A Call for Health Diagnostics to Preserve Coral Reefs

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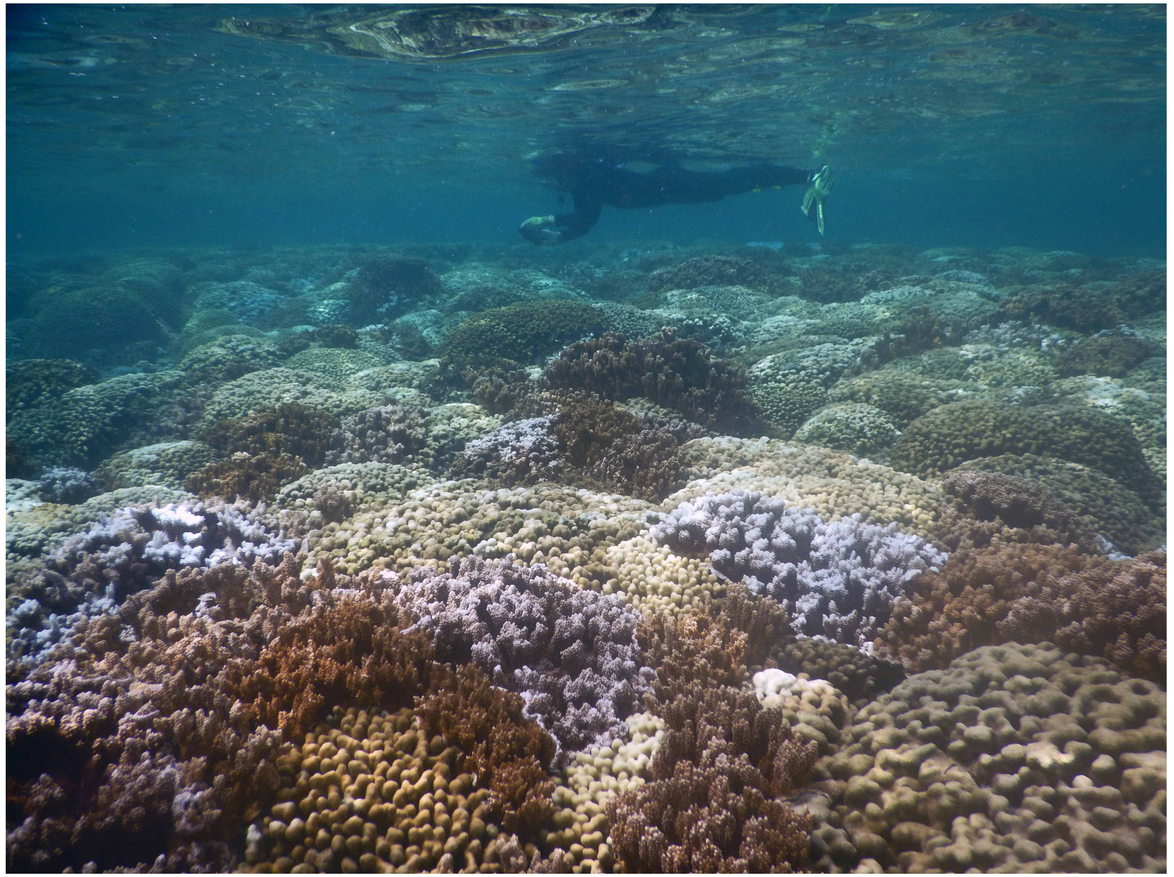
WOODS HOLE OCEANOGRAPHIC INSTITUTION

Abstract

The health and global distribution of coral reefs are declining at an alarming rate in large part due to bleaching, disease, and other human disturbances. A set of health diagnostics based on an emerging understanding of the biochemistry of coral reef ecosystems would help mitigate future reef decline and improve remediation efforts of currently compromised reefs by identifying early-stage stress and health decline in corals and other reef organisms. Importantly, this would allow us to detect underlying health issues in coral reefs that show no visible symptoms of stress, disease, or metabolic malfunction.

