

## RNA Performance Topic 4

### Chapter 9: Eight years of coral reef community monitoring: Results from inside and outside the Dry Tortugas National Park Research Natural Area

#### Investigators

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#### Project Description

The South Florida/Caribbean Network (SFCN) of the National Park Service (NPS) Inventory and Monitoring Program is monitoring coral reef communities within Dry Tortugas National Park (DRTO) to evaluate trends in cover of key

benthic community indicators from selected coral reef sites both inside and outside the Research Natural Area (RNA). This monitoring addresses the need identified in Performance Topic 4 to evaluate the effects of RNA implementation on marine benthic biological communities.

We began monitoring during 2004 at Bird Key Reef (study site termed “Bird Key”; area = 19,765m<sup>2</sup>), adding an adjacent site in 2005 (“Bird Key North”; 25,642m<sup>2</sup>) (Fig. 1). The Bird Key Reef sites are situated within a 2-km long, high-relief spur-and-groove habitat. These sites were selected for management interest in human activities in and around Fort Jefferson, and for comparison with historical monitoring results. Each site consists of 20 permanent, randomly selected 10-m transects that are monitored with a high-definition video camera. Percent cover by benthic groups/categories is quantified by visual identification of 10 random dots placed on 30–35 non-overlapping video images (per transect). Benthic categories

