Center for Applied Tropical Ecology and Conservation

Annual Report September 1st, 2010– August 31st, 2011

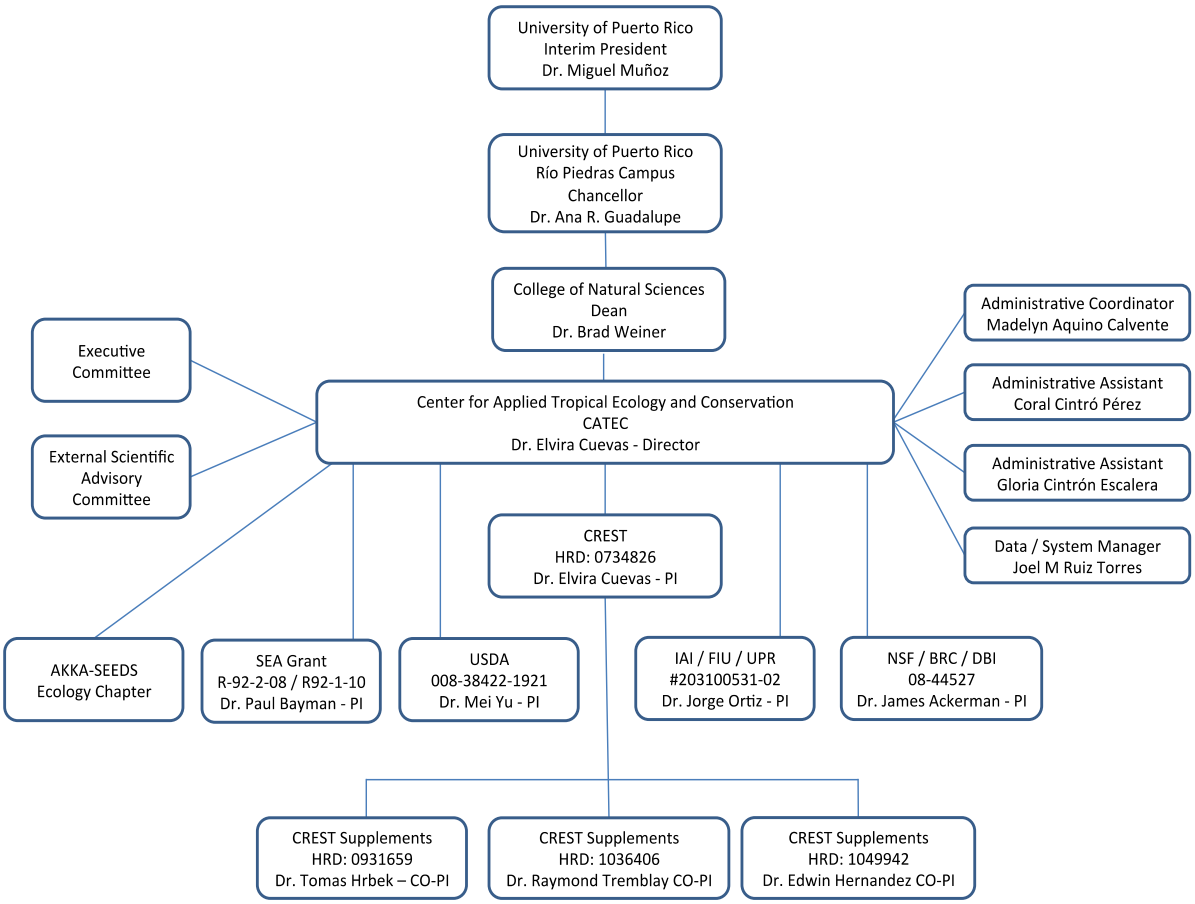
NSF HRD-0734826

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 Institute of Tropical Ecosystem Studies, 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.



I.2 Certification of institutional funds

May 31, 2011

Dr Demetrios Kazakos
Crest Program Director
Division of Human Resources Development
National Science Foundation
4201 Wilson Boulevard Room 815
Arlington, Virginia 22230

Dear doctor Kazakos:

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 Río Piedras Campus of the University of Puerto Rico, I express my full support to the Center, which 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) and the Office of the Chancellor of the UPR-Río Piedras Campus ($75,000) for the period 2011-2012.

Cordially,

Ana R. Guadalupe, Ph.D.
Chancellor

tgc

University of Puerto Rico
Río Piedras Campus
Chancellor's Office

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I.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 synergic 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 151participants in CATEC, of which 79% are students, maintaining a similar ratio of graduate to undergraduates as the previous year. Fifty-two percent (52%) 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, UPR DEGI Honor Scholarships, etc. We also take advantage of undergraduate research training courses in Biology and

Participants by thrust area Period 2010-2011				
Type	**MEEG**	**SPM**	**EPF**	**Total**
Research Fellows	7	9	7	23
Post-Doc	1	1	0	2
Students	**15**	**58**	**47**	**120**
Graduate	5	20	18	43
Undergraduate	10	38	29	77
Technicians	2	3	1	6
Total	25	71	55	151

Environmental Sciences where students receive university credits for the research they are carrying out in our thrust areas.

Center for Applied Tropical Ecology and Conservation
List of Participants 2010-2011

Thrust Area I - MEEG	Thrust Area II - SPM	Thrust Area III - EPF
Research Fellows	**Research Fellows**	**Research Fellows**
Tomas Hrbek	Eugenio Santiago-Valentín	Elvira Cuevas
Maria Gloria Dominguez	Elvia Meléndez-Ackerman	Edwin A. Hernández
Paul Bayman	Raymond Tremblay	Jorge R. Ortiz-Zayas
Stephan Funk	Denny Fernández	Olga Mayol
Ingi Agnarsson	James Ackerman	Mei Yu
Anabella Zuluaga	Miguel Garcia	Juan Felipe Blanco
Riccardo Papa	María-Eglée Pérez	Yogani Govender
	Carlos Diez	
Post-Doc	José C. Rodrigues	**Technicians**
Carlos Toledo- Hernandez		Larry Diaz
	Post-Doc	
Technicians	Julissa Rojas	**Graduate Students**
Maria Dávila		Sondra I. Vega Castillo
Yadira Ortiz-Ruiz	**Technicians**	Michelle Rivera
	Doralis Villanueva	Jessica Fonseca da Silva
Graduate Students	Milka Miranda	Raisa Hernandez-Pacheco
Luis A Ramirez Camejo	Franklin Axelrod	Alex Mercado-Molina
Ida Pantoja		Jeiger Medina Muñiz
Karla Maldonado	**Graduate Students**	Carlos Conde
Pascal Mege	Joel Mercado	Rafael Benitez Joubert
Jose Ortiz-Lugo	Omara Ortiz	Debora Figueroa
	Edgard Almodóvar	Hamlet Pérez
	Cielo Figuerola	Rita Cáceres
Undergraduate Students	Frederick Abbott	Sheila Soler
Melissa Navarro	Mariely Hernández	Betzaida Ortiz
Carolina Camacho	Yobana Mariño	Jorge Viqueria
Veronica Hernandez	Victor Vega	Aristides Martinez
Amy Silvestrini	Luis Villanueva	Ana Arache
Janet Chan	Jose J Fumero-Caban	Harold Manriquez
Jorge Lazaro	Colibri San Fiorenzo	Xochilt Perez
Kassandra M. De Jesus-Laboy	Charito Orengo	
Angela M. Alicea Serrano	Hana Lopez	**Undergraduate Students**
Pamela Padro Juarbe	Luisa Rodriguez	Carlos Juan Cruz Quiñonez
Juan Luis Rivera Correa	Ana A. Cuevas	Eneilis S. Mulero Oliveras
	Julio Lazcano	Desiree Garcia Rivera
	Adriana Herrera Montes	Agnes Torres
	Maria E. Ocasio Torres	Nishma N. Ramos
	Nirzka Martinez	Julie A.M Plaud Gonzalez
		Jean Paul Rodriguez
		Bianca N. Rivera
	Undergraduate Students	Coraly Barreto Bonilla
	Elson Viruet	Angel G. Lopez
	Adrian Valls	Samuel Lacen Boria
	Andrea Diaz	Esteban Grovas Cordovi
	Fernando López Cepero	Emilio Soto
	Yarilis Vázquez Pacheco	Zoleri Rivera Guzman
	Gloriell Cardona	Gisela Marrero Rivera
	Wilfredo Falcon	Erica Ventura Guzman
	Desiree Colon Oyola	Tagrid Ruiz-Maldonado
	Sorgalim Lindsay	Lorna Moreno
	Julio Rodriguez	Jerymar Cabrera Molina
	Keishla Rodriguez	Carmen González
	Sugeily Davila	Julio Oms-Hernandez
	Daisy Ramirez	Alejandra H. Alvarado-Alvarado
	Alichy Ubiles	Jesyka Meléndez-Rosa
	Emily Pérez	Alexandra Marcano
	Leidy González	Bianca Rodriguez
	Efraín Martínez	Josue Sanchez
	Elizabeth Rivera	Larisa Martinez Torres
	Esther Morales	Angel Santiago
	Frances Toledo	Maria del Pilar Ponce
	Francisco Hernández	
	Emmanuel Santa	
	Rocio Garriga	
	Pamela Torres	
	Marella Trifilio	
	Virmarie Diaz	
	Carla Saladini	
	Camille Timossini	
	Betsabe Castro	
	Miriam Toro	
	Lourdes Lastra	
	Cristina Vila	
	Alexandra Lopez	
	Eduardo Hernandez Calo	
	Wilnelia Recart	
	Alvaro Bravo	
	Kristopher Bonefont	
	Carlos Vega	

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 55 presentations in local, national and international meetings, congresses, symposia and seminars. Forty-two per cent (42%) were either presented or coauthored by students. We also had 86 publications (published, accepted, or submitted under review) of which 45% were either authored or co-authored by students.

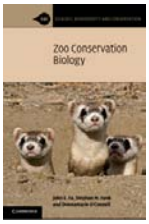
Three (3) CATEC sponsored graduate students, Carlos Conde (PhD), Pascal Mege (PhD) and Jessica Fonseca da Silva (MS), defended this year. Ms. Fonseca was hired by the Center for Energy, Environment and Biodiversity (CEAB), in Manaus, Brazil. Dr. Yogani Govender, former post-doc from the Ecosystems Processes and Function area, was hired in April this year as Scientific Coordinator of the Conservation Trust of Puerto Rico. She will remain as Research Fellow of the Center. Esther Morales is attending graduate school at Michigan State University, Fisheries and Wildlife program. Ms. Lourdes Lastra was named coordinator of the Executive Committee for the North East

Corridor Campaign of the Sierra Club, PR Chapter. Mr. Angel Lopez was awarded second prize in student presentation at the GIS mentorship training in Washington DC. Ms. Raisa Hernandez-Pacheco was the First runner up, Best Student Presentation Award, 63rd Gulf and Caribbean Fisheries Institute Meeting. Elizabeth Rivera received a Fellowship to study in the Genetic Undergraduate program at UI Urbana-Champaign, Illinois.

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 “Conservation Ethics” given by Drs. John Vucetich fom Michigan Technological University and Dr. Michael Nelson from Michigan State University. We also sponsored the “Geospatial analysis Workshop on agricultural and Natural Resources Management and Conservation” given by Dr. Xinyan Ben Wu from Texas A&M College Station and Dr. Humbert Perotto from Cranfield University, United Kingdom.

The book entitled "A Systematic Vademecum to the Vascular Plants of Puerto Rico" authored by Dr. Frank Axelrod, Herbarium assistant at UPR-Rio Piedras is now available from the Botanical Research Institute of Texas Press. The book provides highly relevant information of the plant biodiversity of Puerto Rico to academic and non-academics interested in the vascular plant taxa of Puerto Rico and the Caribbean. The book Zoo Conservation Biology coauthored by CATEC's research Fellow Dr. Stephan Funk is in press at Cambridge University Press and will be available in October 2011.



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 Graduate Program of Environmental Sciences, 5) the 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, 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, 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 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), 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, 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) and Sociedad Ambiente Marino.

CATEC received two NSF supplements: “Experiences in Quantitative Conservation Biology and Critical Thinking for Undergraduate Students” and “Sea Surface Warming as a Determinant Stressor of Coral Reef Decline in the Caribbean: a multiscale, integrative approach to assess the impact of recurrent massive bleaching events”. 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. As there is no post award management office, the management of grants in Rio Piedras follows the rules and regulations of the general financial management of the campus.

And last but not least, we are very proud to have gotten an outstanding evaluation in the Reverse Site visit in April this year. As a result of our efforts the university authorities consider CATEC a model for research, human resource development and outreach and as such want us to start the process of institutionalization of the Center 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: Mrs. Coral Cintron, an Administrative Assistant: Mrs. Gloria Cintron, and two part-time undergraduate students. 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 Rodrígues, 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. 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 17,703 hits from 24 October 2010 till 27 May 2001. Forty-eight per cent (48%) of the hits are from Puerto Rico, twenty-nine per cent (29%) from the United States in general, and the rest from countries such as Germany, Bolivia, Colombia, Canada, United Kingdom, South Africa, Chile, Philippines, Mexico, Ireland, France, Brazil, Dominican Republic, Venezuela, Spain, India, Italy, Turkey, Australia, Argentina, China and Peru. Through 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 last year CATEC is part of the social network via its Facebook page (http://www.facebook.com/profile.php?id=100000649484619). 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. Here are examples of the "likes and dislikes" feedback 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.

- 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 situation has improved and we hope that these steps will help the development of a more streamlined, time and cost effective way of award management.

- 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 have helped in the infrastucture 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 CREST-CATEC.
- 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 we expect to have them fully functional by next year.

- 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 151 participants in CATEC, of which 79% are students, maintaining a similar ratio of graduate to undergraduates as the previous two years. Forty four percent (44%) are funded directly by CATEC.

Catec Participants

	2007-2008				2008-2009				2009-2010				2010-2011			
Type	MEEG	SPM	EPF	Total	MEEG	SPM	EPF	Total	MEEG	SPM	EPF	Total	MEEG	SPM	EPF	Total
Research Fellows	5	16	7	28	7	9	5	21	7	9	6	22	7	9	7	23
Post-Doc	0	0	1	1	0	0	1	1	2	0	1	3	1	1	0	2
Students	**18**	**44**	**15**	**77**	**26**	**50**	**34**	**110**	**14**	**59**	**39**	**112**	**15**	**58**	**47**	**120**
Graduate	9	17	7	33	11	20	10	41	5	22	15	42	5	20	18	43
Undergraduate	9	27	8	44	15	30	24	69	9	37	24	70	10	38	29	77
Technicians	2	2	1	5	3	3	1	7	3	4	1	8	2	3	1	6
Total	25	62	24	111	36	62	41	139	26	72	47	145	25	71	55	151

We leverage resources with other programs such as NIH SCORE, RISE and MARC, NSF Bridge to the Doctorate, IGERT 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.

