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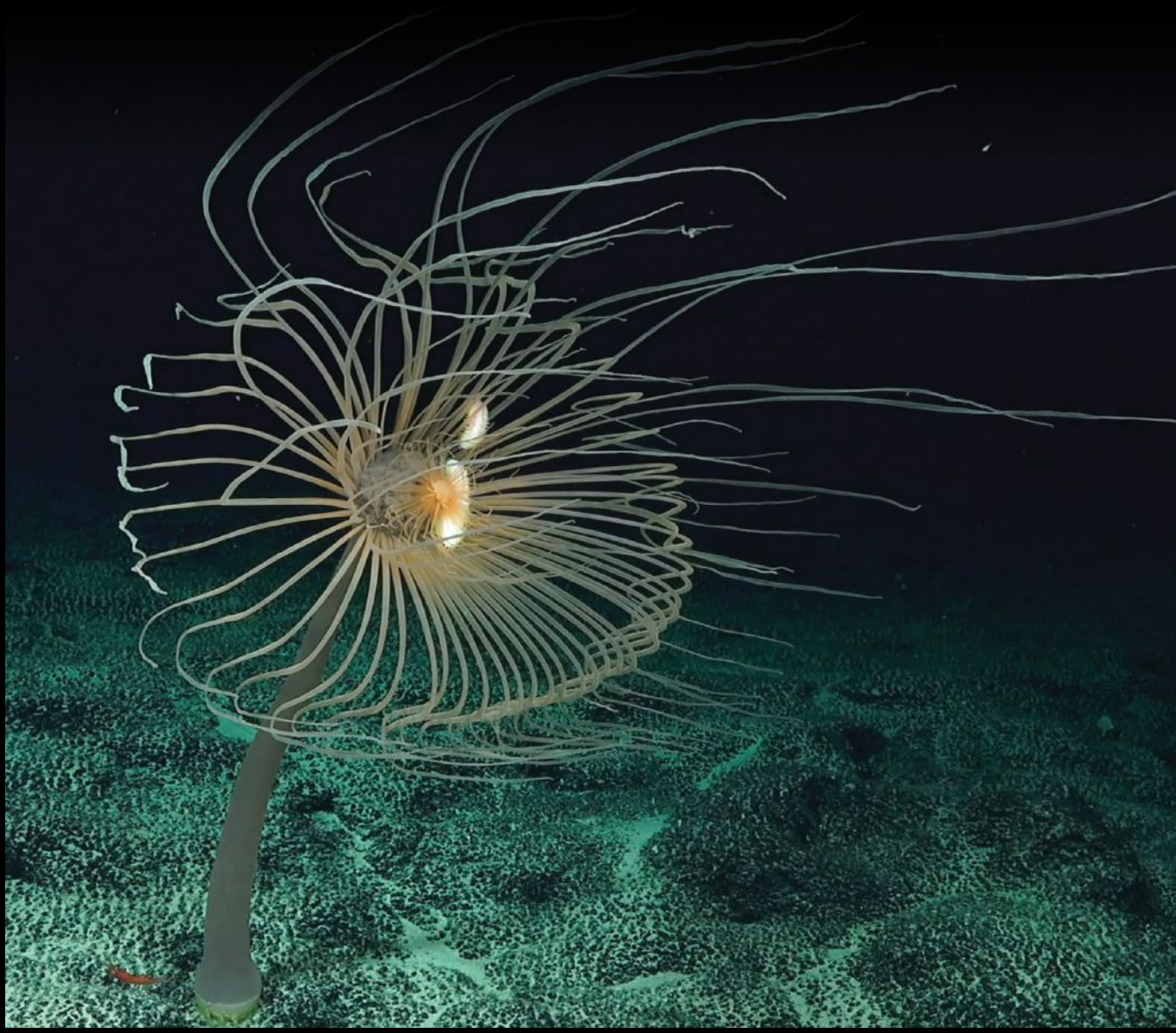
November / December 2018



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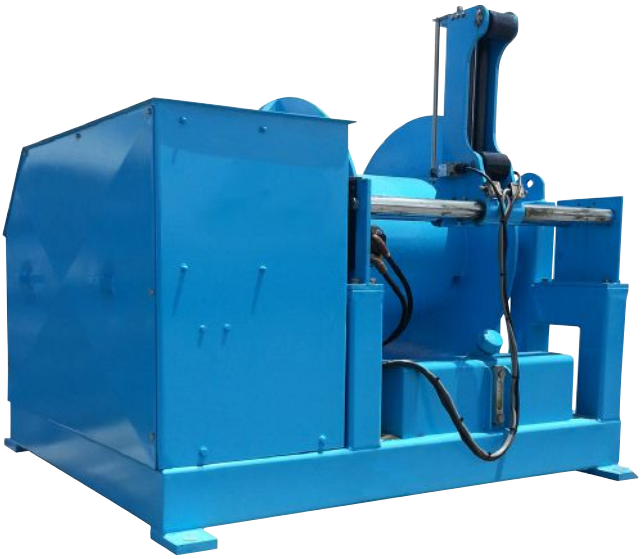

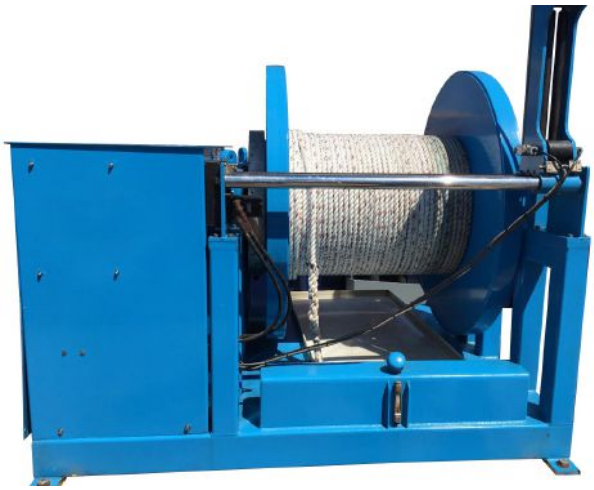

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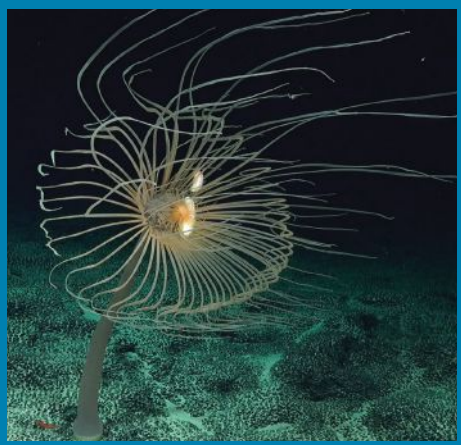

ON THE COVER
A three foot tall predatory solitary hydroid provides habitat for white polychaete worms at more than 6,000 feet deep. Image was taken with ROV SuBastian onboard Schmidt Ocean Institute's research vessel Falkor in the Phoenix Islands Protected Area.

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Editor's Letter

By Kira Coley, Senior Editor

Observing Our Oceans

Humankind's perpetual curiosity propels technological innovation. This, in turn, progresses scientific discovery and exploration as locations that were previously remote and unseen, are now accessible and revealed. The arrival of autonomous underwater robots and surface vehicles has played a leading role in the advancement of the ocean frontier. Better batteries and performance also mean longer-lasting missions, and the miniaturization of sensors has helped to reduce the cost and improve the efficiency of data-gathering. The arrival of smaller sensors has also revolutionized the space industry, igniting the rise of astropreneurship and the ability for research institutes to jump onboard the 'space wagon' by sending up sensors at a fraction of the cost. And so, we have entered the age of Big Data.

Today, there are thousands of sensors swimming in our oceans and flying overhead, trying to make sense of the marine environment and how (and why) it is changing. The satellite altimetry record is unanimously recognized as an invaluable product that tells us by how much sea level is rising globally in response to global warming, says French space geodesist **Anny Cazenave**. As one of the pioneers in satellite altimetry, I am thrilled to have Anny open this issue's theme, Ocean Observing Systems, with her thoughts on why and how we must advance coastal sea level monitoring from space.

"Researchers and engineers are continually working on the next robot or software to help them understand the ocean and all organisms that call it home," writes Carlie Wiener and Katherine Herries from the **Schmidt Ocean Institute** in our main story. For this issue, they reveal how technologies are changing the way scientists study the ocean and highlight recent expeditions aboard research vessel *Falkor* that are redefining how marine research is conducted in the open ocean.

But, as we know, observing the ocean is about more than collecting and analyzing data taken at that one time, in that one place. "So that we can understand how ocean life is responding to human use, we need standardized and regular, long-term observations," writes scientists from the **Global Ocean Observing System (GOOS)**. In this story, they share their thoughts on the challenges the scientific community faces today in ocean observation and what more needs to be done to improve the global ocean observing system.

We also hear from **Esri's** chief scientist Dawn Wright, as she describes how location intelligence is helping scientists understand how to protect an important marine ally, seagrass, in combating global warming. Scientists from **NOAA** and the **University of California Santa Cruz** reveal how they utilized ecological forecasts to develop a NASA-funded dynamic management tool, EcoCast, that aims to increase fishery sustainability by helping fishers avoid bycatch. And last but not least, Jorge G. Alvarez-Romero of the **ARC Centre of Excellence for Coral Reef Studies**, reveals a new global database to better guide marine conservation efforts.

It's great to see so many collaborative efforts underway today that work to combine and share data for the good of all.

To all our readers, thank you for your fantastic support throughout 2018. I hope you enjoy this issue of ECO and have an excellent festive season.

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Study Finds Oceans Are Heating Up Quicker than Previously Thought

For each of the past 25 years, oceans have absorbed an amount of heat energy that is 150 times the energy humans produce as electricity annually, according to a *Nature* study led by researchers at Scripps Institution of Oceanography at the University of California San Diego and Princeton University.

The strong ocean warming researchers have found suggests that Earth is more sensitive to fossil-fuel emissions than previously thought. Study lead author Laure Resplandy, a Princeton assistant professor of geosciences, said that this estimate is more than 60 percent higher than the figure in the most recent assessment report from the United Nations Intergovernmental Panel on Climate Change (IPCC). "Imagine if the ocean was only 30 feet deep," said Resplandy, a former postdoctoral researcher at Scripps Oceanography. "Our data shows that it would have warmed by 6.5°C (11.7°F) every decade since 1991. In comparison, the estimate of the last IPCC assessment report would correspond to a warming of only 4°C (7.2°F) every decade."

Scientists know that the ocean takes up roughly 90 percent of all the excess energy produced as the Earth warms, so knowing the actual amount of energy makes it possible to estimate the surface warming that can be expected, said co-author Ralph Keeling, a Scripps Oceanography geophysicist and Resplandy's former postdoctoral advisor. "The result significantly increases the confidence we can place in estimates of ocean warming and therefore helps reduce uncertainty about climate sensitivity," Keeling said. Climate sensitivity is used to evaluate allowable emissions for mitigation strategies. Most climate scientists have agreed in the past decade that if global average temperatures exceed pre-industrial levels by 2°C (3.6°F), it is all but certain that society will face widespread and dangerous consequences of climate change.

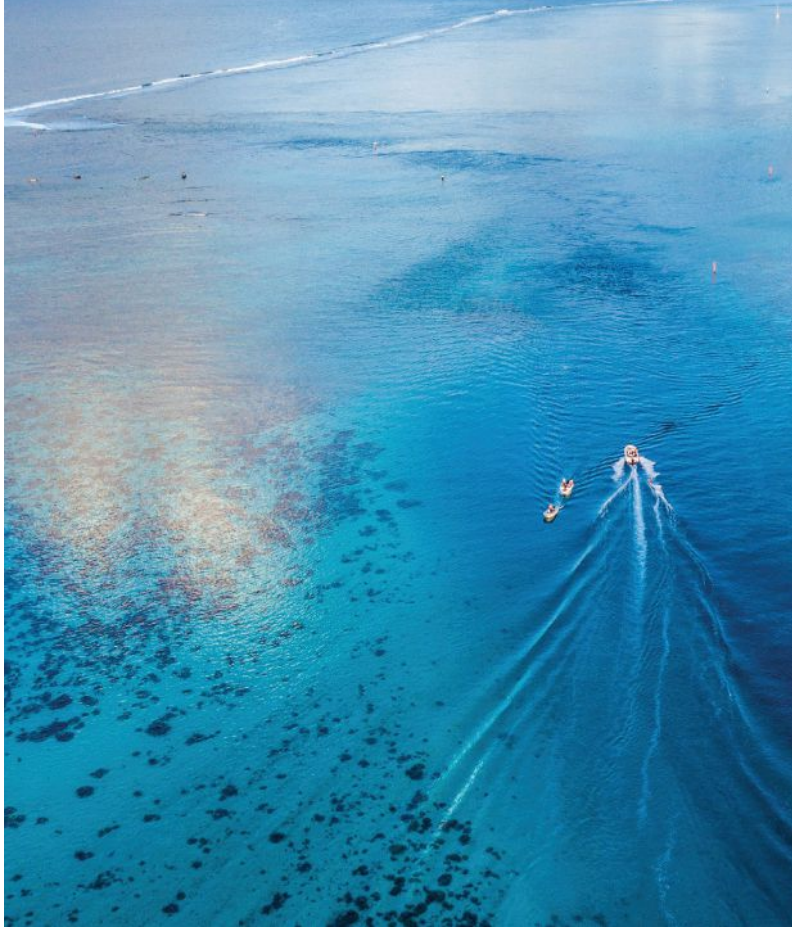
The researchers' findings suggest that if society is to prevent temperatures from rising above that mark, emissions of carbon dioxide, the chief greenhouse gas produced by human activities, must be reduced by 25 percent more than what was previously estimated, Resplandy said. The researchers' results are the first to come from a measuring technique independent from the dominant method behind existing research.

To calculate total heat content, previous estimates relied on millions of measurements of ocean temperature. Many came from a network of robotic sensors developed by Scripps researchers known as Argo. Gaps in coverage, however, made this approach uncertain.

Argo makes comprehensive measurements of ocean temperature and salinity across the globe, but complete network data only goes back to 2007 and only measures the upper half of the ocean. Several reassessments of heat content have been made in recent years using the ocean temperature data – including the recent Argo data — which has led to upward revisions of the IPCC estimate. Resplandy and her co-authors used Scripps' high-precision measurements of oxygen and carbon dioxide in the air made at stations around the world. With it, they determined how much heat the oceans have stored during the time span they studied. They measured ocean heat by looking at the combined amount of O2 and CO2 in air, a quantity they call "atmospheric potential oxygen" or APO. The method depends on the fact that oxygen and carbon dioxide are both less soluble in warmer water.

As the ocean warms, these gases are released into the air, which increases APO levels. APO also is influenced by burning fossil fuels and by an ocean process involving the uptake of excess fossil-fuel CO2. By comparing the changes in APO they observed with the changes expected due to fossil-fuel use and carbon dioxide uptake, the researchers were able to calculate how much APO emanated from the ocean becoming warmer. That amount coincides with the heat-energy content of the ocean. The researchers estimate that the world's oceans took up more than 13 zettajoules of heat energy each year between 1991 and 2016. A joule is the standard unit of energy. One zettajoule equals one sextillion (or the number 1 followed by 21 zeroes) joules.

A New Global Framework Launched to Fund a Sustainable Blue Economy



The world's first global framework to finance a sustainable ocean economy was launched at the Our Ocean conference on October 29.

The Sustainable Blue Economy Finance Principles were developed by the European Commission, WWF, World Resources Institute (WRI), and the European Investment Bank (EIB). Started as a commitment by a dozen financial institutions and key stakeholders just a year ago, they are now set to become the gold standard to invest in the ocean economy—the "blue economy"—in a sustainable way.

Ocean ecosystems are under enormous pressure. With growth of the blue economy expected to double over the next decade, action is urgently needed to reverse this trend. Sustainable finance is a powerful solution. By engaging investors, insurers and banks, the Sustainable Blue Economy Finance Principles bring sustainability into the boardrooms of all ocean-based industries, from shipping, fisheries and tourism, to aquaculture, energy and biotechnology. To put the principles into practice, an IT-based tool is being developed to help investment managers assess whether their investment decisions are verifiably sustainable. The organizations behind the principles are convinced that this will show in practice how profitability can go hand-in-hand with environmental and social stewardship, and how UN Sustainable Development Goal 14 to "conserve and sustainably use the oceans, seas and marine resources" can be achieved.

The Sustainable Blue Economy Finance Principles will become part of a new sustainable blue economy finance initiative under the auspices of the UN Environment Finance Initiative (UNEP FI), which joins the European Commission, WWF, WRI and the EIB as a founding partner. The initiative, anticipated for 2019, will receive initial support from the European Commission. The principles are endorsed by the major international sustainable finance initiatives, including UN Environment's Principles for Sustainable Insurance Initiative (PSI) and the World Bank.

"Through our long-standing work with banks, insurers and investors, UN Environment has delivered landmark global frameworks and initiatives to finance a resilient, inclusive and sustainable global economy. These include the Principles for Responsible Investment in 2006, the Principles for Sustainable Insurance in 2012, and now the upcoming Principles for Responsible Banking, which will be finalized next year. Amid intensifying threats to the ocean, from unsustainable fishing and plastic pollution, to coral reef destruction and ocean acidification, this collaborative initiative to finance a sustainable blue economy is not only timely and complementary—it is absolutely urgent and necessary," said Erik Solheim, Head of UN Environment. A growing number of financial institutions and stakeholders have already endorsed the initiative, including Alimentos Ventures, Aloe Private Equity, Althelia Ecosphere, Bonafide Ltd., Boston Common Asset Management, Fishing Accelerator, Greenbackers Investment Capital, the International Capital Market Association, Investas – Association luxembourgeoise des investisseurs privés, Mermaid Investments, Ocean Assets Institute, the Ocean Data Alliance, Pure Salmon, The Nature Conservancy, Rockefeller Asset Management, SeaAhead, SKY - Ocean Rescue Fund and 8F Asset Management.

Jonathan Taylor, Vice-President of the European Investment Bank, said, "Cooperation is key to tackling global challenges and protecting shared natural resources such as the oceans. Together with its partners, the European Investment Bank has been taking the Sustainable Blue Economy Finance Principles forward to drive investment in this key sector. The welcome endorsement of the Principles by UN Environment will help to ensure that they are implemented successfully. The EIB will continue to mobilize private capital towards the sustainable blue economy, which is critical to secure the livelihoods of over three billion people." With the new UN Environment-hosted sustainable blue economy finance initiative planned for 2019, it is expected that many more institutions will come on board. Meanwhile, interested organizations can consult the European Commission.

Robots to Restore the Great Barrier Reef

A 'reef protector' robot from the Queensland University of Technology (QUT) is set to become 'mother' to hundreds of millions of baby corals in a special delivery coinciding with this month's annual coral spawning on the Great Barrier Reef.

In a world first, QUT's underwater robot *RangerBot* has been transformed into *LarvalBot* by QUT's robotics team, led by Professor Matthew Dunbabin from the Institute for Future Environments.

Scientists collect hundreds of millions of coral spawn from corals that have survived the two recent mass bleaching events. They're reared into baby corals in mass quantities inside large floating enclosures on the reef. Once developed (in around 5-7 days), the semi-autonomous robot, *LarvalBot,* will help deliver the tiny baby coral larvae onto targeted reefs. Reared larvae will also be distributed as 'larval clouds' on damaged reef areas on a larger scale than previously possible. The technique of delivering reared coral larvae onto reefs is known as 'larval restoration'.

