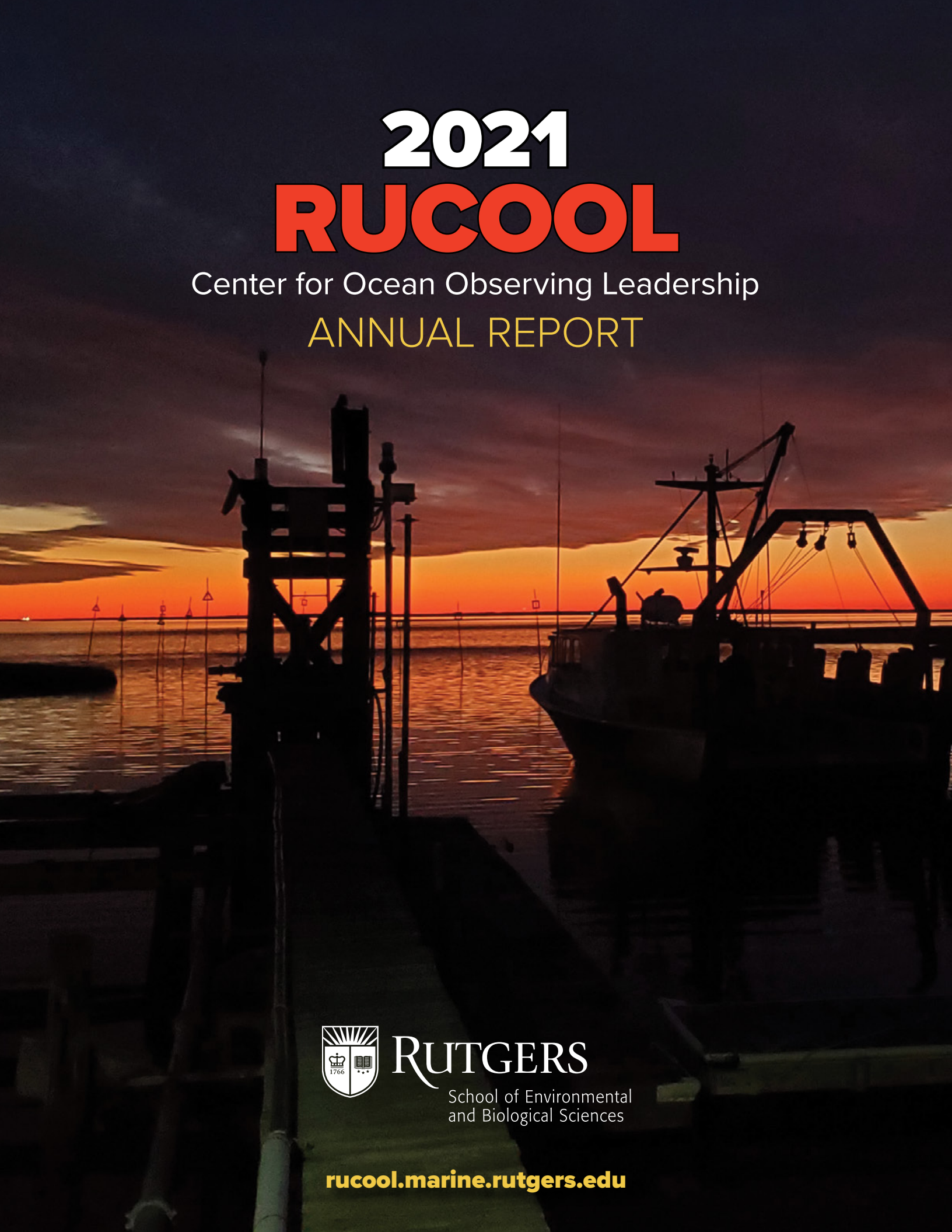


2021 RUCOOL

Center for Ocean Observing Leadership

ANNUAL REPORT

RUTGERS
School of Environmental and Biological Sciences

rucool.marine.rutgers.edu

A Year Unlike Any Other

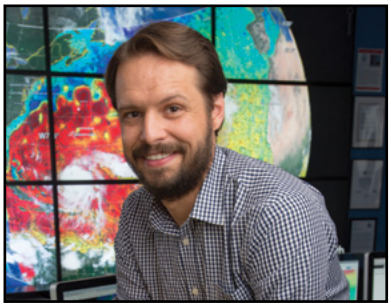
The year of the pandemic has been challenging for everyone. When the COOLroom was formed, one goal was to develop an automated system that minimized the amount of time humans need to be at sea to collect ocean data. Given social distancing and safety considerations, COVID-19 provided a test of the resilience of the COOL network. Throughout the pandemic, the network continued to collect data using satellites, HF-Radar, gliders, and meteorological instruments, which fueled ocean and atmospheric models. Many of the results presented in this annual report highlight the ability of modern tools to enable us to now sample extreme locations of our planet even under extreme local conditions. This ability is becoming available at a critical time as the ocean globally continues to exhibit accelerating changes. These technologies will be critical to meet the challenges laid out in the **UN Decade of Ocean Science for Sustainable Development: 2021-2030.** The UN Ocean Decade is focused on providing a framework to ensure that ocean sciences support actions to sustainably manage the ocean and help achieve the **2030 Agenda for Sustainable Development**. The COOLroom is well positioned to help lead by example the co-development of the global community's response to the UN challenge.