Ten per cent (10%) of CATEC participants are non-US citizens or residents. Eight graduate students are non-US citizens or residents and are paid from other sources than CREST. All the undergraduates (77) and the majority of the graduate students are US citizens of Hispanic origin. The ratio of two to one (2:1) of female to male students is representative of the College of Natural Sciences.

Crest-Catec Participants-Diversity												
Type	2007-2008			2008-2009			2009-2010			2010-2011		
	M	F	Total Participants	M	F	Total Participants	M	F	Total Participants	M	F	Total Participants
Research Fellows	21	7	28	15	6	21	16	6	22	15	8	23
Post-Doc	0	1	1	0	1	1	1	2	3	1	1	2
Students	**35**	**42**	**77**	**36**	**74**	**110**	**33**	**79**	**112**	**40**	**80**	**120**
Graduate	14	19	33	12	29	41	14	28	42	17	26	43
Undergraduate	21	23	44	24	45	69	19	51	70	23	54	77
Technicians	3	2	5	3	4	7	3	5	8	2	4	6
Total	**59**	**52**	**111**	**54**	**85**	**139**	**53**	**92**	**145**	**58**	**93**	**151**

Students are being trained in experimental design, research methodology, and hand-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.

Thrust Area	2007-2008			2008-2009			2009-2010			2010-2011		
	Primary Author	Co-Author	Total	Primary Author	Co-Author	Total	Primary Author	Co-Author	Total	Primary Author	Co-Author	Total
MEEG	**7**	8	**15**	11	10	**21**	22	16	**38**	3	5	**8**
SPM	13	9	**22**	20	13	**33**	23	6	**29**	10	2	**12**
EPF	1	6	**7**	11	15	**26**	13	3	**16**	1	2	**3**

This year we had 55 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, Mexico, Chile, Brazil, Dominican Republic, Spain, St. Eustatius, Puerto Rico, Illinois, Pennsylvania, Washington DC, etc.
Forty-two per cent (42%) were either presented or coauthored by students. We have reached a milestone where our students are totally involved in all the aspects of research.

Authoring and co-authoring of publications are excellent indicators of capacity building in science. The table shows student involvement in publications. Thirty-two of the seventy-six publications (46%) for this year were either authored or co-authored by students, both graduate and undergraduates. This way, students are trained to understand the importance of the peer-review process and dissemination of results.

Publications by Students
Period 2010 - 2011

	Published				
Thrust Area	Total Published	Student Principal	Student Coauthor	% Principal Author	% Coauthor
MEEG	22	5	3	23%	14%
SPM	6	2	1	33%	17%
EPF	6	2	3	33%	50%
Totals	34	9	7	26%	21%

	Accepted, Waiting Publication				
Thrust Area	Total Accepted,	Student Principal	Student Coauthor	% Principal Author	% Coauthor
MEEG	3	2	1	67%	33%
SPM	7	3	1	43%	14%
EPF	10	1	3	10%	30%
Totals	20	6	5	30%	25%

	Submitted, Under Review				
Thrust Area	Total Submitted,	Student Principal	Student Coauthor	% Principal Author	% Coauthor
MEEG	9	3	2	33%	22%
SPM	11	1	1	9%	9%
EPF	2	0	0	0%	0%
Totals	22	4	3	18%	14%

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.
Last year we had a total of 62 publications, of which 30 were published during that time. This year we have 76 publications: 34 published, 20 accepted for publication and 22 submitted for review. Already we surpassed the total amount of publications during Phase I of CATEC.

CATEC Publications				
Year / Period	**Published**	**Accepted, Awaiting Publication**	**Submitted, Under Review**	**Total**
2007-2008	25	15	15	55
2008-2009	21	10	17	48
2009-2010	30	15	17	62
2010-2011	34	20	22	76

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 this prestigious groups is by invitation only**.
5) Dr. Elvira Cuevas was recognized by the USDA Forest Service International Institute of Tropical Forestry for her pioneer research in El Yunque. "It exemplifies the dedication of a Puerto Rican woman to science and her country".
6) 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 Hugenholz, Dr. Eoin Brodie and Dr. Kate Goldfarb.
7) Dr. James Ackerman is collaborating with Dr. Jafet Nassar of IVIC (Venezuela) on the Melocactus phylogeny project.
8) 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.
9) Dr. Elvira Cuevas, Center Director and PI of CREST, is a member the Editorial Board of Ecological Applications.

10) 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.
11) Dr. Ingi Agnarsson is a research associate of the Scientific Research Centre of the Slovenian Academy of Science and Arts, 2007-present.
12) Dr. Ingi Agnarsson is a research associate of the National Museum of Natural History, Smithsonian, Washington DC.
13) Dr. Elvira Cuevas is a Member of the Advisory Committee for RIMI Proyect (Research Infrastructure for Minority Institutions) UPR-Cayey.
14) 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).
15) 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.
16) Dr. Elvira Cuevas is member of the External Advisory Board of the CREST-Center of Forest Ecosystem Assessment (CFEA), Alabama A&M.
17) Drs. Denny Fernandez and Elvira Cuevas are members of the Board of Directors American Association for the Advancement of Science (AAAS), Caribbean Division.
18) 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.
19) 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

- Dr. Jorge Ortiz aquatic ecology lab was finally finished and is fully functional. They moved into the new facilities in early 2011.

- The financial support of CATEC continues to leverage infrastructure improvements for Dr. Fernandez and Tremblay's laboratories at the Humacao campus.

- 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 insitutes 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 UPR Botanical Garden, UPR-Medical Sciences Campus, Texas A&M University, Organization for Tropical Studies, St. Eustasius National Parks (Netherlands Antilles), Fairchild Tropical Botanic Garden, Florida International University, New York Botanical Garden, Inter-American University-Bayamón Campus (Puerto Rico), Universidad Autonoma de Santo Domingo (Dominican Republic),

Instituto Tecnológico de Santo Domingo (Dominican Republic), Jardin Botanico Nacional (Dominican Republic), Colegio de la Frontera Sur (Chiapas, México), University of Sao Paulo (Brazil), Museo de Historia Natural de Tenerife, Universidad Simon Bolivar (Venezuela), Univeristy of Washington-Seattle, Earlham College-Richmond, Indiana, San Diego Zoo, Toledo Zoo, Chelonia Society (local NGO), Fundacion Puertorriquena para la Conservacion (local NGO), Conservation Trust of Puerto Rico (local NGO), University of Hawaii Manoa, J. Craig Venter Institute, North Carolina State University, Carolina Coastal University, Michigan State University, University of Hawaii Manoa.

Cornell University, Department of Energy Joint Genome Institute, Earlham College at Indiana, Fairchild Tropical Botanical Garden, Florida International University, Florida Institute of Technology, 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, 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 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), 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 Para (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, 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) and Sociedad Ambiente Marino.

We also continue our collaborations with researchers from Argentina, Colombia, Brazil and the Czech Republic.

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 additional $1.1 from other grants brought this year.

Submitted:

- 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 (CoPIs). $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 (Pending).
- Population genomics of lionfish across the Caribbean archipelagoes and its ecological impact on the reef community in Puerto Rico. Submitted to Sea Grant ($165,000)
- NSF- 1118344: Selection landscapes on shifting sands: how annual variation in floral traits affects pattern of selection. James T. Ackerman, Raymond Tremblay and Maria Eglee Perez ($1,230,892).

Awarded:

- NSF-HRD 1036406: Center for Applied Tropical Ecology and Conservation: Biodiversity Conservation Under the Scenario of Climate Change. Experiences in Quantitative Conservation Biology and Critical Thinking for undergraduate students. CREST Supplemental funding. $1000,000
- NSF-HRD 1049942: Sea Surface warming as a determinant stressor of coral reef decline in the Caribbean: a multiscale, integrative approach to assess the impact of recirrent massive bleaching events. CREST supplemental funding. $133,229.
- NSF 1052541 Identity and function of Heliconius mimicry genes. Robert Reed, Owen Mc Millan and Riccardo Papa (Co-Pi). $515,000.

I.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. 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.
5. All researchers and students within and associated with MEEG routinely exchange information and ideas that mutually benefits the entire research program.
6. 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. He is directly collaborating on the genetics of feral goats and pigs project, and spent several weeks working in the Hrbek labs at UPR in January and Februray 2011. 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.
7. 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.

8. 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.
9. 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. Dr. Blaser visited UPR over in the past year, where he has served on at least one thesis committee and given a departmental seminar.
10. 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 Hugenholz, and Dr. Eoin Brodie.
11. Dr. Paul Bayman is collaborating with W. Nierman of the J. Craig Venter Institute in the study Metagenome of sea fans infected with aspergillosis.
12. Dr. Paul Bayman is collaborating with Dr. V. Gulis, of the Carolina Coastal University on the study Measure of fungal biomass in tissues.
13. Dr. Paul Bayman is collaborating with Dr. M. Cubeta, of North Carolina State University in the study *Rhizoctonia solani* genomics.
14. Dr. Eugenio Santiago, established colllaborations with Dr. Richard Olmstead of the University of Washington-Seattle, and Dr. Lucía Lohman of the University of Sao Paulo (Brazil) for the project on the systematics of the Bignoniaceae.
15. 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.
16. 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.

17. 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.
18. 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).
19. 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.
20. 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).
21. "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.
22. 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.
23. San Juan ULTRA-ex. Dr. Elvia Melendez-Ackerman from UPR-Rio Piedras, in collaboration with the USDA Forest Service International Institute of Tropical Forestry (IITF) and the Puerto Rican Foundation for Conservation.
24. 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.

25. Michigan State University-University of Puerto Rico initiative. Dr. Elvia Melendez-Ackerman from UPR-Rio Piedras.
26. USDA-NC State University, University of Puerto Rico. Dr. Elvia Melendez-Ackerman from UPR-Rio Piedras.
27. Conservation and Sustainable Management of Plant Resources in the Jaragua-Bahoruco-Enriquillo Biosphere Reserve, Dominican Republic. Dr. Eugenio Santiago, on collaboration with New York Botanical Garden, Universidad Autónoma de Santo Domingo, Cornell University, and Grupo Jaragua (NGO).
28. "Early accounts of the flora of Puerto Rico in the works of Domingo Bello y Espinosa". Dr. Eugenio Santiago, in collaboration with Fairchild Tropical Botanical Garden, Florida International University, and the Museum of Natural History of Tenerife.
29. Headstart Program for the Mona Island Iguana. Dr. Miguel Garcia with personnel of the Puerto Rico Department of Natural and Environmental Resources.
30. Breeding system in Spathoglottis. Dr. Jamez Ackerman and Dr. Paul Bayman (UPR-Rio Piedras), with Raymond Tremblay (UPR-Humacao).
31. Native flower weevils on invasive species. Dr. Dr. Jamez Ackerman and Dr. Paul Bayman (UPR-Rio Piedras), with Jose Carlos Rodríguez (UPR-Mayaguez).
32. 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).
33. 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.
34. Faculty and students of the MEEG group continue to interact with Dr. Jason Rauscher who has left the University of Puerto Rico to pursue other career

opportunities. Dr. Rauscher continues to serve on thesis committees, and contribute intellectually to ongoing projects.

35. 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.
36. 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.
37. 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.
38. 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.
39. 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.

40. 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.
41. 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.
42. 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, Univerisity of Para, Brazil. The research is allowing the understanding of how mid-Holocenic changes in climate, sea level rise and historical land use change has changed the plant biodiversity of the region.
43. 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.

44. 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.
45. 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.
46. Reproductive biology of the Mona Rock Iguana. UPR-Río Piedras and Department of Natural and - Environmental Resources of the Government of Puerto Rico. Ongoing collaboration involving population viability analyses and field studies.
47. Status surveys of marine turtles aggregations inhabiting coastal waters of Puerto Rico. Department of Natural Resources and Environment of the Government of Puerto Rico, NOAA. Provided foundation for continued research on marine turtles.
48. Population biology of black mangroves in Puerto Rico. Dr. Denny Fernandez University of Puerto Rico-Humacao. Provides a forum for inter campus collaboration.
49. 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.
50. 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.

51. Effects of Introduced Feral Ungulates on the native vegetation of Mona Island Reserve. UPR-Río 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.
52. 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).
53. 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.
54. 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.
55. Breeding system in *Spathoglottis*. Dr. James Ackerman and Dr. Paul Bayman (UPR-Rio Piedras), with Raymond Tremblay (UPR-Humacao).
56. Native flower weevils on invasive species. Dr. Dr. James Ackerman and Dr. Paul Bayman (UPR-Rio Piedras), with Jose Carlos Rodrígues (UPR-Mayaguez).
57. Phylogenetics and biogeography of the genus *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).

58. Morphological assessment of the genus *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).
59. 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.
60. 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.
61. 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 "Conservation Ethics" given by Drs. John Vucetich fom Michigan Technological University and Dr. Michael Nelson from Michigan State University (April 1-3, 2011). We also sponsored the "Geospatial analysis Workshop on agricultural and Natural Resources Management and Conservation" given by Dr. Xinyan Ben Wu from Texas A&M College Station and Dr. Humbert Perotto from Cranfield University, United Kingdom (April 18-19, 2011).

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.
- 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 2011 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.
- Dr. Raymond Tremblay and Dr. Denny Fernandez organized a 10-day field workshop for undergraduate students, on critical thinking in science. The workshop was carried out in the island of St. Eustasius, Netherland Antilles (January, 2011.
- 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.

I.10 DESCRIPTION OF SHARED FACILITIES WITHIN THE CREST FRAMEWORK.

The Sequencing and Genotyping Facility is a core research facility designed to allow students and researchers access to state-of-the-art sequencing and genotyping equipment. In addition, the facility is charged with creating essential infrastructure for archiving, manipulating and analyzing large molecular data sets. The facility has capillary-based automated DNA sequencer (MegaBACE™ 1000) and Li-Cor NEN Global DNA Analyzer System and Odyssey Infrared Imaging System. The MegaBACE is a high throughput sequencer and genotyper, instrumental in the characterization and development of the microsatellite loci that are cornerstone of the core MEEG projects. The Li-Cor DNA Analyzer and Imaging systems was purchased specifically for our genotyping needs. The Li-Cor software and LIMs support for analysis of microsatellite or Amplified Fragment Length Polymorphisms (AFLP) data is excellent and will allow researchers to easily manage the large molecular datasets generated over the course of this proposal.

Bioinformatics Satellite Lab: It is already established and acts as a core data processing and storage center for all molecular based research activities associated with CATEC projects.

