

WOODS HOLE OCEANOGRAPHIC INSTITUTION

2019 Q3 REPORT

An Audacious Project *Our Vision and Goal*

OUR VISION

We have embarked on a bold new journey to explore one of our planet's hidden frontiers, the ocean twilight zone, a vast, globe-spanning, and dimly lit region between about 200 and 1,000 meters beneath the ocean's surface. Understanding of the twilight zone is currently limited by its enormous size and lack of easy access.

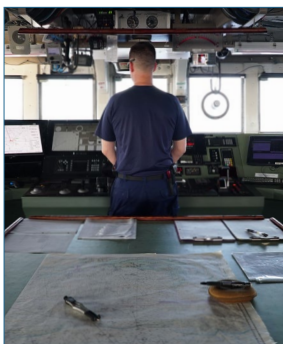
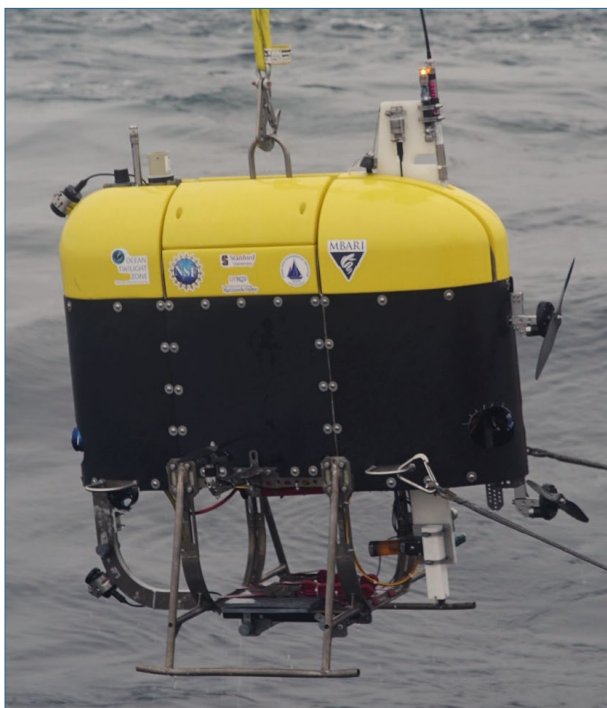
OUR GOAL

Promote sustainability of the twilight zone by closing critical gaps in knowledge, including:

1. The distribution of biomass and biodiversity
2. Food web linkages within the twilight zone and among the twilight zone and other ocean realms
3. The life histories and behaviors of twilight zone animals
4. The role of the twilight zone and its inhabitants in the global carbon cycle



Impacts and Accomplishments



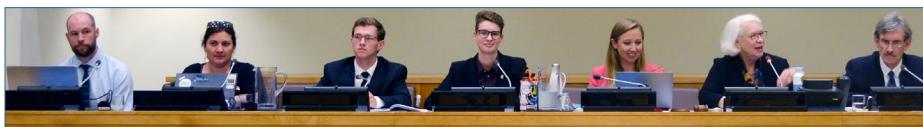
Critical data collection: In August, the OTZ team completed an interdisciplinary data-collection effort in the project's primary operating area, 100 nm south of Nantucket Island, aboard the NOAA ship *Henry B. Bigelow*. This milestone expedition showcased the first true operational deployment of the multi-sensor instrument, *Deep-See*, demonstrating the potential for WHOI to dramatically improve estimates of twilight zone biomass.

First OTZ peer-reviewed scientific publication: *The Proceedings of the National Academy of Sciences* (PNAS) published a paper, co-authored by Simon Thorrold, countering the paradigm that warm-core eddies are unproductive and demonstrating the connection between large ocean predators (blue sharks) and the twilight zone.

Building a better robot: The testing and development of our twilight zone autonomous robot *Mesobot* is accelerating faster than expected in collaboration with our colleagues from the Monterey Bay Aquarium Research Institute. Our next goal is to deploy *Mesobot* on its first operational mission aboard the WHOI-operated research vessel *Neil Armstrong* in mid-November.

Advancing ocean literacy and policy: Op-eds in *USA Today* and *The Hill* raised the profile of the OTZ Project across a broad swath of public and policy makers nationwide.