Dunbabin is working with Southern Cross University's (SCU) Professor Peter Harrison - pioneer of the coral larval restoration technique (coral IVF) - who is heading the overall research project. The collaboration between QUT and SCU, funded by the Great Barrier Reef Foundation, aims at restoring damaged parts of the Great Barrier Reef and speeding up the recovery of ecosystems affected by coral bleaching.

Large volumes of coral spawn will be captured and transferred into fine mesh pools for almost a week until the larvae are ready to be re-settled. "We concentrate the larvae and put some of these into *LarvalBot* to gently squirt the larvae onto dead reef areas allowing it to settle and transform into coral polyps or baby corals," Professor Harrison said. "The surviving corals will start to grow and bud and form new colonies which will grow large enough after about three years to become sexually reproductive and complete the life cycle."

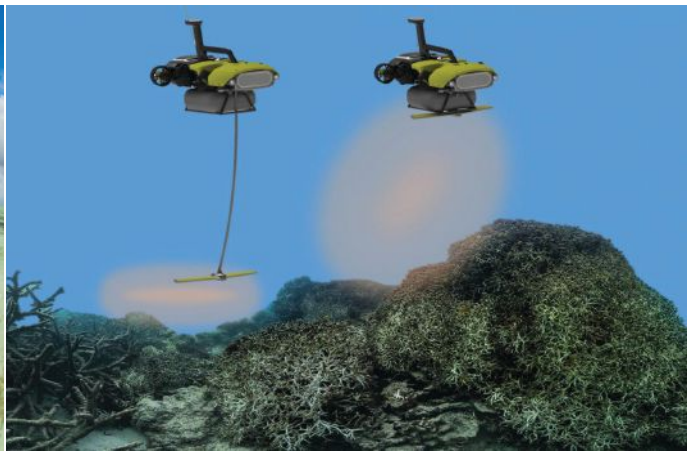
The spectacular synchronized spawning of coral reproduction on the Great Barrier Reef is a highlight on scientists' calendars worldwide and is expected to take place in late November. The researchers say by giving nature a helping hand through artificial means, it allows up to a 100-times increase over previous methods. Dunbabin said delivering baby corals and helping to grow the Great Barrier Reef builds on the pioneering robotics technology developed to control the crown-of-thorns starfish. "I am passionate about protecting the reef in any way I can and extremely excited to have the opportunity to work with world leaders in coral reef restoration," he added.

"We aim to have two or three robots ready for the November spawn. One will carry about 200,000 larvae and the other about 1.2 million. During operation, the robots will follow preselected paths at constant altitude across the reef and a person monitoring will trigger the release of the larvae to maximize the efficiency of the dispersal."

Dunbabin calculated the dispersal would cover 1,500 square meters per hour per robot. "This has the potential to revolutionize coral restoration on reefs worldwide," said Harrison.

The project has come to life after the researchers won $300,000 from the Great Barrier Reef Foundation's Out of the Blue Box Reef Innovation Challenge supported by the Tiffany & Co. Foundation. The Foundation's Managing Director Anna Marsden said the recent IPCC report reinforced the closing window of opportunity for the world to act on climate change and the sharp threat facing coral reefs globally. Dunbabin said it was hoped reef rangers and other managers would use the technology in the future. "Whilst this is new, we have trialed the different technologies and are confident of its success."

Credit: Gary Cranitch, Queensland Museum



LarvalBot gently squirts the coral larvae onto damaged reef areas. Credit: Queensland University of Technology

IMO Plans to Reduce Marine Plastic Litter from Ships

The International Maritime Organization (IMO) has pledged to address the significant problem posed by plastics to the marine environment, with the adoption of an action plan which aims to enhance existing regulations and introduce new supporting measures to reduce marine plastic litter from ships. IMO's Marine Environment Protection Committee (MEPC) adopted the action plan to contribute to the global solution for preventing marine plastic litter entering the oceans through ship-based activities. Recognizing that more needs to be done to address the environmental and health problems posed by marine plastic litter, IMO Member States meeting in the MEPC agreed actions to be completed by 2025, which relate to all ships, including fishing vessels. The action plan supports IMO's commitment to meeting the targets set in the UN 2030 Sustainable Development Goal 14 (SDG 14) on the oceans.

Are We Losing One of Our Biggest CO2 Sinks?

A study published in *Global Biogeochemical Cycles*, spanning coastal areas of the Northern Hemisphere, explored the magnitude of organic carbon stocks stored and sequestered by eelgrass meadows. On average, eelgrass meadows stored 27.2 tons of organic carbon per hectare, although the variation between the regions was considerable. Hotspots for carbon sequestration were identified in the Kattegat-Skagerrak region, and southern parts of the Baltic Sea where the organic carbon stocks were over eight times higher than in the Archipelago Sea of Finland. The high carbon storage capacity of eelgrass meadows urges for protection and restoration of this unique ecosystem. Especially in the areas with the highest carbon stock capacity, eelgrass deserve recognition as part of global carbon marketing programs, say the researchers.

Fish Diversified in Shallow Waters 400 Million Years Ago

A new study published in *Science* suggests that the earliest fish species originated in shallow waters, not coral reefs. Using the fossil record and existing data on family tree relationships from the middle Paleozoic era, 480 to 360 million years ago, researchers created a database that involved 2,728 early records for jawed and jawless fishes. Mathematical modeling was used to fill the data gaps allowing for predictions on the type of environment these primitive fish lived in. The study notes that early vertebrates seemed to stay in shallow waters for long time periods and became well adapted to living both along the seafloor and in deeper waters. Researchers want to understand whether shallow waters are still acting as the biological pump feeding coral reefs. If so, the mass extinction of reefs and the loss of biodiversity may be offset by the diversification found in shallow oceanic waters.

Brexit and Marine Science: Is the Picture Any Clearer?

Insights by Dr. Matt Frost, Marine Biological Association Deputy Director, Head of Policy and Knowledge Exchange, and President of Mars (European Network of Marine Institutes and Stations) ***Note: This article was updated on November 15 when a draft withdrawal agreement has been announced but has yet to be agreed.***

In August 2016, I submitted the Marine Biological Association's (MBA) response to the House of Lords Select Committee on Science and Technology inquiry *'Leaving the EU: implications and opportunities for science and research'.* Since then I have written articles, given talks and run workshops on marine science and Brexit, always with the hope that the next time I was invited to contribute to the debate, the picture would be clear as to the terms in which the UK would be leaving the EU.

It is therefore with some degree of frustration that more than two years after the referendum, marine scientists, along with the rest of the science community, are still far from clear over how best to plan for the future.

Despite a withdrawal agreement now being at least 'on the table', it is uncertain as to whether this will succeed and, even if it does, what a future trade deal will look like. Adding to this uncertainty is the question: why is there now a renewed focus on what happens if no deal is reached at all? To this end, since August 2018 the UK government has published 105 technical notices on the implications for a 'no deal', seemingly indicating that this outcome is a real possibility. Some of these 'no deal' technical notices deal with science funding, which, along with the status of EU marine scientists working in the UK and issues around marine environmental protection, has been a central concern for marine scientists. With many marine science organizations reporting between 10 and 25 percent of their income in recent years as being from the EU, it is no surprise that a frequent topic of discussion has been around ensuring continued access to these funds, or that other funding mechanisms are established.

A key issue is that, according to these technical notices, although researchers could continue to receive money from the EU framework program such as the upcoming Horizon Europe (albeit on a 'third party' status), other types of EU funding such as the prestigious European Research Council (ERC) Grants will not be available. A number of UK marine institutes currently benefit from ERC funding with the MBA alone holding two ERC grants, representing a significant proportion of its income for marine research.

It was good to see the announcement of £1.6 billion for science and innovation in the UK's Autumn 2018 Budget Statement. But there is no indication of how this will be allocated, and marine research often struggles to articulate its importance alongside other priorities despite the huge economic and environmental benefits that investing in marine science is likely to bring. Arguments over the potential impacts of Brexit on marine science funding have been well rehearsed, and how you feel about the eventual outcome – be it positive or negative - will probably reflect your political views and who you are willing to trust in lieu of any definitive decisions or information.

The one thing that is clear is that the ongoing uncertainty is not helpful for UK marine organizations as they develop strategies to meet future challenges. For example, discussions are already underway between UK scientists and their European colleagues on the imminent Horizon 2020 call for project proposals to examine *'Inter-relations between climate change, biodiversity and ecosystem services'*.

UK scientists can only hope that our European colleagues remain open to UK scientists contributing and potentially leading bids when our future links to these programs are so uncertain. Whatever the outcomes of the Brexit discussions, marine science will not stop being highly interdisciplinary and collaborative by nature, and big issues such as how to use the marine environment in a more sustainable manner whilst developing the blue economy will still need to be addressed.

The plea from the UK marine research community is only that whatever the outcome, the UK will be able to maintain and enhance its reputation as a world-class leader in marine science, for the benefit of science, the marine environment and wider society.

Scientists Can Now Watch Whales from Space

Scientists have used detailed high-resolution satellite images to detect, count and describe four different species of whales. The study is a big step towards developing a cost-effective method to observe whales in remote and inaccessible places, helping scientists to monitor population changes and understand behavior.

For the study published in the journal *Marine Mammal Science,* each species was observed in one of their known aggregation areas, where individuals come together to congregate: southern right whales off Argentina, humpback whales off Hawaii, fin whales in the Pelagos Sanctuary in the Mediterranean and grey whales off the coast of Mexico. It has already helped whale conservation bodies to identify 10 key inaccessible whale populations that would benefit most from the application of satellite imagery in studies. Lead author Hannah Cubaynes, a whale ecologist at British Antarctic Survey (BAS) and University of Cambridge explains, "This is the most detailed imagery of whales captured by satellites to date. It's exciting that the improved resolution (now at 30 centimeters) reveals characteristic features, such as flippers and flukes, which can be seen in the images for the first time. Whales live in all oceans. Many areas are difficult to access by boats or planes, the traditional means of monitoring whales. The ability to track whales without travelling to these remote and inaccessible areas, in a cost-effective way, will be of great benefit to conservation efforts for whales."

The study also shows that fin and grey whales are the easiest to identify due to their body coloration, which contrasts with surrounding water. Humpback whales and southern right whales are more difficult to detect as they are a similar color to their environment. The acrobatic behavior of humpback whales also makes them harder to see as their body shape is often obscured. The team studied seven huge images of the open ocean taken by DigitalGlobe's WorldView-3 satellite, covering over 5000 kilometer^2 – an area the size of the UK county of Norfolk or the US state of Delaware.

Whale ecologist Dr. Jennifer Jackson at BAS and an author on the paper, says "This new technology could be a game-changer in helping us to find whales remotely. Critically endangered whale populations like the Chile-Peru right whale (thought to winter in Patagonia) could really benefit from this approach."

Study Suggests Yangtze Dams Threaten Endangered Sturgeons

The damming of the Yangtze river in 1981 has had a detrimental effect on migrating sturgeon fish, according to scientists at the China Institute of Water Resources and Hydropower Research. It was unknown exactly how dam structures were causing declines. This latest study published in the journal *Current Biology*, has finally begun to reveal the mechanism by which dams affect migrating fish such as the Chinese sturgeon. Losses of effective breeding and environmental capacity are highlighted as two crucial issues. Remedial measures of fish rescue for existing dams, including fish passage facilities and restocking, have been insufficient or inefficient. Researcher's hope that their findings will lead to improved measures that will help keep wild populations at a sustainable level.

'Robust' Corals Primed to Resist Coral Bleaching

Using advanced genomic techniques, researchers have found that the group of corals classified as "robust," which includes a number of brain corals and mushroom corals, have a key physiological advantage over "complex" corals such as the staghorn coral.

In a new paper published in *Genome Biology,* researchers report that "robust" corals possess a unique capacity to generate an amino acid which is crucial in repairing tissue or growing new tissue. Furthermore "robust" corals are less choosey about which microalgae can take up residence in the coral's tissue. The ability to host a broader range of microalgae could facilitate more rapid acclimation to higher temperatures.

Deepwater Horizon: Deep Sea Chemical Dispersants Ineffective

A new study published in *Frontiers of Marine Science* of the Deepwater Horizon response shows that substantial amounts of oil continued to surface near the response site, despite 3,000 tons of subsea dispersants injection (or SSDI) — a new spill response strategy meant to curb the spread of oil and facilitate its degradation. Dispersants application to manage surface oil spills has been shown to break the oil into small, easily dissolved droplets. However, the Deepwater Horizon was very different in that the oil entered the system at depth. The turbulent energy and pressure at such immense depths not only contributed to the rapid expansion of the spill, but these natural forces helped disperse oil in micro-droplets and render the dispersant ineffective and unnecessary.

NASA Pushes Exploration of Oceans in Our Solar System

NASA Astrobiology Program awards $7 million to Georgia Tech-led Oceans Across Space and Time alliance to intensify the search for life in our solar system's present and past oceans.

NASA has navigated our solar system with spacecraft and landers, but still, our celestial neighbors remain vast frontiers, particularly in the search for life. Now, an alliance of researchers will accelerate the quest to find it. The NASA Astrobiology Program has announced the establishment of the Network for Life Detection, NFoLD, which connects researchers to pursue the detection of life and clues thereof on our neighboring planets and their moons. NFoLD includes an oceanic research alliance led by the Georgia Institute of Technology. It is called Oceans Across Space and Time, OAST, and has received a $7 million NASA Astrobiology grant with the long-range goal of extracting secrets from present and past oceans on Mars, Jupiter's icy moon Europa, and Saturn's moon Enceladus. But OAST will also ramp up the study of the conditions that spawned first life in Earth's oceans.

"With OAST, we finally hit the perfect mix of people, science questions, and supporting activities to really go after some of the most important unknowns in astrobiology," said Britney Schmidt, OAST's principal investigator and an assistant professor in Georgia Tech's School of Earth and Atmospheric Sciences.

NFoLD is one of five new Research Coordination Networks (RCN) that the NASA Astrobiology Program has announced. The other RCNs pull together research communities that include the study of early Earth and its chemistry, evolution, distant habitable worlds, and exoplanet systems.

Yellow Submarine on Europa

OAST could one day help NASA put a submarine on a rocket to Europa to look for life in the ocean beneath its ice crust. Or OAST could join NFoLD colleagues to help NASA explore parched Martian landscapes that once were oceans. But the path to our space neighbors leads through studying Earth. Field and lab experiments on our planet will divulge more knowledge about chemical and biological evolutionary strategies so that researchers can develop instruments and methodology that reliably detect signs of life on other planets and moons.

"We don't yet have a slam-dunk measurement that we could make on another planet to definitively say 'this is life,'" said Schmidt, who coordinates OAST and led the application efforts to establish it. "OAST's main goal is to take a suite of technologies into the field on Earth to make measurements side-by-side while returning samples to the lab to understand." Then, when that is very finely honed, send it aloft.

Crucial Target Practice

One of NFoLD's goals is to participate in future astrobiology space missions from the start so that they can successfully identify target spots on other planets or moons where signs of life could actually be detected if present.

"A major challenge for life detection is where on a given planet or moon to look for life," said Jeff Bowman, deputy principal investigator of OAST and an assistant professor at Scripps Institution of Oceanography at UC San Diego. "The density of life on our own planet extends across several orders of magnitude. Look for life in the wrong place and Earth could appear lifeless."

OAST's team has the expertise to bridge earthly data and celestial goals. Many of its 18 co-investigators and their teams have already explored biogeochemistry in our own planet's eons-old rock record, in the atmosphere, the oceans, and the icecaps with an eye to extrapolating the data to other worlds. Other OAST researchers have helped design Mars probes or build robotic submarines intended to one day dive into Europa's subsurface ocean to detect life or at least a hint of it.

"OAST researchers have expertise in detecting and characterizing life in a variety of harsh environments like the Antarctic, the deepest ocean trenches, and lakes with extreme chemistry and salinity," Bowman said. "We will leverage this expertise to understand how life may be distributed in different ocean environmental extremes around the solar system."

Diverse Member Institutions

OAST includes investigators from Scripps Institution of Oceanography at the University of California San Diego; the University of Kansas; Louisiana State University; the Massachusetts Institute of Technology; Stanford University; the Blue Marble Space Institute of Science; the University of Texas; Colgate University; the University of California, the University of Central Florida; the University of Auckland; York University; the University of Otago, and the New Zealand National Institute of Water and Atmospheric Research. "I'm particularly proud of the high number of women and pre-tenure scientists we've engaged through our project," said Schmidt. Five leaders in OAST are women, and 12 researchers are early career or pre-tenure. The project will also support graduate and undergraduate students as well as postdoctoral researchers through the NASA Postdoctoral Program.

NERC Celebrates Impacts of UK Scientists in Awards Shortlist

Paving the way for a satellite to monitor climate change by weighing the Earth's forests. Shedding light on the scale of microplastics in our oceans. Finding solutions to the threats to biodiversity in forests across the globe. Inventing an algorithm to predict - and help avoid - turbulence on flights. And uncovering a new type of energy reserve for the UK.

These are just some of the positive real-world impacts generated by UK environmental scientists on NERC's 2018 Impact Awards shortlist, announced this month. Shortlisted and judged by independent panels of esteemed academic, industry and government figures, these awards celebrate NERC-funded scientists, as individuals or teams, whose work has had a big impact on the economy or society in the UK or internationally. This year's judges include former UK Environment Secretary Lord Deben, Chairman of the Committee on Climate Change, and BBC presenter and Professor of Public Engagement in Science Professor Alice Roberts.

Judges will choose a winner from two finalists in three categories: early-career impact, economic impact and societal impact. To further the impacts of their research, the winner of each category will receive £10,000 and the runner-up £5,000. The category winner judged to have had the biggest impact will be the Impact Awards overall winner, and will receive an additional £30,000 funding. Winners will be announced at a ceremony at the Natural History Museum on Monday 3 December 2018.

Dr Peter Costigan, environmental consultant and chair of the 2018 judging and shortlisting panels, said “Headlines celebrating scientific breakthroughs may grab our attention, but the reality is it can take a long time for golden nuggets of research to have an impact in our everyday life. Delivering impact is about keeping sight of the bigger picture - understanding how the detailed work in the lab or analyzing complex datasets can translate into real world benefits. This is my second time acting as chair of the Impact Awards judging panel, and I still find reading impact case studies fascinating. This year's shortlist reminds me that NERC-funded research is dynamic, exciting and incredibly varied. And the impact can be just as exciting and varied, and sometimes comes in ways that were not obvious or expected at the outset.” Find the full list of shortlisted research on the NERC website www.nerc.ukri.org

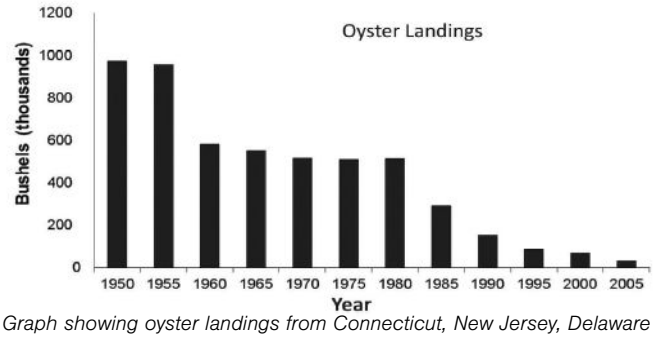
Study Explains Dramatic Decline in US Commercial Shellfish Landings

The 85 percent decline in US commercial shellfish landings between 1980 and 2010 are likely linked to environmental factors, not overfishing.

