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A comparison between boat-based and diver-based methods for quantifying coral bleaching

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ABSTRACT

Recent increases in both the frequency and severity of coral bleaching events have spurred numerous surveys to quantify the immediate impacts and monitor the subsequent community response. Most of these efforts utilize conventional diver-based methods, which are inherently time-consuming, expensive, and limited in spatial scope unless they deploy large teams of scientifically-trained divers. In this study, we evaluated the effectiveness of the Along-Track Reef Imaging System (ATRIS), an automated image-acquisition technology, for assessing a moderate bleaching event that occurred in the summer of 2011 in the Florida Keys. More than 100,000 images were collected over 2.7 km of transects spanning four patch reefs in a 3-h period. In contrast, divers completed 18, 10-m long transects at nine patch reefs over a 5-day period. Corals were assigned to one of four categories: not bleached, pale, partially bleached, and bleached. The prevalence of bleaching estimated by ATRIS was comparable to the results obtained by divers, but only for corals >41 cm in size. The coral size-threshold computed for ATRIS in this study was constrained by prevailing environmental conditions (turbidity and sea state) and, consequently, needs to be determined on a study-by-study basis. Both ATRIS and diver-based methods have innate strengths and weaknesses that must be weighed with respect to project goals.

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1. Introduction

In recent decades, coral bleaching events have been occurring with increased frequency and over extensive areas (Baker et al., 2008; Eakin et al., 2010; Furby et al., 2013; Glynn, 1990; Wilkinson, 2000; Yeemin et al., 2013). Although corals bleach in response to numerous stimuli, mass bleaching events triggered by warm-water anomalies have garnered the most attention because of their devastating consequences over large spatial scales (Baker et al., 2008; Glynn and Colley, 2001; Hughes et al., 2003). Bleaching occurs when there is a loss of pigmentation in symbiotic algae (zooxanthellae) or the algae are expelled by their coral host, leaving the white calcified skeleton clearly visible beneath the translucent tissue (Glynn, 1996). Bleaching leaves corals in suboptimal condition, rendering them susceptible to disease, predation, and/or physiological imbalances that reduce reproduction, growth, and, in extremes cases, causes necrosis (Brandt and McManus, 2009; Bruno et al., 2007; Hoeksema et al., 2013; Miller et al., 2009).

Elevated concern about the increased frequency and magnitude of bleaching events has prompted numerous techniques to characterize and quantify the deleterious effects of bleaching on coral reef communities (Baker et al., 2008; Eakin et al., 2010). Conventional methods have relied on diver-based surveys of coral populations in which individual colonies are visually assessed for the presence and severity of bleaching. Although these surveys provide detailed species-level data on the prevalence of coral bleaching, they are costly to conduct, require large teams of scientifically-trained divers, and can be limited in spatial scale (Burman et al., 2012; Wagner et al., 2010). A potentially effective alternative is to use image-acquisition technologies. Photographic- and video-derived data have been successfully used by coral reef monitoring programs for decades (Aronson et al., 1994; Jokiel et al., 2005; Leujak and Ormond, 2007; Morrison et al., 2012). Larger photographic composites, stitched together from a series of images taken by cameras towed behind vessels or divers swimming near the surface, have yielded illustrative records that can effectively assess damage related to ship groundings and hurricanes (Gleason et al., 2007, 2010).

In this study we evaluated the use of an automated image-acquisition technology, the U.S. Geological Survey (USGS) Along-Track Reef Imaging System (ATRIS) for assessing coral bleaching after a moderate bleaching event in the summer of 2011 in the Florida Keys. Data obtained from ATRIS were compared to diver-based bleaching assessments conducted contemporaneously by the Florida Reef Resilience Program (FRRP). We quantified the similarities and differences between these two methods, which allowed us to evaluate the appropriateness of each methodology for quantifying coral bleaching. Our goal was to determine if a boat-based, rapid-acquisition approach can yield similar results to those obtained from in situ diver assessments.

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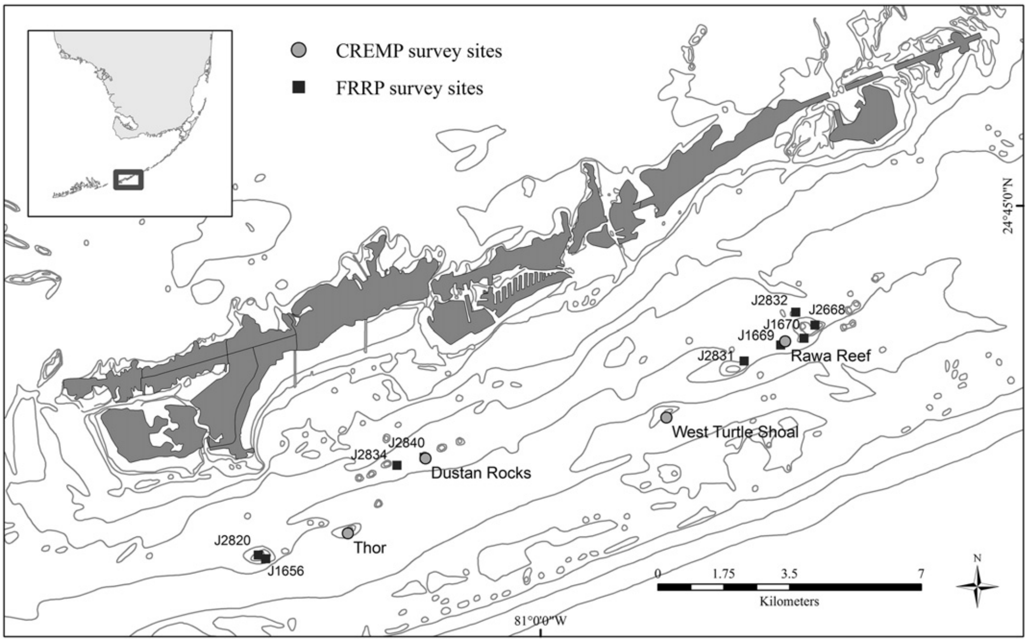

