Session 73A

Co-management: partnerships for achieving effective resource outcomes on coral reefs – partnerships across agencies and organizations

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Expansion of the Coral Reef Early Warning System (CREWS) network throughout the Caribbean

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Abstract The NOAA Coral Reef Early Warning System (CREWS) Network is a growing number of oceanographic and meteorological monitoring stations situated at coral reef areas of critical concern. The near real-time data from these stations are archived at NOAA and form the basis of daily ecological forecasts for coral bleaching, hydrodynamic events, and other marine environmental events of interest to environmental managers, researchers, and the public. The Network began over 15 years ago with NOAA funding as a station in the Bahamas, and grew to include stations in Puerto Rico, St. Croix, Saipan with other sources of funding, Jamaica and Little Cayman. However, storms and other realities resulted in the destruction or removal of all of those stations, excepting the Little Cayman station, which continues operating today as a new buoy design. A new collaboration between NOAA and the Caribbean Community Climate Change Centre has resulted in the expansion of the network to include two stations each in Belize, Tobago, and the Dominican Republic, plus one in Barbados. Each of these sites has required collaborations among each country's environmental managers and agencies before agreement as to where to place the stations and as to who would be conducting maintenance. The second phase is proposed to include four to six new stations among these candidates: Antigua & Barbuda, Aruba, Bonaire, Cuba, Dominica, Grenada, Grenadines, Montserrat, San Andres, St. Kitts & Nevis, and St. Lucia & St. Vincent.

Keywords: coral, monitoring, climate change, meteorology, oceanography

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Introduction

In order to understand the effects of climate change and other stressors on coral reef ecosystems it is first necessary to understand what constitutes the current status and trend at each location of interest. The National Oceanic and Atmospheric Administration (NOAA) of the United States has since 2000 managed the approach of research and conservation of coral reef ecosystems through the efforts of the Coral Reef Conservation Program (CRCP), along with the individual efforts of NOAA's participating laboratories. At the Atlantic Oceanographic and Meteorological Laboratory (AOML) in Miami, Florida USA, researchers have organized various research endeavors under an umbrella program, the Coral Health and Monitoring Program (CHAMP).

One such endeavor, the Coral Reef Early Warning System (CREWS), began in 1997 as a software program designed to gather data from lighthouses and new structures which were instrumented with meteorological and oceanographic instrumentation as part of the SEAKEYS effort in the Florida Keys (Ogden et al. 1994). That software program began as an expert system shell (Hendee 1994, 1995) designed to gather data (sent via satellite relay to AOML), which were then automatically screened to detect conditions thought conducive to coral bleaching (Hendee et al. 1998; Hendee and Berkelmans 2000; Hendee 2004; Hendee et al. 2008). Through time and funding by CRCP and AOML, new stations were built and installed in the Bahamas, Jamaica, St. Croix (US Virgin Islands), Puerto Rico, the Cayman Islands, and Saipan.

Although the originally developed software was called CREWS (Hendee et al. 2001), the name became synonymous for the monitoring stations themselves, i.e., CREWS stations. These stations were originally designed as dynamic pylons, in that they moved slightly with heavy seas, thus helping them to maintain their upright nature. Meteorological instruments were installed at the top, 6.7 m above the ocean surface to meet the World Meteorological Organization standard for measuring meteorological data. The oceanographic instruments were installed just below the surface and also, usually, 1 m above the sea floor.

Sites were selected at a standardized 6.7m water depth (thus, the entire structure was 13.4 m long). This design had, at the time, features that were better than a buoy; however, eventually, all the CREWS pylons were decommissioned, or in a few instances, destroyed by tropical cyclones. During that time, many valuable lessons were learned about instrumentation, installation, logistics, political realities, and host support challenges.

