

**A symposium celebrating 20 years
of integrative research at the
Bocas del Toro Research Station**

Linking Environmental Conditions Across the Landscapes and Seascapes of Bahia Almirante to Biodiversity and Human Well-Being

Monday

March 27th 2023

9:00am - 5:00pm

At the Earl S. Tupper Auditorium

(Live streamed with discussion
and reception at STRI's Bocas
del Toro Research Station)

Simultaneous translation



Smithsonian
Tropical Research Institute



Agenda

SYMPOSIUM | MARCH 27, 2023

INTRODUCTION

- 9:00 **Oris Sanjur - STRI** | Introduction and the importance of Bocas del Toro to STRI
- 9:10 **Rachel Collin - STRI** | Introduction to the celebration of 20 years of the Bocas Station and the vision of Tony Coates

SESSION 1: Coastal Swamps and Land-Sea interface

- 9:20 **Rosabel Miró – Panama Audubon** | The birds of the coastal swamps of Bocas del Toro and their conservation *(SP)*
- 9:40 **Sofie Sjøgersten - University of Nottingham** | Environmental change and San San Pond Sak peat swamp forest
- 10:00 **Yonathan Viquez - STRI** | Mapping changes in mangrove cover in Bocas del Toro and the Comarca Ngäbe-Buglé *(SP)*
- 10:20 **Cinda Scott – SFS Bocas** | Cultural ecosystem services of mangrove ecosystems in Bocas del Toro, Panama
- 10:40 **COFFEE BREAK**
- 11:00 **Brigida de Gracia – STRI** | History and geography of Bahía de Almirante *(SP)*
- 11:20 **Mark Torres – Rice University** | Rock-derived nutrients in Bahía Almirante: riverine sources and implications for coral communities and hypoxia
- 11:40 **Kasey Clark – University of Liverpool** | Rivers, land use landcover and water quality in Almirante Bay
- 12:00 **Panel discussion Q&A**
- 12:30 **LUNCH** *(on your own)*

SESSION 2: Oceanography, Marine Biology and Conservation

- 1:30 **Geno Pawlak – UCSD** | Introduction to physical oceanography of Bahía Almirante *(SP)*
- 1:50 **Anne Adelsen and Kristen Davis – UCSD and UCI** | Physical processes that contribute to oxygen depletion in Bahía Almirante
- 2:10 **Andrew Altieri – University of Florida** | Patterns of coral reef resilience to ocean deoxygenation

(SP) = Presentación en Español | Spanish talk

Agenda

SYMPOSIUM | MARCH 27, 2023

- 2:30 **Jimena Pitty and Eileen Haskett – STRI** | From the station to the street: Incorporating STRI climate science into public education initiatives (SP)
- 2:50 **COFFEE BREAK**
- 3:10 **Noelle Lucey - STRI** | What are the biological consequences of hypoxia in Bocas del Toro?
- 3:30 **Carolina Cesar - STRI** | Coral susceptibility to bioeroding organisms under hypoxia (SP)
- 3:50 **Leon Mach – SFS Bocas** | Wildlife tourism maps and the governance of environmental collapse
- 4:10 **WRAP UP COMMENTS AND PANEL DISCUSSION WITH Q&A**
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Sponsors & Acknowledgements

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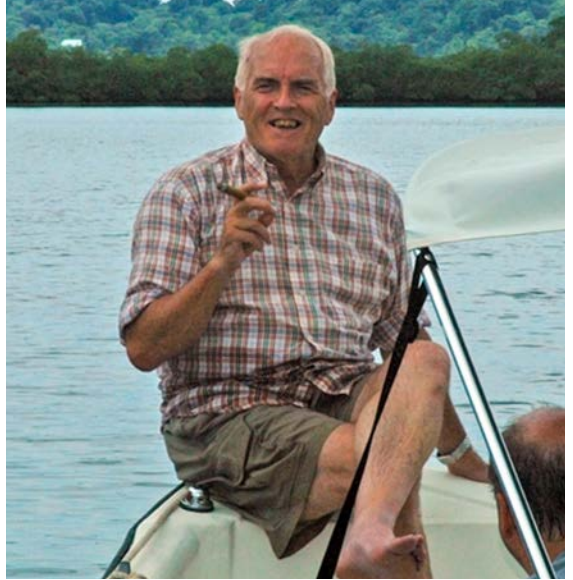
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In memoria

Antony Coates

Tony Coates was the inspiration behind the Bocas del Toro Research Station (BRS) as well as an inspiring teacher and mentor and a leader of STRI science for over 20 years. After Tony retired for a second time from STRI in 2016 he remained a steadfast friend to STRI and many of the scientists who work here until he passed away in 2022.

