ARIZONA STATE UNIVERSITY

DATE: March 31, 2006

TO: Dr. Henry L. Gholz
Program Director, Long-Term Ecological Research (LTER)
Division of Environmental Biology, National Science Foundation

FROM: Nancy Grimm and Charles Redman, CAP LTER Project Co-Directors

RE: 2006 Combined Supplements Request for NSF grant **# DEB-0423704**
(Central Arizona-Phoenix Long-Term Ecological Research: Phase 2)

I. REU; III. International Collaborative Research; IV. Other; Trends in Long-term Ecological Data

I. RESEARCH EXPERIENCE FOR UNDERGRADUATES (REU)

Investigators: Nancy Grimm, Sharon Hall, Thomas Nash and others

We propose a program of undergraduate involvement in research on urban ecological systems. Students will participate in a sequence beginning with an assigned *question* through their own development of a research proposal in which *hypotheses, predictions,* and *tests* are outlined, to collection and analysis of *data*, and then to an oral presentation of *results* in a summer research symposium. Our program builds upon our 16 years of experience in sponsoring undergraduate research in environmental biology (REU-EB), supported by multiple NSF-REU supplements but managed as a single program. The 2006 summer REU program has already received inquiries, and we anticipate little difficulty in identifying qualified students using well-established recruitment methods and an online announcement describing this year's projects. The REU-EB (since 1990) and the Central Arizona–Phoenix Long-Term Ecological Research (CAP LTER) REU program (since 1999) has been successful in mentoring and training of undergraduate students; thus, we retain the philosophy, operational procedures and expectations, and recruitment strategy, which are described briefly here.

Philosophy and Modus Operandi

We assign to each CAP LTER REU student a question we feel is significant, requires no special expertise to answer (at least initially), and can be answered using both descriptive and experimental approaches. We correspond with students before the program begins, presenting the question, along with some background information and a short list of pertinent references. After a brief period (two weeks) of proposal development and intensive field and laboratory experience (with graduate students and postdocs), students collect data, conduct experiments, and analyze data for six weeks (including field trips and periodic oral progress reports). The last two weeks of the 10-week program are dedicated to preparing final reports and presentations.

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CAP LTER PIs, project managers, or postdocs are responsible for direct supervision of REU students. Each selected student is matched with a CAP LTER project, based partly on the investigator's ideas for a doable project and partly on the student's interests. The REU student will be responsible for his or her own project, but the project will interface closely with projects of the research group. It is equally important for students to learn that urban ecology must be cooperative and interactive as it is for them to gain technical skills.

Finally, a formal symposium and other more informal social activities are coordinated with other undergraduate research programs at Arizona State University (ASU). The existence of the university-wide Community of Undergraduate Research Scholars (COURS) program with many REU students working with IGERT in Urban Ecology Fellows, the previously mentioned summer REU-EB program, and the School of Life Sciences Undergraduate Research (SOLUR) program (with >50 student researchers) means there will be ample peer role models and opportunities to interact with other students pursuing similar paths. This interaction among programs has been very successful; each year, 10–15 students from different programs participate in the symposium and report the results of their summer research projects. In past years, ASU has supported the REU program by providing scholarships of $800 for each undergraduate student. This covers a waiver of tuition for six credits of research during the summer.

Recruitment

Recruitment of REU fellows has been from primarily undergraduate colleges, ASU, and other universities. Many of these institutions have our program in their files, as we regularly receive inquiries beginning in December of each year. In addition, we have a Web page and online application (http://sols.asu.edu/ugrad/reu/index.php). We update both this page and the CAP LTER home page (http://caplter.asu.edu) to reflect the CAP LTER REU. Our program contributes to advancement of affirmative action objectives by aggressively seeking women and minority candidates and by providing an opportunity for both female and male students of ecology to interact with female ecologists at faculty member, postdoctoral, and doctoral student levels (Table 1).