Scott Glenn
Board of Governors Professor

Oscar Schofield
Distinguished Professor

Josh Kohut
Professor

Janice McDonnell
Associate Professor

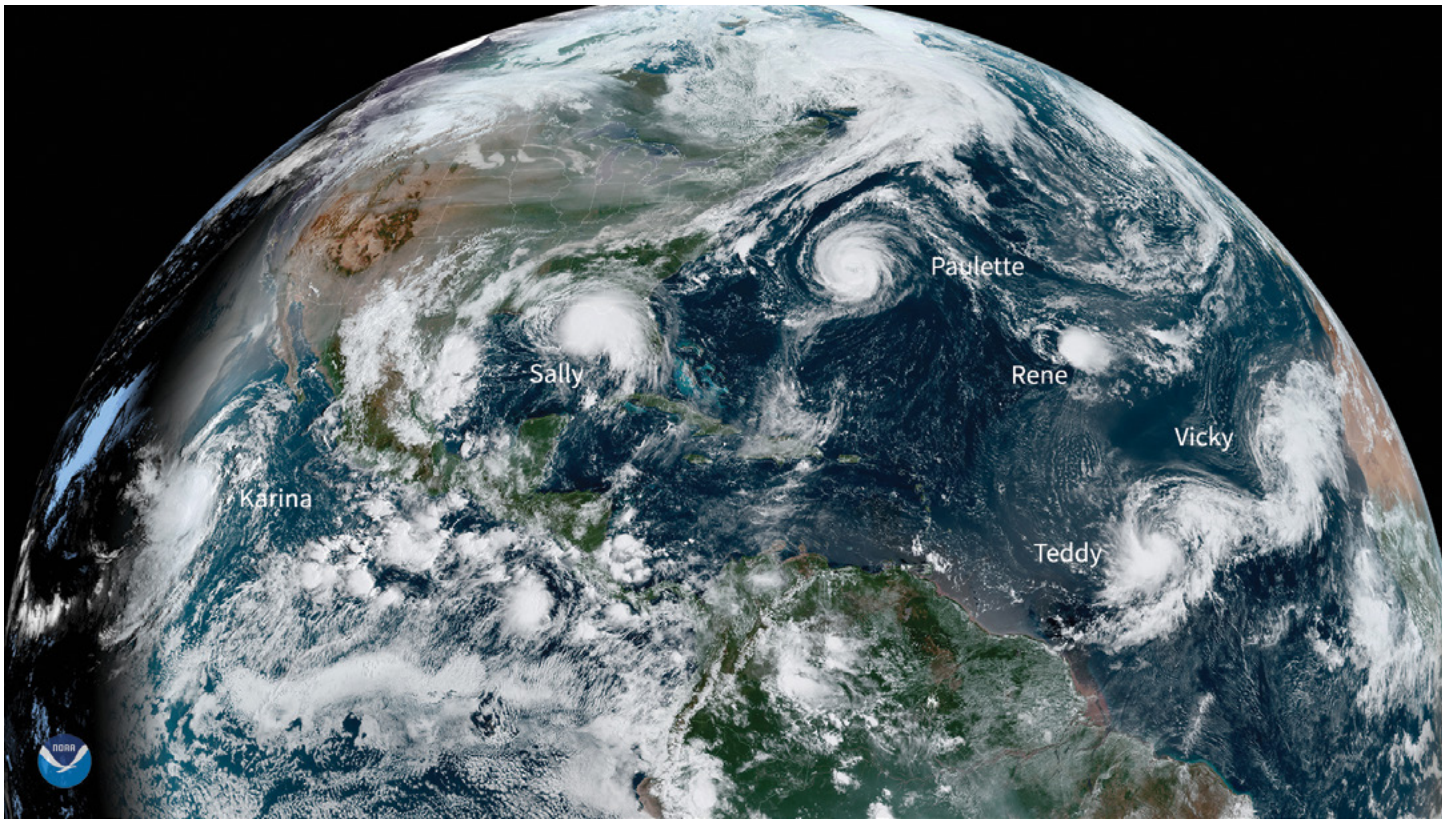


Travis Miles
Assistant Professor

Grace Saba
Assistant Professor

Nicholas Beaird
Assistant Teaching Professor

HURRICANE SCIENCE



On September 14, 2020, the GOES-16 satellite captures 6 tropical cyclones. Photo credit NOAA.