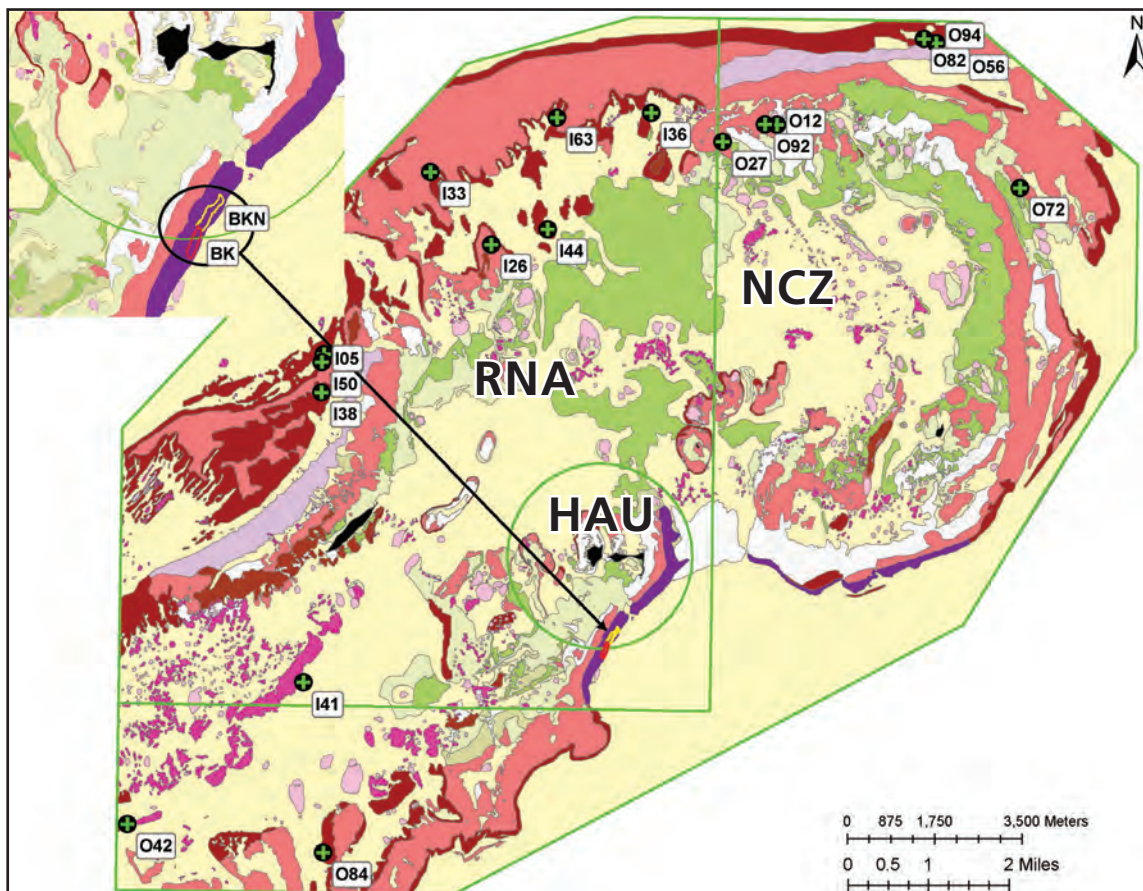


Figure 1. The 2010 Dry Tortugas National Park benthic habitat map showing habitat classifications and location of coral monitoring sites at Bird Key (BK), Bird Key North (BKN), nine sites (labeled with “I” prefix) inside the Research Natural Area (RNA) and nine sites (labeled with “O” prefix) inside the Natural Cultural Zone (NCZ). Refer to Table 1 for the habitat legend.

include living coral by species, macroalgae, turf algae, crustose coralline algae, octocorals, and sponges. Additional field data are collected on coral disease, abundance of long-spined sea urchins (an important algal grazer), stony coral species diversity, rugosity, and reef-depth water temperature. The Bird Key sites straddle the Historic Adaptive Use Zone (HAU) boundary (see map on inside front cover), where 12 of the 40 combined transects fall within the RNA and 28 in the HAU, which may allow a future analysis of boundary effects.

We expanded benthic monitoring in 2008 to include additional randomly selected sites that increased the spatial scale of benthic sampling in DRTO. More than 150 hard-bottom habitat sites were evaluated (2–20 m depth range), which led to 18 sites (termed “extensive” sites; 9 inside the RNA and 9 inside the Natural Cultural Zone (NCZ)) that met the criteria of hav-

ing >5% stony coral cover (see site locations in Fig. 1). Each site consists of four 10-m video transects and the same data are collected as described at the Bird Key sites. Monitoring of all sites by SFCN staff has continued annually.

In 2007, we entered into a cooperative agreement with the Florida Fish and Wildlife Conservation Commission (FWC) to produce a benthic habitat map for the coral reef ecosystems of DRTO. An initial benthic habitat map was completed in 2008 by the contractor, Avineon, Inc. Acquisition of new higher resolution side scan sonar data and 2,054 field data points from multiple sources (SFCN, National Oceanic and Atmospheric Administration, and University of Miami) allowed SFCN to correct classification deficiencies in the 2008 map and improve the detail level of the line work to produce the 2010 DRTO benthic habitat map (Fig. 1, Table 1; Waara et al. 2011).

**Table 1. The 2010 Dry Tortugas National Park benthic habitat map classifications with corresponding color scheme and the areas (in hectares) inside the Research Natural Area (RNA) and the Natural Cultural Zone (NCZ) along with the area totals for Dry Tortugas National Park.**

| Map Classification                              | Color                                                                               | RNA (ha) | NCZ (ha) | DRTO Total (ha) |
|-------------------------------------------------|-------------------------------------------------------------------------------------|----------|----------|-----------------|
| Aggregate Patch Reefs                           |    | 326.08   | 306.97   | 633.06          |
| Continuous Submerged Rooted Vegetation (SRV)    |   | 1,242.18 | 1,025.6  | 2,267.78        |
| Discontinuous SRV                               |  | 672.16   | 783.9    | 1,456.06        |
| High Relief Spur and Groove                     |  | 21.54    | 134.06   | 155.59          |
| Individual Patch Reefs                          |  | 200.78   | 324.82   | 525.6           |
| Land                                            |  | 23.18    | 16.19    | 39.37           |
| Low Relief Spur and Groove                      |  | 249.84   | 167.91   | 417.75          |
| Patchy Coral or Rock in Unconsolidated Sediment |  | 200.79   | 812.94   | 1,013.73        |
| Pavement                                        |  | 170.85   | 36.61    | 207.46          |
| Reef Rubble                                     |  | 47.3     | 80.85    | 128.15          |
| Reef Terrace (high profile)                     |  | 1,226.84 | 655.91   | 1,882.75        |
| Remnant (low profile)                           |  | 1,879.03 | 2,389.03 | 4,268.05        |
| Unconsolidated Sediment                         |  | 5,738.22 | 7,495.31 | 13,233.53       |

## Results

**Bird Key Reef:** Monitoring from 2004 through 2011 indicated a significant decrease in stony coral cover at the Bird Key site (13.2% to 10.6%;  $p<0.0001$ ). This decrease primarily occurred from 2004 through 2007 and then appeared to stabilize. Bird Key North, initiated in 2005, did not show a significant overall trend (Fig. 2). Octocoral cover (such as sea fans, sea plumes, etc.) showed a significant 1-year decline at both Bird Key Reef sites from an average of 20.0% in 2005 to 8.9% cover in 2006 ( $p<0.0001$ ) followed by an increase through 2011. This trend is likely the result of four hurricanes passing over DRTO during the extremely active hurricane season of 2005.