Table 1. Demographic composition of Summer REU applicant pool and fellowships awarded; 1990-2005. Minority category includes Latino/a, African American, and American Indian students; majority category includes Anglo and Asian American students. Values in parentheses are percentages of total applicants or fellowships.

Program	Female	Male	Minority	Ethnicity Unknown	Majority	Fresh or Soph	TOTAL
Applicants	275 (59)	194 (41)	71 (15)	205 (45)	192 (41)	na	469 (100)
Fellows	60 (64)	34 (36)	12 (13)	na	82 (87)	15 (16)	94 (100)

na= Not applicable or not available

Recruiting for this summer's REU applicants is aimed at groups underrepresented in ecology and related disciplines, in particular Latino, American Indian, African American, and female students. ASU's School of Life Sciences currently has a 25% minority enrollment in its undergraduate program, evidence of an increasing ability to reach and attract students underrepresented in the discipline.

Potential Projects

The following are projects that we will offer to students. We organize each project under a question that can be answered (in our experience) within the timeframe available. In addition to individual projects with scientists identified below, the students will be encouraged to aid one another in their field and laboratory work, which gives them a broader range of experiences as well as a sense of camaraderie with their fellow REU students.

Project 1: How does the urban atmosphere affect soil arthropod communities in Sonoran Desert ecosystems? Soil macrofauna, including ants and termites, play important roles in regenerating nutrients within terrestrial ecosystems. In addition to transporting materials across the landscape, these organisms often carry out the first step in decomposition by fragmenting senesced plant tissues and providing substrates with high surface area to microorganisms that complete the degradation process. Soil animals may be even more important to decomposition and nutrient turnover in arid systems like deserts where water may limit microbial processes. The student, working with Dr. Sharon Hall, will refine the question and develop a field-based study. Specific questions that the student can develop into a summer project are:

- What is the distribution and abundance of soil arthropods in Sonoran Desert systems surrounding the Phoenix metropolitan area?
- How important are soil arthropods in moving and/or decomposing organic material from Sonoran Desert plants?
- Does deposition from the urban atmosphere alter the structure of arthropod communities or their role in nutrient transformations?

The student will gain specific skills in macro- and microscopic identification of invertebrates, working with the CAP LTER's insect technician, in field sampling of invertebrates, in decomposition methods, and in designing parsimonious experiments to test hypotheses. He or she will be able to compare results with the students who are working on plant-associated herbivores and soil microorganisms.

Project 2: How does the urban atmosphere affect microbial activity in Sonoran Desert soils? Soil microorganisms require water, moderate temperatures, and essential elements to grow, including carbon (C), nitrogen (N), and phosphorus (P), among others. Human activities in cities produce volatile carbon and nitrogen compounds that travel through the atmosphere and are deposited to soils downwind of the urban area. If carbon and nitrogen deposition have been occurring in soils downwind of Phoenix for years, soil microbes that live there may be "feeding" on these nutrients, causing their growth to be limited by different factors than microbes that are living in soils upwind from the city where pollution is less intense. However, in these arid ecosystems, it is possible that soil microbes will only show their need for nutrients when they are under moderate temperatures and have adequate water to grow. The REU student will work with Dr. Sharon Hall to design and perform a controlled laboratory experiment to examine which nutrients limit microbial activity in soils collected from upwind, within, and downwind of the Phoenix metropolitan area. Examples of specific questions that can be developed into a summer project are:

- How do temperature and water affect microbial activity in Sonoran Desert soils?
- How do laboratory additions of nitrogen, phosphorus, or a range of different carbon compounds affect soil microbial activity?
- Does deposition from the urban atmosphere affect which nutrients limit microbial growth?

The student will gain specific skills in microbiological techniques, in field sampling of soils, in methods of measuring microbial activity, and in designing laboratory experiments to test hypotheses. He or she will be able to compare results with the students who are working on plant-associated herbivores and soil invertebrates.