Both the **Sequencing and Genotyping Facility** and the **Bioinformatics Satellite Lab** are essential for the success of CATEC's Molecular Ecology, Genetics, and Evolution Program. Although NIH provided the primary funding, CATEC provides critical computational support for integrating and managing hardware and software components of both facilities. In addition to allowing CREST researchers to collect and manage large molecular data sets, the expanded facilities are important assets for attracting new researchers and new research funding into CATEC.

I.11 SPECIAL EQUIPMENT/FACILITIES

The plant ecology and conservation laboratory: under the supervision of Dr. Raymond Tremblay at UPR-Humacao. The equipment includes PCR, Centrifuge, Gel ridges,

refrigerator, freezer (-20C°), pipette man and power pack. It is used for research and involves undergraduate students in research activities. The molecular facilities provide an important resource for students and researchers at UPR-Humacao. The facility serves two functions. First it students to conduct most of the molecular techniques needed in the genetic components of our core project at UPR-Humacao. This greatly facilitates training and technology transfer and increases the number of students served by the MEEG group. Second, the establishment of this facility is essential for attracting external research funds to this UPR campus.

UPR-ITES Computer Server. It is used to maintain the "Tropical Plant Ecology and Evolution Laboratory page and an introductory Page on The Mona Project Web Page". On the first page potential students and researchers are able to get information on the PI (E. Melendez-Ackerman), her laboratory activities, funding opportunities and other relevant information. The second web page provides general information on one of the CREST funded project and its main collaborators. There are links for students, opportunities for involvement, and relevant links such as publicly available data on the project, collaborating agencies, contact information etc. Expected databases to be placed in this server will include (but will not be limited to) a digital photo collection of Mona Island Plants, climate data and, annual censuses of permanent plots. It will also provide a better visibility for the CREST-program as well as collaborating departments, programs, institutions and agencies (i.e. Institute for Tropical Ecosystem Studies, The Biology Graduate Program at UPR, NSF-CREST CATEC) will facilitate the goals of the program including, faculty development, student training, dissemination of information to the public.

The Tropical Plant Ecology and Evolution Laboratory under the supervision of Dr. Elvia Melendez-Ackerman is a Wet/Dry lab with capability for work on plant morphology, germination, minor chemical work for terrestrial ecology assays (germination, plant growth). It includes a Computer lab with capability for univariate and statistical analyses, GIS-Remote sensing analyses, Hemispherical photography for forest canopy structure analysis and databasing. In addition there is a digital and wet/dry insect

collections available. Equipments available include two dissecting microscopes (Nikon, Olympus), One compound Microscope Nikon, a Plant Growth chamber, and field equipment for forestry terrestrial ecology work: (Fish eye-camera set, sceptometer, spectroradiometer etc).

The Terrestrial Ecology and Ecophysiology Laboratory at UPR-Humacao, under the supervision of Dr. Denny S. Fernandez, is a dry lab with capability for plant morphology, plant biomass, minor chemical work for terrestrial ecology assays (germination, plant growth). It includes a computer facility with capability for common statistical analyses and geostatistics, mathematical calculations and modeling, GIS-Remote Sensing image analyses. There is also capability for hemispherical photography for forest canopy structure analysis, meteorological measurements with portable microstations, and equipment for plant physiology measurements. Equipment includes one dissecting microscope with digital camera (Olympus-PaxCam) with measurement and database capabilities; Portable photosynthesis system (LI-Cor 6400 with dew point generator, and chlorophyll fluorescence measurement capabilities); and GPS receivers for submeter localization (Trimble - TopCon).

The UPR-Humacao computer server. It houses daily micro-climatic data as well as web page of Dr. Denny Fernandez. This data is site dependent can be linked to organismal data collected at permanent points. This data can be used to look at correlations of spatio-temporal changes between climate and organismal/ecosystem responses. Remote access to these types of data will provide scientific information that may be useful to individual researcher not necessarily related to the project as well as facilitate cross-site collaborations among research groups through data exchanges.
The UPR Herbarium at UPR-Rio Piedras is under de direction of Dr. James Ackerman. Provides plant identification services to scientists and the general public. Houses voucher specimens of scientific studies. Provide access to collections for floristic, systematic, ethnobotanical and ecological studies. Places collection data on the web for local and international access. Our database for the UPR-RP collection is

available at www.herbarium.uprr.pr . In addition, we serve as the depository for the CREST Mona Island project.

The UPR Herbarium at the UPR Botanical Garden, Rio Piedras is under the direction of Dr. Eugenio Santiago-Valentín. The herbarium provides plant identification services to scientists and the general public. Houses voucher specimens of scientific studies. Provide access to collections for floristic, systematic, ethnobotanical and ecological studies. Facilities include dissecting microscope (Nikon), plant driers, computers, herbarium cabinets, and botanical literature. We are a depository for the projects on phylogeography and phylogenetics of *Tabebuia*.

The Coral Reef Research Group (CRRG): Headed by Dr. Edwin Hernandez runs a field station at Culebra Island, Puerto Rico. CRRG equipment includes: 18 SCUBA tanks, 5 full SCUBA diving equipments (buoyancy compensation devices, regulators, consoles), a fully equipped Dell Precision M6300 computer, capacity to conduct GIS-based analysis, Two hand-held GPS units, high resolution digital underwater camera and strobes, digital underwater video camera and light system, metric lines, photoquadrats, and all equipment necessary for standard underwater data collection. Culebra Island field station is a property located at downtown Dewey, rented to the local Catholic Church since 2001. It serves a field station, lodging and storage site. It has two rooms, can accommodate up to 8 persons, and have storage area for SCUBA diving equipment. This facility has been also shared with environmental/educational NGO Sociedad Ambiente Marino (SAM) since 2003. SAM has provided six full SCUBA diving equipments and 12 additional SCUBA tanks.

The Ecosystem Processes and Function laboratory - Ecolab: Headed by Dr. Elvira Cuevas. Ecolab is a wet/dry lab prepared for chemical analyses, preparatory work for stable isotope determinations, plant eco-physiological studies, germination and plant growth studies. The laboratory has the following equipment: Low Temperature Diurnal Illumination Incubator: germination studies, Termo Electron Corp. Low Temperature Incubator: soil incubations for microbial biomass, nutrient leaching and soil respiration.

Kenmore Refrigerator, Frigidaire Commercial Freezer, Marvel Scientific Ice Maker: Storing of samples and chemical reagents; Barnstead Thermolyne Furnace Type 30400 (Series 1262): Ashing of soil and plant samples; Lane Oven, Retsch Mixer Mill and IKA Works MF10 Micro Mill, two Class II Type A Biohazard Cabinets, Eppendorf Centrifuge, VWR 800 Signature Series Stirrer, Barnstead Fistreem III Glass Still, RIOs Millipore Water Purification System two Mettler Toledo Analytical Balances, one Mettler Toledo Top-loading balance: plant and soil sample preparation for stable isotope determinations and nutrient analyses; Nikon SMZ1500 dissecting microscope, One Nikon Eclipse 80i compound microscope: plant morphology studies, soil arthropod studies, seed germinations studies; LI-3100CLeaf Area Meter , Pressure Extractor Soil Moisture Equipment Corp., Portable Chlorophyll Fluorometer WALZ PAM-2100: lab and field plant eco-physiological measurements; Agilent 7890 Gas Chromatograph; plant cell wall (lignin) measurements, measurements of sugar in plant xylematic and tissue extracts, CO2, methane and acetylene measurements from soil incubations for microbial activity and organic residue decomposition; Decagon and Onset computers field sensors and data loggers for soil temperature, humidity and conductivity, air temperature and relative humidity, two Onset Computers Meteorological station: in-situ determination of environmental parameters in the Guanica Dry Forest Coastal Plateau and at El Tallonal research site in Arecibo. Three Desk PCs, one Power Mac G4 with scanner and printer: data processing, inventory management, writing of reports, manuscripts and theses. This newly inaugurated laboratory is the first facility at UPR-Rio Piedras dedicated to plant eco-physiology, soil/plant interactions and nutrient cycling and carbon dynamics research. Students and researchers develop research projects where soil and plant chemical analyses are done on campus. They can also develop eco-physiological studies at the plant level both in the field and lab. The parameters studied are highly indicative of the plant adaptations to diverse growth conditions, and also of processes such as decomposition and mineralization of organic substrates from different species and/or ecosystems. All the projects are relevant to the study of how species and ecosystems adapt to environmental conditions, especially under a scenario of increased climate variability where the understanding of water and nutrient dynamics is essential for restoration efforts and the planning and management of natural and derived systems.

The Tropical Limnology Laboratory, headed by Dr. Jorge Ortiz and Alonso Ramírez at UPR-Rio Piedras. The temporary laboratory facility is equipped with analytical instrumentation to study major ions and to conduct macroinvertebrate and diatom taxomony. It provides space for one graduate student. The equipment available for research at the Tropical Limnology Laboratory are: six Hydrolabs water quality sondes with data logging capacity; LI-COR underwater light sensors with data loggers; Marsh-McBirney flow meter; land surveying equipment (CST Berger); Millipore DI water system; ion chromatograph with autosampler (Dionex ICS 1000); spectrophotometer; BOD system; incubator; freezer and refrigerator; acid and flammable liquids cabinets; ISCO portable water automated refrigerated sampler; TOC analyzer with autosampler (Tekmar Apollo 9000), inflatable 12' boat with 12 HP motor; one DO field sensor (YSI), and one turbidity laboratory meter (LaMotte).

The UPR Honey Bee Research Facility: under the supervision of Dr. Tugrul Giray is Located at the UPR Experimental Station in Gurabo. The Honey Bee facility makes available the non-defensive Africanized bees for behavior, genetics, and genomics research.

High Performance Computer Facility. Located at UPR-Central Administration Facilities in the northern part of UPR Botanical Garden, it houses the CATEC's main platform for web collaboration and data depository.

I.12 PLANS FOR FUTURE COLLABORATIONS WITH OTHER CENTERS.

There are plans for research collaboration with the CREST Center for Forest Ecosystem Assessment from Alabama A & M University, the CREST Center in Tropical Ecology and Evolution in Marine and Terrestrial Environments from University of Hawaii at Hilo and CREST RESSACA as we all share similar research interests. Dr. Elvira Cuevas is already part of the scientific external advisory committees of the first two Centers.

II. ACTIVITIES AND FINDINGS

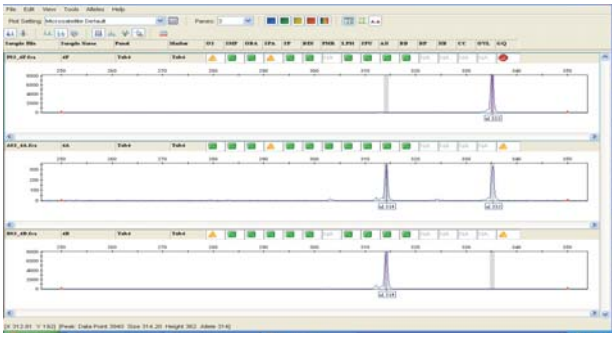
THRUST AREA 1: MOLECULAR ECOLOGY EVOLUTION AND GENETICS (MEEG)

Component 1: Phylogeography and conservation genetics of plants
Investigators: Tomas Hrbek, Eugenio Santiago, Elvia Melendez-Ackerman, José Fumero and Nirzka Martinez.

This component of the project is 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 integrate into larger projects in CREST-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.

Project: Phylogeography and population genetics of *Tabebuia heterophylla*

This year has seen a successful progression of this project, both in terms of refining of tools, data collection and data analyses. We have now developed and tested all necessary microsatellite markers to finalize the screening of populations sampled throughout the Puerto Rican bank. Primers were designed for nearly 50 microsatellite regions. All were tested for PCR, with >90% amplification success. These were then tested for genotyping suitability in the UPR Sequencing and Genotyping Facility. Close to 15 loci were identified as potentially polymorphic, although some markers still need to be optimized.



Example of a newly isolated polymorphic microsatellite locus in *Tabebuia*, showing a heterozygote with two alleles, and two homozygotes.

In addition, work has continued on the chloroplast sequencing project, which so far has included 10 chloroplast regions for a preliminary geographic sampling. This represents a total of approximately 50 kilobases of sequence data for each sample (about 15 so far). Sampling continues to be coordinated with Dr. Eugenio Santiago and a PhD student, Nirzka Martinez. This project has already yielded very interesting results that show a strong genetic differentiation between Mona Island populations and Puerto Rican populations, but these results are still very preliminary and will require additional sampling.

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

Project: Phylogeny of the genus *Tabebuia*

The Tabebuia project has been extended to generating a phylogenetic hypothesis for the genus *Tabebuia*. In late 2010 collecting trips were undertaken in the Dominican Republic, with additional species being collected from Haiti, Cuba and northern South America and Central America. The sampled species were sequenced from three chloroplast and the ITS gene, and analyzed under the maximum likelihood, Bayesian

inference and maximum parsimony framework. These preliminary analyses are very exciting. It appears that Caribbean islands are monophyletic, different phenotypes evolved independently on each island. Furthermore, it appears that the Caribbean is a center of a radiation for *Tabebuia*. The patterns observed in *Tabebuia* is reminiscent of the radiations observed in the genera *Anolis* and *Eleutherodactylus*. Furthermore, the diversity observed in Hispaniola is deeply divergent, and the distribution of these lineages is correlated with the microplates that comprise present day Hispaniola, reminiscent of the patterns observed in the lizards of the genus *Ameiva*.

Project: Conservation Genetics of an endangered Puerto Rican tree: *Guaiacum sanctum*

Guaiacum sanctum commonly known as, lignum-vitae, Holy wood or Guayacan Blanco is an endangered tree of Puerto Rico. In the past this tree has been heavily exploited for its wood, which is extremely strong, tough and dense, and thus had numerous industrial applications. Currently it is found almost exclusively in protected areas of Puerto Rico and Mona Island. The goal of the *Guaiacum* project is to estimate the levels of genetic diversity present in remnant population, look at differences in genetic diversity in young vs. old trees, and to study the system of mating, specifically rates and incidences of self-fertilization and of multiple paternity. We have successfully 15 microsatellite makers, 9 of which are polymorphic and appear to be informative for analyses of systems of matings. It should be noted that all sampling has been done non-destructively. The project is being carried out under the guidance of Dr. Elvia Melendez-Ackerman and a Ph.D. student Jose Fumero. The markers appear to be sufficiently powerful for the study of mating systems and identify cases of self-fertilization and multiple paternity, although a number of otherwise polymorphic markers are homozygous within individuals, and thus are not informative or have low statistical power.

Component 1, Summary of specific accomplishments:

1. Continuation of tissue collection and genetic sampling for *Tabebuia* (including species and populations from Hispaniola, Cuba, northern South America and Central America)

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

Component 1, Goals for year 5:

1. Increased population sampling for *Tabebuia* spp. and *Guaiacum sanctum*.
2. Sample additional species of *Tabebuia* focusing on northern South America and Central America.
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 & Stephan Funk.