Tony's contribution to STRI science was a long one. He co-founded the Panama Paleontology Project (PPP) in 1988. This program brought together and integrated research from 40 scientists in 8 countries to understand the global changes that the rise and closure of the Isthmus of Panama produced about three million years ago. The PPP is one of the most famous STRI research programs and has resulted more than 200 scientific papers. As well as mapping the geology of the Isthmus, the PPP created a framework to understand how it was formed and described the physical repercussions of dividing one great ocean into two. This framework is still used by many scientists working at STRI. The outcrops in Bocas del Toro were fundamental to this effort and it was during this project that Tony first visited Bocas.



Tony contributed significantly to the vision of Smithsonian science as STRI's deputy director from 1991-2000. It was during this time that, he was instrumental in purchasing a six-hectare site in On Isla Colon and lead the way in sketching out the plan for a marine laboratory. With this piece of land and with Tony's vision the Bocas del Toro Research Station (BRS) was launched. At that time, it was difficult to imagine the thriving research station the BRS has become. In those days Isla Colon had no paved roads, a handful of taxis and vegetables were delivered by boat once a week. When Tony retired, he did not slow down. He continued to serve as a spokesperson for science in Panama. During this time Bocas del Toro was never far from his thoughts. Tony hosted numerous donor trips to Bocas, as well as continuing to participate in geological expeditions throughout the archipelago. With Tony's retirement from STRI in 2016, the BRS lost one of its most vocal supporters. In 2019 STRI and the BRS team expressed their gratitude to Tony for his years of service and support by naming the Coates dining hall at the Bocas del Toro Research station in his honor. This year, STRI will award the first Tony Coates post-doctoral fellowship. We only wish that our friend Tony was here to watch this symposium and to hear about all the discoveries that have flown from his vision.



Speakers

Oris Sanjur

STRI



► Introduction and the importance of Bocas del Toro to STRI

STRI has a long history of marine research on both coasts of the country. For the last 20 years Bocas del Toro has been the focus of STRI's Caribbean research. Dr. Sanjur, STRI's deputy director will describe how the station in Bocas del Toro fits into the research agenda and mission of STRI.

Bio

Originally trained as a molecular geneticist, Dr. Oris Sanjur has worked at STRI for over two decades filling various roles including deputy director and acting director of the institution.

Rachel Collin

STRI



► Introduction to the Celebration of 20 years of the Bocas Station and the vision of Tony Coates

The laboratory of the Bocas del Toro Research Station was inaugurated in 2003, so this symposium marks the stations 20th anniversary. This introduction will illustrate how far we have come in understanding the biology, geology and ecology of Bahia Almirante. It will highlight how far the station has come in bringing to life the vision of former STRI deputy director, Dr. Antony Coates, who passed away in 2022 after a long and distinguished career studying the geological history of the tropical Americas.

Bio

Dr. Rachel Collin has been the Director of the Bocas del Toro Research Station since 2002, where her research focuses on understanding the environmental conditions in Bahia Almirante and the responses of marine invertebrates to environmental stressors. She has authored over 100 publications and trained more than 40 undergraduate students in her laboratory. She was originally trained as a zoologist and evolutionary biologist at the University of Washington and University of Chicago.

Rosabel Miró

Panama Audubon



► The birds of the coastal wetlands of Bocas del Toro and their conservation

Abstract

From 1995 to 1998 the Panama Audubon Society was working on the identification of Important Bird Areas in Panama. Of 9 initially identified areas, a subsequent data and methodology review work left us with only 5 sites: San San Pond Sak Wetlands, Bocas del Toro Archipelago, La Amistad International Park, and Palo Seco Protected Forest. Since 2011, Audubon Panama has been monitoring waterfowl and shorebirds in various parts of the country. This has led us to visit the coasts of Bocas del Toro and islands to educate communities and young scientists in the identification of some species of special interest for conservation. During the talk we will present the species of shorebirds that have been recorded in Bocas del Toro, other seabirds that use the beaches and we will talk about some conservation challenges in Bocas del Toro.

Bio

Rosabel Miró is the current Executive Director of the Panama Audubon Society (PAS) and has been working on environmental issues in the Republic of Panama since 1994 when she joined the Panama Audubon Society. Three years after joining the PAS she joined the board of directors, serving as President from 2003 to 2006. As a volunteer she provided administrative and institutional support for various activities, including workshops, fairs, and special events. She worked in environmental education for children, youth, and adults on issues related to the conservation of birds and their habitats. In 2007 she became the Executive Director of PAS, her current position.