Project 3: How does the urban atmosphere affect the body elemental content and abundance of plant-associated herbivores? Scientists are testing the hypothesis that deposition of nitrogen, an essential and often limiting nutrient, from the urban atmosphere will increase the proportion of that nutrient in plant tissues (leaves, roots, and stems of plants like creosote bush and bursage). However, we do not know whether any enrichment of plants is passed up the food chain to the herbivores that feed on those plants. If this urban deposition affects higher levels in the food chain, then we would expect herbivores in downwind positions (affected by urban atmosphere) to be more abundant, or have more nitrogen in their bodies, or both, than herbivores in upwind positions (outside the influence of the urban atmosphere). It is also possible that different species of plant-associated herbivores will become more abundant, i.e., that community structure will shift. Working with Dr. Nancy Grimm, the REU student will design a study to answer this question, incorporating field sampling of plant-associated herbivores at our 15 sites (5 each upwind, inside, and downwind of the city), identification of species, working with the CAP LTER insect technician, and determination of body nitrogen, carbon, and phosphorus content using an elemental analyzer and chemical methods. The student will be able to synthesize results of his/her study and compare them both with the project data on plant tissue chemistry and results of a similar REU study conducted in 2003 at different sites.

Project 4: What characteristics of urban open spaces and wildlife corridors contribute to higher species diversity and the presence of native versus non-native species? We invite applications for an REU position from undergraduates with a strong interest and track record in field ecology to work this summer on biodiversity in urban desert parks. The objective of our study will be to identify habitat and environmental characteristics that contribute to avian and mammalian species diversity and relative abundance, data which will be used to establish guidelines for both land development and preservation of natural areas. Research sites will be located in parks in the Phoenix metro area and the work will be carried out under the joint supervision of researchers from the CAP LTER project and local Arizona Game and Fish Department personnel. The work will consist of small mammal trapping, camera trapping, recreation counts, incidental observations, quadrat and line-transect vegetation sampling, scent station and track plate investigations, and owl broadcast surveys.

Project 5: How are long-term elemental deposition patterns changing in the Phoenix metropolitan areas as reflected in accumulation by lichens? Lichens, which have no roots, are primarily dependent on atmospheric sources of nutrients for their own nutrition, and as a conesquence, are very useful as surrogate receptors for atmospheric deposition. In 2006 a resurvey of 30 sites across Maricopa County is planned relative to an initial investigation made in 1998 and limited additional data from the 1970s. In so far as improved analytical techniques (HR-ICP-MS) are now available, we anticipate obtaining data from more than the 20+ elements analyzed last time. Working with Dr. Thomas H. Nash III and Mr. Ken G. Sweat (graduate student and instructor, ASU East), the REU student will be involved in all phases of the project over a year's period, including sample collection (spring 2006), sample preparation (summer 2006), sample analysis (fall 2006), and interpretation (spring 2007). In the context of analytical capabilities, the

student is expected to select three elements that potentially can be released due to anthropogenic activities, research their likely sources and document whether there are emission sources in the Phoenix metropolitan area. The student will then be able to develop hypotheses as to what the patterns should be, and test whether the patterns actually found in 2006 correspond to the anticipated results. In addition, the student will be able to address the question of whether patterns are varying temporally. It is anticipated that the student will be a co-author on publications resulting from the whole investigation.

Summary of 2004 REU Projects

REU fellows during 2004 conducted individual research in the field of urban ecology. Erin Adley (ASU) worked with Paige Warren to examine the impact of predator density and landscaping schemes on bird behavior in urban parks in Phoenix. Warren is using these research data for a manuscript in preparation. Kristina Waterbury (ASU) conducted work under the mentorship of Leslie Landrum at the ASU Herbarium to database all of its collections and create an interactive identification key online for all plants of Arizona. This work is now accessible through the Southwest Environmental Information Network (SEINet) at http://seinet.asu.edu/navikey/hasskey.jsp and includes interactive keys to vascular plants found in the Hassayampa River Preserve.

