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The Coral Reef Sentinels Program: A Mars Shot for Blue Planetary Health

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ABSTRACT

Up to 90% of global coral reefs are predicted to be severely degraded by 2050 under "business-as-usual" scenarios. To meet the scale and scope of this challenge, we propose designing and demonstrating a multi-modal system that can incorporate data from remote sensing (satellites, aircraft, and aerial drones), acoustics, genetics, sensor arrays, and low-cost imaging systems. The latter will be collected by low-cost smart sensing and autonomous underwater vehicles (AUVs) guided by adaptive sampling modeling software and rapidly analyzed using automated machine learning systems. Development and deployment will be linked to extensive and diversity-enhancing training programs. The Coral Sentinel System will be globally deployed to enable rapid-response adaptive management and to build public engagement in conservation interventions to save coral reefs.

Phase 1 (Year 1) will involve testing assumptions, coalition building, fundraising, and initial system development. Phase 2 (Years 2-4) will focus on engineering and development with a pilot deployment in the Caribbean. Phase 3 (Years 5-6) will involve system expansion and iteration along the Tropical Eastern Pacific corridor. Phase 4 (Years 7-10) will involve global deployment to over 50 reef sites. This will lead during the following decade (Phase 5) to provisioning of low-cost Sentinel systems to coastal communities globally.

Vision and Potential Transformative Impact

Coral reefs are the most biodiverse ecosystem in the ocean, providing habitat for millions of species, supporting over half a billion people, and providing billions of dollars in income annually. However, coral reefs are being lost at an unprecedented rate, which is accelerating due to mass bleaching and ocean acidification, exacerbated by local human impacts.

Our ambitious, achievable, and transformative Coral Reef Sentinels program will deliver actionable data and knowledge about the health and state of coral reefs in near-real time and enable conservation interventions to protect these reefs from harm while ensuring local ecological, economic, and cultural health. We will design and demonstrate an integrated, scalable monitoring, modeling, and decision-support system for reef science and conservation involving remote sensing (satellites, aircraft, aerial drones), sensor arrays, acoustics, eDNA, and imaging systems on fleets of low-cost AUVs powered by artificial intelligence. It will be deployed on reefs around the world to measure coral reefs' responses to environmental changes and efficacy of conservation interventions guided by information processed in near-real time. This will facilitate rapid-response adaptive management, enhance public awareness about ongoing changes to coral reefs, and build local capacity to monitor and respond to changes to local reef systems.

Realizable, With Connections to Existing U.S. Scientific Infrastructure, Technology Development, and Public–Private Partnerships

The Coral Sentinel program brings together scientists, engineers, computer scientists, and conservationists from the Smithsonian Institution, NASA Ames, the Scripps Institution of Oceanography, the University of California San Diego, the California Academy of Science, and Arizona State University, as well as public–private partnerships with Conservation X Labs and Conservify. We also have partnerships with social scientists, environmental lawyers, and conservationists at the Waitt Institute and the Smithsonian's Healthy Reef Initiative.

Scientific/Technological Sectors Engaged Outside of Traditional Ocean Sciences

We are engaging computer scientists with expertise in AI and machine learning (UCSD, NASA Ames, University of Sydney); engineers from non-profits (Conservation X Labs and Conservify), and from NASA Ames, the University of Sydney, and the University of Haifa; and social scientists, environmental law experts, and conservationists from the Waitt Institute and the Smithsonian's Healthy Reefs Initiative. Through citizen science projects (NASA's NeMo Net, Squiddle) and TV and film productions about the project (Nalu Creative, Luc Hardy, James Nikitine and Fabiano D'Amato), we will educate and motivate the public globally to join in Sentinel efforts to save coral reefs.

