UPWELLING

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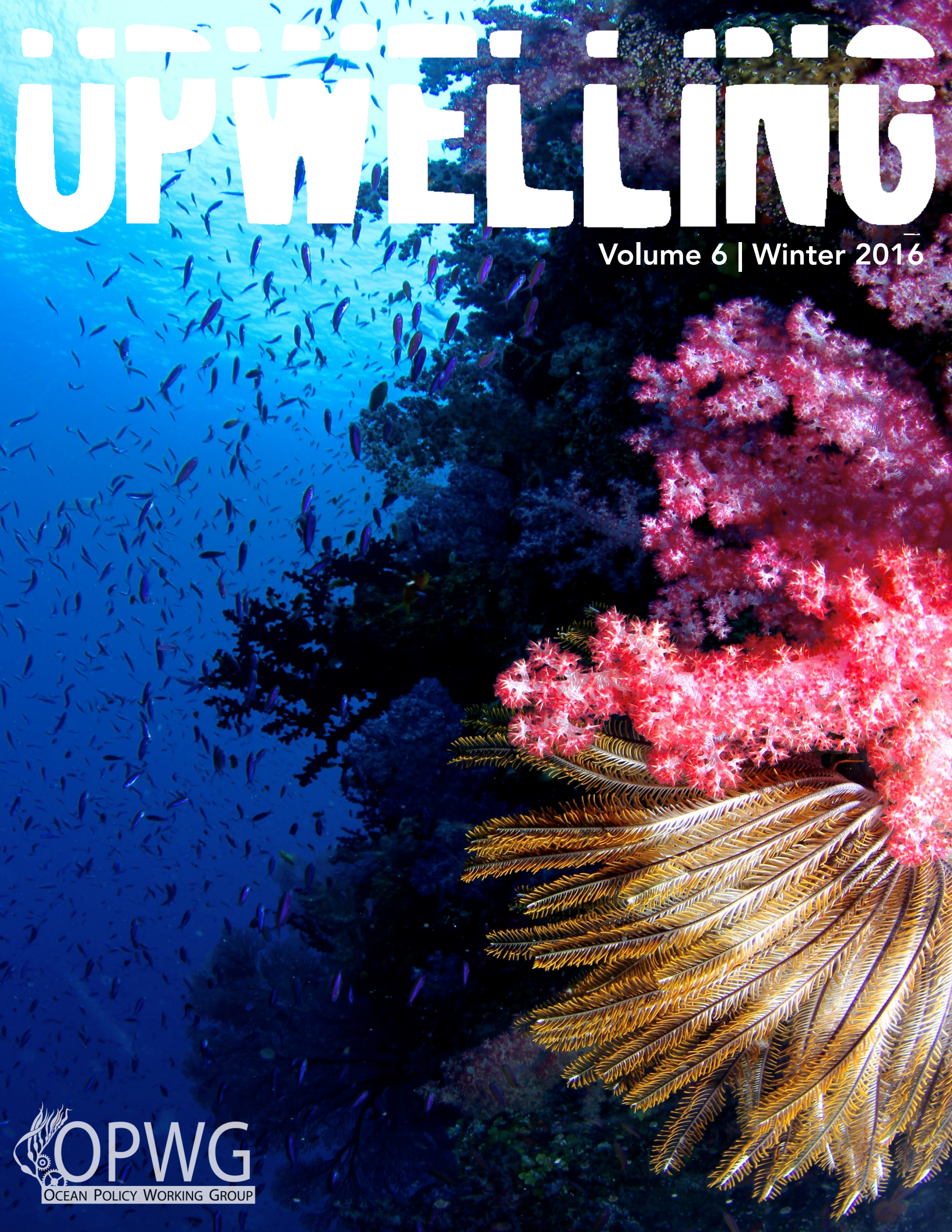

OPWG
Ocean Policy Working Group

A Note from the Editor:

The sixth volume of UPWELLING highlights work from Duke University students, faculty, staff and alumni from numerous departments and disciplines, including the Nicholas School of the Environment, Duke Law School and the Nicholas Institute for Environmental Policy Solutions.

I hope you are inspired by the work of our contributors, whose stories and photographs truly capture the interdisciplinary approach needed to address marine and coastal challenges.

A special thanks to the Nicholas School of the Environment, the Graduate and Professional Student Council and the Duke University Center for International Studies for their continued support of the Ocean Policy Working Group and UPWELLING.

