

AN INTERNATIONAL NETWORK OF CORAL REEF ECOSYSTEM OBSERVING SYSTEMS (I-CREOS)

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Coral Reef Ecosystems and the Threats Facing Them

- Coral reef ecosystems are among the most complex and biologically diverse of all marine ecosystems. Estimates for reef-associated species range between 1 and 9 million species or about 25% of all marine species.
- Coral reefs provide economic, cultural, and environmental services to hundreds of millions of people in terms of sources of food, pharmaceuticals, jobs, and revenue; shoreline protection; and areas of natural beauty, recreation, and cultural identity for the indigenous communities that have evolved around them for millennia.
- Coral reefs are among the most sensitive and threatened marine ecosystems. Coral reef ecosystems worldwide have been deteriorating at alarming rates due to over-exploitation, habitat destruction, disease, invasive species, land-based sources of pollution, marine debris, and impacts associated with global climate change, especially increased ocean temperatures and ocean acidification.

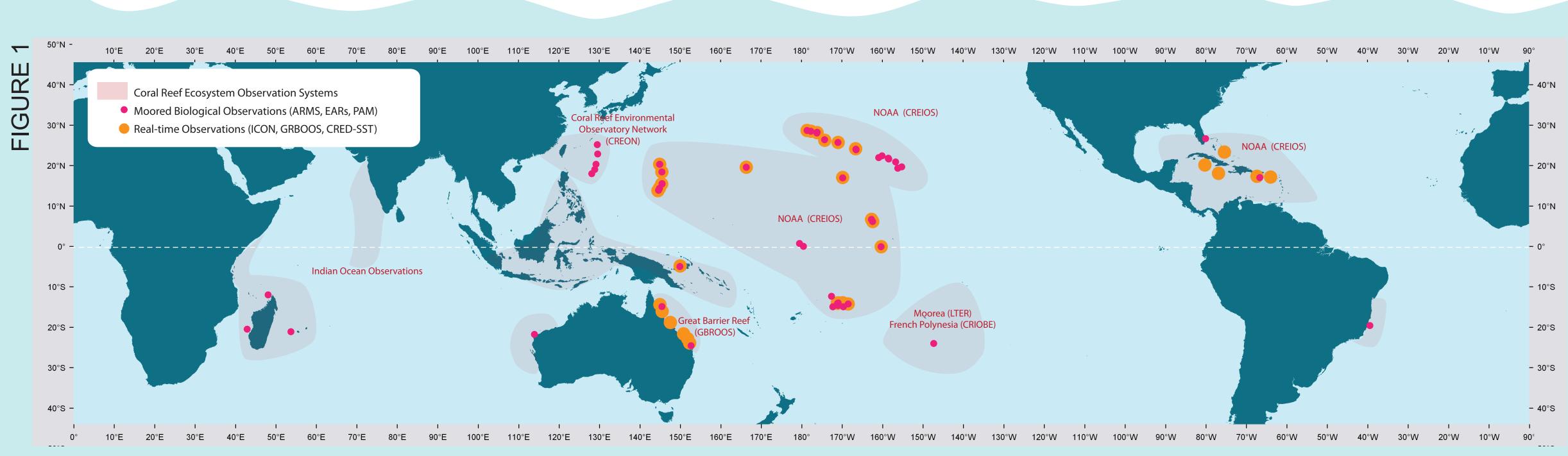
Information Needs for Resource Management and Conservation

- Marine resource managers are required to make decisions that allow humans to sustainably interact with and use complex ecosystems while ensuring long-term conservation and viability for future generations.
 - To assist policy makers and resource managers at international, national, and local levels in effectively implementing ecosystem approaches to sustainable management and conservation of coral reefs and their biodiversity, it is necessary to have timely, unbiased, and integrated observations about the conditions of coral reef ecosystems and the processes influencing them.