Using Ocean Gliders to Improve Hurricane Intensity Forecasts

During the unprecedented 2020 hurricane season, RUCOOL expanded its leadership role in efforts to improve hurricane intensity forecasts using Slocum gliders. Specifically, we contributed and coordinated glider data delivery in the Mid-Atlantic and Caribbean Sea to ocean models linked to the National Weather Service's atmospheric forecast models. NOAA's Integrated Ocean Observing System (IOOS) Mid-Atlantic Regional Association Coastal Ocean Observing System (MARACOOS) continues to be the foundation for funding this research, but we are now working with over 40 academic, industry, and government partners from the Caribbean, Gulf of Mexico, and South Atlantic Bight. Research highlights this year:

- Working with NOAA's Environmental Monitoring Center (EMC), RUCOOL continued to use glider data to evaluate the nation's operational and experimental ocean models coupled to hurricane intensity forecast models. We've found that the experimental systems, which ingest glider and other observational data, represent ocean features more accurately, and better represented hurricane intensity in 2019. This has led to the transition of this experimental system into operations starting in Fall 2020. This research, covering 13 named storms, was detailed in our **RUCOOL Hurricane Blog**.
- RUCOOL has been working with NOAA EMC to incorporate Rutgers Regional Ocean Modeling System (ROMS) into the National Weather Service's United Forecasting System, which will enable the ROMS ocean model to better inform NOAA's hurricane forecast models.
- Rutgers and its MARACOOS partners deployed 18 gliders during the 2020 hurricane season, all of which contributed data to the operational models that weather forecasters all over the world leverage for forecasts. In addition, Rutgers deployed and recovered two US Navy Gliders off the central NJ coast. The work between Rutgers and the Navy is expected to continue and even expand during the 2021 hurricane season.
- RUCOOL kicked off the new Caribbean CORREDORES glider mission, which is supported by the Vetelsen Foundation. This effort is designed to use underwater gliders to sample ocean heat transport in the Caribbean Sea in collaboration with a broad set of international partners. This activity is being coordinated as a contribution to the first year of the UN Ocean Decade.
- RUCOOL is maintaining and expanding its leadership throughout the weather forecasting community with Travis Miles and Scott Glenn contributing in a broad array of leadership roles. This includes Travis Miles co-leading an observations sub-committee of the NOAA Extreme Events Ocean Observation Task Team and participating as a regional representative of the NOAA Hurricane Gliders team.

OFFSHORE WIND ENERGY

Offshore Wind: State and Regional Responsible Development

As NJ continues to develop offshore wind, this past year saw particular focus on the potential environmental impacts. Supporting this state and regional need, RUCOOL participated in multiple workshops, discussion groups, and proposal teams to identify specific research needs. Throughout the year, we worked with state agencies (NJ Board of Public Utilities, NJ Department of Environmental Protection, and the NY State Energy Research & Development Authority) and regional entities (Responsible Offshore Development Alliance, Responsible Offshore Science Alliance, National Offshore Wind Research & Development Consortium, and NOAA's Integrated Ocean Observing System) to deliver our capacity and expertise in ocean observing to these critical discussions. We advised the State of New Jersey on its strategic plan for offshore wind, and hosted a community-based workshop focused on defining the specific criteria for baseline monitoring aimed to assess environmental and ecological impacts of offshore wind. Addressing concerns of turbine impacts on an important ecological ocean feature, the cold pool, we translated existing literature from European sites to local NJ and Mid-Atlantic development. Going forward, RUCOOL will continue to lead efforts to identify and address critical environmental research needs to better inform the responsible development of offshore wind.

Offshore wind turbines. Photo credit: Orsted ECO-PAM project.

Offshore Wind: Environmental Research with Orsted and Atlantic Shores

The RU34 glider off the NJ coast. Photo credit Orsted ECO-PAM project.

RUCOOL continues its work with both New Jersey-based offshore wind projects, Ocean Wind (Orsted) and Atlantic Shores (EDF/Shell), on environmental research pertaining to NJ's offshore wind development. This year, RUCOOL deployed the first four glider missions of the **ECO-PAM project**, which uses advanced passive acoustic sensors to detect the presence/absence of the North Atlantic Right Whale, among other cetaceans. ECO-PAM project, dedicated to improved understanding of Right Whale habitat among wind energy areas, was featured in a short documentary video at the 2020 American Geophysical Union Fall Meeting. Additionally, RUCOOL completed a short study with Atlantic Shores on the visibility of wind turbines from shore, and completed installation of a land-based wind lidar system at RUMFS.