Researchers have identified the causes of the sharp decline in documented landings of the four most commercially-important bivalve mollusks – eastern oysters, northern quahogs, softshell clams and northern bay scallops – in US estuaries and bays from Maine to North Carolina, between 1980 and 2010. Warming ocean temperatures associated with a positive shift in the North Atlantic Oscillation (NAO), which led to habitat degradation including increased predation, are the key reasons for the decline of these four species in estuaries and bays from Maine to North Carolina. The NAO is an irregular fluctuation of atmospheric pressure over the North Atlantic Ocean that impacts both weather and climate, especially in

Clyde Mackenzie, Warren Gaines and Jason Mallory during an October 15 check on the bay scallop populations on Martha's Vineyard. Credit: Deborah M. Gaines

the winter and early spring in eastern North America and Europe. Shifts in the NAO affect the timing of species' reproduction, growth and availability of phytoplankton for food, and predator-prey relationships, all of which contribute to species abundance. The findings appear in *Marine Fisheries Review*. Researchers also note the related decline by an average of 89 percent in the numbers of shellfishermen who harvested the mollusks. The landings declines between 1980 and 2010 are in contrast to much higher and consistent shellfish landings between 1950 and 1980. Exceptions to these declines have been a sharp increase in the landings of northern quahogs in Connecticut and American lobsters in Maine. Landings of



Graph showing oyster landings from Connecticut, New Jersey, Delaware and Maryland-Virginia from 1980 to 2005. Source: US Fisheries Statistics and Fisheries of the US. Credit: Mackenzie et al. 2018

American lobsters from southern Massachusetts to New Jersey, however, have fallen sharply as water temperatures in those areas have risen.

"A major change to the bivalve habitats occurred when the NAO index switched from negative during about 1950 to 1980, when winter temperatures were relatively cool, to positive, resulting in warmer winter temperatures from about 1982 until about 2003," said lead author, Clyde Mackenzie. "We suggest that this climate shift affected the bivalves and their associated biota enough to cause the declines."

Research from extensive habitat studies show that body weights of the bivalves, their nutrition, timing of spawning, and mortalities from predation were sufficient to force the decline. Other factors likely affecting the decline were poor water quality, loss of eelgrass in some locations for larvae to attach to and grow, and not enough food available for adult shellfish and their larvae. In late spring-early summer of 2018, a cool spell combined with extremely cloudy weather may have interrupted scallop spawning, leading to what looks like poor recruitment this year. Last year, Nantucket and Martha's Vineyard had very good harvests due to large recruitments in 2016. "The rates of survival and growth to eventual market size for shellfish vary as much as the weather and climate," Mackenzie added.

Weak consumer demand for shellfish, particularly oysters, in the 1980s and early 1990s has shifted to fairly strong demand as strict guidelines were put in place by the Interstate Shellfish Sanitation Conference in the late 1990s regarding safe shellfish handling, processing and testing for bacteria and other pathogens. Enforcement by state health officials has been strict. The development of oyster aquaculture and increased marketing of branded oysters in raw bars and restaurants has led to a large rise in oyster consumption in recent years. Since the late 2000s, the NAO index has generally been fairly neutral, neither very positive nor negative. As a consequence, landings of all four shellfish species have been increasing in some locations. Poor weather for bay scallop recruitment in both 2017 and 2018, however, will likely mean a downturn in landings during the next two seasons.

Enhanced Views of Earth Tectonics

Scientists from Germany's Kiel University and the British Antarctic Survey (BAS) have used data from the European Space Agency's Gravity field and steady-state Ocean Circulation Explorer (GOCE) mission to unveil key geological features of the Earth's lithosphere – the rigid outer layer that includes the crust and the upper mantle. Published in the journal *Scientific Reports,* the study is a step forward in the quest to image the structure and setting of different continents using satellite gravity data, including Antarctica, the least understood piece of the whole plate tectonic puzzle. Satellite gravity provides a new tool to link the remote and ice-covered continent with the rest of the Earth. This improves our understanding of Antarctica's deep structure, which is particularly important, as the properties of its lithosphere can also influence the overlying ice sheets.

Dissolving Seabed Raises Fears for Future

The ocean floor is dissolving rapidly as a result of human activity, according to study published in *PNAS*. Normally the deep-sea seabed is a chalky white, composed mostly of the mineral calcite (CaCO3) formed from skeletons and shells of planktonic organisms and corals. The seafloor plays a crucial role in controlling the degree of ocean acidification. The dissolution of calcite neutralizes the acidity of the CO2 and prevents seawater from becoming too acidic. But the study shows, at least in hotspots such as the Northern Atlantic and the Southern Ocean, CO2 in the water is so high that calcite is being dissolved. Researchers believe this is only a foretaste of the way that the ocean floor will likely be affected in future. They plan to look at how this deep ocean bed dissolution is likely to evolve over the coming centuries under various potential CO2 emission scenarios.

Oxygen Levels Impact on Species' Ability and Willingness to Fight

Scientists at the University of Plymouth have discovered that different flow regimes and oxygen levels within the marine environment are likely to result in conflict. Writing in the *Journal of Experimental Biology,* they say that conditions also play a key role in an individual's resources of strength and stamina and – consequently – their success in such battles. The study is part of a long-term investigation into the behavior of sea anemones, funded through a grant from the Biotechnology and Biological Sciences Research Council. The study could be particularly relevant amid continuing changes to the marine environment brought on by global warming. The results showed anemones who had been living in aerated water were more likely to initiate combat, and more successful in it, than their oxygen-deprived rivals.

Texas's New Plan for Protecting its Coast Against Storms

On 26 October, the Texas General Land Office (GLO) and the United States Army Corps of Engineers (USACE) announced the release of the Coastal Texas Protection and Restoration Study Draft Integrated Feasibility Report and Environmental Impact Statement, a milestone in the effort to reduce the risk along the Texas coast from dangerous storm surges and other threats.

Since 2015, GLO and USACE have worked cooperatively on a first-of-its-kind feasibility study formulating risk reduction solutions to address coastal storm risks to the vast and important Texas coastline. A copy of the report can be downloaded here http://coastalstudy.texas.gov/.

"Texas is not a state that happens to have a coast, Texas is a true coastal state," said Texas Land Commissioner George P. Bush. "One storm can cost many lives and billions of dollars in damage, so the expense of doing nothing far outweighs the investment to protect and enhance our coast. Texas' coast is home to one in every four Texans and 30 percent of the American oil refining sector resides here. The Coastal Texas Study is about protecting our people, our economy and our national security. The options selected are proven to be effective in mitigating the deadly effects of storm surge on our state. I thank the US Army Corps of Engineers and look forward to continuing this vital cooperative effort."

The draft environmental impact statement released includes the Tentatively Selected Plan (TSP) which uses a multiple lines of defense strategy to reduce risks to our communities and infrastructure along the entire Texas coastline. The TSP develops an integrated comprehensive plan for the coast of Texas that includes constructing surge gates to reduce coastal storm damage risks to the Houston Ship Channel, levees along Bolivar Peninsula and Galveston Island, beach and dune renourishment along the lower coast, and nine landscape scale ecosystem restoration projects to increase resilience and reduce risks to the coast of Texas. The features will work together to greatly increase the resiliency of the Texas Coast. The estimated cost is $23 to $31 billion. The Coastal Texas Study complies with the National Environmental Policy Act (NEPA) and considers the impacts the project will have on natural, economic, social and cultural resources.

A Rare 360 View of the Deepest Part of the Salish Sea

Scientists capture 360-degree video of the deepest part of the Salish Sea from manned submersible

Research scientists and explorers captured 360-degree images to depths of nearly 1000 feet near Friday Harbor in the San Juan Islands during the 2018 Salish Sea Survey Expedition. The Boxfish 360 camera, courtesy of Oceans 360, a non-profit focused on increasing awareness of the importance of the world's oceans, was mounted to the exterior of Cyclops 1, a 5-person manned submersible, owned and operated by OceanGate Inc.

The expedition, conducted in early September 2018, included seven dives over five days to allow three teams of scientists to observe the feeding strategies of deep-sea red urchins, document the sand wave habitat of Pacific sand lances, and assess the potential impacts of scientific trawling on the ecosystem.

An internally mounted GoPro Omni and the external Boxfish 360-degree cameras were deployed during all research projects and helped to document the existence of red urchins at a depth of 284 meters (932 feet) – more than twice the depth previously recorded. Red urchins feed on kelp that typically grows in depths of less than 100 feet, so documenting the existence of urchins at more than nine times this depth validates the flow of this food source from shallow subtidal kelp forests to the deepest parts of the Salish Sea.

"The dive experience was very exciting, and so much was going on that even with the dome viewport I couldn't appreciate it all. I was mostly only looking down because my project was about urchins on the seafloor", said Dr. Aaron Galloway, assistant professor at the Oregon Institute of Marine Biology. "The 360 video allows us to go back and see the whole habitat; the technology allows you to pan around in all dimensions and make new discoveries, long after the thrill of the dive is over."

Scientists also captured photographs using a stereoscopic camera that takes pairs of images to create a three-dimensional effect, similar to human eyesight, and also allows for gathering quantitative information about the environment – such as measuring fish to precise lengths and doing a full 360-degree reconstruction of the visual field. Provided by NOAA's Alaska Fisheries Science Center, this was the first time the stereoscopic camera has been deployed on a manned submersible.

Dive time for all three research projects during the 2018 Salish Sea Survey Expedition was funded by the SeaDoc Society as part of their annual competitive grants program, with additional funding provided by the OceanGate Foundation. The expedition was based at the University of Washington Friday Harbor Laboratories in Friday Harbor, Washington.

"Cyclops class submersibles are equipped with multiple external ports and mounting positions in an effort to accommodate equipment necessary to meet the specific objectives of every single expedition." commented Stockton Rush, OceanGate CEO and Chief Pilot, "Whether it is additional cameras like the 360 and stereoscopic camera used during the Salish Sea Expedition, or other sampling and survey equipment our goal is to provide a deep sea platform that is adaptable to the needs of the client."

Credit: OceanGate

New Antarctic Field Season Begins

Science and support teams from British Antarctic Survey (BAS) are gearing up for the start of the Antarctic summer field season. A major focus for the season is the West Antarctic Ice Sheet (WAIS), one of the largest potential sources of future sea-level rise.

From November 2018 to April 2019, scientists from BAS, UK universities and international research organizations will carry out an ambitious program of scientific investigations to determine how the ice sheet, oceans and wildlife will respond to a warmer world.

BAS's logistics and operational experts in Cambridge, and Antarctica are busy preparing to support science on its ships, at its research stations and at field camps in some of the most remote and inhospitable places on earth.

Construction of a new wharf at Rothera Research Station started in November in preparation for the new polar ship – the RSS Sir David Attenborough. More than 50 expert construction workers from BAS construction partner BAM will be on site.

A team of specialists at Halley Research Station begin a new project to automate scientific instruments that capture data such as ozone concentration, space weather and upper atmosphere observations. At the same time, glaciologists will be investigating the latest behavior of the Brunt Ice Shelf.

In the deep field, BAS is supporting a host of projects including one with a team fromt the University of Manchester who are pioneering new technology to locate the 'lost' meteorites of Antarctica.

Professor David Vaughan, BAS Director of Science, says, "This is one of the most exciting times of year for British Antarctic Survey. Our scientists and engineers and logistics teams at research stations, on ships and on aircraft have spent years planning a very ambitious program that will provide answers to the big questions about Antarctica's changing environment. The deep fieldwork on the West Antarctic Ice Sheet will be extremely challenging for science and support teams, but their efforts will make a huge difference to our understanding of the contribution that this sector of the continent makes to global sea-level rise."

Three major projects focused on how the WAIS will respond in a warming world are:

The biggest single field project in the history of BAS, known as BEAMISH. Using hot-water drilling technology, pioneered by BAS engineers, scientists will drill more than two kilometers through the fast-flowing Rutford ice stream, to the bed of the ice sheet. This is deeper than ever before using the hot-water technique.

Ice core drilling in West Antarctica (WACSWAIN). A European Research Council funded campaign to drill an ice core through to the bedrock on Skytrain Ice Rise to collect climate data spanning 120,000 years.

International Thwaites Glacier Collaboration. This is the first field season for the ambitious UK-US collaboration, which aims to understand the processes on Thwaites Glacier and reduce uncertainty on how it is contributing to global sea-level rise.

Biological research campaigns on board the *RRS James Clark Ross* and at Rothera Research Station will focus on how plants and animals adapt to a changing polar environment. Scientists will collect oceanographic data with a range of equipment including gliders and robotics to understand how the Southern Ocean is responding to environmental change. At the sub-Antarctic research stations of Bird Island, King Edward Point and Signy Island, scientists will continue to study the enigmatic wildlife that inhabit the islands such as albatrosses and fur seals, and gentoo and macaroni penguins.

Opinion:
We Must Advance Coastal Sea Level Monitoring from Space

Words by Anny Cazenave

Anny Cazenave is a French space geodesist and one of the pioneers in satellite altimetry. She works at the Laboratoire d'Etudes en Geophysique et Oceanographie Spatiale (LEGOS) at Observatoire Midi-Pyrénées in Toulouse. Since 2013, she is director of Earth sciences at the International Space Sciences institute (ISSI), in Bern (Switzerland). As one of the leading scientists in the joint French/American satellite altimetry missions TOPEX/Poseidon, Jason-1, and the Ocean Surface Topography Mission, she has contributed to a greater understanding of sea level rise caused by global warming. Cazenave was a member of the Intergovernmental Panel on Climate Change and was the lead author of the sea level sections for their fourth and fifth Assessment Reports.

Today about 600 million people live near the sea (mostly concentrated in several of the largest world megacities), and this number will double by 2060. Sea level rise and its impacts in the coastal zones is a question of growing interest in the scientific community. And with reports of climate change impacts, hurricanes and storm surges, it has quickly caught the attention of the media and the public. Because of the obvious importance for adaption purposes and associated socio-economic issues, measuring and understanding present-day sea level change, as well as accurately projecting future sea level rise under different global warming scenarios, stand among the highest priorities in ocean and climate research.

The Problem with Monitoring Sea Level

Sea level varies over a broad range of scales over time and space. Present-day, decadal changes in sea level are attributed to many factors that result from changes in the ocean, the terrestrial hydrosphere, the cryosphere, and the solid Earth, making sea level monitoring a unique and integral diagnostic of global change affecting the planet. The physical processes causing a rise in global mean sea level and regional changes are not identical, although they are related.

The primary cause of the rise in global mean sea level is the increase in ocean thermal expansion, land ice melt, and land water storage change. Changes to the geographical patterns of sea levels, however, results from the superposition of 'fingerprints' caused by different processes. These processes include changes in seawater density due to variations in temperature and salinity, atmospheric loading, solid Earth's deformations, and gravitational changes in response to mass redistributions caused by past and present-day land ice melt and land water storage changes.

At local scales, particularly in coastal areas, additional small-scale processes overlay the global mean and regional sea level components and can cause coastal sea level to substantially deviate from open ocean sea level rise. For example, changes in small-scale currents, as well as freshwater input in river estuaries, can modify the density structure of sea water, hence coastal sea level. Changes in wind, waves, shelf bathymetry, alongshore and cross-shore sediment transport, vertical land motions, land use change, and urbanization are additional physical processes, known as 'forcing factors', that can modify sea level variations in the coastal zone across interannual to decadal time periods. Unlike global mean and regional sea level, which has been routinely monitored for the last 25 years from space by a series of satellite altimetry missions, coastal sea level changes remain poorly known and mostly un-surveyed on a global scale, even though they have a direct impact on human society.

Monitoring from Space: What have we learned?

When it comes to a global average, sea level is one of the best indicators of climate change. It combines changes occurring in the Earth's climate system in response to natural internal climate variability (known as unforced factors), as well as natural and anthropogenic external climate variability (known as forced factors). These factors include the net contribution of ocean warming, land ice

melt, and changes in water storage in continental river basins. For some components, changes that occur over time are directly reflected in the global mean sea level time series.

Study of the sea level budget (the difference between the calculated and observed global mean sea level) highlights constraints on missing or poorly known contributions such as the deep ocean, which has been under sampled by current observing systems, or still uncertain changes in water storage on land due to human activities (e.g., groundwater depletion in aquifers). The global mean sea level which has been corrected for ocean mass change allows one to independently estimate changes in total ocean heat content over time, from which the Earth's energy imbalance can be deduced.

This global sea level indicator, as well as the global sea level budget, are now considered in the *Statement on the State of the Global Climate*. This is delivered on a yearly basis by the World Meteorological Organization to inform governments, international agencies, and the general public about the global climate, as well as weather and climate trends at the global and regional levels.

What We Still Don't Know

When combined with precise satellite orbits, scientists use altimetry as a technique for measuring sea surface height from space. Satellite altimetry measures the time taken by a radar pulse to travel from the satellite antenna to the surface and back to the satellite receiver. The altimetry record is unanimously recognized as an invaluable product that tells us by how much sea level is rising globally in response to global warming, and how it changes regionally in response to the natural internal climate variability. This means it is essential to ensure that observations of global and regional sea level variations from space are not only sustained, but increasing in accuracy.

A longer, more accurate sea level record will help answer the many questions still asked by the scientific community such as: Does the recently recorded sea level rise acceleration represent a long-term shift towards a new climate regime? As the ice sheets melt, how much and how abruptly will these changes in contribution affect the global sea level? How much heat has already reached the deep ocean? Can we constrain the Earth's energy imbalance and its temporal variations with improved global mean sea level observations? Is the regional variability in sea level solely due to internal climate variability or can we already detect the fingerprint of anthropogenic forcing? And what regions will be affected first?

As well as the need for long-term sea level change monitoring from space at global and regional scales, a major gap still remains. It concerns coastal sea level changes.

Coastal populations want to know the total sea level rise relative to the ground, i.e., the climate-related global mean rise and superimposed regional change, plus local changes. The latter results from a variety of drivers of climatic, natural and anthropogenic origin that interact together in a non-linear manner. A mandatory first step to understanding these processes at work is providing precise observation-based estimates of present-day (relative) sea level variations at the coast. This step will also help us further achieve a realistic evaluation of the impacts of sea level rise in coastal environments.

In order to achieve this, accurate monitoring of sea level changes from space along the world coastal zones must be given top priority. Coastal zones are highly under-sampled by tide gauges and currently unsurveyed (within 20 kilometers to the coast) by conventional altimetry missions. This implies the development of an easy-to-use database of multi-decade-long, multi-mission gridded coastal altimetry products.

Today, such a global coastal-altimetry-based sea level record does not exist, although it could be developed by dedicated reprocessing of conventional nadir altimetry missions such as the Jason series and Envisat, and the systematic use of new synthetic-aperture radar (SAR) technology implemented in recent European Space Agency missions (e.g., CryoSat-2 and Sentinel-3).