Successful implementation of this health diagnostic platform requires the development of novel sensors that are effective over relevant temporal and spatial scales, and integrating wireless communications to enable real-time monitoring of entire reefs. Deployment of these sensors within reefs exposed to a range of stressors is then required to validate the utility of these “infochemicals” as early stage diagnostics for coral health. Our ultimate goal—identifying a set of health indices and sensing platforms for global monitoring of coral reefs—will provide decision-making bodies critical insight into what coral reefs are at risk, the timing required for intervention, and the triggers compromising coral health globally.



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Challenges addressed

Knowledge and solutions challenges

Challenges 1 and 2

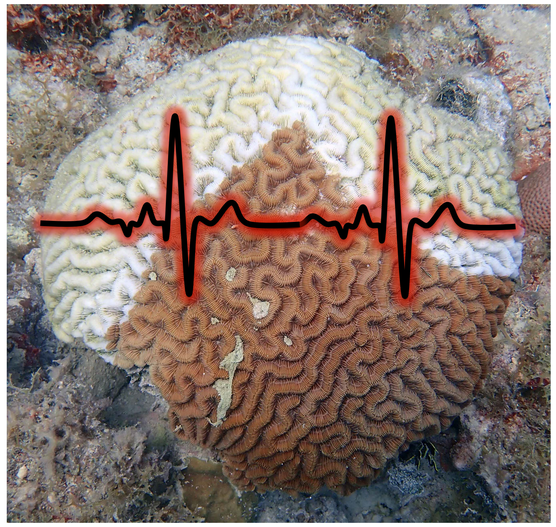
Identifying and monitoring diagnostic chemicals that are indicators of stress and health will provide key insight into the environmental stressors and anthropogenic impacts, including pollutants, on reef ecosystem health

Challenges 3 and 4

Development of tools and approaches for understanding and predicting coral reef health will help preserve these essential ecosystems, which are critical to global fisheries and the ocean economy of developed and developing nations worldwide

Challenge 5

Development of universal health diagnostics and technology required for implementation within global reefs supports the generation of knowledge and engineering innovation necessary to assess reef health and provide crucial insight into the mechanisms and timing required for preventative care and intervention in the face of climate change



Essential infrastructure and foundational challenges

Challenges 6 and 7

Continuous diagnostics monitoring will provide early warning signs of coral reef stress and health decline that will be accessible remotely and worldwide to allow for quick and effective action to relieve the external stress and subsequently mitigate and/or remediate health decline

Challenges 8 and 9

A global diagnostics database will be freely available to scientists, stakeholders, and the general public (Challenge 9) to build an international knowledgebase and for integration into global ocean models and maps of coral reef health in relation to other observables (e.g., sea surface temperature)

Challenge 10

A global health database will help identify triggers impacting coral reef health and allow for predictions of which coral reefs are vulnerable to future health decline allowing scientists and stakeholders to prioritize locations that require proactive measures – a critical step to protecting those vulnerable reefs and the local communities that rely on their ecosystem services for their wellbeing

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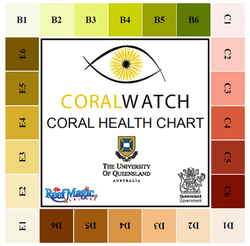
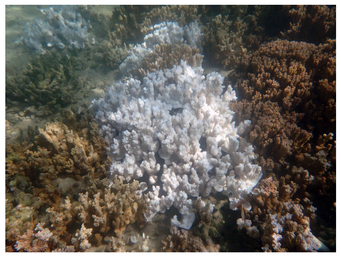
Vision & transformative impact

CURRENT MODEL FOR HEALTH

Currently, 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.





