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Working it Out Together: Toilets, Tourists, and an Interdisciplinary Experience

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In 2019, interdisciplinary teams of anthropology and environmental engineering PhD students went to Placencia Village, Belize to study stakeholder-driven issues related to coastal resilience. Our team explored wastewater management on a few of the more than 400 small cayes peppering the Belize Barrier Reef. These islands have transitioned from temporary sites for overnight fishers to crowded tourism destinations. Wastewater management has struggled to keep pace with these changes, spurring concerns about the health of the reef. Our task was to construct contextualized system dynamic models which would be useful to those concerned. Along the way however, we ran into tensions related to the underlying logic, and representations of people, in mathematical descriptions of social and technical configurations. This article lays out the context and lessons learned from our encounter with interdisciplinary systems modeling.

Keywords: interdisciplinary, wastewater, environment, mathematical modeling, tourism

It is 9 a.m. as we pile into a boat in the coastal town of Placencia Village, Belize. The temperature has already reached 82 degrees, and the fishers have long since gone for the day. Our small vessel is making its way to Laughing Bird Caye National Park.

The 1.8-acre park, one of eight islands we'll visit over the next two weeks, is nestled amidst the Belize Barrier Reef, 11 miles from Placencia's southernmost shoreline. The sea is smooth, and the rhythmic breaking of the waves against the bow is hypnotic. It takes a little over an hour to reach our destination. A smiling ranger greets us upon our arrival.

He gives us a short presentation on the ecological importance of the marine park under a large pavilion with picnic tables in the center of the Caye. Down the beach to our left is a ranger house and a bird sanctuary inaccessible to tourists. To our right, there is a small gift shop and two public bathrooms. You can count the minutes, on one hand, to walk from one end to the other. The series of plastic tanks and pipes behind the bathrooms pique our interest the most.

We are two amongst a group of eight Ph.D. students in Belize funded by a National Science Foundation (NSF) interdisciplinary traineeship from the University of South Florida. The traineeship brings together anthropologists and engineers to investigate different forms of coastal resilience. The goal for the two of us is to develop a complex model of wastewater treatment for some of the small islands off the coast of Belize.

For the past six months, the cohort of students has received training in "System Dynamics" models, which is a method for analyzing the interactions between variables to understand their behavior over time (e.g., Meadows, 2009). We have attended weekly meetings to explore case studies and received certifications through online modules. The trip to Belize is a chance to apply what we've learned and combine our disciplinary knowledge with real-world problems identified by local organizations in Placencia (e.g., Klein, 2014). Each engineer is paired with an anthropologist to explore a particular problem identified by a stakeholder group to one of the project's PIs.

Combining disciplinary knowledge is both methodological and theoretical. Methodologically, it is primarily anthropology—we engaged in informal interviews with key stakeholders such as seaweed farmers, tour operators, island managers, maintenance workers,

Figure 1

The Group's Project Manager, Christy Prouty [Right], Explaining the History of the Wastewater Treatment System on Laughing Bird Caye and How It Works

(Photo by Maya Trotz)

and environmental management professionals. We also observed together several individual treatment systems, tracing their designs and the biochemical processes they provoke. Our different disciplinary backgrounds shape the approach to these methods and what was gleaned from them, however. As an anthropologist who studies technology and development, Alex's focus is drawn to the diversity of strategies people employ to treat wastewater on these small remote islands and the social organizing and systems of meaning going along with them. Daniel, an environmental engineer, is paying attention to the function of the water treatment systems themselves, exploring innovative and effective ways of removing nutrients from wastewater. The challenge is how to integrate these perspectives into a singular model.

After multiple island visits, we started to have some confidence in describing the systems. A list of key variables emerges: nutrient loads, fuel costs, access to fresh water, fish biomass, management, pipes and materials, available land, political boundaries, tourists, park fees, and coral cover. We've identified them based on the implicit goal of our model, which is to improve the environmental health of the reef while maintaining the existing island activities (typically tourism related but not in every case).