POLAR SCIENCE

30 Years of Research in Antarctica Continues...

Despite the current global COVID-19 pandemic, RUCOOL is one of the few groups that has been able to maintain a presence in Antarctica. Rachael Young, a recent Rutgers alumna, was the lead for science operations of the National Science Foundation's Palmer Station Long Term Ecological Research (PAL-LTER) program at Palmer Station. Since 1991, the 30-year PAL-LTER time series has studied how warming atmospheres and oceans along the Western Antarctic Peninsula is altering the ecosystem. The typical year for the LTER project has a Rutgers team of 10 scientists, students, and technicians. Due to extremely high COVID-19 rates in Chile, only one scientist was allowed to deploy. This year RUCOOL graduate students wrote high profile science publications. Schuyler Nardelli found that Antarctic krill populations are probably sufficient to meet the nutritional needs for penguin, seal, and whale populations. Michael Brown showed a surprisingly low planktontic biodiversity in a major species that will increase in importance as the system warms.

Western Antarctic Peninsula. Photo credit NSF LTER.

The Future of Antarctica and the Southern Ocean that Surrounds It

The decade from 2010 to 2020 has been, by far, the most successful in gaining knowledge on ecological processes in the Antarctic. Of particular interest are the reactions of life to climate change and their contributions to global carbon budgets. Equally relevant are evolutionary adaptations to the extreme polar conditions, which, under climate change, determines the survival or extinction of species. Twenty-five experts met in Coimbra (Portugal) in 2019, synthesized hundreds of individual results from the past 10 years, and published a **comprehensive assessment** outlining 10 main messages of the status quo and future of Antarctica and the surrounding Southern Ocean. Assistant Professor Grace Saba was one of the co-authors. The results show how life in the Antarctic responds differently, but also similarly, to environmental changes, in particular climate-induced warming and ice melting. This refers to species, communities, and ecosystems on land, in lakes, and in coastal, shelf, and open ocean.

Mountains of Antarctica: Photo credit: Steve Ackleson.

OCEAN ACIDIFICATION

Global Ocean Acidification

Over the past year, our ocean acidification (OA) research spanned from Antarctica to our Mid-Atlantic waters. **Recent research** by Grace Saba and colleagues shows how adult Antarctic krill feeding, growth, and health exhibit varying responses to effects of elevated temperature and OA. In NJ, we continue to monitor carbonate chemistry in our coastal continental shelves using ocean glider-based pH sensors, research that was recently highlighted in an interview of Grace Saba by ***Marine Technology*** **magazine**. The **first seasonal assessment of OA in the Mid-Atlantic** was recently published by Ph.D. student Elizabeth Wright-Fairbanks. These monitoring efforts highlight the importance of seasonality, water mass mixing, biological production, and freshwater inputs in controlling the ocean carbonate system in the Mid-Atlantic. Saba's continued work in OA monitoring and with the Mid-Atlantic Coastal Acidification Network has ignited efforts by New Jersey Department of Environmental Protection's Coastal Management Program (NJCMP) to collaborate with Rutgers to initiate a focused OA effort in NJ. Through this partnership, NJ recently signed an agreement to join the **Ocean Acidification Alliance**.

Antarctic krill inhabit a rapidly warming and acidifying Southern Ocean. Photo credit: Chris Linder.

MARINE POLLUTION

Microplastics in the sand. Photo credit: NOAA

Microplastics in Rutgers' Backyard:

Although our microplastics research team faced pandemic-related delays in our Delaware Bay field research this past year, focus was shifted to preparing research papers related to investigations of microplastics in the Hudson-Raritan Estuary. The first manuscript from these microplastics-focused projects was recently published in ***Chemosphere***, and presented the sources, sizes, characteristics, and abundance of microplastics in this dynamic, highly urbanized system. The team continues to collaborate on a companion paper focused on the ingestion of these microplastics by zooplankton. This research has been presented to a wide range of audiences this past, year including the New Jersey Department of Environmental Protection, NOAA Marine Debris Program, and New York Society of Cosmetic Chemists.

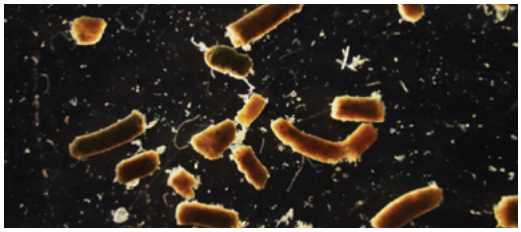
FISHERIES

Fish Ecology and Physiology

Changing ocean conditions are altering habitats that are correlated to changes in fish distributions, metabolism, behavior, reproduction, and abundance. **Recent research** published by Ph.D. student Emily Slesinger concludes that ocean warming is likely leading to poleward range shifts in recreationally important black sea bass, and understanding that longer migration distances in the region where this species' population is expected to increase, could actually lead to lower local availability in New Jersey. These results provide information relevant and necessary to inform both state and regional fisheries management.