This project is designed to investigate feral goat and pig populations from Mona Island, which have been isolated for over 500 years, to understand how invasive species evolve, and as a model for studying 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 project is being done in collaboration with Dr. Stephan Funk, Senior Conservation Biologist for the Durrell Wildlife Conservation Trust, Jersey.

Feral goats (*Capra hircus*) and pigs (*Sus scrofa*) were introduced more than four centuries ago by Spanish settlers to Mona Island. They were set loose to reproduce and provide a source of fresh meat for 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 a 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).

The use of microsatellite markers is one of the most powerful means to study genetic diversity and differentiation among populations. Microsatellite markers are highly polymorphic, randomly distributed throughout the genome and neutral with respect to selection (Agha et al., 2008). The characterization and of the genetic diversity of animals from Mona Island and other islands in the Caribbean will give us a better understanding on 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.

Samples for this project consist of tissues collected during DNR sponsored culls and from fecal samples, all from Mona Island. In 2008-2011 over 200 goat samples have been collected during the hunting season in Mona, and over 60 pigs samples were also collected. Additional pig samples are being collected in collaboration with USDA, and reference samples from European domestic and land race breeds are being provided by Dr. Stephan Funk. For all samples, whole genomic DNA was extracted using QiagenDNA easy kits. We have purchased a set of 30 pig microsatellite markers and 23 goat microsatellite markers, which have been proposed as standard sets of microsatellite

makers by the European-funded EconoGene project (Russell et al. 2003, SanCristóbal et al. 2006). The logic behind the use of these markers is that the data generated in this study can be combined with previous data, and results are immediately comparable between different studies using the same set of markers. Additionally, the use of these markers will allow us to infer the origin and/or origins of the populations of both species from Mona Island.

A total of 23 goat microsatellite primers have been tested. Of these 23 primers, 9 successfully amplified, but in a sample of 20 individuals showed no variation (Table 1). 14 primer pairs amplified polymorphic loci, with 7 loci having 3 or more alleles per locus. Loci were characterized on the ABI 3130, and results were analyzed with GeneMapper Software Version 4. For the polymorphic loci, we analyzed all sampled collected through January 2011.

Microsatellite markers for pigs are being currently screened. As expected, a large number of the 30 tested markers are monomorphic, however, preliminary data indicate that at least 10 markers will be polymorphic.

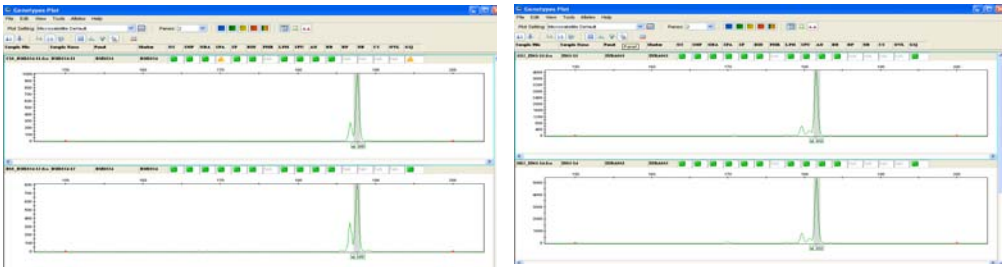
Our results in the analysis of 200+ goat samples show little genetic variation, and a large number of monomorphic loci. Observed heterozygosity in the 200+ goats sampled in the 2008-2011 season was 0.372, which was significantly lower than what reported in screens of various endangered breeds and land 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.

Characterization of goat-specific microsatellite loci in the Mona goat (*Capra hircus)*

Locus	Num. of alleles
BM1818	1
BM1824	1
CSRM60	5
CSSM663	4
ETH104	4
ETH152	5
ETH185	3
ETH225	2
HAUT24	1
HAUT27	2
HEL1	2
ILSTS005	1
ILSTS006	2
ILSTS0113	2
ILSTS030	1
ILSTS0332	2
ILSTS0344	2
ILSTS0541	1
INRA0052	3
INRA023	1
INRA035	1
INRA063	1
MM12	4

BM1824 **INRA063**



Analysis for the microsatellite loci BM1824 and INRA063 using GeneMapper Software Version 4. Two individuals showing homozygosity for both microsatellite loci.

Component 2, Summary of specific accomplishments:

1. Collection of muscle and fecal tissue samples in collaboration with the Puerto Rico Department of Natural Resources.
2. Genomic DNA extraction from all samples.
3. Purchase and optimization of standard goat and pig microsatellite primer sets.
4. Characterization of goat samples collected in the 2008-2011 season.

5. Preliminary estimates of diversity in goats for using 14 polymorphic loci.
6. Characterization of pig microsatellite makers in samples collected in the 2008-2011 season.

Component 2, Goals for year 5:

1. Collect additional tissue and fecal samples for genetic analyses from Mona Island and other Caribbean Islands. Increased population sampling is especially needed for pigs from Mona Island.
2. Finish troubleshooting and optimization of the pig primers.
3. Screen MHC II allelic diversity in goats.
4. Initiate analyses of the goat and pig data within the broad framework of the European Econogene project.
5. Test if the Mona populations represent single or multiple introductions, and from where these introductions most likely were.

Component 3: Digestive microbiomes from animals isolated on an island over 500 years. Investigator: Maria G. Dominguez-Bello

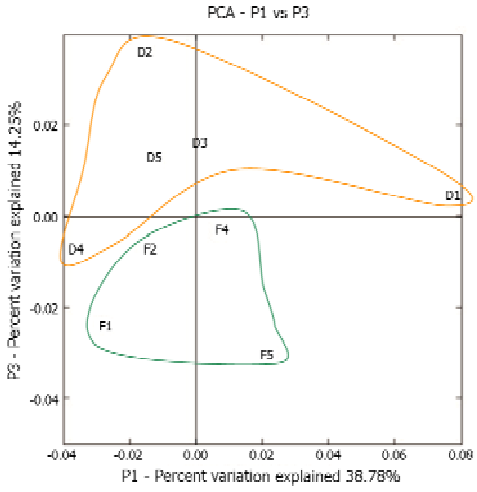
The ultimate goal of this study is to determine how four centuries of feral conditions have preserved a microbial digestive diversity, and whether these microbial systems are open to gene transfer from outside ecosystems.

The aims of this project are: 1. To characterize the digestive ecosystem from Mona Island ungulates, including intestinal community analysis, and comparison with impacted microbiomas from domestic animals; and 2. To address whether there has been bacterial gene transfer and selection of genes from other microbial ecosystems, using antibiotic resistance as the gene transfer model.

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. The working hypothesis was that the feral microbiota would have

preserved a richer bacterial community than the domesticated environment, which has been impacted by both human selection of goat genetic breeds, and by the use of antibiotics among several other human practices that might have exerted selective pressures on the microbiome.

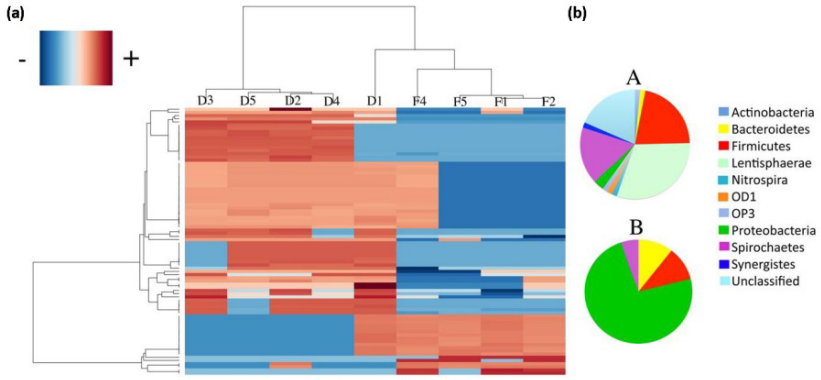
This hypothesis was tested by studying the intestinal bacterial community structure in 4 feral goats from Mona Island and 5 domestic goats from a farm in Puerto Rico mainland. Fecal DNA was extracted and amplified using 16S rDNA universal primers, to hybridize onto the G2 PhyloChip. The freely available PhyloTrac application (www.phylotrac.org) recently developed by Jackes Ravel, for the visualization and analysis of PhyloChip microarrays.Overall, goats had a diverse intestinal bacterial community composed by 42 phyla, but highly dominated by Firmicutes, Proteobacteria and Actinobacteria. A total of 2,000 OTUs were grouped in these 42 phyla. Feral goats had 1,637 bacterial species-level OTUs from 40 phyla, while domestic richness was higher, with 1,895 in 42 phyla. The goat intestinal bacterial community, although typical of other mammalian hindguts, showed no notorious differences between feral and domesticated goats. However, preliminary clustering analysis does indicate a tendency to clustering apart feral and domestic communities, supported also by principal component analysis.



Component 3, Summary of specific accomplishments:

1. A total of 42 bacterial phyla from 153 families were detected in the goat feces.
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. Feral goats had a greater abundance of fecal Proteobacteria and Bacteroidetes while domestic goats were more abundant in Firmicutes, Actinobacteria and Spirochaetes. Both feral and domestic goats carried *tet*(O) and *tet*(W), but domestic goats additionally carried *tet*(Q).
5. Antibiotic resistance was found in Mona animals with no known exposure to antiobiotics.
6. A greater diversity of tetracycline resistance genes has been found in domesticated goats.
7. Diet, antibiotic exposure and host genetics are likely determinant factors in shaping the intestinal microbiota and might explain the differences between feral and domestic goats.

Component 3, Goals for year 5:

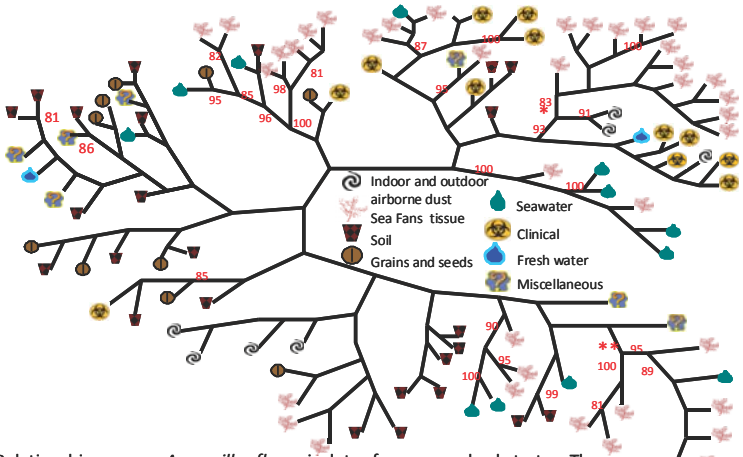
1. Continued collections of new bacterial samples, especially from Mona Island
2. Expanded use of the PhyloChip technology to compare bacterial populations in feral and domesticated goats
3. Next generation sequencing of rDNA genes for all new samples
4. Next generation sequencing of bacterial metagenomes

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.

Two hundred *A. flavus* strains have been isolated and collected, including numerous strains from sea fans (*Gorgonia ventalina*), sea water and dust. Two genes have been sequenced from almost all these strains. AFLP analysis was also performed on almost all of the strains. Statistical analyses based on AFLPs did not reveal specificity for substrate or source. These results were confirmed using sequence data.

One of the interesting and highly surprising results of this study is 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. *Aspergilus flavus* was also found in almost any type of sample, and there was no association with a particular genotype or groups of genotypes and the sample substrate.



Relationships among *Aspergillus flavus* isolates from several substrates. The unrooted neighbor-joining tree is based on 460 AFLP characters. Bootstrap values >80 % are shown in red. Tree length = 4637 CI=0.0992 RI=0.5866.

This result 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 Ruíz 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.

Component 4, Summary of specific accomplishments:

1. 200 *A. flavus* strains were isolated and collected, from sea fans, seawater and dust.
2. Two genes have been sequenced from almost all strains.
3. AFLP analysis completed for nearly all of the strains.
4. Preliminary phylogenetic analysis of DNA sequences completed.
5. Preliminary statistical analysis of AFLP data and decision to use different approach.

Component 4, Goals for year 5:

1. Continued testing of the role (or lack thereof) of *Aspergillus* as pathogens of Caribbean sea fans.
2. Increased sampling and genotype screening of fungal samples from diseased corals using DNA sequencing.
3. Development of new computer models to help us better understand the relationship between the occurrence of the disease and the survival of sea fans.
4. Publication and presentation of results on the role of *Aspergillus* in the disease cycle.

Component 5: Biodiversity of Caribbean spiders. Investigator: Ingi Agnarsson

The purpose of this project is to assess biodiversity of Caribbean spiders, and place this diversity in the global context. Approaches include both species discovery using both traditional morphological methods, as well as sequence based approaches,

including DNA barcoding. This is a component that has been initiated only last year, but has resulted in the discovery of a number of species of spiders, and funding by the NSF.

Component 5, Summary of specific accomplishments:

1. Discovery of *Caerostris darwini* (Darwin's bark spider)
2. Discovery of the toughest biomaterial known to man (silk of the Darwin's bark spider)
3. Award of an NSF Biological Inventories grant

Component 5, Goals for year 5:

1. Initiation of sampling in the Greater and Lesser Antilles.
2. Collection of morphological data.
3. Collection of molecular data.
4. Species discovery using a combination of DNA barcoding and Population Aggregation Analysis.
5. Phylogenetic reconstruction.
6. Phylogenetic hypothesis testing.

Component 6: Speciation genomics of *Heliconius* butterflies. Investigator: Riccardo Papa

The purpose of this project is to investigate the genomic basis of species differences and speciation in the *Heliconius* butterflies. *Heliconius* butterflies are a well established and traditional model for the study of speciation in the Neotropics. *Heliconius* butterflies exhibit both Batesian and Mullerian mimicry. This is a component that has been initiated only last year, but has resulted in funding by the NSF.

Component 6, Summary of specific accomplishments:

1. Discovery of a potential candidate gene responsible for one of the major phenotypic traits associated with species differences.

Component 6, Goals for year 5:

1. Continued identification of potential candidate genes involved in speciation.
2. Continued testing of specific candidate genes.
3. Initiation of breeding experiments and generation of interspecific hybrids.

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 in all species of 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.

Component 7, Summary of specific accomplishments:

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. Bi-direction exchange of Puerto Rican and Brazilian students and researchers.
4. Strengthening of joint collaborative research efforts.

Component 7, Goals for future years:

1. Strengthening of joint collaborative research efforts.
2. Submission of joint research proposals.
3. Publication of results from the demographic analysis.

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

Project: "Operation root out: Invasion of alien orchids".

