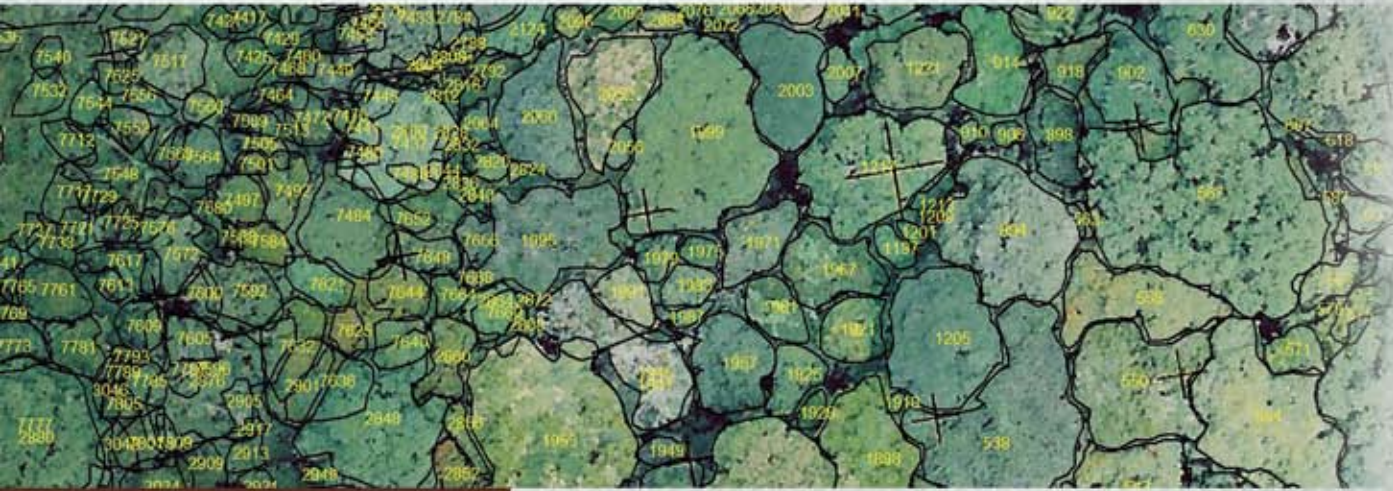




Smithsonian Tropical Research Institute

2008-2013



Strategic Plan

the next five years...

Eldredge Bermingham,
Acting Director,
Smithsonian Tropical Research Institute

Ira Rubinoff,
Acting Undersecretary for Science,
Smithsonian Institution

For further information, contact:

Washington, D.C. Office
Smithsonian Tropical Research Institute
P.O. Box 37012
Quad, suite 3123, 705
Washington, D.C. 20013-7012
(202) 633-4012

In Panama or from outside the United States

Smithsonian Tropical Research Institute
Apartado 0843-03092
Balboa, Ancón
República de Panamá
Country code 507, 212-8000

From within the United States

Smithsonian Tropical Research Institute
Unit 0948
APO AA 34002-0948
USA

Private philanthropy is critical to STRI's work,
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and conservation.

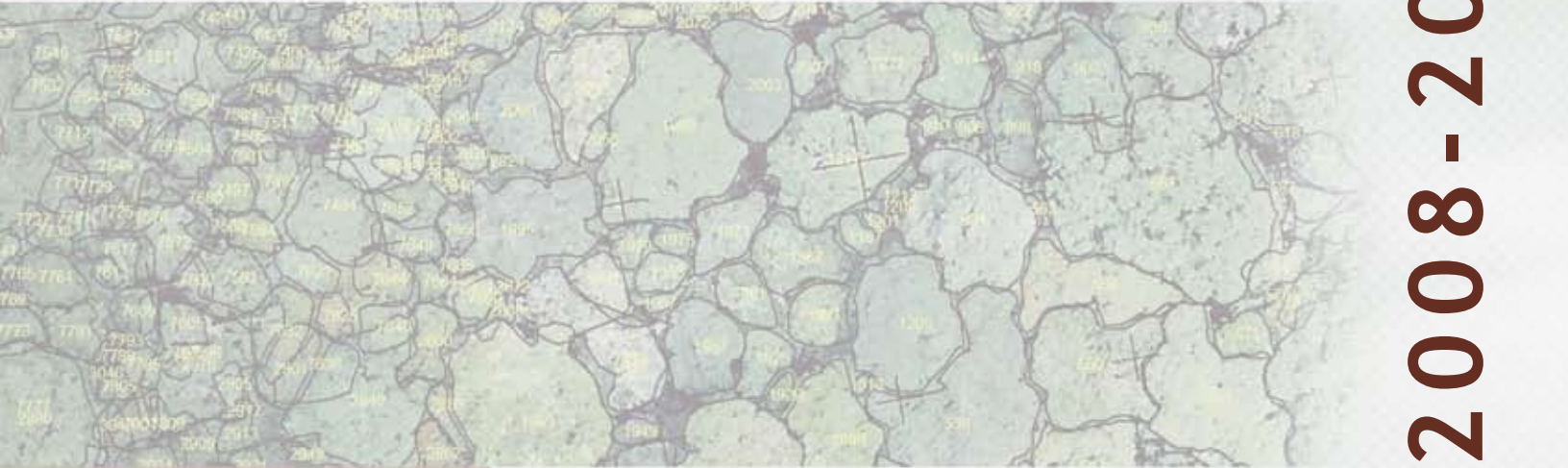
To learn more about making a donation, please
contact Lisa Barnett in the STRI Washington office.
(202) 633-4014
barnettl@si.edu

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Smithsonian Tropical Research Institute

2008-2013



Strategic Plan

the next five years...



Smithsonian Tropical Research Institute

MISSION...

To increase understanding of the past, present and future of tropical life and its relevance to human welfare.

VISION...

To provide the best global platform for tropical research

to train the next generation of students of tropical life

to promote conservation of tropical diversity

to cultivate communication among tropical scientists and with audiences interested in our work



A diverse, interactive group of **PEOPLE...**

35 resident scientists

350 support staff


1000 visiting scientists, fellows
and students each year

Amazing **WORKPLACES...**

9 sites in Panama
representing tropical
forests, reefs, mangroves
and island ecosystems

a field station in Kenya

20 linked forest
observatories
in 15 countries



Message from the Directors

We welcome this opportunity to give you a glimpse of the next five years, 2008-2013, at STRI. This plan celebrates scientist-driven research. Our strategic goals—many of which contribute directly to halting biodiversity loss and mitigating threats to the environment—spring from the ideas of our scientists, passionately pursuing their intellectual curiosity to the benefit of us all.

In 2010, STRI will celebrate the 100th anniversary of the Panama Biological Survey, when U.S. President Taft sent Smithsonian researchers to Panama to conduct an environmental survey associated with the U.S. construction of the Panama Canal. The survey revealed the astounding biological diversity of Panama, and hinted at large-scale geological and biological processes of global importance and interest. Panama's president Porras requested that the survey be extended to the rest of the country, beginning a long-standing partnership between STRI and Panama—a fantastic synergy in service of science and human welfare.

In the next five years Panama will embark on a \$5 billion expansion of the Panama Canal. This will create once-in-a-lifetime research opportunities and will further strengthen our relationship with our host country. New canal excavations will reveal geology and fossils, filling gaps in our understanding of the rise of the Isthmus 3 million years ago and its roles as a biological bridge between continents and barrier between oceans. As trade through the Canal expands, STRI and colleagues at the Smithsonian Environmental Research Center will document the distribution of invasive marine organisms, providing a contemporary vision of invasion biology rivalling our historical analyses of the Great Biological Interchange that occurred when Panama first linked North and South America 3 million years ago.

With an \$8 million donation from HSBC bank, STRI's Center for Tropical Forest Science will set up the largest-ever experiment to understand how tropical land use affects water flow, carbon storage and biodiversity, thus providing the quantitative data required to calculate the environmental services provided by forests in the Panama Canal watershed. Tolls paid by ships transiting the Panama Canal provide one of the most important global examples of payment for such services, in this case the fresh water upon which canal operations depend.



Panama's Secretariat for Science and Technology (SENACYT) supports research at STRI through student fellowships and research grants. These research opportunities will foster our longstanding association with ANAM, the environmental authority of Panama, and promote opportunities with ARAP, the new marine resources authority, as we investigate and test predictions regarding the role that terrestrial and marine protected areas play in ecologically-guided pharmaceutical discovery and in the stewardship of the astounding biological diversity of the Isthmus.

In the next five years we will build a new research center in Gamboa to provide modern laboratories for studies of tropical soils and hydrology, forest ecology, microbial diversity, molecular ecology and evolution. We will promote new education opportunities at our Culebra Point Nature Center at the Pacific entrance to the Panama Canal. This will complement the 2009 opening of the the Bridge of Life: Panama Biodiversity Museum, designed by architect Frank Gehry. These facilities will host peripatetic citizens from the United States, students and an international array of visitors who make their way to Panama, where they will join us to celebrate research at the crossroads of the Americas.

The creation of the Isthmus of Panama three million years ago transformed our planet and set in motion dramatic, biological processes that amaze and inspire scientists today. Thanks to the partnership and the enlightened openness of our host country, STRI scientists and visitors from the world over have the freedom to pursue independent, curiosity-initiated research that advances our knowledge and understanding of life on Earth. Our principal goal over the next five years is to promote the ideals of independent scientific inquiry and excellence that have established STRI as the premier research institution in the tropical world.


Ira Rubinoff


Eldredge Bermingham

Smithsonian Tropical Research Institute



The STRI Scientific Staff during 2007 Fellowship meeting.

Back Row: H. Lessios, D. Piperno, W. Eberhard, N. Knowlton, M.J. West-Eberhard, J. Hall, R. Cooke, W. Laurance, S. Davies, S.J. Wright, A. Aiello, J. Christy, I. Rubinoff, J. Jackson, E. Kalko, E. Bermingham, R. Stallard, S. Heckadon-Moreno, B. Turner, K. Winter. Front Row: D.R. Robertson, F. Santos-Granero, E.A. Herre, C. Jaramillo, D. Windsor, M. Torchin, R. Condit, D. Roubik. Missing: R. Collin, N. Salazar, M. Correa, L. D'Croze, S. Hubbell, E. Leigh, O. Linares, W. Wcislo, H. Guzmán, H. Muller-Landau.

STRI Strategic Plan 2008-2013



INTRODUCTION

A gift

James Smithson, British scientist, stipulated in 1826 that his inheritance would be given "...to the United States of America, to found at Washington, an establishment for the increase and diffusion of knowledge among men."

Part of a larger plan

Most people recognize the "diffusion" role of the Smithsonian museums but are less aware of the "increase" or research role of the institution.

In 2005 the institution-wide science plan, "Science Matters," identified four major themes that unite science at the Smithsonian:

- The origin and nature of the universe
- The formation of the Earth and similar planets
- Discovering and understanding biological diversity
- Study of human diversity and cultural change

Each bureau was directed to establish a strategic plan of its own. Over the long history of the Smithsonian Tropical Research Institute our scientists have focused on the third and fourth themes of "Science Matters." Our efforts over the next five years will focus on the specific strategic goals identified in this plan -- leaving room for the pursuit of serendipitous research opportunities.

Putting change in context

At the root of all STRI research are these questions: How do new life forms arise? How do species, communities and ecosystems respond to change? Which forces unify or stabilize life? Which forces are disruptive and drive change? What is our role as humans in natural systems?

Olga Linares, STRI anthropologist and member of the National Academy of Sciences, showed in the 1970's that Panama's prehistoric peoples actively modified their environment, selecting their favorite fruit trees and useful plants from the surrounding forest. Food plants attracted small game, which people hunted close to home.

In the 1980's, Staff Scientist Dolores Piperno developed methods to understand cultural changes associated with the advent of agriculture which would radically alter human relationships with the tropical environment.

When Columbus came to the New World, his boats shuddered through thousands of sea turtles. STRI Staff Scientist Emeritus Jeremy Jackson has been stumping on the lecture circuit to explain the concept of shifting baselines--each generation aims to conserve what they knew as children, and to view that state as pristine, whereas, thousands of years of human harvesting of natural resources has radically eroded that state.

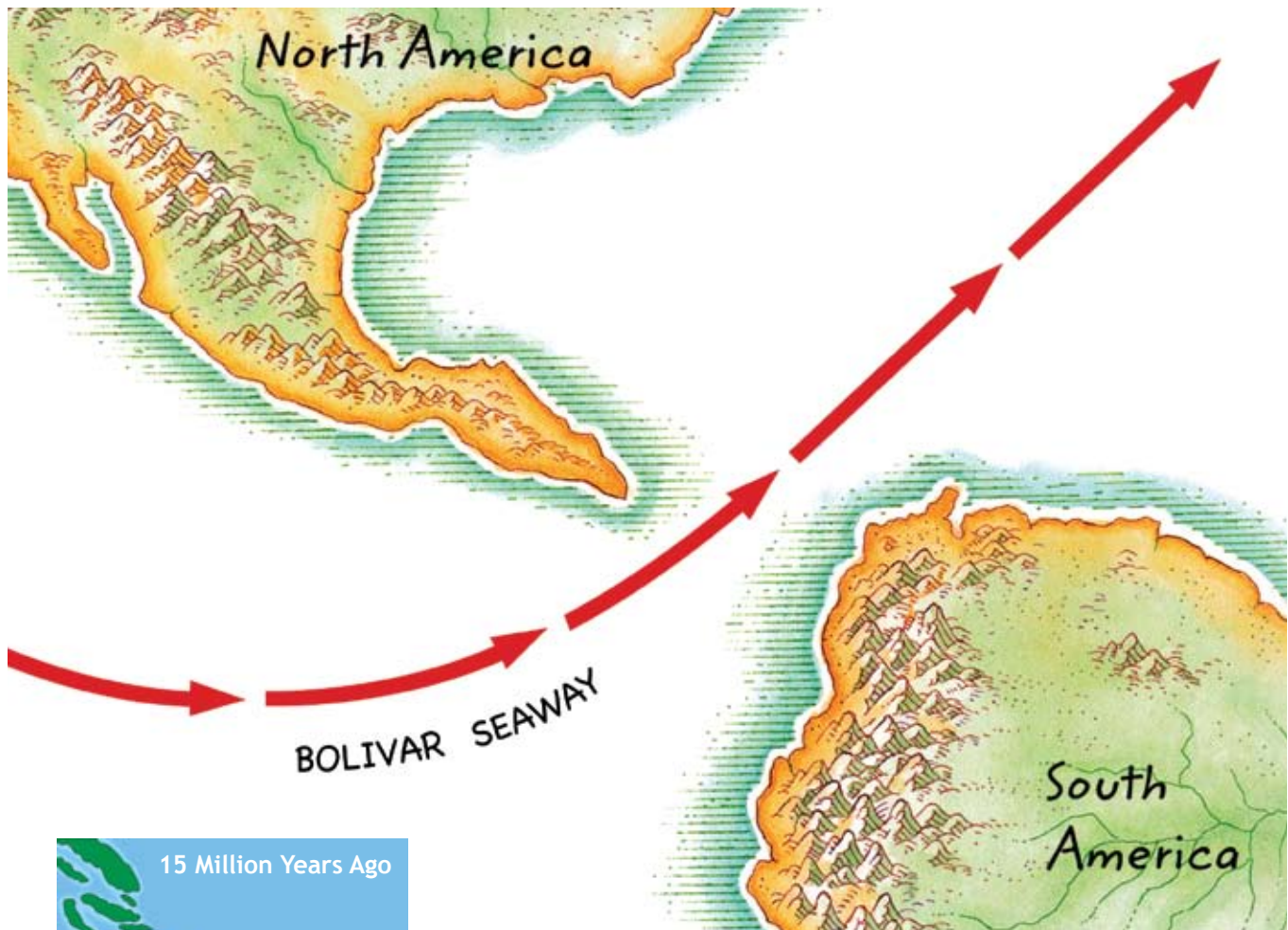
As students of the tropics, STRI scientists are privileged to work in some of the most beautiful, and the most vulnerable, places on the planet. We feel the urgent need to advocate their conservation, a prerequisite for the continued pursuit of our scientific goals.

PANAMA: Two grand experiments

running for 3 million years

Oceans divide

The rise of the Isthmus separated one great ocean into two, creating a natural laboratory for experimental studies of speciation and extinction in the sea.



Fifteen million years ago a deep ocean channel existed where eastern Panama is today. The Isthmus closed as the Earth's crust shifted. By three million years ago, a continuous land bridge connected North and South America.

The emerging Isthmus deflected equatorial Atlantic currents to the North. The Caribbean Sea remained warm. Currents flowing toward the equator on the other side of the Isthmus cooled the Eastern Pacific. Isolated populations of marine organisms were forced to adapt to new conditions. Some became new species.

The builders of the Panama Canal took advantage of a low point in the mountains to reconnect the Caribbean and the Pacific with a freshwater passageway. At least one Caribbean fish, the tarpon, has crossed the Canal. Other species have made the trip in ballast water, providing an opportunity for students to study threats to marine diversity from invasive species.

Continents collide

Panama is a crossroads, a place to learn how living organisms move across the landscape and adapt to changing contexts.

When the bridging of the Isthmus was complete, the cat, dog, bear, pig, horse and elephant families migrated into South America where they made themselves at home. Armadillos, sloths, anteaters, marsupials and porcupines traveled north, mostly with ephemeral success.