**Extensive sites:** Results of annual monitoring at the 18 extensive sites showed that stony coral cover had no significant trends at these sites during 2008–11. Two sites located within the RNA in Loggerhead Forest (I05, I50), had exceptionally high stony coral cover (I05 : 4-year mean = 31.0% [Standard Error (SE)=0.5]; I50: 4-year mean = 20.1% [SE=1.3]). This finding is notable because in June and July of 2008, SFCN staff observed an outbreak of the coral disease white plague in DRTO, much of it located in the Loggerhead Forest area. This outbreak was investigated again in July 2008 by a team of coral disease specialists from the U.S. Coral Disease and Health Consortium and George Mason University. Loggerhead Forest sites (I05, I50) were resurveyed and tissue samples were collected (results pending) but by the time of the resurvey, the outbreak had subsided. Cover by macroalgae varied throughout the study and was inversely related to the turf algae category. Macroalgal cover was ephemeral; when present, cover of turf algae and other substrate categories (sand,

for example) decreased as they were replaced or became covered by macroalgae.

**Temperature:** Analyses of reef-depth water temperature data indicated that benthic communities in DRTO were subject to large variations in water temperature, both seasonally and episodically. Daily average temperatures in the summer regularly exceeded the theoretical 30.5°C bleaching threshold; however, NPS staff stationed at the park did not report widespread coral bleaching, possibly indicating that the bleaching threshold at DRTO may be higher. Daily average temperatures during the winters of 2009, 2010, and 2011 fell below 19.5°C (Fig. 3), with 2009 and 2011 temperatures even lower than those experienced in DRTO during Florida's deadly cold-water event in 2010 (Lirman et al. 2011). Cold-water events also were recorded in the summers of 2009, 2010 and 2011, when temperatures at several monitoring sites (primarily Loggerhead Forest) rapidly dropped 4–8°C in a matter of days, remaining well below temperatures recorded at other DRTO locations for days to weeks. Although these cold temperatures were above the 16°C minimum temperature stress threshold, they demonstrate that benthic communities are exposed to wide fluctuations in temperature, at times exceeding 10°C.

**Benthic Habitat Map:** We conducted an accuracy assessment of the 2008 Avineon, Inc. DRTO benthic habitat map and found the overall classification accuracy to be acceptable (83.2%; lower 90% Confidence Interval (CI)=79.8%). However, upon closer evaluation, the soft-bottom habitat classifications displayed a relatively high level of accuracy (89.4%; lower 90% CI=85.2%), whereas the hard-bottom habitat classifications were below an acceptable level (75.2%; lower 90% CI=69.1%). All unknown areas (10,444 ha) in the 2008 map were identified, and the line work for the hard-bottom areas

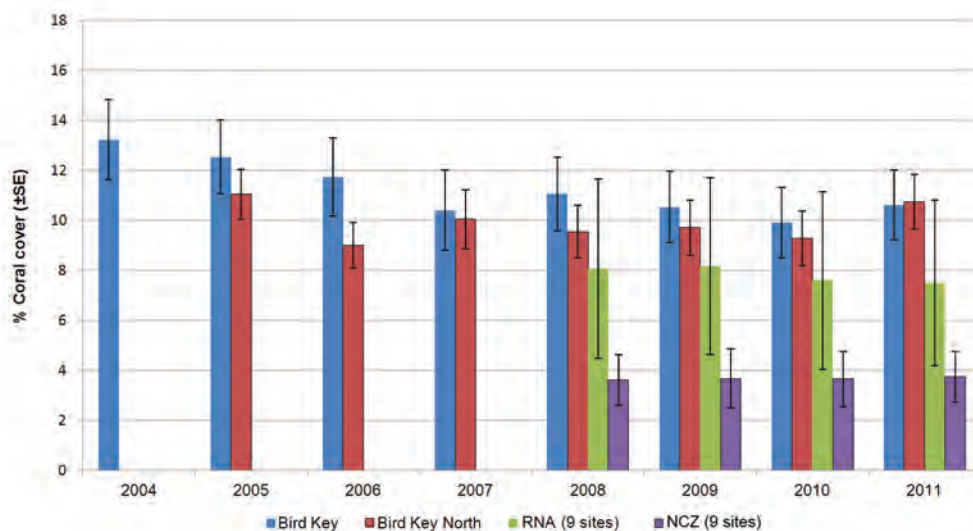


Figure 2. Trends in average percent cover of stony corals at coral monitoring sites grouped into Bird Key, Bird Key North, inside the Research Natural Area (RNA), and the Natural Cultural Zone (NCZ) strata.