Creating our initial model, not yet quantitatively verified, includes conceptualizing associations (either positive or negative) between variables by drawing arrows indicating the type of relationship. For example, as more tourists visit an island, they produce more wastewater and higher nutrient loads; therefore, tourists □ + nutrient loads. Similarly, as coral cover increases, there is more habitat for fish, thus coral cover □ + fish biomass. The expectation is that eventually, these relationships would be modeled using differential equations, which express the rate of change between variables (e.g., as one causal variable changes, what is the rate of change in the variable it has influence over).

For now, we combine all the variables in a hand-drawn map to reflect their relative influences within a system. Our training suggests linking variables together in this way will help us organize and understand some of the complexities of wastewater treatment on the cayes. Working out the relationships among these variables while sitting on the balcony of our beach cabana, both with a thin glossy shine from the sweat on our faces, we stall, however.

Our negotiations begin to wrestle with the old incompatibilities between the positivist physical sciences and the interpretive social sciences—namely, the stability and nature of human behavior and the politics of choice. What is the relationship between tourists and coral cover? How do we elucidate the politics of choice in our dynamic model? Working it out together became a slow process of discussion and reflection. What follows is our account of the context and experiences from which these frictions arose.

Describing the Problem: The Ecological Perspective

Over the past five years, the lead PIs of our research team have been studying infrastructure and development on the peninsula and established a rich network of relationships throughout the community. Our introduction to the problem of *wastewater treatment along the cayes* came through meeting the leadership of a community-based coral restoration NGO, Fragments of Hope, and visiting cayes with some of their staff. The project operates out of Placencia on the south coast of Belize and is one of the most successful coral replanting programs in the Caribbean (e.g., Carne et al., 2018). They have replanting sites on three cayes, with the primary one being Laughing Bird Caye National Park. Since 2006, they have replanted over 49,000 nursery-grown corals around Laughing Bird bringing the island's coral cover to almost 75%. Consequently, it is one of the main attractions for snorkeling trips out of Placencia. The need for a coral restoration project is a complicated story of environmental conservation, development, wastewater, and our changing climate.

Every day as tourists take the hour-long ride out to Laughing Bird, the boat weaves between and passes dozens of islands. Laughing Bird is only one of over 400 cayes studding the Belize Barrier Reef, which itself makes up almost 80% of the total area of the Mesoamerican Reef system. The second-largest barrier reef in the world, the Mesoamerican Reef crosses the entirety of Belize's 190 miles of coastline and contains some of the highest biodiversity on the planet, including 65 of the 70 coral species found in the Caribbean. These corals support habitats for sea turtles, hammerhead sharks, upside-down jellyfish, spotted eagle rays, octopus, conch, lobster, and more than 500 species of fish. Famously,

Charles Darwin referred to it as "the most remarkable reef in the West Indies." Reef conservation has been part of the dialogue in Belize since it gained independence in 1981. Laughing Bird, for instance, was designated as a protected area under the national park system in the early 1980s before being upgraded to a National Park 10 years later. It is now one of seven marine protected areas along the reef. In 1996, the Belize Barrier Reef became a UNESCO World Heritage Site, with Laughing Bird considered a prime jewel.

Tourists Enjoying a Snorkel around Laughing Bird Caye National Park

(Photo by Victor Faux)

The Belize Barrier Reef is and has always been the backbone of coastal livelihoods in Belize. Over the past century, as populations along the coast steadily increased, so has the extent and scope of the reef's economic activity. What were initially local fisheries supplying the coast and interior became major players in the global lobster and conch trade in the last half of the 20th century. Over the past four decades, this has changed, as primary livelihoods convert from commercial fishing to tourism related. The government currently estimates the tourism sector supports a quarter of all jobs in Belize. The shift began in the 1980s when the newly formed Belizean government was searching for a way to modernize the nation. Supported by the UN Development Program, the government initiated the Belize Public Investment Project, which prioritized ecotourism as a central economic development strategy (Pearce, 1984). For two decades, eco-tourism remained small-scale, providing measurable economic benefits to communities but not enough capital for state growth (Lindberg et al., 1996).