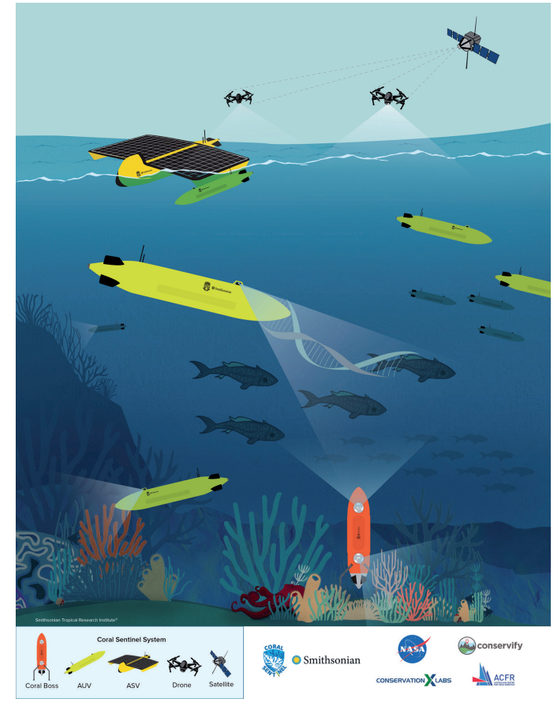

FIGURE 1: The Coral Sentinel Program will use a combination of new and emerging technologies to enable reef monitoring in near-real time, creating an early warning system to detect ocean acidification, warming, hypoxia (low oxygen), mass bleaching events, diseases, invasive species, and in turn, alert and empower reef managers and coastal communities to take action. The program's suite of technology will include cutting-edge remote sensing devices, including satellites and drones, that will anchor our work in broad-scale reef maps and oceanographic conditions. In addition, a self-driving boat on the water's surface will create 3D maps of shallow reef areas while using a custom software system to synthesize multiple data streams. The adaptive software will guide the deployment of swarms of low-cost autonomous under-water vehicles (AUVs). These AUVs will be outfitted with sensors to monitor key environmental variables (temperature, oxygen, salinity, pH, alkalinity, nutrients, light), a mobile DNA barcode scanner to analyze DNA sampled from the surrounding seawater and state-of-the-art 3D cameras to collect high resolution 3D maps of reefs. These maps will capture data on such a fine scale that scientists will be able to monitor the growth and mortality of individual corals over time. AUVs will also be modified to become seafloor observing systems (Coral BOSS) that can remain on the ocean floor for multiple days to measure the diversity and biomass of fish and invertebrate communities while monitoring key environmental parameters. The vehicles will regularly return to a surface vehicle to get recharged—much like an electric car charging station—and upload data to the cloud via satellites. Data will then be rapidly analyzed using a machine learning system and translated into actionable information for local stakeholders and policymakers. Illustration by Paulette M. Guardia.

Opportunities for International Participation and Collaboration

Currently we have international partners at the University of Sydney, the University of Haifa, Bar Ilan University, and at the Technion. Through our collaborations with Smithsonian's Healthy Reef Initiative and the Waitt Institute we will engage and collaborate with coastal communities at over 50 reef sites globally. Our ultimate goal is to provide low-cost automated technologies that coastal communities around the world can use to protect their local coral reefs. Our global partnership of leading conservation organizations, research institutions, technology providers, and civil society groups will develop, implement, and ensure permanent long-term effectiveness of this program.

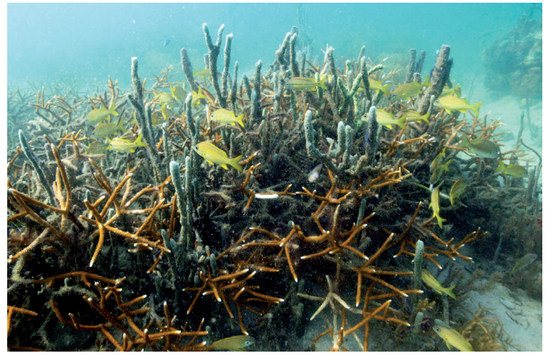

FIGURE 2: Photograph of a healthy Caribbean Acropira cervicornis reef from Bocas del Toro, Panama. By eventually working with local partners, conservation groups and reef restoration programs at over 50 major reef sites globally, scientists will develop a system that can guide conservation interventions to change the trajectory of reef decline. Increasing the health of reefs globally will be essential for climate change adaptation and to ensure thriving blue economies for coastal communities. Photo by David I. Kline.

Develops Global Capacity and Encourages the Development of the Next Generation of Ocean Scientists, Engineers, and Technologists

The Coral Sentinel program will build on partnerships with coastal communities globally to provide technology and training to empower better local management and protection of coral reefs. At all partnering institutions we will offer fellowships to next-generation ocean scientists, engineers and computer scientists, with a focus on growing diversity, to support and enhance global efforts to save coral reefs. We also plan to provide training and opportunities for collaboration for local ocean scientists in every country where we work, to empower and train the next generation of scientists in countries around the world.

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