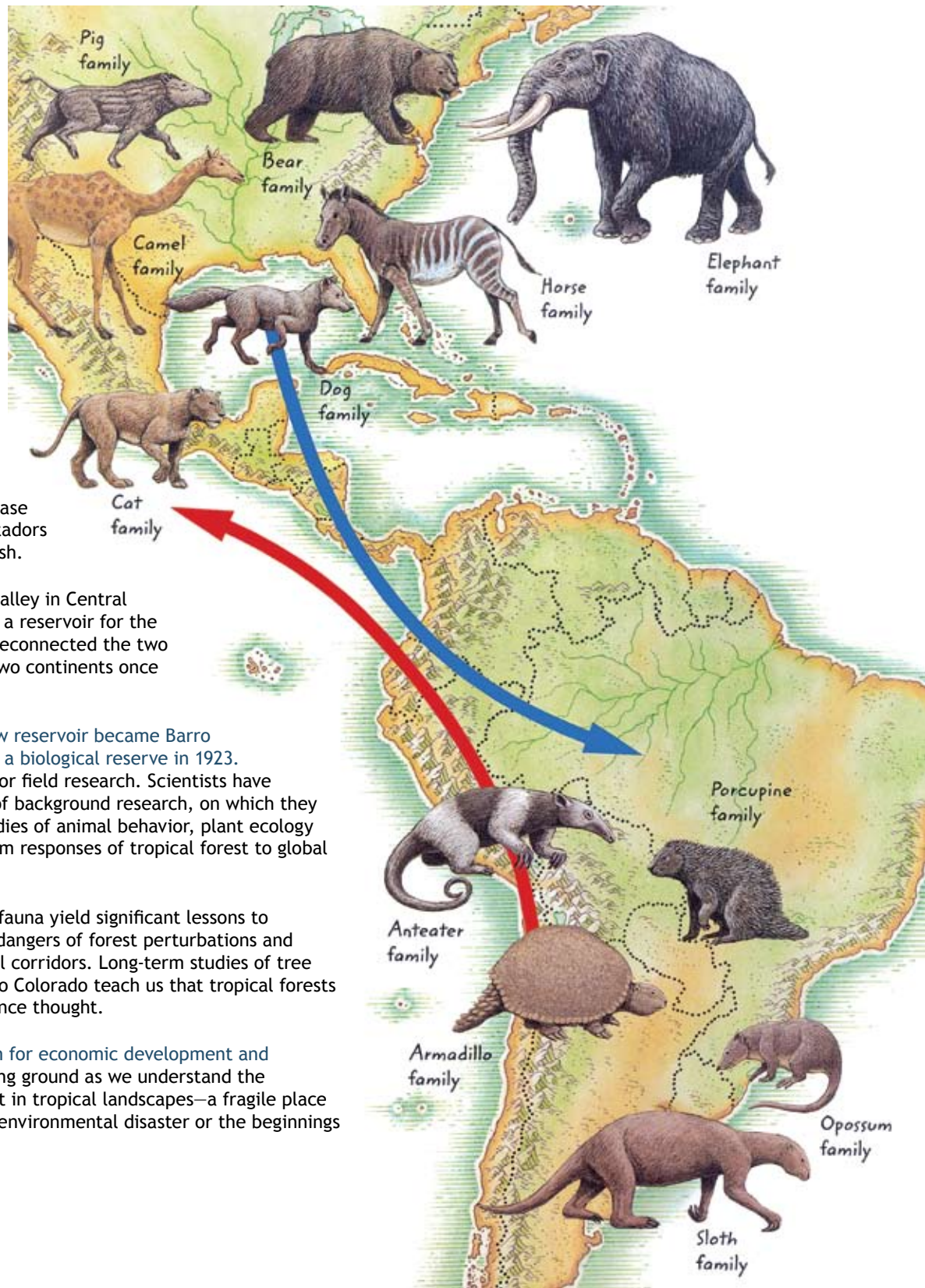
Humans first crossed the Isthmus by 15,000 years ago. STRI archaeologists continue to discover how ancient settlers altered plant and animal distributions. By 500 years ago most of the Pacific slope of the Isthmus was deforested. Death and disease brought by Spanish conquistadors enabled forests to reestablish.

In 1914, the Chagres River valley in Central Panama was converted into a reservoir for the Panama Canal. The Canal reconnected the two oceans and separated the two continents once again.

A hilltop isolated by the new reservoir became Barro Colorado Island, designated a biological reserve in 1923. Barro Colorado is a mecca for field research. Scientists have access to nearly 100 years of background research, on which they can base contemporary studies of animal behavior, plant ecology and physiology and long-term responses of tropical forest to global change.

Changes in island flora and fauna yield significant lessons to conservationists about the dangers of forest perturbations and the importance of biological corridors. Long-term studies of tree population declines on Barro Colorado teach us that tropical forests are much less stable than once thought.

Panama is a true microcosm for economic development and globalization, an ideal testing ground as we understand the implications of development in tropical landscapes—a fragile place where the future may hold environmental disaster or the beginnings of a sustainable economy.



PANAMA shaped STRI

Institutional and Intellectual History

In 1910 U.S. President William Taft asked the Smithsonian Institution to coordinate the Panama Biological Survey of the area that would become the Panama Canal watershed.

Panama's President Belisario Porras asked the U.S. to extend the survey to include the rest of the country.

U.S. doctors and scientists petitioned the Canal Zone governor to set aside the largest island in the Panama Canal waterway as a reserve and research station.

In 1923 Barro Colorado Island (BCI) became a biological reserve.

At the onset of World War II, in 1940, the U.S. Congress assumed control of Barro Colorado Island, renamed the Canal Zone Biological Area (CZBI).

In 1946, Congress appointed the Smithsonian Institution as custodian of BCI.

Alexander Wetmore, the 6th Secretary of the Smithsonian, retired in 1951 to complete his 4-volume "Birds of Panama."

1957 Martin Moynihan was appointed as Barro Colorado Island Naturalist.

The first permanent staff scientists were hired, and additional research facilities were established.

Institutional history

1910



1923



1940



1957



Intellectual history

The explorers who joined the Panama Biological Survey were astounded by the unimaginable diversity of this narrow strip of land between two oceans.

Their efforts focused on collecting museum specimens to classify and catalog. Why were there so many species in Panama?

James Zetek, who studied mosquitoes, became Barro Colorado station director, married María Luisa Gutiérrez and became a friend of Panama's President Porras and a professor at the prestigious Instituto Nacional.

Zetek's annual BCI reports detailed climate data, station visitors, new publications and additions to the island's species list.

From the 1930's on, Ray Carpenter pioneered the study of the social behavior of howler monkeys and Ted Schnerler studied the organization of army ant raids.

During the war years, James Zetek kept the station afloat by testing building materials for termite resistance and by determining how materials stood up to harsh tropical environments.

Moynihan was an evolutionary thinker. He built a community of "first rate" scientists to study this "green hell."

Panama became a unique setting in which to test ideas about evolution. On Barro Colorado, Moynihan studied social behavior-- asking why animals should choose to live in groups.

1966 Smithsonian Tropical Research Institute was founded.

The CZBI became STRI, an independent bureau of the Smithsonian dedicated to the study of biological and cultural diversity in tropical regions of the world.

1974 Ira Rubinoff named Director, beginning 3 decades of leadership in which he established STRI as the preeminent research institute in the tropics.

1977 The Torrijos-Carter Panama Canal Treaties added a buffer zone to Barro Colorado Nature Monument.

In 1985, Panama designated STRI as an International Mission.

December 31, 1999. Panama assumes sovereignty over the Canal.

Rubinoff negotiated and signed agreements with the InterOceanic Canal Authority (1996) and with the Ministry of Foreign Affairs (1997) authorizing continued research activities and use of facilities for the next 20 years, renewable.

1966



1977



1999



In the 1970's, as a result of increased public awareness, more federal funding for environmental monitoring became available, so that climate records going back to 1910 could be extended. STRI's monitoring program expanded to include the responses of marine and terrestrial organisms to a growing number of environmental variables.
<http://striweb.si.edu/esp>

STRI geologists and paleobiologists worked together to date the rise of the Isthmus.

The "molecular clock," a new idea to use random genetic changes to determine how long ago two species diverged, could be tested directly in Panama, given the known date for the rise of the Isthmus.

Work on interactions between organisms facilitated by a growing knowledge base takes center stage.

How do energy and information flow through tropical systems?

What role do they play in the generation and maintenance of biological diversity?

How does global change alter these processes?



Diversity of fruits and seeds from Barro Colorado Island.

Discovering & Understanding Biological Diversity



Encyclopedia of Life



Forces of Change



Biology of Extinction

Plants and animals solve basic problems in order to live. They locate resources, budget time and energy, communicate, mate and provision their offspring. In the next five years we will test ideas about the origins and maintenance of solutions to these problems.

Discovering new organisms—compiling the **Encyclopedia of Life**—is the first step in revealing evolutionary adaptations. Researchers at STRI will elucidate the **Forces of Change** that have shaped living organisms and biological systems over time scales that range from a wink of an eye to a geological era.

The problems faced by the human race are largely biological. As we discover new explanations for biodiversity and understand the **Biology of Extinction** we will be better prepared to face the challenges presented by a changing world.

Encyclopedia of Life

Discover and describe species diversity

In the next five years, STRI researchers will document diversity in threatened ecosystems, describe species in groups that are still little known to science, and understand how species composition changes from place to place. We will contribute to the Encyclopedia of Life <http://eol.org>, an ambitious project bringing together information about all the world's species in a single, universal Web portal.

Discover new species

Only 2 million of the 10-100 million or more species estimated to exist on Earth are known to science. It's not uncommon to find new insects, fishes, plants, fungi, corals and other striking, beautiful organisms, especially when experts look in places they haven't been before. Microbes and inconspicuous organisms promise to be even more diverse. We will seek them out.

Discover new stories

The difference between an elephant and a sea turtle may be obvious, but how do the dynamics of a tropical forest in India, grazed by elephants, differ from those of a sea grass bed in the Caribbean grazed by sea turtles? Species comparisons will reveal processes that engineer our environment.

Identify critical areas for conservation

One of the best ways to conserve healthy ecosystems is to set up large, interconnected reserves. As concerned citizens, business people and lawmakers determine which areas provide ecosystem services and critical habitats, high quality information about the local environment must be available, but often is not, especially in remote tropical areas. STRI will provide critical information to support conservation initiatives.

This mountain gorilla depends on diverse resources, like honey from stingless bee species recently identified by Staff Scientist David Roubik with collaborators in Uganda.
Photo: Rhett Butler, mongabay.com





Coiba National Park will continue to be a source of new species such as the corals shown above.

Justify new reserves

Staff Scientist Héctor Guzmán and colleagues described over 15 new species of soft corals in three years. His documentation of coral diversity and marine life was critical to Panama's successful nomination of Coiba National Park as a UNESCO World Heritage Site.

In the next five years Guzmán will continue to document Panama's marine biological diversity and will contribute scientific information to legislative proposals aimed at the management of marine reserves in the Las Perlas Archipelago and marine conservation in Panama's Bocas del Toro Province and Kuna Yala, an autonomous indigenous area.

Identify hidden diversity

As rich as the tropics were thought to be, they are even richer. Molecular biology identifies new species that look very similar but are genetically distinct. Ricardo Betancur, a research intern from Colombia, identified the marine catfish on the right using molecular biology tools and then described and named the new species. Betancur is now a PhD student at the University of Alabama.



New ribbon worm species from Bocas del Toro, Panama.

Build the Smithsonian Marine Science Network

Bocas del Toro Research Station Director Rachel Collin has used funds provided by the Smithsonian Women's Committee and the Hunterdon/Johnson Marine Research Endowment to invite specialists in the taxonomy of marine organisms to participate in the Bocas del Toro Biological Diversity Survey. The ongoing survey and online data base for STRI's newest research station will be largely completed in the next 5 years, and will make the Bocas del Toro region of Panama one of the best known marine environments in the Caribbean, thus establishing a superb research platform for the study of coral reef, mangrove and sea grass ecosystems.

Visit http://striweb.si.edu/bocas_database/



Notarius biffii.

Characterize tropical soils

Soil is the living skin of the earth. Amazingly, almost nothing is known about the dirt under our feet! Is life around the roots of giant tropical trees as varied as it is in their leafy crowns? STRI hired soil chemist Ben Turner and created a joint appointment for the US Geological Survey's Robert Stallard. If new funds become available, STRI will hire a soil microbiologist to complete this multidisciplinary team.

Turner and Stallard have equipped STRI for comprehensive biogeochemical analysis of soils, including instrumentation for carbon and nitrogen analysis, elemental analysis by inductively coupled plasma atomic emission spectrometry, enzyme assays by fluorimetry, and nutrient analysis by flow injection and column chromatography. We have a new radioisotope facility to trace nutrient dynamics between soil and plants. Now the race to characterize tropical soils and soil processes begins!

Challenge the idea that tropical soils are nutrient-poor

Tropical soils may be poor in "available" inorganic phosphorus but they contain a huge diversity of organic phosphorus compounds (...DNA, RNA and phospholipids from degrading animals). Staff Scientist Ben Turner discovered that microbes and plants access organic phosphorus and are therefore not as nutrient limited as once thought. Turner will collaborate with plant ecologists to find out how fungi that live with plants affect nutrient absorption and how rainfall affects nutrient availability.

Mike Kaspari, University of Oklahoma, will examine the role of insects in nutrient cycles.



This homopteran bug, identified by Staff Scientist Annette Aiello, was killed by a fungus called *Metarhizium anisopliae*. Both will add to the soil nutrient pool.

Produce first soil map for Barro Colorado ("red clay") Island

Collaborators from the University of Potsdam, Germany, the U.K.'s National Soil Resources Institute and STRI will produce the first detailed soil maps of Barro Colorado Island. Mapping soil diversity will clarify the role tropical soils play in plant and insect distributions.

Rosina Grimm and Frauke Berthold, students at the University of Potsdam, Germany, determining soil characteristics as they map island soils.



Looking **LOW** to understand tropical soils



Looking HIGH for diversity that's hard to reach

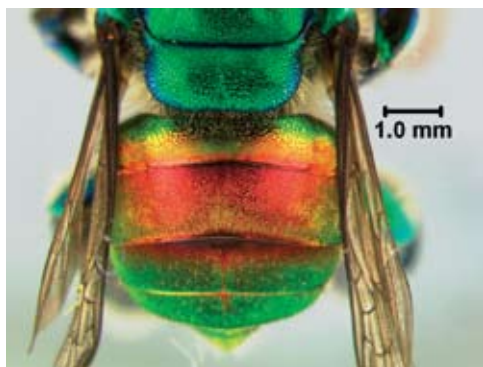
Access tree canopies to study insect diversity

Thirty years ago, Terry Erwin, of the Smithsonian's National Museum of Natural History, calculated that there should be approximately 30 million insect species, based on the number of insects he found in one tropical tree in Panama. More recent estimates are based, in part, on extensive data gathered from STRI's canopy cranes.

STRI's Canopy Science Program Coordinator, Yves Basset, encourages researchers to rise into the canopy to improve our accounting and understanding of the earth's biodiversity.

Produce a guide to bees of the Amazon

Each orchid bee species is exquisitely adapted to pollinate orchids. Staff Scientist David Roubik will assemble a guide to the orchid bees of the Amazon, a region that continues to yield new bee species as collectors have opportunities and resources to work there.



Anatomical detail of new Euglossine bee species.

Find out how 74 bat species co-exist

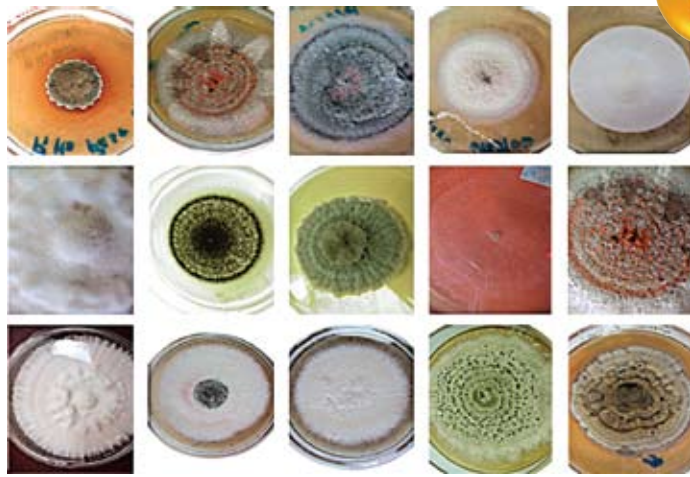
Elisabeth Kalko, STRI Staff Scientist and Professor at the University of Ulm, Germany, uses her Bat Detector to bring bat sounds into the audible range. Bats hunting insects above the rainforest canopy use a completely different set of ultrasound pulses to locate their prey than do bats flying through cluttered understory shrubs. She and her students have used the Bat Detector to identify the presence of about 20 additional bat species on STRI's 15 km² Barro Colorado Island, raising the total number of species recorded on the island to 74. Now Kalko's group is uniquely poised to understand the ecological forces that structure bat communities in the tropics.

Elisabeth Kalko records inaudible ultrasounds.



STRI's two canopy cranes reaching over 30 meters (120 feet) into tree crowns, provide 360° access to Panama's wet Caribbean and drier Pacific tropical forests.





Different fungi isolated from a single leaf of a cacao tree.

Reveal the role of fungi in plant health

Tropical leaves are chock-full of a surprising diversity of fungi called endophytes.

Research funded, in part, by M&M Mars shows that fungi may play a role in defending cacao plants by taking up space that disease organisms would otherwise occupy. In Petri plates, fungi from cacao leaves may even produce antibiotics that curb the growth of the diseases that threaten our chocolate supply.

Staff Scientist Allen Herre's group, visiting scientist Elizabeth Arnold from the University of Arizona, and colleagues aim for improved characterization of this hyperdiverse group.



Looking INSIDE *to discover diverse interactions*

Discover new experts in self defense

Noris Salazar, Staff Scientist and Professor of Botany at the University of Panama, explores the "Forgotten Flora": bryophytes (mosses, liverworts) and lichens so small that they rarely attract attention.

Many bryophytes, particularly liverworts, growing in tropical forests produce an arsenal of chemicals to protect themselves against other inhabitants of these environments. Bryophytes also have endosymbiotic relationships with other organisms. In the next five years, Salazar will characterize chemical diversity of neotropical bryophytes and their partners.



A closeup of leafy liverwort, *Cyathodium*.



Brain corals from the Pacific and Atlantic look similar, but are unrelated.

Explore a very delicate balance

Look inside corals: they are created by animals called polyps, which secrete external skeletons. Senior Staff Scientist Nancy Knowlton and colleagues study the genetic make-up of coral polyps, and find that coral "species" classified on the basis of their looks, are really not the same species.

Also, polyps may harbor different photosynthetic algal species, depending on the availability of sunlight, adding another level of complexity and diversity. Understanding coral diversity is key to reef conservation.

STRATEGIC GOAL

Encyclopedia of Life

Contribute to the Smithsonian barcoding initiative

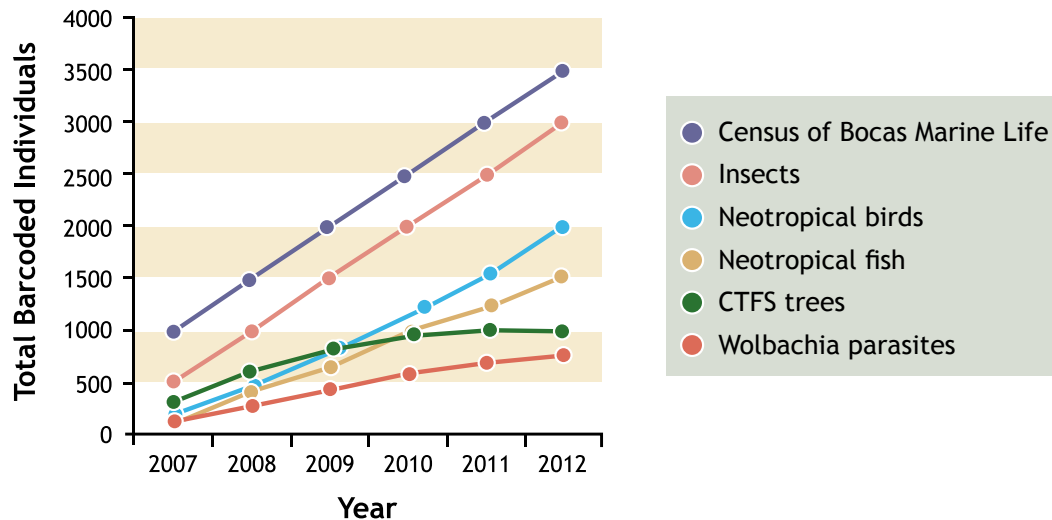
Online databases of DNA sequences will make species identifications easier...



Even specialists are often overwhelmed by tropical diversity.