To understand the impacts of climate change and human interventions affecting the world coastal zones, we must define new types of indicators and monitor them in a sustained way so that we can develop strategies of coastal adaptation for the numerous impacts that affect coastal populations. Coastal sea level being one of them.

Ho Chi Minh City, Viet Nam - October 18, 2016: On a flooded street in Vietnam, a crowd of people try to ride motorcycles and wade in water.

Underwater Paradigm Shift

How advancing technologies are changing the way scientists study the ocean

Words by Katherine Herries and Carlie Wiener, Schmidt Ocean Institute. ***All photos: Schmidt Ocean Institute*****.**

A Flightwave Edge UAV, piloted by Trent Lukaczyk, flies towards R/V Falkor. The Unmanned Aerial Vehicle worked in concert with underwater robotics and the crew onboard the ship gathering data.

People are always looking for the latest technology with the newest phone, computer, or coffee maker to make their lives easier. The same holds true in marine science. Researchers and engineers are continually working on the next robot or software to help them understand the ocean and all organisms that call it home. Traditional oceanographic research methods typically require a ship, sonar, specialist instruments, and a research crew to collect and preserve samples. Most observations of subsurface phenomena from the surface of a ship are fairly restrictive. Satellite and acoustical instruments have been useful in expanding our ability to 'see' the depths but much remains hidden below the surface. "We can see the surface of the ocean using remote sensing, but when it comes to knowing what is going on under water, then it is very difficult. However, this is beginning to change," explains Dr. João Borges de Sousa of the University of Porto.

One group at the forefront of this shift is Schmidt Ocean Institute. Cofounded by Eric and Wendy Schmidt, Schmidt Ocean Institute is creating a space for scientists to both study the ocean as well as test and experiment with new technologies aimed at advancing the pace of ocean science. Expeditions aboard the research vessel *Falkor* frequently carry an array of robots such as autonomous underwater vehicles (AUVs), unmanned aerial vehicles (UAVs), autonomous surface vehicles (ASVs), gliders and the Institute's 4,500-meter capable remotely operated vehicle (ROV) SuBastian. The research teams that come aboard *Falkor* use the newest technologies to redefine how marine research is conducted.

Schmidt Ocean Institute prides itself on being at the forefront of innovative marine research. The development of technology is one of the organization's main areas of focus. Ten separate *Falkor* expeditions in 2018 have been completed with the mission of understanding the ocean using innovative technologies. Each science and engineering team that comes aboard applies their research to solving important questions about ocean health, ranging from such wide interests as tracking the mysterious behavior of white sharks to the mapping of critical deep reef structures.

The scientists and engineers participating in research on *Falkor* are discovering, experimenting, and developing new ways to understand more about ocean cycles, and challenging limitations in how we study and explore the ocean. Along with testing new oceanographic equipment and using multiple robotic systems simultaneously, research teams have created new software programs and approaches to data retrieval and processing. "Everything we send into the ocean to make observations or measurements requires development, redevelopment, and fine-tuning, no matter what,' said Dr. Andrew Babbin, a principal investigator on an expedition earlier this year. "The systems being developed are not only high technology but contain the intelligence of the scientists that created them."

To get a better understanding of the types of technologies and projects being implemented, we review some of the exciting expeditions that have taken place this year.


Tuna-San
大浦
東京大学浦研究室
YAMAHA

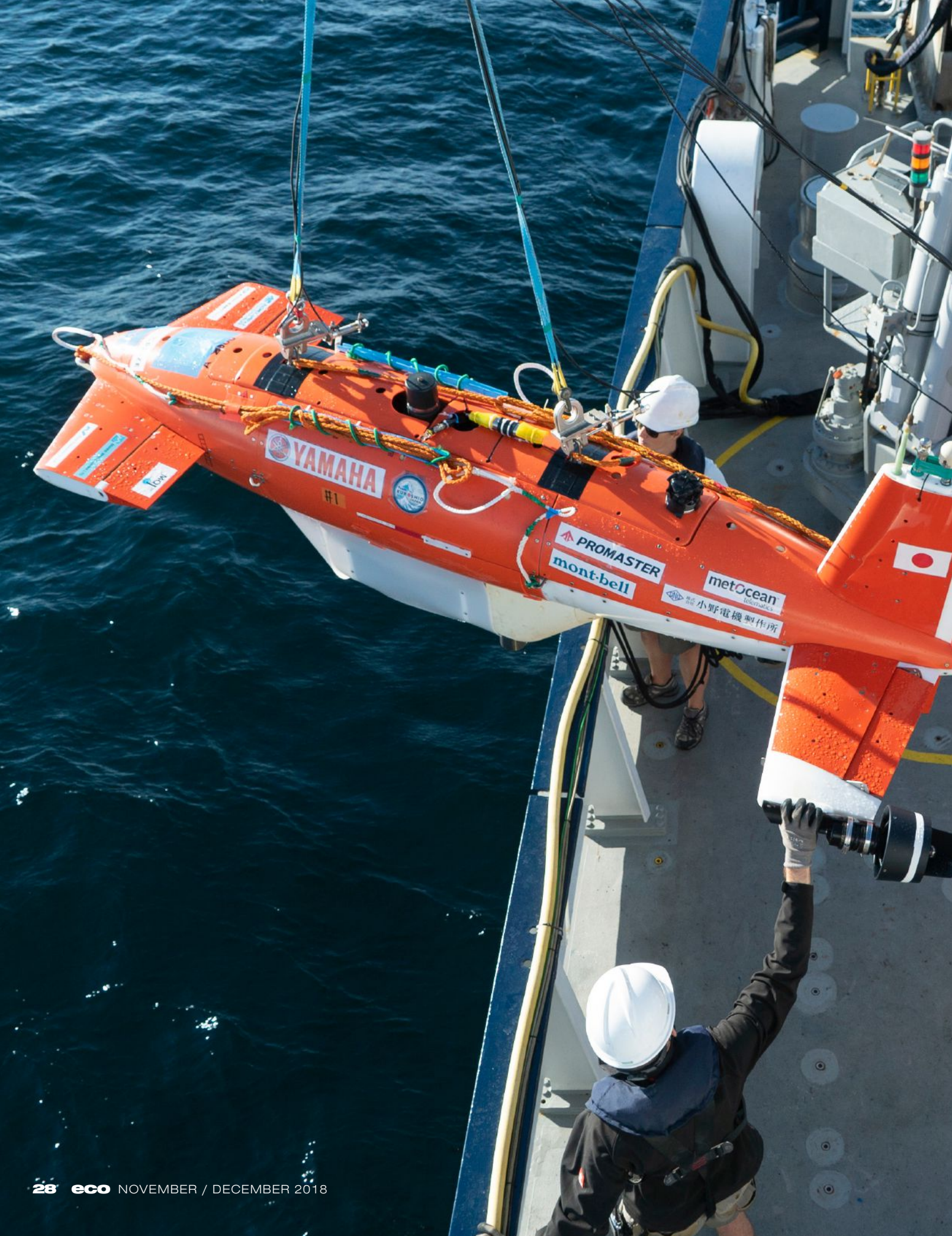
Coordinating Robotics

With six AUVs and two ASVs aboard *Falkor*, the scientists and engineers from the Australian Center for Field Robotics, Woods Hole Oceanographic Institution (WHOI), University of Rhode Island, University of Michigan and Massachusetts Institute of Technology (MIT) continued to refine new ways of habitat mapping. In January, the team set out on the Au'Au' channel off the coast of Maui to operate multiple robots in the water with limited human interaction. "The challenges today are more in terms of trying to get these systems to behave sensibly and predictably enough that we can trust them to do what they need to do if we are not there to tell them," explained principal investigator Dr. Oscar Pizarro from Australian Center for Field Robotics.

Coordinated robots can record more data than a single ship or vehicle, and this was exemplified by the plethora of information collected during their 19-day expedition. Some of the data researchers were able to obtain included imagery, ocean floor mapping, ocean temperature, chlorophyll, current, salinity, and more. The massive amounts of data it takes to get this "big picture" takes too much time for humans to both gather and process, but robotics and machine learning allow for efficient and accurate collection of this information.

Another expedition this year also used a fleet of robots. The "Exploring Fronts with Multiple Robotics" expedition continued to test multiple robotics, but also used *Falkor* as part of a fleet. The ship-based trial integrated a networked vehicle system (called SINVS) which comprised of a Wave Glider and a Saildrone, two unique ASVs, along with multiple AUVs and UAVs, and the shipboard Ocean Space Center set up in the ship's Science Control Room. The SINVS system was supported by a suite of novel software for planning, control, and communication. Using this advanced technology, the scientists on board were able to find, track, and sample various physical, chemical, and biological features of a moving front. "Fronts" are sites where drastic changes occur within the properties of waters, such as regions where warm masses of water meet cold currents. Using this fleet of autonomous vehicles, the team was able to measure the drastically different environments on time-space scales not previously possible by ship or aircraft studies alone.

Dr. Blair Thornton, principal investigator from the University of Southampton (adjunct University of Tokyo), also built on this idea of intelligent robots during his July expedition aboard *Falkor* off the US West Coast. Thornton and his team implemented a form of artificial intelligence, called unsupervised learning, to allow a suite of AUVs to make decisions to map interesting features of a large seafloor and dynamic cold seep. The artificial intelligence algorithm carried out work quickly in the field, that otherwise would have taken a small team of experts several weeks if not months to interpret. The algorithm highlighted areas of interest within hours of the data being collected allowing the team to create dive plans for two more AUVs and ROV SuBastian. This allowed the scientists and engineers aboard *Falkor* to have quick turnaround times for creating better information for site selection. "Many people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think that if we have the robots, then the challenge of studying the ocean is solved. However, the robot is only a platform to collect data, which humans need to interpret and understand in order to build new insight," said Thornton.

Developing New Tools

During the "Eddy Exploration" expedition in northern Hawaiian waters, the robots used did not even have to be brought aboard the ship to retrieve their collected data. Using a combination of *in situ* robotic tools (such as long range AUVs and a Wave Glider ASV) the team was able to characterize the water column features of interest within and across an eddy field, a large 10-100 kilometer circular current. The data was communicated back to *Falkor* in near real-time for integration and display alongside various shipboard instruments. Roman Marin from Monterey Bay Aquarium Research Institute explains that "We need to know what's going on and we need to know quickly." This setup allowed the science and engineering team to adaptively monitor and sample the eddy as it changed across space and time, especially in regards to oceanographic features such as detecting changes in chlorophyll or particle abundance.

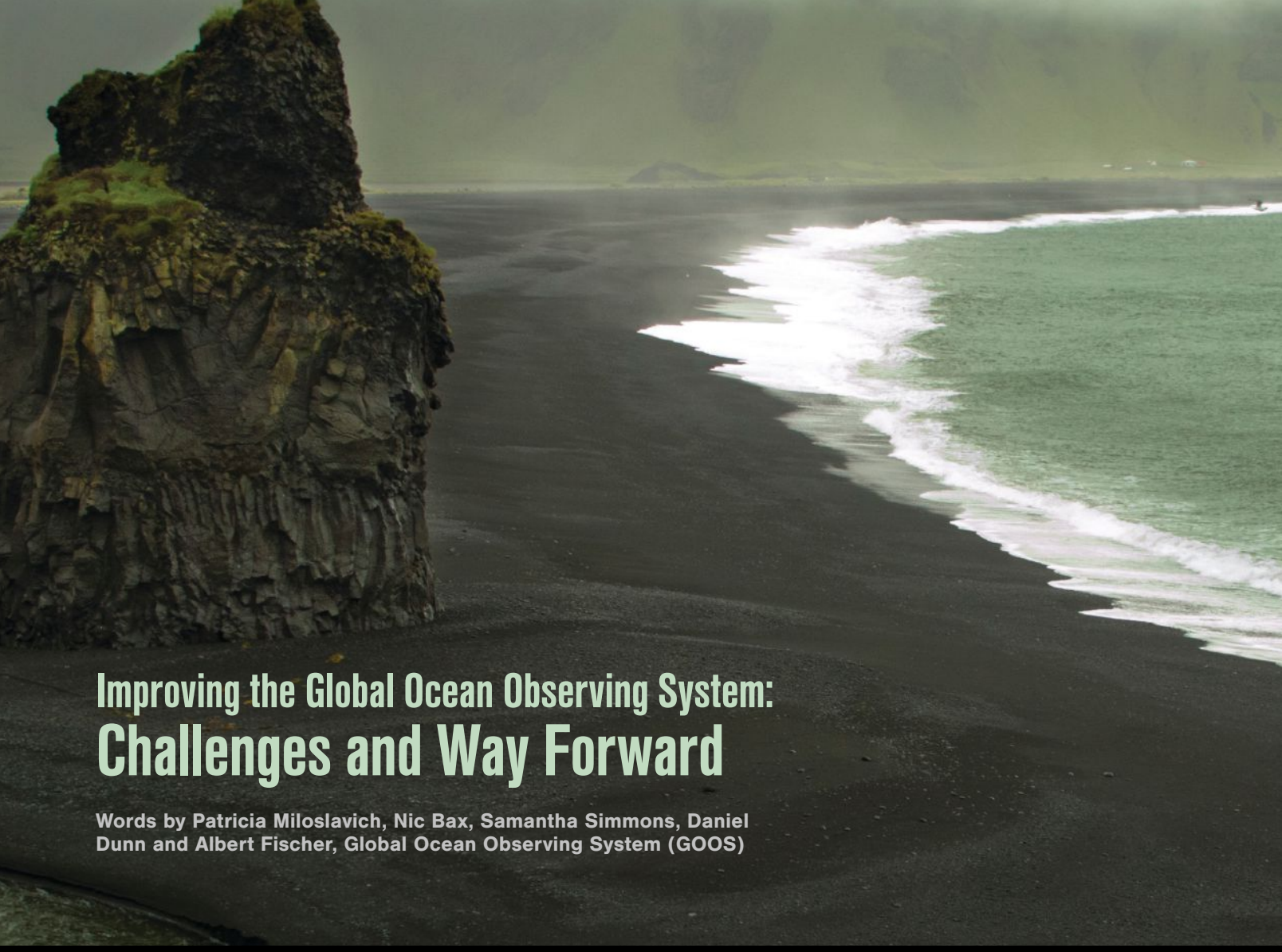
Historically, observation and sampling have relied heavily on ship-based activities, which can limit the resolution of accurate sampling. Drs. Andrew Babbin, MIT, and Karen Casciotti, Stanford University, led a *Falkor* expedition this year in the Eastern Pacific aimed to develop an autonomous sampling technology that can incubate and document microbial processes while underwater. The devices they created send specialized chambers down to various depths and stay there, collecting data for up to 24 hours. Usually, these measurements are made on the ship using water samples in conditions that simulate the state and depth that they were obtained in. With *in situ* devices, the efficiency and number of samples and experiments increased, while reducing the risk of contamination. "There is absolutely no substitute to deploying *in situ* devices in the open ocean at depth," said Babbin. "These findings could be game-changing in our understanding of ocean microbes, and allow researchers to better predict how a warming climate and expansion of low oxygen 'dead zones' will threaten the livelihoods of many coastal communities."

Shifting Tides

New technologies are changing the way scientists can do their work by advancing their progress and efficiency, allowing for greater discoveries in areas that have always evaded scientists. "At the moment humans generally make the decisions. But if we can prove that interpretations made by the vehicles can be trustworthy, then we will be confident enough to hand over the responsibility without jeopardizing valuable opportunities to get important information," explains Thornton.

Having robots work together and make critical decisions correctly allows scientists to cover more ground and make better informed decisions. There is a lot of time and development that goes into each and every robot and algorithm, but "it is a long-term investment that will transform how we do ocean science." The quick wit of these new technologies can create a better understanding of the dynamic ocean which will, in turn, further our knowledge for society, policies, and decisions that need to be made.

Schmidt Ocean Institute (SOI) is unique in its ability to provide science and engineering teams time aboard a technologically advanced research vessel where they can focus their days at sea exclusively on testing and development. "At SOI, we are gearing up for the future, and the new ways oceanography will be done," said Co-Founder Wendy Schmidt. "We're always excited and curious to see what scientists who conduct research on board *Falkor* will come up with, and how, together, we can push the existing boundaries of marine research."



Improving the Global Ocean Observing System: Challenges and Way Forward

Words by Patricia Miloslavich, Nic Bax, Samantha Simmons, Daniel Dunn and Albert Fischer, Global Ocean Observing System (GOOS)

The more we use the ocean, the more it changes.

From transport and recreation to renewable energy and waste disposal, the number of people depending on the oceans is growing each and every day. As changes occur, life within the ocean is being affected. This can have potential consequences for the valuable services the ocean provides, from food to the oxygen we breathe.

So that we can understand how ocean life is responding to human use, we need standardized and regular, long-term observations. Without the knowledge generated by these observations, we will not be able to predict potential future changes and plan accordingly – either by effectively managing or mitigating adverse changes, or by responding to any new opportunities. And yet, not all ocean life can be monitored everywhere, anytime. Nor does it need to be. Relevant changes in marine biodiversity, its function, and the services it provides can be detected by monitoring some of its essential variables.

In the face of climate change, many of the world's nations seek to improve their capabilities in forecasting and managing marine resources. As a result, the Global Ocean Observing System (GOOS) was established. Created in 1991 by the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational and the Scientific and Cultural Organization (UNESCO), GOOS would help to mitigate the effects of natural disasters, for the better use and protection of the ocean and coastal zones.

Over the next three decades, the observing systems developed and implemented by GOOS partners, and efforts of the World Meteorological Organization (WMO), the UN Environment (UNEP), and the International Council for Science (ICSU), have provided the framework to evaluate the role of the ocean in the global climate system. These efforts have also helped to build the operational oceanography infrastructure used by marine industries today such as fisheries and shipping trade, and environmental agencies around the world. What's more, GOOS data streams support climate assessments of the United Nations Framework Convention on Climate Change (UNFCCC). Information which is increasingly becoming the basis for assessing ocean health and changes that may occur in the future.

Framework for Ocean Observing

In the late 1990s, sampling requirements were developed that considered the technical feasibility and impact for improving climate change forecasting for both in situ and satellite observing platforms. These improvements were associated with the ability to monitor a number of "essential variables" outlined by the Global Climate Observing System (GCOS). Essential variables included physical observations (such as sea surface and subsurface temperatures, salinity, sea level, etc), some biogeochemical observations (such as nutrient and carbon dioxide concentrations) and a very limited number of biological observations such as phytoplankton distribution.

A decade later, participants of the OceanObs'09 conference held in Venice, Italy envisioned a societally relevant, multidisciplinary and sustained strategy for ocean observations, defined in the "Framework for Ocean Observing." This framework called for an expansion of new physical, biogeochemical, and biological observations - now known as Essential Ocean Variables. It also promotes the development of innovative technologies while balancing with the need for long-term stability.

Observing a Dynamic System

Following the Framework, multidisciplinary observations under GOOS aims to address climate, real-time services and ocean health. But that is a lot of observations to manage. To help implement, develop and coordinate the observations, three separate panels were formed: the Ocean Observations Physics and Climate Panel (OOPC), working in collaboration with GCOS and the World Climate Research Programme (WCRP), the Biogeochemistry Panel which is built on the International Ocean Carbon Coordination Project (IOCCP), and the Biology and Ecosystems Panel (GOOS BioEco). The panels are also responsible for promoting standards and interoperability of data and information products based on end user needs.