On October 26, 2012, the pylon at Little Cayman, Cayman Islands was destroyed by Hurricane Sandy, but a buoy, manufactured by Yellow Springs Instruments, Inc., was installed on October 23, 2013 in its place to preserve the data continuity for supporting ongoing research efforts at the Little Cayman Research Center, which utilized the data for various studies. Shortly thereafter the Caribbean Community Climate Change Centre (CCCCC), which in a previous organizational incarnation had helped with the installation of the station in Jamaica, approached researchers at AOML with funding and a desire to expand the CREWS Network throughout the Caribbean according to a list of stations proposed at an earlier science meeting in 2007 (Figure 1.)

The key research questions answered by the installation and operation of a CREWS station are: 1) what are the long term trends of meteorological and oceanographic variables at key national and international coral reef areas? 2) Can data from various sources be integrated in near real time to provide ecological forecasts at coral and coastal ecosystem areas? 3) What are the key environmental correlates related to coral bleaching and other coral ecosystem concerns such as adaptation and resilience (Gramer et al. 2016), disease, spawning and migrating organisms?

Fig. 1 These station sites were originally chosen in 2007 for a Caribbean-wide climate change program by a consortium of universities and laboratories. This network was the original goal for expanding the Coral Reef Early Warning System (CREWS) Network of stations

The present report highlights the lessons learned through this continuing project and discusses current efforts at expanding the CREWS Network in collaboration with CCCCC and participating nations throughout the Caribbean.

Materials and methods

The challenges facing the installation and operation of an *in situ* meteorological and oceanographic monitoring network are reported in depth in Halas 1997, Jankulak et al. 2009, Hendee et al. 2012, and Hendee et al. (*unpublished*). However, the steps can be broken down into the following categories: 1) site survey and site selection, 2) host country permitting, 3) instruments and infrastructure, 4) data transmission protocol, 5) data logger programming, 6) buoy, embedment anchor installation equipment, mooring array materials and associated supplies transport, 7) anchor installation and station assembly, 8) station installation, 9) station maintenance, 10) data and information management, 11) outreach and management education and utility, and, if necessary, 12) station removal.

Results

One CREWS buoy was installed by the Little Cayman Research Center in 2013, two CREWS buoys were installed by CCCCC in Belize, two in Tobago, two in Dominican Republic, and one in Barbados over the period 2013 to 2015. The two stations in Belize are currently inoperable. One station in Tobago and the one in Dominican Republic are currently in operation. The station in Barbados was damaged through a mishap by a technician and is currently inoperable. The Little Cayman station is still operating.

The data from these stations, as well as blogs that reflect routine maintenance, may be found at the CHAMP Web site at www.coral.noaa.gov. There is also a data portal http://www.coral.noaa.gov/data/portal.html that delivers real-time data and information from the CREWS buoys and virtual stations around the globe.

Discussion

The installation of CREWS stations requires significant resources and expertise, although the routine maintenance does not, and is currently attended to by local host country stakeholders who intend to use the data for climate change and other research interests, as mentioned above for key research questions. The installation of the CCCCC sites represents Phase 1 of an ongoing project, with new station installations proposed for St. Lucia, Antigua & Barbuda, Dominica, and Guyana/Suriname in the period 2017 to 2019.

Although routine maintenance is not overly difficult, it has been our experience that expecting volunteers to conduct the maintenance proves to be problematic, since they cannot always be held accountable for the required monthly periodic maintenance. The entry of their work experience and tasks on the various CREWS station blogs helps the crew at AOML to check on their progress.

We have found that some instruments are more robust and reliable than others, and these experiences have helped us to improve the design of the stations. The document currently in preparation (Hendee et al., *unpublished*) expounds upon these concepts in more depth.

The use of the CREWS expert system and other software produces daily reports on the CHAMP Web site and helps managers and researchers understand and witness environmental trends and phenomena that are predicted (e.g., coral bleaching; and see Fletcher et al. 2015). Closely following these reports helps managers understand the "pulse" of the ecosystem and the reports thus serve as additional decision support tools for managers' purview.

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