International Network of Coral Reef Ecosystem Observing Systems (I-CREOS)

An international network of Coral Reef Ecosystem Observing Systems (I-CREOS) is proposed by organizing, coordinating, and building upon some of the existing coral reef observation systems being developed around the globe, including the following examples (Fig 1):

- NOAA's Coral Reef Ecosystem Integrated Observing System (CREIOS) provides integrated ecosystem assessments: benthic habitat mapping and long-term ecological, oceanographic, and water-quality monitoring over diverse spatial and temporal scales.
- Australia's Great Barrier Reef Ocean Observing System (GBROOS), including the AIMS Long-term Monitoring Program, monitors the biological impacts of large-scale oceanographic and environmental changes on this iconic coral reef system.
- Moorea Coral Reef Long-Term Ecological Research Site (MCR-LTER) and the Centre de Recherches Insulaires et Observatoire de l'Environnement de Polynésie Française (CRIOBE). The MCR-LTER is an interdisciplinary, landscape-scale program funded by the U.S. National Science Foundation to improve understanding of processes that modulate ecosystem function and structure of coral reefs. CRIOBE observations span14 high islands of French Polynesia.
- The Coral Reef Ecological Observing Network (CREON) is a grass-roots community effort involving scientists from several coral reef research sites to share expertise on deployment of real-time sensors for gathering data to address ecological processes at all scales.
- The Indian Ocean serves as an example of a region with low capacity where different observing systems exist, and form a foundation for an integrated system, but significant barriers prevent full integration and widespread application of more technologically intensive methods.



Weather Station Weather Station Light Wint-Sab Solar Panel Burly Back Buoy Steel Inductive Cable Wint aba Charles Roll ADCP Roll aDCP Roll aDCP

Approaches and Technologies

The developing I-CREOS observing systems use the following approaches and technologies for acquiring biological, physical, and geochemical observations of coral reefs and the processes influencing them:

Visual Surveys provide information on spatial distributions and temporal changes in species composition and diversity, abundance, size/biomass, and condition of fish, corals, macroinvertebrates, and algae (Fig 2a).

Moored Instrument Arrays provide time series observations of biological conditions (Figs 2b-c) and physical and biogeochemical processes (Figs 2d-f) influencing reef ecosystem health. They are designed to:

- Understand the role physical and chemical processes play in structuring the distribution, abundance, diversity, and health of coral reef ecosystems;
- Characterize the variability of oceanographic and water quality conditions;
- Understand the ecological effects of episodic events, climate change, and ocean acidification;
- Provide data assimilation into and validation of hydrodynamic and ecoforecast models;
- Provide near real-time observations about on-reef conditions to support timely and effective management actions and research;
- Existing biological components include:
 - Autonomous Reef Monitoring Structures (ARMS) to assess spatial patterns and temporal changes in cryptic biodiversity (Fig 2b).
 - Ecological Acoustic Recorders (EARs) to monitor biological sounds from marine mammals, fish, crustaceans, and other organisms between visual surveys (Fig 2c).
 - Pulse-Amplitude-Modulating (PAM) fluorometry to monitor physiological stress of corals.
- Existing oceanographic components include:
 - NOAA Integrated Coral Observing Network (ICON, Fig 2d) stations and Coral Reef Early Warning System (CREWS), Moored autonomous pCO2 (MapCO2, Fig 2f), and SST buoys telemeter observations of T, S, PAR, UV-B, Air T, P, pCO2, and wind in near real-time to CREWS expert software to trigger bleaching alerts and provide 'ecoforecasts'.
 - The GBROOS advanced sensor network measures T, S, waves, current profiles, turbidity, fluorescence, DO, solar radiation, and can support video, pCO2, and PAR and provides the information to the internet via multiple communication protocols (Fig 2e).

Spatial Hydrographic and Water Quality Surveys provide an understanding of spatial patterns and processes influencing reef ecosystem health. These surveys provide:

- Vertical profiles of T, S, p, beam transmittance, DO, fluorescence, turbidity;
- Water samples for chl a, phosphates, silicates, nitrates nitrites, DIC, and alkalinity.

Satellite Remote Sensing provides time series observations of surface processes influencing reef ecosystem health at global and regional scales.

- NOAA's Coral Reef Watch provides the following products:
 - Near-real-time global 0.5° night-time SST and anomalies
 - Coral bleaching HotSpots
 - Degree Heating Weeks (DHW)

Hydrodynamic and Ecosystem modeling efforts provide improved understanding of processes influencing reef ecosystems and 'ecoforecasts' of future conditions under various management alternatives and climate scenarios.

Gaps - What's Missing with I-CREOS?

There are few interdisciplinary observing systems in many large coral reef areas around the globe. Even where they do exist, observing systems are sparse and limited. The following fundamental challenges need to be overcome to more effectively support management and conservation.