Our work on the population biology of invasive orchid species is nearing the conclusion on several projects. With the exception of one project, fieldwork of all others has been completed is in nearing completion. Species distribution modeling remains to be done and manuscript preparation has already begun for two articles. We anticipate another 2-3 to come from these studies. We 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. These findings will be presented this summer at the ESA meetings in Austin and at the International Orchid Conservation Conference in the Czech Republic. 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. This will be presented at the Hawaii Conservation Conference this summer as well. In the meantime, we have begun gathering data on the establishment of Pine plantations and expect to begin studies on the invasion of pines from these plantations into other areas of the island. We are particularly interested in whether they have an impact on the species composition and diversity of communities, particularly the fungal and herbaceous floras.

Project: Herbivory of the exotic orchid *Spathoglottis plicata* by the endemic weevil *Stethobaris polita:* The natives fight back: endemic florivorous weevils attack flowers of an alien orchid and reduce plant reproductive success.

Investigators: James D. Ackerman, Carlos Vega, Isamalish Espino, Ana A. Cuevas

Invasive plant species are often generalists in their mutualistic interactions, specialists on widespread taxa, or are adept at self-pollination, or vegetative reproduction. Their invasiveness may be due to release from enemies, such as competitors, herbivores or seed

predators. Or they may be superior competitors as is often suggested for plants that invade islands. From a single naturalized population 30 years ago, the autogamous *Spathoglottis plicata* has spread across the island of Puerto Rico. Inflorescences, though, often become deformed and abort flowers and fruits. An orchid-specialist, endemic florivorous weevil, *Stethobaris polita*, attacks the flowers and reduces reproductive success. Ants that forage at extrafloral nectaries sometimes attack the weevils, but have no effect on plant reproductive success. Plants protected from weevils had 4-6× higher fruit set than those treatments that allowed weevil access. Weevil abundance is weakly density dependent. The frequency of weevils is positively associated with at the number of open flowers on an inflorescence, and the more flowers in the neighborhood, the more weevils that are observed. White and pink morphs exist, and the weevils prefer the pink morphs both in the field and in laboratory choice experiments. Although S. plicata encounters new enemies in Puerto Rico and suffers reduced reproductive success, it remains invasive. With weevil preference for pink flowers, we expect white-flowered morphs to become relatively more frequent until balanced by density dependent effects.

Project: There goes the neighborhood: apparent competition between invasive and native orchids. Investigators: Wilnelia Recart, James D. Ackerman and Ana A. Cuevas

Background/Question/Methods-Apparent competition occurs when one species is negatively affected by the presence of another species because they share a common predator. In Puerto Rico, the exotic Asiatic orchid, Spathoglottis plicata, a naturalized, self-pollinating species that has spread rapidly over the last two decades and has become locally abundant. Two forms exist: one with white flowers and the other with magenta flowers. In parts of the island, they occupy the same habitat as the native xenogamous orchid, *Bletia patula*, which is vegetatively similar to *S. plicata* and bears magenta flowers The two species are hosts to the same endemic florivorous weevil, *Stethobaris polita*, a specialist on orchid flowers. We ask whether the presence of *Spathoglottis plicata* affects the reproductive success of *Bletia patula* by elevating the abundance of the weevil. We measured local densities of the orchids where the two species grow together

and also where *B. patula* grows in the absence of *S. plicata*. Female reproductive success (fruit production) in *Bletia* was recorded at all sites. We also monitored the abundance of weevils and the extent of floral damage they cause to *B.patula*. In addition, we experimentally tested in vitro whether weevils preferred one species over the other. **Results/Conclusions** -We found that the number of weevils per individual of B. patula was significantly higher where S. plicata was also present. Associated with this increment in weevil presence, floral damage to B. patula was also greater where S. plicata was present. Consequently, reproductive effort and success was higher for B. patula in the absence of S. plicata. The weevil choice experiments showed that the beetles preferred B. patula flowers over S. plicata white flowers but prefer S. plicata magenta flowers over similarily colored B. patula flowers. Thus, the invasive S. plicata has detrimental effects on native B. patula by elevating populations of native weevils that specialize on orchid flowers resulting in dire consequences for natural fruit and seed production of the native orchid. Assuming that variation in fruit production in B. patula has demographic consequences as has been shown for other orchids, we suggest that apparent competition between the two species exists through the activity of a shared florivorous weevil.

Project: Hawai'i and Puerto Rico: A story of shared orchid weeds
Investigators: James D. Ackerman, Pablo J. Hernandez-Garcia, Wilfredo Falcón, and Wilnelia Recart

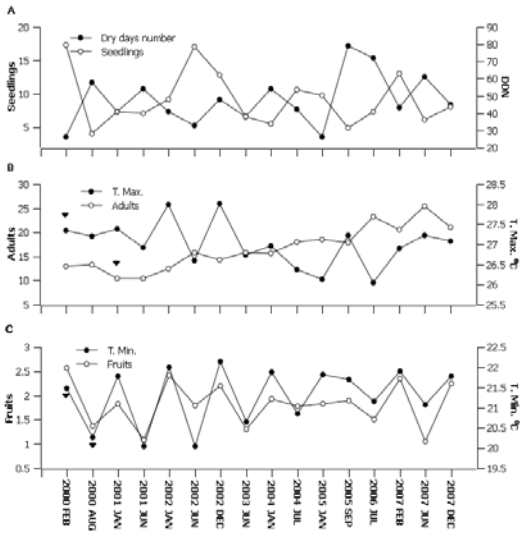
The Hawaiian Islands have suffered from a long history of species introductions that have resulted in the establishment and spread of invasive species. Puerto Rico has had numerous introductions as well, but their prevalence and impact is just beginning to be noticed and studied. Amongst the exotic species that have established to both the Hawaiian and the Puerto Rican archipelagos are populations of orchids (Orchidaceae) that have been introduced through the ornamental plant market. Compared to other species, exotic orchid populations have received little attention from researchers. In this study, we compare the population biology of established *Spathoglottis plicata* Bl., and *Arundina graminifolia* (D. Don) Hochr. in both archipelagos. *Spathoglottis plicata* populations in Hawai'i showed a significantly higher average fruit set when compared to

Puerto Rican populations, with a twofold increase. and a 17.5-fold increase respectively. Populations of *S. plicata* seemed to be autogamous in both archipelagos as no evidence of pollinaria removal was found; the differences in fruit set are attributed to heavy weevil damage to inflorescences of Puerto Rican plants. As for *Arundina graminifolia,* populations in both Hawai'i and Puerto Rico appear to be outcrossing, but Hawaiian populations had a 17.5-fold increase in fruit set over populations in Puerto Rico and pollinarium removals were also significantly higher in Hawai'i (53%) than in Puerto Rico (3%). *Arundina* flowers in Hawai'i are smaller than those in Puerto Rico, which may affect the effectiveness of pollinators and account for the lower reproductive success. Although we do not know how quickly these species have spread in Hawai'i, their march across Puerto Rico faces hurdles not seen in Hawai'i.

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

Project: Demographic response to long-term climate variation by a small epiphytic orchid in the Luquillo Mountains of Puerto Rico. Investigators: Paola Olaya, E. Melendez-Ackerman, Maria Egleé Pérez & Raymond Tremblay

Biotic shifts are inevitable consequences of climate change. Epiphytes may be more susceptible to such shifts but little is known how they might respond. We studied the demographic responses of the epiphytic and lithophytic orchid *Lepanthes rupestris* to variation in precipitation and temperature between 2000 and 2007 at the Luquillo Experimental Forest in Puerto Rico. Overall results show that changes in reproductive and demographic stages are associated with changes in the maximum



and minimum temperatures and number of dry days per observation period. We detected significant negative correlations between the average number of seedlings and the number of dry days without lag times, between the average number of fruits and minimum average temperature with a six-month lag and between the average number of adults and the maximum temperature with a one-year lag. The average number of fruits was positively correlated with the minimum average temperature. In this patchily distributed orchid, neither population growth rate nor probability of colonization and extinction were directly related to climatic variation between 2000 and 2007. Associations between climatic variables and demographic stages could have implications for this orchid within the context of expected long-term climatic changes in the Caribbean. Results argue for the establishment of long-term monitoring studies of orchid populations, as only those would provide the appropriate temporal scale to allow detection and prediction of climate change effects and adaptive management of orchid populations.

Project: Wind-Faciliated Self-Pollination In *Harrisia Portoricensis* (Cactaceae): A Mechanism For Reproductive Assurance. Investigators: Julissa Rojas-Sandoval And Elvia Melendez-Ackerman.

The genus *Harrisia* comprises 20 species, all of them endemic species with limited distributions (14 species are restricted to Florida and the Caribbean region and 6 species are restricted to the southeast of South America; Anderson 2001). *Harrisia* portoricensis is a columnar cactus formerly endemic to four Caribbean islands of the Puerto Rican bank. This species is listed as extinct on the island of Puerto Rico and currently is geographically restricted to the small islands of Mona, Monito and Desecheo. Since 1990, Harrisia portoricensis is listed as a threatened species under US Federal Regulations, a status mostly attributed to habitat loss and vegetation changes due to the presence of feral goats and pigs on these islands (USFWS 1990). A previous study on the breeding system of H. portoricensis conducted on Mona Island demonstrated that this species has hermaphroditic flowers with a morphology that is typical of outcrossing species (Rojas-Sandoval & Melendez-Ackerman 2009). Controlled pollination experiments showed high rates of fruit production under natural conditions (88% of fruit

set in natural-pollination treatment) but suggested that this species has a partially self-compatible breeding system. Even so, flowers are not autogamous, and thus, require an external mechanism for the movement of pollen to set fruit. At the same time, more than 300 hours of direct observations and videotaping on flowers of this species have shown that animal visits to flowers are highly uncommon events (Rojas-Sandoval & Melendez-Ackerman 2009). Under this scenario of extremely low pollinator visitations and high rates of natural pollinations the big question is: How is *H. portoricensis* able to produce fruits under natural conditions? In this work addressed this question with a field experiment that tested the hypothesis of wind-facilitated self-pollination on this cactus species. Based on videotaped observations, we hypothesized that within-flower pollination would be facilitated by the rotation of their large pedunculate flowers in response to strong windy conditions on Mona Island sites. We also hypothesized that plants growing in areas exposed to windy conditions (i.e., plants growing closer to cliffs or in low canopy areas) would have higher probability to set fruits than plants growing in areas protected from wind. Our results do support the occurrence of a wind facilitated pollination strategy (Table 1) and its dominant role in the of fruit production in this cactus species.

Table 1. Fruit set (fruits/flowers) for wind-treatments performed in H. portoricensis. *

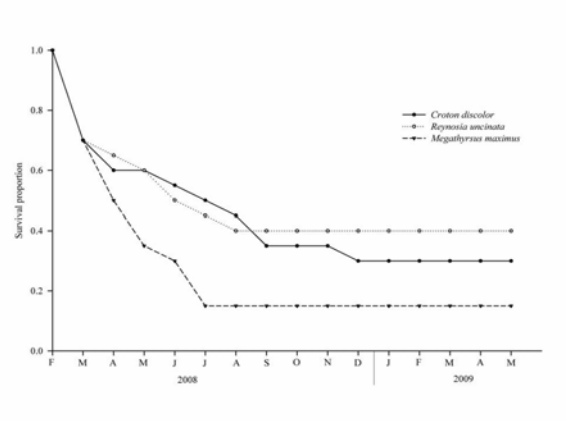
Treatment	No. of flowers	No. of fruits	Fruit set
Enclosed	25	2	0.08
Open	25	23	0.88

**Results are from an experiment that produced a flower treatment (Treatment) that exclosed flowers and prevented wind-assited flower rotation and compared fruit set of these flowers to flowers that were unmanipulated (Open).*

Project: Factors Affecting Establishment Success In An Endangered Caribbean Species. Investigators: 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. We 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), 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 canopies of native shrubs, *Croton discolor* and *Reynosia uncinata,* than beneath the exotic grass species, *Megathrysus maximus,* where temperature and solar radiation values were on average much higher than those obtained under the canopies of native shrubs. Our 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 his endangered cactus species.



Thrust area II: Species and Population Management. Component 2: Studies on the Virgin Island Boa and the Mona Iguana in support of Caribbean-wide management efforts. Investigators: Miguel Garcia, Maria Egleé Pérez, Keyla Pagan-Rivera

Keyla Pagan-Rivera has been working on Bayesian hierarchical models for fitting Von Bertalanffy growth curves with mark recapture data. She is now applying the models proposed by Zangh, Lessard and Campbell (2009) to data from a reintroduced population of Virgin Islands Boa (*Epicrates monensis*). The model is being adapted to incorporate differences by sex. The results obtained to date point to a model with growth rate constant for all individuals, but with differences in maximum size. Once these models have been tried for this dataset, we expecto to be able of building growth curves for Mona Iguana, which will allow to predict approximately age, sexual maturity, etc. For

this, it will be necessary to combine data from young iguanas (available from the headstart) with existing data from capture-recapture studies (taken by N. Pérez-Buitrago). 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 excepcional 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 an scaled beta of the second kind as a prior for scale parameters is being proposed. The combination of a Cauchy Prior for location and Beta2 for scale, yields a novel closed form prior for location that we call Beta2-Cauchy, extremely suitable for Objective Robust Bayesian Analysis.

Thrust area II: Species and Population Maganement. Component 3: Patterns of diversification of an economically important tree genus *Tabebuia.*
Investigators: Eugenio Santiago, Nirska Martinez

During the past year we continued taxonomic sampling, sample processing in the lab, and morphological analyses of *Tabebuia*. Sampling was greatly improved by additional material obtained from the Dominican Republic (all taxa on that island have been collected, this being a major goal), the Bahamas, Nicaragua, and Cuba (kindly provided by the National Botanical Garden, Havana; no NSF funds involved). We also established collaboration with Dr. Lucia Lohman (Univ. of Sao Paulo) who is an expert in Brazilian Bignoniaceae, and will help us with Brazilian taxa. We were invited by Dr. Lohman to give an oral presentation on our project to her lab. Her collaboration is crucial as she have been able to make accesible important brazilian material for the study (including samples from the type species, *Tabebuia cassinoides).* This was carried out by Dr. Jackeline Salazar (collaborator of the project, from Universidad Autonoma, Dominican Republic). We have sequenced the nuclear ITS and chloroplat psbD-trn, as well as the Chloroplast rpl 32-trnL to improve sequence resolution. We continued the morphological assessment of leaf characteristics of *Tabebuia* in collaboration to Dr. Jackeline Salazar. Dr. Salazar visited UPR in March and in May to work on *Tabebuia* samples using the Scanning Electron Microscope (SEM).

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: Cuevas, Ortiz, Govender, Rodríguez, Sternberg, Medina and Canals.