At present she represents the Panama Audubon Society on the Panamanian Committee of the IUCN (International Union of Conservation of Nature), serves as Secretary of the Panama National Wetlands Committee and also represents the organization as the National NGO Communications, Education, Participation, and Public Awareness Coordinator for Ramsar (Convention on Wetlands) in Panama. Internationally she serves as a Council Member for the Western Hemisphere Shorebird Reserve Network.

Rosabel graduated from the Universidad Santa María La Antigua where she majored in Business Administration in Tourism. In 2003 she obtained a Master's degree in Environmental Management from the Universidad Latinoamericana de Ciencias y Tecnología.

Professor Sofie Sjögersten

University of Nottingham



► Environmental change and San San Pond Sak peat swamp forest

Abstract

Tropical peatlands account for 11% of global peatland area but store 19% of peat carbon. While recent work has improved estimates for South American and Central African peatlands, data for Central America is limited. Initial work in Bocas del Toro show that the peatlands in this region store substantial amount of carbon below ground and that the below ground carbon are much larger than the carbon stored in the above ground biomass. The peatlands of Bocas del Toro are also important exchangers of greenhouse gases. These emissions are highly sensitive to climate change with increased carbon dioxide emissions during dry and hot conditions and higher methane emissions in response to higher temperatures during periods of flooding. In summary Bocas del Toros peatlands are nationally important carbon stores which are likely to respond strongly to climate change.

Bio

Professor Sofie Sjögersten is an environmental scientist, interested in how environmental change impacts on biogeochemical cycling and ecosystem processes, particularly the role of wetlands in the global carbon cycle. She has worked extensively in tropical wetlands globally, including in Mexico, Panama, Southeast Asia, and Central Africa.

Yonathan Viquez

STRI



► Using open-source tools to understand changes in mangrove cover in Bocas del Toro

Abstract

Mangroves are critical coastal ecosystems, supporting high levels of biodiversity and providing ecosystem services to coastal communities. They are viewed as providing important natural climate solutions, as the blue carbon sequestered in mangrove forests can support adaptation and mitigation strategies for climate change. Despite their importance, mangrove cover has significantly declined globally and Panama is no exception. We used remote sensing to make compare 10 m resolution mangrove maps derived from Sentinel-2 image data from 2018 to 2022, and 30 m maps derived from landsat images from 1990 to 2015 to document changes in the mangrove forest of Bocas del Toro and Ngobe-Bugle comarca. These results can support management and conservation efforts in Panama, and these open access tools can provide scientists and managers with the ability to accurately assess mangrove cover at the local and national level.

Bio

Originally from Chiriqui Province, Yonathan Viquez is an ocean scientist and remote sensing analyst who graduated from Oregon State University in 2021. As an intern at the Smithsonian Tropical Research Institute in 2022, Yonathan created one of the first 10 m resolution mangrove maps for Panama using satellite imagery from Sentinel-2 combined with Google Earth Engine. He is currently working to generate a time series of maps to understand changes in mangrove cover. His interests are the study of global, regional and local changes of the landscape of coastal regions, similarly the study of the ocean bathymetry and how this controls physical and chemical drivers of the ocean. He plans to pursue this interest in graduate school in the near future.

Cinda Scott

The School for Field Studies,
Bocas del Toro, Panama



► Cultural ecosystem services of mangrove ecosystems in Bocas del Toro, Panama

Abstract

Inequities and unequal power dynamics in the use and distribution of benefits that mangrove forests provide threaten vulnerable coastal regions, communities, and society. Assessing these inequities is challenging as there are difficulties in comprehending and conveying Cultural Ecosystem Services (CES). CES are often contextualized as intrinsically derived, are seen as providing important non-monetary benefits or are lumped into a theoretical bucket for everything that does not fit into established categories or that cannot be easily quantified. Comprehending and conveying CES with nuance and establishing quantifiable benefits is even more difficult when considering different cultural values held within a community. We assessed perceptions of the cultural value of mangrove ecosystems in Bocas del Toro (BDT), Panamá via semi-structured interviews of individuals from culturally diverse groups utilizing two merged conceptual frameworks to highlight the coevolution of differential power dynamics with respect to CES. Three major CES themes were identified: mental health benefits, sense of identity, and inequity. Our findings reveal complex relationships between residents' appreciation for mangrove environments and long-standing power inequities suggesting the need for CES studies to holistically consider different cultural values within communities. Importantly, our study supports the need for understanding sub-group and ethno-racial understandings of mangrove CES and illuminates the need for more equitable mangrove governance throughout BDT to ensure the protection of mangroves and their cultural benefits to all. Future studies should continue to explore CES frameworks that advance knowledge of locally derived CES benefits and that are inclusive of power and equity dynamics.