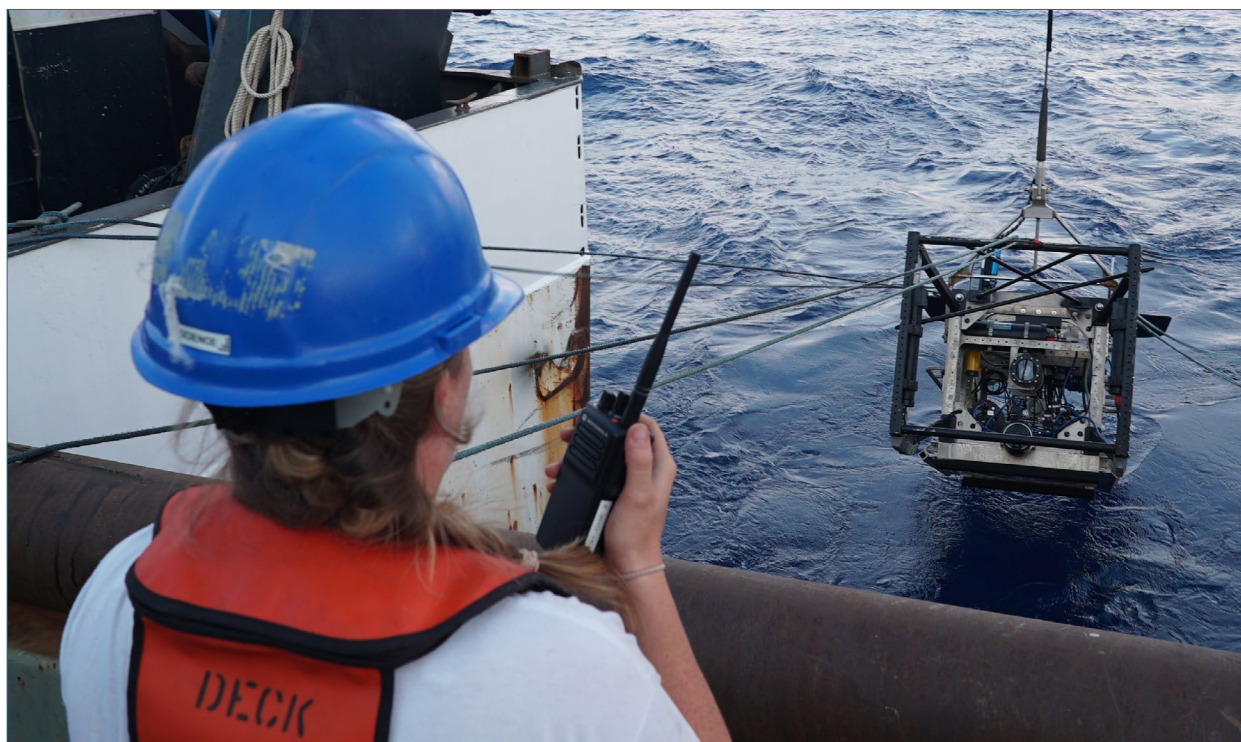
Inserting the ocean twilight zone into international negotiations: Three WHOI OTZ project members and two undergraduates presented the importance of twilight zone sustainability at the 20th meeting of the UN Open-ended Informal Consultative Process on Oceans and the Law of the Sea (ICP-20) in New York.



OTZ at Sea

NOAA SHIP HENRY B. BIGELOW
JULY 24-AUGUST 8

- **15 days** at sea
- **10 *Deep-See* dives** covering 163 nautical miles to a maximum depth of 1200 meters, lasting 112 hrs 20 min in the water
- **12 MOCNESS tows** covering 73 nautical miles to a maximum depth of 1000 meters
- **11 Midwater trawls** covering 40 nautical miles to a maximum depth of 775 meters
- **19 CTD casts** to a maximum depth of 919 meters
- **760 liters** of water filtered
- **113 eDNA samples** collected, preserved, and awaiting analysis
- **153 gelatinous animal specimens** preserved
- **861,502 images** recorded by *Deep-See*



COMING SOON

In mid-November, the OTZ team will launch its first field expedition on a WHOI-operated research vessel with a science and engineering party made up almost entirely of WHOI personnel. *Mesobot* will see its first fully operational science mission and a prototype MINION float will receive its first test deployment. A wide range of additional

sensors and samplers will help also significantly advance knowledge of the mesopelagic in a critical marine habitat and fishery 150 miles south of Martha's Vineyard.

The spring of 2020 will mark a major achievement in national and international collaboration for the OTZ team, when WHOI

once again joins forces with the NASA-led EXPORTS program that will include U.S. (R/V *Atlantis*) and U.K. (R/V *Discovery*) research ships. This time, we'll be sailing on the Spanish fisheries research vessel *Sarmiento de Gamboa* with a twilight zone research agenda that complements and expands on the EXPORTS focus of carbon transport through the mesopelagic.

