Reef Solutions: Convergence of Research and Technology to Restore Coral Reefs

Amy Apprill, Yogesh Girdhar, Colleen Hansel, T. Aran Mooney, Weifeng Zhang, Tom W. Bell III, Steve Elgar, Konrad Hughen, Michael Jakuba, Jeffrey Kaeli, Elizabeth Kujawinski, Robin Littlefield, Yaqin Liu, Matt Long, Anna Michel, Jesus Pineda, Ann Tarrant, Peter Traykovski, Z. Aleck Wang, Daniel P. Zitterbart

Woods Hole Oceanographic Institution

Abstract

Coral reefs are a hub of ocean biodiversity and their health and services are of tremendous economic and social importance. The climate- and disease-induced precipitous decline of coral reefs has highlighted the urgent need for solutions to assess and restore affected reefs. Traditional efforts on that have been diver-based and laborious, limiting effectiveness, timeliness and scalability, and real-time capability. **We seek to converge expertise in ocean observation, biogeochemistry, modeling, technology, and computer science with reef biology, ecology and conservation practitioners to develop solutions to the global coral reef crisis.**

We plan to develop an automated, technology-driven approach to monitoring, diagnosing, and restoring reef health within their specific oceanographic context. **Central to this framework is the creation of a machine-learning-based, model-data-integrated algorithm to assign reefs a "health index," as well as a "solutions center" to help implement interventions.** This health index will enable reef practitioners to tailor treatments and optimize restoration strategies for specific reef conditions. It has the potential to significantly enhance the success of global reef restoration efforts and ultimately improve food security and livelihoods of coastal communities worldwide.

WOODS HOLE OCEANOGRAPHIC INSTITUTION

Reef Solutions: Convergence of Research and Technology to Restore Coral Reefs

Amy Apprill, Yogesh Girdhar, Colleen Hansel, T. Aran Mooney, Weifeng Zhang, Tom W. Bell III, Steve Elgar, Konrad Hughen, Michael Jakuba, Jeffrey Kaeli, Elizabeth Kujawinski, Robin Littlefield, Yaqin Liu, Matt Long, Anna Michel, Jesus Pineda, Ann Tarrant, Peter Traykovski, Z. Aleck Wang, Daniel P. Zitterbart

Woods Hole Oceanographic Institution

Challenges addressed

Current efforts to monitor and restore reefs have limited effectiveness, are not scalable to the large areas of reef in need of restoration, and cannot be adjusted rapidly to improve intervention strategies.

Reef health is assessed via visual observation of symptoms indicative of an underlying condition or disease. Once symptoms present, it is often too late for meaningful or cost-effective preventative intervention or treatment. **Need solutions to rebuild reefs and support health.**

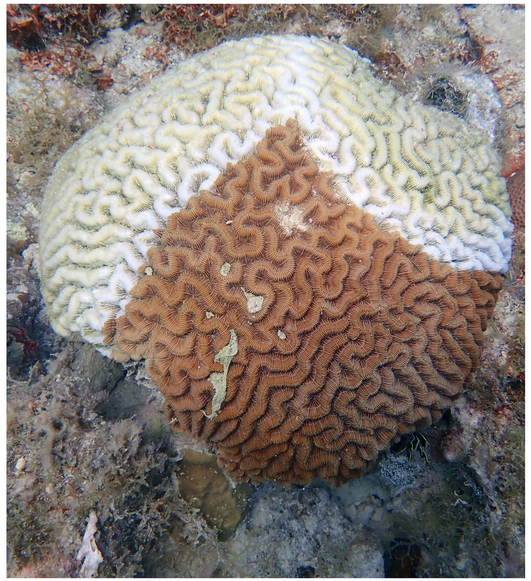
By moving from a 'reactive' to 'proactive' approach based on integrated science and technology, we will improve coral reef monitoring, preservation, and restoration.

This Ocean Shot vision is represented in all challenges, and especially Challenges 2 and 3

Challenge 2

Development of a reef health index will

- Stem from the integration of a suite of measurements;
- Advance understanding of the multiple stressors on reef ecosystems;
- Provide a tangible metric to communicate reef health status to stakeholders;
- Be paired with oceanographic data to tailor specific solutions for conservation and restoration of individual reefs;
- Use continuous measurements to diagnose real-time changes, deploy quick solutions, and establish management strategies.



Challenge 3

The real-time sensors, health index and restoration/solution framework is precisely represented by this challenge, and works towards the ultimate goal of restoring coral reef ecosystem services, including fisheries and coastal protection, for the one-eighth of the world's population that depends on these limited resources.