was fine-tuned in the 2010 DRTO benthic habitat map (Waara et al. 2011). The overall accuracy assessment of the redrawn 2010 DRTO benthic habitat map was 89.7% (lower 90% CI=86.0%). The accuracy of hard-bottom habitats improved to 88.0% (lower 90% CI=83.4%). The 2010 map consists of 13 mapping classes and 1,709 polygons totaling an area of 26,229 ha. A map layer also was developed to identify areas that have a higher potential for fish and benthic biodiversity. In addition, a final bathymetry layer for the park was created by merging the 2004 Light Detection and Ranging (LiDAR) data and newly acquired side scan sonar bathymetry data. To facilitate visualization of underwater sites, a hyperlink tool was developed that displays photos and videos together with field data when a point is selected in ArcGIS.

## Performance Measure Evaluation

The SFCN benthic monitoring program at DRTO was developed, in part, to address the need identified in RNA Performance Topic 4. The program will continue to be a useful tool to evaluate the effectiveness of the RNA in the years to come.

*Bird Key Reef:* Although trends observed at this site are not necessarily representative of park-wide DRTO trends, SFCN monitoring conducted at this site can be evaluated within a valuable historical context. In 1975, coral cover on this site, measured at 11 transects with a line transect method, ranged from 17.9% to 63.9% (mean: 42.3% [SE=4.3]; Jaap et al. 1989). Additionally, monitoring conducted by the FWC at 12 stations in DRTO (including 4 at Bird Key Reef) during 1999–2008 reported a significant decrease in coral cover ( $p<0.001$ ; Ruzicka et al. 2009). Thus, although methods differ, we are

concerned that the current decrease in coral cover during 2004–2011 may be part of a longer downward trend at Bird Key Reef. The observations of very large toppled coral boulders and distinct patches of coral mortality suggest that hurricanes and coral diseases are the likely causes of these dramatic declines in coral cover. Given this context, monitoring of benthic communities is important not only for determining effects of the RNA on this aspect of the ecosystem, but also for correctly interpreting results of other performance measures that could be tied to benthic community health, such as fish abundance and size structure (RNA Performance Topic 1).

*Extensive Sites:* The development of a DRTO GIS-based benthic habitat map has facilitated management-based sample designs in benthic monitoring. In 2008, we installed four benthic monitoring transects at nine randomly selected sites inside the RNA and NCZ with the purpose of tracking changes in the benthic community. Despite the white plague disease outbreak in June 2008, no appreciable coral loss was subsequently observed (Brandt et al. in review). Results of video monitoring during 2008–2011 showed no change in stony coral cover at the nine RNA sites (2011 mean cover: 7.5% [SE=3.3]) or the nine NCZ sites (2011 mean cover 3.8% [SE=1.0]). Although mean stony coral cover in the RNA appears higher than outside, this was driven by the exceptional coral cover at the two previously mentioned sites located within the high profile reef terrace in the northwestern part of the RNA (Loggerhead Forest). This area has relatively high coral species richness and high rugosity, and may contain the highest remaining living stony coral cover within DRTO. During the study period, stony coral species richness remained relatively constant at sites in the RNA and NCZ, with higher diversity at sites in the RNA, again primarily reflecting the high diversity of coral spe-