Targeting the Twilight Zone



In just 18 months, WHOI OTZ research has filled key gaps in knowledge about the twilight zone across the project's scientific themes. In addition to forming a strong base from which to expand WHOI's leadership in mesopelagic science and engineering, this comprehensive effort is also creating new tools and insights for the global research community to improve society's understanding of the twilight zone and for decision-makers to establish science-based policies that will support a healthy ocean for generations.

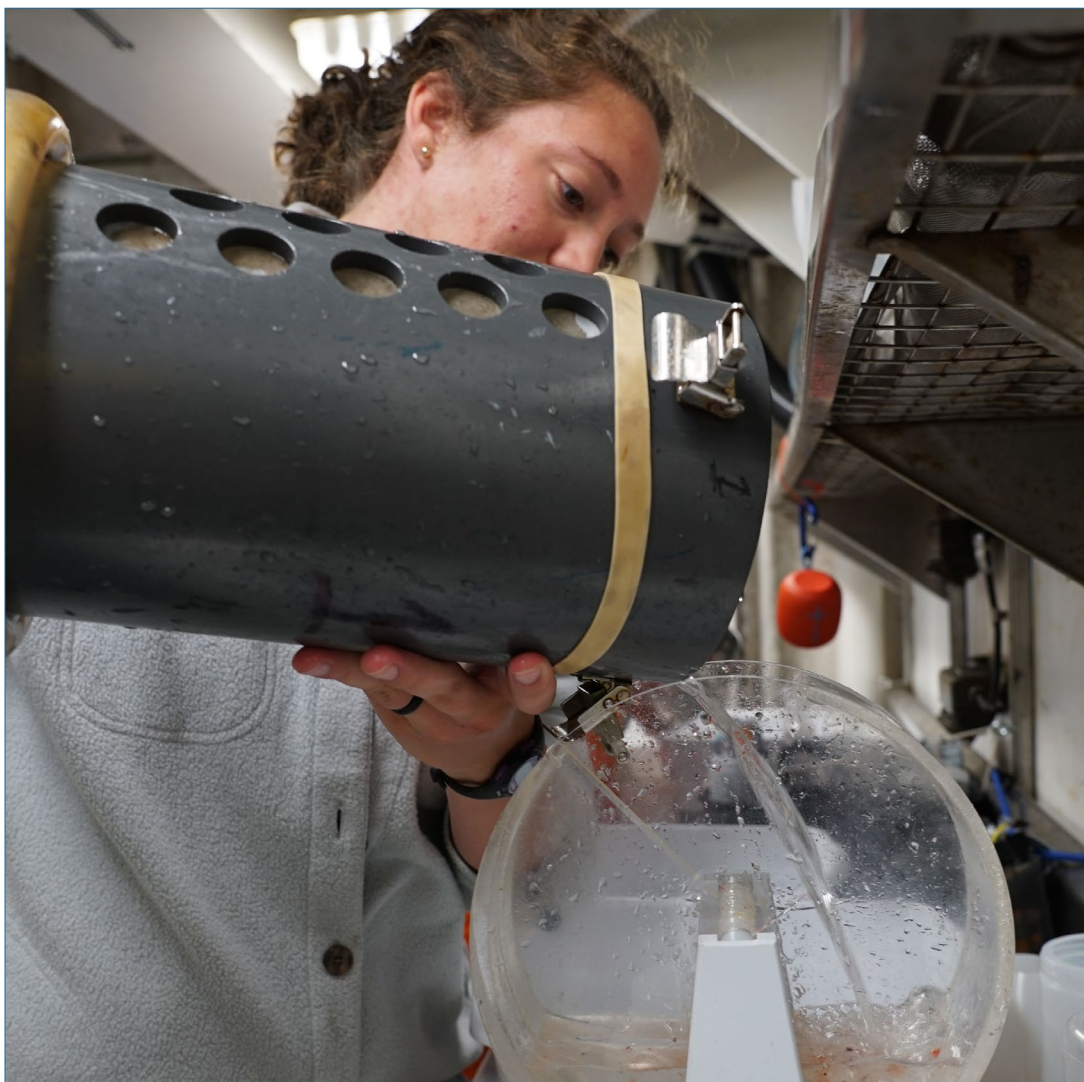
PEER-REVIEWED PUBLICATION

Blue sharks are apex predators and the most exploited pelagic sharks in the Atlantic. By tagging some of these animals, members of the Thorrold lab showed for the first time that blue sharks target the twilight zone on foraging dives in the center of meso-scale eddies—large, swirling water masses once thought to be ocean “deserts.” Insight like this is critical to shape flexible management strategies for individual species and entire ecosystems.

