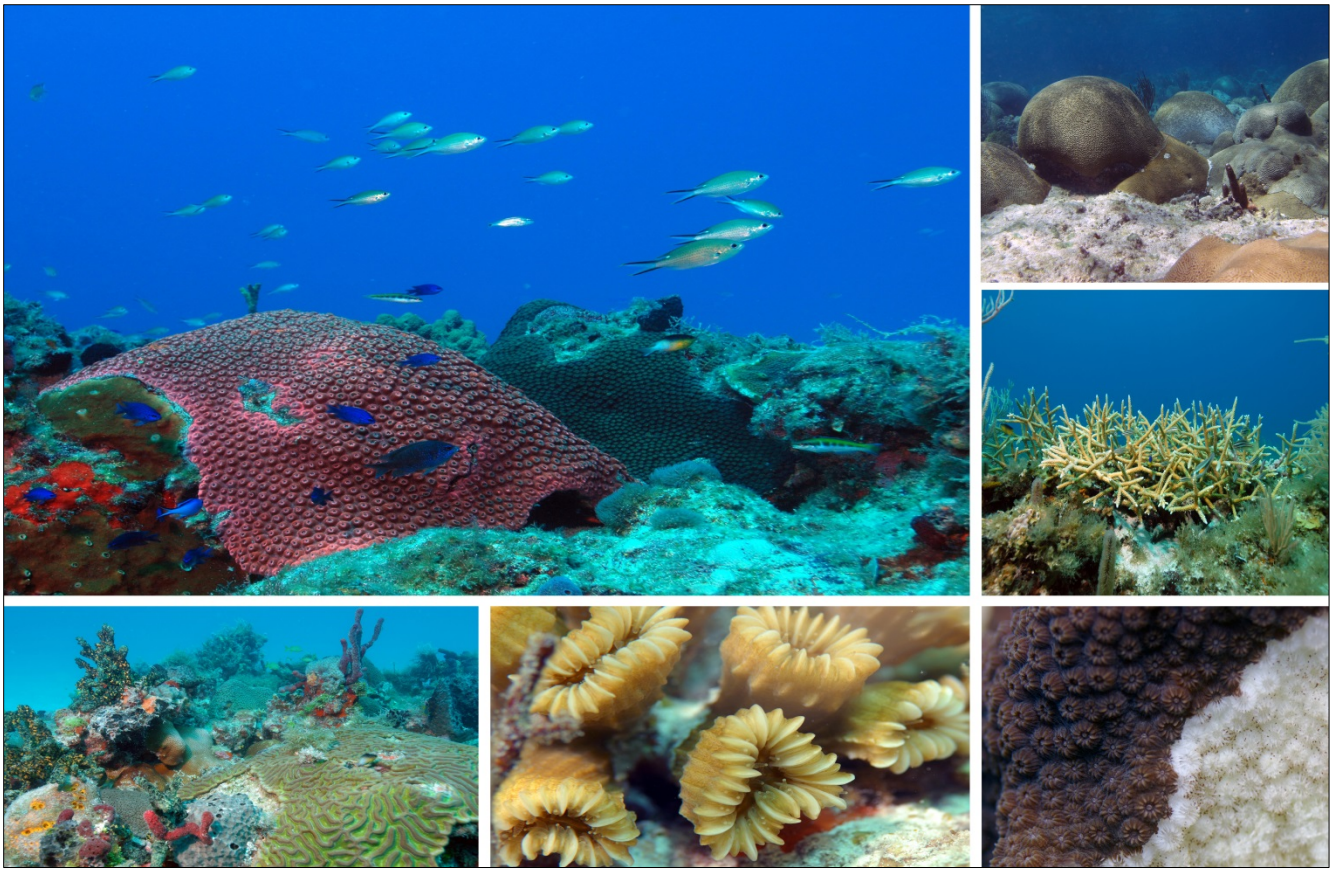
National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Coral Reef Monitoring

Protocol Narrative—Version 2.0

Natural Resource Report NPS/SFCN/NRR—2017/1464



ON THE COVER
Starting from top left going clockwise: Reef habitat in Dry Tortugas National Park; *Pseudodiploria strigosa* colonies located at Buck Island Reef National Monument, St Croix; *Acropora cervicornis* located in Biscayne National Park; white plague coral disease on *Orbicella franksi* colony in Dry Tortugas National Park; *Eusmilia fastigiata* colony in Virgin Islands National Park; and Reef habitat in Dry Tortugas National Park.
Photographs by Rob Waara, National Park Service South Florida / Caribbean Network

Coral Reef Monitoring

Protocol Narrative—Version 2.0

Natural Resource Report NPS/SFCN/NRR—2017/1464

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June 2017

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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NPS 910/138797, June 2017