WOODS HOLE OCEANOGRAPHIC INSTITUTION

Reef Solutions: Convergence of Research and Technology to Restore Coral Reefs

Amy Apprill, Yogesh Girdhar, Colleen Hansel, T. Aran Mooney, Weifeng Zhang, Tom W. Bell III, Steve Elgar, Konrad Hughen, Michael Jakuba, Jeffrey Kaeli, Elizabeth Kujawinski, Robin Littlefield, Yaqin Liu, Matt Long, Anna Michel, Jesus Pineda, Ann Tarrant, Peter Traykovski, Z. Aleck Wang, Daniel P. Zitterbart

Woods Hole Oceanographic Institution

Vision & transformative impact

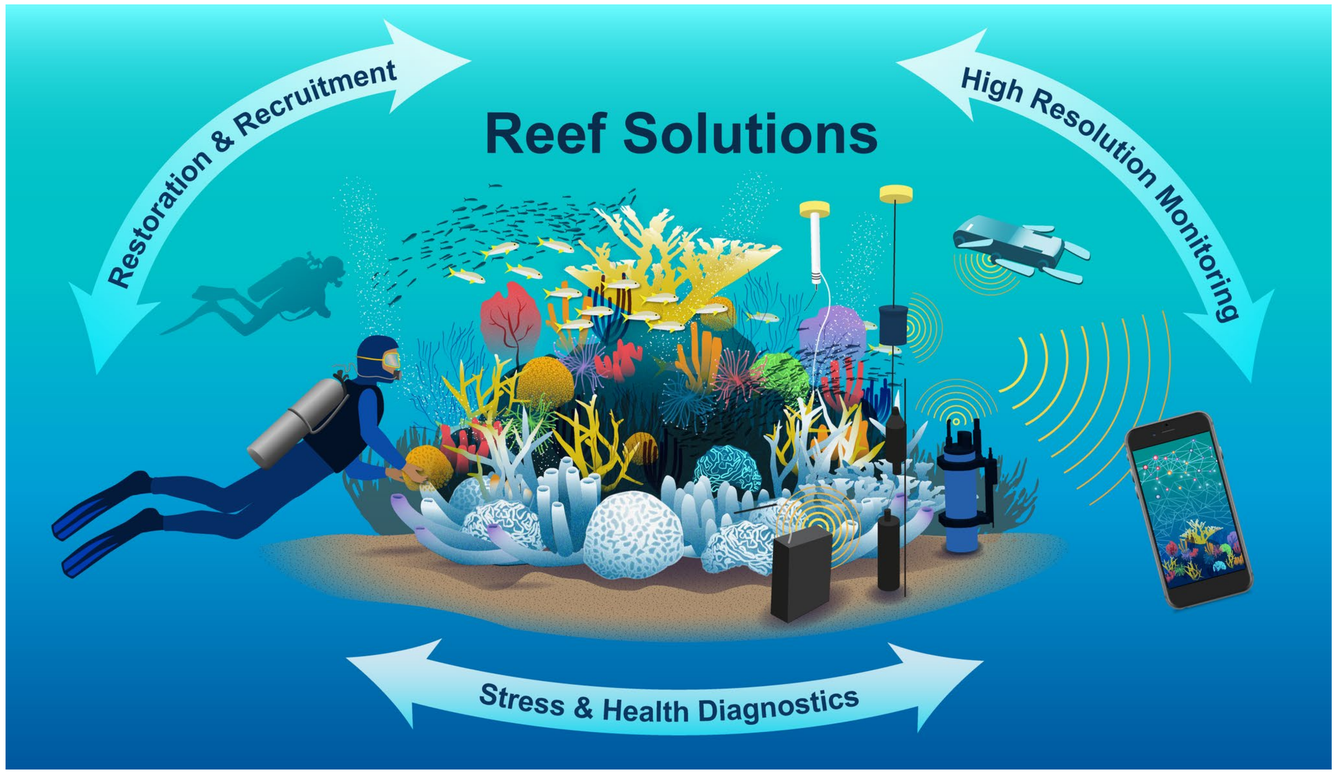
INTEGRATED SCIENCE AND ENGINEERING FOR CORAL PRESERVATION AND RESTORATION

We seek to transform efforts to monitor and rapidly report reef health to enable solutions to reef preservation and restoration.