Next, each GOOS Panel had to define their Essential Ocean Variables (EOVs). The Physics and Climate Panel and Biogeochemistry Panel selected EOV's based on specific scientific and societal requirements, driven mostly by climate change and the need for weather forecasts. The BioEco Panel considers societal needs according to international

conventions and/or multilateral agreements relevant to marine life, as well as the current state of ocean observations and how this knowledge contributes to addressing societal and scientific issues. This includes the status and change of ecosystem components such as phytoplankton, zooplankton, fish, marine mammals, turtles and birds. It also includes changes in habitat extent and health, as well as outlining other microbial and benthic variables.

The implementation of these global networks is coordinated through the Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) Observations Coordination Group and through thirteen GOOS Regional Alliances from all around the world. And additional GOOS projects help to fill gaps in the observing system and to extend its capabilities through technological innovation, focusing on sustainability.

Over the next 10 years, and through the coordinated efforts of these panels, GOOS aims to build a global biological and ecosystem observation network that provides more timely, consistent and informed scientific advice on the status of (and threats to) critical marine resources for national management, regional reporting, and global policy. The continous observation of these elements will serve as the foundation for implementing management and policy that promotes a healthy and sustainable ocean ecosystem. It will also help to answer the overarching questions of: What is the current state of life in the ocean? How is it changing? What are the impacts of these changes? And, what is the potential for recovery?

Challenges in Ocean Observation

The BioEco Panel adopted a collaborative international approach stressing the importance of best practices, new technologies, strengthened data sharing and interoperability, as well as enhancing capacity building and technology transfer - vital developments if we are to increase the availability and impact of scientific advice to decision makers.

To the policy community, the BioEco Panel has stressed the opportunities a more advanced observing system will have by increasing future management options and improving reporting at all levels of government. The panel's strategy has been to develop coordinated global networks around each biological EOV, helping to facilitate regional and global integration of existing networks, and create new ones where needed. But there are two issues that are key for the success of these networks.

The first is improving the communication of results and increasing the network's contribution to decision making at local, national, and global scales. This will enable more informed decisions taking into account the needs of conservation and economic development.

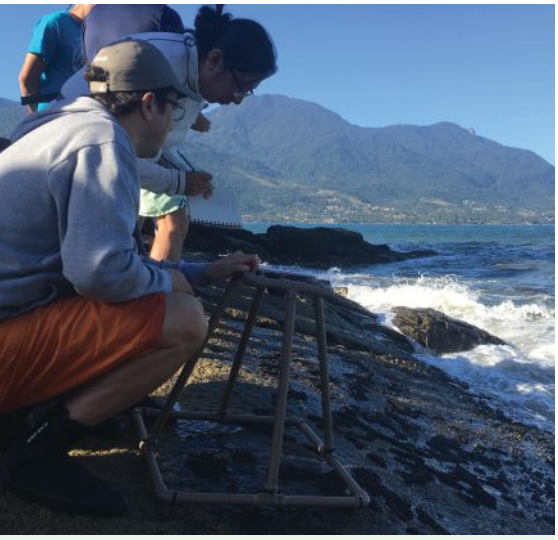
Naked and biomimicking ("Robo-limpet") temperature loggers attached to the rocks of the intertidal zone can measure substrate temperature at intervals of 10 seconds to 18 hours. Data is captured with an app and can be shared immediately providing that there is mobile coverage

The second represents a much bigger challenge, and relates to capacity development and technology transfer. So that we can achieve sustained ocean observations that meet internationally-agreed standards, it's important to endure capacity development and technology. This requires investing in people and their institutions so that they can build infrastructure and long-term support networks with better access to data, tools and technologies. While this can be facilitated by international initiatives, it needs support nationally and institutionally if it is to be sustained.

Capacity development also needs to occur at all stages of the ocean observing process, from identifying requirements and designing systems through to the transformation of data into products and information. This includes the use of best practices at all levels of the process, from instrument deployment to data collection, data analysis, data modelling and management, and in the final reporting.

The importance of capacity development is reflected within the UN Sustainable Development Goal 14. Known as Target 14a, it aims to increase scientific knowledge, develop research capacity and transfer marine technology. The UN wishes to achieve this by 'taking into account the Intergovernmental Oceanographic Commission (IOC) Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries. The IOC Member States have approved a Capacity Development Strategy (2015-2021) with the following vision statement: *"Through international cooperation, IOC assists its Member States to collectively achieve the IOC's high-level objectives (HLOs), with particular attention to ensuring that all Member States have the capacity to meet them."*

There are six major outputs that this strategy is expected to achieve: 1) De-



Monitoring macroalgae and associated biodiversity in rocky shores through photo-quadrats during a training workshop at CEBIMAR, Sao Sebastiao, Brazil. Training workshop organized by the Marine Biodiversity Observation Network (MBON) Pole to Pole and the GOOS Biology and Ecosystems Panel (August 2018). Photo credit: Patricia Miloslavich.

velopment of human resources; 2) Established or improved access to physical infrastructure; 3) Strengthening of global, regional and sub-regional mechanisms; 4) Promotion of development of ocean research policies in support of sustainable development objectives; 5) Increased visibility and awareness; and 6) Reinforced sustained (long-term) resource mobilization (see www.ioc-cd.org/). But the success of these goals rely mostly on public information, continuous professional development, facilitating access to infrastructure, information sharing, development of national marine management procedures and policies, and financial support from member states. Such financial support is critical, as well as its need over a long period of time.

The Future of Ocean Observation

Scientific expertise will certainly have a major impact in advancing the global observing system, but it is the political will and economics which will determine its success. Knowledge without the resources, infrastructure, or technology to apply it will not be enough to improve sustainable use of the marine environment.

"Capacity development" has been recognized as critical on multiple occasions by the United Nations, the IOC of UNESCO and the Large Marine Ecosystem Program of the Global Environmental Facility. Especially for empowering societies in developing countries; for managers to transition into ecosystem-based-management practices; for scientists to better understand the effects of human pressures and climate change, and inform policy for actions to be taken; and for communicators to interface between science, society and politics.

Member states of the UN have proclaimed the decade of 2021-2030 as the 'Decade of Ocean Science for Sustainable Development' aiming "*to gather ocean stakeholders worldwide behind a common framework that will ensure ocean science can fully support countries in the achievement of the Sustainable Development Goal 14 on the ocean."* Needless to say, capacity development will be a key goal for the decade by aiming to form a new generation of ocean scientists and technicians, establish new research networks and a new generation of enhanced observational systems. Some expected outputs will be *"increased scientific knowledge about the impacts of cumulative interacting stressors such as warming, acidification and habitat destruction; and achieving integrated observations and data sharing including the use of satellites, fixed and moving observing platforms, all feeding into common data management and the Global Ocean Observing System (GOOS)."*

This is certainly good news for all ocean stakeholders and for the world, but the success of the Decade will only be achieved if the UN member states, philanthropic institutions and industry support these political decisions with significant financial commitment.

The global ocean observing system, along with developing the capacity and technology for its sustained implementation, requires and builds intensive international collaboration. The system cannot be supported alone by just a few countries or organizations. A long history of ocean observations has taught us that a few governments alone cannot support the entire global system to the required level. We need all maritime and coastal nations within the IOC to make their contribution, and collaboration across all stakeholders including philanthropic foundations and industry will be critical to achieve success.

The Decade represents a unique opportunity for scientists, policy makers, industry and society to work together to address common issues. The GOOS as a community has been working on defining a strategy to strengthen its partnerships and improve the societal impact of its products, better delivering to end users and maximizing resources. It is also building for the future by encouraging innovation of observing technologies and software that will allow for more automated measurements and data analysis, including machine learning and artificial intelligence. But, while the GOOS community is prepared for the challenge, it needs the political will from countries and the support of ocean users to build an observing system that can meet their needs and aspirations.

Further reading:

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UNESCO (2016). IOC Capacity Development Strategy (2015-2021). Paris Available at: http://unesdoc.unesco.org/images/0024/002440/244047m.pdf.

Mapping the Sea's Natural Defense Against Climate Change

Location intelligence is helping scientists understand how to protect an important marine ally in combating global warming

Words by Dawn J. Wright, Esri Chief Scientist

The Intergovernmental Panel on Climate Change (IPCC) recently released a report that presents a more dire picture of the immediate effects of climate change than previously believed. And while leaders often first point to managing economies and slowing the output of pollution, it is sometimes ignored that the earth's ecosystems can self-correct. With the proper data and insight, scientists can be better equipped to foster natural buffers against climate change that already exist in our own wilderness—even in our oceans.

Massive tracts of tree canopy are touted as absorbers of carbon dioxide, but they aren't the only natural defense against man-made pollution. The ocean's modest yet prolific flora plays an even greater role. Bottom-attached seagrasses occur in shallow coasts around the world. These unassuming marine plants store up to 100 times more carbon dioxide compared to tropical forests. Despite their importance, traveling to every shallow part of the ocean to check for their habitats is simply unfeasible. Seagrasses like eelgrass are also, ironically, under threat by factors related to the very thing they may serve as a defense against—climate change. But what if a data-driven model of seagrass health could be built to better protect it?

The challenge of facing global warming in the coming years must be a multitiered approach—one that includes reducing pollution, adapting to the effects of a changing climate, and using the Earth's own defense mechanisms to our benefit. To do that, we must first have data on how they function and how we might be affecting them. As part of this task, an organization called Citizen Science GIS, in concert with the Smithsonian Institution, has begun a project to map and analyze eelgrass in coastal waters all the way from San Diego up to Alaska.

A Clearer Picture

Understanding how the effects of climate change are at play in ocean ecosystems is a relatively new science, especially since the technologies that can help us better understand these relationships themselves have evolved exponentially in only the past few decades. The story of this project began in Belize, which is home to the second-largest coral reef system in the world. The villages along its coast, including its outlying small islands, depend on the reef for their livelihood, as the region has become a draw for tourists. They are also particularly vulnerable to the impacts of climate change, specifically flooding.

In June 2016, Citizen Science GIS, a collaborative effort led by assistant professor Timothy Hawthorne of the University of Central Florida's College of Sciences Geographic Information Systems Cluster, along with the National Science Foundation, the University of Belize, Georgia State University, and the Hopkins Village Council, initiated an undergraduate research training program to map disparities in debris, flooding, and disaster management. They also created the first high-resolution, open aerial imagery of vulnerable coastal and island environments. All this was done through the use of geographic information system (GIS) software. The project gave these communities in Belize location intelligence which is accessible via an online, interactive open data and mapping portal. Up until that point, residents had relied on anecdotal observations to manage these issues and never had a data-driven way to make informed decisions regarding disaster management or conservation.

"Hopkins Village relies on the islands and the barrier reef as a source of income from tourism, but there wasn't a lot of good data about the location out there," said Hawthorne. "If you looked at some of the imagery that was previously available, once you got away from the mainland, there's a lot of cloud cover, it was outdated, or was low resolution. That's problematic for using this imagery as a source for any kind of authoritative data."

Citizen Science GIS set out to replace this with high-resolution imagery captured by affordable, consumer-level drones. One of the reasons the drones needed to be easily operable, as opposed to professional research equipment, is that members of the local community were vital partners of this team effort. University of Belize undergraduates, graduate students, post-doctoral fellows, and other faculty members, as well as Belizean community partners, came together for this focus on open

Mapping an island in Belize with a drone on the barrier reef.

Sampling Eelgrass – An ecology technician from one of the Smithsonian Institution's partner organizations prepares to sample fish from one of the eelgrass beds at Calvert Island, British Columbia. Photograph by courtesy of Dr. Emmett Duffy.

and transparent data sharing, community GIS and citizen science.

The resultant project offered a clearer picture of coastal and island vulnerabilities, boat docks and the damages they sustained, the existence of solar panels and other alternative energy sources on the islands, and seawalls (cement and temporary ones made of recycled materials like tires). Drone2Map for ArcGIS was used to process the imagery into online maps. The team members digitized all of Hopkins and examined roads, culverts and buildings. For structures, they looked at use (residential versus commercial) and proximity to flood-prone areas. The results indicated that 211 out of 239 commercial structures lie outside flood-prone areas. Conversely, 241 out of 273 of the residential structures fall inside flood-prone areas.

The imagery and data showed that new residential structures where families tended to live were being built closer to the lagoon—a more vulnerable, flood-prone area—since these plots were cheaper. This led to the creation of the first map of every culvert in the community, detailing its quality and the buildup that was leading to additional flooding.

"What we kept hearing when we started this work was that the community in Hopkins Village tends to be left behind when resources are allocated or distributed," said Hawthorne. "Now, they have data to support some of the structure improvement initiatives they want to do, like road repairs or cleaning of culverts."

From Microscopic to Bird's-Eye View

A year ago, Dr. Emmett Duffy, director of the MarineGEO program at the Smithsonian Institution, saw the work that Citizen Science GIS had done with Belize, particularly in high-resolution mapping of reefs, and asked it to collaborate on a Smithsonian-led grant proposal. Citizen Science GIS joined partners from three other institutions in a collaborative proposal to the National Science Foundation (NSF) that was ultimately approved for a large-scale marine research and mapping endeavor. The project, which was funded by NSF, involved mapping six eelgrass sites along the entire west coast of the US, Canada and Alaska, using drones to capture high-resolution imagery similar to what had been done in Belize.

Seagrass meadows are one of the major coastal habitats globally supporting fisheries, nurseries, and coastal protection from erosion. The Smithsonian's MarineGEO program has previously coordinated efforts looking at the influence of nutrient pollution and simulated overfishing on seagrass systems. Now, with the combination of drone imaging and ecosystem study, science is moving toward a complete, holistic understanding of these habitats, including the diseases that pose a threat to seagrasses.

"The real excitement in my mind with this new project is connecting what's going on in these seagrass systems, from the molecule to the satellite level,"

said Duffy. "We have one of our scientific partners doing molecular microbiome work, understanding how environmental conditions are changing the microbial community on seagrass, which is very important to whether disease breaks out or not. We then go all the way up from there to the community ecology and what animals live there, as well as the changing climate, to mapping the extent of the eelgrass beds with the drones."

Warm water, increased nutrients, and invasive and changing species, as well as disease—all contribute to depletion of seagrass beds. Ultimately, understanding these factors from several different sites, with the high-level perspective that drones afford, allows scientists to better determine the environmental factors that are leading to the health of seagrasses, why these factors exist, and where they are present.

"We will be drone mapping the sites, and all the imagery will be shared online for free through our open data repository because we want to ensure that not only our team can access it but others can learn from it as well," said Tim Hawthorne. "We'll offer training sessions for community partners to fly our DJI Phantom four drones and any drones that they have as well."

Because seagrasses play an important role in absorbing carbon dioxide and protecting against coastal erosion, it is crucial to understand how to protect sea grasses. And the next step after gathering the data on chemistry, disease, temperature, geography, and other factors is to create a quantitative model that will help predict where and when we can expect these elements to affect the grasses and how to conserve them.

Predicting Marine Ecosystem Behavior

Data is only as good as the use it is put to. "There's really been nothing done on this scope before in seagrass ecology," said Dr. Duffy, "both on a geographic scale and from the molecular scale of microbial interactions on the blades up through the food web and all the way to using remote sensing in the form of drones, to understand what's happening at the ecosystem scale of large areas. The hope is that we come out of all of this fieldwork with a statistical model that can predict disease, take that elsewhere, test it, and refine it to use it in a truly predictive way."

And this is where GIS and the technology of artificial intelligence (AI) meet to aid us in making better decisions for the planet. A machine learning algorithm has already been implemented by Esri to predict global seagrass occurrence based on publicly available data. Global characteristics, such as ocean temperature, salinity, and nutrients, came from a new data compilation and map called the Ecological Marine Units. Publicly available, detailed seagrass data from the Marine Cadastre for the entire US coast acted as the training data for the algorithm. This model was 97.8 percent accurate in predicting the occurrence of seagrass habitats. In the future, a similar algorithm could be applied to the data that Citizen Science GIS and the Smithsonian Institution's MarineGEO program collected. This will allow them to not only see the big picture of how seagrasses are being affected by climate change and other stressors but also learn exactly how to prevent their depletion and where to target solutions. But predicting the behavior of any natural phenomenon must always begin with observation. And the team at Citizen Science GIS has found that drone technology creates unique opportunities in engaging communities to learn about their environments.

A youth from Hopkins Village in Belize documenting the pier as a valued place in the community.

"Much like our Belize work, for the US coastal eelgrass project, we're training citizen scientists in the collection of data through drone imagery," said Tim Hawthorne. "Our team can't be on-site every day for an entire year, so our community partners will be able to fly the drones and also upload the imagery for us to do the spatial analytics. You fly a drone out, oftentimes it's going to open up communication with a stranger that otherwise you might not have had. I see it as a way to start a conversation about science."

Further reading:

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http://www.esri.com/ecological-marine-units

Drone mapping in high-resolution, showing the main roads leading into Hopkins Village. Previously available grainy and out of date satellite imagery of the same area is shown inset left.

Protecting Changing Oceans

Ecological Forecasts to Improve Fisheries Sustainability

By Heather Welch, Elliott Hazen, and Stephanie Brodie (NOAA / University of California Santa Cruz)

In 1872, Yellowstone National Park was established to "provide against the wanton destruction of the fish and game found within said park", and so one of the world's first protected areas was created. The problem, which has been featured in the news cycle many times over the past decade, is that fish and game may roam beyond park borders, and thereby out of park protection. This problem can be exacerbated when protected areas, which were originally designed for land, are applied in the ever-changing oceanic environment.

Unlike their land-dwelling counterparts, the movements of marine animals such as whales and turtles are not restricted by mountain ranges or roads. The ocean is more dynamic than land. And, in response, marine species vary their movements to a much greater extent to remain within suitable habitats, or highly mobile marine animals can swim across sociopolitical borders superimposed onto the marinescape.

So how can we manage the movements of marine species? To address this question, our team is developing dynamic management strategies that are able to follow the species they are designed to protect in real-time.

Dynamic Management

Dynamic management is an emergent strategy in which boundaries are flexible in space and time. It allows scales of management to align with scales of environmental variability, animal movement, and human uses of the ocean. Unlike static protected areas, dynamic management boundaries are updated regularly in response to changing conditions. So, as the ocean's habitats and mobile species move in response to environmental changes, the protective boundary follows suit. This strategy reduces lapses in protection that can occur with static protected areas. And, it's already been proven to be effective. Dynamic

Blue Shark, photo credit: Steve Woods

management has successfully mitigated the bycatch of quota managed southern bluefin tuna in Australian waters since 2006, and helped to avoid the unwanted catch of endangered loggerhead turtles near Hawaii since 2008. Today, tools are being created that continue on from the success of past research, and this is where our work comes in.

In waters off the US west coast, swordfish is the target species of a drift gillnet fishery. Unfortunately, swordfish are not the only thing the fishers find in their nets. Protected species such as leatherback turtles and California sea lions are accidentally caught as bycatch, threatening the environmental and economic sustainability of the fleet. Our team, comprised of governmental, academic, and NGO researchers, received a NASA grant to develop EcoCast: a dynamic management tool intended to increase fishery sustainability by helping fishers avoid bycatch while still catching swordfish. How does EcoCast achieve this? By producing a daily map that shows fishers the best and worst locations to fish based on the likelihood of encountering target catch and bycatch.