In the past, it has been a huge chore to identify and keep track of new species. Computerized databases of DNA sequences promise to make species identifications much easier. STRI will make major contributions in the next five years to the new Consortium for the Barcode of Life (CBOL), housed in the Smithsonian's National Museum of Natural History, by providing samples from our collections of tropical organisms, by hosting teams looking for new tropical species and by using our molecular laboratories to develop DNA barcodes.

Barcoding will allow us to tell whether the species of mosquito buzzing around our ears transmits malaria or dengue. Simple tests will reassure buyers at the fish market that they're not eating mislabeled, threatened species.



Census Marine Life

Rachel Collin, Director of STRI's Bocas del Toro Research Station on Panama's Caribbean Coast, will aid the effort to barcode all marine species in the Bocas region by barcoding the more than 3000 organisms already listed on Bocas' online database.

Identify insects and their parasites

STRI Staff Scientist Don Windsor studies and barcodes insects and the *Wolbachia* parasites that infect them. He will continue collections, focusing in Panama and Australia, and contribute barcodes to elucidate the often complex relationships of hosts and parasites.

Barcode tropical bird and fish collections

Eldredge Bermingham, STRI's Acting Director, chairs the Central American Regional Working Group of FISHBOL, that will assemble a global library of fish DNA sequences. Bermingham also co-chairs the Neotropical Working Group of the All Birds Barcoding Initiative.

Barcode SIGEO trees

More than 3 million trees in the Center for Tropical Forest Science's Forest Dynamics Plots have already been mapped, measured and identified. Barcoding will contribute additional information about the genetic diversity of species across the tropics.

STRATEGIC GOAL

Encyclopedia of Life

Understand brain miniaturization

Create a behavior and evolutionary neurobiology lab

How do changes in neuron size, number, design or packaging conserve the way insects behave as species evolve miniature forms?

In 1959, physicist Richard Feynman delivered the lecture "There is Plenty of Room at the Bottom" in which he outlined the development of nanotechnology.

He emphasized information storage and retrieval, asking: how much information can be stored on the head of a pin?

How do small brains of insects support navigation, foraging and mate choice?

The new lab is equipped to reveal structures and physiology underlying vision, olfaction and cognition--essential processes for living organisms.

Panama is the perfect place to discover evolutionary relationships because of the local diversity of insect families with a range of brain sizes and the presence of experts in insect behavior, taxonomy, ecology and evolution. We are wedding a long tradition in insect biology to modern neuroscience.

Staff Scientist Bill Wcislo (pictured) will work with post-doctoral fellows Jeremy Niven, Marc Seid and John Douglass to relate insect evolution, brain size, neuroanatomy and behavior. Schematic of neuron, background.



Nano-technology engineers will be interested in the outcomes of this project.

Pinhead-sized brains of insects support complex behaviors that the best nano-machines can't duplicate.



A katydid launches itself at a perch. Such movement involves visual perception and action coordinated by a very small brain.



Discover how brain size and function change with body size

Even the smallest insects, exemplified by the tiny moth, accomplish the same basic tasks as do large insects like *Thysania agrippa*, one of the largest tropical moths (photo by Staff Scientist Annette Aiello). By accessing the remarkable diversity in the tropics, we will study brain size and function in small insects and compare them to those of much larger insects in related groups.



How do brains change in response to new environments?

Specialized cells in the brain of this nocturnal sweat bee, *Megalopta genalis*, from Panama, allow the bee to see in much dimmer light environments than expected. What cellular changes in the brain are associated with this bee's adaptation to an environment rarely experienced by other bees?

Image: Rita Wallen, University of Lund, Sweden.

Forces of Change

Develop a deep time, wide world perspective

Breakthroughs in molecular biology, developmental biology and plate tectonics force us to ask if the most powerful tool we have to understand life on earth -- evolutionary theory-- is in need of an upgrade.

A recent article in the New York Times by Smithsonian scientist Douglas Erwin, calls for a new version of evolutionary theory emphasizing the role of history: "...just as the erosive power of a river changes the future options for the course of a river, so evolution itself changes future evolutionary possibilities."

STRI's broad perspective in space and time will lead to exciting contributions. Fossils, family trees and long-term ecological and behavioral studies show how organisms and environments interact and change over time. Comparisons of organisms and environments across landscapes tell us whether similar situations result in the same adaptations.

Over the next five years, STRI will dramatically expand temporal and spatial scales of tropical studies and develop models with increasing predictive power. We will do this to learn how life on earth responds to environmental change. The information we gather will inform critical decisions about our future.



10 cm

A new crocodilian skull (above) and legume (bean family) leaf (right) from the Paleocene (60 million years ago) Cerrejon Formation in northern Colombia.



10 cm

Geological time

Based on the composition and layering of sediments, rocks, fossils and pollen and on shifts in the Earth's magnetic field, the geological time scale extends back to 4 billion years ago when the earth was new. STRI researchers study the period from 130 million years ago, when flowering plants first evolved, to the present.

This timeline extends to 4 billion years ago.



Fossils

reveal the deep history of change



Carlos Jaramillo, who holds STRI's Endowed Chair in Paleontology, studies fossil evidence of changes in tropical plant communities.

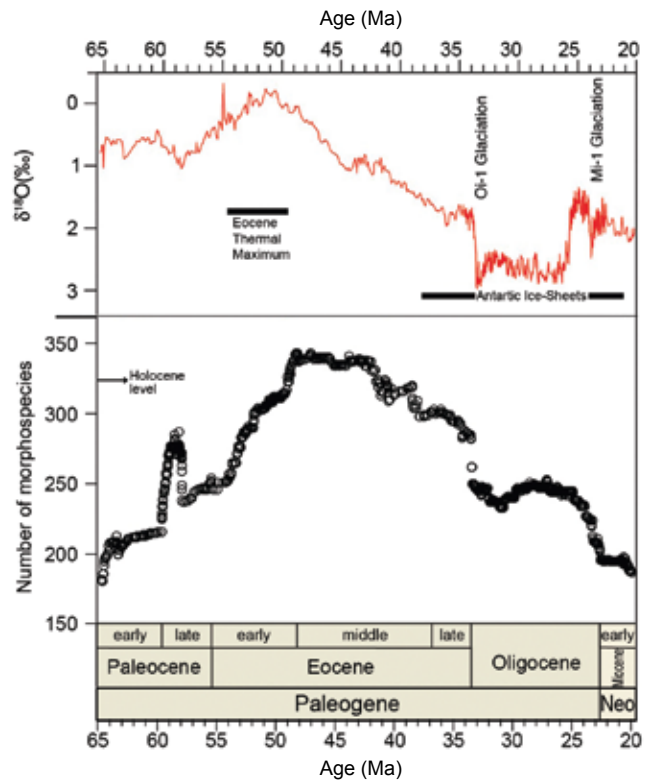
Understand how global warming drives tropical diversity

Staff Scientist Carlos Jaramillo studies fossil plants and pollen to track tropical diversity since flowering plants first evolved.

Although tropical temperatures have not changed much during the past 60 million years, Carlos discovered that forest diversity increased with global warming and decreased during periods of global cooling.

His model for tropical forest change suggests that tropical diversity waxes and wanes as the area of tropical forest cover increases and contracts with climate change. Carlos and his students will test his model with data from new sites.

Tropical plant diversity, indicated by the number of pollen types found in rock cores (black circles), rose and fell with average global temperature, indicated by oxygen isotope data (red line). After Jaramillo *et al.*, *Science* 2005.



Fossilized pollen grain of *Pachira aquatica*.

20 μm

199.9

145.5

65.5

23

present

Triassic

Jurassic

Cretaceous

Paleogene

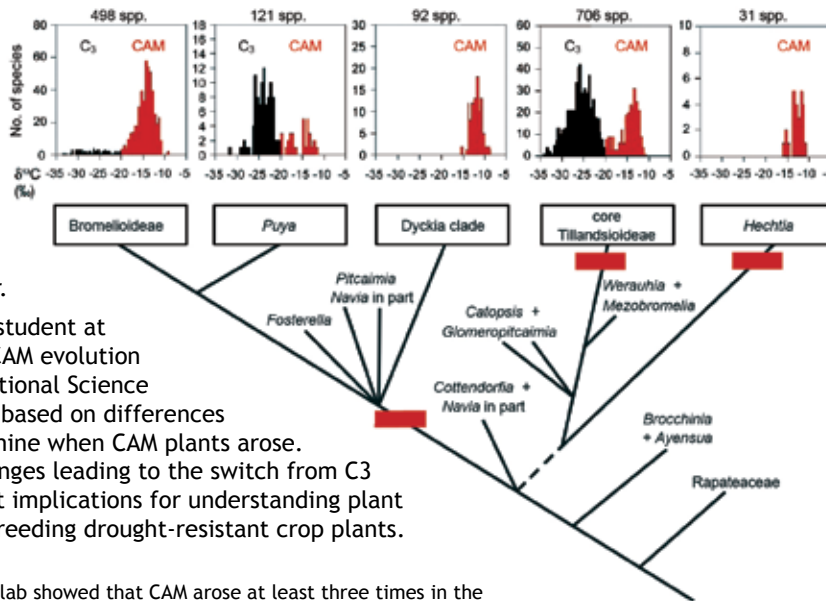
Neogene

Family trees reveal the process and tempo of change

Discover how Orchid families “learned” to conserve water

Plants lose about 6 times less water by using CAM photosynthesis than by using common, C3 photosynthesis. A large proportion of orchid species use CAM. This makes sense because orchids may grow on tree branches where they lack direct access to water.

Katia Silvera, a Panamanian graduate student at the University of Nevada, is studying CAM evolution in orchids with funds from the U.S. National Science Foundation. By building a family tree based on differences in gene sequences, researchers determine when CAM plants arose. They hope to discover the genetic changes leading to the switch from C3 to CAM. This work will have important implications for understanding plant responses to climate change and for breeding drought-resistant crop plants.

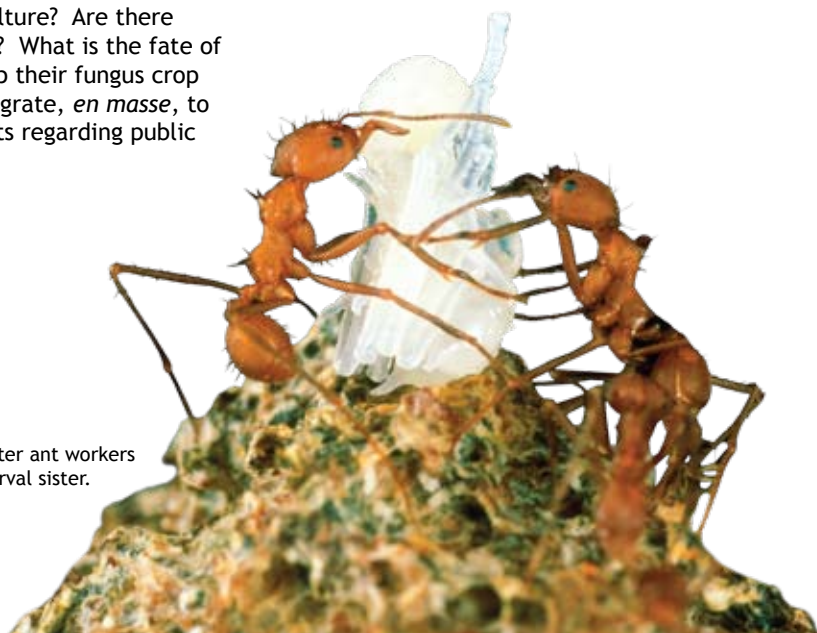


Previous work in Staff Scientist Klaus Winter’s lab showed that CAM arose at least three times in the pineapple family (red boxes). After Crayn *et al.* PNAS. 2004.

Learn from 50 million years of farming

Humans have been farming for 10,000 years-- leaf-cutter ants for 50 million years. Researchers will tease apart this complex system of ants, the fungus crop, fungicide-producing bacteria that suppress fungal invaders in the garden and even a mysterious black yeast.

What caused changes in ant behavior that led to ant agriculture? Are there conflicts between the queen and her all-female work force? What is the fate of freeloaders that parasitize colonies? How do ants keep their fungus crop disease-free? What drives ants to abandon their nests to migrate, *en masse*, to new sites? Leaf-cutter ant research may lead to new insights regarding public health or human agricultural systems.



Two leaf-cutter ant workers tend their larval sister.

Molecular time

By counting the changes in a gene sequence from each of two species, one determines how long ago they diverged, assuming that gene mutations occur at a constant rate.



Pursue organisms that break the law

When lizards, through evolution, lose their legs to become snakes, or when cave fish lose the ability to see, these groups are unlikely to develop the same features again. Scientists were so sure that evolution is irreversible, they codified the observation as "Dollo's Law," after Belgian paleontologist, Louis Dollo.

Staff Scientist Rachel Collin has identified several lawbreakers: snail families in which shell coiling has been lost and regained, limpet families that have lost and then regained motile larvae. She asks: under what circumstances it is possible to break Dollo's Law?

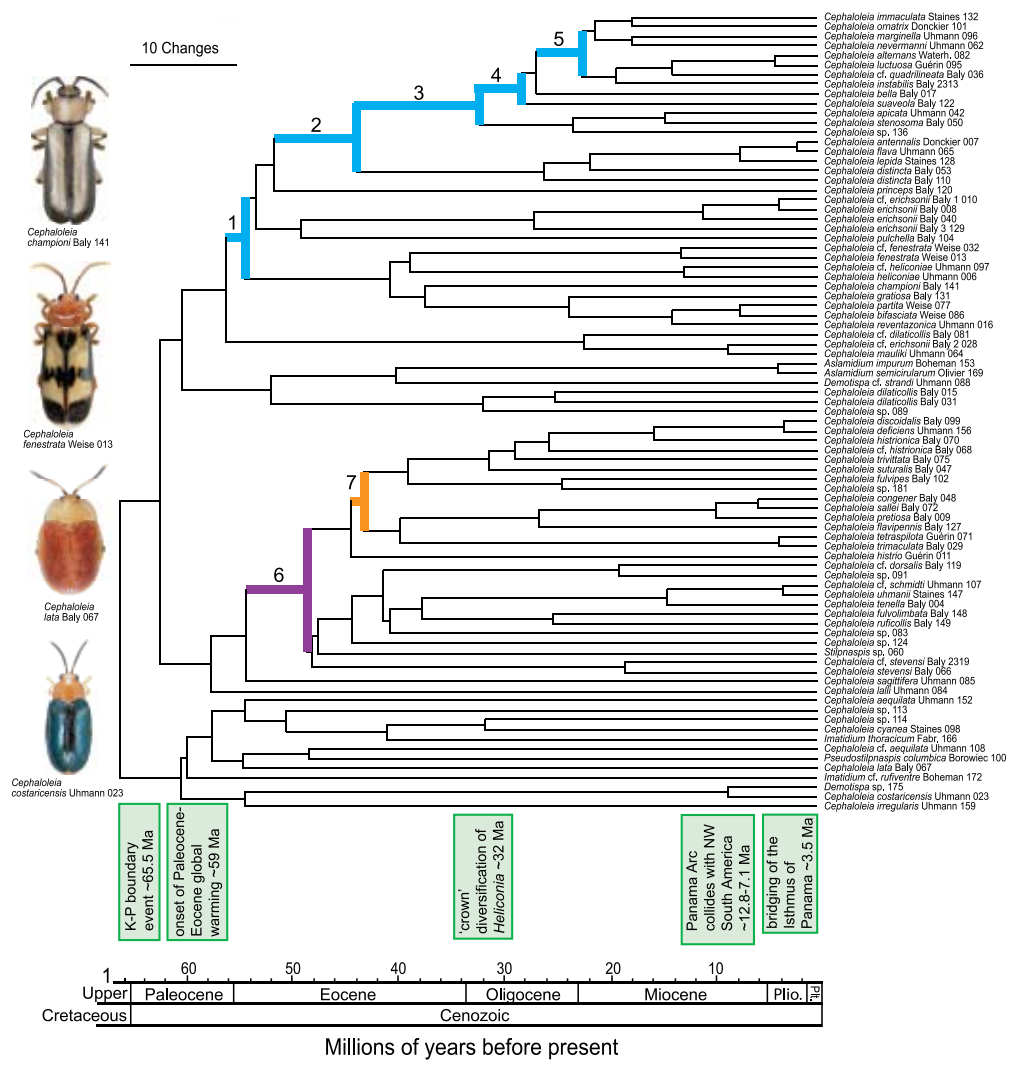
Staff Scientist, Rachel Collin studies the evolution of life stages in marine organisms.

Explain beetle diversity

Astounding increases in beetle and flowering plant species occurred 65 million years ago.

Staff Scientist Don Windsor and colleagues collect beetles from Latin America, Australia and elsewhere, keeping track of what they eat and what eats them. Using molecular tools to understand the history of relationships within beetle families and within plant and pathogen families, Windsor will pinpoint changes in the rules of engagement over time to discover the biotic and abiotic forces that ignited this biodiversity explosion.

Leaf beetles diversified during global warming, and again, when Panama connected North and South America. After McKenna and Farrell, *PNAS*, 2006.



65.5

23

present

Paleogene

Neogene

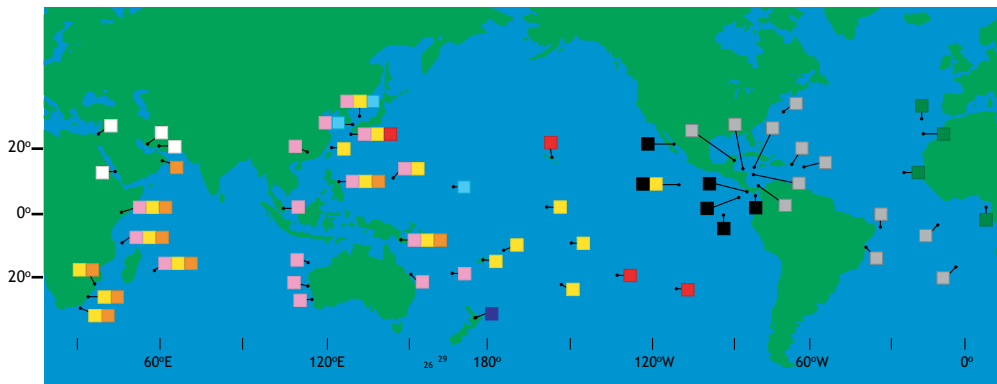
PANAMA

the rise of the Isthmus as a cause of family break-ups

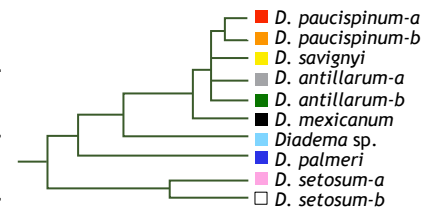
The most far-reaching geological event in recent times was the rise of the Isthmus of Panama, between 15 and 3 million years ago. Tectonic plates ground together and volcanoes spewed lava to form a narrow barrier separating one great ocean into the modern Atlantic and Pacific Oceans. Landscape modification is a powerful force of change. Panama's geography and geological history make it a unique and natural testing ground for some of the most hotly debated ideas about evolution.

Understand how isolated urchins speciated

Speciation can be difficult to demonstrate in the sea, where barriers are not evident. The Isthmus of Panama is a clear barrier that arose at a known point in time. Staff Scientist Harilaos Lessios will study sea urchin (*Diadema*) speciation in order to understand the consequences of separation that led to speciation.