REU Summary Budget

Participant Costs	
Stipends	4,800
Travel	1,500
Subsistence	2,000
Other	2,500
TOTAL Direct Costs	10,800
F&A (25% stipends)	1,200
Total	**$12,000**

III. INTERNATIONAL RESEARCH COLLABORATION

Investigators: Nancy Grimm, Sharon Hall

We request funds to expand an existing comparative study of the effects of urban atmospheric deposition on deserts to Mediterranean and semi-arid ecosystems of Spain and Morocco. Requested funds would support international travel and analytical costs. This new collaboration will supplement an existing comparative study of cities in the Southwest and Mexico supported by separate NSF funding (Grimm et al., Ecosystems). These ecosystem comparisons are intended to test whether patterns established in our detailed study in the CAP LTER study region are robust in other arid and semi-arid cities. The extension outside of North America will open new possibilities for collaboration and allow us to evaluate our hypotheses in an Old World context.

Rationale

Arid and semi-arid regions have supported some of the longest-lived urban centers in the history of civilization (Redman 1999), and growth of cities during the next half-century will be concentrated in drylands, especially in the developing world (UN 2001). Research on urban atmospheric deposition, particularly of nitrogen and organic carbon, includes modeling and monitoring under CAP LTER research, augmented by experiments and short-term studies supported by a recent NSF grant. We have determined a relatively stable gradient of N deposition for Phoenix metro region, and there is reason to believe that most urban centers will exhibit some similar form of deposition gradient, with upwind sites having much lower deposition rates than sites within (core) or downwind of the cities. Very little is known of N and C deposition effects in drylands, as most research has focused on temperate forested ecosystems. To expand our research beyond the "case study" of Phoenix, we have established a regional collaboration of ecologists and atmospheric scientists; this small request would extend that collaboration to the Old World. Because Grimm expects to be on sabbatical in Spain during spring 2007 and our Penn State collaborator, Jason Kaye, has ongoing research in Spain, we have chosen that country as a good starting point for this extension.

Approach

We propose research and international collaborations to study dryland cities of Mediterranean Europe and northern Africa, to supplement our North American desert city network of Phoenix, Albuquerque, Tucson, Las Vegas, and Hermosillo. The research will test the generality of patterns of urban deposition and ecosystem response seen in Phoenix. For each city, we will gather existing information on depositional gradients through interactions with our collaborators, and select appropriate ecosystem sampling sites upwind and downwind from the city. We will then deploy resin collectors developed at our site to measure bulk deposition, and analyze collector, plant, and soil samples from each site. After all samples are processed, we will exchange data and results among all participants in the comparison and develop synthesis products from the work. We hope these activities will form the beginning of a collaborative network of scientists interested in urban deposition effects in drylands. A workshop is planned for 2008 that will be used to formulate a plan for the next steps of this collaboration.

Hypotheses Tested

We will test the hypotheses that N deposition from urban areas causes P limitation in native plant communities, and microbial growth will be less dependent on soil organic matter as micro-

organisms utilize C compounds from the atmosphere. We will test Hypothesis 1 with a simple greenhouse experiment, growing a single desert-annual plant species in soils collected from each site, fertilized with N, P, and N+P. We also will analyze plant tissue collected from each site for C, N, and P. We will test Hypothesis 2 by measuring soil respiration (CO_2 flux, LiCor 8100) under plants and plant interspaces, in both upwind and downwind sites.

Predictions

In the field, foliage from plants exposed to the urban atmosphere (downwind) will have lower C:N and wider variation in N:P than foliage from plants growing in upwind areas. In the greenhouse, productivity of a desert annual grown in soils exposed to urban atmospheres will increase in response to P addition, whereas growth in soils not affected by the urban atmosphere will respond to N. In the field, the difference in CO_2 evolution between soils beneath plant canopies and those from plant interspaces will be larger in soils from downwind sites than in soils unaffected by urban atmospheres (upwind sites).

