their area of specialty. In addition, in recent years, an average of 35 students each year have undertaken summer research with JSD faculty as supervisors. Funded by grants from the Mellon, Keck, Eaton and Rose foundations/endowments, the majority of these projects are conducted at the W. M. Keck Science Center in Claremont, California, but field-orientated faculty have supervised projects in Jamaica, Nevis, Puerto Rico, the Cayman Islands, Costa Rica, and Panama.

Since the summer of 2005, fourteen JSD student research projects in tropical ecology have been conducted at the FCRE. Over the same period, four JSD faculty members have served as Firestone Center summer research supervisors (McFarlane, Baduini, Purvis-Roberts, and Thomson), working with the students prior to their departure for Costa Rica, orienting them on site, and overseeing the research in staggered blocks averaging two weeks per faculty. The first joint student-faculty paper stemming from Firestone Center research is now in press[2], and a second has been submitted.

Research mentors from our partnering institutions (Ryan, Young, Hazlett, and Worthen) each supervise multiple undergraduate research projects/year in environmental science, geology, or biology at their institutions. Each has co-authored numerous papers with students. See below. The project faculty (McFarlane, Baduini, Purvis Roberts, Ryan, Young, Hazlett, and Worthen), professionals (Christenson and Roberts), and graduate student (Redondo-Brenes) have all spent time at the Firestone Center in the last year to set up student research projects as part of a Andrew W. Mellon Foundation sponsored faculty development grant. Baduini, Ryan, Young, Christenson, and McFarlane each have several years experience conducting research or supervising student projects in various areas of Costa Rica.

Project Director (McFarlane). 15 years teaching undergraduates. 12 years experience with undergraduates in Costa Rica. Successful mentoring of summer undergraduate students in Puerto Rica, Jamaica, Cayman Islands, Panama. Lead faculty for 13 summer research students and one senior thesis student at the FCRE since 2005. 4 peer-reviewed publications with undergraduate co-authors.

Research Mentor (Baduini). 6 years of teaching undergraduates. 3 years experience with mentoring summer research students at the FCRE; 3 years experience teaching in Pitzer's semester abroad program in Costa Rica. 1 peer-reviewed publication with undergraduate co-authors.

Research Mentor (Purvis-Roberts). Six years of teaching undergraduates. 1 year of experience mentoring summer research students at the FCRE, 3 peer-reviewed publications with undergraduate co-authors.

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[2] Miller, J. R. and D. A. McFarlane 2007. Haynes estimates of Poison Dart Frog (Anura: Dendrobatidae) densities in recovering tropical forest habitats, southwestern Costa Rica. Herpetological Conservation and Biology, *in press.*

Research Mentor (Ryan): 11 years undergraduate teaching experience at Middlebury, adviser to 27 undergraduate presentations at national and regional conferences, 5 peer-reviewed papers with undergraduate co-authors, mentor to 2 Universidad de Costa Rica students.

Research Mentor (Hazlett): 20 years of teaching undergraduates at Pomona College, including 9 summers supervising 6 -9 geology undergraduates each year on Keck Consortium summer field research expeditions. Seven undergraduate co-authors.

Research Mentor (Worthen): 19 years undergraduate teaching experience, with 12 peer-reviewed publications co-authored with 20 undergraduates. 15 summers supervising undergraduate research, and 8 years teaching a tropical ecology course in Costa Rica.

Research Mentor (Young): 15 years undergraduate teaching experience, 8 summers supervising 20 undergraduate researchers. Two papers with undergraduate co-authors and 2 more submitted. Two courses taught at OTS (Costa Rica).

Graduate Student: (Redondo Brenes) Costa Rican, currently in the doctoral program, School of Forestry and Environmental Studies Yale University. Presently employed as an instructor (tropical ecology) in Pitzer's semester abroad program at the FCRE.

Eighty-five percent of our FCRE summer research students have been women. Of the nine FCRE alumnae who have already graduated, two are applicants for graduate school in ecology/environmental science, one is employed in the environmental field, and one is a current recipient of a Fulbright Fellowship to pursue wildlife research in India.