Global distribution of sea urchin (*Diadema*) genetic groups. After Lessios et al. 2001a



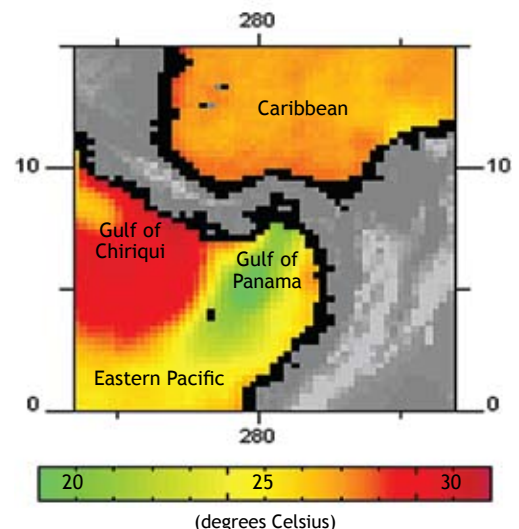
Take advantage of Panama's "three oceans"

Panama's three different marine environments will continue to provide a rich setting for comparative ecological and evolutionary studies. STRI marine labs on both coasts provide excellent research platforms for comparative studies. On the Caribbean side of the Isthmus, low tidal flux and low-nutrient waters gave rise to coral reefs.

In the Gulf of Panama, large tidal fluxes and seasonal upwelling of cold, nutrient-rich water create a high-productivity, high-energy marine environment.

Where mountains block easterly winds across the Isthmus, there is less upwelling. The Gulf of Chiriqui is much warmer and much less seasonal.

Water temperature around the Isthmus of Panama.
March 9, 2006 - 8 AM
http://www.ssmi.com/sst/sst_data_daily.html



Calibrating the clock

Panama Paleontology Project researchers have closely estimated the time when the Isthmus of Panama rose to separate the Pacific from the Caribbean. An exact date of separation between "sister species" that were isolated from each other by the Isthmus makes it possible for geneticists to calibrate the molecular clock.

65.5

23

15 million years

Paleogene

Beginning of the rise of the Isthmus of Panama

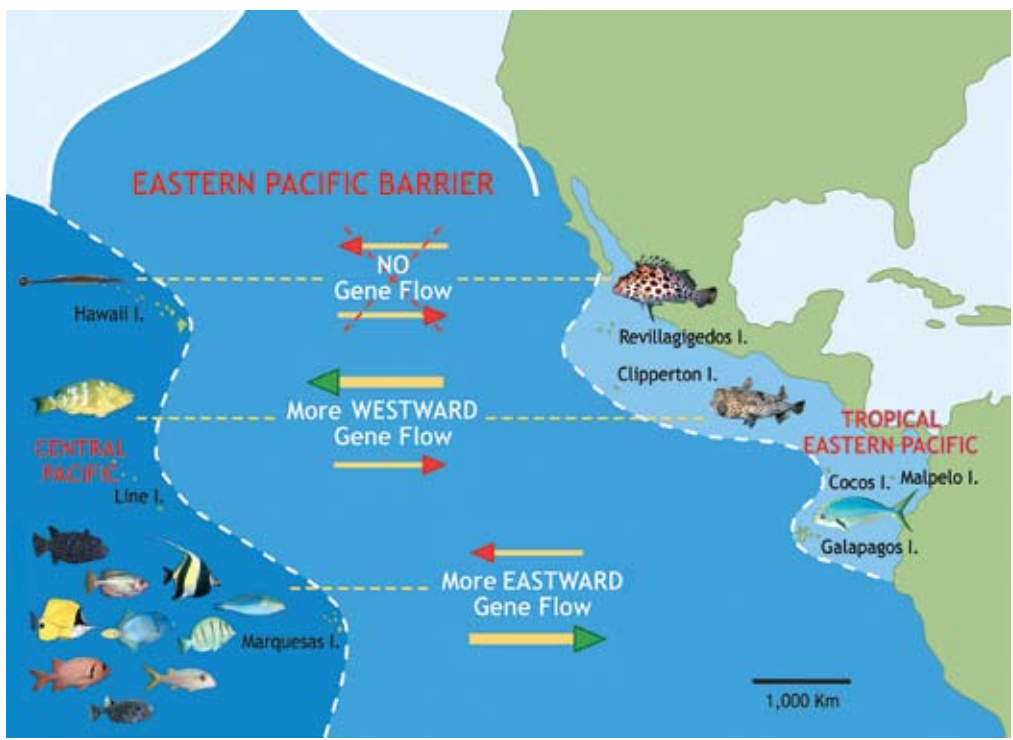


Study cryptic species and build cooperative networks

Cryptic species look the same but are genetically distinct. What causes their reproductive isolation and what can they add to the speciation story? Over the next five years Staff Scientist Nancy Knowlton will aim to answer these questions through her studies of snapping shrimp, abundant on both sides of the Isthmus of Panama.

Knowlton was recently named as the first holder of the Sant Chair for Marine Science at the Smithsonian's National Museum of Natural History, from which she will encourage cooperation among marine scientists both within the Smithsonian Marine Science Network and farther afield.

Staff Scientist Nancy Knowlton showing corals to Smithsonian Regents during their 2006 visit.



Study fish that cross Darwin's "impassable barrier"

Sheer distance -- 4,000+ kilometers -- forms a barrier to dispersal of marine organisms between the Eastern and Central Pacific. Because currents take around 100 days to cross, successful transport of shore fish larvae, which usually do not live that long, is rare.

Staff Scientists Harilaos Lessios and D. Ross Robertson sequenced DNA from species found on both sides of the barrier. Some fish were closely related, indicating recent exchange, whereas others were more distantly related, indicating ancient crossings. Their research not only revealed in which direction fish originally dispersed, but in which direction larvae moved more recently. Over the next 5 years these researchers will continue to use modern molecular approaches to reassess key hypotheses in evolution.

The Eastern Pacific Barrier acts more like a semipermeable filter. Many species only occur on one side. Very few of the species thought to occur on both sides turned out, by genetic analysis, to be distinct. In the majority of the rest, adults or larvae manage to cross, but not very often.



Neogene

3 million years

Isthmus of Panama separates oceans

present

PANAMA

a long history of successive invasions

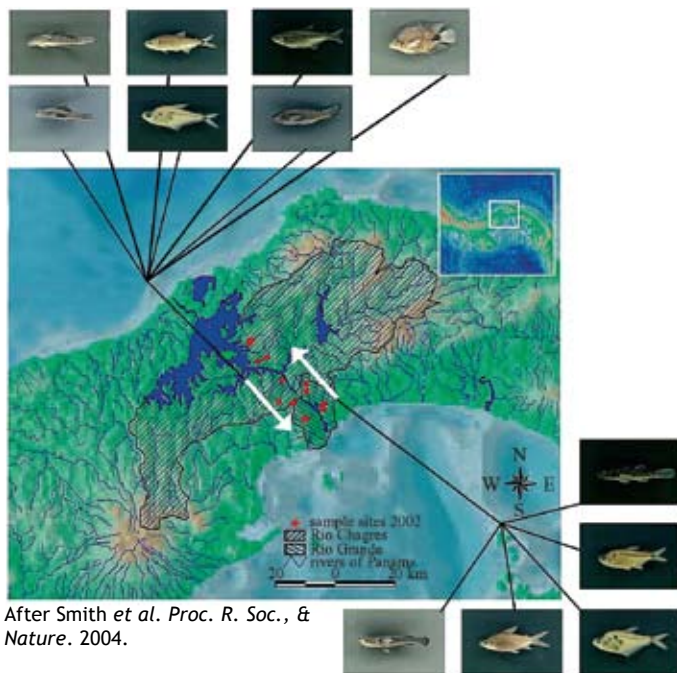
Follow invaders across landscapes

The Panama land bridge connected two continents 3 million years ago. Staff Scientist Eldredge Bermingham's lab will construct family trees and range maps for howler monkeys, birds, fish, frogs, butterflies, plants and crocodiles--sequencing hundreds of genes to determine the outcome of both ancient and contemporary invasions across the Isthmus of Panama. Are invaders forced to diversify as they encounter new situations?

Lowland flycatchers, *Mionectes oleagineus*, colonized Panama from South America on three occasions since the land bridge formed--shown by three mtDNA groups (green, red, and blue circles on map, right).



Lowland Forest Flycatcher, *Mionectes oleagineus*.



After Smith *et al.* *Proc. R. Soc., & Nature.* 2004.

Study the outcomes of invasions: who wins, who loses and why?

The Panama Canal is the only place on earth where a continental divide has been erased. Water flowing from the Chagres River now flows into both the Pacific Ocean and the Caribbean.

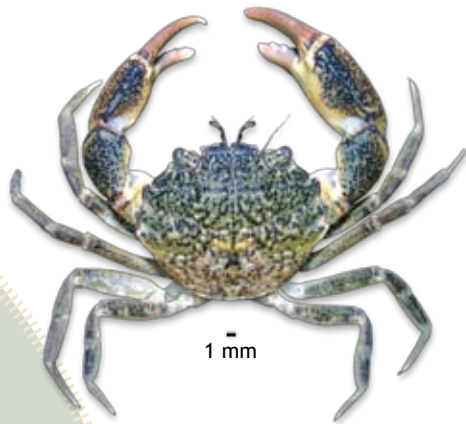
Fish from the Chagres River, which originally drained into the Caribbean, moved onto the Pacific slope following the 1914 completion of the Panama Canal. The invaders did not displace local residents, indicating that dispersal opportunity was more important than ecological interaction in the outcome of this invasion. Is this always the case? The Bermingham lab will continue to use the Panama Canal experiment to study how dispersal influences the origin and maintenance of biodiversity.

Catch invasions in progress

Staff Scientist Mark Torchin and McGill University graduate student Dominique Roche, discovered North American Harris Mud Crabs breeding in the lake that will become the third set of locks as Panama embarks on a 5 billion dollar Canal expansion project.

They will survey the extent of the invasion and use molecular techniques to find out where the crabs came from. Crabs foul pipes and disrupt food chains. What should the fate of the crabs be as engineers connect the lake to the Canal?

Harris Mud Crabs, *Rhithropanopeus harrisi*, are native to the East coast of North America. Now they are found in 21 countries.



Phylogeography

Species maps with information about genetic relatedness combine with family trees to create a powerful technique for understanding evolutionary change. Genetic analysis can date the separations suggested by the maps.



Predict how plants “move”

Plants can't move, but their seeds show a diversity of forms that maximize their movement in water, through the air and in animals' bellies. Seeds disperse away from mom, avoiding competition with her for light and nutrients and avoiding her insect pests and diseases.

As seeds hit the ground, fungi gobble them up. Research Associate Jim Dalling and students from the University of Illinois collect fungi from seeds in Panama and Costa Rica to see if pathogen diversity forces plants to move on.

Post-doctoral fellow Andy Jones uses genetic tools to determine how far away from their relatives trees have moved and how this contributes to community structure.

Staff Scientist and University of Panama botanist Mireya Correa and staff create digital maps of plant distributions across Panama and the Americas that will raise even more questions about how plants came to be where they are today.

Ecologists, including Ran Nathan, Hebrew University and STRI Staff Scientists S. Joseph Wright (pictured) and Helene Muller-Landau, are building a physical seed dispersal model.

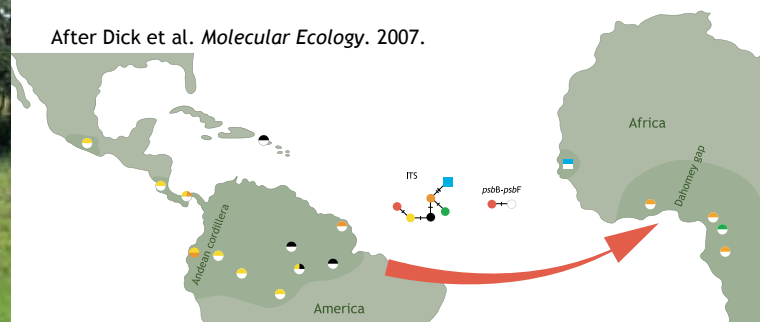


How did Kapok trees cross the Atlantic?

Although it was once thought that Kapok trees (*Ceiba pentandra*) were present in Gondwanaland before it split into South America and Africa 100 million years ago, genetic analysis shows that Kapoks on the two continents are very closely related. Seeds or whole trees must have crossed the Atlantic from South America to Africa fairly recently in evolutionary time, challenging the assumption that tree species separated when the continents drifted apart.

Chris Dick, former STRI post-doctoral fellow, now Assistant Professor of Ecology and Evolutionary Biology at the University of Michigan, will continue to use phylogenetic analysis to understand the geographical distributions of tropical trees.

After Dick et al. *Molecular Ecology*. 2007.



Lifetimes

Understanding behavior



How long does it take for a new species to arise? The traditional view is that it takes about 3 million years. But “ecological speciation”, speciation among organisms that can exchange genes readily, plays out much more quickly--even within a lifetime.

Relate behavioral plasticity to evolution

Staff Scientist and National Academy of Sciences member, Mary-Jane West Eberhard, recently completed a major synthesis and critique of evolutionary theory. In the next five years, she will continue to explore the themes in her book, writing about how opportunities for rapid innovation and adaptation result from changes in gene expression under different circumstances. The ability to change the way one behaves may be crucial to survival and reproductive success.

Staff Scientist Mary Jane West-Eberhard holds her recent book: “Developmental Plasticity and Evolution.”



Early Oligocene



Late Eocene



Early Eocene

20 cm

Traits such as mammalian horns and body size are important in social competition. Fossil titanotheres after Osborn (1929), and West-Eberhard (2003).

Explore sex as a force of change

Darwin wrote about males that strut their stuff to attract females. Work at STRI explores the role of female choice in this process, called sexual selection. Male traits that females perceive and prefer may be passed to the next generation. Mate choice not only influences survival and the ability to produce offspring, it's also a quick way to produce offspring with new ways of doing things.

Staff Scientist John Christy studies evolution by sexual selection in crabs. Research Associate Mike Ryan and Visiting Scientist Maureen Donnelly, both from the University of Texas, Austin, study sexual selection in frogs.

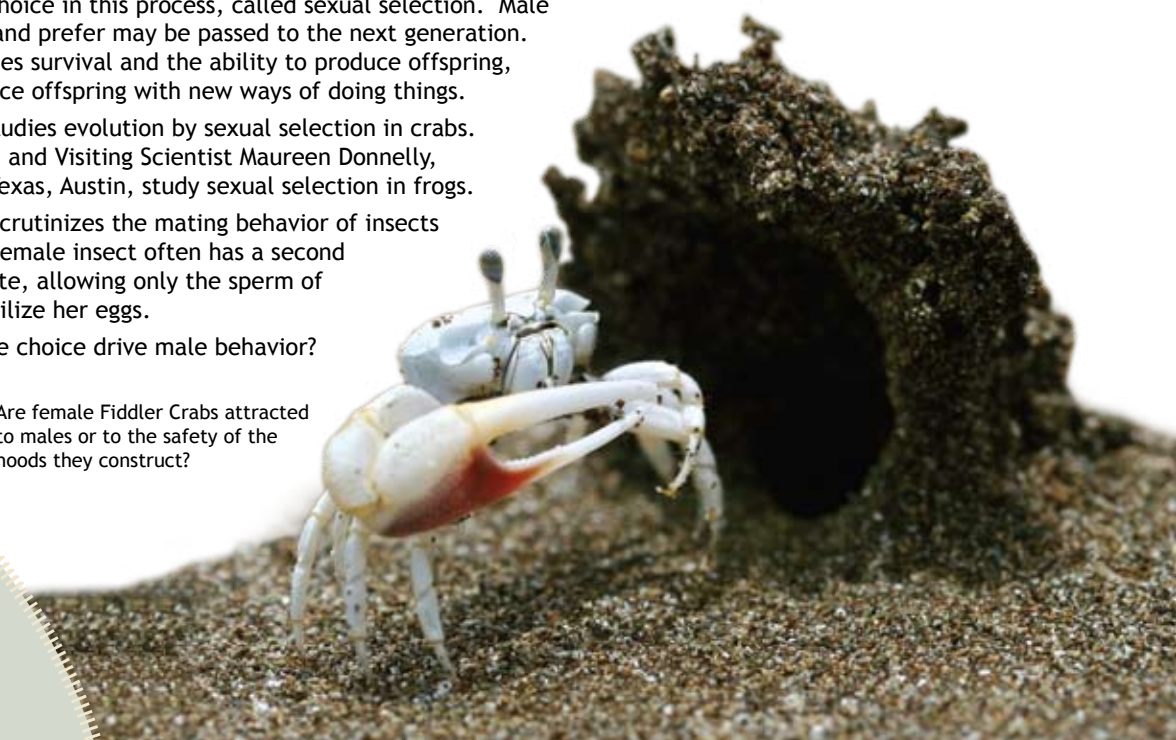
Staff Scientist Bill Eberhard scrutinizes the mating behavior of insects and spiders, showing that a female insect often has a second chance to “select” a mate, allowing only the sperm of certain males to fertilize her eggs.

How does female choice drive male behavior?

Solar and lunar cycles

Life cycles follow seasonal and daily patterns driven by the movement of the earth and tidal fluxes drawn by the moon. Organisms may be sensitive to other patterns in time: the El Niño Southern Oscillation, female fertility, or temperature changes, for example.

Are female Fiddler Crabs attracted to males or to the safety of the hoods they construct?



How does deception drive diversity?

STRI-McGill pre-doctoral fellow, Oscar Puebla, studies hamlet reef fishes to better understand how new species arise. These predatory fish come in a stunning variety of colors and choose mates based on looks. They deceive prey by mimicking the color patterns of non-predatory reef fish. Puebla is testing the idea that these two behaviors of hamlets have worked synergistically to drive rapid speciation on coral reefs in the absence of geographical barriers.

Hamlets (*Hypoplectrus indigo*)



What are the ecological implications of predator avoidance?

Karen Warkentin, Research Associate from Boston University, studies evolution and ecology of critical transitions between life stages - hatching and metamorphosis - in amphibians. As a graduate student, she discovered that red-eyed treefrog eggs, laid on leaves overhanging ponds, hatch prematurely to escape from egg-eating snakes. Tadpoles in the water metamorphose early in response to predatory water bugs, and later in response to froglet-eating spiders. Her new NSF-funded collaboration with James Vonesh, of Virginia Commonwealth University, asks how important these plastic responses to predators are for population processes, and will help to integrate population ecology and life history theory.

Research Associate Karen Warkentin studies tropical frogs.

Can two species make a third?

Hybrid speciation in animals flies in the face of theory. But recently, post doctoral fellow Jesús Mavárez and collaborators from Universidad de Los Andes and Cambridge University recreated a known species of *Heliconius* butterfly in the laboratory by mating two other species of *Heliconius*. Using a variety of behavioral and molecular approaches, this team of collaborators will test models of rapid species formation in cases where hybrid offspring have mate or habitat preferences that separate them from their parental species.

