Center for Applied Tropical Ecology and Conservation
NSF HRD-0734826
Dr. Elvira Cuevas
Director
I. Organizational Chart of the Center

The Center for Applied Tropical Ecology and Conservation (CATEC) is under the Dean of the College of Natural Sciences of the University of Puerto Rico, Rio Piedras campus. It is an intra-campus, multi campus center with participation from professors and students from UPR-Rio Piedras Department of Biology, Department of Mathematics and the Department of Environmental Sciences, UPR-Humacao campus and the UPRM-Rio Piedras Experimental Station, and close collaborative ties with the PR Department of Natural Resources and Environment, the USDA Forest Service International Institute of Tropical Forestry and the USGS Caribbean Water Science Center.
May 14, 2012

Dr. Richard Smith  
CREST Program Director  
Division of Human Resource Development  
National Science Foundation  
4201 Wilson Boulevard Room 815  
Arlington, Virginia 22230

Dear Dr. Smith:

I am pleased to write this letter of support for the CREST Center for Applied Tropical Ecology and Conservation (CATEC) under the direction of Dr. Elvira Cuevas. As Chancellor of the Rio Piedras Campus of the University of Puerto Rico, I express my full support to the center, which I believe has already shown excellent progress in its establishment and development.

I hereby certify that the University of Puerto Rico will continue to provide the matching funds as established in the Cooperative Agreement No. HRD-0734826 of the CREST grant. The matching funds in the amount of $300,000.00 are allocated from the Central Administration ($225,000.00) and the Office of the Chancellor of the UPR-Rio Piedras Campus ($75,000.00) for the period 2012-2013.

Sincerely,

Ana R. Guadalupe, Ph.D.  
Chancellor
1.3 Project participants

CATEC participants reflect our two-fold mission: to train a new generation of Hispanic scientists and professionals with strong education and research experience in applied ecology and conservation that integrates research activities with societal needs, and to become an institutionally established center that promotes and supports state-of-the-art research in applied ecology and conservation. Ninety five per cent of our participants are Hispanic research scientists and students carrying out inter- and trans-disciplinary research in three strategic thrust areas under the unifying theme of biodiversity conservation under a scenario of climate change. All projects foster synergetic interactions within each thrust area, the University of Puerto Rico system, and local, national and international agencies and institutions.

We have been very successful in developing the Center concept at UPR-Rio Piedras. Each thrust area provides a broad research venue so that researchers and students, both at the graduate and undergraduate level, can choose and develop their research interests. The Center concept also provides an excellent opportunity for the members of the thrust areas to interact and collaborate within and across thrust areas. This is a transformative development of interactions across disciplines that have become a role model for other activities at the institution.

This year we had 165 participants in CATEC (including administrative personnel), of which 78% are students, maintaining a similar ratio of graduate to undergraduates as the previous year. Forty percent (40%) are funded directly by CATEC. We leverage resources with other programs such as NIH SCORE, RISE and MARC, NSF
Bridge to the Doctorate, GK-12, LSAMP, IGERT, REU and UMEB, NOAA Sea Grant, NSF/USDA-SF Ultra, EPA, UPR DEGI Honor Scholarships, etc. We also take advantage of undergraduate research training courses in Biology and Environmental Sciences where students receive university credits for the research they are carrying out in our thrust areas.

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I.4 DIRECTOR’S NARRATIVE OF THE CENTER’S ACHIEVEMENTS:

Phase II of CATEC ((NSF-HRD 0724836) expands the research and activities carried in the first phase of the Center to include research under the scenario of global climate change and climate variability in the Caribbean. The research areas of the Center are divided in three major thrust areas: Molecular Ecology and Evolution Group (MEEG), Species Population and Management Group (SPMG) and the Ecosystems Processes and Function Group (EPFG). All the thrust areas interact in research and human resource development by collaborating in the various research projects and actively participating as research mentors of graduate and undergraduate students and members of graduate students’ theses committees. Being the University of Puerto Rico a Hispanic serving institution we considered that increasing the participation of undergraduate and graduate students in research is a top priority. For this reason Phase II of CATEC maintains the commitment for transformative research and human resource development established in Phase I of the Center.

Our graduate and undergraduate students benefited this year from training in laboratories at other universities. Our research fellows and students presented their research results in national and international meetings. This year we had 94 presentations in local, national and international meetings, congresses, symposia and seminars. Fifty-eight per cent (58%) were either presented or coauthored by students. We also had 75 publications (published, accepted, or submitted under review) of which students were main authors in 33% of the publications and co-authors in 28% of them. Some of our research fellows were invited speakers in international meetings and congresses in Venezuela, Bolivia, Colombia and Scotland. This year UPR-Rio Piedras approved the new Department of Environmental Sciences. The Institute of Tropical Ecosystem Studies is now part of the newly created department. CATEC research fellows from the SPM and EPF areas are part of the graduate program in Environmental Sciences. We are very proud of CATEC’s research fellow Dr. Maria G. Dominguez who received a Sloan Foundation grant on Microbiology of the Built Environment Program. She will examine the microbiomes of homes across cultures, from hunter-gatherers in remote villages in the Peruvian Amazon
to modern houses in Manaus, Brazil. This is the first Sloan grant received by the University of Puerto Rico – Rio Piedras.

Some of this year’s accomplishments area as follows:

Four (4) CATEC sponsored graduate students, Alberto Puente-Rolon (PhD - Biology), Rafael Benitez Joubert (MS – Biology), Mariely Hernández (MS - Mathematics) and Keyla Pagán-Rivera (MS - Mathematics) graduated this year. Keyla Pagán-Rivera obtained funding for pursuing PhD studies at the Biostatistics Department, University of Iowa. Dr. Puente- Rolon is assistant professor at the Interamerican University in Arecibo, PR. Mr. Benitez-Joubert is currently working as a limnological researcher with the Agricultural Experimental Station in Rio Piedras. Post-Doctoral Researcher Dr. Julissa Rojas Sandoval, accepted a postdoctoral position at the Smithsonian Institution to start this summer. Five undergraduate students are pursuing graduate studies, one was accepted at Medical school and another is starting Law School next fall, specializing in Environmental Law. One undergraduate student is doing a summer internship at the EPA, Atlantic Ecology Division, NHEERL, Rhode Island. Another is in a student training activity sponsored by NC State and the US Forest Service. This activity is a joint training of NC State and UPR undergraduate students who will visit various key localities for Ecological Research in Puerto Rico and North Carolina.

CATEC continues to be very successful in the following areas:

a) Improvement of administrative management and research facilities, both at UPR-Rio Piedras and UPR-Humacao.

b) Thesis and training support for students working in the area of applied ecology and conservation in CREST sponsored research and others not directly supported in the CREST grant.

c) Promotion, support or sponsoring of activities such as seminars, symposia and workshops, and short courses.

d) Support for researchers' and students' travel for training, courses, or presentations in congresses and symposia.
e) Financial support of additional research projects related to CREST supported thrust areas.
f) Maintenance and development of the web page for the Center.
g) Maintenance and development of web pages for CATEC's research fellows and laboratories.

CATEC co-sponsored along with the Environmental Sciences IGERT Program the course “Policies for Coastal Protected Areas” given by Dr. Maria Gimenez Casalduero, from Universidad de Alicante, Spain. We also sponsored the meeting “Climate change: Coastal Scenarios in the Caribbean”. The Zoology Festival from the Department of Biology, UPR-Rio Piedras was also co-sponsored by CATEC. This is great outreach activity where students and the public in general are exposed to the fascinating world of zoological studies. We had the formal presentation of the CATEC-sponsored book “A Systematic Vademecum of the Vascular Flora of Puerto Rico” where research fellows James Ackerman, Eugenio Santiago and Raymond Tremblay gave short presentations about the history of the project and the relevance of the book for scientists and naturalists interested in the flora of Puerto Rico and the Caribbean.

CATEC closely collaborates with other UPR centers, programs and institutes such as 1) the Resource Center for Science and Engineering, PR-LSAMP, Bridges to the Doctorate and GK-12 program of UPR Central Administration, 2) DEGI (Deanship of Graduate Studies and Research) of UPR-Rio Piedras, 3) the UPR-Rio Piedras IGERT Graduate Program of Environmental Sciences, 5) the UPR-Rio Piedras Department of Environmental Sciences (Institute of Tropical Ecosystem Studies REU and UMEB), 4) the University of Puerto Rico-Mayagüez Caribbean Coral Reef Institute, Department of
Marine Sciences, 6) the UPR-Mayagüez Experimental Station at Rio Piedras, 7) the UPR-Mayagüez Puerto Rico Water and Environmental Resources Research Institute, and 8) the Environmental Health Program of the Department of Public Health at UPR Medical Sciences campus.

We have also established close collaborations with national and international universities and institutions, such as Cornell University, Department of Energy Joint Genome Institute, Earlham College at Indiana, Fairchild Tropical Botanical Garden, Florida International University, Florida Institute of Technology, USDA Agriculture Research Service, Florida Department of Plant Industry, J. Craig Venter Institute, Lawrence Berkeley National Laboratory, Montgomery Botanical Center, New York Botanical Garden, Portland State University, San Diego Zoo, Toledo Zoo, Texas A & M College Station, University of Washington-Seattle, North Carolina State University, Michigan State University, University of Miami, University of New Hampshire, University of Washington, Interamerican University – Bayamon campus, Universidad Nacional Autónoma de México at Iztacala, The Leibniz Center for Tropical Marine Ecology Bremen, Germany, Texas A&M College Station, Organization for Tropical Studies, Universidad de Antioquia (Colombia), Universidad Nacional de Colombia at Palmira, Universidad del Zulia, Universidad Simón Bolivar and Instituto Venezolano de Investigaciones Científicas (Venezuela), National Botanical Garden Rafael Moscoso (Dominican Republic), Universidad Autónoma de Santo Domingo (Dominican Republic), Universidad Tecnológica de Santo Domingo (Dominican Republic), St. Eustatius National Park (Netherland Antilles), Royal Botanical Garden in Melbourne (Australia), Tenerife Natural History Museum (Canary Islands, Spain), Muséum d'Histoire Naturelle du Mans (France), Colegio de la Frontera del Sur, (Mexico), Instituto Argentino de Oceanografía (Argentina), University of South Bohemia (Czech Republic), Universidade do Estado do Rio de Janeiro (Brazil), CENA Universidade do Sao Paulo (Brazil), and Universidade Federal do Amazonas and Universidad Federal do Pará (Brazil) among others.

We continue to build on the collaborative ties with the Department of Natural Resources and Environment of the Government of Puerto Rico, the USDA Forest Service
International Institute of Tropical Forestry, the USDA El Yunque National Forest, the US Geological Survey Caribbean Water Research Center, US Fish and Wildlife Service, the US Environmental Protection Agency, the San Juan Bay Estuary Conservation Program, Puerto Rico Conservation Trust, and the Puerto Rico Aqueduct and Sewer Authority. We also collaborate with non-governmental and community associations in Puerto Rico such as Chelonia, Citizens of the Karst, Coralations, Centro de Apoyo Comunitario de Rio Piedras (Rio Piedras Community Support Center, CAUCE), Coalicion Corredor Ecologico del Noreste (Coalition for the Northeastern Ecological Corridor), Sierra Club, Vegabajeños Impulsando Desarrollo Ambiental Sustentable (VIDAS) and Sociedad Ambiente Marino.

CATEC is participating jointly with IGERT and AlaCima in the NSF-1038166: Maximizing Yield Through Integration (MYTI): Science and Math Education in the Context of a Disposing Society. We also submitted a supplement related to Lionfish invasion in the Caribbean. Our research fellows have also submitted proposals and have been successful in obtaining other grants. They also presented their research results in national and international meetings and increased the number of publications.

CATEC continues to work very closely with our natural partner, the Department of Natural Resources and Environment (DNRE) of Puerto Rico. Our research results provide a basis for the management and policy implementation of the natural resources of the island.

We continue to work together with the UPR-Rio Piedras administration in order to improve the management of large grants.
And last but not least, we are in the process of writing the proposal for the Center’s institutionalization, which will be presented to the University authorities for consideration and approval in the coming year.

**Administrative aspects:**

1- **Headquarters** – In order to maintain administrative efficiency we have a small but highly effective and committed administrative team: an Administrative Coordinator: Mrs. Madelyn Aquino, an Information Coordinator, Mr. Joel Ruiz: an Administrative Secretary: Ms. Adriana Morera, an Administrative Assistant: Mrs. Gloria Cintrón, and two part-time undergraduate students, Juan Carlos Rodriguez and Abigail Rosario. The Center administrative responsibilities continue to expand as a result of the Center’s activities, increased amount of students and research fellows and management of other grants. Our headquarters in the Facundo Bueso building Rooms 301A-C are fully operational. We have two offices and one small conference room already set up via wireless connection for LAN and INTERNET for the administrative personnel and 30 more computers at one time. In the conference room we also have video conferencing facilities. The conference room and video conferencing facility is in constant use for presentations, graduate committee meetings, research and laboratory meetings and even job interviews. We also added the lobby area as a meeting place for students and researchers. This is an example of the added value of ancillary infrastructure development that feeds back into improvement of research and communication.

2- **Grant management** - The administrative team intensively works on the following tasks:
   
a - Contracts and student stipends for the Center participants
b - Purchase of equipment, materials and supplies

c - Administrative work for research fellows Drs. Raymond Tremblay and Dr. Dennis Fernandez - University of Puerto Rico-Humacao, Dr. José Carlos Rodrigues, UPR-Mayaguez, Dr. Miguel Garcia and Mr. Carlos E. Diez - Department of Natural Resources and Environment, Dr. Maria-Egleé Pérez - Mathematics Department, UPR-Rio Piedras, Drs. James Ackerman, Elvira Cuevas, Edwin Hernandez, Eugenio Santiago, Ingi Agnarsson, Riccardo Papa and Paul Bayman - Biology Department, UPR-Rio Piedras, and Elvia Melendez-Ackerman, Jorge Ortiz, Mei Yu and Olga Mayol-Bracero from the Institute of Tropical Ecosystem Studies, UPR-Rio Piedras.

d - Administrative work for additional grants.

e - Administrative work for field work in the various forests and reserves in Puerto Rico and international travel and field work to Dominican Republic, St. Eustatius Lesser Antilles, Mexico and Brazil.

f - Administrative work related to travel for researchers, students and visitors.

g - Arranging and supervising the logistics of the activities sponsored by the Center.

h - General administrative work related to the activities of the thrust areas.

i - Organization and logistics of the Scientific Advisory Committee visits

j - Responsible for the inventory of NSF and other grants purchased equipment.

3- Technical and Information Support:

Web page: Mr. Joel Ruiz, the data/systems-informatics manager, in coordination with the High Performance Computing Facility (HPCF) of the Resource Center for Science and Engineering continues to manage and develop the Web site of CATEC, http://catec.upr.edu/. CATEC's web page provides information about the Center, ongoing research projects and activities such as workshops, symposia, meetings, etc., announces the different activities of the research groups, other research centers, and people related
to CATEC. In addition each member of the program can have his/her own web page in the Web Site. As the center has continued to expand it is a work in progress. This is an example of the highly successful collaboration established between the Resource Center for Science and Engineering and CATEC.

a- Development of web collaboration: This system is a web based application so that the professors, investigators, students and collaborators can save, share, and publish all the information related to their investigations. The system is divided by each sub-project with the capacity to be able to work altogether. Mr. Ruiz continues to create a user-friendly page where researchers can upload all the information and data originating from their research projects. Mr. Ruiz also assists the Dean's Office in other activities and advises and coordinates server management of the UPR-Rio Piedras Biology Herbarium and UPR Botanical Garden Herbarium Digital Plant Collection.

b- Computational support for other laboratories: CATEC continues to provide computational support for integrating and managing hardware and software to all CATEC related laboratories.

c- Coordination and technical support for the research fellows in the Center.

d- Coordination of videoconferencing facility. CATEC and non-CATEC community use the videoconferencing facility at least three times a week.

e- Preparation of audiovisuals for presentations and symposia of CATEC and the College of Natural Sciences.

f- Preparation of Posters, Power Point presentations and flyers.

g- Photographing, videotaping and maintaining a record of the Center activities.

h- Coordinating and supporting the audiovisual needs of conferences, short courses and workshops.
Our web page received 2,520 hits from July 1st, 2011 till 30 May 2012. Fifty-nine per cent (59%) of the hits are from Puerto Rico, thirty per cent (30%) from the United States in general, and the rest from countries such as Brazil, Spain, Germany, France, Colombia, China and Canada. Via our web page we are providing exposure not only to CATEC’s activities but also to the Graduate Programs of Biology and Environmental Sciences of UPR-Rio Piedras.

Since 2010 CATEC is part of the social network via its Facebook page: (http://www.facebook.com/profile.php?id=10000649484619). This way we can broadcast to our students, researchers and collaborators in general the activities, events and research related publications. Our Facebook page also provides an information venue for the public in general about the sponsored activities of the Center. This year we instituted real time view of conferences via our web page simultaneously being announced in our Facebook page. We were even congratulated on the first year of our page thanking us for the help we provide to graduate students! Here are some examples of these activities:
**Issues at hand:**

We continue to receive the full support of the President, Chancellors, Dean of Natural Sciences, Dean of Graduate Studies and Research, and the heads of the Department of Biology and ITES.

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**- University administration**

There has been considerable improvement in the purchasing and response time related to payments, reimbursements, etc. The Human Resources Offices is establishing a proper classification system for research personnel. The Assistant Deanship of External Funding (DAFE, for its Spanish acronym) was created in 2011 and is the operational unit of the Office of the Dean of Graduate Studies and Research (DEGI) that works with the UPR-RP community in the identification of external funding sources, the development and submittal of proposals, and the awarding of grants. Through a Title V grant the post-award management phase of DAFE is now being implemented. We hope that these steps will help the development of a more streamlined, time and cost effective way of award management.

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**- Remodeling of laboratory facilities:**

- CATEC continues to improve infrastructure development in the areas of ecology and conservation. Most of our laboratories are state of the art research facilities and some are being remodeled to become so.

- We continue to help in the infrastructure of the two largest herbaria in Puerto Rico, at the UPR-Rio Piedras Campus (UPRRP Herbarium) and the UPR-Botanical Garden (UPR Herbarium). Both are key facilities for botanical and ecological research related to CATEC. During this year, the Botanical Garden Herbarium facilities reached full capacity for data basing and digitizing specimens.

- Dr. Elvia Melendez-Ackerman, Sub-director of CATEC and research fellow in the Population and Ecology and Management Group, shares a small laboratory in the basement of the Facundo Bueso building. The Dean of Natural Sciences is
very much aware of the unsatisfactory space situation and through ARRA funding remodeling of the new facilities is expected to start by August 2012.

- Graduate Student recruitment:
CATEC has been very effective in island-wide recruitment of graduate students. We need to actively recruit at other universities in continental US. However, stipends continue to be a problem as ours are lower and do not compete with those from other universities in the continent. This is a situation that needs to be resolved with the UPR authorities.

- Other issues:
As the Center continues to develop and become independent of CREST funding, it will benefit with the hiring of an officer in charge of identifying new sources of funding, helping in grant writing and outreach. The institutional funds do not provide for this person, so identifying and following up on sources of funding continues to be one of our goals. As we are going to apply for the institutionalization of the Center within the coming year, this position will be included in the proposal.

I.5 BIOGRAPHICAL INFORMATION OF NEW RESEARCH FELLOWS:

I.6 ACCOMPLISHMENTS

Indicators of progress:
CATEC has had excellent progress on the goals defined since the establishment of the Center. We consider indicators of progress to what level are we meeting the goals established in CATEC. Below are the results of this year accomplishments.

Goal 1: Increase the participation of our undergraduate and graduate students in research activities.

Increasing the participation of Hispanic undergraduate and graduate students in research is a top priority for CATEC as the University of Puerto Rico is a Hispanic institution. Since the first year of Phase-II of CATEC we have continued to increase the number of students. This year we had 159 participants in CATEC, of which 81% are students,
maintaining a similar ratio of graduate to undergraduates as the previous year. Forty percent (40%) of the students are funded directly by CATEC.

We leverage resources with other programs such as NIH SCORE, RISE and MARC, NSF Bridge to the Doctorate, GK-12, LSAMP, IGERT, REU and UMEB, NOAA Sea Grant, NSF/USDAFS Ultra, EPA, UPR DEGI Honor Scholarships, etc. We also take advantage of undergraduate research training courses in Biology and Environmental Sciences where students receive university credits for the research they are carrying out in our thrust areas.

### CATEC Participants by Period

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<tr>
<td>Graduate</td>
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</tr>
<tr>
<td>Undergraduate</td>
<td>44</td>
<td>69</td>
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<td>77</td>
<td>92</td>
</tr>
<tr>
<td>Technicians</td>
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<tr>
<td>Total</td>
<td>111</td>
<td>139</td>
<td>145</td>
<td>161</td>
<td>159</td>
</tr>
</tbody>
</table>

Ten per cent (10%) of CATEC participants are non-US citizens or residents. Three graduate students are non-US citizens or residents and are paid from other sources than CREST. All the undergraduates (92) and the majority of the graduate students are US-citizens or residents of Hispanic origin. The ratio of two to one (2:1) of female to male students is representative of the College of Natural Sciences.

### Participants by Gender by Period

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<tr>
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<td>Research Fellows</td>
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<tr>
<td>Technicians</td>
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<tr>
<td>Total</td>
<td>59</td>
<td>52</td>
<td>111</td>
<td>54</td>
<td>85</td>
</tr>
</tbody>
</table>
Students are being trained in experimental design, research methodology, and hands-on activities in both laboratory and field. They also are trained in how to make effective scientific presentations, and in writing scientific manuscripts. Therefore our students are receiving a very well rounded education in scientific research.

**Presentations in meetings** are very good indicators of student involvement and training in research. Students benefit by not only expanding their cultural horizons but also by being exposed to other scientific groups and a review of their peers.

This year we had 93 presentations in local, national and international meetings, congresses, symposia and seminars. Our graduate and undergraduate students (almost all Hispanics) presented their work at local, national, and international meetings held in Costa Rica, Canada, Mexico, Brazil, Dominican Republic, Colombia, Greece, Puerto Rico, California, Illinois, Washington, New Orleans, Texas, among others.

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</tr>
</thead>
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<td>11</td>
<td>35</td>
<td>25</td>
<td>33</td>
<td>117</td>
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<tr>
<td>SPM</td>
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<td>EPF</td>
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<td>32</td>
<td>21</td>
<td>14</td>
<td>54</td>
<td>137</td>
</tr>
<tr>
<td>Total</td>
<td>52</td>
<td>81</td>
<td>86</td>
<td>55</td>
<td>93</td>
<td>367</td>
</tr>
</tbody>
</table>

Fifty-eight percent (58%) were either presented or coauthored by students. We maintain the milestone where our students are totally involved in all the aspects of research.

<table>
<thead>
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<tr>
<td>MEEG</td>
<td>Primary Author</td>
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<td>Co-Author</td>
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<td>23</td>
<td>44</td>
<td>42</td>
<td>38</td>
<td>80</td>
</tr>
</tbody>
</table>
Authoring and co-authoring of publications are excellent indicators of capacity building in science. The table shows student involvement in publications. In thirty-five per cent (35%) of the publications the students are primary authors. Twenty-eight per cent (28%) are co-authored by students. This way, students are trained to understand the importance of the peer-review process and dissemination of results.