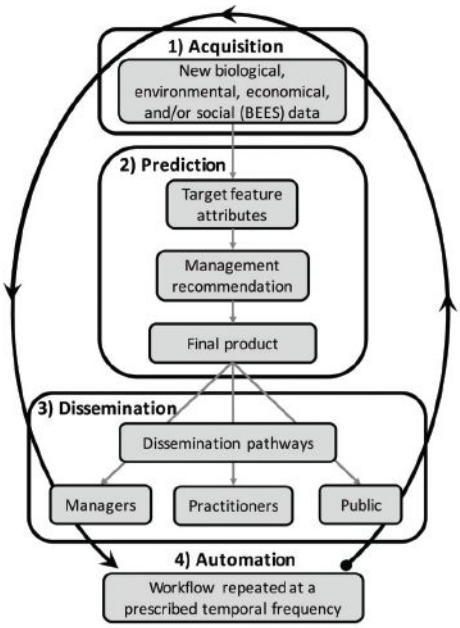
But, the challenge of implementing a dynamic management strategy like EcoCast is that in order to manage the movements of highly mobile marine species we have to be able to predict where the animals are in real-time.

Ecological Forecasting

Physical forecasting is the prediction of the changing environment (for example, daily weather forecasts and hurricane outlooks), and is a well-established field dating back to the turn of the last century. The field of ecological forecasting, however, which is the prediction of biological responses to the changing environment, is still in its infancy. To develop the ecological forecasts needed to create EcoCast, we studied the workflows of established physical forecasts.

During this process, we found that physical forecasting tools follow a consecutive four-stage framework consisting of Acquisition, Prediction, Dissemination, and Automation.

In the **Acquisition** stage, physical forecasting begins with assessments of current environmental state. For example, the National Weather Service uses radar to assess current atmospheric conditions, and the National Hurricane Center uses airplane reconnaissance to monitor real-time hurricane characteristics.



A four-stage framework for operationalizing dynamic management tools. Welch et al. (2018). Practical considerations for operationalizing dynamic management tools. Journal of Applied Ecology. doi: 10.1111/1365 2664.13281

In the **Prediction** stage, physical forecasting tools calculate feature (e.g. weather and hurricanes) attributes based on the newly acquired environmental data. For example, the National Weather Service calculates the locations and severities of weather features, and the National Hurricane Center estimates the location and timing of hurricane tracks.

During the **Dissemination** stage, the predictions are distributed to end-users such as the public, managers, and resource users. Dissemination pathways can vary depending on the intended audience, and can be broadcasted through websites, RSS feeds, e-mail, or text. For example, NOAA Weather Radio disseminates comprehensive weather and emergency information, and the National Hurricane Center's RSS feed provides up-to-date information on storm system progression.

Lastly, in the **Automation** stage, the Acquisition, Prediction, and Dissemination stages are knitted together into an integrated workflow that repeats over a regular timeframe. For example, the National Weather Service creates daily forecast charts, and the National Hurricane Center serves new hurricane outlooks every six hours.

We developed the EcoCast product using the same four-stage workflow.

During the Acquisition stage, EcoCast assesses current oceanographic state by accessing remote sensing data from satellite-borne sensors. These data include ocean temperature, sea surface height, chlorophyll a, and frontal metrics. In the Prediction stage, a machine learning approach for identifying drivers of species distributions (called boosted regression trees) is applied to the newly acquired remote sensing data for each species. This predicts where the target species (swordfish) and bycatch species (leatherback turtle, sea lion, blue shark) are most likely to be based on current oceanic state. These habitat suitability predictions are then combined into a final map product that shows the relative ratios of target catch potential to bycatch risk, standardized between 1.0 (waters that are better to fish) and negative 1.0 (waters that are poorer to fish). The relative importance of finding target catch or avoiding bycatch can be accommodated by weighting the importance of the individual species. To disseminate the final EcoCast product, we use a website with dynamic content that updates daily and an interactive web application built in R Shiny. Lastly, during Automation, the code that underlies EcoCast is scheduled to run each morning once the environmental data are available.

EcoCast was officially launched for use in the drift gillnet fishery in late 2017. Through an iterative feedback process with fishers and managers, we've continued to refine and adapt the tool to meet end-user needs. We're currently developing a survey for fishers to record their on-the-water decision-making in regards to the EcoCast product. This will help us continue to evolve the tool to increase utility.

Developing an Ecological Forecasting Best Practices Handbook

Creating operational tools is only one component of the forecasting process. To increase accuracy, utility, and transparency, physical forecasts also require additional steps, such as forecast validation, inter-forecast comparisons, contingency plan development, and data archiving. While developing these ecological forecasts, we also endeavored to follow these best practices.

Forecast validation (aka figure out how well the tool works and quantify the uncertainty). Just because something can be forecast, does not mean it should. Inaccurate forecasts can waste resources and endanger human lives. For example, 2012's Hurricane Sandy was expected to track into the open Atlantic Ocean, but instead made landfall on the eastern seaboard, making it the most destructive hurricane of the year. To minimize forecast errors, the National Hurricane Center evaluates discrepancies between modeled and observed hurricane tracks in order to calculate the "cone of uncertainty" around predicted tracks. We are taking a similar approach with EcoCast by validating hindcasted predictions against historical catch and bycatch events. This type of information helps us understand tool accuracy, and communicating forecast uncertainty allows end-users to make risk-adverse decisions.

Inter-forecast comparison (aka compare and contrast). There are many different computer weather models, such as the North American Model, the Canadian Model, and the European Model. To improve accuracy, weather

Green Turtle, photo credit: Steve Woods

forecasts from the different models are compared, and sometimes combined to create a more accurate forecast than would be possible with a single model in isolation. We are applying this same concept to refine EcoCast by comparing the accuracy of EcoCast predictions to those made using the reserve design software Marxan. Marxan is specifically designed to handle spatial trade-offs in resource prioritization, which is a similar problem that EcoCast is trying to solve (i.e. maximizing bycatch avoidance while minimizing target catch reduction). By predicting both tools over the same time-series, we can determine the relative strengths and weaknesses of each approach.

Contingency plan development (aka make a backup plan). Tools that have moving components such as the regular acquisition and dissemination of data have the potential for something to go awry. They might fail to acquire data on current environmental state, models might produce implausible predictions, or final products might fail to disseminate as expected. Forecasting tools need contingency plans to deal with these sorts of errors, which can vary among tools. For example, the National Hurricane Center has technicians on hand to address errors in real-time as they occur, which requires a significant budget. EcoCast can have acquisition errors when new satellite data are unavailable for a given day. We conducted a sensitivity analysis to evaluate the utility of different options of handling missing environmental data in order to develop a contingency plan to govern EcoCast's operational response. We tested three different responses: using lagged versions of variables (e.g. temperature from the previous day), dropping variables out entirely, or using lagged versions of the final product (e.g. the EcoCast prediction from the previous day). We found that most individual variables could be lagged by up to a week and still produce a more accurate product than dropping out any single variable entirely. This information on error accumulation helped us build a set of rules that determine how EcoCast responds in real-time to satellite data outages.

Data archiving (aka save everything). Data archiving is an important component of the forecasting process that preserves historical information and allows trends to be monitored. For example, both the weather and hurricane forecasts are archived in public repositories. We took the same approach with EcoCast, and archive all forecasts within the public SWFSC/Environmental Research Division ERDDAP. Through ERDDAP, interested users can download historical EcoCast predictions in a variety of geospatial formats for analysis or exploration. However, because long-running forecasts can produce large volumes of information, their archiving can require significant storage space and funding. To facilitate the archiving of ecological forecasts, which are unlikely to have substantial funds at their disposal, centralized servers may need to be established.

Any new scientific field goes through growing pains as misfires occur and dead-ends are found. A best practices handbook comprised of lessons learned from established fields can help shorten and streamline this maturation phase.

It's clear that static protected areas may not be able to fully protect highly mobile marine animals such as turtles and other pelagic species. In order to improve protection of these species, dynamic management strategies can use ecological forecasts to follow species' predicted habitats in real-time. By borrowing concepts from established physical forecasts like weather and hurricane outlooks, we can increase the utility, transparency, accuracy, and efficacy of ecological forecasting tools. These types of tools offer a novel solution to plan for the increasing variability and

Tagged California Sea Lion, photo credit Michael Milstein / NOAA Fisheries West Coast

change in our dynamic world. Dynamic applications, which by design respond in real-time to changing environmental conditions, can maintain ecological relevance as climate change causes animals to shift in their distributions and creates new interactions with human activities. As our climate changes, our approach to management must change with it.

The Conservation Planning Database

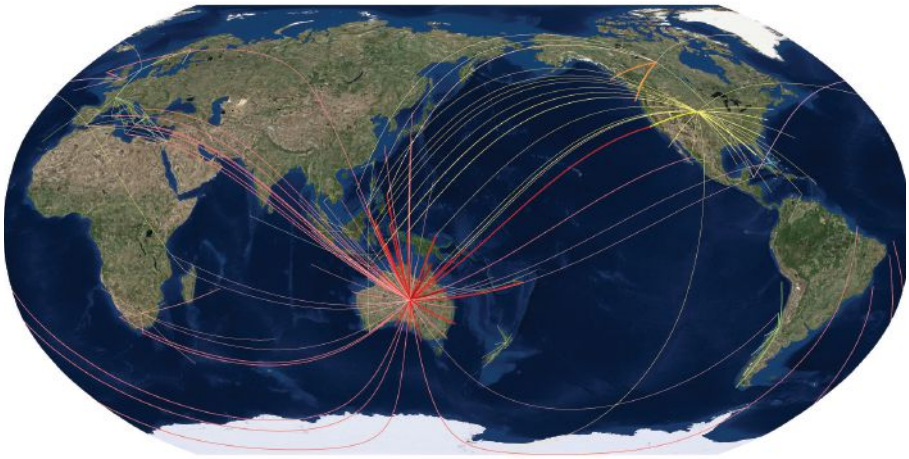
A new global database to better guide marine conservation efforts

Words by Jorge G. Álvarez-Romero, ARC Centre of Excellence for Coral Reef Studies

Over the next few decades, Marine Protected Areas (MPAs) will become an increasingly common feature in oceans all over the world, growing in both number and extent. Behind this increase are new and more ambitious international policy targets. What's more, there is a mounting recognition that we are facing a global marine biodiversity crisis.

This increase in protection is welcome. Especially as it is clear how much our oceans and their inhabitants need and benefit from it. But there are also concerns that the push for quantity is undermining quality, with new MPAs tending to concentrate in residual parts of the oceans where there is limited potential for extractive uses and least need for protection. Although the spirit of the 10 percent Aichi target is to protect places that would otherwise be threatened (Convention on Biological Diversity), there is a risk that countries are gaming international targets by adding still more residual MPAs. The challenge now is in making the expansion of MPA systems count for biodiversity conservation and other planning objectives.

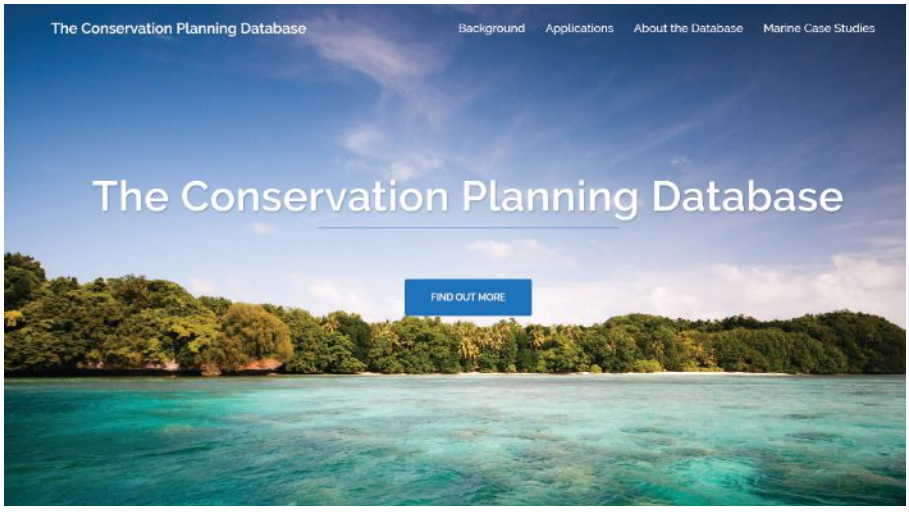
Systematic Conservation Planning (SCP) takes into account both ecological and socioeconomic aspects of conservation. It also provides a robust and transparent approach to spatial allocation of conservation priorities, and planners are increasingly using SCP to identify the best areas to conserve biodiversity. Yet, there is no structured or reliable way of finding information on methods, trends, and progress. There is also varying quality and detail in documentation of plans, limiting opportunities to develop and apply best-practice principles. Over the past ten years, the number of studies added to the marine planning literature has increased exponentially. This accelerating output of marine SCP methods and applications – which includes many in support of new MPAs – urges for systematic documentation and critical analysis of SCP applications.



Marine planning science is growing fast, but there are major gaps in geographic coverage, not enough work done on areas most threatened, and little evidence of input from stakeholders. A new study found that five countries, led by Australia, are forging the way in global marine conservation planning. © Álvarez-Romero et al. 2018, Biological Conservation & ESRI World Imagery.

To address these challenges, we formed an international group of researchers from Australia, Brazil, Canada, UK and US to develop a database that documents SCP exercises. This effort resulted in the creation of The Conservation Planning Database, which aims to help track the development, implementation, and impact of SCP applications, and to learn from these efforts. The marine proof-of-concept database includes information on planning goals; location and spatial extent of the effort; targeted conservation features; methods and outputs; and the roles of stakeholders.

We recently published a study in *Biological Conservation* (Álvarez-Romero et al. 2018) that introduces the database and synthesizes global advances and trends in marine SCP planning. The Conservation Planning Database is the most comprehensive and systematic compilation of marine SCP studies to date, thus pro-



The Conservation Planning Database, led by James Cook University, takes an important step in remedying the lack of transparency and consistency in global conservation planning. The marine proof-of-concept database is the first centralized repository of key information on SCP exercises worldwide. © The Conservation Planning Group 2018, Photo by Rebecca Weeks

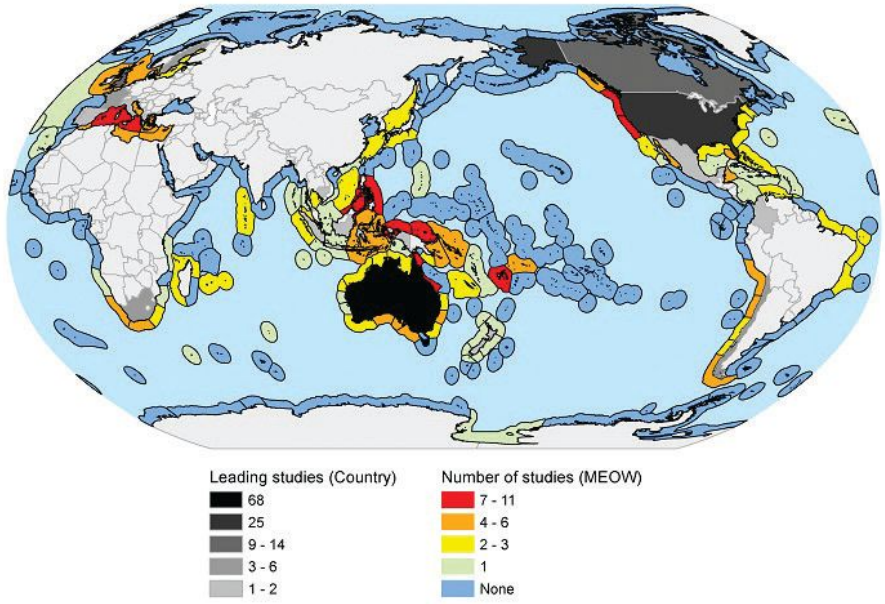
Fiji Islands shoreline

viding a unique opportunity for scientists to access and analyze further aspects of marine planning. The study required documenting and analyzing more than 150 plans found in the peer-reviewed literature. Here is what we found:

Trends in Marine Conservation Planning Studies

The review of marine planning studies revealed an exponential increase in marine SCP over the past 15 years, with over 160 papers in the primary literature and an increased rate of publication over the last five years. It became apparent that more attention is being given to socioeconomic considerations, land-sea planning and, more recently, to ecological connectivity and climate change. Other topics gaining traction, but proceeding more slowly, included marine zoning, planning for pelagic ecosystems, and dynamic oceanographic processes.

We were surprised to find little evidence of input from conservation practitioners and stakeholders in these exercises. The lack of stakeholder participation could be related to our focus on the peer-reviewed literature, but nonetheless is concerning. SCP studies developed without input from conservation practitioners can limit the potential application and validity of findings: limitations include inadequate information, unrealistic assumptions, and methods that are difficult to replicate.



Number of marine SCP studies led by organizations from different countries (in the lightest shade are countries with no organizations recorded as leading any studies) and number of studies undertaken per marine ecoregion (MEOW). © Álvarez-Romero et al. 2018, Biological Conservation

Geographic Coverage and Gaps in Marine Planning Studies

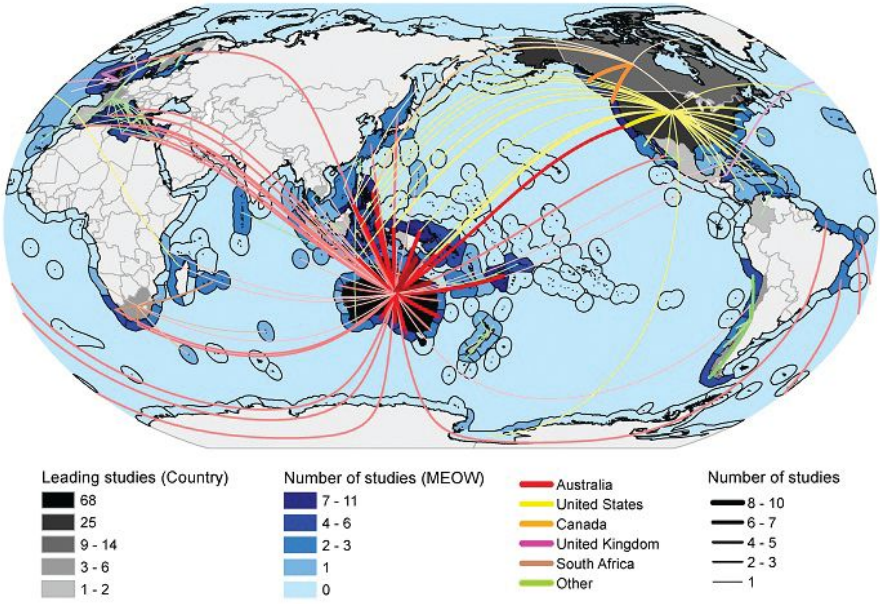
There are important gaps in the geographic coverage of marine SCP studies. Moreover, the geographies covered were not well aligned with the locations conservation scientists have identified to be at greatest risk. For instance, a spatial exploration of the distribution of studies shows that more than half (55 percent) of the marine ecoregions of the world (MEOW), have no planning exercises recorded in the primary literature. Of those ecoregions with studies, about 13 percent have only one exercise recorded.