Sincerely,

Jill Hamilton
OPWG Publication Coordinator
MEM-CEM ‘18

In this edition

4 **A review of the impacts of fisheries on open-ocean ecosystems**
Guillermo Ortuño Crespo

6 **Another victory for the Atlantic coast, but will it last?**
Anna Windle

8 **Pollution in paradise**
Reflections on Waste Management in Bocas del Toro, Panama
Justin Pearce, Caitlin Starks and Ashley Gordon

11 **Reflecting on a summer clerkship in environmental litigation**
Mark Patronella

12 **The not-so-common dolphin from the Southern Caribbean and Southeastern Brazil**
Paula Chavez

13 **Population structure of the Atlantic spotted dolphin (Stenella frontalis) in the Caribbean**
Roosevelt Mesa Gutierrez

14 **Update on the Nicholas Institute's Ocean Policy Program**
John Virdin

16 **I just want to say one word to you. Just one word……plastics**
William Schlesinger

Cover Image: Ian Markham
Namena Marine Reserve is the flagship of Fiji's growing network of over 300 locally managed marine protected areas.

Image on p.2: Jill Hamilton
Schools of fish gather beneath Bonaire's Salt Pier.

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Publication design by Jill Hamilton

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The Ocean Policy Working Group (OPWG) is a student organization at Duke University designed to facilitate cross-disciplinary discussions on human interactions with the ocean. Throughout the academic year, the OPWG hosts a variety of events with the purpose of exposing the Duke community to pertinent issues in our oceans. This working group strives to be a hub for ocean resources.

A review of the impacts of fisheries on open-ocean ecosystems

Guillermo Ortuño Crespo, PhD Student, Marine Science & Conservation

Through resolution 69/292, the United Nations General Assembly (UNGA) pushed for the development of an international legally binding instrument (ILBI) under the United Nations Convention on the Law of the Sea for the conservation and sustainable use of marine biological diversity in areas beyond national jurisdiction (BBNJ). In preparation, the UNGA decided to hold a series of Preparatory Committees (in 2016 and 2017) for the articulation of specific recommendations to the UNGA on the elements which are to be included in the draft text of the new ILBI. Despite widespread consensus that fisheries are a significant source of anthropogenic impact on high seas biodiversity, there has been much deliberation over if and how fisheries management should be incorporated into the new ILBI .

The magnitude and inaccessibility of open-ocean ecosystems (which include the high seas), as well as technological constraints, deterred fisheries from operating intensely in them. However, open-ocean fisheries expanded exponentially from the 1960s through the 1990s. While catches remain at best stagnant , fishing effort and all the ecosystem impacts associated with it has continued to grow in areas beyond national jurisdiction. Despite this rapid growth, ecological research in open-ocean environments has lagged behind coastal environments and has limited our understanding of their dynamics and how they may be affected by anthropogenic stressors such as fishing.

Impacts on open-ocean ecosystems have mostly been enumerated in the last decade and have yet to be aggregated in a single assessment. The Marine Geospatial Ecology Lab (MGEL) at Duke University compiled these impacts into two products: a manuscript (in review) and a policy brief prepared for the first and second Preparatory Committee meetings held at the UN in 2016:

www.nereusprogram.org/policy-brief-bbnj-impacts-of-fisheries/

MGEL's findings suggest that fisheries' impacts on open-ocean ecosystems occur across three distinct, yet interrelated, ecological scales: species, communities and ecosystems. Fisheries' impacts extend beyond the targeted species, and can affect non-target species. These impacts on target and non-target species can propagate into open-ocean communities, and may ultimately affect the stability and function of the entire ecosystem. Further, open-ocean fisheries have reduced the biodiversity and resilience of oceanic ecosystems to other stressors, such as climate change.

With this evidence in hand, should fisheries be included in the new ILBI to protect biodiversity? ■