### Publications by Students

<table>
<thead>
<tr>
<th>Thrust Area</th>
<th>Total Published</th>
<th>Student Principal Author</th>
<th>Student Coauthor</th>
<th>% Principal Author</th>
<th>% Coauthor</th>
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<td>4</td>
<td>28%</td>
<td>22%</td>
</tr>
<tr>
<td>SPM</td>
<td>11</td>
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<td>2</td>
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<td>18%</td>
</tr>
<tr>
<td>EPF</td>
<td>15</td>
<td>3</td>
<td>7</td>
<td>20%</td>
<td>47%</td>
</tr>
<tr>
<td>Totals</td>
<td>44</td>
<td>10</td>
<td>13</td>
<td>23%</td>
<td>30%</td>
</tr>
</tbody>
</table>

### Accepted, Waiting Publication

<table>
<thead>
<tr>
<th>Thrust Area</th>
<th>Total Accepted, Waiting Publication</th>
<th>Student Principal Author</th>
<th>Student Coauthor</th>
<th>% Principal Author</th>
<th>% Coauthor</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEEG</td>
<td>5</td>
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<td>4</td>
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<td>0%</td>
</tr>
<tr>
<td>EPF</td>
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<td>0%</td>
<td>60%</td>
</tr>
<tr>
<td>Totals</td>
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<td>36%</td>
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### Submitted, Under Review

<table>
<thead>
<tr>
<th>Thrust Area</th>
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<th>Student Principal Author</th>
<th>Student Coauthor</th>
<th>% Principal Author</th>
<th>% Coauthor</th>
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<tbody>
<tr>
<td>MEEG</td>
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<tr>
<td>Totals</td>
<td>17</td>
<td>8</td>
<td>4</td>
<td>47%</td>
<td>24%</td>
</tr>
</tbody>
</table>

We also send our graduate and undergraduate students to other laboratories for training and participation in research activities. For example: a) PhD student Michelle Rivera went to the USD-ARS-Cropping Systems Research Laboratory, Lubbock, Texas for training in chemical and genomic determinations of soil microbial communities under the supervision of Dr. Acosta-Martinez (28 November – 14 December, 2011); b) Ph. D. student Nirzka Martinez spent part of the 2011 summer at
the International Molecular Systematics Laboratory of the University of Washington, Seattle to be trained in the amplification of newly developed molecular loci for phylogenetic studies; d) PhD student Alex Mercado went to Morelos, Mexico, to take the international course Light and Photosynthesis on Coral Reefs (15 January – 5 February, 2012); d) undergraduate student Carlos J. Cruz Quiñones went to the Stable Isotope laboratory at the University of Miami, under the supervision of Dr. Leonel Sternberg, to be trained in stable isotope instrumentation and analysis. At present, he is on a three-month summer internship at the EPA, Atlantic Ecology Division, NHEERL, Rhode Island.

Goal 2: Increase the research productivity of our faculty in the field of applied ecology and conservation.

We continue to improve our productivity by providing the necessary infrastructure, research funding, an efficient Center administration, and a continuous development of inter- and trans disciplinary collaborations among our research fellows and with other scientists in other national and international institutions.

<table>
<thead>
<tr>
<th>Thrust Area</th>
<th>Published</th>
<th>Accepted, Awaiting Publication</th>
<th>Submitted, Under Review</th>
<th>Total</th>
</tr>
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<td>MEEG</td>
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<td>5</td>
<td>9</td>
<td>32</td>
</tr>
<tr>
<td>SPM</td>
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<td>3</td>
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</tr>
<tr>
<td>EPF</td>
<td>15</td>
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<td><strong>Total</strong></td>
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<td><strong>14</strong></td>
<td><strong>17</strong></td>
<td><strong>75</strong></td>
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</table>

This year we maintained the same level of publication as the previous year. This year we have 76 publications: 44 published, 14 accepted for publication and 17 submitted for review.
With increased productivity comes the recognition of the Center members in the field of ecology and conservation. Here some examples of how CATEC research fellows are being recognized both nationally and internationally:

1) Dr. Elvia Melendez-Ackerman is a member of the Advisory Committee for Academic Diversity of the Organization for Tropical Studies (OTS). The committee meets twice a year to develop strategies to attract undergraduate students from underrepresented groups to the various OTS programs.

2) Dr. Miguel Garcia is a member of two specialist groups within the International Union for the Conservation of Nature-Species Survival Commission (IUCN/SSC): a) Iguana Specialist Group since 1996 and Co-Chair since 2003, b) Invasive Species Specialist Group (ISSG) – the largest of the six volunteer commissions of IUCN since 2000 and re-invited in 2005. Membership to these prestigious groups is by invitation only.

3) Dr. Raymond Tremblay is Chair of the International Committee for In Situ Conservation of the Orchid Specialist Group, IUCN/SSC. 2001. Membership to this prestigious group is by invitation only.

4) Dr. Eugenio Santiago is the International Union for the Conservation of Nature-Species Survival Commission (IUCN/SSC) Caribbean Island Plant Red Listing Authority since 2004. Membership to these prestigious groups is by invitation only.

5) Dr. Jose Carlos Rodrigues was invited to be dialogue facilitator in the Sustainable Development Dialogues by the United Nations - Bureau for Development Policy (UNDP) and the government of Brazil. The Dialogues are envisaged as a tool for civil society, the public, private and financial sectors, the scientific community, the youth and Academia to discuss key issues related to sustainable development as part of the United Nations Conference for Sustainable Development", better known as Rio+20.

6) Dr. Elvira Cuevas was invited to participate in the Sustainable Development Dialogues by the United Nations - Bureau for Development Policy (UNDP) and the government of Brazil.
7) Dr. Elvira Cuevas and Dr. Edwin Hernandez are members of the Puerto Rico Climate Change Council (PRCCC).

8) Dr. Maria Gloria Dominguez and Dr. Tomas Hrbek are currently collaborating with scientists at the Lawrence Berkeley National Lab and DOE Joint Genome Institute in California on a project to use phylochip technology to look at bacterial diversity in human gut (Dr. Dominguez) and bacterial community composition in the coral holobiont as related to disease resilience (Dr. Hrbek). Collaborators include Dr. Phil Hugenholtz, Dr. Erin Brodie and Dr. Kate Goldfarb.

9) Dr. James Ackerman is collaborating with Dr. Jafet Nassar of IVIC (Venezuela) on the Melocactus phylogeny project.

10) Dr. Tomas Hrbek has several direct collaborations with Brazil, including Dr. Izeni Pires Farias, who heads the Laboratorio de Evolucao e Genetica Animal (LEGAL), Universidade Federal do Amazonas. This laboratory is a leader in evolutionary and conservation genetics of freshwater Amazonian taxa, including fish and mammals. This collaboration led to CREST supplement funding that effective September 2009.

11) Dr. Elvira Cuevas, Center Director and PI of CREST, is a member the Editorial Board of Ecological Applications.

12) Dr. Elvira Cuevas is in the Scientific Advisory Committee of the Jobos Bay Natural Reserve, Puerto Rico funded by NOAA and the Government of Puerto Rico.

13) Dr. Ingi Agnarsson is a research associate of the Scientific Research Centre of the Slovenian Academy of Science and Arts, 2007-present.

14) Dr. Ingi Agnarsson is a research associate of the National Museum of Natural History, Smithsonian, Washington DC.

15) Dr. Elvira Cuevas is a Member of the Advisory Committee for RIMI Project (Research Infrastructure for Minority Institutions) UPR-Cayey.

16) Drs. Elvira Cuevas and Elvia Melendez-Ackerman are members of the Neo-Neon’s D-4 Domain Science and Education Coordination Committee (NEON-National Ecological Observatory Network).
17) Dr. Elvira Cuevas is member of the External Scientific Evaluation Committee, CREST-Center in Tropical Ecology and Evolution in Marine and Terrestrial Environments, University of Hawaii at Hilo.

18) Dr. Elvira Cuevas is member of the External Advisory Board of the CREST-Center of Forest Ecosystem Assessment (CFEA), Alabama A&M.

19) Drs. Denny Fernandez is a member of the Board of Directors American Association for the Advancement of Science (AAAS), Caribbean Division.

20) Dr. Elvira Cuevas is Adjunct faculty at the Department of Management and Conservation of Natural Tropical Resources, Faculty of Veterinary and Zootechnology, Universidad Autónoma de Yucatán, Mérida, México. May 2004 - present.

21) Dr. Elvira Cuevas is a Visiting Scientist at the Plant eco-physiology laboratory, Centro de Ecología, IVIC, Caracas, Venezuela

**Goal 3: Expand the research infrastructure of the University of Puerto Rico**

- We continue to support the research facilities of our research fellows.
- We continue to improve the infrastructure of the two largest herbaria in Puerto Rico, at the UPR-Rio Piedras Campus (UPR-RP Herbarium) and the UPR-Botanical Garden (UPR Herbarium). Both are key facilities for botanical and ecological research related to CREST-CATEC.

**Goal 4: Foster long-term research collaborations among scientists within Puerto Rico and with national and international governmental and academic institutions.**

We maintain our strategic alliance-building partners: Department of Natural Resources and Environment (DNRE), USDA Forest Service International Institute of Tropical Forestry, NOAA, UPRM Rio Piedras Experimental Station, USDA and US Fish and Wildlife Service. We have also expanded our national and international research partners.

CATEC closely collaborates with other UPR centers, programs and institutes such as 1) the Resource Center for Science and Engineering and PR-LSAMP of UPR Central.
Administration, 2) DEGI (Deanship of Graduate Studies and Research) of UPR-Rio Piedras, 3) the UPR-Rio Piedras Graduate Programs in Biology, Mathematics and Environmental Sciences, 4) the UPR-Mayagüez Caribbean Coral Reef Institute, Department of Marine Sciences, 6) the UPR-Mayagüez Experimental Station at Rio Piedras, 7) the UPR-Mayagüez Puerto Rico Water and Environmental Resources Research Institute, and 8) the Environmental Health Program of the Department of Public Health at UPR Medical Sciences campus.

We have also established close collaborations with national and international universities and institutions, such as Cornell University, Department of Energy Joint Genome Institute, Earlham College at Indiana, Fairchild Tropical Botanical Garden, Florida International University, Florida Institute of Technology, USDA Agriculture Research Service, Florida Department of Plant Industry, J. Craig Venter Institute, Lawrence Berkeley National Laboratory, New York Botanical Garden, Portland State University, San Diego Zoo, Toledo Zoo, Texas A & M College Station, North Carolina State University, Michigan State University, University of Miami, University of New Hampshire, University of Washington, Universidad Nacional Autónoma de México at Iztacala, The Leibniz Center for Tropical Marine Ecology Bremen, Germany, Texas A&M College Station, Universidad de Antioquia (Colombia), Universidad Nacional de Colombia at Palmira, Universidad del Zulia, Universidad Simón Bolívar and Instituto Venezolano de Investigaciones Científicas (Venezuela), National Botanical Garden Rafael Moscoso (Dominican Republic), Universidad Autónoma de Santo Domingo (Dominican Republic), Universidad Tecnológica de Santo Domingo (Dominican Republic), St. Eustatius National Park (Netherland Antilles), Royal Botanical Garden in Melbourne (Australia), Tenerife Natural History Museum (Canary Islands, Spain), Colegio de la Frontera del Sur, (Mexico), Instituto Argentino de Oceanografía (Argentina), University of South Bohemia (Czech Republic), Universidade do Estado do Rio de Janeiro (Brazil), CENA Universidade do Sao Paulo (Brazil), and Universidade Federal do Amazonas and Universidad Federal do Pará (Brazil) among others.

We continue to build on the collaborative ties with the Department of Natural Resources and Environment of the Government of Puerto Rico, the USDA Forest Service
International Institute of Tropical Forestry, the USDA El Yunque National Forest, the US Geological Survey Caribbean Water Research Center, US Fish and Wildlife Service, the US Environmental Protection Agency, the San Juan Bay Estuary Conservation Program, Puerto Rico Conservation Trust, and the Puerto Rico Aqueduct and Sewer Authority. We also collaborate with non-governmental and community associations in Puerto Rico such as Chelonia, Citizens of the Karst, Coralations, Centro de Apoyo Comunitario de Rio Piedras (Rio Piedras Community Support Center, CAUCE), Coalicion Corredor Ecologico del Noreste (Coalition for the Northeastern Ecological Corridor), Sierra Club, Vegabajeños Impulsando Desarrollo Ambiental Sustentable (VIDAS) and Sociedad Ambiente Marino. We continue to build on the collaborative ties with the Department of Natural Resources and Environment of the Government of Puerto Rico, the USDA Forest Service International Institute of Tropical Forestry, the USDA El Yunque National Forest, the US Geological Survey Caribbean Water Research Center, US Fish and Wildlife Service, the US Environmental Protection Agency, the San Juan Bay Estuary Conservation Program, and the Puerto Rico Aqueduct and Sewer Authority. We also collaborate with non-governmental and community associations in Puerto Rico such as Chelonia, Citizens of the Karst, Coralations, Centro de Apoyo Comunitario de Rio Piedras (Rio Piedras Community Support Center, CAUCE), Coalicion Corredor Ecologico del Noreste (Coalition for the Northeastern Ecological Corridor), Sierra Club, Vegabajeños Impulsando Desarrollo Ambiental Sustentable (VIDAS) and Sociedad Ambiente Marino.

**Goal 5: Ensure that funding continues after the CREST funding period:**

Various researchers in CATEC had already gotten new awards and other have submitted or in the process of submitting new proposals. CATEC manages and additional $1.1 million from other non-CREST sources. Our researchers submitted various proposals to NSF and other funding agencies. Unfortunately they were not awarded. We will continue to look for other sources of funding in order to maintain and expand the sustainability of the Center.
Submitted:

- “Selection landscapes on shifting sands: how annual variation in floral traits affects patterns of selection”. Submitted to NSF by Raymond Tremblay (PI). J. D. Ackerman, and M. E. Perez (Co-PIs). Amount requested: $500,000.
- “Accelerating Puerto Rican Students into the National Research Effort in Mathematics and Computer Science”. Submitted to NSF by Luis R. Pericchi (PI), with Carlos Corrada, Heeral Janwa, María-Eglée Pérez (Co-PIs. Amount requested: $500,000.

Awarded:

- NSF-1038166: Maximizing Yield Through Integration (MYTI): Science and Math Education in the Context of a Disposing Society. Brad R. Weiner (PI), Michelle Borrero, Rafael Rios, Jorge Ortiz, and Elvira Cuevas (Co-PIs). $1,250,000. Using the *Innovation through Institutional Integration* (I3) model, we seek to “maximize our yields” by building a Center for Science and Mathematics Education (CSME) based on existing NSF funded programs in the broad area of environmental sciences and the relationships they have established with the STEM educational community in Puerto Rico.

1.7 CURRENT COLLABORATIONS AND INTERACTIONS:

CREST - CATEC collaborations document the important synergy between UPR researchers, local and federal agencies and national and international institutions and organizations. It has also documented the important synergy that can be developed among campuses within the UPR University system. The cooperative agreement between
UPR-Rio Piedras and the Department of Natural Resources and Environment of the Government of Puerto Rico and the establishment of a liaison officer between the two institutions, are important milestones in the recognition of synergic collaborative work between an academic institution and a government agency.

**Collaborative research activities:**

CATEC research fellows have for the most part established research collaborations among themselves, one of the goals of the Center. Another source of interaction are the theses committees of students mentored by other CATEC’s research fellows. The synergism established among our research fellows is already showing the results. Some of the examples of the collaborations include:

1. The *Tabebuia* thesis project of Nirska Martinez is a direct result of collaboration between Dr. Eugenio Santiago, Dr. Elvira Cuevas, Dr. Jason Rauscher and Dr. Tomas Hrbek, and integrates a broad array of research from taxonomy and systematics, to population genetics, to ecophysiology.

2. The *Guaiacum sanctum* project includes collaboration between Dr. Elvia Melendez-Ackerman and her PhD student José Fumero, who focus on the ecology and conservation of this species and Dr. Tomas Hrbek, who is developing the molecular genetic aspects of this project.

3. An interest in coral reef systems, coral reef health, and bacterial communities associated with coral reefs has fostered interaction and the initiation of direct and indirect collaborations among several laboratories, including those of Dr. Tomas Hrbek, Dr. Paul Bayman, Dr. Maria Gloria Dominguez, and Dr. Alberto Sabat.

4. Dr. Riccardo Papa and Dr. Elvira Cuevas are collaborating in the Lionfish invasion research.

5. Common collaborative interests also connect the bacterial diversity project (Dr. Dominguez) with the goat and pig project (Dr. Hrbek, Dr. Funk) and institutions such as the PR-DNRE.

6. All researchers and students within and associated with MEEG routinely exchange information and ideas that mutually benefits the entire research program.
7. The recent article of Dr. Papa published in Nature is a clear exemplification of the product of an incredible international effort of researchers from all over the world, Colombia, USA, Puerto Rico, UK, France, and Panama just to mention few of them.

8. A core collaborative effort developed within the MEEG group is with Dr. Stephan Funk, Director of Nature Heritage, Jersey, Channel Islands. Dr. Funk is a Senior Conservation Biologist, and an expert in the application of genetics and molecular genetics to conservation biology. His expertise has also been of great value to students working on various projects, and he has served as a valuable reference for much of the other research in this group, including the development of microsatellites for *Tabebuia heterophylla* and other plants.

9. Dr. Tomas Hrbek has several direct collaborations with Brazil, including Dr. Izeni Pires Farias, who heads the Laboratorio de Evolucao e Genetica Animal (LEGAL), Universidade Federal do Amazonas (UFAM). This laboratory is a leader in evolutionary and conservation genetics of freshwater Amazonian taxa, including fish and mammals. This collaboration led to the 2009 CREST supplemental funding and has provided opportunities for students from UPR to visit UFAM, creating an enriching source of interaction for both students and faculty at UPR.

10. Dr. Maria Gloria Dominguez has an ongoing and fruitful collaboration with two researchers, Dr. Ruth Ley and Dr. Jeffrey Gordon, at Washington University in St. Louis, MO. They are working closely with Dr. Dominguez and Dr. Filipa Godoy on the project characterizing bacterial diversity in the crop of the Hoatzin (an Amazonian leaf-eating bird), and this collaboration has resulted in various publications.

11. Dr. Maria Gloria Dominguez is also collaborating with Dr. Martin Blaser of New York University on several projects related to the characterization of bacterial diversity.

12. Dr. Maria Gloria Dominguez and Dr. Tomas Hrbek are currently collaborating with scientists at the Lawrence Berkeley National Lab and DOE Joint Genome Institute in California on a project to use phylochip technology to look at bacterial
diversity in human gut (Dr. Dominguez) and bacterial community composition in
coral holobiont as related to disease resilience (Dr. Hrbek). Collaborators
include Dr. Phil Hugenholtz, and Dr. Erin Brodie.

13. The international collaboration established by Dr. Dominguez to study bacterial
diversity in humans has recently resulted in a publication in *Nature*.

14. Dr. Paul Bayman is collaborating with W. Nierman of the J. Craig Venter Institute
in the study Metagenome of sea fans infected with aspergillosis.

15. Dr. Paul Bayman is collaborating with Dr. V. Gulis, of the Carolina Coastal
University on the study Measure of fungal biomass in tissues.

16. Dr. Paul Bayman is collaborating with Dr. M. Cubeta, of North Carolina State
University in the study *Rhizoctonia solani* genomics.

17. Dr. Eugenio Santiago, established collaborations with Dr. Richard Olmstead of
the University of Washington-Seattle, and Dr. Lucia Lohman of the University of
Sao Paulo (Brazil) for the project on the systematics of the Bignoniaceae.

18. Dr. Eugenio Santiago, in collaboration with Dr. Jackeline Salazar of the
Universidad Autónoma de Santo Domingo are working on the study of the leaf
epidermis of the *Tabebuia* Alliance and its systematic significance.

19. Dr. Eugenio Santiago, in collaboration with Dr. Armando Rodríguez of the Inter-
American University-Bayamón Campus, are working on the role of bats in the
dispersal of the endangered tree *Stahlia monosperma* and in the history of
Mastozoology in the Caribbean Islands.

20. Dr. James Ackerman from UPR-Río Piedras, in collaboration with colleagues of
the Eustatius National is working on the Parks Population viability of native
orchids of St. Eustatius Parks, Netherlands Antilles and the Flora of St. Eustasius,
Netherlands Antilles.

21. Dr. James Ackerman and Dr. Eugenio Santiago from UPR-Río Piedras and UPR
Botanical Garden, in collaboration with the New York Botanical Garden, The
Smithsonian Institution, and the University of Puerto Rico-Mayagüez Puerto Rico
are working on the Endangered Plants Initiative (PREPI).

22. Demographic Analysis of the Virgin Islands boa. Raymond Tremblay form UPR-
Humacao, Dr. Miguel Garcia, and Mr. Carlos Diez, both from the Puerto Rico
Department of Natural and Environmental Resources, in collaboration with Dr. Peter J. Tolson of the Toledo Zoo, Ohio.

23. Strengthening Educational Capacities in Geospatial Science and Technology for Agricultural and Natural Resources Management. Dr. Elvia Melendez-Ackerman from UPR-Rio Piedras, in collaboration with Scientists of Texas A&M, and USDA Forest Service International Institute of Tropical Forestry (IITF).

24. "From Hectares to Nanometers: GK-12 Multidisciplinary Explorations of Functional Nanoscience and Tropical Ecosystems". Dr. Elvia Melendez-Ackerman from UPR-Rio Piedras, in collaboration with the UPR Resource Center For Science and Engineering.

25. Annual Vegetation Census, Mona Island. Dr. Elvia Melendez-Ackerman from UPR-Rio Piedras, in collaboration with personnel of the Puerto Rico Department of Natural and Environmental Resources.

26. San Juan ULTRA. “Vegetation biodiversity of the Rio Piedras watershed”. Dr. Elvia Melendez-Ackerman from UPR-Rio Piedras, in collaboration with the USDA Forest Service IITF, Fundacion Puertorriqueña para la Conservacion, Clark University, SUNY, UPRCM-Public Health, UPRRP-Planning, Arizona State University.

27. Vegetation biodiversity of the Rio Piedras watershed. Dr. Elvia Melendez-Ackerman from UPR-Rio Piedras in collaboration with the USDA Forest Service International Institute of Tropical Forestry (IITF), the Puerto Rican Foundation for Conservation, and Clark University.

28. Michigan State University-University of Puerto Rico initiative. Dr. Elvia Melendez-Ackerman from UPR-Rio Piedras.

29. USDA-NC State University, University of Puerto Rico. Dr. Elvia Melendez-Ackerman from UPR-Rio Piedras.


32. Headstart Program for the Mona Island Iguana. Dr. Miguel Garcia with personnel of the Puerto Rico Department of Natural and Environmental Resources.

33. Breeding system in Spathoglottis. Dr. James Ackerman and Dr. Paul Bayman (UPR-Rio Piedras), with Raymond Tremblay (UPR-Humacao).

34. Native flower weevils on invasive species. Dr. Dr. James Ackerman and Dr. Paul Bayman (UPR-Rio Piedras), with Jose Carlos Rodríguez (UPR-Mayaguez).

35. Phylogenetics and biogeography of the genus *Tabebuia* in Hispaniola. PhD student Nirzka Martinez, and Dr. Eugenio Santiago-Valentin (UPR-Rio Piedras) in collaboration with Dr. Yolanda Leon (Instituto Tecnologico de Santo Domingo) and Dr. Jackeline Salazar (Universidad Autonoma de Santo Domingo).

36. Dr. Paul Bayman is collaborating with the J. Craig Venter Institute for the sequencing of the bacterial metagenome of *Gorgonia ventalina*, and to also confirm the presence, abundance and strains of *Aspergillus sydowii* or any other species of *Aspergillus* that might be found on diseases individuals.