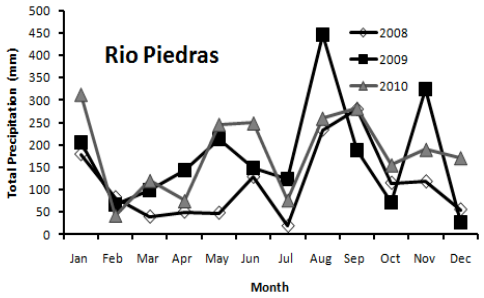
The fieldwork in Guanica Dry Forest started in October 2007. Replicate trees of five species: *Coccoloba microstachya, Tabebuia heterophylla, Ficus citrifolia, Pisonia albida and Erithalis fruticosa* were tagged and georeferenced in the Coastal Plateau. All species are natives and grow from the ridge to the coast in the dry forest. Replicate trees from the mangrove species *Avicennia germinans, Laguncularia racemosa and Conocarpus erectus* were selected, tagged and georeferenced for sampling and phenology studies. The mangroves are 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. At the same time water sampling for Deuterium and **δ**18O in the water sources are being carried monthly in surface soil, rainwater, ground water and in the Coastal lagoon. Since January 2008, soil temperature and humidity is being monitored under each of the trees being studied. 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 from the University of Miami. During summer 2009 we established three piezometers to 50 cm depth between trees where stable isotope studies are being conducted. Two piezometers were established in the area, one to 2.5 m depth and the other where fresh water was located (8.5m depth). Every four weeks we sample the water from each piezometer for salinity and stable isotope determinations. The results so far confirm the karstic terrain with cave formation at 8 meters depth.

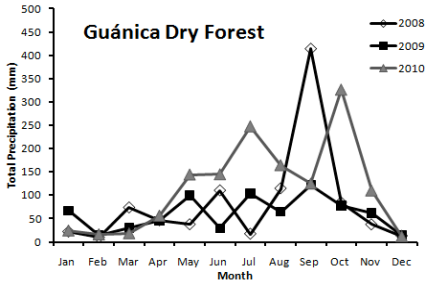
An oral presentation of our work entitled: "**Spatial and temporal variation in isotopic composition of precipitation and groundwater in contrasting precipitation regions in Puerto Rico, an island located in Northeastern Caribbean,** was presented at the

2010 AWRA International Water Congress and 8TH Caribbean Water Resources Congress and submitted to the Journal of Hydrology. One of the strongest critiques was that our dataset from 2008 to 2009 was too short to determine the effects of climate variability on precipitation spatial and temporal patterns. We now have data on isotopic signature of precipitation and ground water for three consecutive year and reanalysis of data with suggestions of reviewers. Reanalysis showed significant differences in the amount of precipitation collected between 2008 until 2010 between our sites and showed significant differences in isotopic signature for rainfall for the three years.

Average precipitation amount (mm) recorded for three years in the Guanica Dry forest and Rio Piedras Experimental Station.

Site	**2008**	**2009**	**2010**
Ave. Precipitation Guánica Dry Forest (mm)	229.5	210.7	261.4
Ave. Precipitation Rio Piedras Station (mm)	258.2	313.0	322.6



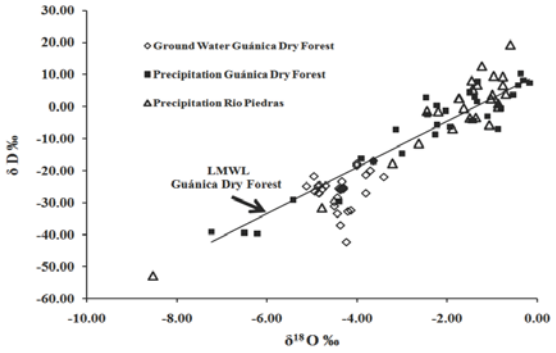


We also included local weather variables to determine why rainfall isotopic signature changes throughout the year. We found significant correlation between local and regional variables between isotopic signature of rainfall in Guanica and Rio Piedras. In the Guanica Dry Forest variability in isotopic signature for precipitation was significantly explained by sea surface

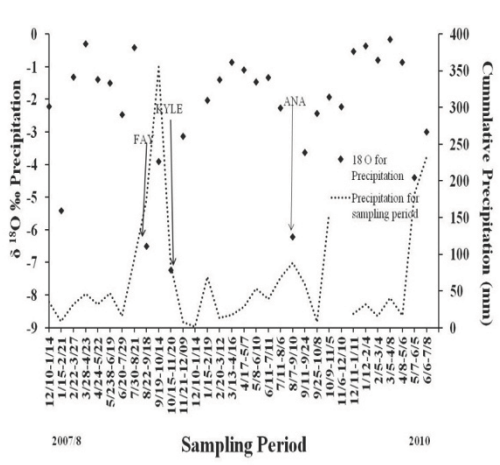
Isotopic Signature Percipitation Guanica Dry Forest	Climatic Variable	Spearman's Correation	Significance
Avg δ 18O ‰	Total Percipitation Guánica Dry Forest	-0.29	0.11
Avg δ 18O ‰	Air Temperature	-0.37	0.04*
Avg δ 18O ‰	Relative AirHumidity Ponce	-0.24	0.20
Avg δ 18O ‰	SST (oC) (Lapaguera)	-0.48	0.007*
Avg δ 18O ‰	WindDirection (degree) (la Paguera	-0.03	0.88
Avg δ 18O ‰	Windspeed (m/s) (lapaguera)	0.16	0.41
Avg δ D ‰	Avg δ 18O ‰ Percipitation Guanica Dry Forest	0.84	0.0001*
Avg δ D ‰	Total Percipitation Guánica Dry Forest	-0.31	0.09
Avg δ D ‰	Air Temperature (Ponce)	-0.22	0.22
Avg δ D ‰	Relative AirHumidity Ponce	-0.26	0.16
Avg δ D ‰	SST (oC) (Lapaguera)	-0.43	0.02*
Avg δ D ‰	WindDirection (degree) (la Paguera	0.20	0.29
Avg δ D ‰	Windspeed (m/s) (lapaguera)	-0.11	0.55

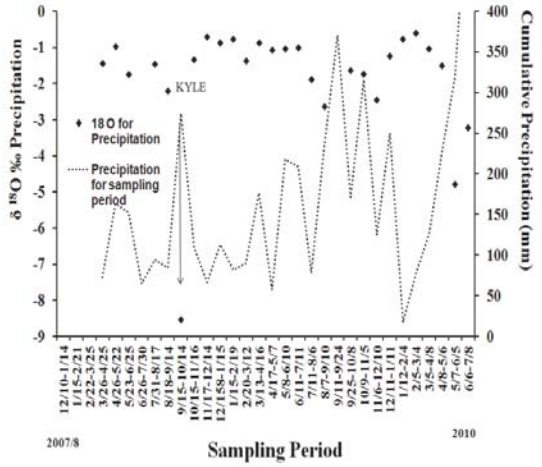
Isotopic Signature Percipitation Rio Piedras	Climatic Variable	Spearman's Correation	Significance
Avgδ 18O ‰	Air Temperature (MSJU)	-0.65	0.0002*
Avgδ 18O ‰	Rel Humidity (TSJU)	-0.40	0.04*
Avgδ 18O ‰	Total Precipitation (SJU) Rio Piedras (mm)	-0.48	0.01*
Avgδ 18O ‰	SST (oC) (san juan)	-0.60	0.40
Avgδ 18O ‰	WindDirection (degree) (San Juan)	-0.14	0.48
Avgδ 18O ‰	Windspeed (m/s) (San Juan)	-0.09	0.65
Avgδ 18O ‰	Avg δ D ‰ Precipitation Rio Piedras	0.70	0.004*
Avg δ D ‰	Air Temperature (MSJU)	-0.33	0.09
Avg δ D ‰	Rel Humidity (TSJU)	-0.31	0.11
Avg δ D ‰	Total Precipitation (SJU) Rio Piedras (mm)	-0.37	0.057*
Avg δ D ‰	SST (oC) (san juan)	0.00	1.00
Avg δ D ‰	WindDirection (degree) (San Juan)	0.05	0.80
Avg δ D ‰	Windspeed (m/s) (San Juan)	-0.06	0.76

temperatures and air temperature. In Rio Piedras the isotopic signature is explained by air temperature, relative humidity and amount of precipitation. Similar to data from 2008-2009, our new analysis confirms that ground water recharge in the Guanica Dry Forest only occurs during heavy rainfall periods, such as during tropical storms and hurricanes. The isotopic signature of rainfall throughout the study period was highly variable for Guanica when compared to Rio Piedras. For all years, in both sites we found a significant decrease in $\delta^{18}O$ values during tropical storm events. These negative values are a natural tracer that has allowed us to determine the exact periods when ground water recharge occurred in the Guanica Dry Forest.

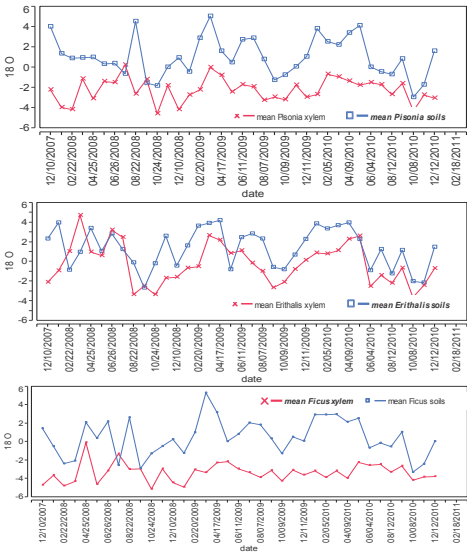


Therefore we are able to determine in which months plants switch water use from soils ground water. We will continue to monitor in isotopic signature of rainfall throughout will continue to relate the regional and local temperature and humidity to these changes.

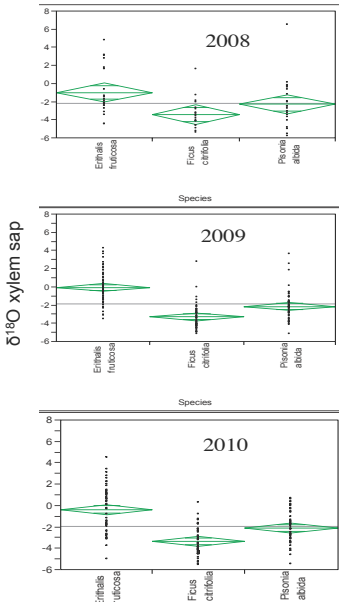




The project entitled: **Water uptake patterns for native tree species in the Guanica Dry Forest** started in December of 2007. The purpose of this study is to determine the temporal dynamics of the relative utilization of different water resources using naturally occurring δD and $\delta^{18}O$ to distinguish among the potential water sources (precipitation, ground water, soil water) for three plant species with different life habits, (*Erithalis fruticosa*, *Ficus citrifolia* and *Pisonia albida*), in the



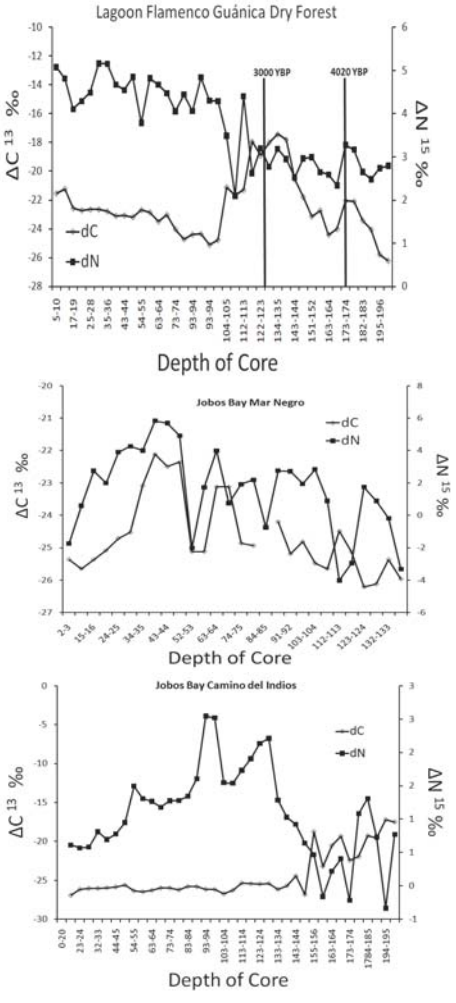
Guanica Dry Forest. We hypothesize that changes in the isotopic signature of xylem sap of plants in the Guanica Dry Forest will reflect the inter/and intra-annual fluctuations in precipitation. We measured the isotopic signature of xylem sap, ground water and soils from December 2007 until March 2011. Since in dry environments plants are found to use belowground stored soil water our objective was to determine the source of water used by plants of different life habits during different times of the year. We found significant differences in the month-to-month isotopic signature of xylem sap for all plants in Guanica Dry Forest. Based on the comparison on



of isotopic signature of soils and xylem sap we conclude that there is strong partitioning of ewater uptake throughout the year. *Erithalis fruticosa* uses only water from the soil surface. *Pisonia albida* is utilizing both surface soil and aquifer water, while *F. citrifolia* seems to utilize mostly water from the aquifer. For each year, the monthly variations reflected the seasonal precipitation/ground water dynamics with the isotopic signature decreasing during the month of high storm activity and thus higher rainfall (Fig. We found significant differences among years between the three species. *E. fruticosa* always used water source that was more evaporated. All three species displayed the water use patterns for the three years even though we had higher rainfall in 2010 (Fig.9). The

ability of plants to maintain their water utilization patterns with varying precipitation regimes is a possible mechanism allowing the coexistence of species in the Guanica Dry Forest.