Tourism in Belize changed in 2000 with the introduction of a cruise ship port in Belize City. The massive floating hotels ushered in rapid growth to northern Belize, as ships brought 3.5 tourists per eco-tourist by 2002 (CESD, 2006). The location of the cruise ship port in Belize City encouraged extensive growth on the largest barrier islands to the north. During this same period, residents of Placencia, located in southern Belize, began investing more heavily in tourism, preferring its perceived stability compared to the volatility of the global fisheries (Key, 2002). Investment in large-scale tourism slowly made its way south with a new cruise ship port developed on Harvest Caye just off the coast of Placencia in 2017. Currently, over 200 ships carry nearly a million people, double the population of the country, to Belize every year, making it the fastest-growing tourism market in the Caribbean in 2018. The wastewater infrastructure to accommodate this growth has struggled to keep pace, both on the cayes and the mainland (Niña, 2011).

The impacts of development have weighed heavily on Belize's reefs, which, like reefs all over the world, are under considerable duress from our changing climate. As sustained elevated water temperatures stress corals, leading to bleaching events, the acidification of the ocean slows the growth of their unique calcium carbonate formations. The inundation of nutrients from inadequately treated wastewater exacerbates the effects of climate change by upsetting the ecosystem's delicate balance. We got some insight into these dynamics during a stakeholder consultation meeting in Placencia. Under a large tent in the middle of an outdoor basketball court, Brian Lapointe of Florida Atlantic University presented the culmination of 25 years of research suggesting it is the ratio of nutrients, more than the nutrients themselves, that are detrimental to the reefs. Specifically, human waste and agricultural runoff contain high levels of nitrogen compared to phosphorus. High relative levels of nitrogen lead to excessive algae growth, which outcompetes coral for the remaining phosphorus making it difficult to recover from bleaching events (Lapointe et al., 2019).

The sources for these nutrients are ubiquitous throughout Belize. During the same wastewater consultation meeting, a Canadian engineering firm, speaking into microphones and backed by a PowerPoint presentation on a projection screen, shared the results of their 12-month nutrient study of the immediate areas surrounding Placencia. Their analysis pointed to agriculture runoff from banana farms and shrimp aquaculture operations as well as poorly treated wastewater from resorts and residential homes.

These dynamics seem to be at play up and down the coast. For instance, in 2009, the combination of climate change impacts and tourism development led to the reef's UNESCO status being in danger. Through monitoring, advances in technology, and more environmentally conscious development, the health of the reef has improved. But its fate hangs precariously in the air, hinging on how Belize proceeds with future development.

Let's go back to those pipes and tanks behind the bathrooms on Laughing Bird Caye. During the high season, which runs from approximately December to June, the island will receive over 100+ tourists a day. A typical day trip might include getting there by 9:30 a.m., going

Silke Caye Is Only a Few Meters Wide, Making It Difficult to Install a Robust Wastewater Treatment System

(Photo by W. Alex Webb)

for a snorkel around the island, taking a break for lunch provided by the tour operators, and then a second snorkel in the afternoon before heading back. Throughout the day, of course, tourists make use of the restrooms. The Southern Environmental Association, or SEA, manages the park and recently upgraded the wastewater treatment system to include a biodigester and leach field to help meet the demand.

Standing in the noon sun, after our first snorkel trip and lunch, we inspected the system with Daniel describing how each part works. The wastewater travels from the bathrooms to a large tank, the first of two biodigesters. The biodigester works like a septic tank and collects solids in the water by allowing them to sink to the bottom of the tank; all the while, bacteria and other microorganisms break down and absorb pollutants in the water. The water exits the first biodigester into a second biodigester that operates identical to the first. Allowing wastewater to slowly fill two biodigesters extends the time the water is treated. After the second biodigester, the water travels through a rock filter and finally into a plot of soil with a plastic lining underneath called a leach field. Leach fields absorb nutrients from wastewater before the water sinks to the water table or other nearby water bodies but are only viable on islands with enough landmass and the right soil characteristics. Silke Caye, another high-volume tourist destination, for example, is too small to install one.