Mesoscale eddies release pelagic sharks from thermal constraints to foraging in the ocean twilight zone

Camrin D. Braun, Peter Gaube, Tane H. Sinclair-Taylor, Gregory B. Skomal, Simon R. Thorrold
Proceedings of the National Academy of Sciences, Aug 2019, 116 (35) 17187–17192; DOI: 10.1073/pnas.1903067116

Science Updates



LIFE HISTORIES AND BEHAVIOR THEME

The Llopiz Lab is examining fish collected during OTZ expeditions, specifically their reproductive organs and structures called ear stones to determine the age of individual fish and how fast they grow, knowledge that is critical to sustainable management of twilight zone fish stocks. In addition, our flagship technologies—*Deep-See* and *Mesobot*—are teasing out the light-following behavior of twilight zone residents to measure and record previously unknown details about the largest animal migration on the planet.

FOOD WEBS THEME

The incredible bounty of fish from net tows filling freezers at WHOI is also filling critical parts of the growing food web puzzle and establishing links between the mesopelagic and other parts of the ocean. The Llopiz Lab is identifying the stomach contents of fish captured in net tows and finding many of the smaller prey fish, such as bristlemouths and lanternfish have distinctly different diets from one another. At the same time, the Thorrold Lab is measuring carbon and nitrogen isotopes in fish tissue to tease out the microorganisms that form the base of the twilight zone food web. And the Govindarajan Lab is ensuring that the specimens underpinning both of these analyses are accurately identified by DNA-barcoding the fish being tested.

Science Updates



BIOMASS AND BIODIVERSITY THEME

The Govindarajan Lab continues to pioneer the use of environmental DNA (eDNA) sampling and analysis in the twilight zone. Govindarajan and Yoerger's teams worked closely to develop a new high-volume eDNA sampler designed to enable a more detailed view of biodiversity that made its debut on *Mesobot* this fall. In addition, Govindarajan is analyzing DNA data collected on the *Henry B. Bigelow* cruises and expeditions with OceanX and SEA (Sea Education Association). So far, she has found that eDNA sampling may be far more effective than net tow sampling, in terms of the number of animal types identified per liter of water.

Data collected with the acoustic, optical, and biological sensors on Lavery's *Deep-See* vehicle are already returning some critical insights. First, her team has found that the distribution of organisms in the twilight zone is extremely uneven across the depth and breadth of the ocean. Second, the data it has returned after just two cruises are showing that acoustic sensors placed directly into the twilight zone, instead of on a ship, are capable of not just detecting organisms, but of counting them, and even measuring their size. Finally, the combination of acoustic sensors and cameras have shown that gelatinous organisms have likely been under-estimated and could be one of the most common life forms in the twilight zone.

CARBON & CLIMATE CHANGE THEME

Climate models incorporate as many processes controlling atmospheric carbon dioxide as possible. Marine snow falling through the twilight zone carrying carbon rich organic material to the ocean floor is a key process, but is not yet well understood on a global scale. Work by the Buesseler Lab to develop new geochemical tracers has already shown that the amount of carbon remaining in marine snow as it makes its way through the gauntlet of hungry twilight zone organisms depends strongly on location. Why this removal happens more in one part of the ocean than another is just one portion of the larger puzzle they are trying to solve.

Talent Pool

ENSURING THE FUTURE OF OCEAN SCIENCE

The future of human knowledge about the ocean rests in a motivated graduate student or post-doctoral researcher, a curious undergraduate, or a bright young high school student. The OTZ project is helping shape this future by offering a wide range of opportunities for students and young scientists at all stages of their development to make a tangible impact in knowledge about the twilight zone.

Elizabeth Allan—Postdoctoral Investigator (Annette Govindarajan)

Paul Caiger—Postdoctoral Investigator (Joel Llopiz)

Emma Cotter—Postdoctoral Scholar (Andone Lavery)

Montserrat Roca Marti—Postdoctoral Investigator (Ken Buesseler)

Kevin Archibald—MIT-WHOI Joint Program PhD student (Heidi Sosik)

Samantha Clevenger—MIT-WHOI Joint Program PhD student (Ken Buesseler)

Kayla Gardner—MIT-WHOI Joint Program PhD student (Simon Thorrold)

Rachel Kahn—MIT-WHOI Joint Program PhD student (Andone Lavery)