Emily Slesinger, holding a black sea bass. Photo credit: Eric Morrow.

Changes in the abundance and distribution of fishes will also impact biogeochemical cycles. Recently published work by Grace Saba and colleagues highlights the previously under-emphasized role that fishes play in the export and sequestration of carbon in the ocean via the 'biological pump' (**Martin et al. 2021**; **Saba et al. 2021**). Saba's first-authored paper on this topic produced the first review of the global impact that fishes have on carbon flux, highlighting a significant contribution – roughly 1.65 billion tons and 16% of total flux out of the euphotic zone annually. This information is essential to improve parameterization of key processes affecting the biological pump and develop more accurate regional and global carbon models.



Fish fecal pellets collected from the Santa Barbara Channel off California. Photo credit: Grace Saba.

EMPOWERING THE NEXT GENERATION

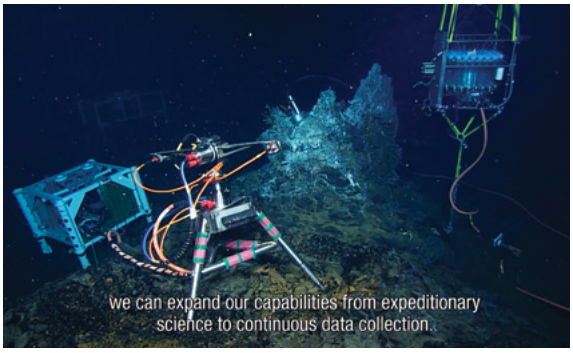
Screenshot of 2020's REU students online.

Virtual Research for Undergrads Across the World

Two weeks. That is how long the RUCOOL Education Team had to create an eight-week intensive, hands-on virtual research program for undergraduate students. Last year, many Research Experience for Undergraduates (REU) programs were canceled due to the pandemic. In response, NSF reached out to RUCOOL's Janice McDonnell and Sage Lichtenwalner to create a virtual program based on their experience building virtual communities of educators. In the end, this team, in partnership with Rutgers Internships in Ocean Science (RIOS), hosted an eight-week REU program for 16 students from across the country, including Alaska, Guam, and Puerto Rico. The experience included a two-week professional development workshop, where students learned about working with large datasets, how to use Python to analyze and visualize data, and science communication. The workshop also included career and graduate student panels featuring Rutgers students and graduates. Students then spent six weeks working on individual research projects with 17 faculty mentors from Rutgers and institutions across the country. Their **final posters** as well as a **participant map** are available on the project site.

Making Advanced Science Available to High Schools and Community Colleges

RUCOOL's Lori Garzio worked with the Consortium for Ocean Leadership to develop a new resource of curated datasets from the National Science Foundation (NSF) Ocean Observatories Initiative (OOI). The new collection of **OOI Data Nuggets**, which are exemplary datasets curated from data collected by the NSF OOI and were selected based on their quality and alignment with broader OOI Science Themes. The nuggets explore various concepts common in upper-level high school and introductory college courses, and are designed and packaged to be readily accessible to educators to integrate into their existing curriculum.



Axial Caldera off of the Washington coast. Photo credit: NSF/OOI/University of Washington.

Grad Student Success!

Fourteen graduate students were central to RUCOOL's success during this unprecedented year. We could write pages of information on their successes and awards, but here are a few highlights from the graduate team:

- RUCOOL graduated a Ph.D. student, master's student, and our first two students from the new Masters in Operational Oceanography program. Most importantly, all of our graduates were immediately hired and are working full-time in their areas of research. Congrats!
- Our graduate students authored nine peer-reviewed research papers, seven of which they served as lead authors. Nothing like getting started early on publications.
- Our graduate students earned nine awards and fellowships from within Rutgers and external entities such as NOAA, Con Edison, and NSF.

Rutgers grad students: Joe Gradone, Jackie Veatch, Emily Slesinger, Quintin Diou-Cass, Liza Wright-Fairbanks, Schuyler Nardelli, and Sam Coakley.

Advancing Research Impact In Society photo: Christine Bean exploring the oceans with NJ middle school students at the Rutgers Geology Museum.