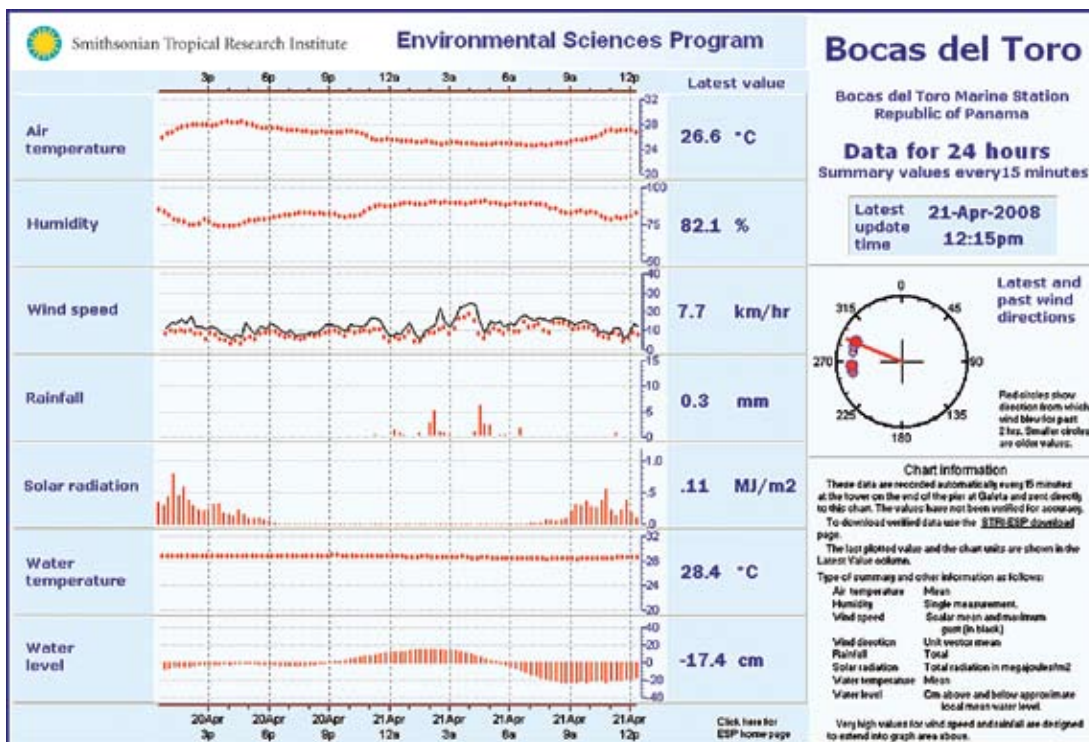
Wing color in *Heliconius* butterflies influences mate choice.



Long-term environmental monitoring to understand responses to changing environments

Keeping a finger on the pulse: long-term environmental monitoring

In 2006, STRI's Physical Monitoring Program combined formerly separate marine and terrestrial environmental monitoring programs that had been in existence since the 1970's. Data collection will be increasingly automated. Ongoing work includes the expansion of graphical presentations of data, more thorough data validation and faster presentation of validated files to users. Increased automation and streamlining and management of data and equipment will allow for future expansion and more reliability at a lower cost.

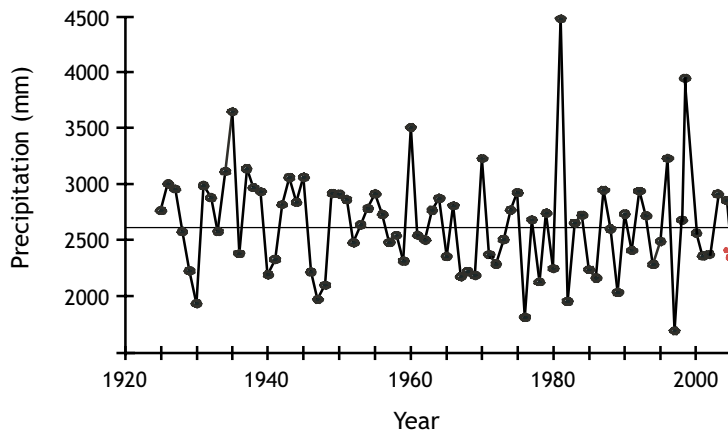


Rainfall records have been kept for the tropical lowland forest on Barro Colorado Island, Panama for nearly 90 years (below). Now data from two STRI monitoring sites appear graphically on the web, updated every fifteen minutes (above).

Funding cycles

Long-term studies of environmental change are few and far between. Only institutions that depend on the environment, like the Panama Canal Authority insurance companies that calculate the frequency of natural disasters and government agencies keep records of long-term change.

Yearly Precipitation





Can coral reefs recover?

Thirty-five years of coral research in Panama, Costa Rica and Ecuador by Research Associate Peter Glynn, from the University of Miami predates the first documented coral bleaching events in the 1980's. Glynn continues to use STRI's research vessel, the *Urracá*, to find out how stronger, more frequent El Niño events disturb eastern Pacific coral reefs.

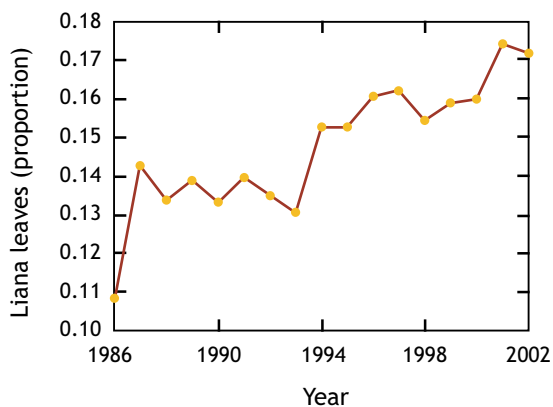
Staff Scientist and University of Panama professor Luis D'Croze experimentally simulates climate change events with corals in aquaria at STRI's Naos Marine and Molecular Laboratories.

Healthy coral reef, Coiba National Park, Panama

Are vines strangling tropical forests?

Vines are becoming more common in tropical forests, according to studies in Panama and Brazil. On Barro Colorado Island, long-term studies by Staff Scientist Joe Wright and assistant Osvaldo Calderón show that vines are contributing a higher proportion of leaves to leaf litter than they used to. Why?

Staff Scientist Klaus Winter will find out if higher carbon dioxide levels favor the growth of vines over tree seedlings. Stefan Schnitzler and his students at the University of Wisconsin and Steve Hubbell at the University of California, Los Angeles, will ask whether the increased presence of vines radically alters the composition of tropical plant communities.



The proportion of leaf litter dry mass contributed by lianas. After Wright, Calderón, Hernández and Paton. *Ecology*. 2004.



Tropical lianas take advantage of the woody stems of trees as they shoot into the canopy. But they are hard to reach and hard to study. Why is the presence of lianas on the rise in tropical forests?

Predicting change

using field data to test explanatory models



Staff Scientist Egbert Leigh

How are ecosystems like economies?

Staff Scientist Egbert Leigh (left) invites visiting scientists to his house on Barro Colorado Island for evening conversation. He encourages students and experts in far-flung fields to talk about work at sites from Manu to Madagascar.

Leigh is on the lookout for common dilemmas that force organisms to come up with new solutions. How do innovations end up as stable processes or parts, thus increasing diversity? Competition for a scarce resource drives innovation. A common need drives organisms to cooperate in new ways. The book that Leigh is working on now will explore the driving forces that lead to analogies between ecosystems and economics.

Will there be enough water to run the Panama Canal?

Yearly movement of water vapor across the Isthmus of Panama equals about half the discharge of the Amazon River. Staff Scientist Bob Stallard will work with Panama Canal hydrologists to install a fixed water-flux observatory--a powerful tool to assess climate shifts and test climate models.

View from Sherman Canopy Crane of Chagres River flowing into the Caribbean.



How do emerging diseases evolve?

How do dangerous new diseases emerge? Although malaria is common in birds, surprisingly little is known about its evolution and ecology. Research Associate Robert Ricklefs from the University of Missouri, St. Louis, and colleagues will sequence host and parasite genes to find out how parasites spread and jump from one host to another in the past. Will malaria spread more quickly as temperatures increase?

As avian malaria parasites evolved, how have they impacted the rate of speciation and extinction. Will we face similar threats as global temperatures increase and tropical diseases spread to new areas?

The Challenge of the Century

"...to emphasize valid emotional and ethical arguments for conserving biological diversity, but also to... ask questions--often cold and difficult ones--about which actions will...be most effective in sustaining...the biological riches and the unaccounted ecosystem services we have inherited...not an easy recipe for a new beginning to a new millenium."

Sir Robert May,
Chief Scientific Advisor, United Kingdom

Carbon credits for reforestation —how do trees use carbon?

Knowing how trees use carbon contributes to accurate carbon cycle models, and helps investors and conservationists choose which trees to use for reforestation projects funded by carbon credits. Staff Scientist Klaus Winter studies the CO₂ physiology of whole plants. His research has implications for the role of tropical trees in climate change. Winter finds that under a wide range of environmental conditions, tropical plants release less water into the atmosphere when grown in a high carbon dioxide atmosphere.

Over the next five years, Winter will explore the relationship between environment and photosynthetic pathways in order to predict how plants will sequester carbon as CO₂ and temperatures rise.



Staff Scientist Klaus Winter at the Gamboa facility



Staff Scientist Helene Muller-Landau

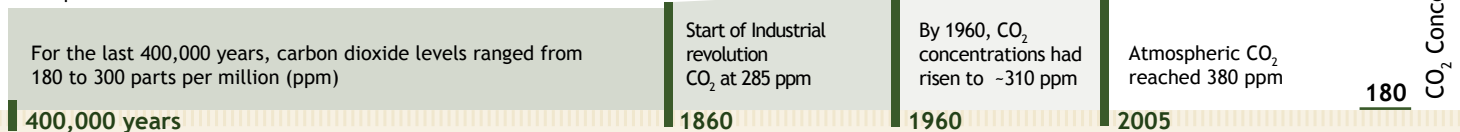
Will trees mitigate global warming?

Staff Scientist Helene Muller-Landau tests and retests models until they reflect what researchers observe in the field. To model forest responses to climate change and predict their role in removing greenhouse gasses from the atmosphere, accurate calculation of carbon storage in trees is essential.

Muller-Landau's team will determine how fast trees are growing at Smithsonian Global Observatory sites across the tropics with a new instrument invented by research assistant Milton García. They will also measure the carbon content of leaf litter, seeds and fruit in each forest.

What's next?

Atmospheric carbon dioxide concentrations



For the last 400,000 years, carbon dioxide levels ranged from 180 to 300 parts per million (ppm)

Start of Industrial revolution
CO₂ at 285 ppm

By 1960, CO₂ concentrations had risen to ~310 ppm

Atmospheric CO₂ reached 380 ppm

380
280
180
CO₂ Concentration (ppm)

STRATEGIC GOAL

Forces of Change

Establish the Smithsonian Institution Global Earth Observatory

Frank Levinson, a visionary supporter, has challenged the Smithsonian to transform an experiment designed to understand tree diversity into a global earth observatory capable of detecting subtle effects of climate change.

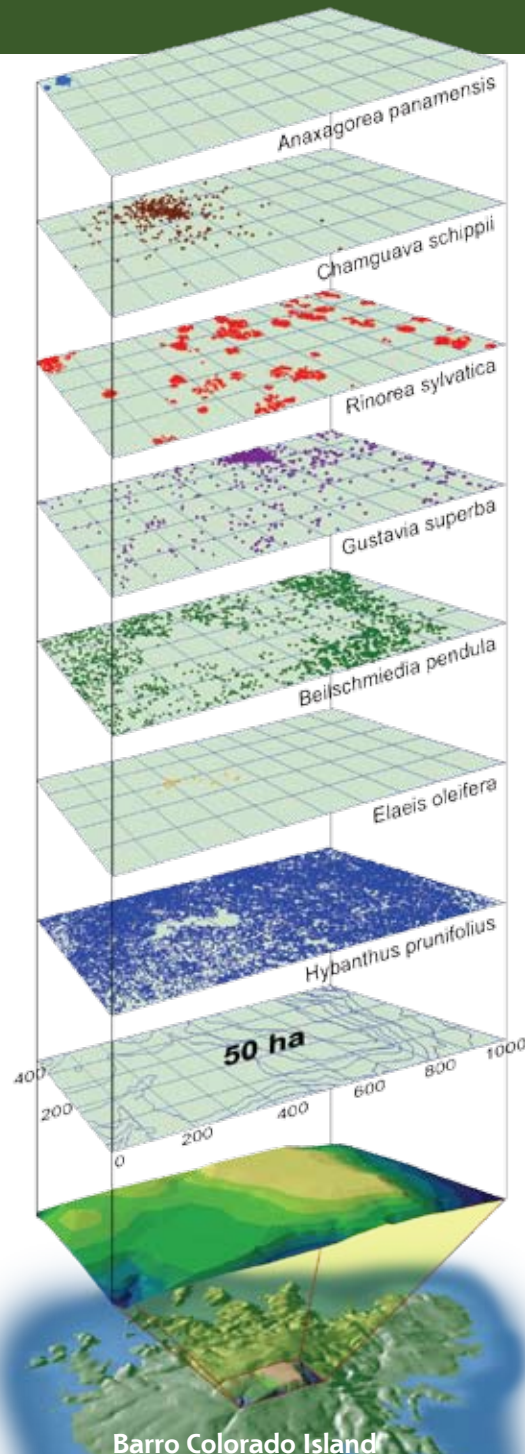
In 1980, ecologists Robin Foster and Steve Hubbell decided to identify, map and measure more than 250,000 trees in a 50 hectare area on Barro Colorado Island--every five years.

This long-term census technique was so useful to ecologists and foresters, that 27 years later, the multi-institutional Center for Tropical Forest Science (CTFS), under the leadership of Director Stuart Davies, oversees 20 sites in 15 countries, generating an actuarial table that shows changes in 3.5 million trees and 6,500 species over time.

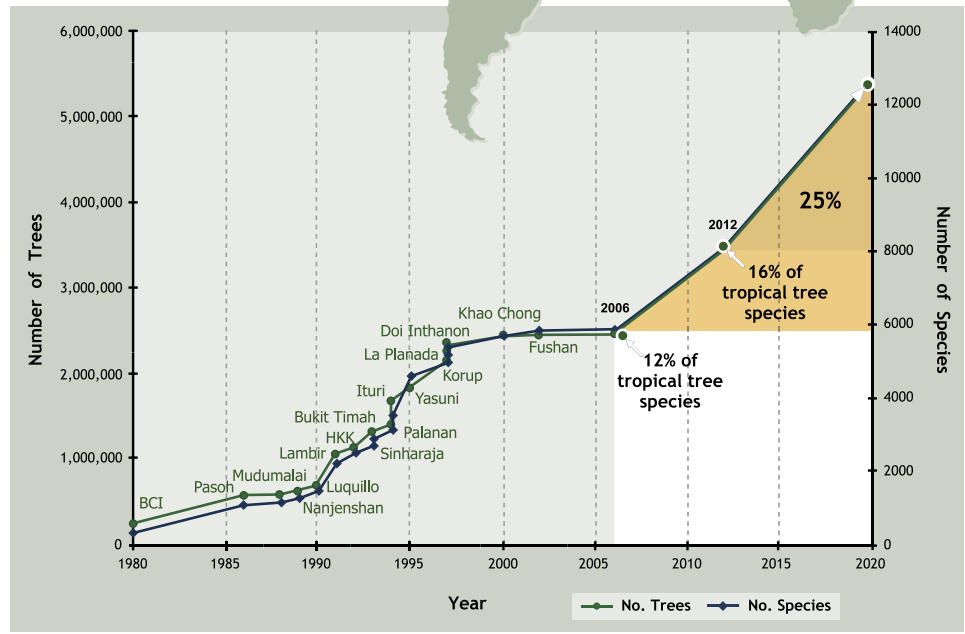
With more than \$10 million from Levinson and additional funds from HSBC, Harvard University, Yale University's School of Forestry and Environmental Studies, the National Science Foundation and other sources, the CTFS will morph into SIGEO, dramatically increasing the time- and spatial scale of forest research.



CTFS will organize thematic workshops for leaders in the fields of global carbon cycling, climate change, soil ecology and other interests to develop powerful research protocols for the network.



Maps of the trees on the Barro Colorado Island, Panama plot show that some tropical species are very rare. They would be missed in studies of smaller patches of forest.



● **Future Sites**
allow temperate-tropical comparisons

To become a true Global Earth Observatory, network partners will:

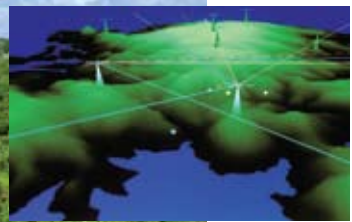
- Accurately measure carbon storage by adding annual measurements of tree growth and leaf litter accumulation.
- Add focused surveys of organisms thought to broker change in forests: animals, pathogens, microbes responsible for carbon uptake and storage.
- Integrate new tropical sites for broader coverage.
- Add new sites in North America, England and Asia to create temperate-tropical comparisons.

The Levinson challenge aims to add new plots such that 25% of all tropical tree species will be under study by the year 2020.



New technologies

New data collection and sharing systems will give researchers immediate access to information from forests around the world. The Automated Radio Telemetry System already in place on Barro Colorado Island (pictured at left) will make it possible to study animal behavior in a way that has never been possible before. Staff Scientist Richard Condit will coordinate data analysis across the plot network as researchers add new variables to the mix.



By standardizing methods we will detect global patterns that would otherwise be impossible to recognize.

STRATEGIC GOAL

Forces of Change

Discover new medicines and protect natural areas

This applied research began as a basic ecology project 30 years ago

1974

Phyllis Coley arrives in Panama as a student to ask "Why is the World Green? Why don't insects eat all of the plants?"

1980

Coley finds that plant defense strategies change with age, published in the journal *Nature*

1991

Coley and Kursar describe defense chemicals in young leaves

1996

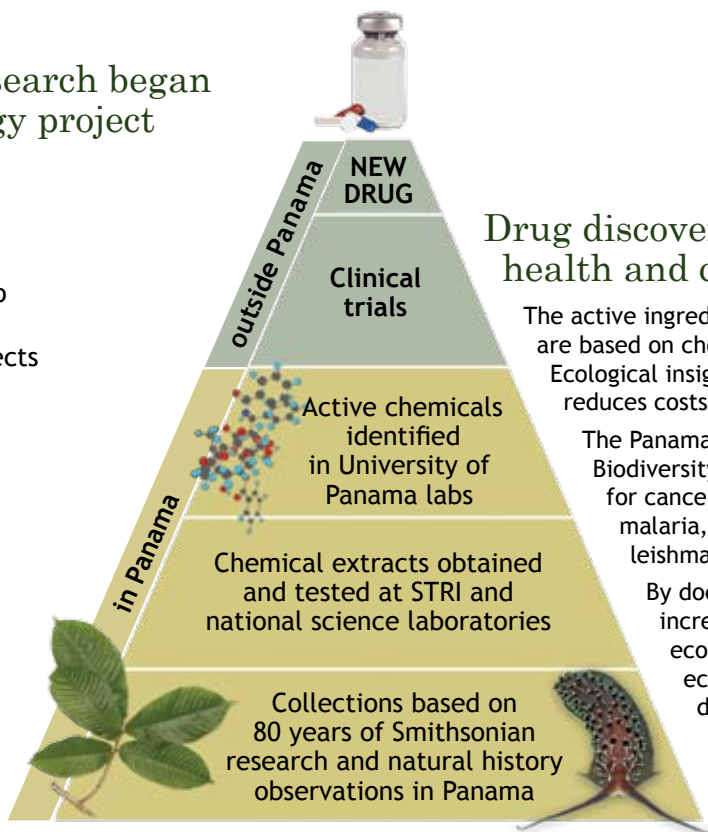
Idea: Basic ecological insights would make drug discovery more efficient

1998

ICBG Panama Program begins

2008

This program is funded until 2008 by the U.S. National Institutes of Health, the U.S. National Science Foundation and the U.S. Department of Agriculture.