Our work on the **Paleoclimate of the South Coast of Puerto Rico, including the Guanica Dry Forest**, was presented during the Biology seminar series at the University of Puerto Rico and at UPR-Arecibo. In March 2010 we sampled three areas in the south coast of Puerto Rico to determine paleoclimate. Sediment cores were collected in Jobos Bay Estaury; Mar Negro a mangrove site toward the ocean and Camino de Indios is the landward side of the Bay. In the Guanica Dry Forest we collected cores from Flamenco Lagoon. Training on sample collection and preparation were given to graduate and undergraduate students by visiting Professors Dr. Marcelo Cohen (Universidad de Pará en Brazil) and Dr. Ruben Lara (Center for Tropical Marine Ecology, Germany) at the EPF lab. Samples were prepared for radio carbon dating, pollen analysis and stable isotopic analysis. In October 2010, during an exchange training course at the University of Miami, Dr. Yogani Govender completed the isotopic analysis ($\delta^{13}C$ & $\delta^{15}N$) of sediment cores collected in the Flamenco Lagoon in Guanica, and Mar Negro and Camino del Indio in Jobos Bay Estuary. In November 2010, an undergraduate student, Eneilis Mulero, was sent to the University of Para, Brazil for training in palinological studies. We also sent sediment samples for Lagoon Flamenco for radiocarbon dating to the Center for Tropical Marine Ecology, Germany. We continue to prepare samples for pollen analysis and radio



carbon dating from the cores collected at the Jobos Bay Estuary. We found that there were changes in the $\delta^{13}C$ and $\delta^{15}N$ in all cores, Mar Negro and Camino de Indios in Jobos and Flamenco Lagoon in Guanica. In the Flamenco Lagoon the $\delta^{13}C$ & $\delta^{15}N$ values indicate most drastic changes occurring about 3000 years before present. We do not have the age of sediments for Jobos Bay but $\delta^{13}C$ & $\delta^{15}N$ values indicate changes precipitation through the years. In Camino de Indios the high $\delta^{15}N$ values at depth 133-134 cm possibly indicate a period when the Caribbean sea was closed off from the Bay while the higher $\delta^{15}N$ values at depth 43-44 for Mar Negro indicate changes in land use to heavy fertilization during the sugar cane era in Puerto Rico. The pollen analyses in the Flamenco Lagoon in Guanica indicate that the lagoon was formed around 4000 years before present.

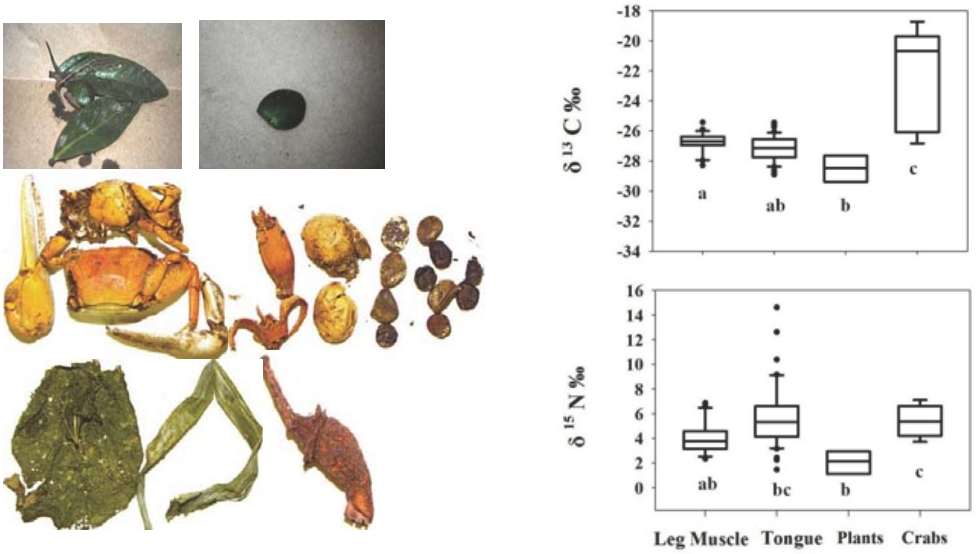
Animal eco-physiological responses to food availability: native and invasive reptile species. Investigators: Elvira Cuevas, Yogani Govender, Sondra vega

An isotopic study of diet and muscles of the Green Iguana (*Iguana iguana*) in Puerto Rico: accepted for publication 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.

The non-native Green Iguana, *Iguana iguana,* originally introduced as a pet, has become naturalized and proliferated throughout the Caribbean islands. To what extent their naturalization has affected their diet and trophic level has been subject to speculation. Published reports of the diet in its native range indicates exclusive herbivory but observations in their non native range occasionally include animal materials. The aim of our study was to determine the diet and trophic level of *I. iguana* in the island of Puerto Rico, using gut content and the natural abundance of ^{13}C and ^{15}N of muscle tissues (tongue and leg). This species in Puerto Rico has successfully dispersed through the island causing disruption and infrastructural damage. Forty-nine *I. iguanas* were collected in Piñones mangrove forest and Vista Bahia Golf Course, Rio Grande in Puerto Rico and gut content was analyzed in the laboratory. Undergraduate and graduate

students participated in this project, in collaboration with The Department of Natural and Environmental Resources, as part of their training in scientific investigation.

The gut contents showing diet consisting primarily of leaves of black mangrove, *Avicennia germinans*, suggests a potential strong impact of defoliation for this species. In some of the iguanas the gut content had fruits of the introduced Brazilian pepper, *Schinus*



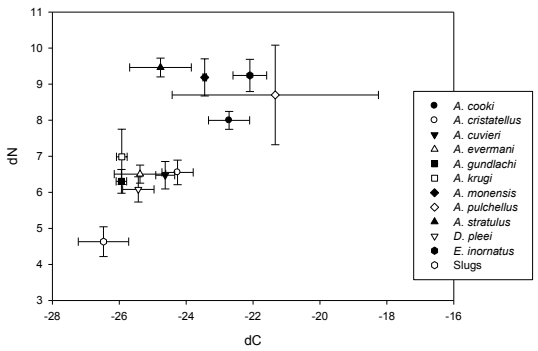
terebinthifolius, a potentially invasive plant in Puerto Rico. Gut analysis provided a first report of *I. iguana* eating snails and crabs, *Uca* sp, which points toward opportunistic omnivory behavior. The significant enrichment of $\delta^{13}C$ in the leg muscle tissue from the leaves signatures confirms a shift towards omnivory. The non-significant differences in the $\delta^{15}N$ values among the muscle tissues and the mangrove leaves could be attributed to possible similarities in their protein and amino acid content, although this hypothesis needs to be verified. Our results point towards the need for further investigation, especially when the population expansion of *I. iguana* further inland raises conservation concerns regarding its ecological role and impact on the native fauna and flora of the islands.

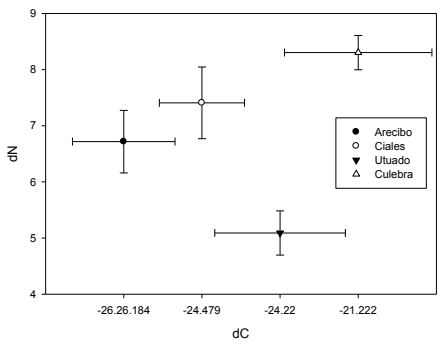
Omnivory in *Anolis* lizards along a precipitation and elevational gradient in moist areas on karst in Puerto Rico - Sondra Vega PhD dissertation - All *Anolis* lizards are omnivorous, however degree of omnivory varies among species and within the same species from different localities indicating opportunistic response to food availability.

A total 104 muscle samples of *Anolis* tails were collected: 86 samples were prepared for stable isotope analysis and 18 samples were lost during the tissue extraction. All samples, including comparative samples of the snake *E. inornatus*, a slug and a grasshopper, were analyzed for the natural abundance of $\delta^{15}N$ and $\delta^{13}C$. The results from the isotopic analyses indicate that there is significant variability of isotopic signature of $\delta^{15}N$ between species (One way ANOVA: df = 6, p = 0.043) and also for the isotopic signature of $\delta^{13}C$ (Kruskal-Wallis One Way Analysis of Variance on Ranks: df = 7, P = 0.006). *Anolis stratulus* and *A. monensis* show the highest $\delta^{15}N$ values and *A. gundlachi* and *A. cuvieri* the lowest. *Anolis stratulus* present the highest $\delta^{15}N$ values, however it is the average of three individuals due to the loss of the other samples during tissue preparation. More samples are needed in order to determine the $\delta^{15}N$ values for this species.

Species	$\delta^{15}N$ (‰)		$\delta^{13}C$ (‰)	
	Mean	S.E.	Mean	S.E.
Anolis cooki	7.996	0.248	-22.717	0.614
Anolis cristatellus	6.554	0.341	-24.257	0.468
Anolis cuvieri	6.475	0.38	-24.626	0.283
Anolis evermani	6.505	0.251	-25.381	0.769
Anolis gundlachi	6.304	0.33	-25.937	0.158
Anolis krugi	6.984	0.768	-25.925	0.159
Anolis monensis	9.188	0.515	-23.445	0.055
Anolis pulchellus	8.701	1.381	-21.336	3.084
Anolis stratulus	9.463	0.261	-24.768	0.922

When the isotopic values of *Anolis* lizards are compared with isotopic values of slugs and the strict carnivore *E. inornatus*, found that the signatures of *Anolis* fall within the omnivory range. On the other hand, $\delta^{15}N$ and $\delta^{13}C$ varied between individuals of *A. cristatellus* captured at different locations. When we compared individuals of *A. gundlachi* captured at different locations the signature for both stable isotopes varied according with the location. At the moment there is no relation between isotopic signature and ecomorph, as more data is needed for further analysis.





The preliminary data suggest that *Anolis* lizards are omnivorous. *Anolis cuvieri* and *A. gundlachi* show the more omnivore's signature, these results for *A. cuvieri* agree with diet studies where the consumption of fruits has been reported for this species (Reagan, 1996, Lister, 1981). In the case of *A. gundlachi*, the presence of fruits has not been reported in dietary studies. The consumption of fruits has not been reported also for *A. cristatellus, A. cooki,* and *A. krugi*. The omnivore signature for *A. krugi* represents the first report of fruit consumption for the grass-bush anole ecomorph.

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. Stable isotopes are an alternative method to reconstruct the diets, analyze the contributions of food items and determine omnivory (Peterson and Fry 1987). Detailed studies will be carried to determine the level of omnivory/frugivory and trophic position of *Anolis* lizards. 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.

Component 2: Ecohydrology of critical habitats in the Guanica Biosphere Reserve Investigators: Ortiz, Cuevas and Canals.

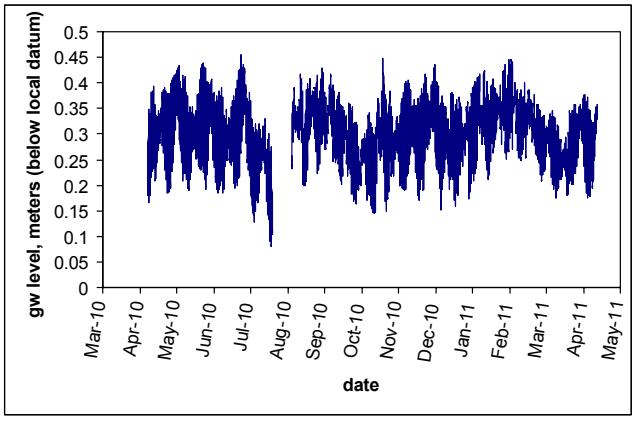
There is concern that climate change may reduce rainfall in the Caribbean and increase sea levels thus altering groundwater supplies and coastal habitats. The potential effects of rainfall reduction and sea level changes will likely be more evident in dry lowland subtropical forests, which are more susceptible to fires and to sea level changes. In order to improve management decisions, a systematic monitoring program of surface and groundwater levels was established in 2005 at an ephemeral coastal pond located in the Guanica Biospheric Reserve in Southwestern Puerto Rico. The American Zoo and Aquarium Association funded the first phase of this project. The second phase is funded by NSF-CATEC and started in 2008. This project focus on understanding the hydrology of an ephemeral ponds that serves as a breeding site for the threaten Puerto Rican Crested

Toad (PRCT, *Peltophryne lemur*). Understanding the hydrology of this pond is important because it is the only natural breeding site for this species. Our studies have revealed that:

1. After heavy rains, the karstic forested mountains of Guanica supply most of the water to the pond for up to three months;
2. That infiltration water losses are negligible and that an impermeable clay layer maintains freshwater conditions in the pond despite the pond's proximity to the ocean;
3. Most of the water leaves the pond as water vapor due to evapotranspiration, and
4. The pond can be sensitive to storm surge events that seem to open underground conduits that connect the surface water with the groundwater system.
5. Related isotopic research led by Drs. Cuevas and Govender revealed that halophytic plants in the vicinity of the pond are able to switch their water source depending on climatic conditions. They can withdraw water from groundwater or from rainfall during dry and wet conditions, respectively.

About 30 months of continuous groundwater level and salinity data are now available as part of a collaborative project with the Interamerican University (IAU) of Puerto Rico through Jorge Viqueira, an IAU master degree student. These data are being analyzed to develop a base line study of sea-level effects on the groundwater system in the Guanica coastal zone.

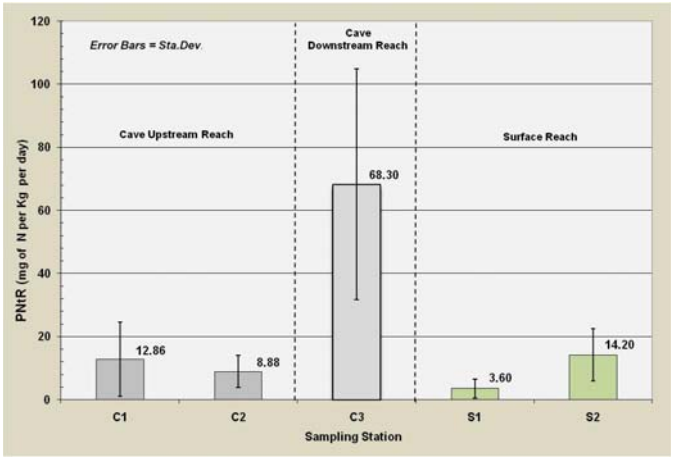
The research project has provided invaluable data in support of conservation of endangered wildlife. The data suggest the ephemeral coastal ponds are critical habitats highly susceptible to climate change, to sea level changes and storm surges. These forces can drastically alter habitat conditions



posing stresses to freshwater endangered fauna. Rita Caceres, a Ph.D. student from the Biology Program, is conducting her dissertation research on habitat selection of juveniles and population dynamics at a new release site in Gabia near Coamo, P.R.

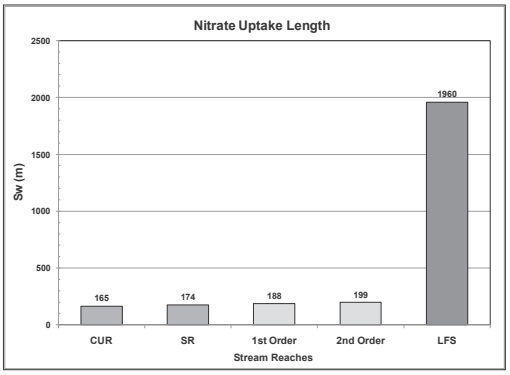
This research project currently supports two graduate students from the University of Puerto Rico at Rio Piedras (UPR-RP) and Interamerican University of Puerto Rico and one undergraduate student from UPR-RP. It has led to an undergraduate thesis, a paper in an UNESCO-sponsored publication, and a manuscript submitted for publication to the Caribbean Journal of Science in 2008. This paper was finally reviewed in 2011 and not accepted. We are currently evaluating where to resubmit the paper.