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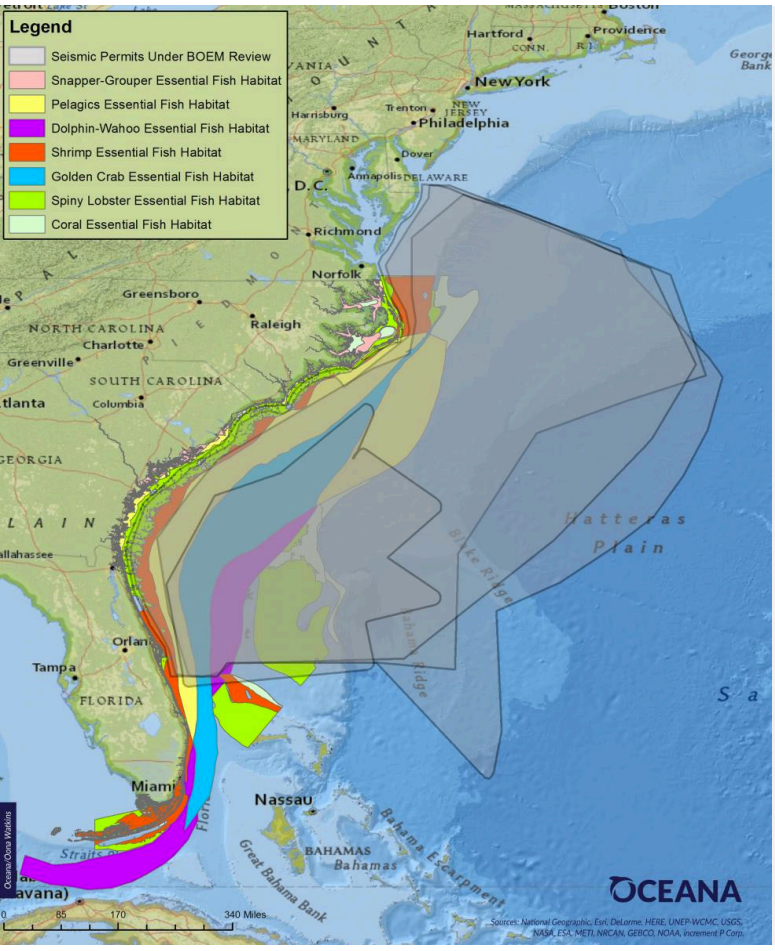
Image: Ian Markham, MEM-ESC '15
Fiji is known as the "soft coral capital of the world," made famous for its vibrantly colored Dendronephthya and Gorgonians. These organisms may prove more resilient to ocean acidification, but increasingly frequent high sea surface temperature events and severe cyclones, such as Winston, which passed directly over the Namena Marine Reserve, may prove too much for the reefs to handle.

Another Victory for the Atlantic Coast, but will it Last?

Anna Windle, MEM-CEM '18

Seismic testing, the exploration of oil and gas reserves under the seabed, uses air guns that create dynamite-like blasts. If allowed, seismic testing could disturb, injure and even kill up to 138,000 marine mammals. Currently prohibited, will a changing political climate mean an increased threat for our marine mammals and ecosystems?



> *President Obama denied all six permits to oil and gas companies wishing to conduct seismic testing off the Atlantic coast. But the fight isn't over. The president-elect has goals to reverse Obama's decision...with plans to open up the coast to offshore drilling.*
>
> *Call your legislators, share the news on social media and educate others about the harmful effects seismic testing has on marine life.*

Figure: Oceana
Seismic permits off the Eastern United States that were under review, overlaid with essential fish, spiny lobster and other marine species' habitat.

We all remember the 2010 Deepwater Horizon Oil Spill. Our media outlets were flooded with photos of birds covered in slick oil, dead fish floating on top of water, beached whales and dolphins. This tragic event occurred due to an explosion on an offshore oil rig located in the Gulf of Mexico, where 4.9 million barrels of oil spilled, impacting 8,332 different marine species.

Citizens living along the Atlantic Coast noticed the destruction the BP oil spill had on the Gulf. Enough of these people raised their voices to the Obama administration to convince them to ban offshore drilling until 2022. This was a huge victory for citizens living along the Atlantic Coast.

Seismic testing, the exploration of oil and gas reserves under the seabed, is just as damaging to marine life as offshore drilling. Vessels with seismic air guns would create dynamite-like blasts into the seabed, gathering information about the amount of oil and gas found deep beneath an area. This was planned to occur in an area twice the size of California, stretching from Delaware to Florida.

I still get excited when I look out onto the ocean and see a pod of dolphins swimming. To me, it is a sign of a healthy and thriving ocean. If seismic testing does begin along the Atlantic coast, dolphins would flee the area. Loud blasts of air occurring every 10 seconds, 24 hours a day, for days to months at a time would have extreme impacts on marine life. Seismic air guns create noise 100,000 times more intense than someone would experience standing near a jet engine. Imagine being trapped in a world that loud with no way out—this is what marine animals in a seismic testing zone would experience. Numerous studies show that seismic testing could disturb, injure and even kill up to 138,000 marine mammals up to 100 miles away from blast sites.

Additionally, declines in fish catch due to the blasts would decrease the productivity of fishing industries that in turn, could impact the marine tourism industry. Oceana released a report in 2013 that predicts seismic testing will put more than 730,000 coastal jobs at risk.

Environmental groups and coastal citizens have persevered during the past year and insisted that the federal government reconsider permitting seismic testing and use the best available technology and the least harmful methods. A public comment period and a public hearing allowed scientists, fishermen and citizens to voice their concerns about the impact on the marine life some of them depend on to survive. The collective action of concerned citizens influenced yet another important decision made by the Obama administration. With the little time he has left, President Obama has decided to deny all six permits to oil and gas companies that were wishing to seismic test off the Atlantic Coast.

But the fight isn't over. The president-elect has goals to reverse Obama's decision about the seismic testing permits, with plans to open up the coast to offshore drilling. The lack of research on the impacts of marine life, the lack of data about the amount of oil and natural gas in the region and the fact that offshore drilling is not intended to occur in the next five years makes my argument simple: there is absolutely no reason to conduct seismic testing off the Atlantic Coast. I urge you to make your voices heard. Call your legislators, share the news on social media, and educate others about the harmful effects seismic testing has on marine life.