Levi Kai—MIT-WHOI Joint Program PhD student (Dana Yoerger and Yogesh Girdhar)

Zhaozhong Zhang—MIT-WHOI Joint Program PhD student (Andone Lavery)

Jessica Todd—MIT PhD student (Dana Yoerger)

Rune Oyerhamm—NORCE Norwegian Research Centre PhD student (Andone Lavery)

Jackson Sugar—University of Rhode Island MS student (Ken Buesseler and Melissa Omand)

Riley Sennott—Santa Clara University (Di Jin)

Helena McMonagle—Post-graduate research assistant, now at the University of Washington (Joel Llopiz)

5 Summer Student Fellows

22 Sea Education Association students

Conserving a Sea of Shadow and Substance: Should There be a Moratorium on Harvesting Twilight Zone Fish?

Sally Dowd
UC Berkeley, Molecular Environmental Biology
WHOI Summer Student Fellow

Mentor: Porter Hoagland, WHOI Marine Policy Center



Letting the Tether Go

In late June, Dana Yoerger and engineers from WHOI were joined by a team from Monterey Bay Aquarium Research Institute (MBARI) and Stanford to test *Mesobot* in a test tank and the field for the first time. The test tank trials proved the vehicle's ability to lock onto and track a simulated animal for extended periods of time without disturbing the environment. In *Mesobot*'s offshore tests, the team demonstrated *Mesobot*'s tethered and untethered modes, acoustic navigation and communications, and

basic autonomous controls and also briefly tracked a live target.

In September, members of Yoerger's and Govindarajan's teams accompanied *Mesobot* on its first scientific mission aboard NOAA's R/V *Manta* on a project with Lehigh University molecular ecologist (and former MIT-WHOI JP student) Santiago Herrera. Their goal was to use a new high-flow eDNA sampler to study deep-water corals living in the Flower Gardens

National Marine Sanctuary. The sampler consists of electrical, mechanical, and software systems designed by Yoerger and Govindarajan and incorporates a pump system developed by Amy Kukulya and Dan Gomez-Ibanez from WHOI's REMUS group. It was able to filter a remarkable 2,100 liters in only 12 hours down to depths of 400 meters, which will enable detection of much lower concentrations of DNA than is possible with sampling systems that filter much lower volumes of water.



Technology Advancements

MINION

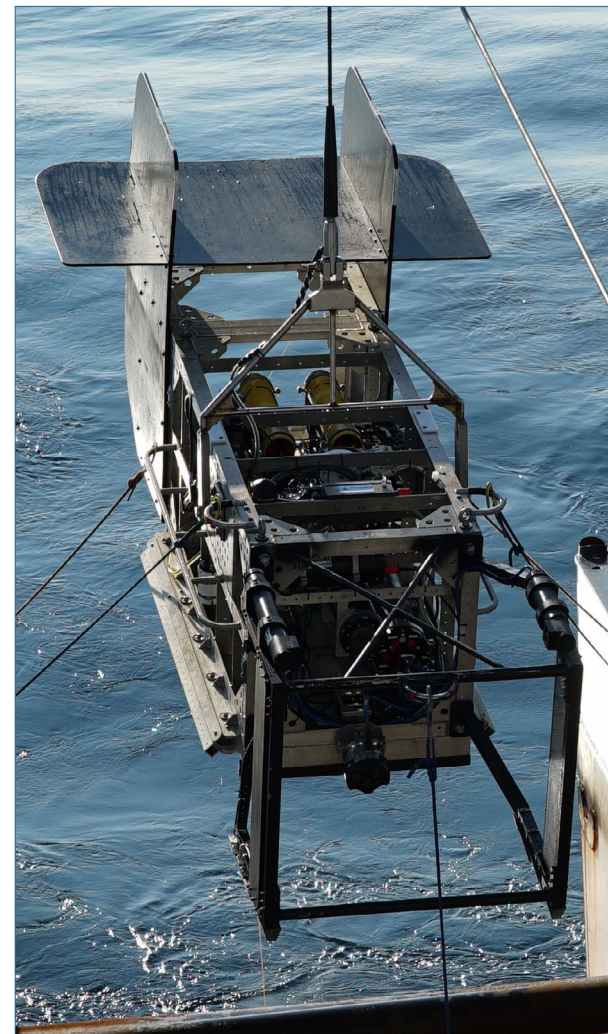
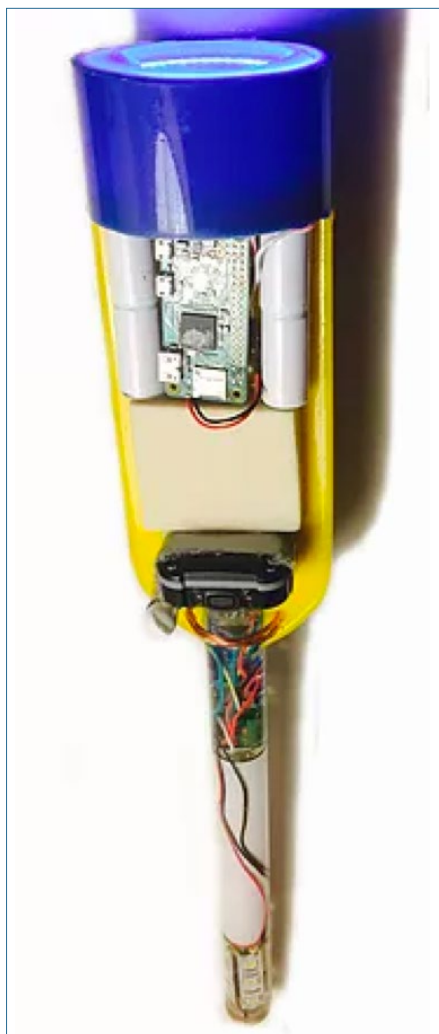
Final construction of the prototype MINiature IsOpycNal float (MINION) is almost complete and the device will make its debut on the fall 2019 OTZ expedition aboard WHOI's Ocean Class research vessel *Neil Armstrong*. These small, inexpensive floats, designed to drift beneath the surface to capture video and environmental data, will allow researchers like Ken Buesseler to provide more accurate estimates of carbon being transported through the twilight zone to the deep ocean.