Bio

Dr. Cinda P. Scott is a marine biologist, educator, ocean equity advocate, science communicator and world traveler. She completed her Ph.D. in 2009 at the University of Miami's Rosenstiel School of Marine Earth and Atmospheric Science. Since 2014, she has directed The School for Field Studies, Center for Tropical Island Biodiversity Studies program in Bocas del Toro, Panamá. She manages a team of faculty, staff and students dedicated to the study of anthropogenic impacts of tourism on the natural environment of Bocas del Toro. Her work includes teaching and lecturing, administrative and grants management, and scientific research. She has presented to a wide range of audiences, including students of all ages, government authorities, and concerned community stakeholders. Her current research examines mangrove habitat complexity and cultural valuation of mangroves throughout the Bocas del Toro Archipelago. She maintains interests in marine protected areas, coral reef ecology, and ocean equity. Follow her adventures around the world at www.cindaseas.world.

Mark Torres

Rice University



► Rock-derived nutrients in Bahia Almirante: riverine sources and implications for coral communities and hypoxia

Abstract

Rivers are major sources of both freshwater and essential nutrients to coastal ecosystems. Given the importance of coastal systems to fisheries, tourism, and other human endeavors, efforts to thoroughly understand the exact role that rivers play in sustaining or perturbing these systems is a major research goal. On-going anthropogenic changes to Earth's climate further underscore the need to study coupled river-coastal systems as, without a mechanistic understanding, it is not possible to robustly predict future change. Here, we report the results of our on-going work investigating the subset of rock-derived nutrients (e.g., Si, P, Ca, and Fe) in Bahia Almirante and its surrounding rivers. By combining our new data with published measurements of other rivers in Panama, we identify the different rock types and chemical reactions that charge river waters with rock-derived nutrients. Using measurements of the isotopic compositions ($^{18}\text{O}/^{16}\text{O}$ and D/H) of rain, river waters, and seawater, we disentangle how the relative contributions of water and nutrients from different rivers change in space and time within the bay. Furthermore, combining these isotopic data with nutrient measurements allows us to quantify the extent of rock-derived nutrient utilization by aquatic ecosystems including coral communities. Altogether, our results allow us to constrain the role of rivers in the nutrient cycles of Bahia Almirante as well as provide insights into how these cycles may impact the development of hypoxia and change in a warming climate.

Bio

Dr. Mark Torres studies the chemistry of natural waters and related problems in biogeochemistry. This work allows him and his laboratory group to ask questions like, “what makes and keeps planets habitable?” and “how can we use natural processes to mitigate the effects of climate change?”. He received a bachelor's degree in Geology from Pitzer College in 2010 and a Ph.D. in Geochemistry from the University of Southern California in 2015. From 2015 to 2017, Dr. Torres was a Texaco/AGEP postdoctoral fellow at the California Institute of Technology. Since 2017, Dr. Torres has been an assistant professor at Rice University in the Department of Earth, Environmental, and Planetary Sciences. In 2019, Dr. Torres was selected for the Alfred P. Sloan Fellowship in Ocean Sciences and in 2021, he was awarded the F.W. Clarke Medal by the Geochemical Society.

Kasey Clark

University of Liverpool



► Rivers, land use landcover and water quality in Almirante Bay

Abstract

There are six main rivers that flow into Almirante Bay. There are three groups: 1) small mountain rivers along the coast, they are flashy in nature, and have more nutrient inputs into the bay as they are fed from agricultural/towns; 2) peat swamp rivers, including San San Pond Sak, with unique water quality and some fed solely by rainfall; and 3) the Changuinola river, which is the third largest river in Panama, it had a very large discharge volume, and can enter the Bay and impact conditions there. In this talk I will present the distinct characteristics of these landscape and rivers that flow into Almirante Bay, with some discussion about potential role the rivers may play in enhancing hypoxia and impacting coastal ecosystem health.

Bio

Kasey Clark is a Lecturer in Environmental Change, in the School of Environmental Sciences, in the Department of Geography and Planning at the University of Liverpool. Their work focuses on evaluating freshwater inputs (rainfall and river discharge) and nutrient fluxes into Almirante Bay as potentially important drivers of the annual hypoxic cycle. Additionally, they work evaluating the impact of land use and land cover change on river biogeochemistry in the Agua Salud Project in Panama.