Stakeholder participation in planning is critical. Community members in Fiji using outputs from a systematic conservation planning analysis to inform the design and establishment of a network of locally managed MPAs. Source: Weeks & Jupiter 2013. Photo © Rebecca Weeks

Expertise and Knowledge Sharing in Marine Planning

Understanding where planning has occurred and where there is expertise in SCP is critical for advancing marine conservation. The review revealed that research institutions or organizations from five countries have led the majority (~80 percent) of marine studies (Australia, US, Canada, UK, and South Africa). This suggests there are organizations with strong resources and expertise in SCP within these countries. These countries also have extensive networks, spreading over 80 countries, which suggest the potential for capacity building through collaboration with international organizations.

Australian organizations have contributed significantly to developing methods and tools that are widely used in SCP, which further explains the role of Australia as an important "marine SCP hub". For example, the Marxan conservation planning software, developed to support the rezoning of the Great Barrier Reef (GBR) Marine Park, was used in 56 percent of all studies in our database (64 percent when including Marxan relatives). The GBR planning hotspot illustrates the importance of some regions in supporting the development of best



Number of marine SCP studies led by organizations from different countries with links to ecoregions covered by those studies and number of studies undertaken per marine ecoregion (MEOW). © Álvarez-Romero et al. 2018, Biological Conservation

practices in marine planning across the board.

Consolidating a Global Conservation Planning Database

The Conservation Planning Database is an important step towards a centralised repository of information of planning exercises. With this database in hand, donors and non-government organizations can identify regions and topical areas needing further work, and scientists, practitioners and policy-makers can learn from previous plans. It also gives the scientific community – including peer reviewers – a means of assessing trends in conservation planning methods and applications, so that we can learn from our previous work and shape our new work accordingly. And yet, there's more work to be done!

It's important to enrich the information about stakeholder participation so that it includes lessons learned about which stakeholders to involve in planning (and when and how) to facilitate planning and implementation in different contexts. Likewise, documentation of planning outputs can be enriched by providing functionality to match and compare the configuration of initial designs with the implementation of conservation actions, such as protected areas registered in the World Database of Protected Areas (WDPA).

Planning for marine connectivity and climate change is gaining traction. Álvarez-Romero et al. 2017, Photo © Octavio Aburto

An ongoing collaboration with UNEP's World Conservation Monitoring Centre can help bring the additional expertise and resources needed to consolidate the database, including securing hosting and maintenance arrangements. The database can further improve by adding functionality to match and compare the configuration of initial designs with the implementation of conservation actions, such as protected areas registered in the WDPA.

Further, collaboration with key international organizations (e.g. Convention on Biological Diversity, Society for Conservation Biology, IUCN's World Commission on Protected Areas) will be needed to reach the international community for support, and to encourage organizations and countries to include and update their plans. Consolidating the global SCP database will be an important step in supporting the international community in achieving the CBD's Aichi biodiversity targets and the revised targets after 2020.

Implementing new protected areas is a cornerstone conservation strategy to address key threats to global biodiversity. Ensuring the expansion of our global system of protected areas is effective in halting biodiversity loss requires new protected areas to be well designed, located in areas of most need, and effectively implemented. To this end, the Conservation Planning Database will help us learn from past and ongoing planning exercises and provide a tool for tracking progress from the design through to implementation phases.

For more information, visit database.conservationplanning.org.

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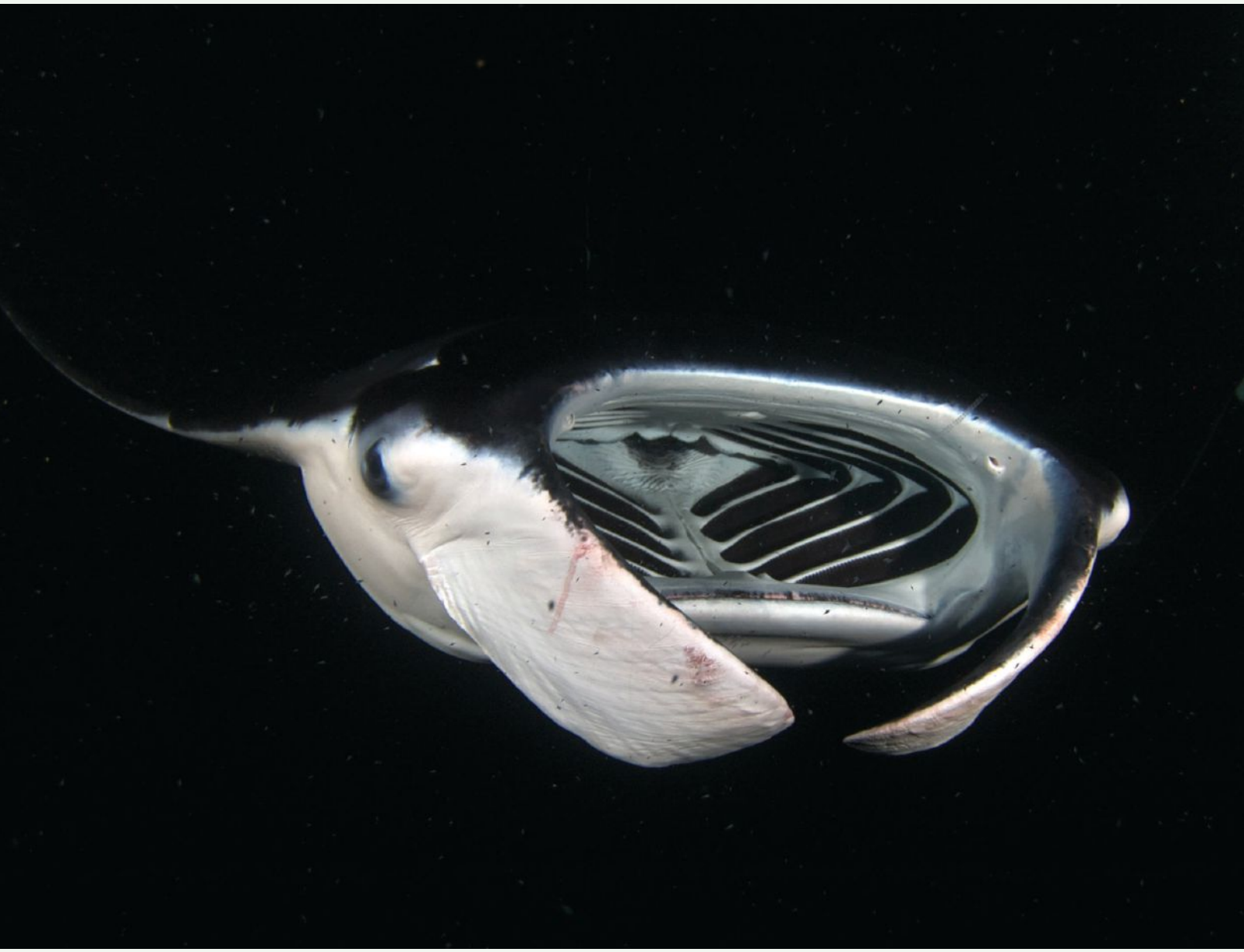


The giant oceanic manta ray (Manta birostris) uses lobe-shaped structures to bounce plankton off their gill filters and into their mouth. Credit: S Kajiura/Florida Atlantic University

Manta Ray Mouthparts Offer Insights Into New Filtration Technologies

By Ellis Moloney, Institute of Marine Sciences, University of Portsmouth

Researchers at Oregon State University have recently discovered that manta rays are able to filter plankton from seawater using a system never seen before in the natural or industrial world. The findings, published in *Science Advances,* describe a unique mechanism which resists clogging and therefore offers a new approach for designing filtration systems on an industrial scale.

Manta rays are large cartilaginous fish closely related to sharks, skates and other rays. They feed by filtering small crustaceans and zooplankton through their open mouths before flushing the remaining water out through their gills. Unlike most conventional filtration systems used worldwide, manta rays can resist clogging by using leaf-shaped lobes to bounce the food away.

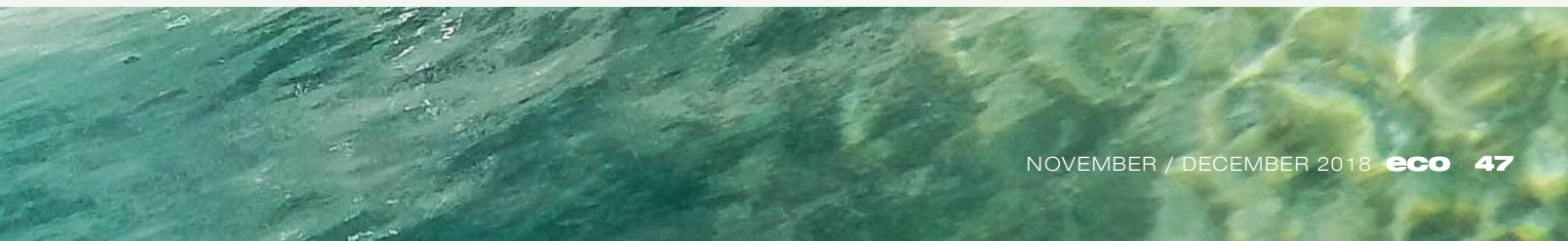
“Manta rays appear to utilize a novel mechanism for filtering particles out of fluids," said study co-author Jim Strother, assistant professor of integrative biology in the OSU College of Science. "Their filtering apparatus has a special structure that causes plankton particles to ricochet off the filter and become concentrated in the mouth cavity, so the fish can then ingest them."

Strother and colleagues took CT scans of manta ray specimens from museum collections and then built a 3D printed replica of the filter found in the giant oceanic manta ray, *Manta birostris*. The replica was then placed in a flow tank with small objects and a coloured dye to represent various sized food particles. Computer modeling also helped calculate the trajectory of the particles as they entered the mouth.

This incredible design raises questions concerning the importance of manta rays to marine habitats and how they are distributed. This system might conceivably enable larger animals to exist in areas with less food because it’s energy efficient, says Stuart Humphries, an evolutionary biophysicist at the University of Lincoln in England who wasn’t part of the study.

Rays are increasingly being targeted by illegal fishing practices and a greater understanding of the physiology of filter feeding may be useful for predicting the habitat usage of manta rays and implementing appropriate protective measures. Furthermore, the strategy could inform better filter designs at wastewater treatment plants, which fail to catch microplastics. A filter inspired by the manta ray’s mouth might trap tiny pollutants before they escape into our oceans and harm wildlife.

Raj V. Divi, James A. Strother, E. W. Misty Paig-Tran. Manta rays feed using ricochet separation, a novel nonclogging filtration mechanism. (2018) Science Advances, 2, 4 (9): eaat9533 DOI: 10.1126/sciadv.aat9533



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Six Steps to Creating the Perfect Elevator Pitch for Science Conferences

Words by Kira Coley, The Chatty Scientist

You're at a conference and just finished the first morning round of talks. On your way to snag one of those free scones and mini-jams, the leading expert in your field of study steps into the elevator with you. It's your time to shine and make an impact. Here's when you hit them with the Elevator Pitch. An elevator pitch isn't just something used by salespeople. It is also a statement a scientist can use to quickly summarize important facts about their research, avoid the waffle and wow science colleagues. It's an opportunity for you to tell people how you, your research or your organization is unique and make a lasting impression. Keeping in mind that elevator rides are usually pretty quick, the pitches should be around 30 seconds. They are brief, compelling and memorable. But, explaining years of research in less than a minute can be tough and a little daunting. So, here is some advice to get you started.

Six Steps to Creating the Perfect Elevator Pitch

STEP 1 Science communication is all about finding ways to effectively deliver your message. So, think about what message you want your pitch to deliver. Is it to showcase what you've done? Highlight the importance of your work? Tell them about a new method you've created? Or, simply introduce yourself and your project? Write down your goal, as this will help you decide what to include in step 2.

STEP 2 Write a draft pitch. Only use the key information needed to meet your goal and get your points across. Write it in no more than five sentences. You can use the suggestions below for inspiration:

- Introduce yourself. Start by explaining who you are and where you work.
- What do you do? Summarize your research and why it is important.
- What makes you unique? This is important. Why is your research relevant? What gap does it fill? Who benefits? Why should he/she care?
- How do you do it? Are you using a method you have designed yourself or is a little unusual?
- Who do you work with? Are you collaborating with anyone they might find of interest? If they aren't well known, is there a special reason why you are working together?

STEP 3 Create a balance. You want to get your message across but only use the information they want to know. We go to science conferences to discover the latest developments in our fields, network and because we are naturally curious about each other's research; what you are doing, who is involved and perhaps in search of opportunities for collaboration.

Just be aware only a select few will want to know the finer details of how you chose your methods or set up your experiments. Be informative but high level, unless they ask for more information.

STEP 4 Think about language. Personally, I believe that it's fine to use some science terms at conferences which are well-known in your field. But be prepared to explain it simply if asked. If you are attending a networking event for people from different industries, then swap the science terms for everyday language.

STEP 5 Timing is everything. Don't unleash your pitch before they even say hello. The pitch is designed to help you clearly explain your work without the waffle, but only use it if it fits into the conversation without being forced.

STEP 6 Finally, remember to say your pitch out loud and get feedback. It may read great on paper, but it doesn't mean it will sound natural during a conversation. Avoid the infomercial trap!

Have a go at writing your own pitch to use at your next conference or networking event. The elevator pitch could lead to new collaborations, funding opportunities or, at the very least, the start of an interesting conversation over a free scone. Head over to www.chattyscientist.com for more resources.

Finalists Named In $10 Million Race Against Toxic Algae

The George Barley Water Prize is our "best hope" to solve algae crisis threatening waterways worldwide.

After more than two years of testing their technologies in laboratories and in the field, the four finalists in The George Barley Water Prize – a $10 million incentive award to find a new technology capable of removing phosphorus from polluted fresh body waters – were announced last month at a formal ceremony in Toronto. The four finalists each received $125,000 to support their continuing research and development.

Phosphorus is widely used in chemical fertilizers, and while essential for plant growth and human health, excess amounts in waterways nurtures the growth of algae that is killing fish and spoiling water quality worldwide. According to the World Resources Institute, more than 15,000 freshwater bodies in the United States alone are affected by phosphorus pollution.

The George Barley Water Prize Finalists who will advance to phase 4 are:

- Clean Water Machine – University of Idaho – Moscow, Idaho
- Wetsus NAFRAD – Leeuwarden, the Netherlands
- Green Water Solution, Inc. – Wellington, Florida
- US Geological Survey - Leetown Science Center – Kearneysville, West Virginia

"These finalists represent our best hope for solving the algae crisis that is choking waterways worldwide," said Eric Eikenberg, CEO of The Everglades Foundation, which is hosting the competition with presenting sponsor The Scotts Miracle-Gro Foundation.

The George Barley Water Prize was launched in 2016, following a state of emergency in Florida that lasted for 242 days as a result of toxic algae blooms that devastated the state's waterways. The competition attracted 104 international competitors, which were then narrowed down to nine competitors who tested their technologies under cold weather conditions in Toronto for a 90-day stretch in early 2018. The four remaining teams will now advance to the final phase of the competition, the "Grand Challenge," where they will test their technologies in warm water conditions at Lake Jesup, near Orlando, Florida. The Florida Department of Environmental Protection is contributing $1 million towards the final phase

"The four finalists will engage in 14 months of intensive field testing under moderate and warm weather conditions," Eikenberg said. "These final four teams will need to prove their technologies' ability to work in both freezing and warm temperatures. This will be their opportunity to showcase the global applicability of their solutions."

Modeled after the incentive prizes that encouraged Charles Lindbergh to make the first nonstop trans-Atlantic flight and that led to the invention of fire extinguishers and commercial hydraulic turbines, The George Barley Water Prize is a $10 million award to the team that can develop a safe, effective and affordable method to remove phosphorus from waterways on a large scale. The Prize is named after the late George Barley, one of the two founders of The Everglades Foundation, Eikenberg noted.

"It's clear that groundbreaking innovation is needed to solve for harmful algae blooms caused by excess phosphorus," said Jim King, President of The Scotts Miracle-Gro Foundation. "Stage 3 marked a turning point in the Barley Prize competition, bringing innovations into the real world for testing. While our company removed phosphorus from routine lawn products a number of years ago, The Scotts Miracle-Gro Foundation continues to stand behind this race for a solution to phosphorus pollution as it enters its final stage–a chance to solve this global problem, once and for all."

Runoff from man's long-standing use of phosphorus-based fertilizers is so extensive, scientists believe, that even if its use were to be eliminated altogether, there is so much of the mineral already stored in water and soil that it would continue to be a serious pollutant, creating algae blooms for decades, if not centuries, to come.

"Using today's technologies, it would cost upward of $3 trillion to reduce the current worldwide flow of phosphorus by just 10 percent," explained Loren Parra, Director of the Barley Prize. "Living and working here in Florida, we could certainly benefit from a solution and we are excited, hopeful and anxious to see what comes from the Grand Challenge."

The George Barley Water Prize is hosted by The Everglades Foundation in association with the Scott's Miracle-Gro Foundation as presenting sponsor, the National Fish and Wildlife Foundation, the Ontario Ministry of Environment, Chicago Community Trust, the Knight Foundation, The Field Museum, and Xylem, Inc.

TCarta Delivers Satellite-Derived Mangrove Health Assessment to Abu Dhabi

TCarta, a global provider of geospatial products and services, has been commissioned by Environment Agency – Abu Dhabi (EAD) to carry out a landmark mangrove health assessment covering the entire Emirate of Abu Dhabi. The assessment contains mangrove condition information derived from high-resolution multispectral satellite imagery.

"The satellite-derived vegetation analysis process we developed for this project can be applied to large-area crop and forestry health mapping anywhere in the world," said Chris Burnett, TCarta Project Manager.

For EAD, the TCarta report delivered some promising results. With 80 percent of the Emirate's mangrove forests found to be healthy, this was encouraging news. The innovative project also enabled EAD to designate conservation areas for immediate protection. The data helped EAD to assess the relative success of existing schemes with the view to applying the lessons learned into practice for future endeavors.

"As part of the assessment, we created a Disturbance Index showing precisely where the most mangrove stress is occurring," said Burnett. "EAD will use this to determine – and potentially mitigate – the external factors causing the mangrove conditions to decline."

For the assessment, TCarta obtained high-resolution multispectral imagery acquired by the DigitalGlobe WorldView-2 and -3 satellites during the months of December through March. Computer algorithms were applied to the Coastal Blue, Visible Green, Visible Red and Near Infrared bands to differentiate mangroves from other vegetation across the Emirate. A total of 155 km^2 of mangroves were identified and mapped. "We then derived several vegetation indices from the spectral bands to rate the health of the mangrove forests, divided into small grids," said Burnett.

Next, TCarta analysts obtained coarse-resolution Landsat imagery from 1987, 2001 and 2017 to chart mangrove coverage over three decades. The combination of WorldView and Landsat data analysis clearly showed where mangrove loss had occurred over time. From this, TCarta generated the Disturbance Index correlating health to external factors, such as urban development.

"Urban development near Abu Dhabi City appears to pose the primary threat to the Emirate's mangrove forests," said Burnett. "EAD, which is a government agency tasked with protecting the local environment, will use this report for remediation efforts, including the selection of more favorable areas to plant new mangroves to balance those that have already been lost." Based on the success of the Abu Dhabi project and accuracy of its results, TCarta is now offering the satellite-derived vegetation mapping and health assessment technique as a commercial service available worldwide.