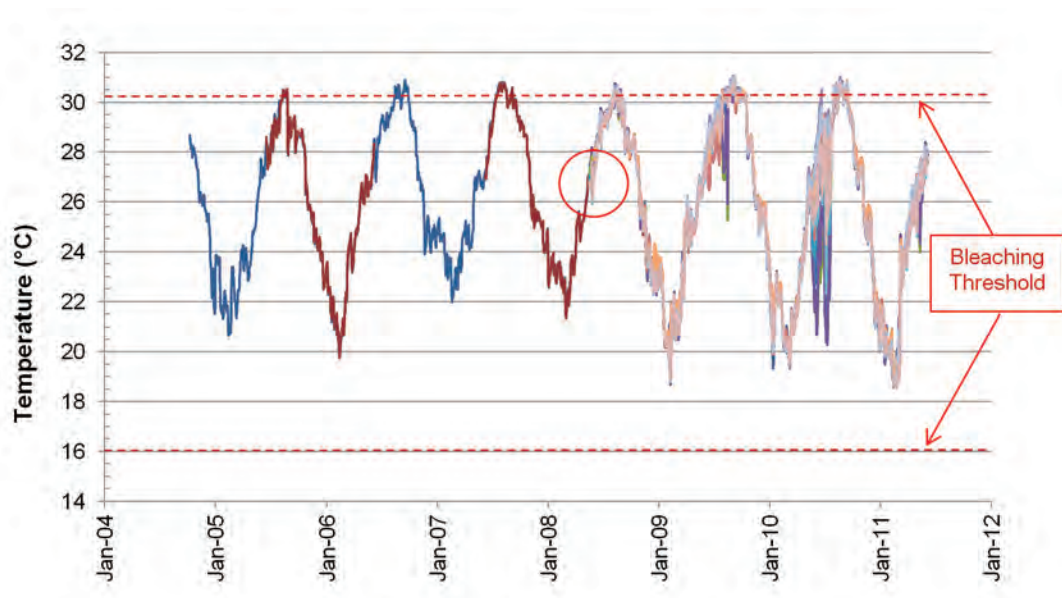


Figure 3. Water temperature measured at coral monitoring sites in Dry Tortugas National Park, 2004–2011. Prior to the introduction of 18 extensive monitoring sites in 2008 (indicated by red circle), temperature was recorded only at Bird Key (blue) and Bird Key North (red). Cold-water stress threshold of 16°C and bleaching threshold of 30.5°C are shown.

cies in Loggerhead Forest. Cover by sponges, octocorals, macroalgae, and turf algae was not significantly different between the two management zones, with macroalgae being the most abundant benthic community group.

*Benthic Habitat Map:* The greater accuracy and detail of the 2010 DRTO benthic habitat map as well as the new bathymetry layer should facilitate both monitoring and management planning. As an example, the proportions of different habitats can be shown for the management zones. Soft-bottom habitats (such as unconsolidated sediment, continuous or discontinuous submerged rooted vegetation, or reef rubble) comprise 65.8% of the area in the RNA and 71.7% in the NCZ. In both management zones, remnant reef (low profile) is the dominant hard-bottom component, followed by reef terrace (high profile). However, there is more than twice the amount of reef terrace inside the RNA than inside the NCZ. Patch reefs are common features in both strata, comprising 12.9% of the hard bottom in the RNA and 15.7% in the NCZ; while the area of individual and aggregate patch reefs are nearly equal in the NCZ (324.8 ha vs. 306.9 ha, respectively), there are fewer indi-

vidual patch reefs in the RNA (200.8-ha vs. 326.1-ha aggregate patch). Spur-and-groove reefs are moderately abundant hard-bottom features in DRTO. In the RNA, the majority are low relief (249.8 ha low relief vs. 21.5 ha high relief); distribution is more equal in the NCZ (167.9 ha low vs. 134.1 ha high).

The additional habitat delineated in the 2010 map includes areas with potential for high coral cover, diversity, and rugosity, primarily in the northeastern and southwestern sections of DRTO (for example, low- and high-relief spur and groove, and reef terrace). We are currently considering revising our extensive-site study design to include these areas in the survey domain. Monitoring for status and trends in the benthic community, specifically coral cover, requires a well-designed monitoring program. Declines in coral cover can occur rapidly (such as from hurricane effects or disease outbreaks) or be prolonged (for example, from climate change). Given the very slow rate of coral growth, quantifying increases in coral cover takes many years if not decades. We are structuring our monitoring program to capture declines and increases in coral cover and growth.



Monitoring of coral cover and other benthic communities is important not only for determining effects of the RNA on the ecosystem, but also for correctly interpreting results of other performance measures that could be tied to benthic community health, such as fish abundance and size structure. Photo by the South Florida/Caribbean Inventory and Monitoring Network, NPS.

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