Collaborators

We have existing or developing collaborations with individuals in Spain, Morocco, and Mexico. Several of these individuals have agreed to host our visits and collaborate in establishing deposition patterns and collecting samples. The Mexico collaboration, with Hermosillo ecologists Alberto Búrquez-Montijo and Angelina Martínez-Yrízar, Universidad Autonóma de Mexico, is already established and funded. In Spain, Kaye has collaborated with soil scientists Joan Romanya and Ramon Vallejo (Universitat de Barcelona) and Jordi Cortina (Universidad de Alicante); Grimm has ties to ecologists Eugenia Marti Roca (Centre d'Estudis Avançats de Blanes), Carlos Montes (Universidad de Madrid), and Maria Rosario Vidal-Abarca (Universidad de Murcia). Moroccan collaborator Bachir Raissouni, an environmental scientist and director of the Alakhawayn University's Center of Environmental Issue and Regional Development (CEIRD), will be contacted through a developing relationship with the Global Institute of Sustainability (Redman, Director).

International Summary Budget

Travel	
Foreign	4,000
Domestic	
Materials/Supplies	2,000
TOTAL Direct Costs	6,000
F&A other (26%)	1,560
Total	**$7,560**

IV. OTHER

We request "other supplemental funds" in two categories: 1) personnel time for one-time, critical data acquisition to fill a gap in our long-term monitoring; and 2) information management to automate the flow of information from the field and laboratories into CAP LTER databases, and to develop a more efficient and effective system for archiving reference (voucher) samples. Project 1 is part an existing CAP LTER project, the Phoenix Area Social Survey.

Comparison of Public and Scientists' Understandings of Local Environmental Problems
Investigators: Sharon Harlan and the PASS Team

This request is to support a one-time study which will compare understanding of local environmental problems between two groups – scientists and the public. This study is an extension of the Phoenix Area Social Survey (PASS) and builds on the data that will be gathered through administration of the PASS in spring 2006 to households in 40 neighborhoods in the greater Phoenix area.

During the planning phase for the PASS 2006, in which 20 CAP LTER social and biophysical scientists and graduate students took part, we identified a new area of study that expands our research aims to include: (1) a comparison of the general public's and CAP LTER scientists' understandings of local environmental problems; and (2) a comparison of attitudes of the general public and CAP LTER scientists toward the effectiveness of contrasting policy solutions to these problems. This new study will focus on the following areas of environmental concern (which are also embedded in PASS 2006): water shortages, urban sprawl, the spread of the urban heat island, and air pollution. Understanding/knowledge will be measured by respondents' ratings of statements that are designed to elicit perceived relative importance of natural forces, socioeconomic drivers, and individual responsibility as causes of environmental problems. Attitudes toward solutions will be measured by respondents' ratings of statements that elicit factors reflecting support or opposition to regulation, taxes and fees, price incentives, technological fixes, and public education approaches to environmental problem-solving. This study will reveal the extent and character of differences in public and scientific understandings of environmental problems and remedies, and will establish a baseline for measuring changing over time.

We believe this is one of the most innovative areas of inquiry that emerged from the PASS 2006 interdisciplinary collaboration. Conducting this more in-depth study will allow us to better understand how to bridge scientific knowledge and policy to improve the quality of the environment and human life in our study area. In order to take advantage of this opportunity, we are seeking supplemental funds for one-time sample and data acquisition using social survey and focus group methods. The funds will be used to pay for services of the Institute for Social Science Research (ISSR) at Arizona State University, which is currently administering PASS 2006 surveys. ISSR will implement the data collection and preparation phase for the comparative study of local residents and scientists. The data will be analyzed and published by the PASS research team.

Streamlining the flow of information into databases and reference-sample archiving
Investigators: Corinna Gries and Stevan Earl

We propose to capitalize on existing but underused technology to (1) automate the flow of information from the field and laboratories into CAP LTER databases, and (2) develop a more efficient and effective system for archiving reference (voucher) samples.

We propose to streamline data transfer by replacing field data sheets with hand-held computers (PDAs). We will develop custom programs for entering field data directly into PDAs that will incorporate features such as pull-down menus. Synchronizing PDAs with CAP LTER databases will reduce time required and mistakes associated with typing information into the database. Non-volatile memory, now standard in PDAs, will ensure that data collected in the field are secure. We request funds to purchase PDAs, develop custom programs, and establish procedures for dumping field data into the database. Programming efforts will be informed by the Jalama project (http://jalama.ecoinformatics.org) and experiences at other LTER sites.