CSA Welcomes New Underwater Acoustic Project Scientist

CSA Ocean Sciences Inc. (CSA), a marine environmental consulting firm that specializes in multidisciplinary projects concerning potential impacts of activities in coastal and marine ecosystems, is happy to announce that Kayla Hartigan has joined the team at CSA's headquarters in Stuart, Florida, as an underwater acoustic project scientist. In this role, she will use her experience gained while studying for her Master's Degree in Coastal Environmental Management from Duke University in North Carolina and her expertise as a soundscape ecologist to assist with CSA's projects that address underwater sound.

Marine-i Backs Innovative Research Approach for Coastal Wildlife

Marine-i, the EU funded program set up to boost marine innovation in Cornwall, UK has made a grant award to The Rock Pool Project. This organization is led by marine ecology specialists and has a mission to raise awareness of the wide variety of species that inhabit rock pools and their importance to the marine ecosystem. The funding from Marine-i has been used to carry out initial development work for an app which would be used by students and by the general public to gather valuable data on rock pool wildlife.

Sonardyne Acquires Technology Specialist Chelsea

Subsea technology developer Sonardyne International Ltd. has acquired maritime and marine science technology specialist Chelsea Technologies Group Ltd. The acquisition is part of a long-term growth strategy to diversify into markets where it sees an opportunity to build on its core technology base and expertise in underwater acoustic and optical communications, navigation and autonomous monitoring systems. Chelsea has a broad base in environmental sensing technology in fresh and waste water, oceanography and a wide range of industrial applications.

World-Leading Center to Train Next Generation of Global Change Scientists

Multimillion-pound center between Newcastle University and Northumbria University will train scientists to transform our understanding of planet Earth.

The ONE Planet Doctoral Training Partnership will draw on the research expertise and specialist facilities of both universities in Newcastle upon Tyne (UK) to provide a world-leading training environment tackling grand challenges in climate and environmental sciences.

Funding for ONE Planet was announced on October 10 by the Natural Environment Research Council (NERC) and comes in the same week that the Intergovernmental Panel for Climate Change (IPCC) declared that limiting global warming to 1.5°C requires rapid, far reaching and unprecedented changes in all aspects of society.

The universities' world leading research and expertise in climate change, earth systems and the environment were key to the success of the funding application.

Researchers joining the program will study a diverse range of topics including earthquakes and volcanoes, pollution, weather extremes, sea level change, and frozen environments such as the ice caps and glaciers.

The partnership includes more than 40 local and national business, government and industry partners including the Environment Agency, the National Trust, Northumbrian Water Group, and a host of other engineering, environmental and charitable organizations.

Hayley Fowler, professor of climate change impacts at Newcastle University, will lead the program and said, "To really understand how our planet is changing we need to work across subject disciplines and explore the connections between human activity and the Earth's natural systems. The period where humanity is now the key agent in planetary-scale change is termed 'The Anthropocene'. Our researchers will learn in an interdisciplinary environment which will give them the skillset required to analyze and design the responses needed to address intensifying global change."

Professor Fowler, who leads part of the World Climate Research Program and is an expert in the impacts of climate change on water systems, added: "We are going to be working across science, engineering, statistics, agriculture, history, planning and many other disciplines. Both universities in the city have established world leading research in many different aspects of The Anthropocene and by working together we will produce researchers and leaders who can design the responses we need to the ways in which our planet is changing."

Ulrich Salzmann, professor of palaeoecology at Northumbria University, said: "Our vision is to provide a training environment for independent research scientists and future leaders that develops innovative new ways to analyze and design the sustainable responses needed to address intensifying global change.

"I am delighted to see that the world leading research in Geography and Environmental Sciences at Northumbria University has been acknowledged and I am looking forward to work together with Newcastle University on training the next generation of independent research scientists and future leaders as part of our new One Planet NERC Doctoral Training Partnership."

The training program will use specialist research facilities at both universities including Newcastle University's Blyth Marine Station and research vessel, Urban Observatory, University Farms, Newcastle Helix, and Northumbria University's Environmental Sciences Laboratories. There is scope too for researchers to influence governmental policy and there will also be an annual event that will share progress, results and debate with the public.

A list of all successful projects can be found on the NERC website.

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Seabed 2030 Project: First Regional Mapping Meeting for Arctic, Antarctic & North Pacific

The first regional mapping meeting for The Nippon Foundation-GEBCO Seabed 2030 Project has been held in Stockholm, covering the Arctic, Antarctic and North Pacific regions.

The successful meeting held last month, brought together leading ocean mapping experts, oceanographers, scientists and private companies to discuss various technical elements of the Project including data acquisition, visualization, expedition coordination and the role of future technologies. With the goal of mapping the entirety of the world's ocean floor by 2030, The Nippon Foundation-GEBCO Seabed 2030 Project divides responsibility for different areas of the ocean between four Regional Data and Coordination Centers (RDACC). The meeting heard presentations from individuals representing a variety of organizations including research institutions and private sector organizations that have acquired new bathymetric data since the last GEBCO grid was published in 2014; the most recent update to the global map of the seafloor.

This data will be donated to The Nippon Foundation-GEBCO Seabed 2030 Project, and will represent a significant increase in the area of the world's ocean floor that has been mapped using high-resolution direct measurement techniques. In total, the meeting identified numerous sources of new bathymetric data. The combined area of these contributions in terms of square kilometers will be announced later this year.

CSA Completes Nassau Sound Survey to Support Amelia Island Beach Restoration

CSA Ocean Sciences Inc. (CSA), a leading global marine environmental science consulting firm, announced the completion of a survey to collect data for hydrodynamic model calibration and verification in Nassau Sound, located north of Jacksonville, Florida.

The CSA team measured inshore and offshore water level, tides, current and waves to calibrate and validate a hydrodynamic model. The team installed water level recorders and a wave-enabled Acoustic Doppler Current Profiler (ADCP) and conducted an estuarine water discharge survey to gather the needed data.

Morgan & Eklund, Inc. (M&E), CSA's sister company, a licensed survey company specializing in hydrographic surveys, teamed with CSA on this project. The project was contracted and managed by Olsen Associates, Inc. (Olsen), an industry leader in coastal engineering and experts in beach restoration projects.

The survey and the subsequent hydrodynamic modeling by Olsen supported sand borrow area development and permitting analyses for the South Amelia Island Shore Stabilization Project. The project is an ongoing engineered beach nourishment project managed by the South Amelia Island Shore Stabilization Association in Nassau County, Florida, and the Florida Park Service.

"CSA's estuarine water discharge surveys collected tidal current data as ADCP profiles of current velocity and direction, said Tim Shaw, CSA's Project Operations Manager. "We conducted ebb and flood tide surveys in a series of transects crossing the South Amelia River, the Nassau River, the Intracoastal Waterway, and the Nassau Sound throat. Tidal prism transects were run continuously over a full tidal cycle across the mouth of Nassau Sound (parallel with the A1A Bridge). The transects were conducted using a vessel-mounted ADCP equipped with bottom tracking and integrated with the vessel's navigation and positioning system," Mr. Shaw continued.

To ensure survey integrity, M&E established project horizontal and vertical control and took vertical measurements of the instruments twice during the deployment period to identify any potential vertical shifts of the instrumentation. "The data collection went very well, especially the ADCP work... I think that's the first time the tidal prism has been calculated like that at this location. The model calibration for prism came out really tight as well," said Dr. Albert E. Browder, the Olsen Project Manager.

Editorial Calendar 2019

eco environment coastal & offshore

Editorial Focus	Products & Services Focus	Deadlines	Show Distribution	Pending / Digital

January/Febuary

Deep Sea	Laboratory Equipment and Clothing Benthic Sampling Tools and Services	**Editorial:** December 14 **Ads:** January 03	**Oceanology International Americas** **World Ocean Summit** **Benthic Ecology Meeting**	February 25-27 March 5-7 April 3-6

March/April:

Polar Science	Polar Field Equipment and Clothing Expedition Consultation and Logistics	**Editorial:** February 06 **Ads:** February 14	**Polar Marine Science** **Monaco Ocean Week** **Ocean Business** **EARTHXOcean** **Artic Circle**	March 17-22 April 8-14 April 9-11 April 26-28 October 11-13

May/June:

Marine Ecosystems	Diving Equipment Underwater Cameras and Lights	**Editorial:** April 24 **Ads:** May 02	**Dredging Summit & Expo** **IMBeR Open Science** **Clean Pacific** **Blue Planet Symposium**	June 4-7 June 17-21 June 18-20 TBD

July/August:

Fisheries and Aquaculture	Fisheries and Aquaculture Equipment and Services Environmental Impact Assessment Services	**Editorial:** June 25 **Ads:** July 03	**AquaNor** **Ocean Obs 19** **Coastal Management** **American Fisheries Society & The Wildlife Society** **Florida Association of Environmental Professionals**	August 20-23 September 16-20 September 24-26 Sept 29 - Oct 3 TBD

September/October:

Coastal and Estuaries	Oil Spill Cleanup Remediation Product and Services Processing and Analysis Software	**Editorial:** August 28 **Ads:** September 05	**OCEANS'19** **Coastal & Estuarine Research Federation** **Restore Americas Estuaries** **Clean Gulf**	October 28-31 November 3-7 December 9-12 TBD

November/December:

Ocean Exploration	Pelagic Sampling Tools PAM/MMO Tools and Services	**Editorial:** October 30 **Ads:** November 07	**Marine Mammal Conference**	December 9-12

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Coral Sea Foundation Seek Partners for Unique Vessel Development Program

The Coral Sea Foundation are actively seeking partners to share in a unique vessel development program, leading to active operations of their 140ft multihull expedition yacht.

Designed by One2Three naval architects to run on wind power, sunshine, and coconut biofuel, this innovative vessel will facilitate missions through the Coral Sea region. It will also make an important statement about the values of the Coral Sea Foundation and its partners, and their commitment to sustainable management of coral reefs and the people they support.

The Coral Sea Foundation is a multi-skilled team of ecotourism guides, marine scientists, business people, professional mariners, and environmental engineers committed to raising awareness of the ecological and social value the Coral Sea and Eastern Coral Triangle and being proactive in its sustainable management. Combining an ethos of science, ecotourism, and sustainability, the Foundation works with traditional owners in Melanesia to develop marine reserves that enhance fisheries and ecotourism resources, while improving the basic quality of life of people in their partner villages.

Dr Andy Lewis, CEO and founder of Coral Sea Foundation, said "This vessel will provide a compelling platform for marine science, community support and Eco-expedition cruising. It represents a fantastic opportunity for a partner to be involved with a team and an organization that is taking pragmatic steps to manage and conserve some of the best coral reefs on the planet."

Interested? Please see their Vessel Development Program briefing paper for more information at www.coralseafoundation.net

Upcoming Conferences

CommOCEAN
www.commocean.org

December 4-5, 2018
Southampton, UK

National Summit on Coastal and Estuarine Restoration and Management
www.estuaries.org/2018-summit-general-info

December 8-13, 2018
Long Beach, California

Oceanography & Marine Biology
marinebiology-oceanography.euroscicon.com/

December 3-4, 2018
Rome, Italy

Oceanology International Americas
www.oceanologyinternationalamericas.com/

February 25-27, 2019
San Diego, CA

World Ocean Summit
www.woi.economist.com/world-ocean-summit/

March 5-7, 2019
Abu Dhabi, UAE

Polar Marine Science
www.grc.org/polar-marine-science-conference/2019/

March 17-22, 2019
Lucca, Italy

Eastern Canadian Fisheries Expo
www.ecfx.ca/

January 25-26, 2019
Nova Scotia, Canada

Gulf of Mexico Oil Spill & Ecosystem Science
www.cvent.com/events/2019-gulf-of-mexico-oil-spill-and-ecosystem-science-conference/event-summary-c987a69c633f42e09b8d17d70192fee8.aspx?pmd=1

February 4-7, 2019
New Orleans, Louisiana

FSBPA Beach Preservation Technology
www.fsbpa.com/tech-conference.html

February 6-8, 2019
St. Augustine, Florida

ASLO Aquatic Sciences Meeting
aslo.org/page/aslo-2019-aquatic-sciences-meeting

February 23-March 2, 2019
San Juan, Puerto Rico

Opportunities

Marine Technician / Oceanographer (US)

Tetra Tech, Inc., is seeking a part-time Marine Technician / Oceanographer for the Bothell, WA location. Marine Services Division specializes in high resolution hydrographic and geophysical surveys for inland, nearshore and offshore underwater investigations, including detailed dam and underwater infrastructure assessments, site surveys, engineering, archaeological and benthic habitat investigations, and remediation efforts. Survey equipment used include single beam, multibeam and phase bathymetry hydrographic survey systems, sidescan sonar and sub-bottom profilers. Oceanographic and biological assessment equipment included bottom and mooring-mounted ADCPs, MetOcean buoy systems, underwater digital video, sediment grab samplers and corers. Visit www.tetratech.taleo.net for more information.

Science and Strategy Intern (US)

Oceana seeks intern(s) with quantitative experience and a passion for conservation.

The intern will work with the Science & Strategy team at Oceana's headquarters to help answer important questions for Oceana and support 50+ staff working on science and policy in their eight global offices. Internships are paid, full-time in the Washington, DC office for a minimum of three months. Applications are accepted on a rolling basis and are reviewed periodically. These internships do not always align with the academic calendar. Be aware that your cover letter is viewed as a writing sample and please highlight why your experience is a good fit for this application. Also include the dates you are available. Visit www.oceana.org for more information.

Florida Coral Reef Fisheries Mapping GIS GLOBE Intern (US)

The Nature Conservancy's GLOBE summer internship program hires undergraduate students, graduate students, or recent college graduates to fill paid positions during a 10-week summer internship. These positions are available throughout the US and provide a unique opportunity to bridge the gap between academics and real-world conservation work. The program recruits individuals from a variety of backgrounds and experiences who are interested in contributing to their conservation goals in various fields. The Florida Coral Reef Fisheries Mapping GIS GLOBE Intern will play an integral role in developing spatially-explicit data that allow managers and fishing stakeholders to understand how and where fishing may be affecting reef-associated fish stocks and the distribution of current fish stocks. For more information, visit www.careers.nature.org

Ocean Color/Remote Sensing - Assistant Professor of Ocean, Earth and Atmospheric Sciences (US)

The Department of Ocean, Earth and Atmospheric Sciences at Old Dominion University seeks candidates for a tenure-track Assistant Professor position with research interests in remote sensing and ocean color, who use field observations and numerical models to explore the impacts of climate change on coastal ocean.

The successful candidate will be expected to develop and maintain an independent and externally funded research program, contribute to teaching in the department at the graduate and undergraduate level, and mentor graduate students. Visit www.jobs.odu.edu/postings/8922 for more information.

Postdoctoral Researcher, University of Delaware (US)

A postdoctoral researcher position is available at the School of Marine Science and Policy, University of Delaware. The postdoctoral researcher will undertake work on existing projects related to air-sea interactions and fluid dynamics with opportunities to develop projects in new directions. Applicants should have experience with laboratory and/or field experimental methods as well as strong quantitative and writing skills. Applicants must have a PhD in Physical Oceanography, Mechanical or Civil Engineering, or a closely related discipline. The position is available for a year, with renewal for one-year contingent upon performance and funding. The School of Marine Science and Policy at UD hosts a lively community of ocean science researchers at both the Newark and Lewes campuses. The postdoctoral researcher will have the opportunity to interact with scientists in both places.

Research Associate I, University of Miami (US)

The University of Miami, Rosenstiel School of Marine and Atmospheric Science (RSMAS) is seeking a Research Associate in coastal resilience and coral reef restoration. Duties will include, but are not limited to: 1) Coordinating and leading coral restoration activities; 2) Conducting coral reef and reef-fish monitoring surveys; 3) Maintaining field and lab equipment; 4) Securing scientific permits; 6) Completing quarterly and annual reports; 7) Managing the project's database; 8) present research findings at scientific meetings and give classroom lectures, 9) Participating in the lab's education and outreach activities through the Rescue A Reef Citizen Science Program; and 10) Supervise undergraduate and graduate students.

British Antarctic Survey PhD Opportunities 2019

The British Antarctic Survey (BAS) is pleased to announce that opportunities with their five NERC Doctoral Training Projects (DTPs) are now live. The five projects are ARIES, C-CLEAR, GW4+, Iapetus and INSPIRE.

BAS has a broad range of projects with their DTP and Centers for Doctoral Training (CDT) partners every year. Each DTP and CDT has a separate application process, which is usually through the university at which the project is linked. For GW4+ and Iapetus projects, you should apply directly to the lead supervisor. In all cases, you are advised to check the application process carefully to ensure you meet the criteria and deadlines.

Eligibility: NERC studentships are bound by the Research Councils UK Grant Terms and Conditions including residency and minimum qualifications. Doctoral Training in Environmental Research in the UK provides a useful summary of these. For more information about the PhD Opportunities available under each project, visit www.bas.ac.uk/science/science-and-students/nerc-doctoral-training-partnerships/

Ecological Modeler (UK)

The British Antarctic Survey (BAS) is looking for an Ecosystem Modeler to join the Ecosystems team. This role will involve modelling the distribution and behavior of key polar marine organisms in response to environmental changes.

They are looking for someone with a PhD in Marine Ecology or an equivalent discipline. You will need to have experience in ecosystem modelling, and a familiarity with evolutionary behavior and bioenvelope climate modelling would also be desirable.

This job will principally entail the modelling of the distribution and behavior of key polar marine organisms in response to environmental change. The post-holder will be part of two separate but complimentary projects, DIAPOD and CHASE, and will deliver different model products to each in collaboration with the respective research teams.

Deadline: December 2, 2018. For more information about this post, visit www.bas.ac.uk

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Founded in 1970 as a marine environmental consulting firm, CSA specializes in multi-disciplinary projects concerning potential environmental impacts throughout the world and offers a wide variety of desktop and field survey services. CSA is headquartered in Stuart, Florida, with regional offices in Tampa, Florida; Houma, Louisiana; Salinas, California; Houston, Texas; Port-of-Spain, Trinidad; Doha, Qatar; Rio de Janeiro, Brazil and Perth, Australia. We provide clients with objective data collected in the field and scientific research while maintaining an appreciation for the environmental, legal, and political sensitivities.

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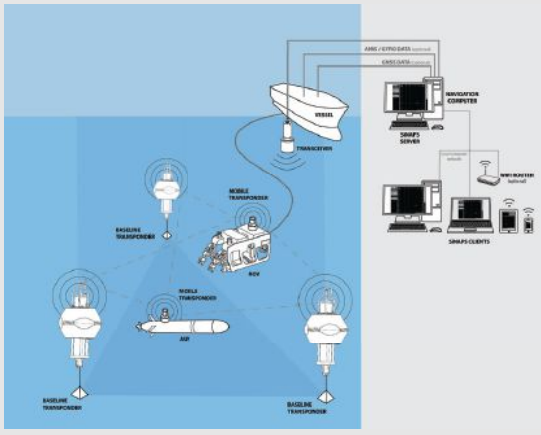

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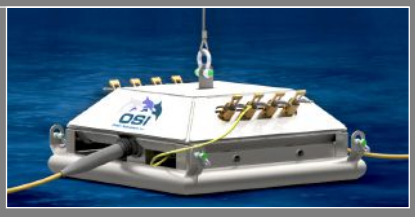

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