They received a DPhil from the University of Oxford, where they studied landslide dynamics, organic carbon river geochemistry, and catchment hydrology in Peru. They were part of the Andes Biodiversity and Ecosystems Research Group (ABERG). As a postdoctoral researcher at the University of Pennsylvania in the Department of Earth and Environmental Science, they carried out research as part of the Luquillo Critical Zone Observatory (LCZO) in Puerto Rico. They evaluated the impact of extreme rainfall events on carbon fluxes in the Luquillo Mountains.

Geno Pawlak Tejada

University of San Diego



► Introduction to physical oceanography of Bahia Almirante

Abstract

Bahia Almirante is a shallow, semi-enclosed tropical embayment on the Caribbean coast of Panama with a rich ecosystem that has been the subject of extensive biological research. The bay's ecosystem has been shown to be affected by multiple stressors in the form of thermal stress and low oxygen conditions. We use long-term monitoring data along with focused in situ measurements to examine the physical processes that drive circulation and determine water characteristics in the bay. STRI has carried out regular, spatial sampling of water properties at a set of sites in and around the bay from 2010 to present. In addition, we conducted a focused field study between 2019 and 2022, that included in situ measurements within the bay, at the entrance channels and offshore to measure water properties and flow velocities. Observations show persistent high salinity stratification across the bay that leads to an isolated region of water at depth that results in temperature inversions and low oxygen conditions. These deep regions are refreshed intermittently when favorable flow at the entrance channels coincides with weak offshore stratification. Flow measurements in the channels reveal periods of strong mean flow into the bay from the westernmost channel at Boca del Drago balanced by outflows at two other primary channels. Analysis of global model data indicates that mean flows in the entrance channels are correlated with offshore flows which are, in turn, connected to mesoscale variability in the Caribbean Current. Residence times for the bay are significantly affected by the strength of flows in the channels.

Bio

Dr. Geno Pawlak Tejada is a professor at the University of California San Diego in Mechanical and Aerospace Engineering (MAE) with a joint appointment at Scripps Institution of Oceanography. Dr. Pawlak Tejada received his PhD in Applied Mechanics and Engineering Science from UCSD in 1997. After postdoctoral appointments at Scripps Institution of Oceanography and at the University of Washington, he served on the faculty in Ocean Engineering at the University of Hawaii at Manoa between 2001 and 2012, where he founded and directed the Kilo Nalu cabled ocean observatory. At UCSD, he leads the Environmental Fluid Dynamics Laboratory in MAE which carries out lab and field-based research focused on coastal ocean physical processes including turbulence, stratified flows, estuarine dynamics, and flow over kelp forests and coral reefs.

Anne E. Adelson

Scripps Institution of Oceanography,
University of California at San Diego



Kristen A. Davis

University of California at Irvine

► Physical processes that contribute to oxygen depletion in Bahía Almirante

Abstract

Dissolved oxygen (DO) affects ecosystem function, biodiversity, and biogeochemistry in the ocean. There is a critical need to understand the dynamics and drivers of low oxygen events, or hypoxia, in the tropics, as these events are likely under-reported and poorly studied relative to their temperate counterparts. From September 2019 to September 2021, we conducted an intensive observational study of Bahía Almirante, a shallow, multiple-inlet tropical estuary, in the Bocas del Toro region on the Caribbean coast of Panama, which has experienced documented hypoxia and warming events with adverse impacts on marine organisms. We examine the physical processes that are important in regulating hypoxia and temperature inversions in Bahía Almirante. DO reductions correspond to periods with high freshwater input, including direct precipitation, resulting in strong salinity stratification that isolates bottom waters, allowing biological oxygen demand to draw down DO. Evidence indicates that lateral advection can contribute to reoxygenation events, and the relationship between near bottom DO and bottom salinities in the mid bay and back bay is consistent with deep water renewal as the mechanism for bottom water ventilation. These hypoxia and temperature inversion events impact the biological communities of Bahía Almirante, and the physical dynamics that regulate these coincident and persistent stressors for marine organisms are likely present in other shallow, tropical estuaries. Last, we will present preliminary results from a regional numerical circulation model under development called, “Modelo de Archipiélago de Bocas” (MAR-Bocas).