37. Faculty and students of the MEEG group continue to interact with Dr. Jason Rauscher and Dr. Tomas Hrbek (who is on leave without pay since June 2011). Dr. Rauscher continues to serve on thesis committees, and contribute intellectually to ongoing projects.

38. Terrestrial-coastal linkages in the Caribbean. Dr. Jorge Ortiz from UPR-Rio Piedras and Dr. Michael McClain from Florida International University. It involves regional collaboration between scientists and government officials from Cuba, Dominican Republic, Jamaica, and Puerto Rico.

39. Dr. Jorge Ortiz is the Coordinator of the Luquillo Mountains UNESCO’s Hydrology for the Environment, Life and Policy Program (HELP). This program promotes the dissemination of integrated water resources management principles among an international network of catchments.
40. Strengthening Educational Capacities in Geospatial Science and Technology for Agricultural and Natural Resources Management, This is a joint program with Texas A&M, College Station and UPR-CATEC. DR. Elvia Melendez-Ackerman and Mei Yu are the leaders in this effort.

41. Effect of invasive species on the soil nutrient dynamics of wetlands in Puerto Rico. Dr. Elvira Cuevas UPR-Río Piedras, Dr. Ariel Lugo from USDA Forest Service International Institute of Tropical Forestry, Dr. Ernesto Medina from Venezuelan Institute from Scientific Research (IVIC) and Puerto Rico Conservation Foundation. We are determining how the Mezquite, an invasive tree species, *Prosopis juliflora*, is affecting the soil water availability in a seasonally dry area in Puerto Rico in order to establish management strategies for the control and use of this invasive tree.

42. Downstream effects of plant species plasticity at the ecosystem level in a seasonally dry forest in Guanica, Puerto Rico. Dr. Elvira Cuevas UPR-Río Piedras, Dr. Ariel Lugo from USDA Forest Service International Institute of Tropical Forestry, Dr. Ernesto Medina from Venezuelan Institute from Scientific Research (IVIC) and Puerto Rico Conservation Foundation. Will provide a better understanding of how species diversity affect ecosystem functioning, and to develop better management strategies for selection of tree species for rehabilitation of degraded areas. The PhD dissertation of Michelle Rivera on tree species effects on microbial biodiversity and dynamics is part of this collaborative effort. We are also working with Dr. José Carlos Rodrigues, research fellow from the UPR Experimental Station in Rio Piedras and Dr. Cal Welbourn from in the identification of the soil arthropod samples from the Dr. Barberena's dissertation from CATEC's Phase I studies.

43. Morphological and physiological plasticity of tropical trees modulated by physicochemical stressors: nutrients, salinity and wind. Dr. Elvira Cuevas UPR-Río Piedras, Dr. Ariel Lugo from USDA Forest Service International Institute of Tropical Forestry, Dr. Ernesto Medina from Venezuelan Institute from Scientific Research (IVIC), Dr. Sandra Molina, Catholic University, Ponce PR, and Citizens of the Karst. Will provide a better understanding of how species diversity affect
ecosystem functioning, and to develop better management strategies for selection
of tree species for rehabilitation areas under different environmental stressors.

44. Climate change and sea level rise as measured by $^{13}$C and $^{15}$N natural abundance
in a dwarf mangrove peat substrate in northeastern Puerto Rico. Dr. Elvira Cuevas
UPR-Río Piedras, Dr. Ariel Lugo from USDA Forest Service International
Institute of Tropical Forestry, Dr. Ernesto Medina from Venezuelan Institute from
Scientific Research (IVIC). The research is allowing the understanding how sea
level rise and paleoclimatic changes in the last 4500 years have occurred in the
Caribbean region.

45. Paleohistorical and historical changes in the Guanica dry forest and Jobos Bay in
the semi-arid region of Puerto Rico. Dr. Elvira Cuevas is collaborating with Dr.
Leonel Sternberg, University of Miami, Dr. Ruben Lara, ZMT, Germany and Dr.
Marcelo Cohen, Universiy of Para, Brazil. The research is allowing the
understanding of how mid-Holocene changes in climate, sea level rise and
historical land use change has changed the plant biodiversity of the region.

46. Updated revision on the systematic status of the Antillean-endemic plant genera.
Dr. Eugenio Santiago is collaborating with scientists from Florida International
University and Fairchild Tropical Garden (Miami). This revision will allow the
identification of future research routes and priorities, helping developing research
for studies on the Antillean flora.

47. Propagation of Endangered Plants of Puerto Rico. Dr. Eugenio Santiago-Valentín
from UPR-Rio Piedras and Puerto Rico Department of Natural Resources and
Environment/US Fish & Wildlife Service. After performing the experimental
phase on pollination, plant material propagated will be used for recovery activities
outlined by the Fish & Wildlife Service.

48. Hydrologic evaluation of the habitat of the endangered crested toad (*Peltophryne
lemur*) in Guanica, Puerto Rico. UPR-Río Piedras and Department of Natural and
Environmental Resources of the Government of Puerto Rico (DNRE), US Fish
and Wildlife Service, and Toronto Zoo. Dr. Jorge Ortiz is the PI of this project.
This work was expanded to include the repopulation of the crested toad in the
northern karst area of the island. Dr. Ortiz is in charge of monitoring the artificial
ponds established for the release development and of the tadpoles brought from the Toronto Zoo.


52. Metapopulation dynamics of an endangered riparian orchid. UPR-Río Piedras and UPR-Humacao, Dr. Raymond Tremblay. Provides funding for molecular/field project on endangered riparian orchids. Many Puerto Rican undergraduate students from Humacao are actively involved in this project.

53. Evaluation of metapopulation dynamics. Dr. Raymond Tremblay from UPR-Humacao and Dr. Pavel Kindlmann from University of South Bohemia, Czech Republic. CATEC is supporting Dr. Tremblay research in this area.

54. Effects of Introduced Feral Ungulates on the native vegetation of Mona Island Reserve. UPR-Rio Piedras, Department of Natural Resources and Environment, USDA Forest Service International Institute of Tropical Forestry, UPR-Humacao, UPR-Bayamón and University of Minnesota. CATEC is providing most of the funds for materials, student and faculty salaries, equipment and travel. By providing student funding, CATEC allows this project to expand its scope to ecosystem parameter. The Humacao campus leveraged matching funds to Dr. Denny Fernandez and Dr. Raymond Tremblay (CATEC research fellows) to complement research activities related to the CREST project. The project is generating data on the relationship between plant and insect diversity at the site.
The information generated addresses questions related to the indirect effects of introduced herbivores on trophic structure.

55. Forest inventory and health monitoring on Mona Island, Puerto Rico. Dr. Elvia Melendez-Ackerman from UPR-Rio Piedras, in collaboration with Scientists of the USDA Forest Service-SRS, and the International Institute of Tropical Forestry (IITF).

56. Spatial ecology, home range and habitat use of feral goats in Mona Island Nature Reserve. Dr. Elvia Melendez-Ackerman from UPR-Rio Piedras, in collaboration with personnel of the Puerto Rico Department of Natural and Environmental Resources.

57. The future of trees on rangelands in La Sepultura Biosphere Reserve buffer zone, Chiapas Mexico. Colibrí Sanfiorenzo from UPR-Rio Piedras in collaboration with ECOSUR.

58. Breeding system in \textit{Spathoglottis}. Dr. James Ackerman and Dr. Paul Bayman (UPR-Rio Piedras), with Raymond Tremblay (UPR-Humacao).

59. Native flower weevils on invasive species. Dr. Dr. James Ackerman and Dr. Paul Bayman (UPR-Rio Piedras), with Jose Carlos Rodrigues (UPR-Mayaguez).

60. Phylogenetics and biogeography of the genus \textit{Tabebuia} in Hispaniola. PhD student Nirzka Martinez, and Dr. Eugenio Santiago-Valentín (UPR-Rio Piedras) in collaboration with Dr. Yolanda Leon (Instituto Tecnológico de Santo Domingo) and Dr. Jackeline Salazar (Universidad Autonoma de Santo Domingo).

61. Morphological assessment of the genus \textit{Tabebuia} in Hispaniola. PhD student Nirzka Martinez, and Dr. Eugenio Santiago-Valentín (UPR-Rio Piedras) in collaboration with Dr. Jackeline Salazar (Universidad Autonoma de Santo Domingo).

62. Dr. Tomas Hrbek has several direct collaborations with Brazil, including Dr. Izeni Pires Farias, who heads the Laboratorio de Evolucion e Genetica Animal (LEGAL), Universidade Federal do Amazonas. This laboratory is a leader in evolutionary and conservation genetics of freshwater Amazonian taxa, including fish and mammals. This collaboration has led to visits to UPR by Dr. Pires Farias and her students, creating an enriching source of interaction for both students and
faculty at UPR.

63. Dr. Elvira Cuevas is collaborating with Drs. Flora Barboza and Miguel Pietrangeli from Universidad del Zulia, Venezuela in a reforestation project in the Guasare coalmine in the Zulia State, Venezuela.

64. Dr. Elvira Cuevas is collaborating with the USDAFS IITF and Citizens of the Karst in the evaluation of CO2 emissions from a wet karst area in Arecibo, Puerto Rico.

I.8 SEMINARS, SYMPOSIA AND WORKSHOPS

- CATEC co-sponsored along with the Environmental Sciences IGERT Program the course “Policies for Coastal Protected Areas” given by Dr. Maria Gimenez Casalduero, from Universidad de Alicante, Spain. 2-4 March, 2012.

- We also co-sponsored the meeting “Climate change: Coastal Scenarios in the Caribbean”. 18 November 2011.

- Dr. Veronica Acosta-Martinez, from USDA ARS, Lubbock, Texas, presented the seminar "The Role of Microbial Community Composition and Functionality on the Sustainability of Semiarid Agroecosystems". 1 May, 2012.

- Dr. Javier Francisco Ortega, from Florida International University, presented a conference "Biogeography of the Macronesian Islands” in the course Biol 4999 Island Biology.

- Dr. Papa and Dr. Dominguez organized several genomic 454 workshops with the support of CATEC. These workshops provided the opportunity to bring scientists from Notre Dame University and from the University of Colorado at Boulder and to establish new collaborations with them. Overall, all of these workshops were very successful and provided the possibility for students and faculty to experience and learn the latest genomic techniques.

I.9 INTERNATIONAL ACTIVITIES

The international activities carried out by CATEC fellows allow the recognition of the scientific work being carried out in Puerto Rico. It has also exposed students and researchers to other laboratories where collaboration can be developed. The proven
expertise in conservation and applied ecology are being sought by international institutions to have a better understanding of research problems.

CATEC continues to develop international activities. In order to reach our landmark, we are developing plans to establish collaborations, student and faculty exchanges, publications and short courses.

- Drs. James Ackerman and Raymond Tremblay have developed collaborative activities to study the population dynamics of native orchids of St. Eustatius Parks, Netherlands Antilles.
- Dr. Elvira Cuevas has ongoing collaboration with Dr. Flora Barboza, from Universidad del Zulia, Venezuela and Elizabeth Olivares from the Centro de Ecología, Venezuelan Institute for Scientific Research (IVIC) in Caracas, Venezuela. This collaboration encompasses research activities in Venezuela, particularly in the Maracaibo area where we are working on mangrove dynamics and developing effective techniques for the restoration of areas affected by mineral charcoal exploitation in the region.
- Dr. Cuevas maintains collaborative interactions in Brazil with Dr. Mario Soares from State University of Rio de Janeiro and Dr. Marcelo Cohen, from University of Para, Brazil.
- Dr. Elvira Cuevas maintains collaborative interactions with Dr. Ruben Lara from the Argentinian Institute of Oceanography, Bahia Blanca, Brazil.
- Drs. Jorge Ortiz and Elvira Cuevas from UPR-Rio Piedras are involved in the International Nitrogen Initiative, a multinational International Geosphere-Biosphere Program (IGBP) sponsored project. The International Nitrogen Initiative is dedicated to optimizing the use of nitrogen in food production, while minimizing the negative effects of nitrogen on human health and the environment as a result of food and energy production. Among the many facets of the International Nitrogen Initiative are scientific assessment, development of solutions to solve a wide variety of nitrogen-related problems, and interactions with policymakers to implement these solutions.
• Dr. Tomas Hrbek collaborates with Dr. Izeni Pires Farias from Laboratório de Evolução e Genética Animal (LEGAL), Universidade Federal do Amazonas, Brazil. Their research relies on molecular data (DNA sequences, microsatellites and AFLPs) to study the architecture of genetic variation in freshwater taxa in an ecological context.

• Drs. Elvia Melendez-Ackerman and Denny Fernandez collaborate with Dr. Zdravko Baruch from Universidad Simon Bolivar in Venezuela in the effect of African invasive grasses on native cacti.

• Dr. James Ackerman collaborates with Dr. Jafet Nassar, from the Instituto Venezolano de Investigaciones Científicas in Venezuela and other researchers from Brazil in a Melocactus phylogeny project.

• Dr. Elvia Melendez-Ackerman attended to the 2012 Annual Meeting Assembly of Delegates of OTS, and OTS Board Meetings.

• Dr. Edwin Hernandez is collaborating in the Dominican Republic with the Punta Cana Ecological Foundation that along with Counterpart International, Sociedad Ambiente Marino and University of Miami are developing management strategies for the coral reefs in the region.

• Student Nirzka Martinez carried out field sampling for her thesis research along Northern, Northwestern, and Central Hispaniola, together with Dr. Eugenio Santiago (UPR-Rio Piedras) and Dr. Jackeline Salazar, Universidad Autónoma de Santo Domingo.

• Dr. Eugenio Santiago participates in field projects in the National Parks of Southwestern Hispaniola (Lago Enriquillo, Sierra de Bahoruco, Parque Nacional Jaragua). The John D. And Catherine T. Mac Arthur Foundation Grant to the New York Botanical Garden and the Grupo Jaragua are sponsoring this project.
II. ACTIVITIES AND FINDINGS

Thrust area 1: Molecular ecology and evolutionary genetics (MEEG)

Component 1: Phylogeography and conservation genetics of plants. Investigator: Tomas Hrbek

Tabebuia heterophylla (DC.) Britton (Bignoniaceae) (Figure 1) is a charismatic Neotropical tree species known for its attractive flowers and economically valuable wood. The species is considered to have an extremely widespread distribution throughout the Caribbean, where it thrives in a diverse range of habitats, soil conditions, and altitudes (Gentry, 1992). In Puerto Rico, where it is very common, the species is found from dry forest to wet habitats (Figure 2), from sea level to high altitudes, with the morphological versatility known for the species (e.g., leaf size and leaflet number variation) (Figure 3). This wide range of morphological and ecological variation has been accepted as characteristic of the species. This has led to the acceptance of several morphotypes such as *T. heterophylla* variation, which is found in Puerto Rico and its adjacent islands. However, it is not known whether the variation is due to phenotypic plasticity, genetically distinct populations or different evolutionary lineages.

![Figure 1. T. heterophylla (DC.) Britton: (a) flower, (b) leaf](image1)

![Figure 2. Habitat diversity: (a) Dry forest, (b) Wet forest](image2)

![Figure 3. Herbarium specimens showing the morphological variation found in *T. heterophylla* in Puerto Rico.](image3)

This project was designed to look at the population and conservation genetics of endemic Puerto Rican plant species of conservation and economic interest, with a focus on dry forest species found in places such as Guanica Reserve and Mona Island. Each project is designed to be
integrated into larger projects in CATEC, including studies of phylogeography of *Tabebuia heterophylla*, phylogeny and ecophysiology of *Tabebuia* sampled from throughout the Caribbean, and conservation genetics of *Guaiacum sanctum*. Specifically, the goal is to develop molecular tools, including DNA sequences and microsatellites to better understand the distribution of genetic variation for these species, test phylogenetic and phylogeographic hypotheses, and use this information to help us better understand and manage these species in the future.

Preliminary results suggested a strong genetic differentiation with Mona island populations with respect to main island populations (Figure 4).

![Figure 4](image.png)

**Fig 4.** Chloroplast DNA gene tree for populations samples of *Tabebuia heterophylla*. Lines represent single nucleotide changes between sequences.

![Figure 5](image.png)

**Figure 5.** A preliminary maximum parsimony analysis based on *psbD-tmT+ rpl/32-tmL+nrITS+AT5G39980* that is consistent with the 50% majority-rule consensus tree. The numbers on the nodes represent maximum parsimony bootstrap values.

However, more recent data based on an interspecific molecular phylogenetic analysis (Figure 5) show *T. heterophylla* from Mona forming a monophyletic group with *T. bahamensis*, while samples from main island populations are found in another clade with other species. These
results clearly suggest that *T. heterophylla sensu lato* may not be as simple as what was thought and raise questions that need to be answered; particularly whether *T. heterophylla* from Mona has been a cryptic species. Currently, more material from Mona, as well as material from *T. bahamensis* is being evaluated in order to answer this important question. Moreover, in addition to the chloroplast sequencing project, we are continuing to develop microsatellites markers to be used for the population genetic study of *Tabebuia heterophylla* in Puerto Rico. Furthermore, sampling continues to be coordinated with Dr. Eugenio Santiago and a PhD student, Nirzka Martinez (SPM thrust area).

**Summary of specific accomplishments for this project:**
Continuation of tissue collection and genetic sampling for *Tabebuia* (including species and populations from Hispaniola, Cuba, northern South America and Central America)

1. Continuation of sampling of *Guaiacum sanctum* and establishment of protocols for DNA extraction from fruits.
2. Additional chloroplast and nuclear gene sequencing and phylogenetic analysis for *Tabebuia*.
3. Over 300 clones sequenced from the three microsatellite libraries constructed for the species *Tabebuia heterophylla* and *Guaiacum sanctum*.
4. All microsatellite library sequences were analyzed with bioinformatic software (WebSat) to find repetitive elements and design primers
5. Over 60 primer sets of potential microsatellites for all three species were ordered, optimized and tested for PCR.
6. In *Tabebuia heterophylla*, 15/49 primers identified as polymorphic.
7. In *Guaiacum sanctum*, 9/15 primer sets tested are polymorphic.

**Goals for next year:**
Increase population sampling for *Tabebuia* spp. and *Guaiacum sanctum*.

1. Sample additional species of *Tabebuia* focusing on northern South America and Central America.
2. Sample populations of *T. heterophylla* throughout the island based on geology and rainfall.
3. Sampling of fruits of *Guaiacum sanctum*.
4. Additional testing of *Guaiacum sanctum* is necessary to achieve sufficient statistical power for assessing mating systems.
5. Prepare for publication primer note for *Tabebuia heterophylla*.
6. Generate a robust phylogenetic hypothesis for the genus *Tabebuia*.
7. Test hypotheses of a radiation and repeated incidences of convergent evolution of phenotypes of *Tabebuia* on different Caribbean islands.

**Component 2: Population genetic analyses of feral goat and pig populations on Mona Island and on other Caribbean Islands. Investigator: Tomas Hrbek**
Feral goats (*Capra hircus*) and pigs (*Sus scrofa*) were introduced by Spanish settlers to Mona Island more than 500 years ago. Since then the pig and goats of Mona island have been genetically and reproductively isolated from their origin populations. This natural experiment provides a unique possibility to understand how species evolve, and to study the dynamics of genes of adaptive significance in small, isolated populations. What we learn from the pigs and goats may help us better understand the evolutionary dynamics of other island species including
species of conservation concern. This study is the master project of the student Yadira Ortiz and has being done in collaboration with Dr. Stephan Funk, Senior Conservation Biologist for the Durrell Wildlife Conservation Trust, Jersey. Mona wild pigs and goats were originally brought to the island in order to reproduce and provide a source of fresh meat for Spanish travelers to Mona and other the Caribbean islands. Pigs and goats can be found in a wide range of habitats ranging from wet to dry ecosystems. Both species can also survive in harsh environments due to various physiological and behavioral adaptations.

Because of their ability to adapt to different environments (Moran-Fehr et al., 2004) the goat, as well as the pigs are expected to show genetic responses to the range of environmental conditions they experience (Galal 2005). In this study we developed microsatellite markers to study genetic diversity and differentiation among ancestral populations and the one on Mona Island. Microsatellite markers are highly polymorphic, randomly distributed throughout the genome and neutral with respect to selection (Agha et al., 2008). The characterization of the genetic diversity of animals from Mona Island will give us a better understanding of the ecological and evolutionary processes affecting the long term survival of the regionally adapted land races. The genetic characterization also provides us with data that can be used for more efficient management.

A total of 310 samples, 230 goats and 80 pigs, have been collected since 2008 in several locations of Mona Island (Figure 6). Additional pig samples are being collected in collaboration with USDA, and reference samples from European domestic and land race breeds have been provided by Dr. Stephan Funk. A total of 60 microsatellites markers has been tested, 30 specific to pigs and the other 30 specific to goats. Out of the 30 microsatellites markers tested for the pigs 23 amplified but only 15 resulted polymorphic (more than one alleles) (Table 1, Figure 7). In regard to the goats, 23 out of the 30 microsatellites markers tested amplified and only 14 resulted polymorphic (more than one alleles) (Table 1, Figure 7).
The advantages of the microsatellites markers developed (Table 2) in this study are to provide the possibility to utilize the data to compare results between different studies. Additionally, the use of these markers will allow us to infer the origin of the populations of both species from Mona Island. Our preliminary analysis of 200+ goat samples shows little genetic variation, and a large number of monomorphic loci. Observed heterozygosity in the 200+ goats sampled in the 2008-2011 season was 0.372, which was significantly lower than what reported in screens of various endangered breeds and land races of European, Middle Eastern and North African goats. More individuals are being genotyped to validate these results, but low genetic diversity would be a possible consequence of a founder effect during initial colonization, and years of isolation and inbreeding on Mona Island.

We have also initiated a screen of MHC II diversity in the goat samples. Preliminary analyses indicate that MHC II diversity is much higher than allelic diversity and heterozygosity observed in microsatellite makers.

Table 2. Microsatellites that successfully amplified in the pigs and goat of Mona Island. The name of each locus and the number of alleles identified in a subset of 20 individuals are shown.

<table>
<thead>
<tr>
<th>Primer</th>
<th>Annealing Temp (°C)</th>
<th>Size Range (bp)</th>
<th>Dye</th>
<th>Num of Alleles</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSRM60</td>
<td>59</td>
<td>94-106</td>
<td>FAM</td>
<td>5</td>
</tr>
<tr>
<td>CSSM663</td>
<td>55</td>
<td>198-229</td>
<td>HEX</td>
<td>4</td>
</tr>
<tr>
<td>ETH104</td>
<td>59</td>
<td>207-225</td>
<td>FAM</td>
<td>4</td>
</tr>
<tr>
<td>ETH152</td>
<td>59</td>
<td>212-232</td>
<td>HEX</td>
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</tr>
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<td>59</td>
<td>274-296</td>
<td>FAM</td>
<td>3</td>
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<td>144-160</td>
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<td>112-226</td>
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<td>176-184</td>
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<td>SW1828</td>
<td>59</td>
<td>111-115</td>
<td>FAM</td>
<td>4</td>
</tr>
</tbody>
</table>

Figure 7. An example of a monomorphic (A) and polymorphic microsatellite marker.
Summary of specific accomplishments for this project:

1. Two additional trips to Mona Island to collect more samples. Collection of muscle and fecal tissue samples in collaboration with the Puerto Rico Department of Natural Resources.
2. Completed the genomic DNA extraction from all samples.
3. Completed the optimization and characterization of the microsatellites markers for all the pigs and goats collected.
4. Preliminary estimates of genetic diversity in pig and goat samples using the results obtained with the microsatellites.