As with field data sheets, transferring output from analytical instruments to databases is both time-consuming and mistake-prone. We will establish a protocol whereby the output from our analytical instruments is formatted properly and dumped into a database via an online server. The initial phase of this project will require a considerable investment in programming due to the unique output formats of analytical instruments and to establish quality-control routines. We request funds for this development work to be completed by a student programmer.

We propose to link reference samples to sample information contained in the database by labeling reference samples with barcodes. We will dedicate an archival room to house reference samples. Procedures and database design will be modeled after the plant voucher-specimen collection, developed and implemented successfully in collaboration with the ASU Herbarium. In addition to equipment, we request funds for an undergraduate student worker to label and catalog a backlog of over 8000 water, soil, and arthropod reference samples. Following this initial phase, samples collected as part of our monitoring and research programs will be entered by the technical staff during routine operations.

Other Supplement Summary Budget	
Shelving	300
PDA (3 @ $400/unit)	1,200
Barcode generating software	200
Barcode scanner	100
Personnel, professional	3000
ERE (25%)	750
Personnel, graduate hourly	4,900
ERE (4%)	196
Personnel, undergraduate	8,840
ERE (4%)	354
TOTAL Direct Costs	19840
F&A other (26%)	5158
Total	**$24,998**

ADDITIONAL REQUEST

Trends in Long-Term Ecological Data

Investigators: Christopher Boone and Corinna Gries

The goals of the Trends project are to create a platform for synthesis by making long-term data accessible and to illustrate the utility of this platform in addressing within-site and network-level scientific questions. To do this, we are collecting long-term data sets from all 26 LTER sites, 8-10 US Forest Service sites, and 8-10 USDA Agricultural Research Service sites. Four types of data are being collected for each site: (1) climate and physical variability, including disturbances, (2) human population and economy, (3) biogeochemistry, and (4) biotic structure, including biodiversity. We are generating two products: (1) a book to be published by Oxford University Press on trends in long-term data within and among sites, and examples that illustrate the value of long-term data in addressing important questions; (2) a web page containing derived data and metadata that are easily accessible for synthetic analyses.

This supplement request will provide funds for the collection, synthesis, and documentation of available human population and economic data for each site for the period from 1790 to 1960 (a separate supplement through the University of Georgia will do the same, using different data sets, for the period 1970 to 2000). Data collection will be based on a successful pilot project Boone already carried out for the Baltimore Ecosystem Study. Data will be collected, synthesized, and documented for the given extents of each LTER site using federal data sets, including the population, economic, and agricultural censuses, as well as specialized volumes such as the county and city data books, and labor statistics. The data are available through the Inter-University Consortium for Political and Social Research web site (http://www.icpsr.org), of which Arizona State University is a member, the Center for International Earth Science Information Network (http://www.ciesin.org/), the US Census Bureau (www.census.gov), the USDA National Agricultural Statistics Service (http://www.ciesin.org/), and the US Department of Labor Bureau of Labor Statistics (http://www.bls.gov/). All data will be attributed to a GIS geodatabase derived from the Historical United States County Boundary Files (HUSCO). The GIS geodatabase will allow spatial organization and queries of data and permit visualization of long-term trends. Standard Federal Geographic Data Committee metadata protocols will be used, and the data will be archived in the CAP LTER database.

Trends Budget

Personnel, faculty	3,172
ERE (25%)	793
TOTAL Direct Costs	3965
F&A other (26%)	1031
Total	**$4996**

LITERATURE CITED

Redman, C. L. 1999. Human dimensions of ecosystem studies. *Ecosystems* 2:269-298.

UN (United Nations). 2001. *World Urbanization Prospects: The 1999 Revision.* United Nations Population Division, New York.