DEEP-SEE

Following the 2018 cruise on *Henry B. Bigelow*, Andone Lavery's team made critical upgrades to the vehicle to improve its performance. In addition to its existing combination of multi-frequency acoustic sensors, low-light video, high-resolution still, stereoscopic, and holographic cameras; eDNA samplers, and environmental sensors, they added a radiometer designed in collaboration with engineers at MIT. This will ultimately permit researchers to relate behavior of midwater animals to environmental conditions, particularly light levels, that may regulate the daily vertical migration that is a hallmark of the twilight zone.

COMING SOON

Knowledge gained refining *Deep-See's* instruments will enable the team to incorporate custom-built sensor packages onto commercially available platforms and vehicles.



Supporting Smart Decision-making

The OTZ policy team is hard at work to influence revisions of the UN's international legally binding instrument (ILBI) that would promote sustainable development of the high seas. The WHOI-led team has already made headway in raising delegates' awareness of the twilight zone and the many services it provides us, both directly and indirectly.

In June, Porter Hoagland, Annette Govindarajan, and Paul Caiger, and two SEA students served on a panel for a side-event to the Informal Consultative Process on Oceans and Law of the Sea (ICP20) in New York City. The students connected with Hoagland during the Marine Biodiversity and

Conservation Semester that he has taught the past two years and were motivated to extend their work on the twilight zone beyond what they had done during SEA Semester.

MIT Ph.D. candidate Aria Finkelstein and OTZ policy consultant Michael Holland participated as observers at the Marine Biodiversity of Areas Beyond National Jurisdiction Intergovernmental Conference (BBNJ IGC3) in August. At this third session of the negotiations, both participants were encouraged to hear the deep sea had a presence both in side events and in interventions with the general working group.



Impact on Awareness

LOCAL

In June, the Explorer's Club in NYC hosted their third-annual World Oceans Week with a number of sessions and events that included a presentation by Heidi Sosik as part of a panel discussion (right) titled "Big Ocean, Big Ideas: Bold Ocean Initiatives for World Oceans Week" moderated by journalist Ann Curry.

In July, Phil Renaud gave an OTZ brief at the Tabor Academy in Marion, Mass., to regional WHOI supporters.

In August, several OTZ members represented the team at the Woods Hole Science Stroll, an annual event that attracts several thousand people to learn about the scientific and maritime work being done by more than a dozen local institutions.

In both August and September, Heidi Sosik traveled to Martha's Vineyard to introduce the twilight zone to new audiences on the island.

In September, Annette Govindarajan, Dana Yoerger, and Phil Renaud hosted colleagues from OceanX for a workshop on eDNA analysis and instrument design.

NATIONAL

In July, James Cameron authored an op-ed coinciding with the 50th anniversary of the Apollo 11 moon landing that called for a mesopelagic "moon shot" to better understand the ecological role of the twilight zone before exploiting it.