Goals for next year:

1. Screen MHC II allelic diversity in goats and pigs.
2. Initiate population genetic analysis of the goat and pig data within the broad framework of the European Econogene project.
3. Test if the Mona populations represent single or multiple introductions, and from where these introductions most likely were.
4. Start writing the manuscript

Component 3: Comparison of the Fecal Microbiota in Feral and Domestic Goats.

Investigator: Maria G. Dominguez-Bello

Animals have co-evolved with mutualistic microbial communities, known as the microbiota, which are essential for organ development and function. We hypothesize that modern animal husbandry practices exert an impact on the intestinal microbiota. In this study, we compared the structure of the fecal microbiota between feral and domestic goats using the G2 PhyloChip and assessed the presence of five tetracycline resistance genes [tet(M), tet(S), tet(O), tet(Q) and tet(W)] by PCR. The ultimate goal of this study is to determine how four centuries of feral conditions have preserved a microbial digestive diversity, and whether these microbial systems are open to gene transfer from outside ecosystems.

Goats (Capra hircus) were introduced to Mona Island by the Spaniards in colonial times. Even though invasive species represent a serious ecological problem to native species, they represent a rare opportunity to study the genetics and evolutionary process that take place between isolated wild populations and animals subject to the selection forces of domestication. To explore the fecal bacterial communities on the Mona Island feral goats, feces were collected from 10 goats: 5 domestic from a farm in the main island of Puerto Rico and 5 feral from the remote dry island of Mona.

Using the High-density 16S rDNA microarray, the PhyloChip, we identified 42 bacterial phyla from 153 families (Table 3) with many OTUs detected in the Firmicutes (35%), Proteobacteria (33%), and Actinobacteria (9%) (Figure 8) at the phylum level. Moreover the composition of the bacterial community in goat feces appeared similar among all goats, regardless lifestyle (Figure 8), and to the fecal bacterial composition in other mammals.

We also detected the specific taxa responsible for suggested group differences by performing an ANOVA test, which indicated 84 (4.2%) PhyloChip- OTUs accounting for group differences (Figure 9). In summary, we found that the differing OTUs belonged to 34 families and 11 phyla. Domestic goats had higher representation of 28 of the 34 families that differed between feral and
domestic goats. Bacterial families overrepresented in domestic goats belonged to Actinobacteria (7 of 7 families), Bacteroidetes (2 of 3 families), Firmicutes (4 of 4 families) and Proteobacteria (9 of 13 families), among others (Table 3). Feral goats were enriched in Proteobacteria (5 of 13 families), Bacteroidetes (1 of 3 families) and Nitrospira (1 of 1 family). In this study, all animals harbored fecal tet(O) and tet(W) genes (both in the digestive tract of swine and cows). The exclusive presence of tet(Q) in domestic goats is consistent with higher antibiotic exposure in farm animals. Interestingly, tet(M), found in human gut bifidobacteria, pig gut streptococci and cow rumen bacteria, was absent in all goats in this study. They also lacked tet(S), a gene typical of human oral bacteria.

Concluding, feral and domestic goats of Puerto Rico differed in the structure of their fecal bacterial communities, and, despite the absence of antibiotic pressures, feral goats carried fecal antibiotic resistance genes, although fewer than domestic goats. Diet, host genetic differences and antibiotic exposure might account for the differences in the microbiota between feral and domestic goats. Overall, the results of this study are consistent with those in other studies.

Table 3. Number of bacterial taxonomic groups (OTUs ± s.e.) in feces from feral and domestic goats.

<table>
<thead>
<tr>
<th>Taxonomic level</th>
<th>Feral goats (n = 4)</th>
<th>Domestic goats (n = 5)</th>
<th>Total N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phylum</td>
<td>38 ± 1</td>
<td>40 ± 1</td>
<td>42</td>
</tr>
<tr>
<td>Class</td>
<td>45 ± 1</td>
<td>48 ± 1</td>
<td>52</td>
</tr>
<tr>
<td>Order</td>
<td>73 ± 2</td>
<td>76 ± 3</td>
<td>92</td>
</tr>
<tr>
<td>Family</td>
<td>157 ± 1</td>
<td>132 ± 4</td>
<td>153</td>
</tr>
<tr>
<td>Subfamily</td>
<td>290 ± 28</td>
<td>335 ± 46</td>
<td>548</td>
</tr>
<tr>
<td>OTUs</td>
<td>1,121 ± 47</td>
<td>1,268 ± 74</td>
<td>1,982</td>
</tr>
</tbody>
</table>

Figure 8. Richness distribution of the 1,982 OTUs in 42 bacterial phyla among the feces of five domestic (D) and four feral (F) goats. (A) abundant phyla. (B) Phyla less represented (i.e., ‘others’).
comparing captive and feral or wild animals, which showed that domestic or urban animals have higher antibiotic resistance. The increase in antibiotic resistance genes in the past couple of decades has been attributed to the use of antibiotics, since bacteria develop resistance when exposed to low antibiotic doses. This and many other studies confirm that antibiotic resistance genes (and resistant populations) persist in the mammalian intestinal tracts even in the absence of antibiotics. The mechanisms for the persistence of these reservoirs are not clear, but it appears that the benefits for the survival of bacterial species are worth the costs.

Summary of specific accomplishments for this project:
1. A fecal bacterial community structure was characterized for the feral goats of Mona Island.
2. There were significant differences in the fecal microbiota structure between feral and domestic goats, with 84 bacterial OTUs accounting for these differences.
3. The microbial fauna of goats from Mona Island and Puerto Rican mainland clustered together, respectively, suggesting common shared history within sampling localities.
4. The diet and selective breeding might affect gut bacterial community structure.
5. Antibiotic resistance was found in Mona animals with no known exposure to antibiotics, suggesting that the goat’s gut bacteria is possibly a reservoir of antibiotic resistance genes.
6. A greater diversity of tetracycline resistance genes has been found in domesticated goats.

Component 3, Goals for year 5:
1. This project has been completed

Component 4: Aspergillosis of sea fans. Investigator: Paul Bayman
The purpose of this project is to assess the role of *Aspergillus* species as pathogens of sea fans in the Caribbean, determine the source of inoculum, and project the potential impact of global warming on the disease. The extensive literature on aspergillosis of sea fans holds that the pathogen is *Aspergillus sydowii* and the most likely source of inoculum is dust storms from the
Sahel of Africa. The results of this study were most interesting and highly surprising due to the fact that *A. flavus* was not found on any of the diseased *Gorgonia ventalina* sea fans, but was commonly found on non-diseased individuals. This result was confirmed through culture experiments as well as by PCR. *Aspergillus flavus* was also found in almost every type of sample, and there was no association with a particular genotype outgroups of genotypes and the sample substrate.

a) Phylogeography of the fungus *Aspergillus flavus*. Recently a study of fungi in sea fans lead by the Bayman’s lab has contributed to provide new understanding in human disease. The fungus is *Aspergillus flavus*, common in sea fans and many other environments. It produces toxins in foods and causes aspergillosis diseases in humans, but its effect on its sea fan hosts is unclear. Luis Ramírez, a graduate student, applied Amplified Fragments Length Polymorphisms (AFLP) DNA fingerprinting techniques to a worldwide collection of 200 individuals of *A. flavus* (Table 4). Strains of the fungus from sea fans and seawater were indistinguishable from those from terrestrial substrates, suggesting there is no specialization for life in the sea vs. life on land (Figure 10). Although the two sexes were in 50:50 proportions in strains from sea fans, the sex ratio in clinical strains was 85:15. This

<table>
<thead>
<tr>
<th>Culture</th>
<th>Substrate</th>
<th>Geographic origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>RO 1-25</td>
<td>Healthy Gorgonia tissue</td>
<td>Jobos, Salinas, Puerto Rico</td>
</tr>
<tr>
<td>RO 27</td>
<td>Healthy Gorgonia tissue</td>
<td>Jobos, Salinas, Puerto Rico</td>
</tr>
<tr>
<td>RO 28</td>
<td>Healthy Gorgonia tissue</td>
<td>Jobos, Salinas, Puerto Rico</td>
</tr>
<tr>
<td>RO 35</td>
<td>Healthy Gorgonia tissue</td>
<td>Jobos, Salinas, Puerto Rico</td>
</tr>
<tr>
<td>RO 35-35</td>
<td>Healthy Gorgonia tissue</td>
<td>Jobos, Salinas, Puerto Rico</td>
</tr>
<tr>
<td>RO 29</td>
<td>Healthy Gorgonia tissue</td>
<td>Jobos, Salinas, Puerto Rico</td>
</tr>
<tr>
<td>RO 40</td>
<td>Healthy Gorgonia tissue</td>
<td>Jobos, Salinas, Puerto Rico</td>
</tr>
<tr>
<td>RO 40</td>
<td>Healthy Gorgonia tissue</td>
<td>Jobos, Salinas, Puerto Rico</td>
</tr>
<tr>
<td>RO 49</td>
<td>Healthy Gorgonia tissue</td>
<td>Jobos, Salinas, Puerto Rico</td>
</tr>
<tr>
<td>LP 1</td>
<td>Healthy Gorgonia tissue</td>
<td>Luis Peña, Cojadera, Puerto Rico</td>
</tr>
<tr>
<td>LP 2</td>
<td>Healthy Gorgonia tissue</td>
<td>Luis Peña, Cojadera, Puerto Rico</td>
</tr>
<tr>
<td>V 1-3</td>
<td>Healthy Gorgonia tissue</td>
<td>Vieques Island, Puerto Rico</td>
</tr>
<tr>
<td>MAT 1</td>
<td>Microbial soil</td>
<td>Salinas, Cabo Rojo, Puerto Rico</td>
</tr>
<tr>
<td>RF 01</td>
<td>Orchard</td>
<td>Wellesley Experimental Farm, Winnsboro, CA (55)</td>
</tr>
<tr>
<td>RF 05</td>
<td>Orchard</td>
<td>Wellesley Experimental Farm, Winnsboro, CA (55)</td>
</tr>
<tr>
<td>RF 03</td>
<td>Orchard</td>
<td>Wellesley Experimental Farm, Winnsboro, CA (55)</td>
</tr>
<tr>
<td>RF 12</td>
<td>Orchard</td>
<td>Wellesley Experimental Farm, Winnsboro, CA (55)</td>
</tr>
<tr>
<td>CS 6</td>
<td>Seawater</td>
<td>Cabo Rojo, Puerto Rico</td>
</tr>
<tr>
<td>CS 7</td>
<td>Seawater</td>
<td>Cabo Rojo, Puerto Rico</td>
</tr>
<tr>
<td>CS 8</td>
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</tr>
<tr>
<td>DI 6</td>
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<td>Cabo Rojo, Puerto Rico</td>
</tr>
<tr>
<td>DI 5</td>
<td>Seawater</td>
<td>Cabo Rojo, Puerto Rico</td>
</tr>
<tr>
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<td>Seawater</td>
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</tr>
<tr>
<td>DI 30</td>
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<td>Cabo Rojo, Puerto Rico</td>
</tr>
<tr>
<td>LP 1</td>
<td>Seawater</td>
<td>Luis Peña, Cojadera, Puerto Rico</td>
</tr>
<tr>
<td>LP 12</td>
<td>Seawater</td>
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</tr>
<tr>
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<td>Seawater</td>
<td>Mona Island, Puerto Rico</td>
</tr>
<tr>
<td>MO 4</td>
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<td>Mona Island, Puerto Rico</td>
</tr>
<tr>
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<td>Seawater</td>
<td>Vieques Island, Puerto Rico</td>
</tr>
<tr>
<td>V 1-7</td>
<td>Seawater</td>
<td>Vieques Island, Puerto Rico</td>
</tr>
<tr>
<td>AN 2</td>
<td>Soil</td>
<td>Mona Island, Puerto Rico</td>
</tr>
<tr>
<td>AN 6</td>
<td>Soil</td>
<td>Mona Island, Puerto Rico</td>
</tr>
<tr>
<td>DO 1-4</td>
<td>Soil</td>
<td>New Delhi, India</td>
</tr>
<tr>
<td>DO 8-9</td>
<td>Soil</td>
<td>New Delhi, India</td>
</tr>
<tr>
<td>F 54</td>
<td>Soil</td>
<td>Wellesley Experimental Farm, Winnsboro, CA (55)</td>
</tr>
<tr>
<td>I 1</td>
<td>Soil</td>
<td>Ignacio, Argentina</td>
</tr>
<tr>
<td>I 3</td>
<td>Soil</td>
<td>Ignacio, Argentina</td>
</tr>
<tr>
<td>L 15</td>
<td>Soil</td>
<td>La Punta, Argentina</td>
</tr>
<tr>
<td>P 1-4</td>
<td>Soil</td>
<td>La Punta, Argentina</td>
</tr>
<tr>
<td>F 5</td>
<td>Soil</td>
<td>La Punta, Argentina</td>
</tr>
<tr>
<td>F 9</td>
<td>Soil</td>
<td>La Punta, Argentina</td>
</tr>
<tr>
<td>S A 3-10</td>
<td>Soil</td>
<td>Nigeria</td>
</tr>
<tr>
<td>S A 0-7</td>
<td>Soil</td>
<td>Nigeria</td>
</tr>
<tr>
<td>SMA 1-2</td>
<td>Soil</td>
<td>Herrera, China, Panama</td>
</tr>
<tr>
<td>W 1-4</td>
<td>Soil</td>
<td>El Salidinal, San Juan, Puerto Rico</td>
</tr>
<tr>
<td>26 Stock wt</td>
<td>Soil</td>
<td>Yuma, Arizona, US</td>
</tr>
<tr>
<td>70 Stock wt</td>
<td>Soil</td>
<td>Yuma, Arizona, US</td>
</tr>
<tr>
<td>DOE 1-3</td>
<td>Territorial</td>
<td>New Delhi, India</td>
</tr>
<tr>
<td>F 55</td>
<td>Unknown</td>
<td>California</td>
</tr>
<tr>
<td>T 15</td>
<td>Unknown</td>
<td>California</td>
</tr>
<tr>
<td>T 16</td>
<td>Unknown</td>
<td>California</td>
</tr>
<tr>
<td>T 25</td>
<td>Unknown</td>
<td>Jobos, Salinas, Puerto Rico</td>
</tr>
<tr>
<td>T 30</td>
<td>Unknown</td>
<td>Jobos, Salinas, Puerto Rico</td>
</tr>
<tr>
<td>W 1-1</td>
<td>Unknown</td>
<td>El Verde, Rio Grande, Puerto Rico</td>
</tr>
</tbody>
</table>
suggests that a gene linked to the sex-determining genes may be contributing to the ability to cause disease in humans, and may eventually lead to new ideas for antifungal therapies. The research, funded by NOAA Sea Grant and supported by Creat-CATEC was published in the journal Fungal Biology: Ramírez-Camejo L. A., Zuluaga-Montero A., Lázaro-Escudero M., Hernández-Kendall V., Bayman P. (2012). Phylogeography of the cosmopolitan fungus Aspergillus flavus: is everything everywhere?, Fungal Biology, 116, 3: 452-463.

In summary a total of two hundred A. flavus strains have been isolated and collected, including numerous strains from sea fans (Gorgonia ventalina), sea water and dust (Table 4). Molecular analysis was performed on almost all of the strains (terrestrial and marine) was performed using AFLP markers in order to determine if phylogeny can predicts substratum specificity. A total of 460 variable AFLP markers were detected among 201 isolates using 8 primer combinations, which generated between 19 and 59 polymorphic alleles each. Statistical analyses based on AFLPs did not reveal specificity for substrate or source. These results suggested a lack of population structure in A. flavus and that all isolates may compose a single population, with no clade particular to marine environments. Same results were confirmed using sequence data.

The lack of population structure of A. flavus in this study suggests there is sufficient gene flow to prevent population differentiation among different places and substrata (Figure 10). This supports the classical theory of microbial biogeography most succinctly stated by Bass-Becking in 1934: “Everything is everywhere; the environment selects”.

This study has led to the rethinking of sea fan diseases, and to the development of two mathematical models to describe the fate of diseased sea fans. A graduate student in computer science, Claudia Patricia Ruiz Díaz, has started trying to model survival of sea fans infected with a pathogen. Parameters for the model have been taken from our data. It is possible that this project will become the PhD thesis of the student. Also, Alberto Sabat is using data on incidence...
of aspergillosis lesions on sea fans to build a model to predict effects of disease on sea fan populations. Both of these approaches are novel for coral diseases.

Summary of specific accomplishments for this project:
1. 200 \textit{A. flavus} strains were isolated and collected, from sea fans, sea water and dust.
2. 323 variable AFLP markers were detected among 30 isolates from very diverse substrates, using 10 primer combinations.
3. Analysis completed.

Goals for next year:
2. This project has been completed

b) Virulence in \textit{Aspergillus}.
\textit{Aspergillus flavus} is an opportunistic pathogen of humans, birds, insects and plants; it is common in sea fans as well, though it is not clear if it is a pathogen. We compared isolates from a variety of substrates for virulence on \textit{Drosophila}. Recent studies have shown that \textit{Drosophila} has a more sophisticated immune system than previously recognized, and is a good model for the study of virulence. Isolates differed significantly in virulence, but those from clinical sources and sea fans were not significantly more virulent than those from soil or plants (Figure 11). Mutants deficient in melanin biosynthesis were significantly less virulent than the wild type in \textit{A. fumigatus}, which agrees with studies showing a role for melanin in fungal virulence.

![Fig. 11. Virulence and isolates from different strains. \textit{D. melanogaster} survival rate and days of infection with isolates from different substrates (shown with different colors). Difference between the control flies and the one inoculated with \textit{A. flavus} are displayed.](image-url)
Summary of specific accomplishments for this project:
1. 100 flies (D. melanogaster) have been infected with A. flavus and A. fumigatus strains.
2. Tested 10 different substrates isolates.
3. Determined mortality rates for different Aspergillus strains included mutants deficient in melanin biosynthesis.
4. Preliminary statistical test does not suggest correlation between virulence difference and sources of isolates. Aspergillus isolated from sea fans was not significantly more virulent than those from soil or plants.
5. Established a new model to test the immune response induced by Aspergillus infection.

Goals for next year:
1. Continue testing the pathogenicity of different Aspergillus isolates in D. melanogaster, and increase the number of flies assessed.
2. Design an experiment to test the interaction between the fungus and the insect.
3. Characterize gene expression changes in D. melanogaster after the infection with the Aspergillus.
4. Identify possible immune genes target that causes the death of the flies after exposure to the fungus.

Component 5: Population ecology and genetics of the invasive lionfish in Puerto Rico
Investigator: Riccardo Papa
Among the invasive species in the Atlantic, the two lionfish P. volitans and P. miles seriously concern conservation biologists as well as management authorities for its fast diffusion, rapid population growth and its ability to out-compete native fish for food and territory. Lionfish are venomous, predatory reef fishes endemic to the Indo-Pacific Ocean that only recently have been introduced into the Atlantic. Since their first sightings in Florida in the mid 1980’s, they have spread throughout the Northern Atlantic to the majority of the Caribbean (Figure 15). Pterois volitans has rapidly colonized the Atlantic northwest and the Caribbean Sea, with an incredibly rapid adaptation to different marine environments. Thus, it represents a major threat for native species and communities across the Greater Caribbean. Coupled with climate change, anthropogenic stress factors and diseases that affect reef corals, lionfish constitute a very serious menace for one of the most endangered marine ecosystems: the coral reef in the Western Atlantic.

Fig. 12. Lionfish invasion. Lionfish expansion and distribution in the Western Atlantic from few years of his first appearance to the present.
Given the magnitude of lionfish invasion, studies on this system can generate broad information in several fields of biology such as ecology, conservation, evolution and biogeography that in our opinion feed on each other’s. For example management strategies should not be implemented without taking into consideration population connectivity on a large scale and relate this information to local cases. Moreover reconstructing the patterns and processes of marine biological invasions will generate an overall knowledge on population larval dispersal in marine systems.

Preliminary data from this study on lionfish from 24 sites around the coastal waters of Puerto Rico demonstrated that \textit{P. volitans} L. is the only lionfish species present in the island, most likely originating from the Florida invasive population. Moreover only 4 haplotypes out of the 9 haplotypes identified in the Atlantic, were detected suggesting a secondary founder effect after the initial invasion (Fig. 16). This work is contributing to the reconstruction of the expansion routes and the population structure of the lionfish in the Caribbean and provides baseline data to understand and monitor the progression of the invasion in the Antilles. Despite strict data interpretation it is important to note that even using a marker that has inherent limitations for fine-scale population structure, such as the mitochondrial d-loop, it was possible to detect genetic differentiation at both regional (Northern Atlantic and the Caribbean) and local (Puerto Rico) scales.

Finally using lionfish as an invasive model organism can provide general and predictive understanding of invasion’s mechanisms, population connectivity in ocean systems, community assembly, ecosystem function, adaptation, evolution and the response of species to changing environment and especially to climate change.

**Summary of specific accomplishments for this project:**

1. Collected lionfish samples.
2. Collected data for the ecological and genetic study.
3. Analyzed the data.
4. Lionfish in Puerto Rico are represented by only \textit{P. volitans}. 

![Fig. 13. Mitochondrial DNA analysis of lionfish invasion. Recent results for Lionfish d-loop mtDNA haplotype composition in seven sites in Greater Caribbean/US east coast as reported by Freshwater et al. 2009 and Betancur et al. 2001 (left), and from our study in Puerto Rico (right) are shown.](image)
5. In Puerto Rico only 4 out of the 9 Atlantic haplotype have been identified.
6. Possible secondary founder effect in Puerto Rico
7. 

Goals for next year:
1. Finish the analysis.
2. Writing the manuscript and submitted for publication.
3. Initiate a bigger project to study the whole lionfish invasion.

Component 6: Speciation genomics of Heliconius butterflies:
This is a new component of the MEEG thrust area, headed by Riccardo Papa. The present research is leveraged by other NSF funds. Investigator: Riccardo Papa

Population genomics of Heliconius butterflies hybrid zones
A common aspect to ecology, evolution and any studies that deal with biodiversity in general is to understand how adaptive variation arises, spreads, and influences the origin of new species. Much about this process can be learned from the study of genomic changes that occur during adaptive radiations, when bursts in evolution cause explosions of biodiversity. Recent radiations, in particular, provide ideal opportunities to study the genomic changes responsible for adaptive divergence and how they might drive reproductive isolation between groups. They are in earliest stages of differentiation and are likely to yield the keenest insights into some of the most fundamental questions of evolutionary biology. For example, are stochastic (i.e. drift) or directional (i.e. selection) evolutionary processes responsible for the origin of an adaptive trait? Can adaptive divergence in the presence of gene flow actually lead to speciation? And lastly, how repeatable is evolution and predictable are the genomic changes that underlie convergent evolution. Answering these questions requires the establishment of new “model” systems that complement and extend research on traditional genetic model organisms-systems with a rich source of natural variation, an extensive history documenting the adaptive significance of this variation, ample genomic resources and good possibilities for both field and laboratory based research.

The proposed project draws from the natural diversity in the wing patterns of Heliconius butterflies, the growing genomic resources, and the emerging genomic technologies to study how genomes evolve during adaptive radiations. Using next-generation sequencing technology (Illumine RAD sequencing) we will examine genomic divergence across H. erato and H. melpomene butterflies hybrid zones of divergent color pattern to study how genomes evolve during the incipient stages of speciation. These within and between species hybrid zones provide powerful “natural” laboratories to examine the degree of genomic divergence that accumulates during the speciation process.

Summary of specific accomplishments for this project:
1. Collected hybrid zones samples of H. erato and H. melpomene for two hybrid zones, one in Peru and one in Ecuador.
2. Generated RAD tags Illumina libraries for both hybrid zones.
3. Sequenced all the Illumine RAD libraries.
4. Started analyzing the data.