3.2. Research Facilities:

3.2.1. The Firestone Center for Restoration Ecology provides:

- A new Ecology Center with science laboratory and classroom
- Wireless internet connection and laptop computers
- Basic laboratory equipment (drying oven, balances, meters, glassware etc.)
- Field equipment (nets, traps, survey equipment, rubber boots, snake gaiters)
- Weather station and back-up rain gauge with logger. Ultrasonic stream flow meter/logger
- A digital library of FCRE research, bibliographic references for the projects
- Full-time, on-site staff: bilingual director of the Firestone Center, property caretaker and reserve supervisor, reserve worker, reserve park ranger.

3.2.2. Other Resources Related to Research

- Claremont Colleges Digital Library (e.g. electronic journal access, accessible to all student and faculty participants from the FCRE)
- GIS – ArcGIS ESRI site license and workstation at the Joint Science Department, GIS support at Honnold Library of the Claremont Colleges
- Hacienda Barú National Wildlife Refuge. We maintain an excellent relationship with the management, who continue to support our student research.
- Management services for the FCRE from Pitzer College.

3.2.3. Student Life on Site

- Student dormitory for eight students. Accommodation for 4 faculty

- Program House with dining facilities and wireless internet connection.
- Proximity to medical care (three clinics within a twenty-minute drive. A hospital within an hour's drive.)
- Support for the travel and intercultural dimensions of research abroad through the Center for Intercultural and Language Education at Pitzer College.
- Spanish Language conversation practice
- Ready access to other nearby protected areas and restoration projects

4. Student Recruitment and Selection:

We will accept eight students each summer for a total of 24 students over three years. Each year, two students will be selected from the Joint Science Department (Pitzer, Scripps, and Claremont McKenna Colleges.) Three additional students will be drawn from the other partnering liberal arts colleges in this proposal (Furman, Middlebury, and Pomona). Three students will be selected from other colleges, with particular attention given to students from schools offering limited research opportunities. We are particularly interested in accepting women and minority participants. An important goal of our REU program is *recruitment*; to that end, we will actively seek undergraduates early in their careers (freshman and sophomores) who have demonstrated an interest in the natural environment but may not yet have committed themselves to majoring in the hard sciences.

4.1. Recruitment:

We will use a combination of recruitment activities to produce an applicant pool with significant numbers of women and minority students:

4.1.1. Website: The project will have a website hosted by the Joint Science Department and linked to the websites of the participating colleges. The site will include

- A description of the overall program for "Integrating Tropical Ecology Research into the Undergraduate Curriculum" plus synopses of the four longitudinal research projects. Information on previous projects will be included after the first summer
- For each Research Mentor, a photo, biographical statement, personal statement on her/his particular interest in leading one of the projects for undergraduates.
- Details for the program, such as dates, description of responsibilities, safety guidelines, accommodation, meals, travel and cultural adaptation support, stipends, requirements for eligibility and recommended prerequisites or preparation.
- Contact information for the Director and the Center for Intercultural and Language Education at Pitzer College will be given to provide a source of advising and encouragement during the application process.
- A link to the Joint Science Department website for the FCRE, which supplies background information on previous and current research activities as well as GIS data and maps specific to the Firestone Center biological baseline assessment.

4.1.2. **Advertisements**: We will place advertisements in the newsletters or publications, including but not limited to the following:

Minorities in Science

- Society for Chicanos and Native Americans in Science (SACNAS)
- JustGarciaHill.org

Women Students:

- American Women in Science
- Earth Science Women's Network (ESWN)

4.1.3. Mailings: With the help of NSF and PKAL, we will identify 100 institutions with strong programs of environmental science and/or biology at Historically Black Colleges and Universities, Hispanic Serving Institutions, Tribal Colleges and Universities, and institutions serving Asian American and Pacific Islander students (as identified by the United States Department of Education List of Post Secondary Minority Institutions.) We will send announcements and flyers about the project to the chairs/deans of these programs.