Drug discovery links health and conservation

The active ingredients in half of our pharmaceuticals are based on chemicals from natural sources. Ecological insight into chemical defenses drastically reduces costs of developing new medicines.

The Panama International Cooperative Biodiversity Group (ICBG) seeks new treatments for cancer, AIDS and five tropical diseases: malaria, dengue, chagas, trypanosoma and leishmaniasis.

By documenting species richness and increasing awareness of the potential economic value of biodiverse ecosystems, this project links drug discovery to conservation.

Training host country biologists

Investment in training and infrastructure catapults host country institutions into international scientific collaborations. Appropriate technology, like the non-radioactive test for malaria developed in Panama, flows from "underdeveloped" to "developed" nations. Host country biologists become conservation advocates.



First row: Alicia Ibáñez, William Gerwick, Luz Romero, Eduardo Ortega, Todd Capson, Kerry McPhail and Yali Hallock. Second row: Thomas Kursar, Roger Linington, Luis Cubilla, Joshua Rosenthal and Phyllis Coley.

STRATEGIC GOAL

Forces of Change

Predict Caribbean reef futures

Coral reefs are dying.

In the Caribbean, coral cover declined by 80% over the last thirty years.

Making conservation decisions without basic knowledge of coral biology is like trying to save an emergency room patient without her medical history, says Emeritus Staff Scientist Jeremy Jackson. A healthy reef is a delicate symbiosis between colonies of coral polyps (animals) and their associated algae and bacteria. Algae use sunlight to produce carbohydrates that sustain the corals. When under stress, polyps expel their algae, resulting in coral "bleaching" (shown in photo below), bacterial overgrowth and, too often, reef death.

A consortium of young researchers -- Mónica Medina, University of California-Merced, Davey Kline, University of Queensland Australia, Mary Alice Coffroth, State University of New York-Buffalo and Steve Vollmer, Northeastern University -- all of whom received STRI fellowships, will continue to utilize STRI facilities as they answer the following questions:

What causes disease?

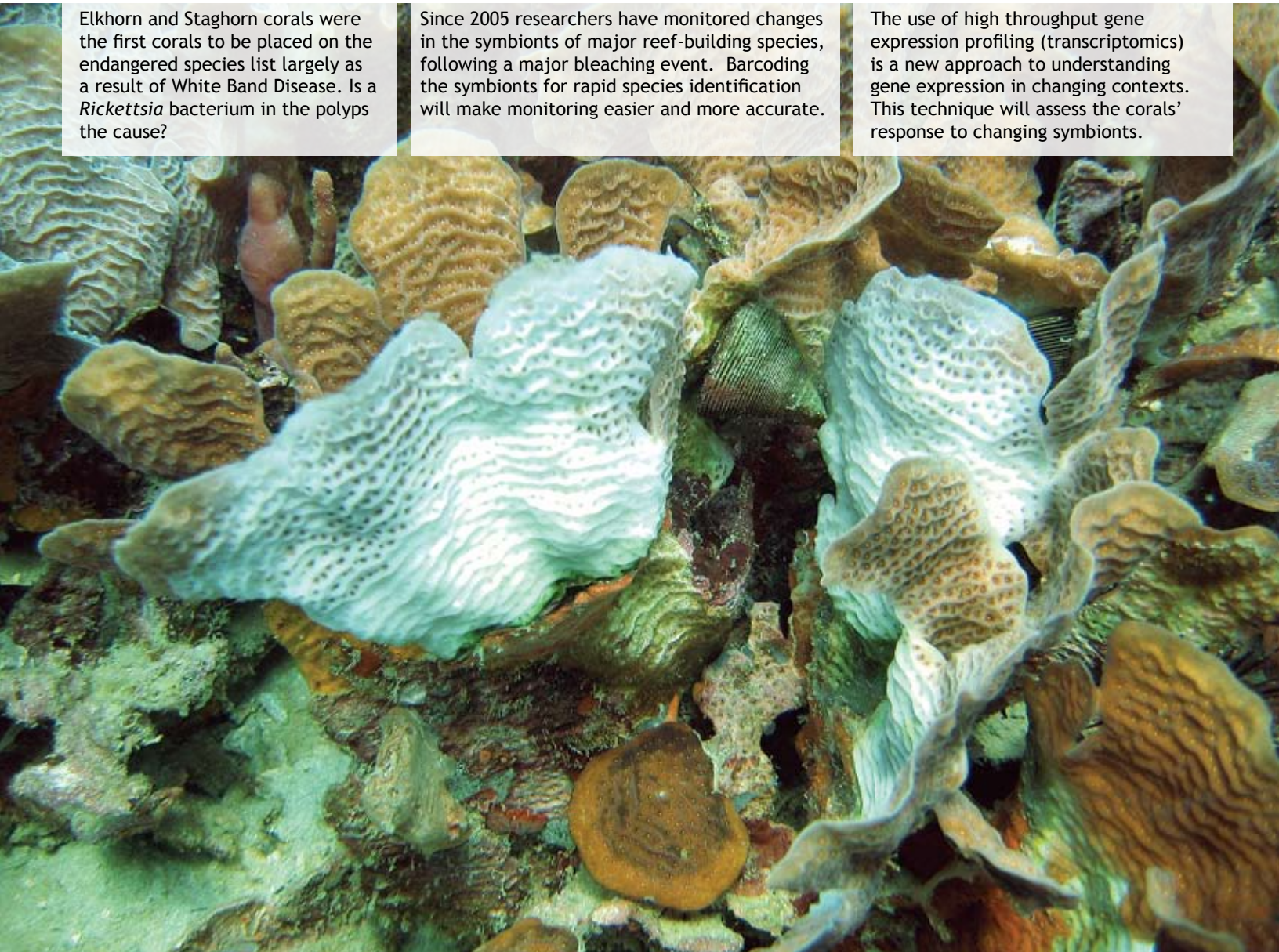
Elkhorn and Staghorn corals were the first corals to be placed on the endangered species list largely as a result of White Band Disease. Is a *Rickettsia* bacterium in the polyps the cause?

Can corals recover?

Since 2005 researchers have monitored changes in the symbionts of major reef-building species, following a major bleaching event. Barcoding the symbionts for rapid species identification will make monitoring easier and more accurate.

Does context matter?

The use of high throughput gene expression profiling (transcriptomics) is a new approach to understanding gene expression in changing contexts. This technique will assess the corals' response to changing symbionts.



Biology of Extinction

Identify processes that result in extinction

Most organisms in the fossil record disappear, on average, about 4 million years after they first appear. Humans radically alter ecosystems as we develop new technologies and cultural practices. There were five great extinctions before humans evolved, and we are creating a sixth great extinction. Natural extinctions are cases in which organisms cannot adapt to change. The “Biology of Extinction” deserves special scrutiny.

Earth's Major Extinction Events			
Million years ago	Geological period	% of families lost	Probable cause
444	Ordovician/Silurian	25	Unknown. Sea level change?
360	Devonian	19	Climate change
251	Permian/Triassic	54	Climate change, plate tectonic events
200	Triassic/Jurassic	23	Unknown
65.5	Cretaceous/Tertiary	17	Asteroid impact and vulcanism triggered climate change
The present	Holocene	1000 - 10,000 times normal background rate	Human-induced climate and landscape changes

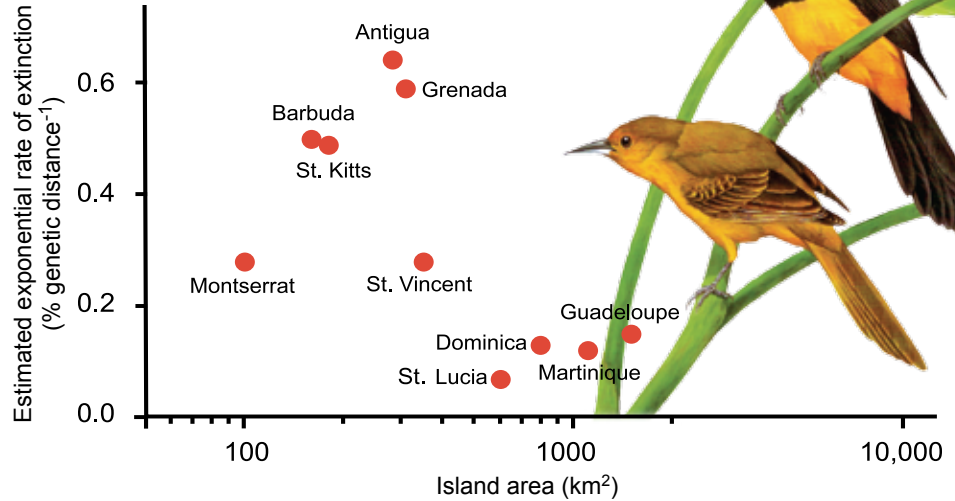
60 million year old fossil turtle from Cerrejon coal mine, Guajira Peninsula, Northern Colombia. Edwin Cadena, working with Staff Scientist Carlos Jaramillo at STRI's Center for Tropical Paleoecology and Archaeology, will study these fossils to find out what caused the extinction of these turtles.



Track extinctions on Caribbean Islands

Competitive new arrivals on islands impact settled residents. One theory holds that residents retreat inland and up mountainsides, diminishing in numbers through time. Such changes make these populations vulnerable to extinction.

Staff Scientist Eldredge Bermingham and Research Associate Robert Ricklefs will continue their decade-long study of mechanisms that drive speciation and extinction on Antilles Islands and on nearby continents.



Montserrat Orioles, pictured, are on the verge of extinction on the small island of Montserrat, whereas the closely related Martinique Orioles on the larger island of the same name, are not.



Salvage history

The Panama Canal, the biggest engineering feat of the early 20th century, is one of the Eight Marvels of the Modern World. Panama's decision to expand the Canal beginning in 2007 is an extraordinary opportunity to unite a major engineering enterprise with a major scientific endeavor. Once-in-a-lifetime access to new fossils may radically change our understanding of evolution, climate history, tectonic theory and extinction.

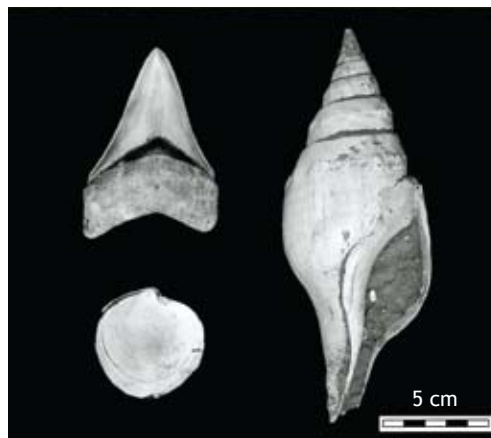
Massive new excavations associated with the Panama Canal expansion provide Staff Scientist Carlos Jaramillo and colleagues with an incredible opportunity.

Explain delayed extinction

Two million years after the rise of the Isthmus closed the seaway between the Atlantic and Pacific, 33-50% of all coral and snail species went extinct along the coast of Central America. Why such a long delay?

Tupper Fellow, Aaron O'Dea, and Jeremy Jackson, Emeritus STRI Staff Scientist and professor at Scripps Institution of Oceanography, will collect and study fossil evidence from Panama, Jamaica and Florida to determine why there is such a lag time between changing environmental conditions and extinctions.

The tooth of an extinct animal resembling a great white shark, a large shell and a clam (left) are typical fossils from the 10 million year old Gatun Formation (right) in Panama, which tells us that the places we live and work now were once underwater.





Red Eyed Treefrogs (*Agalychnis callidryas*) pose on a stem.



Researchers visited study sites that had been healthy the year before, and collected jars of recently dead frogs in order to determine cause of death. Yellow signs warn visitors to clean their boots as they travel from one natural area to the next.

Will tropical frogs disappear during our lifetimes?

Frogs evolved before the dinosaurs and survived their extinction, 65 million years ago. But over the last 25 years, frogs have disappeared from the habitat where they're most diverse: high altitude tropical streams.

Panama is at the frontline of tropical amphibian decline, but it is also a site for pioneering efforts to rescue and restore endangered local frog species.

A chytrid fungus is the likely culprit, but nobody knows how it spreads, or whether declines are indirect results of habitat degradation, pollution or global warming.

Local amphibian declines have alarming consequences for entire ecosystems. Predators may decline. Mosquitoes and other insects may prosper. The Tropical Amphibian Declines in Streams research group will assess these secondary effects. Researchers will conduct new surveys in Eastern Panama, where little monitoring has been done.



Atelopus chiriquiensis



Mangrove trees tolerate salty, oxygen-poor environments. Their roots anchor sediments, protect coastlines and provide habitat for newly spawned fish. The new mangrove boardwalk at Galeta keeps visitors above the mud, where they can watch birds and learn how mangroves sustain local fisheries and protect coral reefs from sedimentation.

Contribute to mangrove biology and conservation

Mangroves stink like rotten eggs. They are home to stinging sand flies, mosquitos and mud. But without mangroves as a buffer, storms devastate coastlines and a wide variety of marine species would lack nurseries for their young.

One of the most comprehensive studies of mangrove community ecology ever conducted is underway at Galeta Point Marine Laboratory, led by Wayne Sousa, University of California, Berkeley and Le Wang, Texas State University. The mangroves at Galeta are threatened by ongoing development of container fields near the Atlantic entrance to the Panama Canal and the city of Colón.

Near the Atlantic entrance to the Panama Canal, coral reef and sea grass beds around STRI's Galeta Point Marine Laboratory have been continuously monitored since 1973.



STRATEGIC GOAL

Biology of Extinction

Understand forest fragmentation and restoration

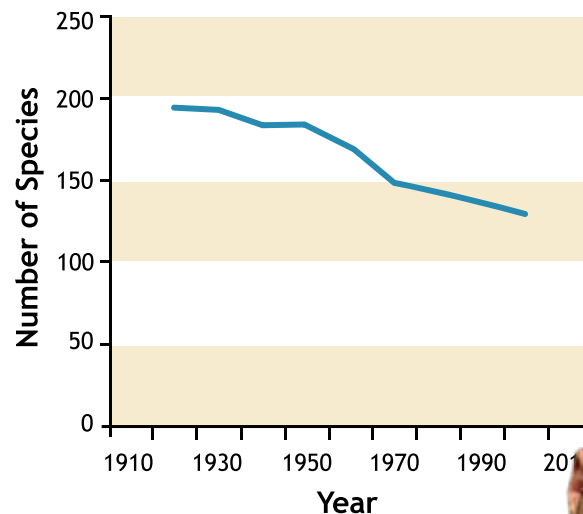
Carved up into pieces, the world doesn't work the same way...

Conservation of tropical forest ecosystems and critical environmental services requires large, inter-connected reserves. What happens when forests are carved up into smaller "islands" surrounded by a matrix of water or pastureland?

Explain why birds disappeared

Barro Colorado mountain became the largest island in Lake Gatun in 1910 when Panama Canal builders flooded the surrounding lowlands to create an immense reservoir. Over the next eighty years, 65 bird species, 35% of the original total, disappeared. Some birds preferred open habitat that shrank as island forests matured. But birds preferring mature forest disappeared from the Island as well, even though they are common on the mainland only 250 meters away. Doug and Tara Robinson, from Oregon State University, showed that a bird's inability to fly long distances across water is directly linked to its extinction. In the next five years they will examine the causes of poor flight performance and predict bird decline when forests become fragmented.

Bird decline, Barro Colorado Island



Randy Moore, visiting researcher, holding a Keel Billed Toucan. Barro Colorado Island (background).



Follow the fate of Amazon forest “islands”

In 1979, the Brazilian government planned to open up an area of the Amazon for development. Tom Lovejoy convinced them to leave intact forest fragments of specific sizes within a matrix of cattle pasture. The Biological Dynamics of Forest Fragments Project (BDFFP) in Brazil is now in its 28th year, managed by Brazil's Instituto Nacional de Pesquisas da Amazonia (INPA) and STRI. Results show that small patches of forest and their wildlife are at much greater risk than wildlife from large patches. Fire burns away at their edges. Drying and treefalls reduce patch size even more.



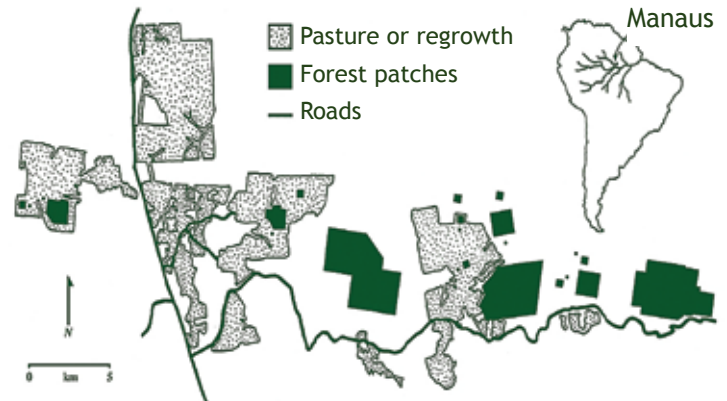
Birds, small mammals and frogs that avoid the surrounding matrix decline or disappear in fragments. Those that tolerate or exploit the matrix often survive and increase in number -- as demonstrated by STRI postdoctoral fellow Susan Laurance and colleagues.

Does the matrix matter?

Not all species respond similarly to forest fragmentation. Some disappear or decline sharply in abundance, others remain stable, and yet others increase, sometimes dramatically. Why? One of the key factors thought to affect species persistence in fragmented landscapes is their capacity to use the matrix of modified habitats surrounding forest fragments: matrix-avoiding species are far more likely to vanish because their populations in fragments become isolated genetically and demographically. Active study of the dynamic changes in the matrix surrounding fragments and how this affects animal movements and species survival are critical for predicting the future of the Amazon.