- Due to the biogeophysical complexities and high societal value of coral reefs, there is a paramount need to fully integrate biological observations into the mainstream of observing system infrastructure.
- Increased coordination of research and development are needed across the coral reef community and technology vendors.
- Standardized sampling regimes with agreed upon minimum sets of parameters, methodologies, and formats, including data schemas, quality control, products, datums, and sensor calibrations, should be established.
- Sensors need to be developed to monitor: biological parameters at both high temporal frequencies and over long time periods, bacterial reactions to environmental toxins, levels of water-based organic compounds, primary production and within organism cellular processes, and community structure and abundance of fish and invertebrates.
- Instrumentation to monitor carbonate chemistry and surveys to observe in situ calcification rate changes of corals and other reef-building organisms, as well as shifts in community structure and biodiversity, need to be further developed.
- Increased funding and development of simple off-the-shelf observing system tools that could be easily deployed and maintained with reasonable end-to-end costs are needed to expand I-CREOS to other important coral reef areas, such as the Indian Ocean, Coral Triangle, and Micronesia.

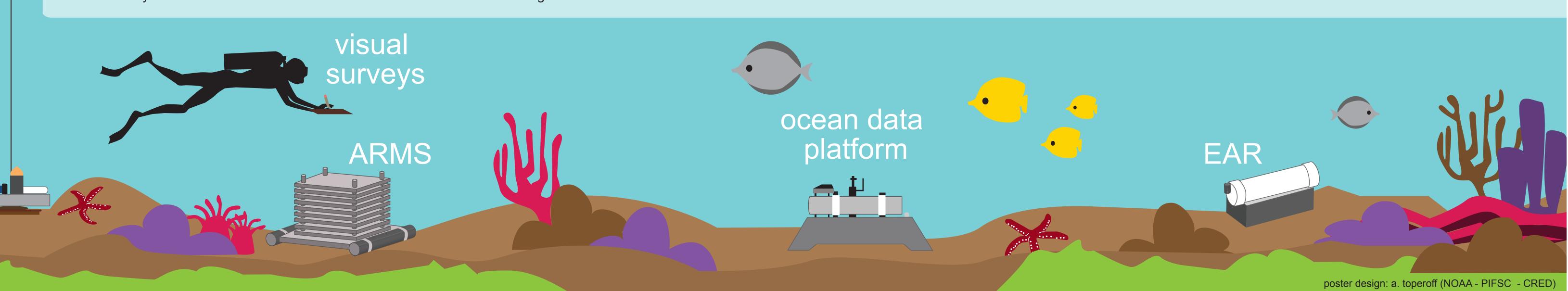
Conclusions

The fledgling I-CREOS represents the early stages of an integrated ecosystem observing system for coral reefs capable of providing policymakers, resource managers, researchers, and other stakeholders with essential information products needed to assess various responses of coral reef ecosystems to natural variability and anthropogenic perturbations. With common goals to maximize the versatility, accessibility, and robustness of the observations, the existing infrastructure and capacity provides a foundation by which increased global cooperation and coordination to develop common protocols and standards could naturally lead to a broader, more globally comprehensive I-CREOS. The issues facing coral reefs and the logistics of observing coral reefs globally suggests that automated "smart" systems should play a key role in how we monitor, manage and sustain these ecosystems. Issues such as climate change and ocean acidification are amenable to observation technologies but many gaps remain. To effectively conserve coral reefs, the global community needs to start addressing these challenges immediately.

We envisage that I-CREOS could sit at the pinnacle of the larger coral reef ecosystem monitoring and assessment network, providing the scientific validation and explanation for data obtained through government and community-level monitoring. I-CREOS efforts should be complemented by socioeconomic assessments to ensure that the explanations are complete and conveyed to affected communities. A nested network would permit greater coverage of the world's coral reef areas and provide increased awareness of status and concerns of coral reefs.

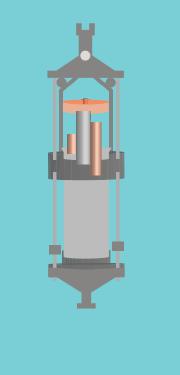
The proposed I-CREOS network fulfills the UNESCO Strategic Design Plan for the Coastal Component of the Global Ocean Observing System (GOOS) mandate to "increase our ability to detect and predict the changes that are occurring in coastal ecosystems", particularly addressing the "lack of spatially and temporally synoptic observations of key physical, chemical, and biological variables."

While significant challenges and gaps in the I-CREOS network remain, it demonstrably fulfills the requirements of an operational, integrated, interdisciplinary, coastal component of GOOS.



weather station

current meter



QTD