Goals for next year:
1. Complete the analysis of the data
2. Start writing the manuscript
Component 7: Supplement – An Evaluation of Pleistocene Climate Change on the demographic history of Amazonian fishes. Investigator: Tomas Hrbek

The purpose of this supplement was to extend and elaborate on ongoing collaborations with researchers at the Federal University of Amazonas and the National Research Institute of the Amazon, both in Manaus, Amazonas, Brazil. The project facilitated the collection and analysis of data from seven different species of fishes widely distributed in the Amazon basin, the visit of three students and one researcher from Manaus to the University of Puerto Rico, and the visit of one student from Puerto Rico and the investigator to Manaus. The results are exciting and indicate that all the species analyzed, independent of higher-level taxonomic group, have experienced a significant demographic expansion on the order of one to two orders of magnitude during the Pleistocene. We have identified two principal periods, one associated with the transition between the last glacial period and the present-day interglacial, and another associated with the accentuated sea level oscillations in the early Pleistocene.

Summary of specific accomplishments for this project:
1. Collection of data from seven freshwater fish species for approximately 200 individuals per species.
2. Demographic analyses implementing a Bayesian model (implemented in BEAST).
3. Submission of a scientific article to Molecular Ecology.
4. Submission of a research grant to CNPq.
5. Bi-direction exchange of Puerto Rican and Brazilian students and researchers.
6. Strengthening of joint collaborative research efforts.

Goals for next year:
1. Strengthening of joint collaborative research efforts.
2. Publication of results from the demographic analysis.

Thrust area II: Species and Population Management.

Component 1: Factors that promote plant invasibility and their effect on endangered plant species.


The work on the population biology of invasive orchid species is nearing the conclusion on several projects. Two papers have been submitted and field work for others is in nearing completion. Species distribution modeling remains to be done for one study (Conquering the islands one fruit at a time: Arundina graminifolia (Orchidaceae) visits Puerto Rico and Hawaii). We anticipate another 2-3 to come from these studies. We have found that invasive Spathoglottis plicata is attacked by a native florivorous beetle which severely diminishes the orchid's fruit and seed production. The Spathoglottis elevates beetle populations which in turn attack more of the sympatric native orchid, Bletia patula, reducing its reproductive success as well. We also found that reproductive success for two invasive orchids, the Spathoglottis and Arundina graminifolia, in Hawaii and Puerto Rico differs, largely due to the florivore beetles in Puerto Rico, and the better pollinator visitation rates in Hawaii. In the meantime, we have begun gathering data on the establishment of Pine plantations. We first intend to use species distribution modeling techniques to determine whether there are potential limits to the spread of pines on the island and
whether spread is currently limited by mycorrhizae availability. The second phase of the study will assess whether they have an impact on the species composition and diversity of communities, particularly the fungal and herbaceous floras.

**Thrust area II: Species and Population Management. Component 1: Factors that promote plant invasibility and their effect on endangered plant species.**

**Project: Impacts of the exotic grass, *Megathyrsus maximus* on *Harrisia portoricensis* in Mona Island Reserve. (J. Rojas-Sandoval and E. Melendez-Ackerman).**

This study revolved on plant community dynamics of a tropical semi-arid system following experimental removals of an exotic grass (developed by J. Rojas-Sandoval and E. Melendez-Ackerman). The main objective was to determine if the presence of the exotic grass *Megathyrsus maximus* influence the abundance and richness of plant communities on Mona Island Reserve. Data was obtained from established plots with different management treatments of *Megathyrsus* (complete and partial grass removal), in order to evaluate the effects of grass removal on plant community composition, coupled with measurements of microclimatic characteristics at this site. The study found that plant abundance increased following grass removal but changes in abundance were not necessarily linear over time. Species richness was significantly higher in grass removal plots but differences resulted from a consistent decrease in richness in plots with *Megathyrsus*. Both abundance and richness were highly variable over time regardless of treatment. The evaluation of temporal community dynamics suggested that these may be driven by temporal changes in climate, and in the case of manipulated plots, by changes in microclimatic conditions. Even when new species arrived into plots following grass removal these failed to establish. An evaluation of successional trajectories showed that removing the invasive grass does not lead to communities that are more similar to non-invaded sites, most likely due to changes in precipitation dynamics. In conclusion, grass removal does not necessarily result in predictable successional changes in plant communities where natural regeneration is allowed to occur. Restoring grass-invaded areas in this semi-arid reserve to conditions that simulate current non-invaded sites would likely require restoration strategies that combine grass management with activities that facilitate the establishment of native species. This may be a general occurrence in grass-invaded areas in semi-arid regions (Figure 1).

![Figure 1. Non-metric multidimensional scaling (NMS) ordination with successional vector overlays for plant community composition under different management treatments performed on Mona Islanda between 2007 and December 2009. Porep: Opuntia repens, Megmax: Megathyrsus maximus, Agasis: Agave sisalana, Pectin: Pectis linifolia, Rhymin: Rynchosia minima, Stiema: Stigmaphyllon emarginatum.](image)
Project: Factors affecting establishment success of the endangered Caribbean cactus *Harrisia portoricensis* (Cactaceae). (J. Rojas-Sandoval and E. Melendez-Ackerman).

Early plant stages may be the most vulnerable within the life cycle of plants especially in arid ecosystems. Interference from exotic species may exacerbate this condition. This project evaluated germination, seedling survival, and growth in the endangered Caribbean cactus *Harrisia portoricensis*, as a function of sunlight exposure (i.e., growing under open and shaded areas), different shade providers (i.e., growing under two native shrubs and one exotic grass species), two levels of predation (i.e., exclusion and non-exclusion) and variable microenvironmental conditions (i.e., temperature, PAR, humidity). Field experiments demonstrated that suitable conditions for germination and establishment of *H. portoricensis* seedling are optimal in shaded areas beneath the canopy of established species, but experiments also demonstrated that the identity of the shade provider can have a significant influence on the outcome of these processes. *Harrisia portoricensis* seedlings had higher probabilities of survival and grew better (i.e., larger diameters) when they were transplanted beneath the canopy of native shrubs, than beneath the exotic grass species, where temperature and solar radiation values were on average much higher than those obtained under the canopies of native shrubs. The study also detected that exclusion from potential predators did not increase seedling survival. The combined results for *H. portoricensis* suggested that the modification of microenvironmental conditions by the exotic grass may lower the probability of recruitment and establishment of this endangered cactus species. (Figure 2).

![Figure 2. Survival of Harrisia portoricensis under three different shade provider: the native shrubs Croton discolor and Reynosia uncinata and the exotic grass Megathyrsus maximus. N initial = 20 seedlings/treatment.](image)

Project: Reproductive phenology of the Caribbean cactus *Harrisia portoricensis*: rainfall and temperature associations. (J. Rojas-Sandoval and E. Meléndez-Ackerman).

Phenological patterns often influence the extent of reproductive success of plants as well the interaction among species. In this study, we evaluated the association of local climatic factors and plant size with the reproductive phenology of the threatened cactus *Harrisia portoricensis* in the Caribbean dry forest of Mona Island. Analyses of phenological data
gathered monthly in 572 plants over 2 years concluded that for this species, reproductive activity is continuous throughout the year and reproductive output is positively correlated with plant size. Bud production in *H. portoricensis* was positively associated with temporal changes in monthly mean and minimum temperatures, while flower production was positively associated with total monthly rainfall. When compared with other columnar cacti species, the combined phenological responses to temperature and rainfall in *H. portoricensis* represent a different strategy. We hypothesize that contrasting phenological responses among columnar cacti may stem from site-specific differences in the degree of intra-annual rainfall or temperature variability. If that is the case, then monitoring reproductive responses of cacti to expected changes in climate at a global scale would require gathering phenological data for this taxon across different geographic regions (Figures 3 and 4).

Project: New distribution record of *Cybocephalus kathrynae* (Coleoptera, Cybocephalidae) on Mona Island, Puerto Rico. (Jean Carlos Curbelo-Rodríguez, Elvia J. Meléndez-Ackerman, Julissa Rojas-Sandoval, Alejandro Segarra-Carmona).

A new record of *Cybocephalus kathrynae* T.R. Smith (Cybocephalidae) is reported for Puerto Rico. Adults were collected from the flowers of *Mammillaria nivosa* (Cactaceae) on Mona Island Reserve. Prior to this study, this beetle species was only reported for Monroe and Miami-Dade Counties, Florida, USA. (Figure 5).
Component 2: Population viability analysis (PVA) of the Mona Island endangered reptiles in support of Caribbean-wide management efforts.


Keyla Pagán-Rivera finished her Master’s thesis on the use of Bayesian hierarchical models for fitting Von Bertalanffy growth curves with mark recapture data. In particular, she worked with data from a reintroduced population of Virgin Islands Boa (*Epicrates monensis*). She modified the models proposed by Zangh, Lessard and Campbell (2009) to incorporate differences in growth by sex. The deviance information criterion (DIC) and the Bayesian p-value (Meng, 1994) were used for model selection, and the selected model is the one that allows variability among individuals for the maximum size but considers the growth rate fixed by sex.

Problems appearing in practical applications of Bayesian Statistics to Ecology have suggested the need of reducing shrinkage between different groups or individuals in order to allow exceptional cases to be identified or to avoid excessive influence of bigger groups on smaller ones. With this objective, the use of heavy tail priors is being explored, and the use of a scaled beta of the second kind as a prior for scale parameters is being proposed as a robust alternative to the usual Inverse Gamma distribution. We have been exploring further consequences of the use of the scaled Beta 2 as robust priors for variances, also in applications to Bayesian Dynamic linear models, and we are developing guides for assigning the parameters of these priors in practice.

Component 3: Patterns of diversification of economically-important tree genus *Tabebuia*.


During 2011-2012, we carried out taxonomic sampling in in the field in Puerto Rico, Mona Island, the Dominican Republic, Jamaica, and Grand Cayman. We also obtained hard-to-find material from herbarium specimens (NY Botanical Garden), and from the USDA subtropical Experiment Station (Cuban material in cultivation). We have sampled ca. 60% of the genus Tabebuia, and have all the Greater Antilles represented. Samples have been process for DNA extraction, amplification, and sequencing (Chloroplast regions: psbD-trnT, and rpl32-trnL;
Nuclear regions: ITS, AT5G39980-Pentatricopeptide Repeat – PPR—a new addition to the project). Here we present a phylogram (Figure 6) of a Maximum Parsimony analysis based on the combined dataset of noncoding chloroplast rpl32-trnL, psbD-trnT, nrITS, and PPR AT5G39980. This preliminary analysis provides the following insights: 1. the confirmation that the Caribbean species are part of Tabebuia sensu stricto by the position of genus type species T. cassinoides, which is for the first time included in a phylogenetic analysis of the group, 2. the monophyly of Caribbean species of Tabebuia, 3. the close relationship to the predominantly continental species T. rosea, and 4. the validity of additional species in Hispaniola and Puerto Rico.

![Figure 6](image-url)

Thrust area III: Ecosystem Processes and Function Group

Component 1: Water source, plant phenology, and plant water use efficiency in native tree species under similar mesoclimatic conditions but contrasting hydrogeologic settings in a tropical dry forest. Investigators: Elvira Cuevas, Jorge Ortiz, Yogani Govender, Jesús Rodríguez, Leonel Sternberg, Ernesto Medina and Miguel Canals.

The fieldwork in Guanica Dry Forest started in October 2007. Replicate trees of five species: Coccoloba microstachya, Tabebuia heterophylla, Ficus citrifolia, Pisonia albida and Erithalis fruticosa were tagged and georeferenced in the Coastal Plateau. All species are natives and grow from the ridge to the coast in the dry forest. Trees from the mangrove species Avicennia germinans, Laguncularia racemosa and Conocarpus erectus were selected, tagged and
georeferenced for sampling and phenology studies in the Tamarindo area where the Puerto Rican Crested Toad pond is located. Sampling for eco-physiological measurements, nutrients and stable isotope analyses started in November 2007. The sampling will continue until December 2012. The mangrove sampling was finished and we are in the process of analyzing the results and manuscript writing. We do monthly sampling of the water sources (surface soil, rainwater and ground water) and in the Coastal Flamenco lagoon. Each sample is analyzed for Deuterium and δ18O and salinity. Meteorological data is accessed from nearby costal station (500m away from study site). The samples for stable isotopes are prepared in the lab and are analyzed Leonel Sternberg, research collaborator, at the Stable Isotope Laboratory from the University of Miami. Since summer 2009 we are also sampling and analyzing water from three piezometers to 50 cm depth between trees and two piezometers, one to 2.5 m depth and the other where fresh water was located (8.5m depth). The results so far confirm the karstic terrain with cave formation at 8 meters depth, the aquifer research during periods of maximum rain and the evaporated oceanic origin of the rainfall.

In order to determine the effects of climate variability on precipitation spatial and temporal patterns we need to have a long-term dataset that will allow us to establish possible differences among years. We now have data on isotopic signature of precipitation and ground water for four consecutive years. There are significant differences in the amount of precipitation collected between 2008 until 2011 between our sites with significant differences in isotopic signature for rainfall for the last four years.

<table>
<thead>
<tr>
<th>Site</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>60 year- average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guánica Dry Forest (semi-arid)</td>
<td>976</td>
<td>731</td>
<td>1388</td>
<td>1296</td>
<td>670</td>
</tr>
<tr>
<td>Rio Piedras Experimental Station (humid)</td>
<td>1389</td>
<td>1647</td>
<td>2273</td>
<td>1927</td>
<td>1744</td>
</tr>
</tbody>
</table>

We also included local weather variables to determine why rainfall isotopic signature changes throughout the year. We found significant correlations between local and regional variables between isotopic signature of rainfall in Guanica and Rio Piedras. In both the Guanica Dry Forest and Rio Piedras sites, variability in isotopic signature for precipitation was negatively correlated with average air and sea temperature and total precipitation. The isotopic signature of rainfall throughout the study period was highly variable for Guánica (Figure 1). For all years, we found a significant decrease in δ18O values during tropical storm events (Figure 2). This is typical of the “storm effect” where at high rain rate, the precipitation through a layer is less equilibrated with the water vapor because the isotopic equilibration time is long compared to the fast transit time, and there is preponderance of large drops, which take longer to equilibrate. The δ18O of vapor in the lower

![Figure 1. Annual precipitation (mm) from 2008 until 2011 in the Guánica Dry Forest (semi-arid region) and the Rio Piedras Experimental Station (humid region) in Puerto Rico.](image)

![Figure 2. Cumulative precipitation and respective δ18O signature for sampled periods from 2008 to 2011 in the Guánica Dry forest.](image)
atmosphere becomes lower as a result of the interaction with these raindrops of low $\delta^{18}O$, and the degree of depletion of $^{18}O$ is higher when precipitation rates are high.

We are also seeing the evaporated signature of the rainfall (positive $\delta^{18}O$, higher Deuterium excess) during low rainfall periods reflecting the increased temperatures affecting the Tropical Atlantic and the Caribbean (Figure 2). As the rainfall is of oceanic origin, the stable isotopic signature is a proxy for the increased global climate variability reflected at the regional level.

The isotopic signatures of rainfall and groundwater negative values are natural tracers that allows us to determine the exact periods when ground water recharge is happening in the Guánica Dry Forest. Figure 3 shows that ground water recharge is based on rainfall input in the area. Therefore the system is pulse-based system where plant growth and ecosystem dynamics are limited by water availability.

We will continue our sampling and isotopic determinations isotopic until May 2013 in order to cover the rainfall variability of the area and publish the results of the first four years.

Project 2: Paleoclimate variability and historical anthropogenic changes in land use effects on ecosystem structure and function in a sub-tropical dry forest in Puerto Rico:
Elvira Cuevas, Yogani Govender, Leonel Sternberg, Miguel Canals, Rubén Lara, Marcelo Cohen and Eneilis Mulero.

The stable isotope analyses, radiocarbon dating and pollen determinations of the sediment cores from the Flamenco lagoon are now complete. The data presents a very complete picture of the paleoecological fluctuations in the area during the past 5700 years (Figure 4). Both the stable isotopes and pollen indicate changes in vegetation from dominance of dry forest woody vegetation that changed to Rhizophora mangroves in 300 hundred years. This implies sea level rise that brings the seaward mangrove inland caused by wetter periods that shift into a drier period around 4600 yBP where sea level stabilized. The seal level stabilization in the northeastern Caribbean is near 3000 years later than in the western Caribbean, which reflects regional variability. We consider that the southern migration of the Tropical Convergence Zone five thousand years ago as shown by Thedesco and Thunnel in 2003 established drier conditions thus reducing the rate of sea level rise in the Caribbean.

The lack of mangrove pollen and the increase in herbs and grasses indicate a shift toward a drier period and dune formation in the ocean side of the lagoon ratifying the drier conditions. The Little Ice Age brought about considerably drier conditions where the dune vegetation was eliminated. We do not see any charcoal remains thus eliminating anthropogenic indigenous influence in the vegetation. The stable isotopes confirm this situation as the signature and C/N ratio of the decarbonated sediment is predominantly phytoplankton. The continuous increase in evaporation due to high temperatures increased the salinity of the water to the extent that there is no aquatic vegetation present to this day.
The increase in trees, herbs and grasses in the area seems to be correlated with the elimination of the sand dune and new colonization in the former sand dune area, especially by exotic grasses (Figure 5). In the last fifty years there has been considerable beach erosion with loss of coastal vegetation. The wave line is now 5 meter inland than 50 years ago. The same situation is seen throughout the island, confirming the increased sea level rise during the past decades. For next year we will send the manuscripts of the studies for publication in peer-reviewed journals.

Figure 4. Stable isotope signatures and pollen diagram along the sediment core in the Flamenco lagoon, Guánica Dry Forest.

Figure 5. Stable isotopic signatures and AMS radiocarbon age of sediments from the Flamenco Lagoon, Guánica Dry Forest.
ANIMAL ECO-PHYSIOLOGICAL RESPONSES TO FOOD AVAILABILITY: NATIVE AND INVASIVE REPTILE SPECIES. Investigators: Elvira Cuevas, Yogani Govender, Sondra Vega and Ruber Rodríguez.

Project 3. An isotopic study of diet and muscles of the Green Iguana (Iguana iguana) in Puerto Rico: The study will be published in an issue dedicated to invasive species in the Journal of Herpetology. Stable isotopes studies of muscle and gut content indicate opportunistic omnivory in herbivorous iguanas. This is the first published result of Iguanas eating Uca crabs and snails. Jhoset Burgos, undergraduate student that will graduate in June 2012, will continue this research for his Master’s thesis at the University of Rhode Island under the mentorship of Dr. Jason Kolbe. This is especially important as the population expansion of I. iguana throughout the whole island raises serious conservation concerns regarding its ecological role and impact on the native fauna and flora of the islands.

Project 4. Omnivory in Anolis lizards along a precipitation and elevational gradient in moist areas on karst in Puerto Rico - Sondra Vega, PhD dissertation - All Anolis lizards are omnivorous, however degree of omnivory varies among species and within the same species from different localities indicating opportunistic response to food availability. The lack of data about fruit consumption by these lizard species might be because dietary studies only can reveal fruits that were consumed whole and during the time immediately preceding capture of animals. In contrast, stable isotopes reflect the isotopic values of the food consumed at least five to six month before sampling. Detailed studies are being carried out in the northern karst region of Puerto Rico at the El Tallonal Private Conservation reserve and Mata de Platano Reserve in Arecibo, Puerto Rico to determine the monthly diet sources (airborne and litter insects and fruits) and availability, and level of omnivory/frugivory of Anolis lizards. Tail samples and insect samples are gathered monthly. Subsamples of the insects, the lizards’ tails and fruits are prepared and sent to the Stable Isotope Laboratory of Dr. Leonel Sternberg at the University of Miami for δ15N and δ13C determinations. There is a manuscript in preparation from the preliminary results using stable isotope technology where it was shown that land use and insect availability determines the degree of insectivory versus omnivory of two Anolis species. The information gathered in those studies will allow determining the role of anoles lizards in food webs as well as in the function and dynamics of insular tropical ecosystems.

Project 5. Tree species diversity and water availability affects belowground microbial functional groups dynamics and enzymatic activity in the Guánica Dry Forest. Michelle Rivera – Ph.D. dissertation - Ecologists have long recognized that vegetation can exert a strong influence over soil properties, and that individual plant species play an important role in determining soil fertility in natural ecosystems. Given that plant species vary in their effects on soil properties it can be expected that the processes regulated by microbes will also be responsive to plant species effects. The study site is the Dwarf forest of the Guánica Dry Forest Reserve, located at the Southwestern part of Puerto Rico. The climate is semi-arid with a mean annual precipitation of 670 mm. Although rainfall can vary from months with higher precipitation (August – October) to those of none or very low precipitation (December – April), the variability among months and among years is such that the area is driven by pulsing events. In this area the trees are dwarfed due to low rainfall, high temperatures, strong winds and salt spray. Different species of dwarfed trees are found growing in the cracks of the calcareous rocks isolated from one another, forming monospecific islands of leaf litter and organic matter creating, diverse
microhabitats for the soil microbiota. The substrate is very shallow, highly organic, with very little to no mineral soil present. The monospecific islands created by the dwarf trees makes the Guánica Dry Forest an interesting site to study the plant species effect on soil microbial communities because most of these studies have been done in greenhouse pot experiments under controlled conditions and in monocultures where trees are not isolated from one another. Our aim is to understand how plant species affect soil diversity by a) determining the differences in microbial biomass in the substrate (soil) of different tree species, b) understand how plant species affects microbial enzymatic activities by assaying three different microbial enzymes that are present in soils, c) identifying microbial functional groups related to biogeochemical cycles using the fatty acid methyl ester technique, d) to create microbial phylogenies using the Phylochip technology and e) to determine soil nutrients and physical chemical characteristics in order to correlate them with microbial biomass, activity and functional groups. Dr. Veronica Acosta-Martínez, from the ARS-USDA at Lubbock, Texas is collaborating in this study.

Table 1 presents the results of the enzymatic analyses and some soil parameters. The soils are highly organic with a near neutral to alkaline pH. Soil textures suggest that soils from our sampling site have similar physical chemical characteristics and that certain microbial communities may be shared, however, the organic matter derived from each tree species could add extra microbial biodiversity. The majority of the enzymes assayed presented significant differences under the selected tree species, suggesting that tree species traits may have a direct effect on the microbial activities taking place in these soils.