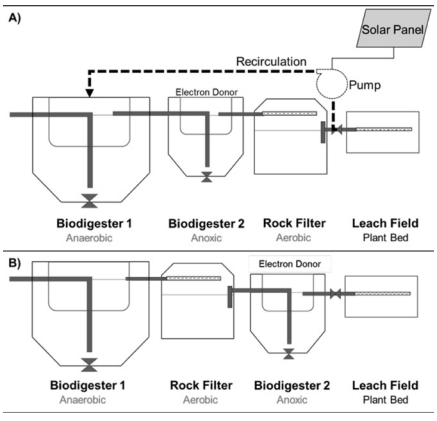
One of the biggest challenges to wastewater treatment is access to fresh water. Cisterns are the only method for storing water on the cayes, although some islands supplement with "wells," which consist of digging a hole in the ground wherever the land depresses to collect rainwater. Laughing Bird does not have a cistern for their bathrooms; instead, guests use seawater from 50-gallon drums to refill the toilet tank after each use. The high salt content in seawater may negatively impact the efficiency and capacity of the system—something Daniel took note of to experiment in his lab back home. Other islands use different strategies. For instance, arriving in Tobacco Caye, we meet Roy while he's pumping water from one cistern into another. He is the property manager for the four hotels on the approximately 3-acre landmass. The resorts are collections of raised multiroom buildings with bottomless cement septic tanks underneath. Throughout the small island, there are enough cisterns to hold tens of thousands of gallons of water. While they had secured enough water to run the toilets, the bottomless septic tanks presented another potential problem. Bottomless septic tanks require a minimum of two feet of soil to filter out waste. The sandy porous island soil is unlikely to meet this requirement, meaning in the event of storm surges or rainy weather, the rising water table may communicate with the sludge in the tank carrying it out to the nearshore coastal environment. Roy suggested they installed them because pumping out a filled septic was not an option due to the island's remote location and frequent traffic of multi-day visitors—another technical problem for us to consider.

Another island, Carrie Bow Caye, is home to an eco-conscious research station operated by the Smithsonian. They have installed three large composting toilets to support up to six researchers living on-site. But the toilets become overwhelmed in the high season when visiting tour groups come; this was something underestimated in the original design. Additionally, composting toilets need frequent maintenance. The research coordinator, Zac, expressed openness to any innovative designs our engineers come up with, although he also was concerned about their lack of freshwater and the cost of installing a system on the remote Caye.

It was apparent over our trips that there is no silver bullet for wastewater treatment for the cayes. The existing built infrastructure, the scope of activities, and the physical environment all influence the treatment of wastewater. Although an affordable, saltwater-friendly design would likely be a welcomed starting point. Two weeks later, in USF's library, we are once again drawing maps of our systems model. We abandoned a universal model because the dynamics of treatment

Two Options for Improving Waste Treatment Performance at the Laughing Bird National Park Using the Existing System

Option A) is more complex and efficient due to recirculation, but option B) has a smaller operation and maintenance cost. (Illustration by Daniel Delgado)



options across sites are too complex. Instead, we began to make a model just for the system at Laughing Bird as a microcosm of these dynamics. As an anthropologist, however, one of Alex's challenges to making these models is they rely on a "natural" way for humans to behave, something up for considerable debate (e.g., see Wynter, 2003; Strathern, 2017). By relying on variables and their associations, system dynamics models make it difficult to include the role of choice and the motivations for upgrading systems. In our Laughing Bird case, we initially implied that fewer tourists would come to the island if the coral cover wasn't so spectacular. This logic suggests economics as the motivating factor for maintaining coral cover. For Daniel, this appeared intuitive based on the current operations of the islands. These kinds of fixed relationships are also easier to design and engineer at scale. Alex wondered, however, if we can really be certain of the relationship between tourists and coral cover.

The Tourist Imaginary and Environmental Health

Snorkeling through the restored reef at Laughing Bird Caye National Park is a beautiful experience. The water is warm, the colors bright, and there is a magic to floating amongst the enormous boulder and elkhorn coral formations and all the life they support. The signs, instructions, tour guides, and island manager all present the corals as synonymous with the value of the tourism experience.