As Rachel Carson once said:

"The more clearly we can focus our attention on the wonders and realities of the universe about us the less taste we shall have for destruction." ■

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Pollution in Paradise: Reflections on Waste Management in Bocas del Toro, Panama

Justin Pearce, Caitlin Starks and Ashley Gordon, MEM-CEMs '17

Image on p.8: Justin Pearce
While some local business advocate against littering with signs like this, solid waste management in Bocas del Toro is still a pervasive problem.

In October 2016, we were fortunate to be part of a group of students accompanying Dr. Humberto Diaz to Bocas del Toro, Panama as part of a Duke University Marine Lab course on Tropical Marine Ecology. Bocas del Toro (locally referred to as "Bocas") is an assemblage of islands off the Caribbean coast of Panama. Through a series of snorkeling surveys and field experiments, we explored the local marine ecosystems, familiarizing ourselves with the vibrant diversity of the coral reefs, seagrass beds and mangroves. In our surveys, we compared sites of varying proximity to Isla Colón, the most populated region of Bocas del Toro. While areas further from town supported thriving communities, we were caught off guard by the dramatic degradation of marine habitats close to town.

In conversations with local researchers, we learned that the pollution problems here are quite complex. The marine environment surrounding Bocas is affected by excess nutrients and sediments from nearby banana plantations, local wastewater and solid waste. While touring the residential areas of Isla Colón, we observed an abundance of trash lining the streets. In empty lots, bottles, cans and Styrofoam containers were collected in piles to be burned. This mismanagement of waste on land directly impacts the surrounding ocean, as evidenced by the alarming amount of debris floating in the water, entangled in mangrove roots and littering the ocean floor.

The lack of solid waste management infrastructure in Bocas illustrates the challenges many developing islands face regarding trash disposal. Scarce government funding and access to waste management facilities on the mainland are major barriers to proper waste disposal. Without a landfill or a reliable system in place to remove trash from the island, the locals are forced to dispose of it through other means, often by burning it or creating unsanctioned dumps. Furthermore, a lack of potable water makes the use of plastic water bottles unavoidable. This creates a conundrum in which excessive plastic waste is generated without pathways to recycling facilities, but unrestricted access to local waterways.

As Master of Environmental Management (MEM) students, we couldn't help but brainstorm some ideas that could potentially benefit places like Bocas in dealing with their waste more sustainably. Before we even understood the environmental issues facing the region, we remarked at the affordable $3 visitor entrance fee. Increasing this fee by an order of magnitude and using the additional revenue to improve waste management seems like a no brainer; however, we later learned the funds generated from this fee are rarely directed toward local development due to government corruption.

While digging around on the Internet for the latest news about Boca's environmental challenges, we stumbled upon a 2014 study by Tilmans et al., in which the authors argue for the installation of small-scale wastewater treatment through the recovery of biogas. Although wastewater management doesn't directly address the issue of marine debris, their paper spurred additional thought from our group. In Panama, where public resources are devoted to subsidizing propane gas for households, using biogas from wastewater could reduce the demand for propane. In theory, the remaining funds could be used to address the trash or poor quality drinking water.
> *continued on page 10*

Simple ways travelers can minimize their plastic waste:

- Use dry bags to keep items dry, instead of Ziploc bags.
- Bring lightweight, reusable shopping bags for souvenirs and groceries to avoid using plastic bags.
- Assemble a plastic-free meal kit including reusable silverware, plates and straws to carry with you.
- Purchase a reusable water bottle that has an all-in-one filtration system that removes viruses, bacteria and chemicals.

While the waste management and pollution issues in Bocas del Toro were conspicuous and pervasive, they did not detract from our learning about the local ecology. Instead, looking at these ecosystems in the context of local environmental problems enhanced our educational experience. Seeing the contrast between the healthy ecosystems we visited and those affected by human impacts reinforced the importance of effective management. The knowledge we have gained in the MEM program encouraged us to look at these problems from a management perspective and to think more critically about potential solutions. Overall, we would recommend this course to students who may be considering taking it next year. We would also like to thank Humberto Diaz and Beatriz Orihuela for organizing such an enriching course. ■

For more information on Duke University travel courses such as this one, visit the Duke University Marine Lab website, nicholas.duke.edu/marinelab.

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Images: Caitlin Starks
Above: On the last day of the course we visited Isla de Pájaros, a small island off Panama's eastern coast home to several species of nesting birds including brown boobies and red billed tropicbirds.

Below: The colorful Island of Colón, from the boat.

"Seeing the contrast between the healthy ecosystems we visited and those affected by human impacts reinforced the importance of effective management.