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<tbody>
<tr>
<td><strong>Ficus citrifolia</strong></td>
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</tr>
<tr>
<td>Alkaline Phosphatase</td>
<td>904.60 (176.81)</td>
<td>917.40 (232.12)</td>
<td>792.94 (92.88)</td>
<td>952.50 (405.09)</td>
<td>791.49 (238.74)</td>
</tr>
<tr>
<td>Acid Phosphatase</td>
<td>720 (714.61)</td>
<td>1069.66 (790.62)</td>
<td>1213.1 (352.29)</td>
<td>1996.71 (134.20)</td>
<td>2116.94 (90.97)</td>
</tr>
<tr>
<td>Aryl-Sulfatase</td>
<td>404.62 (239.01)</td>
<td>493.19 (281.58)</td>
<td>309.74 (266.87)</td>
<td>402.33 (190.26)</td>
<td>482.57 (344.00)</td>
</tr>
<tr>
<td>β-Glucosidase</td>
<td>295.57 (74.14)</td>
<td>285.86 (51.82)</td>
<td>265.02 (99.86)</td>
<td>295.31 (41.88)</td>
<td>300.69 (66.49)</td>
</tr>
<tr>
<td>β-Glucosaminidase</td>
<td>212.27 (69.97)</td>
<td>139.28 (27.89)</td>
<td>158.53 (43.26)</td>
<td>160.98 (16.15)</td>
<td>177.45 (14.57)</td>
</tr>
<tr>
<td>Phosphodiesterase</td>
<td>978.28 (687.26)</td>
<td>532.38 (137.87)</td>
<td>616.22 (257.24)</td>
<td>856.31 (116.17)</td>
<td>739.58 (60.05)</td>
</tr>
<tr>
<td>Soil Humidity (%)</td>
<td>60.9 (49.61)</td>
<td>147.67 (114.64)</td>
<td>72.6 (61.28)</td>
<td>93.44 (70.80)</td>
<td>78.68 (63.66)</td>
</tr>
<tr>
<td>Soil pH</td>
<td>7.9 (0.23)</td>
<td>8.16 (0.11)</td>
<td>8.13 (0.17)</td>
<td>8.04 (0.15)</td>
<td>7.89 (0.11)</td>
</tr>
<tr>
<td>Soil Total Organic C</td>
<td>72.77 (15.14)</td>
<td>79.92 (10.40)</td>
<td>70.42 (17.89)</td>
<td>71.32 (7.15)</td>
<td>71.65 (9.19)</td>
</tr>
<tr>
<td><strong>Pisonia albida</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Alkaline Phosphatase</td>
<td>985.62 (114.97)</td>
<td>2300.84 (2141.97)</td>
<td>954.77 (265.96)</td>
<td>2246.96 (1601.43)</td>
<td>875.07 (342.14)</td>
</tr>
<tr>
<td>Acid Phosphatase</td>
<td>604.68 (80.65)</td>
<td>1398.97 (934.19)</td>
<td>992.16 (363.70)</td>
<td>1518.89 (625.39)</td>
<td>1228.91 (368.20)</td>
</tr>
<tr>
<td>Aryl-Sulfatase</td>
<td>384.02 (135.85)</td>
<td>332.06 (146.53)</td>
<td>678.84 (303.21)</td>
<td>319.40 (140.09)</td>
<td>390.33 (217.36)</td>
</tr>
<tr>
<td>β-Glucosidase</td>
<td>186.30 (84.84)</td>
<td>466.82 (83.90)</td>
<td>287.81 (179.26)</td>
<td>278.33 (19.86)</td>
<td>284.00 (98.18)</td>
</tr>
<tr>
<td>β-Glucosaminidase</td>
<td>121.27 (69.97)</td>
<td>430.55 (455.24)</td>
<td>240.59 (101.24)</td>
<td>482.90 (250.42)</td>
<td>209.20 (143.41)</td>
</tr>
<tr>
<td>Phosphodiesterase</td>
<td>246.08 (30.65)</td>
<td>241.38 (133.84)</td>
<td>667.49 (155.60)</td>
<td>363.96 (97.02)</td>
<td>502.51 (150.75)</td>
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<tr>
<td>Soil Humidity (%)</td>
<td>41.92 (51.74)</td>
<td>166 (208.24)</td>
<td>44.75 (90.83)</td>
<td>63.57 (142.42)</td>
<td>41.51 (87.47)</td>
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<tr>
<td>Soil pH</td>
<td>7.53 (0.72)</td>
<td>7.60 (1.27)</td>
<td>7.95 (0.29)</td>
<td>6.87 (1.04)</td>
<td>7.64 (0.22)</td>
</tr>
<tr>
<td>Soil Total Organic C</td>
<td>77.50 (14.35)</td>
<td>82.50 (17.89)</td>
<td>78.37 (18.88)</td>
<td>84.53 (16.93)</td>
<td>80.90 (15.45)</td>
</tr>
<tr>
<td><strong>Ficus heterofila</strong></td>
<td></td>
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</tr>
<tr>
<td>Alkaline Phosphatase</td>
<td>1553.33 (627.68)</td>
<td>1839.88 (540.76)</td>
<td>2238.43 (685.54)</td>
<td>2115.50 (191.29)</td>
<td>2023.09 (157.78)</td>
</tr>
<tr>
<td>Acid Phosphatase</td>
<td>1152.78 (154.18)</td>
<td>1030.66 (357.45)</td>
<td>1363.12 (238.60)</td>
<td>1387.89 (257.10)</td>
<td>1253.58 (108.40)</td>
</tr>
<tr>
<td>Aryl-Sulfatase</td>
<td>537.25 (348.90)</td>
<td>588.85 (305.69)</td>
<td>1041.71 (1028.21)</td>
<td>565.80 (280.53)</td>
<td>386.19 (135.85)</td>
</tr>
<tr>
<td>β-Glucosidase</td>
<td>545.20 (381.20)</td>
<td>443.79 (102.76)</td>
<td>903.87 (628.43)</td>
<td>454.71 (95.08)</td>
<td>454.66 (76.71)</td>
</tr>
<tr>
<td>β-Glucosaminidase</td>
<td>124.96 (65.75)</td>
<td>124.97 (73.91)</td>
<td>121.83 (40.70)</td>
<td>123.29 (34.34)</td>
<td>88.82 (26.86)</td>
</tr>
<tr>
<td>Phosphodiesterase</td>
<td>443.81 (91.21)</td>
<td>761.02 (59.20)</td>
<td>870.29 (286.63)</td>
<td>811.81 (236.83)</td>
<td>986.07 (99.97)</td>
</tr>
<tr>
<td>Soil Humidity (%)</td>
<td>46.28 (54.77)</td>
<td>128.64 (156.25)</td>
<td>79.56 (90.19)</td>
<td>95.56 (97.76)</td>
<td>67.04 (90.90)</td>
</tr>
<tr>
<td>Soil pH</td>
<td>7.91 (0.28)</td>
<td>8.12 (0.11)</td>
<td>7.61 (0.21)</td>
<td>8.10 (0.08)</td>
<td>7.99 (0.17)</td>
</tr>
<tr>
<td>Soil Total Organic C</td>
<td>69.89 (13.72)</td>
<td>79.18 (5.88)</td>
<td>74.00 (13.39)</td>
<td>74.85 (8.94)</td>
<td>65.15 (2.65)</td>
</tr>
</tbody>
</table>
Alkaline phosphatase activity was the highest with no significant differences for acid phosphatase activity (Figure 6B). Phosphodiesterase activity was significantly lower under Pisonia than Tabebuia and Ficus (Figure 6D). Beta-glycosidase activity was higher under Tabebuia and lower under Ficus and Pisonia (Figure 6D). B-glucosaminidase activity was significantly higher under Pisonia and lower under Tabebuia and Ficus (Figure 6E). Aryl-Sulfatase activity was the same for all the tree species (Figure 6F).

EL-FAME
Using Canonical discriminate analysis to compare the FAME profiles identified under each of the three tree species, we found significant differences (P<0.0001) in the microbial community structure under each tree species (Figure 7). Canonical Plot grouped the FAMES according to tree species (Figure CANONICAL FAMES). All of the 13 FAMES used for analysis showed a high influence on the positive side of canonical axis 1 and canonical axis 2. Results for canonical axis 1 suggest

Figure 6. Enzymatic activity of the tree species under study during the months of July 2011-November 2011.

Figure 7. Canonical Discriminant Analysis of the soil FAME profiles under tree species at the Guánica Dry Forest for the months of July 2011 – November 2011.
that soils under Pisonia contained FAME profiles with higher amounts of i17 and w9c18. Whereas soils under Ficus contained FAME profiles with higher amounts of w6c18:2, Me16 and i15. Results for Canonical axis 2 suggest that soils under Tabebuia contained FAME profiles with higher amounts of a15. These differences in microbial diversity may be due to the quality and quantity of the organic matter of each tree species. We are currently analyzing the organic matter of each tree species in order to identify their organic and inorganic components.

Project 6. Diet of sea urchins in the Northeastern coast of Puerto Rico – Ruber Rodriguez, Ph.D. dissertation - Sea urchins are an integral part of the food web in tropical reefs. As herbivorous they are important grazers of the sea floor. However, what is their food source and if there are differences among sea urchin species are questions that need to be answered. Diadema antillarum, a former ubiquitous species that went into massive decline in the 18980s is now slowly recovering. It is, therefore, of utmost importance to determine their food source. We did a preliminary study to determine the stable isotope signature of three species of sea urchins and the sea grasses and algae present in their home range. The samples were prepared according to the established protocol in the EPF laboratory and sent to the Stable Isotope Laboratory of Dr. Leonel Sternberg at the University of Miami for δ15N and δ13C determinations. The preliminary studies show that there are significant differences in the δ13C signature among the three sea urchins studied. These signatures reflect the marine carbon source (dissolved bicarbonate) and their food source. Tripnestes ventricosum’s signature reflect their preference for sea grasses, Syringodium filliforme and Thallasia testudinum, and also the epiphytes on T. testudinum. (Figure 8). Diadema antillarum’s signal is similar to the calcareous algae, whereas Echinometra lucunter’s signature seem to reflect that they are eating both calcareous and non-calcareous algae. Our results indicate partitioning rather than competition for food resources among the three species.

Component 2: Ecohydrology of critical habitats in the Guanica Biosphere Reserve

Investigators: J. Ortiz, E. Cuevas and M. Canals.

Project 1. Ecohydrology of critical habitats in the Guánica Biosphere Reserve. For the past four years, graduate student, Rita Cáceres have worked on the characterization of the physical and chemical properties of the water in the natural breeding ponds and in the artificial reintroduction ponds associated to the conservation of the Puerto Rican crested toad (PRCT) in the south of Puerto Rico. The water parameters influencing tadpole growth and timing to metamorphosis appear to be water salinity, temperature, pond duration and, water depth. Biological factors such as tadpole density and competition with an invasive species can also influence the transition from tadpoles to metamorphs. Due to the unpredictability of the climate in Gunica’s Dry Forest and of unexpected breeding events of the PRCT, we have not been able
to measure the effect of abiotic and biotic parameters in the field. However, in an experimental setting, Rita has been able to measure the effect of water salinity on the survival, growth and timing to metamorphosis of the PRCT. Tadpoles of the PRCT were exposed to six water salinity treatments, freshwater, 2, 4, 6, 8, and 10 ppt. As tadpoles of PRCT were exposed to increasing water salinity concentrations, their growth was reduced; their time to metamorphosis increased and tadpoles exposed to 8 and 10 ppt of water salinity did not survive. These results provide valuable information on a water parameter that is negatively impacting the fitness of tadpole in the natural environment. By concentrating some of the conservation efforts provided for the PRCT in monitoring ponds we can better ensure that more breeding events result in successful and fit juvenile population of PRCT. Figures 1a and 1b show these data.

CATEC is currently sponsoring Rita Cáceres in her research project. CATEC has also sponsored in the past graduate student, Jorge Viqueira, Interamerican University of Puerto Rico. Viqueira has developed a three-year data base on groundwater levels from three observation wells located along the Guánica Forest coastline.

![Figure 1](image)

Figure 1. Relationship between salinity treatments and tadpole survival (a) and body length (b).
Project 2. Nitrogen dynamics in tropical aquatic environments. Two studies were underway by our research group to investigate how nitrogen cycles in aquatic tropical systems. The first study led by Carlos Conde finished in June 2011 when Carlos completed the requirements of his Ph.D. program. His research focused on understanding the effects of bat guano on the nitrogen dynamics in a karstic cave river in Southwestern Puerto Rico. The project has revealed that water flows through the cave occur year round and are rich in nitrate and organic nitrogen. In addition, nitrification rates are very high inside the cave stream suggesting a very effective oxidation of ammonia to nitrate, which tends to accumulate in concentrations of up to 5 mg/L. These nitrification rates are among the highest ever reported in the reviewed literature. The project yielded a paper to the Journal of Karst and Cave Studies on the hydrology of the Convento cave system, currently under review after receiving comments from the editor. The paper will be resubmitted to the same journal this summer. CATEC provided support in this project by providing funds to purchase critical instrumentation and materials.

The second study, led by Hamlet Perez (Ph.D. student), focuses on the effects of anthropogenic disturbances on the nitrogen dynamics of the San Juan Bay Estuary, a tropical estuary located in the middle of the San Juan Metropolitan Area. Typically the primary productivity of coastal waters is nitrogen-limited. In tropical developed countries, like Puerto Rico, estuaries are highly eutrophied due to uncontrolled non-point and point sources of pollution rich in inorganic and organic nitrogen. Therefore, controlling the flux of nitrogen to estuaries in Puerto Rico is seen as a way to control their eutrophication. Denitrification is a natural pathway by which nitrogen can be expelled out from eutrophied waters, however, in tropical eutrophied waters, the role of denitrification has been poorly studied. Therefore, a study was initiated in 2006 to understand the dynamics of nitrogen fluxes in the San Jose Lagoon of the San Juan Bay Estuary of Puerto Rico. Hamlet is currently writing his dissertation that he plans to defend by the end of this summer.

Project 3. Anthropogenic influences on the carbon cycle in tropical inland waters. Urbanization strongly impacts stream ecosystems and little information is known about how it affects dissolved organic carbon (DOC) in rivers and how consequently it affects tropical rivers. DOC is an important energy source in aquatic ecosystems. Bianca Rodriguez, an undergraduate student from the Environmental Sciences Program, developed a project focusing on changes in DOC biodegradability along a tropical urban river in Puerto Rico. The Río Piedras runs through the heart of the San Juan Metropolitan Area, making it susceptible to human impacts. By measuring the biodegradability constant (k) of the organic matter present in water samples she was able to assess water quality conditions of the Río Piedras. Figure 2 compares the k constant at five stations along the Río Piedras. The k constant...
increased downstream during high flow conditions while in low to base flow conditions, the k constant increased upstream. The biodegradability constants compare well with those reported in raw sewage or well-treated sewage, confirming the poor water quality conditions of the Rio Piedras. Thanks in large degree to CATEC research infrastructure support, Bianca successfully completed the requirements of the Environmental Sciences Program and will start graduate studies at the University of New Hampshire this year.

The role of urbanization on the flux of carbon compounds from tropical watersheds has been poorly documented. Particularly, unknown are the impacts on the quality of dissolved organic carbon that fuels the metabolism of rivers and estuaries. Given the importance of the biodegradability of the organic matter on the energy flow in aquatic ecosystems, studies that characterize the carbon metabolism are critically needed to better manage inland and coastal aquatic ecosystems. Figure 3 shows a comparison between the rates of gross primary production between the two tropical stratified estuaries studied by Rafael Benítez-Joubert, a graduate student from the Department of Biology, and rates reported in other tropical estuaries. The studied estuaries were Mameyes and Sabana, which proved to be more productive than the other tropical estuaries. During this reporting period, Rafael Benitez, completed the requirements of a Master in Science degree. CATEC contributed greatly to his project by providing stipends and materials to conduct field studies. He is currently working as a limnological researcher with the Agricultural Experimental Station in Rio Piedras.

Debora Figueroa is a Univ. of New Hampshire PhD student and is receiving logistic support from the Tropical Limnology Laboratory at UPR. Miss. Figueroa research evaluates the effects of wastewater disposal on the assimilative capacity of wastewaters in tropical rivers. She has been conducting nutrient releases and evaluating the river retention rates of nitrogen and phosphorus. She presented her project in two national meetings last year.

![Figure 3. Comparison of the gross primary productivity (GPP) from different sites from the United States of America National Estuarine Research Reserves from Caffrey (2004) represented by the black bars. The white bars represent the GPP reported in this study.](image-url)
Some anthropogenic organic inputs are considered endocrine disrupting chemicals (EDCs). Particularly, hormone compounds, like estrogen, have been detected in urban waters that receive effluents from wastewater sources or urban runoff. However, these chemicals have not been studied in waters in Puerto Rico. Concern exists that EDCs may interfere with the endocrine system of both humans and wildlife. During this reporting period, Mrs. Sheila Soler, a Biology Ph.D. student, started to sample urban rivers in Puerto Rico to assess the estrogenic activity in these waters. She has been validating a recently developed bioassay based on genetically modified yeast cells that are sensitive to estrogen producing a luminescent signal that is proportional to the estrogenic activity present in the water sample. With funding from CATEC, Sheila has traveled to the University of Texas to receive training with the author of the bioassay technique, Dr. Marc B. Cox of the Border Biomedical Research Center and Department of Biological Sciences of the University of Texas at El Paso. Preliminary data revealed estrogenic activity levels in the picomoles (pM) range. However, the dynamic nature of human activities in an urban watershed requires a more comprehensive monitoring approach. A GC-MS will be used to characterize estrogenic compounds in water samples. In a future project phase, Soler plans to also study the effect of wastewater treatments on the removal efficiency of estrogenic compounds by sampling different wastewater treatment plants.

Project 4. Hydrological implications of land use change in tropical urban watersheds. In an attempt to evaluate historic land use changes in coastal wetlands, Mr. Aristides Martinez, a Ph.D. graduate student in Environmental Sciences, has started to characterize the relationship between land use patterns and trace metal speciation content in sediment soils, at La Malaria Canal drainage system of Las Cucharillas Marsh, in the Municipality of Cataño, in northern Puerto Rico. Utilizing historical maps, IKONOS® Infrared, and Color Infrared (CIR) aerial images, Martinez conducted a preliminary analysis of land coverage/use change from 1889 - 2010. The analysis revealed that more than 95% of agricultural lands had disappeared by 2010. Several cultural traits or anthropogenic footprints have proliferated as soils have been modified by man through hydrological changes resulting from dredging and filling of wetlands. Ecological restoration of impacted riparian areas has been initiated in some impacted rivers as results of urban sprawl. Mr. Harold Manrique, an MS student from the Environmental Sciences Program, is studying a restored segment of a headwater tropical creek called Quebrada Chiclana using the current conditions of riparian vegetation features as success indicators. He expected that if the reforestation plan considered the pre-impacted condition of the riparian features then current conditions should reflect the pre-impacted conditions. He established eight cross-sections along the restored creek each one divided in two plots: left bank and right bank. Each plot was divided into five sub-plots. Three plots were considered as reference for pre-impacted conditions. He determined the number, frequency and diversity of plant genera present per plot. Plots used as reference of pre-impacted conditions showed the highest genera diversity and community complexity. Figure 4 shows the results of his analysis. While we cannot conclude that the restoration was not environmentally successful, we present results were the reference non-impacted plots shows higher vegetation complexity and composition than the impacted plots.

Research activities during the cycle of May 2011 to May 2012 have mainly focused on:

1) Continuing the coral reef long-term ecological monitoring activities of the project, with a significant expansion on the geographical extension of research to other reefs in Puerto Rico in order to increase our spatial resolution.

Preliminary analyses of collected data suggest several important findings. First, coral reefs have not shown any meaningful recovery from the post-bleaching mass coral mortality of 2005-2006. Percent coral cover and coral species richness has remained largely unchanged during the last few years across sites (Figure 1). Second, there has been a 54% mean magnitude decline in % coral cover, with individual declines ranging from 12 to 87%/locality (Figure 2).

Figure 1. Before- and after comparisons of percent coral cover across several coral reefs from Northeastern Puerto Rico.

Figure 2. Percent magnitude change of living coral cover after the 2005-2006 massive coral bleaching event across Northeastern Puerto Rico.
Coral mortality trends have largely impacted the most significant reef-building species complex across the Atlantic, the Star coral *Montastraea annularis* species complex (Figure 3). Populations of this species complex have shown a mean 69% decline, with ranging values of 35 to 100% loss across sites (Figure 4). Principal component ordination analysis (PCO) of part of the data clearly suggests a dramatic change in coral reef benthic community structure suggesting a highly significant community phase shift (Figure 5). Many coral reefs used to be dominated by *Montastraea annularis* species complex, and are now dominated by macroalgae and other non-reef building taxa.

**Figure 5.** Principal component ordination analysis of spatio-temporal variation in benthic community structure along the eastern shelf of Puerto Rico.

2) Continuing and expanding the long-term coral recruitment monitoring effort.

Coral recruitment has been actively monitored across permanent coral reef monitoring sites since 2008. Currently, undergraduate student Alejandra H. Alvarado-Alvarado is conducting a thorough analysis of digital images of permanent transects across several reef monitoring sites to address spatio-temporal variation on coral recruitment rates for her B.Sc. thesis project in the Department of Environmental Science. However, some recent preliminary findings from an ongoing coral recruitment assessment and its relationship to grazing activities by the long-spined sea urchin, *Diadema antillarum*, conducted with the collaboration of undergraduate student Nicole M. Resto in Culebra Island, has shown a very important link between herbivory and coral reef recovery ability through coral recruitment. There was a significantly higher density of coral recruits in habitats showing higher densities of sea urchins (Figures 6-8). There was also a mean higher coral recruit species richness (Figure 9) and overall colony density (Figure 10) in coral reefs with higher urchin densities and herbivory. There was also higher % cover of living corals and CCA at reefs with higher urchin densities (Figures 11-12). In contrast, there was higher %...
macroalgal and % cyanobacterial cover at reefs with lower herbivory by *D. antillarum*. Similarly, though not significant yet, there was a trend of increasing coral recruit species diversity index and evenness under higher herbivory (Figure 13-14). These results are part of an ongoing study and point out at the critical role that maintaining high herbivory levels will play to maintain coral reef recovery ability from disturbance and resilience under climate change.

Figure 6. Absolute density of long spined sea urchin, *Diadema antillarum* by locality.

Figure 7. Mean relative density of coral recruits at Punta Soldado, Culebra Island.

Figure 8. Mean relative density of coral recruits at Bahía Tamarindo, Culebra Island.
Figure 9. Mean coral recruit species richness by site (±95% confidence intervals).

Figure 10. Mean coral recruit density by site (±95% confidence intervals).

Figure 11. Percent benthic components cover at Punta Soldado, Culebra Island.
Figure 12. Percent benthic components cover at Bahía Tamarindo, Culebra Island.

Figure 13. Coral recruit species diversity index (H’n) by site (±95% confidence interval).

Figure 14. Coral recruit species evenness (J’n) by site (±95% confidence interval).
3) Continuing targeted monitoring of the ecological fate of physiological fragments of lobbed star coral, *Montastraea annularis*.

This study has been conducted over a period of nearly six years at Culebra Island with a special focus in addressing what has been the fate of surviving physiological fragments of *M. annularis* following the massive bleaching event of 2005 and the post-bleaching mass mortality of 2006. Preliminary findings point out at the dramatic loss in % live tissue cover in *M. annularis* and the nearly total lack of colony recovery (Figure 15). Tissue cover loss has been more significant at Punta Soldado in comparison to localities within the Canal Luis Peña no-take Natural Reserve. Current work is focusing on running a population model using calculated mortality rates for different physiological fragment size categories, as well as calculated transitions, either grow to a next size category, remaining on the same size or colony size retrogressions. Data will be used to forecast the fate of the remaining populations and to estimate what would be the impact on the species of recurrent massive bleaching events in the near future.

![Figure 15. Percent living tissue cover loss in *M. annularis* from permanent monitoring photoquadrats in Culebra Island.](image)

4) Setting up and initiating the early stages of a field experiment to test hypotheses associated to coral physiological fragment survival.

This aspect of the project got delayed for nearly a year. Currently, almost all materials for the experiment were already obtained. This phase of the project will be aimed at testing the null hypothesis that there are no significant differences in fragment survival and tissue regeneration ability among *M. annularis* physiological fragments of different size categories. Briefly, triplicate plots will be established following a random block design to test tissue regeneration ability in *M. annularis* of four different size categories (<25 cm²; 25-50 cm², 50-100 cm², >100 cm²). Treatments will include: tissue lesions of two sizes (1 cm²; 5 cm²) without adjacent algae/sponge removal, tissue lesions of two sizes (1 cm²; 5 cm²) + adjacent algae/sponge
removal; algae/sponge removal, but without tissue lesions (controls); and unaltered controls. Corals will be tested for tissue regeneration of artificial lesions and for tissue expansion to adjacent substrates.