We plan to develop a **technology and data-driven approach** to monitoring, diagnosing and restoring the health of coral reefs within their specific oceanographic context. Central to this framework is the development of a **health index** which is dynamically updated based on how key health parameters compare to those of healthy reefs.

In practice, an integrated science and engineering approach will:

- **Evaluate reefs holistically, supporting greater understanding and enable solution development**
- Enable cost-effective evaluations, catalyzed initially on a reef but scalable across ocean ecosystems
- Allow practitioners to optimize restoration strategies for specific reef conditions
- Present a prototype, thereby transforming our ability to understand, diagnose, treat and conserve ocean resources



Reef Solutions: Convergence of Research and Technology to Restore Coral Reefs

Amy Apprill, Yogesh Girdhar, Colleen Hansel, T. Aran Mooney, Weifeng Zhang, Tom W. Bell III, Steve Elgar, Konrad Hughen, Michael Jakuba, Jeffrey Kaeli, Elizabeth Kujawinski, Robin Littlefield, Yaqin Liu, Matt Long, Anna Michel, Jesus Pineda, Ann Tarrant, Peter Traykovski, Z. Aleck Wang, Daniel P. Zitterbart

Woods Hole Oceanographic Institution

Connections to existing infrastructure, technology, and partnerships

REALIZATION

Prototypes for this vision are realizable for the US Virgin Islands, where partnerships among i) academia (Woods Hole Oceanographic Institution, University of Virgin Islands), ii) industry (Loggerhead Instruments), iii) NGOs (The Nature Conservancy), and iv) regulatory agencies (National Park Service, VI Territory) already exist. ***Expansion of the partnerships will accelerate use-inspired research and develop reef solutions.***

Our scientists bring expertise in diverse fields:

- Physical oceanography
- Reef soundscapes
- Biodiversity and larval ecology
- Sensing technology
- Chemical and microbial health diagnostics
- Benthic biogeochemistry
- Underwater robotics
- Machine learning and modeling

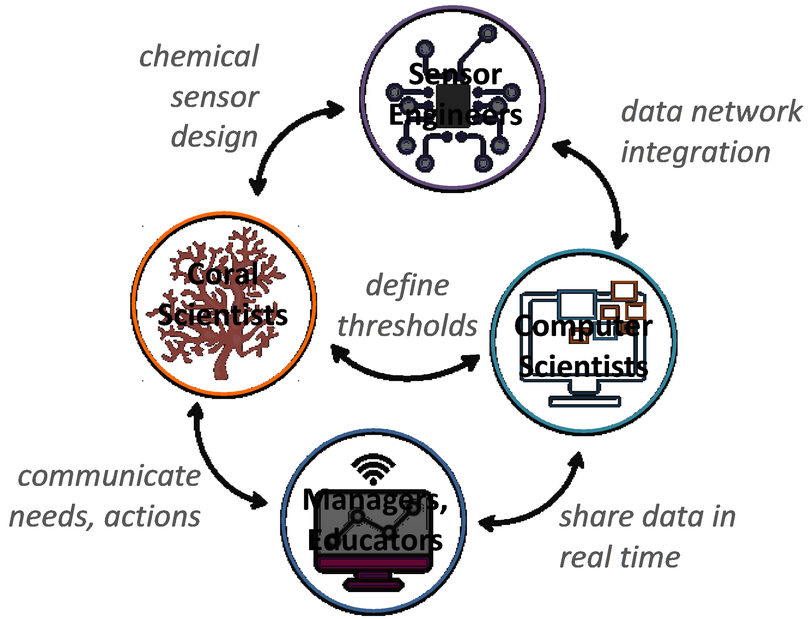
Loggerhead Instruments provides the design and manufacture of cost-effective sensors and connections to help us build worldwide industry connections.

NGOs and government agencies provide historical data and connection to the public sector, with a focus on resource protection.

EXISITING CONNECTIONS

This vision will specifically

- Target collaboration between US academic institutions, governmental agencies and labs, private foundations, and NGOs.
- Leverage domestic expertise in coral reef science, sensor engineering, and computer technologies and provide a mechanism for exchanging critical information.
- Leverage existing essential infrastructure that is in place, including domestic and international field stations and academic and governmental facilities, to conduct field measurements and sensor testing.