Advancing Research Impact in Society

National Science Foundation grants not only advance knowledge, but benefit society and better our world - what we call Broader Impacts (BI). As CO-PIs in the Advancing Research Impact in Society (ARIS) project, our RUCOOL Education Team has developed a suite of tools to support the creation of high quality BI projects. The newly renovated BI Wizard is an online tool designed to help researchers learn the basics of how to construct a BI plan. Researchers can use the output of the BI Wizard as the basis for their plan or to organize their thoughts prior to meeting with a BI professional. The BI Checklist was developed from the National Alliance for Broader Impacts (NABI) Guiding Principles as a practical tool to help build and evaluate a BI project. And finally, the BI Rubric was designed to help provide context for reviewing BI projects, either prior to submission or during panel review sessions. Janice McDonnell is providing hands-on training on the use of this suite of tools to professionals around the country.

Masters in Operational Oceanography

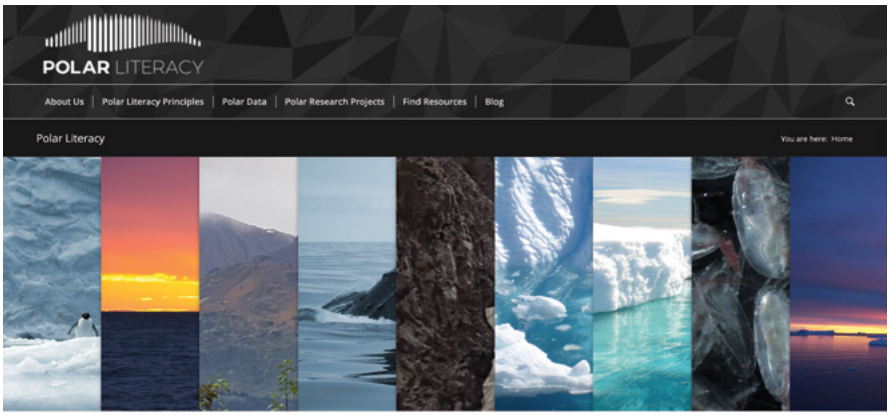
The first cohort of the Operational Oceanography program defended their theses in July 2020. Julia Engdahl and Joe Anarumo immediately put their skills to work, Julia for NOAA's Center for Operational Products and Services, and Joe as an Environmental Science Analyst at Sage Services.

The second cohort is wrapping up their theses after a challenging but successful year. The program was able to effectively navigate a remote format while achieving student learning goals. With safety precautions in place during the spring semester, students were still able to get the extensive hands-on field experience that is a hallmark of the curriculum.

The program continues to grow and establish its reputation as a leader in workforce development, having been highlighted in a new book, *Preparing a Workforce for the New Blue Economy*, edited by Dr. Richard Spinrad, NOAA Administrator.

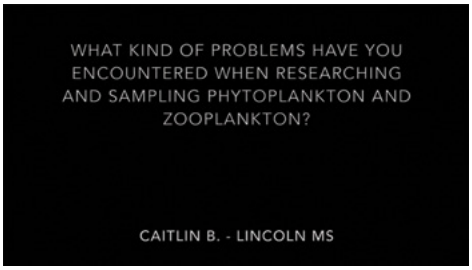
Oceanography master's students Theodore Thompson and Ailey Sheehan take water samples after deploying a glider. Photo credit: Chip Haldeman.

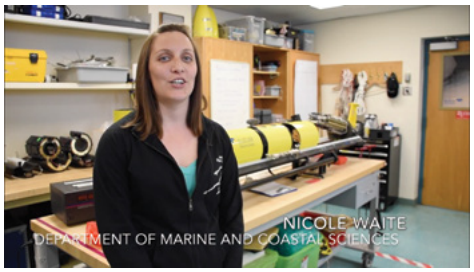
4-H Polar Literacy Camps



The many faces of Antarctica. Photo credit polar-ice.org.

Fifty-five youth in grades 4–9 participated in Polar Week activities as part of the National Science Foundation (NSF) Science, Technology, Engineering, and Mathematics (STEM) focused **Polar Literacy project**. Underrepresented minorities were heavily represented in this gender-diverse group, where retention was high: the majority of youth (78%) who participated from Newark and Trenton, NJ, attended all five days of programming. The group reported moderate to large gains in building their science identity. We define science identity as the confidence or capability of acquiring the knowledge necessary to understand science concepts, confidence in showcasing science skills in public settings, and recognition of their competence in their community and among science peers. *Science identity has recurrently emerged as an important concept in the understanding of interest, motivation, and persistence in STEM*. Science identity can be bolstered through strategies that include showcasing non-stereotypical scientists and providing opportunities to do and to talk about science. Both strategies were important components of Polar Week activities. We are excited to offer several virtual Polar Weeks in the coming summers. Stay tuned for more information on this exciting project!