In August, Mark Abbott teamed up with MBARI president and CEO Chris Scholin to produce an op-ed for the policy-oriented print and online publication *The Hill* calling on UN delegates to include the twilight zone in ongoing negotiations over a treaty addressing biodiversity beyond national jurisdictions.



Impact on Awareness

GLOBAL

In May, Joel Llopiz represented the OTZ project at the UN's first planning meeting for the Decade of Ocean Science for Sustainable Development in Denmark (right).

Also in May, Peter Wiebe led a break-out session on mesopelagic ecosystems at the annual Ocean Outlook meeting that resulted in a successful proposal for a twilight zone-focused session at the 2020 International Council for the Exploration of the Sea (ICES) conference in Denmark.

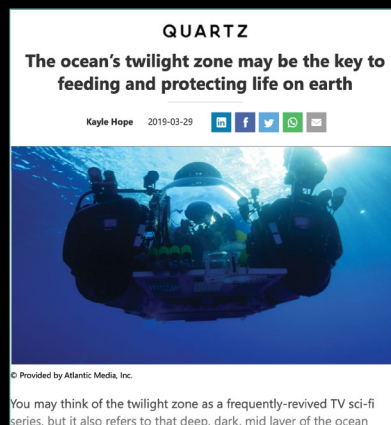
In July, four OTZ team members (Ken Buesseler, Dana Yoerger, Helena McMonagle, and Kevin Archibald) attended the BIARRITZ workshop in the UK and met with colleagues involved in twilight zone research around the world.

In September, Heidi Sosik was recently invited to serve on advisory committees for two new European Commission-funded projects: the Sustainable Management of Mesopelagic Resources (SUMMER) project and the Ecologically and Economically Sustainable Mesopelagic Fisheries (MEESO) project. By developing global partnerships and connections like these, the OTZ team is helping to lead a global effort to sustainably manage the resources of the mesopelagic zone.



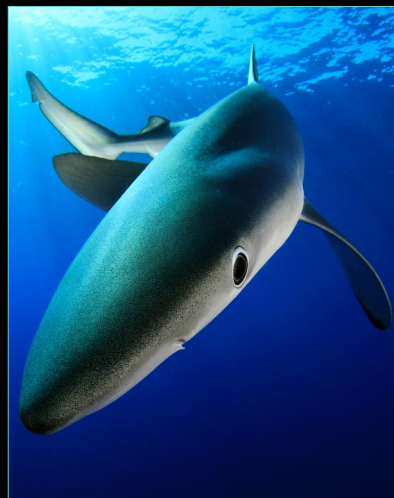
OTZ Media (12 months ending 9/30/2019)

FEATURED MEDIA



GOTHAMIST

11,000,000 REACH



SCIENCE DAILY

7,000,000 REACH

EARNED MEDIA

98 STORIES WORLDWIDE
259,132,500 POTENTIAL REACH

SOCIAL MEDIA

230 TOTAL POSTS
147,945 TOTAL ENGAGEMENTS
 NEARLY **3,000,000** ENGAGEMENT

WEB

44 STORIES
40,600 TOTAL ENGAGEMENTS

MAIN SOCIAL CHANNELS

94 POSTS
1.6 MILLION IMPRESSIONS
46,530 ENGAGEMENTS



97 TWEETS
1.26 MILLION IMPRESSIONS
11,070 ENGAGEMENTS



29 POSTS
88,905 ENGAGEMENTS



TOP FACEBOOK POST

Woods Hole Oceanographic Institution (WHOI)
 August 5 · 🌐

Strawberry squid forever.... 🍓🐙

As sampling continues aboard the NOAA Office of Marine and Aviation Operations ship, #HenryBBigelow, researchers found this little wizard fellow jetting around the #OceanTwilightZone. Recently this gorgeous little guy. A member of the cock-eyed squid group, so named for their mismatched eyes (one eye looks up into the dim light, the other looks down scanning for flashes of bioluminescence). It's also known as the reverse jewel squid because of the complex arrangement of jewel-like photophores studying its body. Incredible Photo by #PaulCaiger