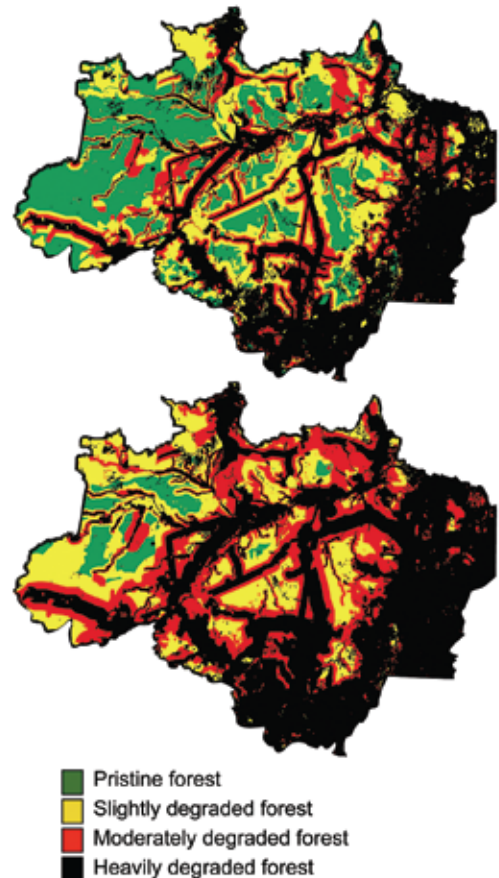
The Future of the Amazon

Staff Scientist William Laurance and other researchers involved in the Biological Dynamics of Forest Fragments Project, and active in conservation planning and strategic analyses in Amazonia, use remote sensing and geographic information systems to map and study the impacts of proposed roads, highways, river-canalization projects, railways, and other infrastructure. A key goal is to project the future condition of forests in Brazilian Amazonia under different development scenarios, and to highlight policy implications for Amazonian decision-makers.



Biological Dynamics of Forest Fragments Project

Forest fragments of different sizes, green islands in a sea of pastureland, afford the opportunity to document the consequences of isolation for the forest and its inhabitants.



Projections of Amazon forest cover in 2020 based on computer simulations of several development schemes. After Laurance *et al.* *Science* 2001.



"King Congo," a folk character celebrating Cimmaron freedom from Spanish captors, is portrayed at STRI's Galeta Point Laboratory by a resident of Panama's port city, Colon.

Study of Human Diversity & Cultural Change



Human-Environmental Interactions through Time



Human Impacts on the Environment



Cultural Responses to Globalization

Since the 1960's STRI has hosted anthropologists who view humans as integral players in tropical ecosystems.

STRI archaeologists develop tools to understand human impact on the environment in the past. Plant pollen, starch grains and microfossils found on stone tools contribute to our understanding of one of the greatest changes in human land use: the origin of agriculture in the humid tropics.

Historical studies show that humans do not always make the right decisions. Over-hunting and over-fishing lead to extinctions that, in turn, affect our diet and health. Will marine reserves reverse the effects of over-fishing? Will reining in corrupt governments improve the management of national parks? How does land use affect local and global human economies, climate change, water availability and biodiversity?

Experiments to further our understanding of land use from an integrated perspective will inform political and economic decisions.

Human-Environmental Interactions Through Time



Barriles Culture chief carried on the shoulders of another man, Panama, circa 800 A.D.



Richard Cooke, STRI Staff Scientist, excavates at the Cueva de los Vampiros, the oldest carbon isotope dated pre-Columbian archaeological site found on Panama's Central Pacific coast.

Your life force is mine! How does perception influence politics?

The king, the chief, the Big Man--western societies link the emergence of chieftainships to concentration of control over economic factors: land and material resources.

Staff Scientist Fernando Santos-Granero investigates the notion that the emergence of complex societies with rigid social hierarchies was due to the elite's control not only of land and material resources, but also of "life forces" or vitality.

Strong chieftainships and complex societies emerged as leaders began to monopolize life forces wrested from the enemy in the form of captive slaves, warriors' souls, body trophies and even significant ritual objects. This powerful ideology may be at the foundation of the Maya, Aztec and Inca state formations.

How did humans adapt to change in the past?

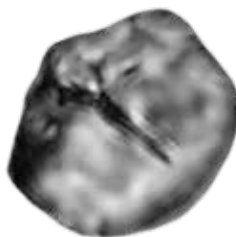
When ice-age hunters camped at the Cueva de los Vampiros (above) 11,500-9000 years ago, the coast was many kilometers away. As sea level rose after the last ice age, this small cave was isolated from the mainland and abandoned. It became connected to dry land a second time about 2200 years ago. People came back to the site to smoke and salt fish.

During the next five years, STRI's archaeology group will continue to explore how pre-Spanish peoples adapted to environmental change in seasonally dry areas of the Neotropics. They will concentrate on the analysis of faunal and cultural materials from already excavated sites as well as participate in new archaeological projects financed by Panama's Science and Technology Secretariat (SENACYT) and the University of California's Cotsen Institute of Archaeology.

*How did we make it this far?
What worked?
What didn't work?*



Corn (*Zea mays*) pollen grain



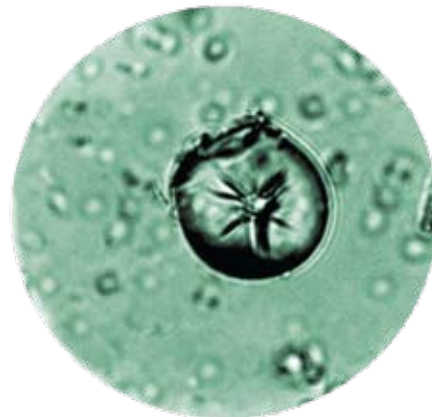
Starch grain from maize



Maize race (*Maiz Ancho*) phytolith



Squash fruit (*Cucurbita moschata*) phytolith



Manioc (*Manihot esculenta*) starch grain

Discover how we shape life to meet our needs

The origin of agriculture 12 thousand years ago represents one of the most drastic shifts in resource use wrought by humankind. Crops could be stored for periods of need. The number of people on the planet soared and wildlands were radically altered.

STRI Staff Scientist Dolores Piperno has pioneered the use of starch grains and phytoliths to determine which wild plants were the first to be domesticated and where. She maintains the most complete reference collection of these microfossils in the world at STRI's Center for Tropical Paleoecology and Archaeology in Panama.

After thousands of years of tropical rot, only plant silicate microfossils (phytoliths), pollen in sediments, and starch grains embedded in the faces of grinding tools remain to tell the story of the origins of agriculture.

In the next five years she will study genetic control of phytolith and starch grain shape in Maize and Teosinte (a wild ancestor of Maize) in order to identify and date the changes that marked the transition from wild to domesticated corn, an event that shaped cultural change in the Americas and worldwide.

Staff Scientist Dolores Piperno shown coring a lake with her long-term research assistant, Enrique Moreno (right). Recently elected to the U.S. National Academy of Sciences, based on her research at STRI, Piperno was the first scientist to hold a joint appointment at STRI and at the Smithsonian's Museum of Natural History where she is now Curator of Archaeobotany and South American Archaeology.



Human Impacts on the Environment



Evaluate the impact of hunting

Game species face hunters with increasingly powerful weapons and access to hungry urban markets. Bushmeat hunting can radically alter tropical forest composition. Prey species may be key seed dispersers, grazers and food for predators high on the food chain. Ongoing research by Staff Scientists S. Joseph Wright in Panama, and William Laurance in Africa and the Amazon basin, provide documentation of specific effects of bushmeat hunting on forest composition and animal abundance, providing critical information aimed at improved conservation measures.

Living Green Iguanas (*Iguana iguana*), bound by poachers who were detained by STRI park guards.

Determine the impact of global trade on marine invasions

Ships carry passengers that don't appear on the cargo list. Plants, animals and microorganisms hitch a ride on the surfaces of sea-going vessels or in ballast water, arriving unannounced at ports of call around the world. As part of a global project to evaluate the spread of marine and freshwater invaders, scientists from the Smithsonian's Environmental Research Center (SERC) and STRI will team up to evaluate the role of ships transiting the Panama Canal in regional and global invasions.

Ships transiting the freshwater Panama Canal carry invasive organisms from ocean to ocean.



Cultural Responses to Globalization



Large, Africanized honey bees take the place of native honey bees as habitat and the cultural knowledge that sustained native bees disappears.

Contribute to conservation of wild honey bees

For most of human history, honey has been the sweetest substance available for human consumption. Until antibiotics were developed after World War II, honey was also the best antiseptic dressing for wounds. A bottle of natural rainforest honey can sell for the same price as a bottle of French champagne. Without the bees, not only do people lose their source of honey, flowering plants may face local extinction and pollinator-dependent crops may also fail.

Staff Scientist David Roubik will work with indigenous bee keepers in Africa and the Americas to understand the ecological roles of wild and semi-domesticated stingless bees.

He will also study the role of bees as pollinators of coffee and other significant tropical crops.



Jola couple waters their home garden.

Reveal the contributions of home gardens to biological diversity maintenance

Staff scientist Olga Linares has spent most of her career understanding how tropical peoples use resources close to home. In a recently published book with Pablo B. Eyzaguirre, she wrote:

"In the final analysis, whether we conserve the biological and cultural resources of our world depends upon how close to home the issues are felt. Those millions of households throughout the tropics that keep their biodiversity close at hand, that use it daily for multiple purposes, that imbue it with cultural and spiritual value are providing a lesson to all humanity about the importance and value of biodiversity. If only for this reason, home gardens are to be celebrated, supported and conserved."

Organic cacao for birds and chocolate lovers

Have your chocolate and contribute to a sustainable, environmentally friendly economy in Panama's Bocas del Toro!

Tupper post-doctoral fellow Sunshine Van Bael and colleagues from the Smithsonian Conservation Research Center at the National Zoo have shown that when organic cacao farmers grow their crops under rainforest trees, their farms support more resident birds and migratory birds from North America. The presence of birds on a farm reduces insect damage to crops.

Shaded cacao farms are by far the most sustainable land use in the area, yet many farms are being converted into cattle pasture. Van Bael will continue to document the value of shaded cacao farms, and to pursue creative ways to promote forest-shaded cacao farms in the region.

The Lozada family (front row) pose with their organically grown cacao pods and raw chocolate and with Allen Herre, Staff Scientist; Jeff Burnside, NBC TV, Miami; Sunshine Van Bael, STRI post-doctoral fellow and Daniel Herre (back row).



These migratory birds spend the northern winter on cacao farms in Bocas de Toro.



Chestnut-sided Warbler
Dendroica pensylvanica



Tennessee Warbler
Vermivora peregrina



Baltimore Oriole
Icterus galbula



Summer Tanager
Piranga rubra



Yellow Warbler
Dendroica petechia

STRATEGIC GOAL

Cultural Responses to Globalization

Evaluate tropical land use options

Cold cash and global warming



Members of the media and STRI Communication Office staff visit the reforestation experiment in Panama's Soberania National Park.

Through the generous support of HSBC bank and a challenge grant from Frank Levinson, STRI's Center for Tropical Forest Science (CTFS) will grow a system of Global Earth Observatories (SIGEO) to provide citizens, policy makers and the greater scientific community with information about long-term, global effects of climate change and land use practices.

Jefferson Hall, Applied Ecology Director of the CTFS, will coordinate research that contributes critical information to the development of a scientifically sound understanding of the environmental services provided by forests. The Panama Canal watershed, where water supply directly affects the cost of world commerce, will be the first tropical testing ground for applied ecology models intended to put exact numbers on water quality and availability (hydrology team: Robert Stallard, STRI Staff Scientist and USGS; Helmut Elsenbeer, University of Potsdam and Fred Ogden, University of Wyoming), carbon storage and movement (coordinated by Helene Muller-Landau, Staff Scientist) and the biodiversity value of a given land use.

Models will be tested in natural tropical forests and in experimental plots to determine the biological and economic viability of reforestation with native tree species, a long-term project carried out in collaboration with the School of Forestry and Environmental Studies at Yale University.

A pioneering experiment in tropical land-use established by McGill University's Catherine Potvin has helped kick-start the Panama Canal Watershed experiment and will expand the spatial scale of lessons learned. Potvin will also coordinate studies on the economics of avoided deforestation aimed at providing additional incentives to indigenous people and small, rural landowners to conserve tropical forests.

STRi's collaboration with Yale has also yielded a new 5-year program in Environmental Leadership and Training (ELT) supported by the Arcadia Foundation and headed by Javier Mateo Vega that aims to translate SIGEO findings, such as best choices for land use, into practical solutions for policy makers.

STRATEGIC GOAL

Cultural Responses to Globalization

Accelerate scientific support for marine conservation

People ask: What can I do to conserve the oceans?

It helps to be an informed consumer. It may help even more to support major legislative action to protect areas where marine life lives and breeds.

Panama's marine life is incredibly diverse and increasingly threatened by new development. The National Government and Maritime Authority of Panama are taking major steps to protect and improve coastal environments, but better science is needed to support their efforts. New reserves must be justified and that's where STRI contributes: by producing high quality scientific information.

Contribute to conservation in Kuna Yala

The Kuna, an indigenous group who live on coralline islands in the Caribbean, accepted STRI Scientist Héctor Guzmán's recommendations for eight protected areas. Negotiations to create the first two reserves are underway in the Kuna General Congress.

STRI-McGill NEO students Oscar Puebla and Sandra Binning mark an underwater transect to census marine organisms near Utila, Honduras.

Coordinate planning for Coiba National Park

Panama created Coiba National Park and Marine Reserve in 2005, based, in part, on data from STRI scientists and the ICBG (see page 31). Now a UNESCO World Heritage Site, Coiba forms part of the Marine Biological Corridor extending from Costa Rica to Ecuador.

STRI Research Associate Juan Maté was designated by Panama's National Environmental Authority (ANAM) to lead the UNESCO-funded team who will author an innovative plan that the sustainable use of marine and terrestrial resources throughout the region. STRI aims to establish a much-needed Pacific marine lab on Coibita, a neighboring island.

Johnrandallia nigrirostris, Cabo San Lucas National Marine Park, Baja California, Mexico photographed by STRI's Dive Officer, Edgardo Ochoa.





Promote Resource Management in Bocas del Toro Province

Panama's Bocas del Toro Province, site of STRI's newest laboratory, is undergoing extremely rapid, unplanned development. STRI participates in land use planning and brings the destruction of coral reefs, marine resources and mangroves to the attention of the local and national government and international organizations.

STRI Staff Scientist Héctor Guzmán's group surveyed the entire archipelago of Bocas del Toro for Queen Conch and produced distribution maps for abundance. Based on these results, the government will ban conch harvesting for five years to allow populations to rebound. Lobster and sea cucumber declines have also been documented.

Involve the community

It's essential for local neighbors of marine reserves to participate in biological diversity protection. STRI's Director of Communications and Public Programs, Stanley Heckadon, will continue to convince local businesses to contribute to environmental education, and to training for fishermen as tourist guides at STRI's Galeta Point Marine Laboratory. This laboratory is located near Colón, on Panama's Caribbean coast, where high unemployment and destruction of mangroves contribute to an unsustainable environmental and economic future for the region.

Guides encourage kids from local schools to touch marine organisms at Galeta Point Marine Laboratory.



Support protection of the Las Perlas Archipelago

STRI Staff Scientist Héctor Guzmán participated in a three year project to survey and map marine and terrestrial habitats to establish a framework for zoning and management of the Las Perlas Islands. This has already resulted in the passage of a law for its protection. Guzmán also supports a team who will train local fishermen as whale watching guides, a sustainable activity within the reserve.

Irving Bethacourt, volunteer, and Aileen Terrero, assistant, rescuing an Olive Ridley turtle, *Lepidochelys olivacea*, in the Gulf of Panama.



STRI's aging research vessel, the R.V. Urracá, supports marine and terrestrial surveys and paleontology research. Funding for its replacement will be sought during this planning period.

Scientific Support

Adapt facilities and support services to research needs: STRI provides access to tools and field sites. Since 1990, the number of scientific visitors to STRI facilities has increased five-fold from 200 per year to 1000 per year.

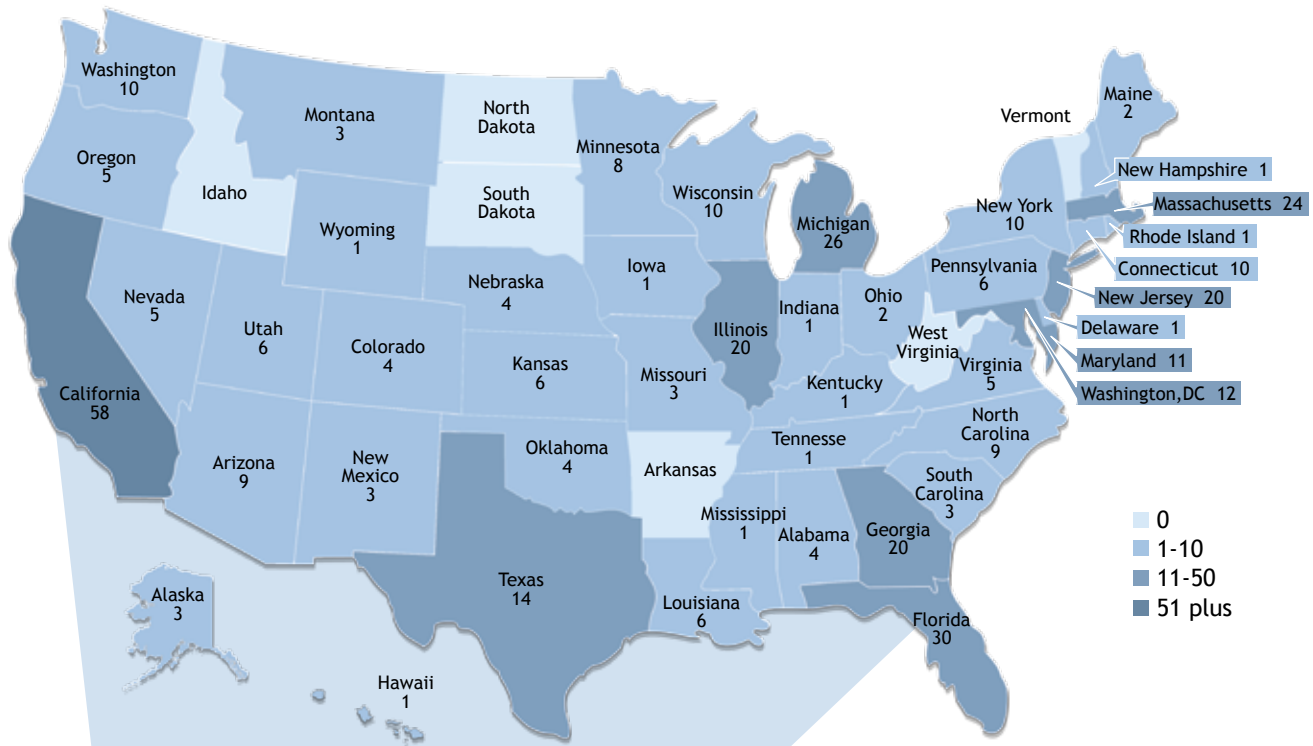
New strategic goals, such as the development of a true Global Earth Observatory, imply a daunting set of international logistical and administrative challenges.

Nearly half of the scientific staff will reach retirement age over the next ten years. We will implement a strategic, multi-year staffing plan to ensure recruitment, retention and training of members of a diverse, high-quality group of researchers.