Fig. 1. Study sites. All the patch reefs in this study are located within 4.5 km of Marathon, Florida. Gray dots denote CREMP sites and black squares the FRRP sites. Inset shows southern Florida and the location of the study sites within the Florida Keys.

2. Material and methods

2.1. Overview of experimental design

The original design of this study was to conduct simultaneous ATRIS and diver surveys at multiple sites surveyed annually as part of the Coral Reef Evaluation and Monitoring Project (CREMP) of the Florida Fish and Wildlife Research Institute. ATRIS imagery was collected at four permanently established CREMP sites. Data from diver surveys at these sites prior to the bleaching event (May 2011) were used to determine the coral-size detection limit of ATRIS. Because several complications prevented diver surveys at the four CREMP sites during the bleaching period, FRRP bleaching data from randomly-selected patch reefs neighboring the CREMP sites were used instead for the comparative analysis. This experimental change necessitated the additional step of verifying the equivalency of coral density, as a function of colony diameter, between the CREMP and FRRP coral population data. The coral-size threshold for ATRIS was applied to the FRRP bleaching data prior to comparison with the ATRIS-derived bleaching data.

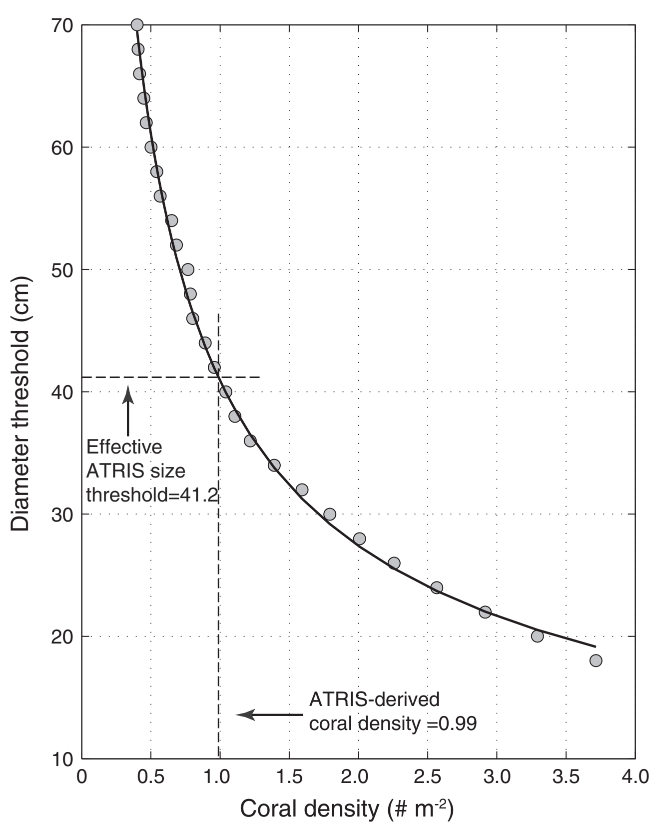

Fig. 2. Coral-diameter threshold calibration. For a range of possible coral-diameter thresholds, resultant coral densities were determined for pooled CREMP transects. A regression relation was used to compute the minimum diameter-threshold for ATRIS.

2.2. Along-Track Reef Imaging System surveys

ATRIS is a boat-based, high-speed, digital imaging system that allows simultaneous acquisition of geo-located, color, digital images and corresponding distances from the substrate. The equipment can be deployed either from a movable pole mounted to the side of a boat or from a towed vehicle. The pole-mounted version is typically used for surveys in the 2–7 m depth range, the shallow limit being governed by the draft of the boat. Under ideal conditions, successful surveys have been conducted as deep as 13 m. The towed version can be operated over a 2–27 m depth range. Replacing its control- and data-transmission wire cable with fiber optics would extend this range to 90 m.

We used the pole-mounted configuration for the relatively shallow patch reefs surveyed in this study. A camera, transducer, and two lasers were co-located on the bottom of the pole and a global positioning system (GPS) antenna affixed to the top (Lidz and Zawada, 2013). The transducer continuously streamed the distance to the seafloor. The pole was manually adjusted to maintain a nominal distance of ~3 m above the reef substrate resulting in a field-of-view of ~1.6 m × ~1.2 m for each ATRIS image. The lasers projected two red spots in each image, separated by a fixed distance, which provided a size-scale reference. Custom software, developed in-house, controlled the camera and saved the individual color digital images, as well as the corresponding GPS and imaging-range data.