Earthjustice: Reflecting on a Summer Clerkship in Environmental Litigation

Mark Patronella, JD Candidate '18

In the face of partisan gridlock and politicized opposition to environmental science, national legislative endeavors to protect our environment have been stifled in recent years. Consequently, our judicial system represents an increasingly important tool in protecting our marine ecosystems. While a legal approach to environmental sustainability features unique challenges and frustrations, it has also yielded key victories in preserving and restoring our oceans.

This summer, I had the opportunity to see this firsthand through an internship with Earthjustice's Seattle office. For those unfamiliar with the organization, Earthjustice is an environmental nonprofit that uses litigation as a tool to further a number of important environmental causes. Many of these initiatives directly or indirectly benefit our marine ecosystems. Earthjustice has protected key species, conserved habitats, and fought to limit pollution. In the Seattle office, Earthjustice's accomplishments include protecting fragile Orca populations as well as keystone salmon species. Earthjustice has achieved these victories, and many more, by challenging government and private actors on behalf of Native American tribes, recreational fishermen and other organizations that are impacted by threats to our oceans.

The work done by my supervisors was unquestionably impressive and produced significant victories. Environmental litigation, however, is not without its challenges. I was stunned by the crawling pace and halting progress of federal litigation, particularly in the crowded 9th Circuit courts. Many of Earthjustice's efforts can span decades and feature numerous appeals before a final decision is rendered. For the hardworking attorneys leading these charges, personal dedication to environmentalism and the enormous time spent on cases renders victories uplifting and losses heartbreaking.

Additionally, the attorneys at Earthjustice must make do with the mechanisms provided by existing law. The laws protecting the environment can vary vastly by state, and the absence of legal support for a given environmental issue was a significant obstacle. Furthermore, I saw that our legal process is by no means immune from politics. The policymakers that Earthjustice seeks to impact feature a wide array of ideological backgrounds and are, in turn, influenced by a range of external political pressures. This influences the government's willingness to collaborate in some lawsuits and compromise where they are opponents in others. As a result, litigation nonprofits such as Earthjustice must understand and accommodate political factors.

Earthjustice overcomes these obstacles by delving into the various environmental law statutes, court-made precedent, and the regulatory codes. Though perhaps not the most glamorous work, this research and impressive oral advocacy skills allow Earthjustice attorneys to overcome better-funded opposition.

In addition, the benefits of procedure in environmental law is often understated. Prior to this experience, I was skeptical of the potential offered by procedural statutes like the National Environmental Policy Act (NEPA). While courts are often highly deferential to agencies' substantive decisions, an agency's procedural failure to follow federal environmental protocol opens the door for Earthjustice. The ensuing environmental lawsuits engenders consideration of environmental implications, contemplation of alternatives and increased public participation in meaningful decisions.

Finally, I was impressed by the attorneys' ability to create diverse coalitions of governments, tribes, nonprofits, fishermen and other interest groups. Assembling these heterogeneous groups and maintaining coalitions in the face of adversity allows for greater resources, influence, and likelihood of success. In employing these approaches, Earthjustice, and organizations like it, are able to use our legal system to make significant contributions to protecting our oceans. ■

"...personal dedication to environmentalism and the enormous time spent on cases renders victories uplifting and losses heartbreaking.

Image: Roosevelt Mesa Gutierrez
Long-beaked common dolphin (Delphinus capensis) from La Guajira, Colombia.

The not so common dolphin (Delphinus sp.) from the S. Caribbean and Southeastern Brazil

Paula Chavez, MEM-CEM '18

Two species of common dolphins have been recognized since the 90's: The Short-beaked common dolphin (Delphinus delphis), and the Long-beaked common dolphin (Delphinus capensis).

Although taxonomic relationships among this genus are not completely resolved, these two species are currently valid. In the Western South Atlantic, D. capensis is distributed from Venezuela through Argentina, with a new report in 2012 for La Guajira, Colombia, extending the species distribution range to the Caribbean. During 2013 and 2014, skin samples of common dolphins were collected in coastal waters of La Guajira using the PAXARMS remote biopsy system. Additionally, samples from southeastern Brazil and Venezuela were provided. When barcoding analyses were conducted using mitochondrial markers (Control Region D-loop and Cytochrome b) specimens from La Guajira and Venezuela were genetically identified as D. delphis.

Phylogenetic tools were used to assess the taxonomic identity of common dolphins from La Guajira, Venezuela and southeastern Brazil. Molecular tools were also used to determine genetic diversity and population structure of these populations. Results from phylogenetic analyses using both genes showed that common dolphins found in La Guajira/Venezuela and southeastern Brazil are phylogenetically nested within the D. delphis complex. These results also show that there is no reciprocal monophyly between both recognized common dolphin species, meaning that the distinction between both species is not clear. On the other hand, results from analyses of the mtDNA control region showed low haplotype diversity compared with common dolphin populations from the Northeast Atlantic (NEA). Significant population structure was found between La Guajira/Venezuela and southeastern Brazil in relation to the NEA populations.