Bios

Kristen Davis is an Associate Professor in the Department of Civil & Environmental Engineering at the University of California, Irvine. She is a physical coastal oceanographer who studies how physical processes shape coastal waters – combining principles of fluid mechanics, oceanography, and ecology. Kristen earned a Ph.D. in Civil & Environmental Engineering at Stanford University in 2009, was a postdoctoral researcher at the Woods Hole Oceanographic Institution and the Applied Physics Laboratory at the University of Washington, and joined the faculty at UC Irvine in 2012. Leading the Coastal Dynamics Laboratory at UC Irvine, Dr. Davis uses both field observations and numerical tools to examine circulation in the ocean, its natural variability, and influence on marine ecosystems and human-nature interactions. Her recent research is focused on understanding nonlinear internal wave dynamics, circulation on coral reefs, and strategies for marine carbon dioxide removal, including seaweed cultivation.

Annie Adelson is a graduate student in Physical Oceanography at Scripps Institution of Oceanography, advised by Geno Pawlak. Broadly, she is interested in estuarine and coastal ocean processes and biophysical interactions. Her dissertation is focused on the physical dynamics that contribute to hypoxia in tropical estuaries, with her research conducted in Bahía Almirante.

Andrew Altieri

University of Florida



► Patterns of coral reef resilience to ocean deoxygenation

Abstract

Ocean deoxygenation in coastal marine ecosystems is accelerating globally due to eutrophication and climate change. While the response of biological communities and their trajectories of recovery are well understood in temperate regions, we know relatively little about how tropical ecosystems respond to low-oxygen events. Here I present the results of recent synthetic and empirical work that establishes the potential for resilience of coral reefs to ocean deoxygenation. I first place coral reefs within a contextual framework with other tropical ecosystem types in their general response and recovery potential following hypoxia. I then examine several case studies that suggest how coral reef communities are likely to shift due to variation among functional groups in their tolerance to hypoxia and recovery times following low-oxygen events. I conclude by reviewing the observational and mechanistic evidence that underlies that apparent ability of members of coral reef communities to tolerate hypoxia. Despite documented occurrences of mass mortality associated with hypoxia on coral reefs, we suggest that reefs are likely to adapt and change with the onset of ocean deoxygenation.

Bio

Dr. Andrew H. Altieri is an Assistant Professor in the Environmental Engineering Sciences Department at the University of Florida. He earned his B.A. in Marine Biology from U.C. Santa Cruz and Ph.D. in Ecology and Evolutionary Biology from Brown University. Dr. Altieri was a staff scientist at the Smithsonian Tropical Research Institute in Panama before joining the faculty at UF. His research group examines the response of coastal ecosystems to global change. Dr. Altieri's research group is interested in how anthropogenic factors (e.g., species extinction, invasions, habitat degradation, climate change, overfishing) interact with biodiversity, species interactions, and emergent ecosystem functions. Much of his work has focused on the dynamics of ecologically important habitats created by living organisms including corals, mangroves, seagrass, and shellfish. Of particular interest is the study of ecological impacts of ocean deoxygenation. This work, which started in temperate estuaries, has shifted to tropical ecosystems and grown to employ an interdisciplinary approach that spans from organismal responses to community interactions.



Eileen Haskett

STRI



Jimena Pitty

STRI

► **From the station to the street: Incorporating STRI climate science into public education initiatives**

Abstract

In an effort to bridge the gap between climate research performed at STRI and the understanding of pertinent findings by local citizens, the STRI Bocas Research Station and the STRI Punta Culebra Nature Center have collaborated to create outreach programs that educate local Panamanians on STRI-backed climate and environmental research relevant to their community. Jimena Pitty and Eileen Haskett will discuss past, current, and future projects that aim to strengthen STRI's relationship with the public and build a foundation and appreciation for science amongst community members, such as incorporating the station's work on marine hypoxia into educational games and modules for local schools, piloting teacher training workshops centered on incorporating creativity in the classroom, and an upcoming citizen science experiment to determine the root cause of algal deposits on a popular beach in Bocas Town.

Bios

Eileen Haskett is a Canadian marine biologist and program coordinator residing in Bocas del Toro, Panama. She works on behalf of the Bocas Station to increase public knowledge of STRI research in tandem with local educators.

Jimena Pitty is an educator and the Manager of STRI's Punta Culebra Nature Center (PCNC). Jimena earned a B.A. in International Affairs and Latin American and Caribbean Studies from the Florida State University. She worked at the United Nations Children Fund Latin American Regional Office in Panama and in the Country Office in Brazil. After completing her M.Sc. Biodiversity, Environment and Sustainable Development from the Universidad de Navarra in Spain, she ventured into the world of science education and programming. Teaching Biology and Environmental Science at a high school level was a passion of hers before joining STRI as the Science Education Specialist and later as the PCNC Manager. She creates and oversees several education programs that encourage science learning and curiosity among teachers, students and general audiences connecting them to the research that goes on behind the scenes in tropical ecosystems.