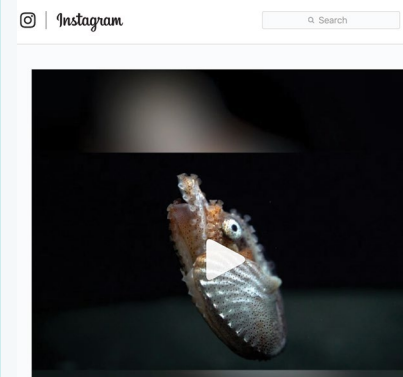
TOP TWEET

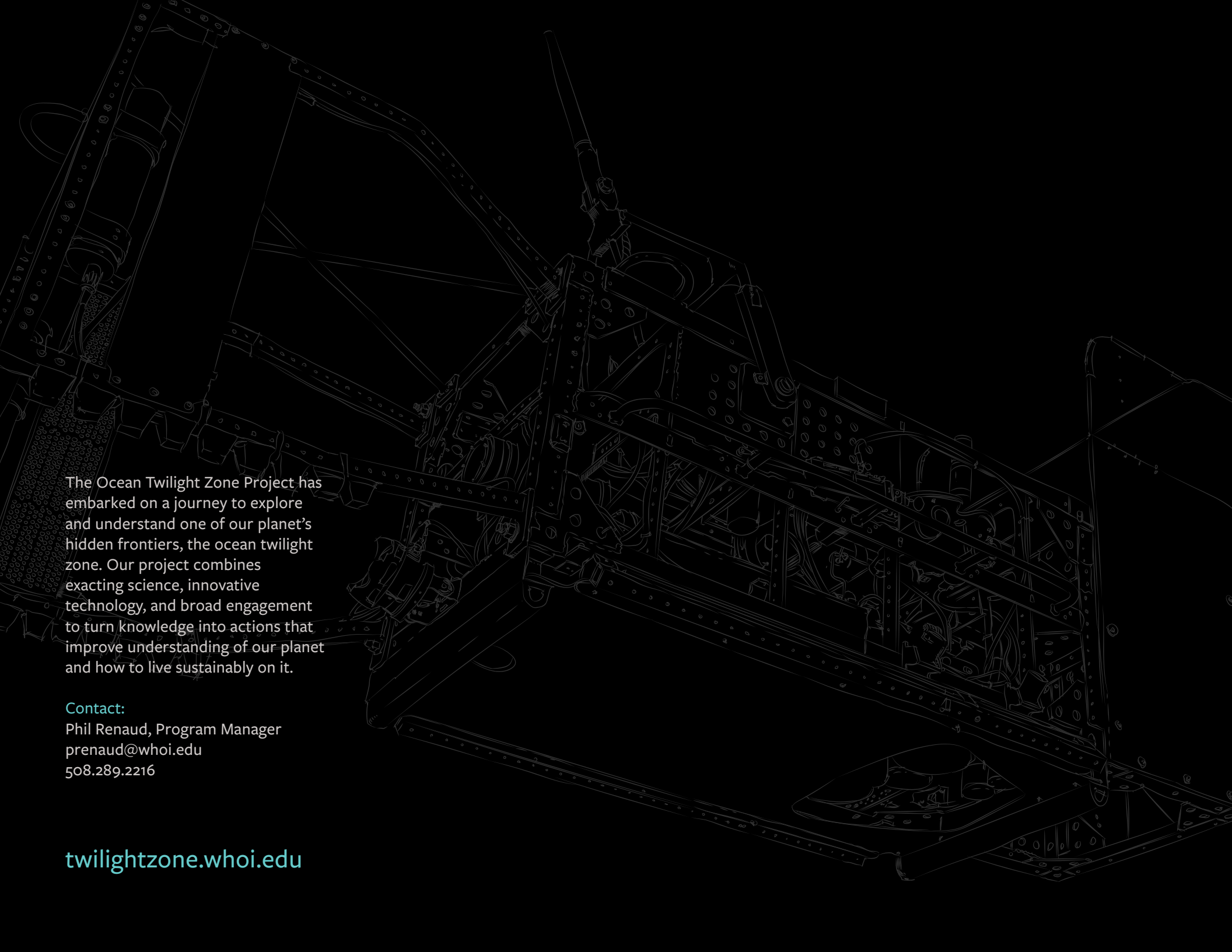
WHOI @WHOI · Aug 7

Scientists track hungry blue sharks as they ride swirling currents down to the #OceanTwilightZone—a layer of the ocean containing the largest fish biomass on Earth. With @SimonThorold @UWOcean @nasa whoi.edu/news-insights/...



TOP INSTAGRAM POST





The Ocean Twilight Zone Project has embarked on a journey to explore and understand one of our planet's hidden frontiers, the ocean twilight zone. Our project combines exacting science, innovative technology, and broad engagement to turn knowledge into actions that improve understanding of our planet and how to live sustainably on it.

Contact:

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508.289.2216

twilightzone.whoi.edu