These results cast further doubt on the traditional recognition of distinct species within the genus Delphinus and whether common dolphins in South America are either one or two species. Also, our results suggest that there is low connectivity between D. delphis populations of the Northeast and Southwest Atlantic. It is critical to conduct a regional study to resolve the taxonomic identity of common dolphins in the Southwest Atlantic, in order to define adequate Management Units for the conservation of the species in this region. ■

Population Structure of the Atlantic Spotted Dolphin (Stenella frontalis) in the Caribbean

Roosevelt Mesa Gutierrez, MEM-CEM '18

The Atlantic spotted dolphin (Stenella frontalis) has a large distribution through the Atlantic Ocean from the north Atlantic coast of the United States to southeastern Brazil.

Despite this wide distribution, little is known about the genetic status of its populations in the Caribbean. To date, most studies regarding this have been conducted along the North Atlantic Ocean. With the purpose of carrying out an initial approach to the genetic status of this species in the Caribbean, a genetic analysis using mitochondrial and nuclear markers was conducted, sequencing partial mtDNA Control Region and genotyping of eight microsatellite loci, respectively. Skin samples were obtained from dolphins in La Guajira (Colombian Caribbean) using the PAXARMS remote biopsy system. Also, additional samples were obtained from Islas del Rosario, the Colombian Caribbean, the Virgin Islands and Puerto Rico. Mitochondrial results showed two new unique haplotypes not reported before in the Caribbean or elsewhere in the Atlantic. Results from microsatellite analysis showed that there is not population structure between these Caribbean islands and La Guajira region; suggesting that there is a high genetic flow within populations of the Atlantic spotted dolphin in the Caribbean. It is known that this species can travel long distances and, particularly for these specimens, it is plausible that they have long range movements in response to the constantly changing resource availability along tropical waters of the Caribbean. The lack of knowledge regarding a population's genetic status represents a high risk, as designing conservation plans and recognizing external negative effects on the population become impossible. It is needed to continue sampling in the Caribbean to increase knowledge on the genetic status of S. frontalis and use that information to suggest effective conservation strategies for the species in the region. ■

"The lack of knowledge regarding a population's genetic status represents a high risk, as designing conservation plans and recognizing external negative effects on the population become impossible.

Right Image: Nohelia Farias Research team and the local artisanal fishermen who helped with field work. **Left Image: Paula Chavez** Atlantic spotted dolphin from the coast of La Guajira, Colombia.

Update on the Nicholas Institute's Ocean Policy Program

John Virdin, Director, Coastal and Ocean Policy Program

John Virdin is the Director of the Coastal and Ocean Policy Program at the Nicholas Institute for Environmental Policy Solutions.

Given the physical distance between the Nicholas School of the Environment and the Nicholas Institute, I know that we can sometimes be 'out of sight, out of mind' for students. So I wanted to share a quick update on our current work, and remind everyone that we're always willing to collaborate or provide any case studies or information that we can to support students' research.

For those who don't know us, the Nicholas Institute is focused on connecting the University's expertise to inform better environmental policy, and in the case of the oceans, we're particularly focused on supporting policy decisions in developing countries (largely in the tropics), where marine resources can make the greatest contribution to poverty reduction.

The ocean policy program is currently supporting work on three broad themes: (i) the blue economy and sustainable economic growth from the ocean, (ii) fisheries and food security and (iii) blue carbon and climate change mitigation. We have a number of projects underway for each of these themes, carried out in collaboration or support of a number of faculty and students, and we're always looking to collaborate wherever possible. Here is the current work underway:

i. The Blue Economy

and economic growth from the ocean

- **Caribbean**

Finance Ministers and Central Bank Governors asked to understand more about the blue economy concept in 2015 at a regional dialogue for the G20, so we have worked with the World Bank to produce a short and quick publication to demystify the concepts, and show if/how it might be relevant for ocean policy-making in the Caribbean Sea.

- ***External Partners:*** *Organization for Eastern Caribbean States (OECS), Commonwealth Secretariat, World Bank* ***Current/Potential Faculty Partners:*** *Pat Halpin and MGEL, Jay Golden*

- **South Asia**

We may pursue a similar effort for governments in Bangladesh, Maldives, India, Pakistan and Myanmar, working in collaboration with students from Jay Golden's lab.

- **North Carolina**

We've just completed an initial assessment of the size of the ocean economy in North Carolina, and potential implications for policy-making.