Noelle Lucey

STRI



► What are the biological consequences of hypoxia in Bocas del Toro?

Abstract

Deoxygenated waters are occurring more regularly in tropical coral ecosystems, and they are thought to cause stress for the animals that live within them. Unfortunately, we do not have a good understanding of how much oxygen animals really need, or how much oxygen is available in their habitats. In this talk I will present new data on the physiological tolerances of corals and associated reef animals to low oxygen and to warming. These tolerances, measured in the Bocas Research Station laboratories, identify the oxygen and temperature limits of these animals (i.e., how much stress can they take). Using hourly temperature and oxygen records on 5 distinct reefs in Almirante Bay I have identified how stressful the oxygen and temperature conditions on the reefs currently are by relating the measured physiological limits of corals and associated reef-invertebrates with the known occurrence and severity of low oxygen/high temperature conditions on reefs. I will discuss what these organisms do when there is not enough oxygen in the water to breathe, which ones suffer the most, and which ones do not suffer at all. We can use these biological responses to predict how marine ecosystems in this area will change in the future.

Bio

Noelle Lucey is an organismal marine biologist with a focus on animal physiology. Using long-term laboratory manipulations and natural field experiments, she advances our understanding of how different types of marine animals survive climate change. This involves merging the disciplines of physiology, ecology, and physical oceanography. Her current research identifies physiological adaptations, extirpations, and biogeographic range shifts arising from climate-driven extremes in tropical ecosystems. Lucey received a BS in Marine Biology and MA in Marine Affairs and Policy from the Rosenstiel School of Marine and Atmospheric Science, University of Miami, USA. She received her doctoral degree in Marine Ecosystem Health and Conservation from the University of Plymouth, UK and University of Pavia, Italy. Lucey is currently a postdoctoral fellow at the Smithsonian Tropical Research Institute and based full-time at the Bocas Research Station.

Carolina Cesar

STRI



► Coral susceptibility to bioeroding organisms under hypoxia

Abstract

Ocean deoxygenation driven by warming and eutrophication is increasing rapidly worldwide. Tropical coastal waters and their coral reef ecosystems are very susceptible to low levels of oxygen (hypoxia), as it can negatively impact their physiology and weaken their structure. This potentially makes them more prone to bioeroders, such as boring bivalves, which additionally can have a negative impact on corals reef health causing structural damage. This study determines the abundance of bioeroders in the common coral *Siderastrea* spp. along a natural hypoxia gradient in Bahía Almirante, Bocas del Toro. We did this by surveying the prevalence of boring bivalves in *Siderastrea* spp. colonies along a 50 x 2 m transect in two sites with different levels of oxygen at 12 m depth. To determine if corals are more susceptible to bioeroders when exposed to hypoxia we also evaluated the hypoxia tolerance of the boring bivalves compared to their coral hosts. We found coral colonies from hypoxic sites had significantly more boring bivalves compared to the colonies from the normoxic site, and from photos and dissected coral colonies we found the genus *Lithophaga* was the most common bivalve species. Laboratory respirometry trials suggest that the hypoxia tolerance of *Lithophaga* bivalves is significantly higher than the *Siderastrea* coral colonies Together these results indicate that coral structure and physiology are threaten by deoxygenation. As a future direction, more work is needed to disentangle the effects of pH from oxygen.

Bio

Carolina César Ávila is a marine biologist graduate from the Maritime International University of Panama (UMIP) in 2021, now working in 2021, now working in the Smithsonian Tropical Research Institute. She is a Research Technician in the NSF Project on the Biodiversity and resilience of corals and their microbiomes in response to ocean deoxygenation. She is researching the effects of hypoxia in corals, as well as monitoring the long-term temperature and oxygen trends occurring on coral reefs. Her interests are climate change, coral reef ecology and physiology, chemical and physical properties of the ocean, and ocean policy.