Reef Solutions: Convergence of Research and Technology to Restore Coral Reefs

Amy Apprill, Yogesh Girdhar, Colleen Hansel, T. Aran Mooney, Weifeng Zhang, Tom W. Bell III, Steve Elgar, Konrad Hughen, Michael Jakuba, Jeffrey Kaeli, Elizabeth Kujawinski, Robin Littlefield, Yaqin Liu, Matt Long, Anna Michel, Jesus Pineda, Ann Tarrant, Peter Traykovski, Z. Aleck Wang, Daniel P. Zitterbart

Woods Hole Oceanographic Institution

Opportunities for international collaboration and capacity-building

A WORLDWIDE PROBLEM

The coral reef health crisis is a global phenomenon, impacting 1/8 of the world population.

BROADENING PARTICIPATION

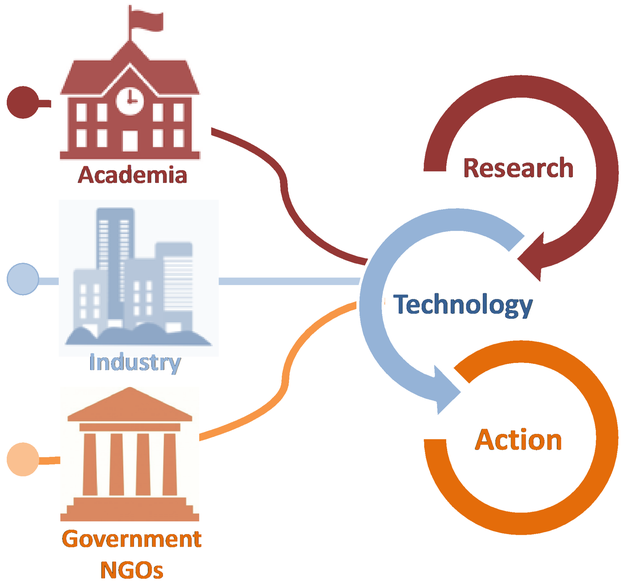
- Converge scientists and engineers to create vital real-time measurements and tackle big problems with new sensors and platforms that enable transdisciplinary measurements.
- Team up with computer scientists to integrate diverse data streams and ocean models; apply machine learning to detect patterns and develop health thresholds; and develop web-data visualization and communication to make the data relatable.
- Engage resource managers, economists and local agencies to support solution-recommendations for each reef system.
- Use robotics to scale up restoration efforts, with expertise sought from industries conducting large-scale automated construction projects.
- **Reef decline disproportionally impacts developing nations; conversely health indices and reef solutions will greatly support their needs.**
- **Operations and observations will directly partner with diverse stakeholders in coastal communities and island nations**

INTERNATIONAL COLLABORATION

- Implementation of this reef solutions program necessitates global partnership, and provides opportunities for universities, agencies, and institutions to break down international barriers and work together towards a common goal.
- Development of the reef health index will rely on measurements from geographically diverse reefs, thus necessitating immediate international coordination and cooperation.
- This effort will form the framework for future collaboration in reef restoration and other solutions.

A GLOBAL CALL TO ACTION

- **Reefs in transition are in need of better data and tested solutions to ensure their health and long-term viability.**
- This Ocean Shot is a forward-thinking initiative poised to develop a global framework to encourage development of the next generation of ocean scientists.
- Participants will span all areas of engineering and ocean science and include reef practitioners, managers, and educators, especially those in traditionally under-represented regions where threats to reefs are most pressing.
- The reef sensor arrays and health indices will empower more people than ever to connect with reefs and coastlines, bringing home their vitality and the changes they face, engaging and inspiring future ocean scientists, and enabling citizen scientists to participate in restoring the future of our reefs.



Reef Solutions: Convergence of Research and Technology to Restore Coral Reefs

Amy Apprill, Yogesh Girdhar, Colleen Hansel, T. Aran Mooney, Weifeng Zhang, Tom W. Bell III, Steve Elgar, Konrad Hughen, Michael Jakuba, Jeffrey Kaeli, Elizabeth Kujawinski, Robin Littlefield, Yaqin Liu, Matt Long, Anna Michel, Jesus Pineda, Ann Tarrant, Peter Traykovski, Z. Aleck Wang, Daniel P. Zitterbart

Woods Hole Oceanographic Institution

Collaborators…

WOODS HOLE OCEANOGRAPHIC INSTITUTION

NOAA

UNIVERSITY OF THE VIRGIN ISLANDS · 1962 ·

Loggerhead INSTRUMENTS

THE UNIVERSITY OF CHICAGO MARINE BIOLOGICAL LABORATORY

The Nature Conservancy

NATIONAL PARK SERVICE

SCHMIDT MARINE TECHNOLOGY PARTNERS

Raytheon Technologies

Join us…

contact us: aapprill@whoi.edu