Nicole Waite sharing her experiences in Antarctica virtually with students. Photo credit: polar-ice.org, Ask a Polar Scientist.

4-H Award!

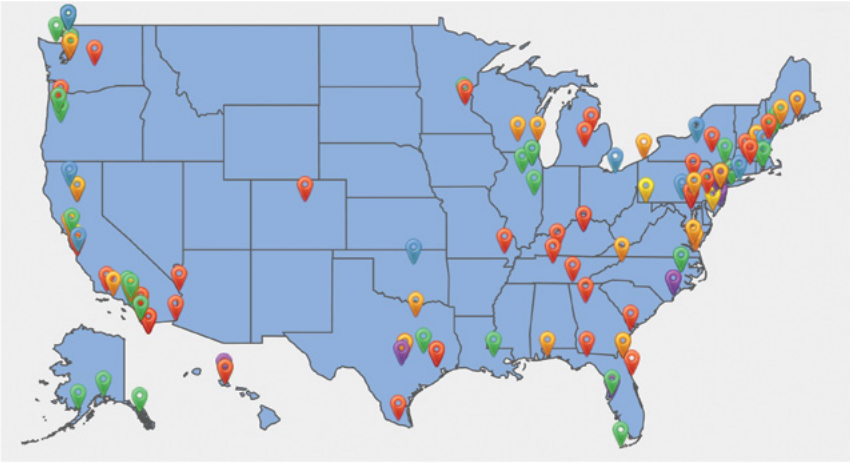
The Rutgers 4-H Science, Technology, Engineering, and Mathematics (STEM) Ambassador Program received the **2020 Team Excellence Award**. Established in 2009, the program is led by a team of Rutgers faculty and staff from multiple departments and units and is designed to serve traditionally underserved urban youth throughout the state to enrich their interest and competency in STEM. The program is a nationally recognized model that has been shared through several publications and has been replicated in other states. The team has successfully engaged collaborators from inside and outside the university, and across multiple campuses and schools across the country. RUCOOL is currently designing additional online modules to support the 4-H STEM program. Congrats to RUCOOL Education team members Janice McDonnell, Christine Bean, and Alesha Vega.

Rutgers University STEM Ambassadors! Photo credit: Rutgers 4-H program.

Data Labs Community Continues to Grow!

The National Science Foundation's Ocean Observatories Initiative (OOI) Ocean Data Labs Project is developing, testing, refining, and disseminating easy-to-use, interactive Data Explorations and Data Lab Notebooks that will allow undergraduates to use authentic ocean science data in accessible ways that are also easy for professors to integrate into their teaching. Over the last year, our community has grown to 300 members, 160 of which are continuously active, writing blogs, working on developing new explorations, giving webinars, or implementing new Data Labs Resources.

Our Fall 2020 **webinar series** featured new Data Explorations developed by faculty teams. As one of our faculty put it during this pandemic year, *"Thank goodness for Data labs! They have really been a remote learning life jacket!"*



Data Labs Community Continues to Grow: Data Labs expanding across the U.S.! Credit Ocean Data Labs website.

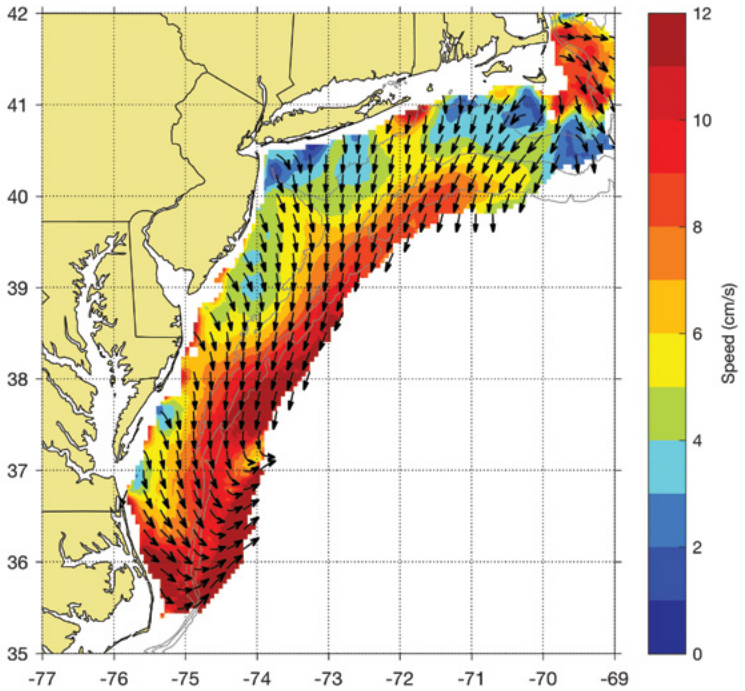
Our 2020 **Data Labs Fellows** wrapped up their projects researching the use of Data Explorations and OOI datasets in their classrooms – thanks to a combination of creativity, flexibility, and persistence necessitated by the shift to remote learning. In Spring 2021, they shared their results in a series of **Community Forum** blog posts on the Data Labs website.