Leon Mach

School for Field Studies, Bocas del Toro, Panama



► **Wildlife tourism maps and the governance of environmental collapse**

Abstract

In Bocas del Toro, Panama, tourists are shuffled on panga boats between Dolphin Bay, Starfish Beach, and Sloth Island in hopes of seeing and photographing those species specifically – one at a time. The aim of this research was to explore the governance of the wildlife tourism industry by gauging tourist satisfaction and assessing the relationship between industry operations and tourist demand. A mixed method approach utilized semi-structured interviews with tour operators and surveys with wildlife tourists. Empirical evidence demonstrates that a collectivist organization with de facto ownership/control of wildlife tourism sites has not been effective at self-governing towards a sustainable industry capable of ensuring the well-being of target species and conservation. Communication issues between tourists and guides are also shown to be behind the creation of the de-territorialized and reductionist (and consequentially detrimental) wildlife tourism attraction map. This, along with survey results demonstrating unaddressed demand for providing more education, better wildlife treatment and conservation, together, poke holes in the assumption that industry governance might be best steered by global efforts to shift consciousness to include demand for wildlife equity. Findings instead place priority on the need to interrogate the financial incentives that drive industry governance and towards understanding how the profitability of wildlife equity and conservation could be empirically demonstrated to those who control industry operations.

Bio

Leon Mach is an Associate Professor of Environmental Policy and Socioeconomic Values at the School for Field Studies in Bocas del Toro, Panama. His research, which focuses on the human dimensions of natural resource governance and sustainable tourism, has been published in top-tier journals and has been implemented in community development and resource conservation initiatives in many coastal communities. Leon was a 2021/2022 Fulbright Scholar Award recipient and co-founder of both the International Association for Surfing Researchers and SeaState Educational Travel.

Six stakeholders and community members from Bocas del Toro have been invited to participate in this event. They will enrich our discussion with their deep local knowledge. We welcome them to STRI and look forward to hearing their thoughts and opinions.



► Darlenys Villareal

She is currently regional director of the Ministry of Environment in Bocas del Toro, she is an engineer in watershed and environmental management, has the mission and vision to protect and conserve the natural resources of the province, has worked in different companies and institutions, also has a teaching degree in diversified media, which has allowed her to provide education and awareness to young people and adults to take care of the environment.

► Eligio Castillo Morales

**Head of the administrative unit ñökribo Agency
Regional Directorate Ngäbe - Buglé**

Since 2014 to date, he works at the Ministry of Environment, of the Ngäbe - Buglé regional directorate. He has contributed to the process of studies and creation of the protected areas Damani - Guariviara and Escudo de Veraguas.

Contributed to the formation of community-based organizations (CBOs), with a view to strengthening local capacities and promoting entrepreneurship. He has been part of different consultancies in protected areas. He is currently in the final phase of his agroforestry engineering degree at the University of Panama.



► Alberto Saa

Oceanographer at the Aquatic Resources Authority of Panama in the province of Bocas del Toro, is part of the Research and Development Department.

He is currently in charge of the biometric data collection of the Caribbean spiny lobster in B.D.T. within the framework of the Integration Policy of Fisheries and Aquaculture and the regulation OSP-02-09 of the Central American Integration System (SICA) that seeks to protect the peak breeding season of the *Panulirus argus* lobster.



► **Dra. Vanessa V. Valdés S.**

University of Panama, Bocas del Toro Regional University Center and the Technological University of Panama, Bocas del Toro Regional Center

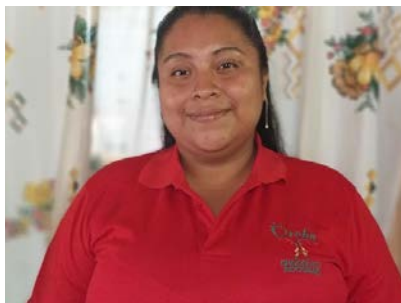
She has been a Regular Professor level III and researcher at the University of Panama for more than 27 years and at the UTP for more than 10 years. She has a PhD in Natural Resources Management, as well as master's degrees in Biology, Environmental Education and Higher Education. She has dedicated most of her life to research and publications in the area of ecology, environment and university teaching. She participates in research, in which she integrates her students so that they learn and understand the importance of research as an engine for the development of a country. She also supports SENACYT in the evaluation of projects for financial support.

► **Eduardo Sinclair Nelson Griffith**

Chemist by profession with vast experience in analytical instrumentation, water treatment and purification, mathematics teacher in middle and high school, physics and chemistry teacher in high school.

General Manager of the Bocas Recycle Center, recycling center in Isla Colon, Bocas del Toro and until recently served as project coordinator and planner and compliance officer in the Municipality of Bocas del Toro.

Enthusiastic lover of nature, the environment and everything related to the care, protection, conservation, and preservation of our ecosystems.



► **Nicooll Abrego**

Secretary in the reservation department at Örebä Chocolate



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