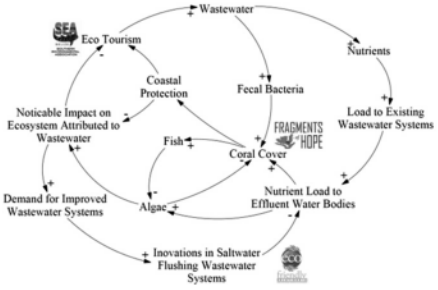
But this isn't to say our model should indicate that fewer corals will equal fewer tourists, less coral cover □ - tourists. During a community meeting, Lisa Cairn, the director and founder of Fragments of Hope, shared her recent research trip in Cancun, Mexico. The ecosystems she studied, still very much a part of the Mesoamerican reef system, have been devastated over years of mass tourism development. Despite coral cover being down, however, more tourists continue to come. This phenomenon is observable throughout the Caribbean. There has been a measured decline in coral cover throughout the Caribbean over the past few decades, yet Caribbean tourist arrivals nearly doubled from 16 million in 1995 to 30 million in 2018. Tourism in Belize skyrocketed during this period, from 130,000 visitors in 1995 to almost 1.5 million in 2018 (Caribbean Tourism Organization, 2019). The dynamics between coral cover and tourists are particularly telling in Ambergris Caye, the most popular island in Belize, with a coral cover estimated at only 12%.

There is a tourism imaginary associated with the Caribbean. Typically, Caribbean marketing revolves around the 3 S's: Sun, Sand, and Sea. The degree to which coral cover, and the many ecosystem services associated with it, contribute to this equation is uncertain. Nearly every island we visited had other tourists on them, although they were just as often sunning themselves and enjoying drinks on the beach as they were snorkeling. It was at this point that we started to approximate an awkward truth for positivist thinking. If SEA maintains the health of the reef surrounding Laughing Bird, they will attract both tourists who are coral enthusiasts and those who are, for lack of a better word, indifferent. If the health of the reef suffers, tourists will likely still come, and it will be up to the management and tour operators whether to promote the ecology of the system or just the experience of being on the beach—your skin touching the warm water, your face in the tropical sun. Alex's concern is using economics to justify the relationship between tourists and environmental health in our model. If the health should fall and tourists still come, as they have throughout the Caribbean, what is the justification for change? A lot is occurring in the arrows between the variables in our model.

Figure 5

Final Rendering of Conceptual System Dynamics Model

(Illustration by Daniel Delgado)



Daniel was concerned that without some consensus on prototypical behavior, we wouldn't be able to design a model at all. We finally settled on articulating eco-tourists as being less likely to come to an island without a reef. Although Alex still has lingering doubts about conceptualizing a model for an eco-tourism product when mass tourism, on nearby Harvest Caye, stands to upset it. As it is, both these futures exist as forks in the road. What remains now is a constellation of tensions between the ability of technology to rise to the occasion of treating the waste of the increasing number of visitors, the political will to slow tourism growth to match the capacity of the existing systems, and linkages between ecosystem health and tourism products.

Concluding Thoughts

The purpose of this article is to outline an interdisciplinary encounter as experienced by an anthropologist and engineer. Integrating our points of view into a model was largely a conceptual and intellectual exercise. It was one mediated through multiple conversations. Engineers understandably tend to want to fix sets of relationships to make them stable or predictable over time. Doing so requires reducing complexity to measurable and manageable variables, including the behavior of people. Anthropologists,

equally understandable, prefer to view these dynamics creatively, to understand them while imagining new ways of organizing. It was in this push-and-pull state between the matters-of-fact and potential-could-be where we spent much of our time.

However, we would note the same way it is potentially hazardous to attempt to engineer a system that purports more stability than is present, the anthropological tendency to deconstruct and pontificate on the life of the mind can be equally perilous as problems like leaky wastewater treatment persist. We both walked away with a sense that the expectations of complex models that include people should be softened. Instead of a rigorous representation of reality, system dynamics models may be more useful as a "backbone" or starting place for visualizing and thinking about the different aspects of a problem.

Based on his experience working with anthropologists, Daniel is committed to finding ways to include different parties in the analysis of these models, to approach more sustainable solutions. Alex's hope in the future is to find ways to articulate human agency and historical structures into engineering models better while also remembering that the material aspects of projects have their own power, requirements, and agencies as well (e.g., Latour, 2005).

There is no shortage of ingenuity or energy from our engineering and anthropology colleagues, tour operators, fishermen, island managers, local scientists, and community leaders regarding these challenges. The question, in Belize and elsewhere, is a well-worn one. How can these small coastal communities simultaneously embrace global tourism, improve the lives of their citizenry, and manage the health of their unique environments? While we certainly don't presume to know the answer, we're grateful and optimistic to be part of a community of dedicated people determined to find out.

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