- ***External Partners:*** *North Carolina Sea Grant Office*

Image on p. 14: Seth Sykora-Bodie, 2nd Year PhD Student, MSC
Tunisian Boats. Even though the oceans are changing at unprecedented rates, sometimes we still interact with and rely on them in the same ways that we have for thousands of years.

ii. Fisheries and Food Security

• Western Pacific

We are working on projects that explore tuna fisheries and increasingly small-scale fisheries, supporting the Parties to the Nauru Agreement Office (PNAO) with whom Duke has a Memorandum of Understanding (MOU) to collaborate. Over the past year we prepared a scenario analysis for the potential of the region's tuna fisheries by 2040 with various policy reforms, for publication with the World Bank and discussion with Finance Ministers in the region. We are currently working with the Environmental Defense Fund (EDF) to look at a monitoring framework for the new management scheme in place for the tropical longline tuna fishery.

• ***External Partners:*** *PNAO, EDF, University of Wollongong, University of the South Pacific, World Bank;* ***Current/Potential Faculty Partners:*** *Pat Halpin, Marty Smith, Xavier Basurto*

• Financing fisheries governance reform

We are preparing a paper looking at the role of different types of capital (philanthropy, public, private) in supporting fisheries governance reform.

• ***External Partners:*** *EDF*

• Small-scale fisheries governance assessment

We are working to support Xavier Basurto's lab as they conduct a global scan of both the theory and practice of small-scale fisheries governance, as well as a snapshot of global aid flows, as the basis of a workshop in Durham among experts, fishing association representatives, intergovernmental organizations, philanthropies and NGOs.

• ***External Partners:*** *Oak Foundation* ***Current/Potential Faculty Partners:*** *Xavier Basurto leads, with support of a faculty group: Lisa Campbell, Pat Halpin, Elizabeth Havice, Kay Jowers, Grant Murray, Marty Smith*

• West Africa

We are working on projects focusing on the coastal bottom trawl fisheries and their interaction with small-scale fisheries (one of the region's most valuable fisheries, but almost entirely foreign and highly controversial given interactions with local small-scale fisheries). We're looking at the size and distribution of the economic benefits generated by this fishery across four countries, as the basis of a meeting among Governments and development partners in Dakar, Senegal in February.

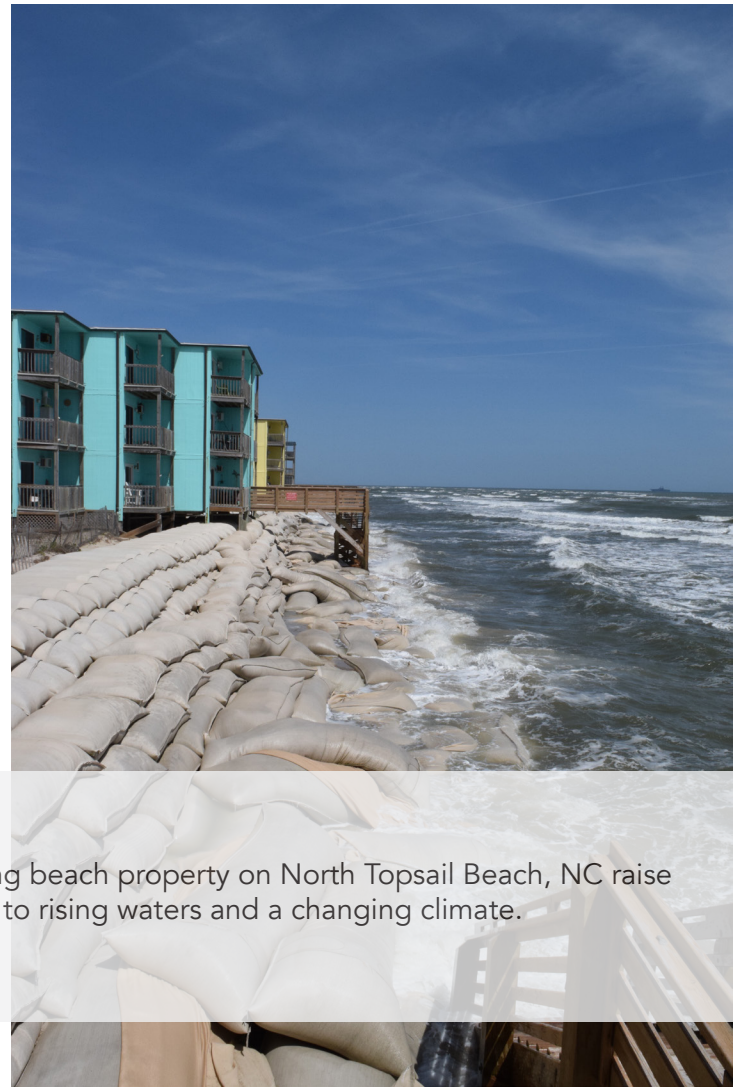
• ***External Partners:*** *Sub-Regional Fisheries Commission of West Africa, World Bank;* ***Potential Faculty Partners:*** *Pat Halpin*

iii. Blue Carbon
and climate change mitigation

• West Africa

We're just completing an initial assessment of the potential for climate finance to support mangrove conservation in West Africa, based on 'blue carbon' storage.