5) Monitoring of physiological activity in *M. annularis* and *M. faveolata* across anthropogenic stress gradients.

This phase of the study will be aimed at determining coral metabolic activity based on DNA/RNA ratios. Briefly, samples from colonies of different size categories of both species will be identified, georeferenced and tagged in the field for seasonal sampling at duplicate inshore degraded and offshore remote reefs. Data will be obtained from colonies of different size categories as above and analyzed for DNA and RNA concentrations to test for the null hypotheses of no significant spatio-temporal and taxonomic difference in metabolic performance in corals. Corals will also be tested if there are any significant pulse events (i.e., extreme rainfall and flooding).

6) Coral coring of selected *Montastraea annularis*, *M. faveolata* and *Solenastrea bournoni* colonies to address climate change impacts on coral growth rate, skeletal density, and calcification rates.

The coral coring collection component of the project is been carried out by Ph.D.C. Raisa Hernández-Pacheco, Dr. Anne Cohen (Woods Hole Oceanographic Institution -WHOI) and P.I. Edwin A. Hernández-Delgado. It is expected to be completed within the upcoming months. However, preliminary sample collection was carried out at Las Croabas (LC) in Fajardo, Puerto Rico (18°21′51″N, 65°37′28″W) during the spring season of 2011. The reef at LC is a linear reef. This site is characterized by strong inland-runoff influences due to its location 4 km north off the Fajardo River estuary. However, corals did not show any sign of stress (e.g. bleaching, infectious disease) at the moment of sample collection. We collected six coral cores from living colonies of *Solenastrea bournoni* and two from *Montastraea annularis* at 5 m of depth using a Stanley DL-07 hand-held submersible hydraulic driller with a 5 cm-diameter barrel. We also collected three cores of *M. faveolata* from Cayo Diablo, located at 11 km northeast of the Fajardo River estuary. Core holes were filled with premade cement plugs to prevent impacts by boring sponges. Samples were rinsed with fresh water, dried in the oven at 60°C for no less than 24-48 hours, and shipped to the Computerized Scanning and Imaging Facility (CSI) at the WHOI. Following Cantin et al. (2010), intact coral cores were scanned using a Siemens Volume Zoom Spiral Computerized Tomography (CT) Scanner and annual skeletal density, linear extension rate, and calcification rate were estimated using OsiriX Imaging software. The latter was possible due to the alternating annual high-low density band patterns that the calcium carbonate skeleton of corals exhibits. Therefore, by measuring the distance between successive high-density bands we were able to estimate the annual linear extension rates. Calcification rates were estimated by multiplying the density value of each annual band by its corresponding skeletal extension. Measurements of each parameter were obtained in triplicates for each core and average annual linear extension and calcification rates were calculated. Sclerochronologies for the past 30 years were analyzed in order to reconstruct the skeletogenesis data of these corals from 1980 to 2010.
During the mass bleaching event of 2005, populations of one of the principal Caribbean reef-building coral, *Montastraea annularis*, suffered significant decline at multiple localities. A different response was observed among other taxa resulting in an increase in their relative coral cover. However, an assessment on the relationship of coral cover change and skeletal parameters following a thermal stress event is absent. We collected coral cores of *M. annularis* and *Solenastrea bournoni* from a monitored site at the eastern shelf of Puerto Rico. Skeletal density, linear extension rate, and calcification rate were estimated using three-dimensional computed tomography tracing back annual growth rates to 30 years. Historical sea surface temperatures correlated positively with *M. annularis* linear extension and calcification rates having the highest calcification rate during 2010 (1.64 g/cm²/yr, $R^2 = 0.266$) and the lowest in 1989 (0.395 g/cm²/yr, $R^2 = 0.442$). This is unexpected owing the fact that *Montastraea* has proven to be highly sensitive to thermal stress by undergoing significant decline in coral cover following a bleaching event. Conversely, a negative correlation between sea surface temperature and *S. bournoni* was found. Although this could be interpreted to mean that *Solenastrea* is less thermally tolerant than *Montastraea*, the community data suggests the opposite. Our findings recommend the interpretation of thermal tolerance in coral core studies to be reviewed. Because of its link to growth rate, calcification is a major component of coral resilience and, therefore, a key issue to assess under the predicted global warming scenarios.

Corresponding sea surface temperatures (SST) from 1980 to 2010 were obtained from the National Oceanic and Atmospheric Administration (NOAA) Extended Reconstructed Sea Surface Temperature (ERSST) v3b climatology. In order to determine the relationship between sea surface temperature and skeletal growth parameters, summer SST anomalies [July, August, and September (JAS)] – as well as annual linear extension and calcification rate anomalies – were calculated and correlation analysis was carried out. Preliminary results show interesting contrasting trends among species. For instance, *S. bournoni* showed a slightly declining trend in its linear skeletal extension anomaly (Figure 16) as SST anomaly increased through time. In contrast, *M. annularis* showed a significant increasing trend in its linear skeletal extension anomaly (Figure 18) and in its mean annual calcification rate anomaly (Figure 19) with an increase in SST anomaly through time. Similarly, *M. annularis* showed also a significant increasing trend in its linear skeletal extension anomaly (Figure 18) with an increase in SST anomaly through time. These results are highly significant because they suggest that interpretation of sclerochronological data can be highly variable among species and interpretation of environmental changes in coral reefs using such tools should be carried out with caution.

Both species, *M. annularis* and *M. faveolata* showed a significant increase in skeletal growth with increasing temperature suggesting a positive physiological or metabolic response to increasing temperatures, but apparently up to a threshold point associated to massive bleaching events. During peak SST years both species showed a decline in skeletal density as a result of increased linear extension rates. But in years immediately following the massive bleaching events of 1987, 1998 and 2005 both species showed a significant drop in skeletal growth and calcification rates, thus resulting in rapid increased in skeletal density (Figure 20). Interestingly, the trend was inverted in *S. bournoni*. Again, this is important to consider such variable patterns when skeletal parameters are used for historical environmental reinterpretation of coral reefs. The next steps of this phase of the project will be to complete further coral coring, particularly on *Montastraea* spp. across a distance gradient off the Fajardo River estuary and complete all core measurements.
Figure 16. Relationship between standardized linear skeletal extension anomaly (cm) in *Solenastrea bournoni* from Las Croabas Reef and JAS SST anomaly.

Figure 17. Relationship between mean annual calcification rate anomaly (g/cm²/y) in *Solenastrea bournoni* from Las Croabas Reef and JAS SST anomaly.

Figure 18. Relationship between standardized linear skeletal extension anomaly (cm) in *Montastrea annularis* from Las Croabas Reef and JAS SST anomaly.
Figure 19. Relationship between mean annual calcification rate anomaly (g/cm²/y) in *Montastraea annularis* from Las Crobas Reef and JAS SST anomaly.

Figure 20. Relationship between standardized linear skeletal extension anomaly (cm) in *Montastraea faveolata* from Cayo Diablo and JAS SST anomaly.

Figure 21. Temporal variation in mean skeletal density (g/cm³) in *Solenastrea bournoni*, *Montastraea annularis*, and *M. faveolata*. 
Preliminary analyses combining rainfall rates measured at different locations throughout Fajardo River watershed as part of a parallel collaborative study with Dr. Carlos E. Ramos-Scharrón (Dept. Geography and the Environment, University of Texas, Austin) and Damaris Torres-Pulliza (Island Resources Foundation), where the three coral parameters yielded no clear trends. Comparisons with annual streamflow measured at the USGS Rio Fajardo station (Station No. 50071000) showed some promising relationships that merit further analyses. A general trend of lower annual calcification rates and lower annual extension rates was noted with increasing annual flow rates (Figure 22). In addition, skeletal densities were generally higher for years with high streamflows.

Figure 22. Relationship between observed annual normalized streamflow for the Río Fajardo gaging station and Montastrea annularis calcification rates, annual linear extension, and density.

7) Expansion of the spatial resolution of coral core on reefs located across anthropogenic stress gradients.

Coral coring activities have been significantly delayed due to an abnormal seven month delay in the bureaucratic process of permit renewal at the Department of Natural and Environmental Resources. The situation is now resolved. The next steps of the process will be collecting coral cores at Mona Island and Guánica coral reefs during early June 2012.

8) Other efforts

CATEC’s CRRG efforts have also focused in expanding our existing collaboration with NGOs Sociedad Ambiente Marino, Coralations, Vegabajenos Impulsando Desarrollo Ambiental Sustentable (VIDAS), and with the NOAA RestorationCenter by conserving, restoring and protecting remnant populations of the threatened Staghorn coral (*Acropora cervicornis*) and Elkhorn coral (*A. palmata*). Low-tech coral aquaculture methods have been successfully used in
Culebra Island, PR, since year 2003 to propagate threatened Staghorn coral (*A. cervicornis*) (Figure 23). Harvested corals are being used through the Culebra Island Community-Based Coral Aquaculture and Reef Rehabilitation Program to restock their populations and rehabilitate bomb-cratered coral reefs (Figure 24). This project has included one of the most significant stakeholders and base communities involvement, direct participation and support. It has also become more critical in recent years in face of imminent climate change impacts. We have been successful at propagating warm water-resistant genetic strains of corals. Most colonies survived the 2005 warming event and exhibited growth rates several orders of magnitude faster than wild populations. But adaptive responses in coral farming and reef restoration will be critical to keep up with climate change stress in the near future. This project got recent NOAA funding through NGO Sociedad Ambiente Marino in partnership with CATEC, and NGOs Coralations and Vegabajeños Impulsando Desarrollo Ambiental Sustentable (VIDAS).

This project is aimed at rehabilitating shallow-water fish nursery grounds across several representative coral reefs in PR by applying low-tech methods to culture, harvest and transplant threatened Acroporid corals. During the second phase of the first year we applied locally-developed and proved low-tech, community-based coral propagation methods to expand and monitor existing Staghorn coral (*Acropora cervicornis*) farms at Arrecife El Banderote in Bahía Tamarindo (BTA) and Punta Soldado (PSO), Culebra Island (Figure 23). An initial total of 1,440 fragments of six different phenotypical clones were harvested from wild populations and grown on coral farms at both sites (Figure 24). At the end of the second phase we doubled the number of corals grown in farms to 2,880. The total corals being raised across all farming systems is currently estimated at 5,500. Corals in farming units showed a 81% and 95% survival rate at PSO and BTA, respectively, over the first year of the project. Survival rate at Punta Melones (PME) reached only 64% due to significant impacts by Hurricane Irene during August 2011, which caused localized destruction of some of the farming units and significant coral mortality. Details of these impacts were included in Progress Report 1 in October 2011. Farms were relocated to an alternative site at BTA, where surviving fragments showed an outstanding recovery. Percent live tissue cover ranged from 86% at PME to 97% at BTA. Mean total colony length ranged from 46 to 62 cm at PME and BTA, respectively. Initial transplants had a mean length of 21 cm. This resulted in a mean month growth rate of approximately 2.4 to 3.4 cm. Branchiness index (>6 cm) ranged from 2/colony at PME to 2.5/colony at BTA, or a 5.5 to 8.8-fold increase. There was a total branch >6 cm production ranging from 198 to 323, or a 4.5 to 9.4-fold increase. Branchiness index (>10 cm) ranged from 1.1/colony at PME to 1.7/colony at BTA, or a 28 to 53-fold increase at PME and BTA, respectively. There was a total branch >10 cm production ranging from 111 to 198, or a 27 to 55-fold increase. Total number of branches/colony ranged from 3.9 to 5 at PME and BTA, respectively, or a 1.2 to 2.3 fold increase. There were clone-specific variations on the result. At the end of the first year, a total of 2,000 harvested colonies were outplanted to adjacent coral reefs. Also, preliminary monitoring of previously outplanted vs. control (no outplanting) sites suggests that outplanting can significantly enhance juvenile reef fish communities. We also used a low-tech experimental farming approach to collect, stabilize, grow, harvest and outplant 144 opportunity fragments of Elkhorn coral (*Acropora palmata*) at Vega Baja and Manati, PR. Coral growth was overall significant over the first nine months of the project, in spite of some negative impacts caused by runoff and hurricane-associated and winter storm-associated sediment bedload during the project. Survival rates of Elkhorn coral have averaged 80-90% across sites. Survival rate was largely site-specific and coral condition-specific, since corals of opportunity were used and we
had no control on fragment condition at the moment of collection. Environmental history of each coral transplanting site, as well as the positioning of farming units, and regular maintenance of units appear to be a critical factor to improve project success. However, our data show that the project have had a significant success after the end of the first year.

Figure 23. Partial view of Staghorn coral (*Acropora cervicornis*) farming units at Culebra Island. From top left: A-B) “A”-frame coral farms; C-D) Horizontal rope nursery farms; E) Diver during the process of monitoring data collection; and F) Team of SAM’s divers working on the replenishment of coral farms with harvested fragments.
Figure 24. Outplanting of Staghorn coral (*Acropora cervicornis*) in Culebra Island. From top left: A-B) Fragments were outplanted natural reef bottoms on patches that ranged from 57 to 165 corals; C-D) Divers during the outplanting process; and E-F) Details of outplanted colonies.
Summary results of A. cervicornis farming during the first year

In spite of hurricane and extreme rainfall impacts during 2011, Staghorn coral farming during the first year was highly successful. For instance, corals in farming units showed a 81% and 95% survival rate at PSO and BTA, respectively, over the first year of the project (Figure 25). These values exceeded the expected 80% survival rate. Survival rate at Punta Melones (PME) reached only 64% due to significant impacts by Hurricane Irene during August 2011, which caused localized destruction of some of the farming units and significant coral mortality. Details of these impacts were included in Progress Report 1 in October 2011. Farms were relocated to an alternative site at BTA, where surviving fragments showed an outstanding recovery and showed a 95% survival rate. Percent live tissue cover ranged from 86% at PME to 97% at BTA (Figure 26). These values are considered excellent and exceeded the expected 80% live tissue cover value. Mean total colony length ranged from 46 to 62 cm at PME and BTA, respectively (Figure 27). Initial transplants had a mean length of 21 cm. These results suggest a ratio of increase in total colony length that ranged between 1.3 and 1.9-fold in PME and BTA, respectively (Figure 28). Mean month growth rates ranged from approximately 2.4 to 3.4 cm (Figure 29). Total number of branches/colony ranged from 3.9 to 5 at PME and BTA, respectively (Figure 30), or a 1.2 to 2.3 fold increase (Figure 31). Branchiness index (>6 cm) ranged from 2/colony at PME to 2.5/colony at BTA (Figure 32), or an impressive 5.5 to 8.8-fold increase (Figure 33). Branchiness index (>10 cm) ranged from 1.1/colony at PME to 1.7/colony at BTA (Figure 34), or a dramatic 28 to 53-fold increase at PME and BTA, respectively (Figure 35). There was also a total >6 cm branch production ranging from 198 to 323 (Figure 36), or a 4.5 to 9.4-fold increase (Figure 37). There was a total >10 cm branch production ranging from 111 to 198 (Figure 38), or a 27 to 55-fold increase (Figure 39). There were clone-specific variations on the results. Particularly, clones C4 and C6 showed a slightly lower % survival and growth. But no statistical analysis has been carried out yet.

At the end of phase 2 after one calendar year, we completed the coral farming cycle by outplanting 2,000 corals, or approximately 1,000 corals at each one of PSO and BTA during late March and early April 2012. No fragments were harvested from the PME farming units as these suffered the strongest impacts from Hurricane Irene. Therefore, we had to readjust the original number of outplanted colonies after one year from 2,880 to 2,000. Nonetheless, farms from only two of the three sites were capable of producing nearly 70% of the originally estimated outplanting amount. With adequate management and cultivated colony growth, and if there are no significant ecological surprises during 2012, existing farms would be capable of producing enough outplanting material to compensate the first year loss and comply with projections for the end of the project.

In summary, there were important findings during phase 2 of the coral farming project of the project:

- Corals continued to show outstanding % survival and colony growth rates.
- Once temperatures dropped below the MMM (28.5°C) no significant colony mortality occurred associated to any disease and/or syndrome.
- Remnant surviving coral colonies from the PME farming units showed significant recovery and rapidly resumed regrowth after relocation to an alternative BTA site.
- Regular maintenance of “A” frame units was important in maintaining high % survival and colony growth rates by limiting potential outcompetition by fouling taxa.
In spite of the significant damage inflicted by Hurricane Irene to coral farms, particularly to those at PME (See Progress Report no. 1), farms from BTA and PSO were capable of providing approximately 70% of the originally estimated amount of colonies for outplanting. This was considered a success.

An alternative coral farming unit design is being tested at PSO with horizontal rope nurseries. These require much less maintenance efforts and are expected to foster faster colony growth rates. A parallel comparative study will be conducted to test differences in coral parameters between “A” frames and rope nurseries during 2012-2013.

Figure 25. Mean Staghorn coral percent survival rates after one year (±95% confidence intervals).

Figure 26. Mean Staghorn coral percent live tissue cover after one year (±95% confidence intervals).
Figure 27. Mean Staghorn coral total colony length (cm) after one year (±95% confidence intervals)

Figure 28. Ratio of increase in Staghorn coral total colony length after one year.

Figure 29. Mean Staghorn coral monthly colony growth rate (cm) after one year.
Figure 30. Mean Staghorn coral branch abundance/colony after one year (±95% confidence intervals).

Figure 31. Ratio of increase in Staghorn coral branch abundance/colony length after one year.

Figure 32. Mean Staghorn coral branchiness index (>6 cm) after one year (±95% confidence intervals).
Figure 33. Ratio of increase in Staghorn coral branchiness index (>6 cm) after one year.

Figure 34. Mean Staghorn coral branchiness index (>10 cm) after one year (±95% confidence intervals).

Figure 35. Ratio of increase in Staghorn coral branchiness index (>10 cm) after one year.
Figure 36. Total Staghorn coral >6 cm branch abundance after one year (±95% confidence intervals).

Figure 37. Ratio of increase in Staghorn coral total >6 cm branch abundance after one year.

Figure 38. Total Staghorn coral >10 cm branch abundance after one year (±95% confidence intervals).
In the coming year, we will:
1) Continue data collection of long-term permanent monitoring sites and complete data analysis to produce two peer reviewed papers.
2) Continue data collection of long-term monitoring of coral recruitment to produce two peer-reviewed papers.
3) Continue data collection of long-term monitoring of the ecological fate of *Montastraea* spp. physiological fragments and run population models to produce a peer reviewed paper.
4) Continue collection and data analysis of small *Montastraea* spp. coral cores to produce a peer reviewed paper.
5) Run the tissue regeneration experiments and the physiological fragment performance targeted monitoring component to produce two peer reviewed papers.
6) Continue reef fish data collection of long-term permanent monitoring sites and complete data analysis to produce two peer reviewed papers.
II. ACTIVITIES

Thrust Area 1: Molecular Ecology and Evolutionary Genetics

Component 1: Phylogeography and conservation genetics of plants  
Tomas Hrbek, Elvira Cuevas and Eugenio Santiago  
This project was designed to look at the population and conservation genetics of endemic Puerto Rican plant species of conservation and economic interest, with a focus on dry forest species found in places such as Guanica Reserve and Mona Island. Each project is designed to be integrated into larger projects in CATEC, including studies of phylogeography of Tabebuia heterophylla, phylogeny and ecophysiology of Tabebuia sampled from throughout the Caribbean, and conservation genetics of Guaiacum sanctum. Specifically, the goal is to develop molecular tools, including DNA sequences and microsatellites to better understand the distribution of genetic variation for these species, test phylogenetic and phylogeographic hypotheses, and use this information to help us better understand and manage these species in the future.

Component 2: Population genetic analyses of feral goat and pig populations on Mona Island and on other Caribbean Islands. Tomas Hrbek  
Feral goats (Capra hircus) and pigs (Sus scrofa) were introduced by Spanish settlers to Mona Island more than 500 years ago. Since then the pig and goats of Mona island have been genetically and reproductively isolated from their origin populations. This natural experiment provides a unique possibility to understand how species evolve, and to study the dynamics of genes of adaptive significance in small, isolated populations. What we learn from the pigs and goats may help us better understand the evolutionary dynamics of other island species including species of conservation concern. This study is the master project of the student Yadira Ortiz and has been done in collaboration with Dr. Stephan Funk, Senior Conservation Biologist for the Durrell Wildlife Conservation Trust, Jersey.

Component 3: Comparison of the Fecal Microbiota in Feral and Domestic Goats. Maria G. Dominguez-Bello  
Animals have co-evolved with mutualistic microbial communities, known as the microbiota, which are essential for organ development and function. We hypothesize that modern animal husbandry practices exert an impact on the intestinal microbiota. In this study, we compared the structure of the fecal microbiota between feral and domestic goats using the G2 PhyloChip and assessed the presence of five tetracycline resistance genes [tet(M), tet(S), tet(O), tet(Q) and tet(W)] by PCR. The ultimate goal of this study is to determine how four centuries of feral conditions have preserved a microbial digestive diversity, and whether these microbial systems are open to gene transfer from outside ecosystems.

Component 4: Aspergillosis of sea fans. Paul Bayman  
The purpose of this project is to assess the role of Aspergillus species as pathogens of sea fans in the Caribbean, determine the source of inoculum, and project the potential impact of global warming on the disease. The extensive literature on aspergillosis of sea fans holds that the pathogen is Aspergillus sydowii and the most likely source of inoculum is dust storms from the Sahel of Africa.
Component 5: Population ecology and genetics of the invasive lionfish in Puerto Rico. Riccardo Papa
Among the invasive species in the Atlantic, the two lionfish *P. volitans* and *P. miles* seriously concern conservation biologists as well as management authorities for its fast diffusion, rapid population growth and its ability to out-compete native fish for food and territory. Lionfish are venomous, predatory reef fishes endemic to the Indo-Pacific Ocean that only recently have been introduced into the Atlantic. Since their first sightings in Florida in the mid 1980’s, they have spread throughout the Northern Atlantic to the majority of the Caribbean. *Pterois volitans* has rapidly colonized the Atlantic northwest and the Caribbean Sea, with an incredibly rapid adaptation to different marine environments. Thus, it represents a major threat for native species and communities across the Greater Caribbean. Given the magnitude of lionfish invasion, studies on this system can generate broad information in several fields of biology such as ecology, conservation, evolution and biogeography that in our opinion feed on each other’s. Using lionfish as an invasive model organism can provide general and predictive understanding of invasion’s mechanisms, population connectivity in ocean systems, community assembly, ecosystem function, adaptation, evolution and the response of species to changing environment and especially to climate change.

Component 6: Speciation genomics of Heliconius butterflies: Population genomics of *Heliconius* butterflies hybrid zones. This is a new component of the MEEG thrust area. The present research is leveraged by other NSF funds. Riccardo Papa
A common aspect to ecology, evolution and any studies that deal with biodiversity in general is to understand how adaptive variation arises, spreads, and influences the origin of new species. Much about this process can be learned from the study of genomic changes that occur during adaptive radiations, when bursts in evolution cause explosions of biodiversity. Recent radiations, in particular, provide ideal opportunities to study the genomic changes responsible for adaptive divergence and how they might drive reproductive isolation between groups. They are in earliest stages of differentiation and are likely to yield the keenest insights into some of the most fundamental questions of evolutionary biology. The proposed project draws from the natural diversity in the wing patterns of *Heliconius* butterflies, the growing genomic resources, and the emerging genomic technologies to study how genomes evolve during adaptive radiations. Using next-generation sequencing technology (Illumine RAD sequencing) we will examine genomic divergence across *H. erato* and *H. melpomene* butterflies hybrid zones of divergent color pattern to study how genomes evolve during the incipient stages of speciation. These within and between species hybrid zones provide powerful “natural” laboratories to examine the degree of genomic divergence that accumulates during the speciation process.