In 2020, a team of 12 faculty developed an OOI-focused, online laboratory manual for use in typical Introductory Oceanography courses. The manual was piloted in Fall 2020 by 20 faculty around the country. An updated Lab Manual 2.0 will be released in Summer 2021.

INTEGRATED OCEAN TECHNOLOGY

Where is the Ocean Going in the Mid-Atlantic?

Rutgers led a **decade-long study** of the surface currents from Cape Cod, MA, to Cape Hatteras, NC. The currents were measured by the Mid-Atlantic Regional Association Coastal Ocean Observation System High Frequency Radar network. These currents were compared to wind and river data to explain the patterns observed in the flows. Near the coast, the average currents flow offshore. Away from the coast, the average currents flow along the coast toward the south. Fall is the season with the most variability from year to year. Its higher variability can be traced to different regional weather patterns that change the wind fields and the amount of freshwater delivered by the rivers to the coastal ocean. This is the first study to use a decade of observed surface current maps that uniquely and simultaneously observe the changing patterns of the average flow structure along a segment of the eastern United States. The improved understanding of the coastal circulation over a wide area, and what drives its variability, has implications for pollutant transport, plankton transport at the base of the food chain, fish and shellfish reproduction, and multiple ocean-based human activities including fishing, marine transportation, and offshore wind energy development.



10 year averages of ocean surface currents in the mid-Atlantic. Credit Hugh Roarty.

RUCOOL's Mission

RUCOOL is creating knowledge of our ocean planet by pushing the limits of science and new technologies while inspiring future generations of ocean explorers, under eight core focus areas:

Research Focus Areas

HURRICANE SCIENCE

The RUCOOL Hurricane Science Team develops and uses advanced observing technologies and models to better understand coupled ocean-atmospheric processes in tropical cyclones.

OFFSHORE WIND

The RUCOOL Offshore Wind team develops and advances the science that informs decision-making around offshore wind, both at a state and national level.

POLAR SCIENCE / LTER

RUCOOL scientists are engaged in polar research using both regional and global climate models, and via large collaborative efforts that utilize undergraduate and graduate fieldwork.

OCEAN ACIDIFICATION

The RUCOOL Ocean Acidification Team develops and uses advanced observing technologies to address hypotheses related to identifying and evaluating the drivers of acidification.

OCEAN POLLUTION

RUCOOL conducts a combination of laboratory and field studies to investigate the fate and transport of microplastics in the marine environment to inform potential mitigation strategies.

FISHERIES

RUCOOL integrates observations with laboratory and field research to investigate fishes and their habitats to improve stock assessment models and guide existing and future management decisions.

EMPOWERING THE NEXT GENERATION

RUCOOL is innovating education practices to enable all humanity to be active explorers of their ocean planet, and to develop the next generation of ocean scientists and engineers.

INTEGRATED OCEAN TECHNOLOGY

RUCOOL develops and operates state-of-the-art ocean sensor technologies, integrating their data products together to get the most comprehensive 3-D view of the ocean possible.

31
ACTIVE AWARDS
(grants, donations, cooperative agreements)

$9.3
MILLION in funding per year

122
UNDERGRADS
taught per year

17
Deployments

8526
kilometers flown

435
days at sea

SURFACE CURRENT COVERAGE
216,000 KM^2

268
COLLABORATORS
142 institutions, 22 countries

29
PUBLICATIONS

17
GRADUATE STUDENTS
annually

NOAA $4.8M National Oceanic and Atmospheric Administration

$405K Higher Education

NSF $2.4M National Science Foundation

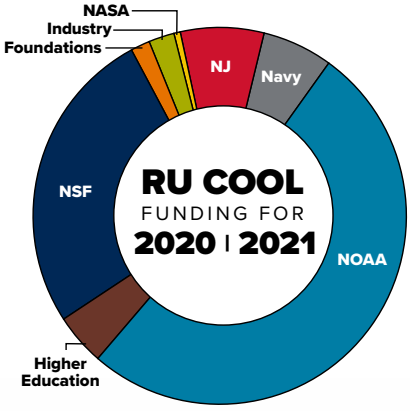
$150K Foundations

$195K Industry

NASA $75K National Aeronautics and Space Administration

NJ $546K State of New Jersey

Navy $664K United States Navy



Department of Marine and Coastal Sciences
71 DUDLEY ROAD | NEW BRUNSWICK | N.J. | 08901-8520