Project 2. Nitrogen dynamics in tropical aquatic environments. Two studies are underway by our research group to investigate how nitrogen cycles in aquatic tropical systems. The first study is led by Carlos Conde (Ph.D. Candidate) and intends to understand the effects of bat guano on the nitrogen dynamics in a karstic cave river in Southwestern Puerto Rico. So far, this 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 that tends to accumulate in concentrations of up to 5 mg/L. These nitrification rates are among the highest ever reported in the reviewed literature.

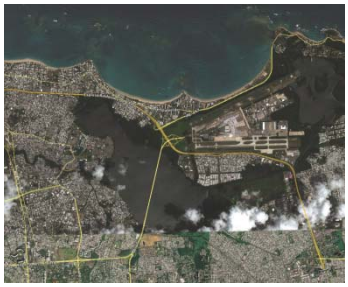


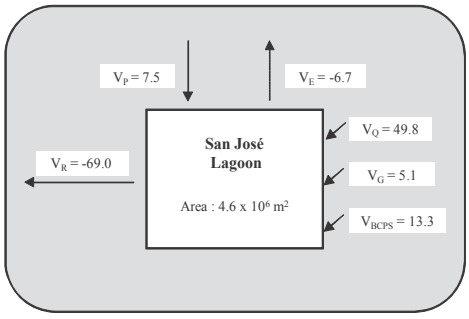
Nitrate uptake seems to be an important process in the cave which removes nitrate from the water. Nitrate uptake was directly measured using tracer injections. The figure shows that uptake lengths are not significantly different across the cave stream. When

compared to other tropical headwaters streams in the Luquillo Experimental Forest, however, nitrate uptake in the cave stream was much smaller confirming that the biogeochemical mechanisms nitrification/denitrification/assimilation are highly coupled and effectively cycle nitrogen in this unique ecosystem. Bat guano from a large bat colony consisting of six species of several hundred thousand bats is the main source of allochtonous nitrogen to the cave stream. At such, bats are considered important vectors of terrestrial nitrogen into the cave stream. Because the creek disappears downstream from cave before reaching the ocean, these cave systems maybe acting as regional funnels of terrestrial nitrogen into coastal aquifers.



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 Metropoitan 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. But 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





Surface runoff from tributaries and a pump station are the main water input to the lagoon

the San Jose Lagoon of the San Juan Bay Estuary of Puerto Rico. Based on published data, Hamlet has computed a preliminary annual water budget for the San Jose Lagoon. The budget shows that surface runoff from tributaries constitutes the main water input. However, a considerable amount of runoff water enters artificially through a pump station. In terms of outflow, most of water leaves through the Canal Suarez and via surface evaporation. Hamlet will use this data to compute nitrogen and phosphorus loadings in and out of the lagoon. This research will also evaluate the role of denitrification in the overall nitrogen budget of this altered ecosystem. An undergraduate student majoring in Biology, Angel Santiago, has been collaborating in this project receiving training in limnological research.

Project 3. Anthropogenic influences on the carbon cycle in tropical inland waters. The role of urbanization on the flux of dissolved organic carbon (DOC) 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 quality of DOC are critically needed to better manage inland aquatic ecosystems.

Two graduate students are currently studying carbon cycling in rivers and estuaries in Puerto Rico: Debora Figueroa and Rafael Benitez. 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.

The second graduate student, Mr. Rafael Benitez studies how tropical stratified estuaries cycle carbon from wastewater treatment plants. Preliminary data collected by Mr. Benitez has revealed that wastewater discharges labile dissolved organic carbon (DOC) to estuaries, which in turn becomes partially processed in the estuary before it is exported

to the ocean. River DOC seems more recalcitrant than wastewater DOC. Mr. Benitez is currently writing his thesis and plans to defend it before May 2011. He is currently receiving a research assistantship through CATEC.

Alexandra Marcano is an undergraduate student interested in the characterization of DOC quality and biodegradability in rivers under different land uses. Alexandra studies the effect of land use on DOC quality and had sampled three watersheds in Puerto Rico three times over the last two years. She measures DOC quality through measurements of the Specific UV Absorbance Index (SUVA) and BOD5. She has conducted detailed land use analysis based on aerial images. The data will allow Alexandra to evaluate the relationship between DOC quality and quantity and land cover. She is currently writing a paper for later submission into a peer-review journal.

Some anthropogenic organic inputs are considered endocrine disrupting chemicals. Particularly, hormone compounds, like estrogen, have been detected in urban waters that receive effluents from wastewater sources or urban runoff. However, these chemical have not been studied in waters in Puerto Rico. Mrs. Sheila Soler attempts 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 will travel 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. After this visit, she will start collecting water samples to assess the estrogenic activity in effluents of wastewater treatment plants.

Component 3: 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.

Research activities 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 (2) continuing and expanding the long-term coral recruitment monitoring effort, (3) continuing targeted monitoring of the ecological fate of physiological fragments of lobbed star coral (*Montastraea annularis*) and laminar star coral (*M. faveolata*), (4) developing preliminary population and community modeling products regarding the ecological fate of coral reefs under climate change impacts; (5) setting up and initiating the early stages of a field experiment to test hypotheses associated to coral physiological fragment survival; (6) Initiating small coral core collection of selected *Montastraea* spp. physiological fragments to address impacts of climate change-related physiological fragmentation on coral growth rate, skeletal density, and calcification rates, (7) significantly expanding the spatial resolution of coral core on reefs located across anthropogenic stress gradients; (8) Setting up the sclerochronological analysis (large coral cores) phase of the project, and (9) Advancing the implementation of the recently approved NSF supplement. Other activities completed or currently in progress have included providing theoretical and hands-on training of new students in field methods, image and data analysis, including Ph.D. student, Ms. Raisa Hernandez and several new undergraduate students, and optimizing field methods for the long-term monitoring of the fate of *M. annularis* and *M. faveolata* physiological fragments.

Our subproject has fostered applied research that has already contributed to the advancement of fundamental knowledge regarding climate change impacts on Caribbean coral reefs. It has also allowed the opportunity to carry out several subprojects focused in applied coral reef management, fisheries biology, conservation biology, and marine ecology. This information would be paramount to support decision-making processes regarding the conservation and management of marine resources in face of climate

change. Research findings of the Coral Reef Research Group (CRRG) during year 2010 and part of 2011 were fundamental in addressing long-term impacts of ecological change in coral reefs, and part of these were already published in significant peer reviewed journals. For instance, preliminary studies from long-term monitoring of coral reefs at the pristine oceanic Mona Island suggest that most colonies of large reef-building species, such as star corals, *Montastraea annularis* species complex, suffered significant tissue mortality immediately following the unprecedented sea surface warming episode of 2005. Observed coral loss has dangerously compromised their reproductive output of the most significant reef builders at least during the following decades. There was a significant incidence of mortality in corals such as *M. faveolata* (97%), *M. annularis* (70%), *Colpophyllia natans* (79%), *Agaricia agaricites* (65%), and *Diploria clivosa* (45%). Subsequent long-term monitoring shows extremely limited recovery as a result of coral recruitment. This is the first known mass coral mortality event reported in Mona Island and may represent an unequivocal sign of climate change impacts and an increased vulnerability of reef-building corals to disturbance. Under the forecasted trend of sea surface warming and ocean acidification, particularly under overfished conditions, this may compromise net reef accretion rates. If these types of events become recurrent in the near future, coral reef ecosystem resistance to disturbance, resilience, functionality, ecological services, and economic value might be significantly impaired and coral reefs might be about to suffer an entire ecosystem collapse with potential negative consequences to regional fisheries due to losing a mosaic of habitats.

Similar findings were found at Culebra Island as part of a 13 year long coral reef monitoring effort partly supported by CATEC. Coral species richness declined by a mean factor of 54% during the period of 1997 to 2010. Percent living coral cover plummeted by 81%, or an annual mean of 6.8% loss. Coral cover loss following the 2005 unprecedented sea surface warming and mass bleaching event was 66%. Macroalgal % cover has increased by 10-fold. This suggest unequivocal impacts by recurrent sediment- and nutrient-loaded runoff pulses, in combination with recurrent impacts from meso-scale gyres that can increase background chlorophyll a concentrations by a 5-10 fold factor. Mortality trends in the *M. annularis* species complex have averaged 80% during the same

period and 50% since 2005. These trends are similarly widespread through different locations in PR, suggesting that coral reefs are in the peril of an ecosystem collapse. The catastrophic warming event occurred during 2005 through the northeastern Caribbean Sea that caused a mass coral bleaching event in Puerto Rico was followed by an unprecedented mass mortality of star coral species complex (*Montastraea annularis* and *M. faveolata*), among other species. It resulted in a severe net physiological fragmentation of large coral colonies. Permanent photo-stations were established in 4-6 m deep reef terraces dominated by *Montastraea* spp. at four sites in Culebra Island, Puerto Rico. Digital photography was used to document changes in benthic community structure before (2005) and after (2007, 2008. 2009, 2010) this event. All colonies bleached during 2005. Physiological fragment analysis has shown so far that mass coral mortality caused a 72 to 99% decline in % living tissue cover in both species. No significant difference in % living tissue cover loss was documented among sites. Abundant physiological tissue fragments were formed in each colony. Recent analyses have shown a significant increase in coral fragment mortality. Coral mass spawning also collapsed in both species between 2006 and 2009.

Stochastic population model work to predict what would be the fate of *M. annularis* under different massive coral bleaching and coral mortality frequencies was recently published in Ecosphere by Hernandez-Pacheco et al. Major findings of that study suggested that massive bleaching and mortalities can significantly impact coral population growth rates down to the point of potentially causing the species extinction if massive bleaching and mortality frequencies maintain at one per decade (10%) or increase to at least two per decade (20%). We are currently developing similar products to test the fate of surviving physiological fragments for this species. Further modeling efforts using the Coral Mortality and Bleaching Output (COMBO) model to include climate change indicators and long-term ecological change data to determine what would be the future of Caribbean-wide coral reefs in the face of climate change impacts. Efforts under way by the CRRG also include several experiments to test possible hypothesis to explain the lack of coral tissue regrowth. In addition, sclerochronological studies in *M. annularis* and *M. favolata* will provide important information regarding large-scale

temporal trends in several physiological parameters associated to coral growth and regarding changing environmental conditions as a result of long-term trends of land use patterns and climate change. On this regards, we established a direct collaboration with Dr. Anne Cohen (Woods Hole Oceanographic Institution) where Ph.D. student Raisa Hernandez-Pacheco is at present in a two-month research internship to process and analyze coral cores using CT scan technology. Our current efforts include completing data analysis from several permanent monitoring locations in PR, and completing the expansion of the project in Guanica to compare data among different locations under different conditions.

Another major highlight of the CRRG also includes targeted research focused at determining the ecological fate of surviving physiological fragments of *M. annularis* in Culebra Island following the 2005-2006 post-bleaching mortality. Mass coral mortality caused a 70 to 99% decline in % living tissue cover in *M. annularis*. There was a significant decline in % living tissue cover through time, among sites, particularly at a control site outside a no-take MPA. Abundant physiological tissue fragments were formed in each large parental colony with mean sizes often below 10 cm2, which showed higher mortality trends. Fragment density declined from 15 to 33% between 2007 and 2010. There are not known precedents through the Caribbean of catastrophic events of this magnitude. The synergistic consequences of climate change and variable local anthropogenic impacts in major reef engineer taxa still remain largely unknown. However, a single warming event was unequivocally capable of causing an acute coral mortality event that resulted in a major ecological collapse for the most significant and formerly resilient Atlantic coral reef building species complex. Current efforts also include targeted sclerochronological studies aimed at comparing the physiological response of coral growth parameters following the 1987, 1998, and 2005 large-scale bleaching events. Also, there is an effort to model long-term population dynamics in M. annularis following mass mortality and physiological fragmentation events.

CATEC's CRRG efforts have also focused in 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*). 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. 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).

In the other hand, long-term evidence suggests recent significant mortality of threatened Elkhorn coral (*Acropora palmata*) stands in at a candidate Natural Reserve site at Vega Baja Beach, PR during 2009. Percent living *A. palmata* across six reefs in Vega Baja declined by 29% within 1997 and 2008, for an annual mean of 2.65% loss. But mortality rocketed to 52% between December 2008 and June 2009 across the zone. Overall, a total of 62% loss of Elkhorn coral occurred between 1997 and 2009. Mortality was lower at reefs with stronger oceanographic conditions (34-37%), in comparison to reefs located inside the shallow platform, closer to the shoreline (52-69%), or closer to sewage-polluted areas, which were also subjected to anthropogenically-driven sediment bed load (81-97%). There is no recent previous record (quantitative or anecdotal) of such massive coral mortalities through the area. Current efforts by the CRRG include fostering the designation of the area as a Natural Reserve, develop a management plan, foster modification of local development plans and foster coral reef restoration across the area.

We have also successfully contributed to cultivate a broadly inclusive science workforce by training two full time Ph.D. students (Raisa Hernandez-Pacheo, Alex Mercado-Molina), four full time undergraduate students within CATEC, as well as over a dozen of

volunteer undergraduate students, stakeholder and base communities members through our different projects in Culebra Island, Vega Baja, Mona Island, and now in Guanica. These efforts also resulted in sending Miss Raisa Hernandez-Pacheco into a summer research internship program at the Central Caribbean Marine Lab, Little Cayman Island, Grand Cayman, which has resulted in a manuscript preparation and in a collaborative effort with colleagues from other institutions lead by Dr. Carrie Manfrino (Rutgers University). Undergraduate student training will be further enhanced in 2011. We have currently 4 undergraduate students in our CATEC's project. Our efforts have also resulted in expanding the scientific literacy of all citizens by means of a combination of actions that have included the publication of peer reviewed papers regarding the impact of non-point source sewage pollution in coral reef habitats, and the preparation of several manuscripts regarding the impact of climate change on coral reefs which will be send to peer revision within mid to early 2012. We have also been engaged into a wide number of educational and outreach activities on behalf of CATEC, including seminars to the general public, presentation at base communities, newspaper articles, press interviews (TV, radio, newspapers), and other types of activities aimed at the general public and non-scientific audiences.

In the coming year, we will:

1) Continue data collection of long-term permanent monitoring sites.

2) Continue data collection of long-term monitoring of coral recruitment.

3) Continue data collection of long-term monitoring of the ecological fate of Montastraea spp. physiological fragments.

4) Continue collection and data analysis of small Montastraea spp. coral cores.

4) Complete the second phase of the project regarding the sclerochronological studies of corals as recorders of climate change impacts.

5) Publish part of the preliminary findings of the coral reef monitoring component, the physiological fragment targeted monitoring component, the long-term impacts of the 2005 massive coral bleaching and mass mortality event, and the population modeling products.