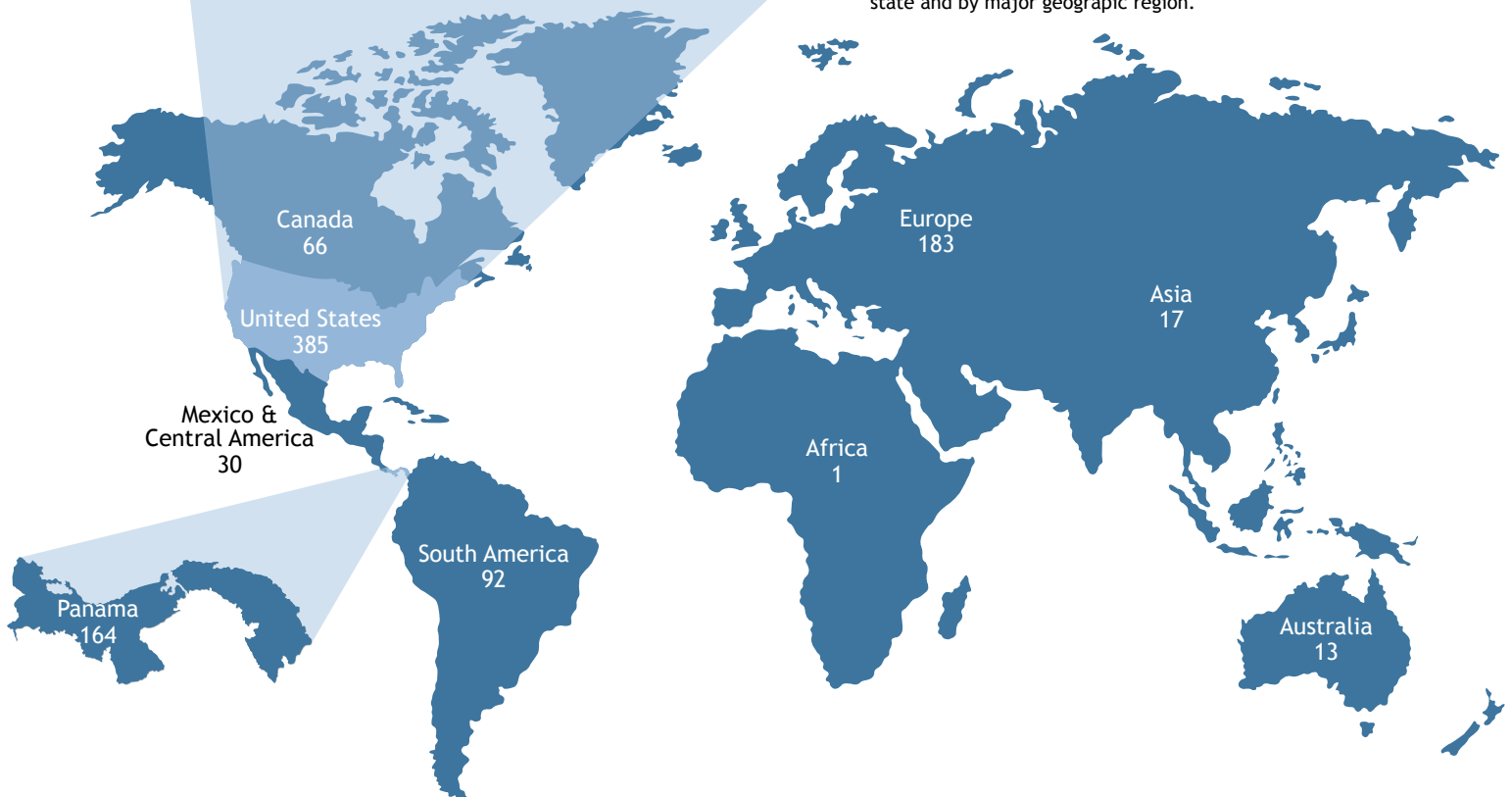
Inspire and educate: STRI research is of interest to an extremely wide range of audiences, from scientific specialists to the general public, including children. STRI will identify audiences and anticipate scientific achievements in order to establish a communication strategy that truly fulfills SI founder James Smithson's wish to diffuse knowledge.

STRATEGIC GOAL

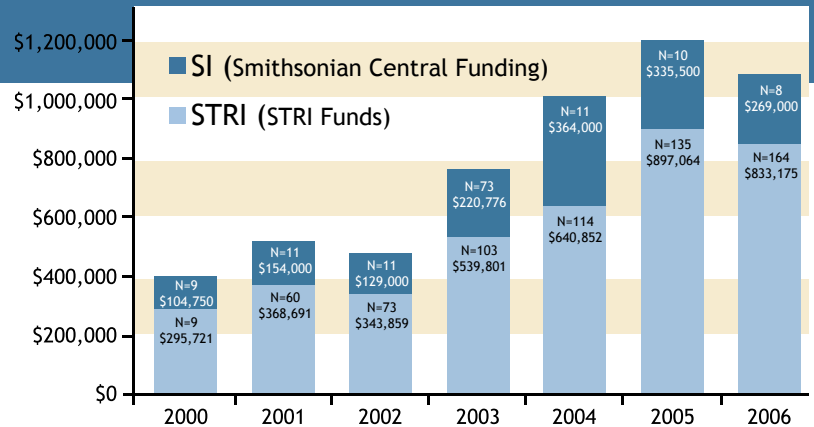
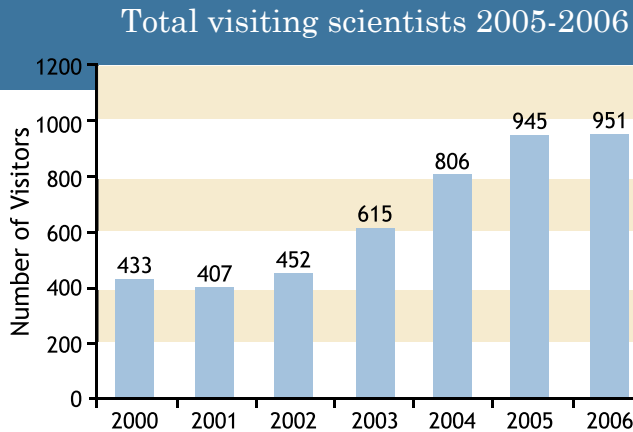
Train the next generation of tropical scientists



STRI hosts researchers from the U.S. and from the international scientific community. These maps show the number of researchers and students who visited STRI in 2005-2006 by U.S. state and by major geographic region.



Fellowship & Internship Program Budget allocated & awardees



Improve visitor services

The number of scientific visitors to STRI has doubled over the last five years. Investigators who established research projects as students return with their own students and families. STRI will improve facilities and logistical support as visitor numbers increase.

Because new ideas and skills invigorate our research, STRI provides direct support to the majority of the fellows and interns who participate in student programs. Total STRI and SI support for fellowships totaled a million dollars. We actively seek stable funding sources to support a larger percentage of highly qualified applicants. STRI will hire an Academic Dean to better coordinate academic programs.

Manage short term fellowships for Latin American students

In FY 07 STRI established a new short-term fellowship program for Latin American students supported by the "Grupo Adelante," an informal association of business people from Central America and Panama interested in sustainable development and education in the region. These donors have pledged \$210,000 to be used over a period of four years, beginning December 2006. To date, eleven (11) students have been selected to carry out independent research and/or received internships (2-3 months in duration). The program provides not only financial support for outstanding students, but also encourages gifted individuals from Latin America by helping them forge connections with scientists active in their fields of interest, as well as introducing them to a world class research center.

Host more international fellows and interns

Global challenges compel STRI to play a leading role in training the next generation of tropical biologists and anthropologists. We currently host nearly 200 university students per year, many for extended stays.

STR I will seek funds to stimulate the productivity of the Center for Tropical Forest Science observatories by increasing the number of CTF S fellows and hosting Yale University's Environmental Leadership & Training Initiative Program (ELTI).

Staff Scientist Richard Cooke teaches a student group to sort archaeological remains.



STRATEGIC GOAL

3 Build a new center for research and education

Gamboa, a small town located on the east bank of the Panama Canal and north of the Chagres River, is the jumping-off point for scientists going to STRI's Barro Colorado Island research station. At the end of the road and bordered by Soberania National Park and Lake Gatun, Gamboa is protected from development and is an ideal center for STRI's terrestrial research programs.

The construction of laboratories, housing and space for educational programs at a new site in Gamboa will solve overcrowding problems at other facilities, provide new research opportunities and encourage synergies among disciplines. The new Gamboa facilities will support expanding research programs in soil science and hydrology, molecular and microbial biology, animal behavior and forest ecology.



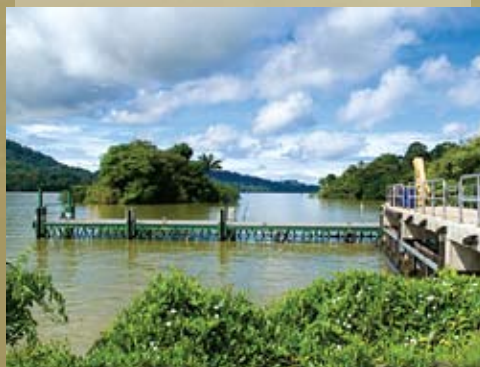
1 Access to Soberania National Park

Panama's Environment Authority (ANAM), protects 22,000 hectares of lowland forest surrounding Gamboa. Long-term censuses on Pipeline Road, which extends 17 km north through the park, provide the best bird population data in Central America.



2 Access to Barro Colorado Island

Dock in Gamboa for scientists and support staff who commute between the mainland and STRI's research station on Barro Colorado Island.



4 Nursery

Native tree seedlings for studies to demonstrate that large-scale tropical forest restoration is feasible, socially attractive and financially viable. Managed by STRI and Yale School of Forestry & Environmental Studies.





5 Tropical Plants and Climate Change

STRI's plant physiologists ask how tropical plants respond to environmental change (increased atmospheric carbon dioxide concentrations, temperatures and drought stress) in a sophisticated outdoor laboratory.



6 Frog pond

An artificial pond for studies of frog behavior, larval amphibians and aquatic invertebrates. In 2011, STRI will celebrate 25 years of sexual selection research on túngara frogs in Gamboa.



7 Insectaries

House studies of:

- 1) leaf-eating beetles and plant defense,
- 2) leaf-cutting ants and the organisms in their fungus gardens,
- 3) butterfly speciation.



9

8 Gamboa School

Classrooms, dormitories and dining hall for field courses and seminars, limited lab space and storage areas. To be replaced by a new facility.

9 Building 183

Housing, desk space and limited laboratory facilities. To be replaced by new facility.



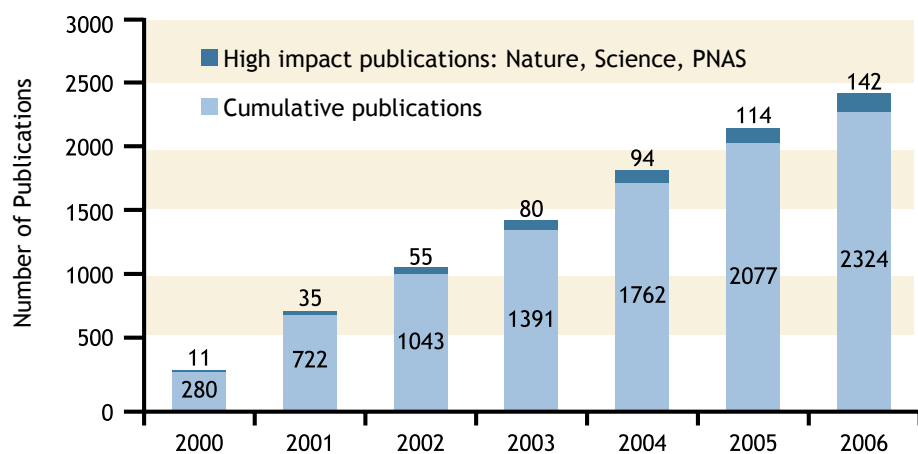
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10 Access to Panama City

Gamboa lies 27 km north of Panama City-airports, shopping, schools and other amenities, STRI's Earl S. Tupper Research and Conference Center, Center for Tropical Paleontology and Archaeology, and Naos Marine and Molecular Laboratories.

STRATEGIC GOAL

Increase access to STRI data and collections



Communicate our results

A principal measure of our success as scientists is the number and quality of the peer-reviewed publications we produce. In the next five years, we will improve access to STRI results by increasing the number of papers we publish and by focusing on high impact journals, held in high esteem by our peers and consulted by researchers from different disciplines, other professionals and the public. We will also continue to improve the STRI bibliography and the number of STRI research articles that are available on the web.

Total publications in high impact journals [Proceedings of the National Academy of Science, Science, Nature] and cumulative publications

Increase electronic access to the STRI library

The STRI Library in Panama represents the most complete collection of bibliographic resources for neotropical research. To keep researchers up-to-date, the library will provide ever-increasing access to electronic journals and bibliographic databases, as well as remote access for scholars worldwide.



Extensive online databases will be developed by Staff Scientist D. Ross Robertson to facilitate interactive research on the fish faunas of the Greater Caribbean. The existing database for Eastern Pacific fish will also be accessible on line.

Put collections and data on the internet

STRI researchers manage increasingly large amounts of information. STRI has established a new Bioinformatics Office to put data and collections on the internet and to speed the development of new web-based tools.

A new online photo database will allow researchers to add to the collection generated by staff photographers. A new GIS service will make it easy to create maps of research data on local and regional scales.



STRI Librarian, Vielka Chang-Yau, alerts visiting scientists and friends of STRI to the availability of a wide range of historical, printed and electronic resources.



(Left) Staff Scientist Richard Cooke shows archaeological artifact collections during Smithsonian Institution Regents visit, 2006.



(Right) Staff Scientists Mireya Correa and Noris Salazar manage 13,000 plant specimens representing ~4,000 species from Panama. Online images simplify plant identifications that used to involve mailing herbarium samples back and forth between experts.

Reorganize specimen collections

As the first major cohort of STRI senior scientists nears retirement, they express concern about the fate of personal reference collections. Because of the enormous effort and expense of collection management and storage in tropical environments; because many collections—especially archaeological remains—belong in Panama; and because some large collections—like the fossil and contemporary mollusk collections of the Panama Paleontology Project—are mostly useful in the regional settings where they were collected, STRI has a compelling need to insure the long-term storage and management of collections.

Insect collections, like this drawer of specimens curated by Staff Scientist Annette Aiello, are currently maintained by individual staff members. STRI's wet collection representing the majority of reptiles and amphibians in Panama, and collections of fresh- and salt-water fish also require special care.



Replace STRI's floating laboratory

Dredging ocean sediments to understand the history of past climate change and extinctions, collecting marine organisms new to science and accessing archaeological sites on distant islands would be impossible without a well-staffed and equipped ship. STRI's ocean-going laboratory, the RV Urracá, is essential transportation and base station for projects in both the Atlantic and Pacific Oceans and in remote areas on land. STRI will seek funds to replace this floating facility over the next five years.



(Above) *Tylodina fungina*, a new species of sea snail collected in the eastern Pacific from the RV Urracá.

Move frozen collections

50,000 specimens representing 6000 species, many from hard-to-reach tropical regions, are stored in aging -80°C freezers. In the next 5 years we will move these invaluable collections into a liquid nitrogen cryogenic storage system and improve access through database development.

Oris Sanjur, molecular lab manager, stores genetic material in a minus 80°C freezer. These samples, enzymes and reagents are vital to STRI's Molecular Systematics and Evolution projects.



STRATEGIC GOAL

Inspire and educate

visitors from the United States, citizens of our host nation and a growing number of international tourists at our sites.

STRI's tiny (1.5 hectare) Culebra Point Nature Center is the only public marine educational facility on all of Panama's 1500 km Pacific Coast. Visitor numbers have jumped over the last several years as more school groups take advantage of STRI's marine education program, certified by Panama's Ministry of Education and sponsored by the local business community through the Fundación Smithsonian.

The Amador Causeway at the Pacific entrance to the Panama Canal, where Culebra is located, is under extensive development for tourism and is a favorite place for Panama's urbanites to go for a walk or a drive. The new Panama: Bridge of Life Biodiversity Museum, designed by architect Frank Gehry, and featuring STRI research, is currently under construction and will draw more visitors to the site.

Drop-in visitors expect the same, excellent interpretive facilities they associate with Smithsonian Museums in Washington—a stretch for STRI's limited outreach budget.

A new Master Plan for the Culebra Point Nature Center, based on input from the local community and international consultants in interpretation, envisions significantly broadening STRI's offering at the site to send a strong biodiversity-conservation message while maintaining the site as a place to relax and contemplate the ocean.



New touch-pool design (Right).

Part of a science communication strategy

STRI research is of interest to an extremely wide range of audiences including scientists, school children, web surfers, conservationists and visitors from around the world.

In Panama, STRI hosts approximately 70,000 day visitors each year at four research sites: Culebra Point Nature Center, Galeta Point Laboratory, Barro Colorado Nature Monument and Bocas del Toro Station. STRI also hosts weekly science seminars at the Earl S. Tupper Center in Panama City and monthly seminar series for residents of Panama City and Colón.

The next 5 years will see a new communication and outreach plan which focuses on improving the quality and speed at which we communicate our science and will include a significant evaluation component.



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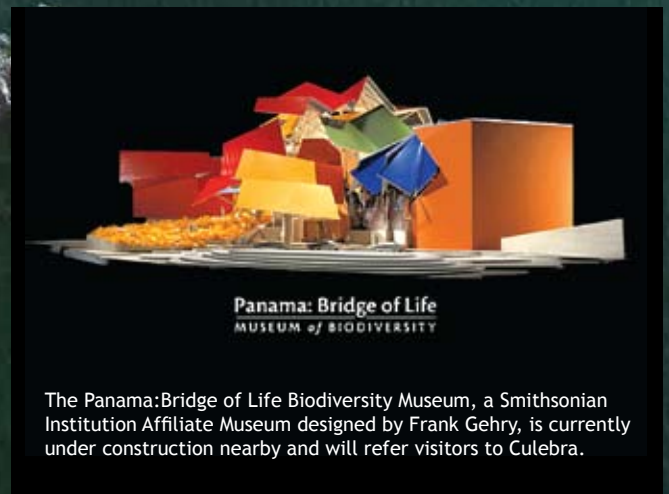
- 1 Crab Beach
- 2 Exhibition/Information Center Offices
- 3 Turtle Pool
- 4 Exhibit area
- 5 Aquaria in "La Casita"
- 6 Lookout site/telescope
- 7 New Touch-Pools
- 8 Dry Forest Trail

8

Culebra Point Nature Center: One of Panama's major attractions

(Approximate number of visitors per year)

Explora Panamá (childrens' science center)	35,000
Museo del Canal Interoceánico	55,000
Culebra Point Nature Center	58,000
Summit Nature Park (zoo/botanical garden)	129,000
Panama Canal Miraflores Visitors Center	400,000



Panama: Bridge of Life
MUSEUM of BIODIVERSITY

The Panama: Bridge of Life Biodiversity Museum, a Smithsonian Institution Affiliate Museum designed by Frank Gehry, is currently under construction nearby and will refer visitors to Culebra.

Smithsonian Tropical Research Institute Strategic Goals 2008-2013



Advance Smithsonian
Institution Global
Earth Observatories



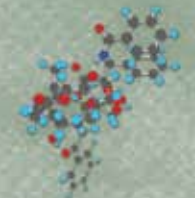
Train the next
generation of
tropical scientists



Accelerate support
for marine conservation



Understand how
small brains make
complex decisions



Discover new
medicines and
protect natural areas



Predict Caribbean
reef futures



Increase access
to STRI data and
collections



Build a new
center for research
and education



Understand forest
fragmentation
and restoration



Evaluate tropical
land use options



Inspire and educate



Contribute to
the Smithsonian
barcoding initiative