TAKING A CUE FROM HUMAN MEDICINE

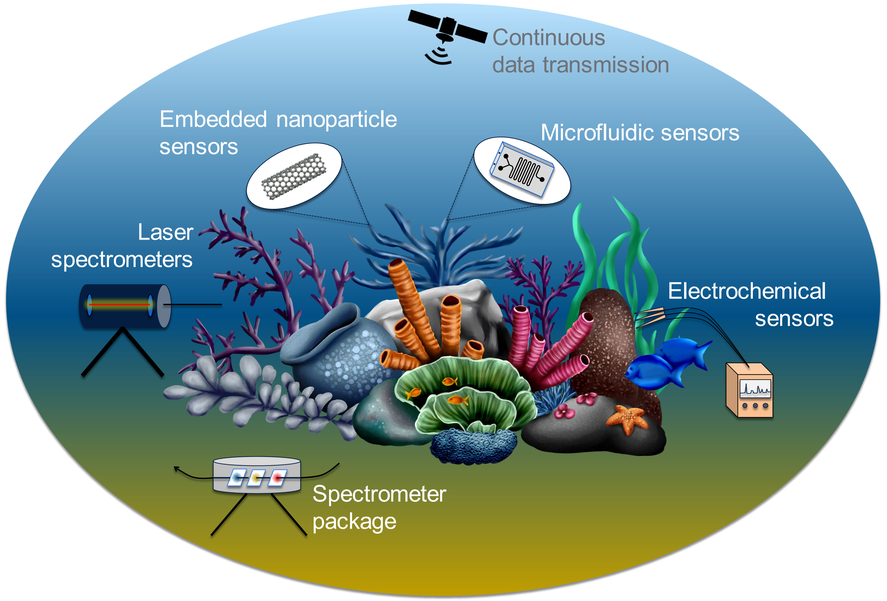
Healthcare has traditionally been **'reactive'** based on limited physiological data collected months or years apart. Most diseases are only detected once critical symptoms present. The longstanding healthcare model has been geared to manage disease symptoms at their onset, rather than preventing or reversing the underlying etiology.

Periodic testing is now known to be insufficient for early diagnosis of underlying health problems, inhibiting preemptive detection and treatment of conditions or diseases. There is a recent movement to develop approaches and technologies to allow for **(near) continuous monitoring of health diagnostics** for early detection and intervention.

TRANSFORMING CORAL SCIENCE

Health diagnostics are essential for early detection of underlying stress, disease, and metabolic disorders prior to the onset of visible symptoms.

Our vision is to develop submersible, deployable sensors that measure specific chemicals ('**infochemicals**') diagnostic of coral health that manifest *before* symptoms present and the host immune system is irreparably compromised. This information will be relayed and analyzed in real time, allowing for coral health assessment and timely intervention.



In practice, early stage diagnostics in coral reefs will:

- Allow governmental agencies and NGOs to intervene and employ solutions to help relieve that stress and preserve coral reefs
- Provide critical fundamental insight on coral health enabling effective remediation of compromised reefs
- Present a model for other ocean ecosystems, thereby transforming our ability to understand, diagnose, treat and conserve ocean resources

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Connections to existing infrastructure, technology, and partnerships

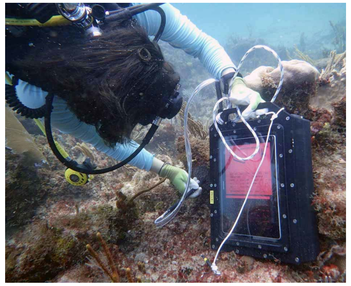
REALIZATION

The development and implementation of a preventative care strategy for coral reef ecosystem health is within reach for ocean sciences and engineering. In the past few years, significant progress within the scientific community has been made in identifying specific stress molecules. These molecules include from short-lived radicals, volatile organic compounds, and organic metabolites. Similar to human healthcare, a suite of diagnostic molecules will be needed to assess the health state of coral reef ecosystems.

EXISTING TECHNOLOGY

In parallel with the advances in identifying health infochemicals, advances have recently been made in development of novel submersible sensors for measuring them.

For example, collaboration between Woods Hole Oceanographic Institution, governmental agencies, and private foundations led to the development of novel *in situ* sensors for measuring reactive oxygen species (ROS), short-lived chemicals indicative of coral health.