• ***External Partners:*** *GRID Arendal, Abidjan Convention Secretariat provided by the United Nations Environment Program (UNEP)* ***Current/Potential Faculty Partners:*** *Pat Halpin and MGEL* ■



A picture is worth a thousand words...
Large sandbags slowing erosion and protecting beach property on North Topsail Beach, NC raise important questions about future adaptations to rising waters and a changing climate.

Images: Emily Hall, MEM-CEM '17

I just want to say one word to you. Just one word……plastics

William Schlesinger, James B. Duke Professor Emeritus of Biogeochemistry

As I walk along the shore of our property in Maine, I am astounded at the amount of human debris that washes up on the beach. Nylon rope and plastic bottles dominate the flotsam, but bottle caps are probably the most numerous item. And every now and again, I encounter one of the large plastic crates that fishermen use to bring their catch to market. My wife and I clean up the beach a couple of times a year, and we never come back empty-handed.

We live in a fishing village, so perhaps we have a larger than average dose of plastic washing down our bay to the sea. But evidence suggests that plastic pollution of the seas is a global problem. A recent study reported that every day 4.1 tons of plastic washes down the Danube, Europe's second largest river, to the Black Sea. In the Danube, more than 300 plastic particles are found per 1000 cubic meters of river water. The weight of these plastic particles exceeds that of larval fishes in the same volume. Human debris in the river exceeds nature's productivity.

Worldwide production of plastics approaches 300 million tons per year, and a recent estimate suggests that 4.8 to 12.7 million tons reaches the sea. It is hard to know exactly, because the sources are diffuse and some plastics, such as grocery bags and balloons, are carried to the sea by the winds. Various oceanographic expeditions have reported vast rafts of plastic—bottles, flip-flops, nets, and bottle caps—swirling in the central oceanic gyres of the Atlantic and the Pacific oceans. Old mariners report that the problem is much worse now than 20 years ago.

Plastics are more than an aesthetic problem in the marine environment. Larger pieces of plastic debris are degraded by sunlight, in a process known as photo-oxidation, and fragment into smaller pieces, which can be a millimeter or less in diameter. Small pieces of plastic, such as bottle caps and fragments, are easily ingested by marine organisms, such as albatross, seals and whales. The smallest fragments of plastic can be eaten by zooplankton and passed up the marine food chain. The ingestion of plastics is not an occasional event. Plastics in the stomachs of the Northern Fulmar, a pelagic seabird, are closely correlated to the plastic contamination measured in seawater by independent means.

Sinking and consumption by animals mean that plastics disappear from seawater fairly rapidly, so that the mean life time of the plastics in the surface water is about 20 days[1]. This does not mean that the plastic is gone; most plastic molecules are thought to persist for hundreds, if not thousands of years, in the sediments.

Fragments and pellets derived directly from the plastics industry have declined in recent years, reflecting a worldwide effort on the part of manufacturers to develop Best Management Practices (BMPs) to keep their product out of nature. But, plastics derived from retail products are increasing in many areas. Only a small fraction of the world's annual production of plastic is recycled—about 30 percent in the U.S.—so a lot of it is left where it can wash (or blow) to the sea. In some areas, plastic water bottles are not even accepted at recycling centers, because they have so little value as scrap.

Plastics have improved our daily life in many ways, bringing fresh water in bottles to many regions where municipal water is contaminated or unavailable and allowing sterile medical procedures in hospitals throughout the world. Most plastic is used in packaging, which has a short life time before disposal. It behooves us to minimize that packaging, including bans on the use of plastic bags in grocery stores. And, it behooves us to collect and recycle as much of the waste as possible, even if it costs us a little to do so.

About 40 years ago, in The Graduate, Mr. McGuire was right to advise the young Ben Braddock, played by Dustin Hoffman, to pursue a career in plastics. Today, the accumulation of plastic waste in the environment leaves a geologic record of the globalization of our disposable economy. ■

[1] Calculated by dividing an estimate of the amount of plastic debris in the oceans (270,000 tons; Eriksen et al. 2014) by the lower estimate for the annual input (Jambeck et al. 2015), resulting in a mean residence time of 0.056 years, which is slightly more than 20 days.

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Image: Ian Markham, MEM-ESC '15
An upside down jellyfish drifts towards its home in a sheltered bay of Glover's Atoll off the coast of Belize. Unlike many of her brethren, she will settle with her bell flush against the ocean floor, her tentacles straining the water above.

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Ocean Policy Working Group

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