4.1.4. Consortial Links: Pitzer College is a member of the FIPSE sponsored CIEL consortium (Consortium for Innovative Learning Environments), which includes a number of institutions that have limited opportunities for undergraduate field research. At the CIEL consortium meetings, we will make presentations to recruit women and minority student applicants to all the schools http://www.cielearn.org/ and particularly from members Alverno College, a women's college and Johnson C. Smith University, an historically black university.

4.1.5. Poster Sessions: Joint Science Department of The Claremont Colleges Summer Research Poster Sessions and Pitzer College's International Undergraduate Research Symposium provide two regular venues for showcasing the projects for recruitment purposes after the first year.

4.2. Selection:

Students will fill out an on-line application form, which will ask for basic demographic information, background in science, why they are interested in participating in this program, and what their career goals and expectations are. We will ask them for current transcripts and two letters of recommendation. Those writing on behalf of the applicants will be asked to describe the intellectual potential of the applicant, her/his interest in ecology, personal maturity, their ability to collaborate with others, and their potential for success in a field-based setting abroad. Considering these materials, the Director and Research Mentors will then select eligible participants who meet as many of the following criteria as possible:

- Have the basic scientific background and ability to succeed in program
- Contribute to the diversity of the student group
- Come from institutions where opportunities for undergraduate research are limited
- Are considering careers in biology or environmental science
- Have not had an overseas study experience
- Are early in their undergraduate careers.

5. Project Evaluation and Reporting:

The project will be evaluated in four steps. Assessment will be guided by a university-based consultant with expertise in qualitative and quantitative assessment as well student development. The evaluation data will be regularly reviewed by the Director/PI, Senior Mentors, and the evaluation consultant to determine if adjustments need to be made in the program as it proceeds.

5.1. Evaluation One: Prior to each summer research session, students will complete a survey specific to knowledge of their project area, field research methods, problem-solving strategies, program expectations, and career aspirations. Some open-ended questions will be included on anticipated challenges of studying in a rural setting outside the US, personal motivation for participating in the project, and potential areas of academic and personal concern for the students. An interactive, course management web-site (Sakai) will be set up for the project to allow students to post "work-in-progress" reports, share bibliographic resources, and receive feedback from Research Mentors and the Director.

5.2. Evaluation Two: At the mid-point of the summer research session, students will repeat the survey, participate in a focus group facilitated by a Research Mentor at the FCRE, and present oral and written "work-in progress" reports to the Research Mentor. Written progress reports will also be posted on the Sakai site with required commentary on work completed, data collected, problems encountered, support/resources needed, and emerging questions.

5.3. Evaluation Three: A third survey will be conducted at the end of each summer session with a final "work-in-progress" report posted on the Sakai site.

5.4. Evaluation Four: Students will have until the second week of September to write up and submit their final projects. Copies will be posted on the Sakai site and reviewed by the Research Mentors. Participants will prepare a poster presentation to display at their respective campuses. A digital version of the poster will be saved on the Sakai site so it is accessible to all participating campuses. After final review by Research Mentors, final papers will be posted in the Claremont Colleges Digital Library (CCDL). Students will be encouraged to continue the projects as senior theses. Each college with students participating in the program will be asked to commit to funding at least one of its students to do a poster presentation at a national conference in a relevant field.

5.5. Final Evaluation: In addition to these evaluation procedures, we will track the participants after leaving the program and offer advising and support toward graduate studies and career choices. Through the Sakai site, all current and past program participants will have the opportunity to remain connected to the project and future research initiatives at the Firestone Center. We will encourage project alumni who go on to graduate work to consider using the Firestone Reserve in their proposals, where relevant.

5.6. Reporting:

Annual reports will be provided through NSF Fastlane. Human subjects protection will be followed in all evaluation and reporting procedures. Abstracts of the REU projects will be created in English and Spanish and posted on the FCRE website. Copies of final reports will also be made available to ASANA (*Asociación de Amigos de la Naturaleza del Pacífico Central y Sur Costa Rica*)**,** the local environmental education association in the Barú region near the Firestone Center for Restoration Ecology. Summaries of the projects will be given each year in Spanish to the principal and science faculty of the local Platanillo High School, Platanillo, Costa Rica.