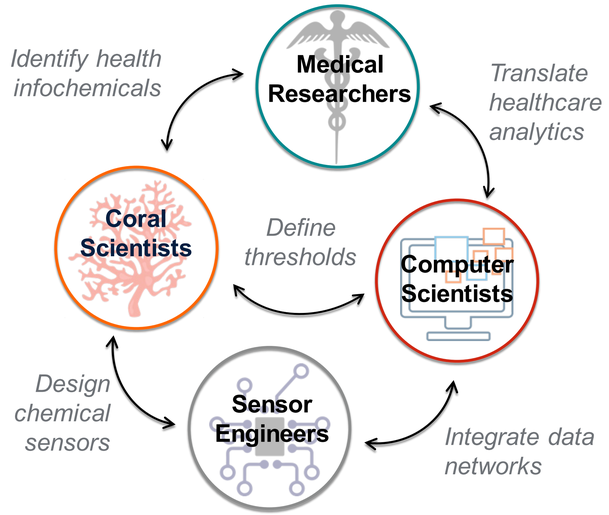


DISCO, developed at WHOI and shown in action in these two images, is the first submersible sensor for measuring in situ ROS – critically important chemicals in coral health.

Further advances in various sensing technologies, including microfluidics, carbon nanotubes, and laser spectroscopy, show enormous potential for application in measuring health diagnostic chemicals within coral reefs.

EXISITING CONNECTIONS

A universal diagnostics platform will specifically target collaboration between US academic institutions, governmental agencies and labs, private foundations, and NGOs. These collaborations will leverage domestic expertise in coral reef science, sensor engineering, and computer technologies and provide a mechanism for exchanging critical information.



This partnership will also leverage existing essential infrastructure that is in place for conducting field measurements and laboratory testing of sensors. These include domestic and international field stations and academic and governmental facilities.

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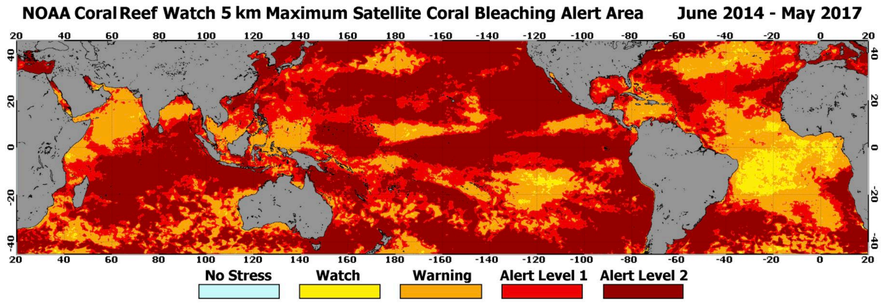
Opportunities for international collaboration and capacity-building

A WORLDWIDE PROBLEM

The coral reef health crisis is a global phenomenon, impacting almost every continent and island nation, and especially developing countries. Maps of coral bleaching warnings – just one of many external stressors felt by coral ecosystems – highlights the severity of the global threat for coral health (e.g., NOAA coral bleaching status map below).



INTERNATIONAL COLLABORATION

Implementation of a global reef health diagnostics program provides an opportunity for partnerships between universities, agencies, and institutions to target diverse reef ecosystems spanning the globe. Adoption of this diagnostics program will provide opportunities for worldwide participation in outfitting and monitoring reefs, breaking down international barriers for collaboration in reef science and preservation. Adoption of universal health indices will also provide critical capacity for effectively communicating the state of coral reef health to decision-making bodies, enabling mitigation and remediation efforts.

Research and Development
Identify diagnostic infochemicals, design and build sensors, build analytics and communication platform

Academic and governmental agency scientists

Deployment and Monitoring
Outfit reefs with sensors and monitor operation, with global coverage of healthy and compromised reef ecosystems

Academic and governmental agency scientists, citizen scientists, and NGOs

Intervention and Action
Respond to early stage health declines with preventative and remediative actions and initiate policy changes when warranted

Academic and governmental agency scientists, NGOs, policy makers, governmental officials

A GLOBAL CALL TO ACTION

The health crisis facing coral reefs provides motivation and opportunity for emerging, established, and citizen scientists and engineers to get involved for the preservation of our planet. The importance of coral reefs for humanity across the globe spanning ethnicities and socioeconomics provides a unique opportunity for global collaboration and entrainment of underrepresented communities to collectively outfit reefs with diagnostic sensors and train future scientists to collect, analyze, and interpret that data for fast and effective action.

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