Component 7: Supplement – An Evaluation of Pleistocene Climate Change on the demographic history of Amazonian fishes. Tomas Hrbek
The purpose of this supplement was to extend and elaborate on ongoing collaborations with researchers at the Federal University of Amazonas and the National Research Institute of the Amazon, both in Manaus, Amazonas, Brazil. The project facilitated the collection and analysis of data from seven different species of fishes widely distributed in the Amazon basin, the visit of three students and one researcher from Manaus to the University of Puerto Rico, and the visit of one student from Puerto Rico and the investigator to Manaus. The results are exciting and indicate that all the species analyzed, independent of higher-level taxonomic group, have experienced a significant demographic expansion on the order of one to two orders of magnitude.
during the Pleistocene. We have identified two principal periods, one associated with the transition between the last glacial period and the present-day interglacial, and another associated with the accentuated sea level oscillations in the early Pleistocene.

**THRUSt AREA II: SPECIES AND POPULATION MANAGEMENT.**

**Component 1:** Factors that promote plant invasibility and their effect on endangered plant endangered species.

*Project: “Operation root out: Invasion of alien orchids”. James Ackerman, Paul Bayman and Jose Carlos Rodriguez.*

The Orchidaceae is perhaps the largest family of flowering plants, and is replete with rare and threatened species. Orchids are thought to be particularly sensitive to climatic conditions; many occupy specific habitats, have limited ranges, and enjoy obligate interactions with pollinators and mycorrhizal fungi. But there are also orchids that are truly weedy and invasive. What makes these species invasive and others rare? We seek to characterize invasive species by examining breeding systems and symbiotic associations. We also propose to evaluate their ecological impact by assessing patterns of spread across biotic and abiotic gradients, testing their effect on local mycorrhizal communities, and evaluating their tolerance and propensity to carry plant diseases and their vectors. We have been studying correlates of their success from three perspectives: a demographically-based population analysis for evaluating vital rates and the rate of invasiveness; dynamics of associations with mycorrhizal fungi; and tolerance for pests and diseases. Understanding population dynamics, symbioses and responses to climate variation in these orchids may suggest how they will respond to increasing climatic variability as well as what strategies may be used to control their spread, and how to conserve populations of rare, native orchids. The research is in its final stages of conclusion. We have begun gathering data on the natural establishment of the non-native *Pinus caribbaea* populations in the island. We first intend to use species distribution modeling techniques to determine whether there are potential limits to the spread of pines on the island and whether spread is currently limited by mycorrhizae availability. The second phase of the study will assess whether they have an impact on the species composition and diversity of communities, particularly the fungal and herbaceous floras.

*Project: Impacts of the exotic grass, *Megathyrsus maximus* on *Harrisia portoricensis* in Mona Island Reserve. (Julissa Rojas-Sandoval and Elvia Melendez-Ackerman).*

This study revolved on plant community dynamics of a tropical semi-arid system following experimental removals of an exotic grass (developed by J. Rojas-Sandoval and E. Melendez-Ackerman). The main objective was to determine if the presence of the exotic grass *Megathyrsus maximus* influence the abundance and richness of plant communities on Mona Island Reserve. Data was obtained from established plots with different management treatments of *Megathyrsus* (complete and partial grass removal), in order to evaluate the effects of grass removal on plant community composition, coupled with measurements of microclimatic characteristics at this site.

*Project: Factors affecting establishment success of the endangered Caribbean cactus *Harrisia portoricensis* (Cactaceae). (Julissa Rojas-Sandoval and Elvia Melendez-Ackerman).*
Early plant stages may be the most vulnerable within the life cycle of plants especially in arid ecosystems. Interference from exotic species may exacerbate this condition. This project evaluated germination, seedling survival, and growth in the endangered Caribbean cactus *Harrisia portoricensis*, as a function of sunlight exposure (i.e., growing under open and shaded areas), different shade providers (i.e., growing under two native shrubs and one exotic grass species), two levels of predation (i.e., exclusion and non-exclusion) and variable microenvironmental conditions (i.e., temperature, PAR, humidity).

**Project: Reproductive phenology of the Caribbean cactus *Harrisia portoricensis*: rainfall and temperature associations.** Julissa Rojas-Sandoval and Elvia Meléndez-Ackerman.

Phenological patterns often influence the extent of reproductive success of plants as well the interaction among species. In this study, we evaluated the association of local climatic factors and plant size with the reproductive phenology of the threatened cactus *Harrisia portoricensis* in the Caribbean dry forest of Mona Island. Analyses of phenological data gathered monthly in 572 plants over 2 years concluded that for this species, reproductive activity is continuous throughout the year and reproductive output is positively correlated with plant size.

**Project: New distribution record of *Cybocephalus kathrynae* (Coleoptera, Cybocephalidae) on Mona Island, Puerto Rico.** Jean Carlos Curbelo-Rodríguez, Elvia J. Meléndez-Ackerman, Julissa Rojas-Sandoval, Alejandro Segarra-Carmona.

A new record of *Cybocephalus kathrynae* T.R. Smith (Cybocephalidae) is reported for Puerto Rico. Adults were collected from the flowers of *Mammillaria nivosa* (Cactaceae) on Mona Island Reserve. Prior to this study, this beetle species was only reported for Monroe and Miami-Dade Counties, Florida, USA.

**Component 2: Population viability of endangered reptiles in Mona Island.**

**Project: Growth patterns, and growth curves of the endangered Virgin Island Boa, *Epicrates monensis granti*.** María Egleé Pérez, Raymond Tremblay and Miguel García). Keyla Pagán-Rivera finished her Master’s thesis on the use of Bayesian hierarchical models for fitting Von Bertalanffy growth curves with mark recapture data. In particular, she worked with data from a reintroduced population of Virgin Islands Boa (*Epicrates monensis*). She modified the models proposed by Zangh, Lessard and Campbell (2009) to incorporate differences in growth by sex.

**Component 2: Phylogenetics, diversification and biogeography of Caribbean Tabebuia.** Eugenio Santiago and Nir ска Martinez.

This project will advance our knowledge of and ability to manage the island flora by focusing on the conservation genetics of two contrasting species. *Tabebuia heterophylla* is a widely distributed native species found in nearly every habitat in Puerto Rico and nearby islands such as Mona. Efforts to conserve the diversity and uniqueness of the Puerto Rican flora include both strategies to protect native areas and endangered species (e.g., natural reserves like Mona Island), as well as to include native species in reforestation and urban beautification projects. However, conservation efforts are often hindered by a lack of fundamental information about the species they are trying to protect or utilize. Protecting
endangered species requires consideration of their short-term survival and long-term evolutionary potential. Understanding the geographic distribution of genetic variation of such species can provide critical information for prioritizing conservation efforts to maximize diversity, as well as provide insights into such biological processes as gene flow and genetic drift 7. Similarly, abundant but economically important species utilized in planting programs can benefit from such genetic information by documenting the geographic distribution of genetic variation in populations used as seed sources. Maximizing this diversity may protect the urban landscape against pathogens and perhaps suggest source seeds with adaptive advantages in different environments. Molecular tools, which can directly address such questions of genetic diversity, therefore have an important role to play in conservation, from species to entire communities or ecosystems. Little, however, is known about the genetic structure of this species, or even whether it may include multiple cryptic species adapted to different habitats.

Thrust area III: Ecosystem Processes and Function Group

Component 1: Water source, plant phenology, and plant water use efficiency in native tree species under similar mesoclimatic conditions but contrasting hydrogeologic settings in a tropical dry forest. Elvira Cuevas, Jorge Ortiz, Yogani Govender, Jesús Rodríguez, Leonel Sternberg, Ernesto Medina and Miguel Canals.

The fieldwork in Guanica Dry Forest started in October 2007. Replicate trees of five species: Coccoloba microstachya, Tabebuia heterophylla, Ficus citrifolia, Pisonia albida and Erithalis fruticosa were tagged and georeferenced in the Coastal Plateau. All species are natives and grow from the ridge to the coast in the dry forest. Trees from the mangrove species Avicennia germinans, Laguncularia racemosa and Conocarpus erectus were selected, tagged and georeferenced for sampling and phenology studies in the Tamarindo area where the Puerto Rican Crested Toad pond is located. Sampling for eco-physiological measurements, nutrients and stable isotope analyses started in November 2007 and will continue until December 2012. We do monthly sampling of the water sources (surface soil, rainwater and ground water) and in the Coastal Flamenco lagoon. Each sample is analyzed for Deuterium and $\delta^{18}$O and salinity. Meteorological data is accessed from nearby costal station (500m away from study site). The samples for stable isotopes are prepared in the lab and are analyzed by Dr. Leonel Sternberg, research collaborator, at the Stable Isotope Laboratory from the University of Miami. Since summer 2009 we are also sampling and analyzing water from three piezometers to 50 cm depth between trees and two piezometers, one to 2.5 m depth and the other where fresh water was located (8.5m depth).

Component 2: Paleoclimate variability and historical anthropogenic changes in land use effects on ecosystem structure and function in a sub-tropical dry forest in Puerto Rico: Elvira Cuevas, Yogani Govender, Leonel Sternberg, Miguel Canals, Rubén Lara, Marcelo Cohen and Eneilis Mulero.

Paleoenvironmental studies carried out in some areas in the Caribbean indicate that the region has gone through dry and humid phases during the Holocene. To what extent these varying conditions affected plant biodiversity in Puerto Rico is still unknown as there have been no studies on Holocene terrestrial paleoenvironmental reconstructions in the island. In order to understand how resilient is the system to climate change shifts in plant biodiversity in the future we need to know how it affected biodiversity in the past. It is also important to know to what extent and for how long historical land use change affected plant species composition and to compare to present situation in order to understand the recovery capacity.
of the system. We are carrying paleoenvironmental reconstructions of two sites: the Guánica Dry Forest and the Jobos Bay mangrove system. Both sites are located in the Southern coast of Puerto Rico and reflect a gradient from the ecotone between moist and semi-arid in Jobos Bay (southeastern) to semi-arid (southwestern). We sampled sediment cores down to bedrock in the landward and the ocean side of Jobos Bay and in the Flamenco Lagoon in the coastal side of the Guanica Dry Forest. The stable isotope analyses, radiocarbon dating and pollen determinations of the sediment cores from the Flamenco Lagoon are now complete and we expect to have a manuscript for publication by December 2012. The Jobos bay samples are being analyzed for pollen and radiocarbon determinations.

Other projects:

Project 3. An isotopic study of diet and muscles of the Green Iguana (Iguana iguana) in Puerto Rico: The study will be published in an issue dedicated to invasive species in the Journal of Herpetology. Stable isotopes studies of muscle and gut content indicate opportunistic omnivory in herbivorous iguanas. This is the first published result of Iguanas eating Uca crabs and snails. Jhoset Burgos, undergraduate student that will graduate in June 2012, will continue this research for his Master’s thesis at the University of Rhode Island under the mentorship of Dr. Jason Kolbe. This is especially important as the population expansion of I. iguana throughout the whole island raises serious conservation concerns regarding its ecological role and impact on the native fauna and flora of the islands.

Project 4. Omnivory in Anolis lizards along a precipitation and elevational gradient in moist areas on karst in Puerto Rico - Sondra Vega, PhD dissertation - All Anolis lizards are omnivorous, however degree of omnivory varies among species and within the same species from different localities indicating opportunistic response to food availability. The lack of data about fruit consumption by these lizard species might be because dietary studies only can reveal fruits that were consumed whole and during the time immediately preceding capture of animals. In contrast, stable isotopes reflect the isotopic values of the food consumed at least five to six month before sampling. Detailed studies are being carried out in the northern karst region of Puerto Rico at the El Tallonal Private Conservation reserve and Mata de Platano Reserve in Arecibo, Puerto Rico to determine the monthly diet sources (airborne and litter insects and fruits) and availability, and level of omnivory/frugivory of Anolis lizards. Tail samples and insect samples are gathered monthly. Subsamples of the insects, the lizards’ tails and fruits are prepared and sent to the Stable Isotope Laboratory of Dr. Leonel Sternberg at the University of Miami for $\delta^{15}N$ and $\delta^{13}C$ determinations. There is a manuscript in preparation from the preliminary results using stable isotope technology where it was shown that land use and insect availability determines the degree of insectivory versus omnivory of two Anolis species. The information gathered in those studies will allow determining the role of anoles lizards in food webs as well as in the function and dynamics of insular tropical ecosystems.

Project 5. Diet of sea urchins in the Northeastern coast of Puerto Rico – Ruber Rodriguez, Ph.D. dissertation - Sea urchins are an integral part of the food web in tropical reefs. As herbivorous they are important grazers of the sea floor. However, what is their food source and if there are differences among sea urchin species are questions that need to be answered. Diadema antillarum, a former ubiquitous species that went into massive decline in the 18980s is now slowly recovering. It is, therefore, of utmost importance to determine their food source. We
did a preliminary study to determine the stable isotope signature of three species of sea urchins and the sea grasses and algae present in their home range. The samples were prepared according to the established protocol in the EPF laboratory and sent to the Stable Isotope Laboratory of Dr. Leonel Sternberg at the University of Miami for $\delta^{15}$N and $\delta^{13}$C determinations.

**Project 6. Tree species diversity and water availability affects belowground microbial functional groups dynamics and enzymatic activity in the Guánica Dry Forest.** Michelle Rivera – Ph.D. dissertation - Ecologists have long recognized that vegetation can exert a strong influence over soil properties, and that individual plant species play an important role in determining soil fertility in natural ecosystems. Given that plant species vary in their effects on soil properties it can be expected that the processes regulated by microbes will also be responsive to plant species effects. The study site is the Dwarf forest of the Guánica Dry Forest Reserve, located at the Southwestern part of Puerto Rico. Different species of dwarfed trees are found growing in the cracks of the calcareous rocks isolated from one another, forming monospecific islands of leaf litter and organic matter creating, diverse microhabitats for the soil microbiota. The substrate is very shallow, highly organic, with very little to no mineral soil present. Our aim is to understand how plant species affect soil diversity by a) determining the differences in microbial biomass in the substrate (soil) of different tree species, b) understand how plant species affects microbial enzymatic activities by assaying three different microbial enzymes that are present in soils, c) identifying microbial functional groups related to biogeochemical cycles using the fatty acid methyl ester technique, d) to create microbial phylogenies using the Phylochip technology and e) to determine soil nutrients and physical chemical characteristics in order to correlate them with microbial biomass, activity and functional groups. Dr. Veronica Acosta-Martínez, from the ARS-USDA at Lubbock, Texas is collaborating in this study.

**Component 3: Ecohydrology of critical habitats in the Guanica Biosphere Reserve**

**Investigators: Jorge Ortiz, Elvira Cuevas and Miguel Canals.**

**Project 1. Ecohydrology of critical habitats in the Guánica Biosphere Reserve.** For the past four years, graduate student, Rita Cáceres have worked on the characterization of the physical and chemical properties of the water in the natural breeding ponds and in the artificial reintroduction ponds associated to the conservation of the Puerto Rican crested toad (PRCT) in the south of Puerto Rico. The water parameters influencing tadpole growth and timing to metamorphosis appear to be water salinity, temperature, pond duration and, water depth. Biological factors such as tadpole density and competition with an invasive species can also influence the transition from tadpoles to metamorphs. Due to the unpredictability of the climate in Gunica’s Dry Forest and of unexpected breeding events of the PRCT, we have not been able to measure the effect of abiotic and biotic parameters in the field. However, in an experimental setting, Rita has been able to measure the effect of water salinity on the survival, growth and timing to metamorphosis of the PRCT. These results provide valuable information on a water parameter that is negatively impacting the fitness of tadpole in the natural environment. By concentrating some of the conservation efforts provided for the PRCT in monitoring ponds we can better ensure that more breeding events result in successful and fit juvenile population of PRCT.

**Project 2. Nitrogen dynamics in tropical aquatic environments.** Two studies were underway by our research group to investigate how nitrogen cycles in aquatic tropical systems. The first study led by Carlos Conde finished in June 2011 when Carlos completed the requirements of his
Ph.D. program. His research focused on understanding the effects of bat guano on the nitrogen dynamics in a karstic cave river in Southwestern Puerto Rico. The project yielded a paper to the Journal of Karst and Cave Studies on the hydrology of the Convento cave system, currently under review after receiving comments from the editor. The paper will be resubmitted to the same journal this summer. CATEC provided support in this project by providing funds to purchase critical instrumentation and materials.

The second study, led by Hamlet Perez (Ph.D. student), focuses on the effects of anthropogenic disturbances on the nitrogen dynamics of the San Juan Bay Estuary, a tropical estuary located in the middle of the San Juan Metropolitan Area. Typically the primary productivity of coastal waters is nitrogen-limited. In tropical developed countries, like Puerto Rico, estuaries are highly eutrophied due to uncontrolled non-point and point sources of pollution rich in inorganic and organic nitrogen. Therefore, controlling the flux of nitrogen to estuaries in Puerto Rico is seen as a way to control their eutrophication. Denitrification is a natural pathway by which nitrogen can be expelled out from eutrophied waters, however, in tropical eutrophied waters, the role of denitrification has been poorly studied. A study was initiated in 2006 to understand the dynamics of nitrogen fluxes in the San Jose Lagoon of the San Juan Bay Estuary of Puerto Rico. Hamlet is currently writing his dissertation that he plans to defend by the end of this summer.

Project 3. Anthropogenic influences on the carbon cycle in tropical inland waters.
1) Urbanization strongly impacts stream ecosystems and little information is known about how it affects dissolved organic carbon (DOC) in rivers and how consequently it affects tropical rivers. DOC is an important energy source in aquatic ecosystems. Bianca Rodriguez, an undergraduate student from the Environmental Sciences Program, developed a project focusing on changes in DOC biodegradability along a tropical urban river in Puerto Rico. The Río Piedras runs through the heart of the San Juan Metropolitan Area, making it susceptible to human impacts. By measuring the biodegradability constant (k) of the organic matter present in water samples she was able to assess to water quality conditions of the Río Piedras. Thanks in large degree to CATEC research infrastructure support, Bianca successfully completed the requirements of the Environmental Sciences Program and will start graduate studies at the University of New Hampshire this year.

2) The role of urbanization on the flux of carbon compounds from tropical watersheds has been poorly documented. Particularly, unknown are the impacts on the quality of dissolved organic carbon that fuels the metabolism of rivers and estuaries. Given the importance of the biodegradability of the organic matter on the energy flow in aquatic ecosystems, studies that characterize the carbon metabolism are critically needed to better manage inland and coastal aquatic ecosystems. Rafael Benítez-Joubert, a graduate student from the Department of Biology, studied estuaries Mameyes and Sabana in northeastern Puerto Rico, which proved to be more productive than the other tropical estuaries. During this reporting period, Rafael Benitez, completed the requirements of a Master in Science degree. CATEC contributed greatly to his project by providing stipends and materials to conduct field studies. He is currently working as a limnological researcher with the Agricultural Experimental Station in Rio Piedras.

3) Debora Figueroa is a Univ. of New Hampshire PhD student and is receiving logistic support from the Tropical Limnology Laboratory at UPR. Miss. Figueroa research evaluates the effects of wastewater disposal on the assimilative capacity of wastewaters in tropical rivers. She has
been conducting nutrient releases and evaluating the river retention rates of nitrogen and phosphorus. She presented her project in two national meetings last year.

4) Some anthropogenic organic inputs are considered endocrine disrupting chemicals (EDCs). Particularly, hormone compounds, like estrogen, have been detected in urban waters that receive effluents from wastewater sources or urban runoff. However, these chemicals have not been studied in waters in Puerto Rico. Concern exists that EDCs may interfere with the endocrine system of both humans and wildlife. During this reporting period, Mrs. Sheila Soler, a Biology Ph.D. student, started to sample urban rivers in Puerto Rico to assess the estrogenic activity in these waters. She has been validating a recently developed bioassay based on genetically modified yeast cells that are sensitive to estrogen producing a luminescent signal that is proportional to the estrogenic activity present in the water sample. With funding from CATEC, Sheila has traveled to the University of Texas to receive training with the author of the bioassay technique, Dr. Marc B. Cox of the Border Biomedical Research Center and Department of Biological Sciences of the University of Texas at El Paso.

**Project 4. Hydrological implications of land use change in tropical urban watersheds.**

1) In an attempt to evaluate historic land use changes in coastal wetlands, Mr. Aristides Martinez, a Ph.D. graduate student in Environmental Sciences, has started to characterize the relationship between land use patterns and trace metal speciation content in sediment soils, at La Malaria Canal drainage system of Las Cucharillas Marsh, in the Municipality of Cataño, in northern Puerto Rico. Utilizing historical maps, IKONOS® Infrared, and Color Infrared (CIR) aerial images, Martinez conducted a preliminary analysis of land coverage/use change from 1889 - 2010. The analysis revealed that more than 95% of agricultural lands had disappeared by 2010. Several cultural traits or anthropogenic footprints have proliferated as soils have been modified by man through hydrological changes resulting from dredging and filling of wetlands.

2) Ecological restoration of impacted riparian areas has been initiated in some impacted rivers as results of urban sprawl. Mr. Harold Manrique, an MS student from the Environmental Sciences Program, is studying a restored segment of a headwater tropical creek called Quebrada Chiclana using the current conditions of riparian vegetation features as success indicators. He expected that if the reforestation plan considered the pre-impacted condition of the riparian features then current conditions should reflect the pre-impacted conditions. He established eight cross-sections along the restored creek each one divided in two plots: left bank and right bank. Each plot was divided into five sub-plots. Three plots were considered as reference for pre-impacted conditions. He determined the number, frequency and diversity of plant genera present per plot. Plots used as reference of pre-impacted conditions showed the highest genera diversity and community complexity. While we cannot conclude that the restoration was not environmentally successful, we present results were the reference non-impacted plots shows higher vegetation complexity and composition than the impacted plots.

**Component 4: Effect of climate change and contrasting land use patterns on historical dynamics on reef-building corals in Puerto Rico. Investigators: Edwin Hernandez and Elvira Cuevas.**

This project considers three interconnected questions related to climate change and historical and present anthropogenic effects on Caribbean coral reefs: 1) how have historical and current climate change and sedimentation dynamics affected coral reefs ecosystems, 2) given
the present and future scenarios of sea surface temperature and salinity variability, will the coral reef benthic community structure change over time, and 3) given the present and future scenarios of sea surface temperature and salinity variability, how will coral survival and recruitment rates change over space and time? Research activities during the cycle of May 2011 to May 2012 have mainly focused on:

a) Continuing the coral reef long-term ecological monitoring activities of the project, with a significant expansion on the geographical extension of research to other reefs in Puerto Rico in order to increase our spatial resolution.

b) Continuing and expanding the long-term coral recruitment monitoring effort. This study has been conducted over a period of nearly six years at Culebra Island with a special focus in addressing what has been the fate of surviving physiological fragments of *M. annularis* following the massive bleaching event of 2005 and the post-bleaching mass mortality of 2006. Preliminary findings point out at the dramatic loss in % live tissue cover in *M. annularis* and the nearly total lack of colony recovery.

c) Continuing targeted monitoring of the ecological fate of physiological fragments of lobbed star coral (*Montastraea annularis*).

d) Setting up and initiating the early stages of a field experiment to test hypotheses associated to coral physiological fragment survival.

e) Monitoring of physiological activity in *M. annularis* and *M. faveolata* across anthropogenic stress gradients.

6) Coral coring of selected *Montastraea annularis*, *M. faveolata* and *Solenastrea bournoni* colonies to address climate change impacts on coral growth rate, skeletal density, and calcification rates.