Change History

Version #	Date	Revised by	Changes	Justification
1.00	1999	Jeff Miller, Caroline Rogers	Initiated annual coral videography index site monitoring transects at Newfound (NF) and Yawzi (YZ) reef sites in VIIS with Digital Video. Published Protocol: Miller, J. and C. Rogers. 2002. Using Videography To Monitor Coral Reefs. U.S. Geological Survey Technical Report. Published Protocol: Miller, J. 2002. Using the AquaMap System at a Study Site. U.S. Geological Survey Technical Report.	High priority reefs for monitoring in VIIS with historical monitoring occurring using chain transects. Original published Videography protocol. Original published AquaMap protocol.
1.01	2000	Jeff Miller	Initiated annual coral videography index site monitoring transects at Mennebeck (MB) in VIIS and Western Spur and Groove (WSG) in BUIS (19 transects only installed at WSG).	High priority reef on undeveloped watershed for monitoring in VIIS. WSG originally was established as a comparison site outside the park. This became part of the park when the boundaries expanded in 2001.
1.02	2003	Jeff Miller, Matt Patterson	Initiated annual coral videography index site monitoring transects at Haulover (HA) in VIIS and South Fore Reef (SFR) in BUIS; Added 20th transect to WSG.	High priority reefs for monitoring. Adding 20th transect to WSG simplified analyses and made all sites consistent.
1.03	2004	Jeff Miller, Matt Patterson Jeff Miller	Initiated annual coral videography index site monitoring transects at Amanda's Reef (AM) and Ball Buoy reef (BB) in BISC and Bird Key Reef (BK) at DRTO (origins marked with brass survey pin). Initiated sea urchin (Diadema antillarum) monitoring at BK and YZ sites.	Ball Buoy reef was a previously known well defined reef in BISC with historic monitoring. Amanda's Reef was a previously known and well-defined patch reef. Bird Key was a previously known spur and groove reef in DRTO with historic monitoring. The sudden crash in long-spined sea urchin populations was a concern as an important herbivore of algae on coral reefs. This pilot tested whether adding this monitoring was feasible.

Version #	Date	Revised by	Changes	Justification
1.04	2005	Jeff Miller, Matt Patterson	Initiated annual coral videography index site monitoring transects at Tektite (TK) in VIIS and Bird Key North (BKN) in DRTO. Initiated coral disease monitoring at VIIS and BUIS sites including the type of disease, number and area of lesions, and coral species affected. Expanded annual sea urchin (*Diadema antillarum*) monitoring to all sites.	Expanded coral monitoring protocol to highest coral cover reef in VIIS where a lot of historical research was done. Expanded coral monitoring to highest known coral cover reef in DRTO. Disease monitoring initially added as part of a USGS research project. It was determined to be highly valuable and added to protocol. Initial pilot testing showed additional workload was minimal for information gained so urchin monitoring added to protocol.
1.05	2005	Jeff Miller	Expanded monitoring to include episodic monitoring at HA, MB, NF, TK, SFR sites in response to Bleaching / Disease event.	Bleaching event followed by disease event monitored additional times during year (episodically) in order to provide quick information to park management and to the research community.
1.06	Oct. 2005	Jeff Miller	Initiated recording 4 category levels of coral bleaching in late 2005: BL1, BL2, BL3, BL4.	Previous to the extreme 2005 bleaching event, any bleaching was quantified as labeling a point “BL” in the comments. Once the 2005 event occurred, different levels of bleaching were described with different codes to better describe the range of bleaching that was occurring and the recovery rates.
1.07	2006	Jeff Miller	Initiated disease monitoring at BK site.	Disease monitoring initially added as part of a USGS research project. It was determined to be highly valuable and added to protocol.
1.08	2007	Jeff Miller Jeff Miller Andrea Atkinson	Expanded annual coral disease monitoring to remaining coral monitoring sites. Added rugosity monitoring on most index sites (periodic). Developed extensive coral sub-site sampling design for management areas and large reefs. Investigated potential extensive coral monitoring sub-sites inside / outside DRTO Research Natural Area.	Disease monitoring initially added as part of a USGS research project. It was determined to be highly valuable and added to protocol. Rugosity is a common metric in coral monitoring and was added to protocol. New design developed to allow comparison of changes inside and outside managed areas and allow monitoring of larger coral reefs than typically found at VIIS.

Version #	Date	Revised by	Changes	Justification
1.09	2008	Andrea Atkinson	Installed 18 extensive coral monitoring sub-sites in DRTO: I_26, I_33, I_36, I_38, I_41, I_44,I_63, I_05, I_50, O_12, O_27, O_42, O_56, O_72, O_82, O_84, O_92, O_94.	New extensive sub-site design applied to monitor inside and outside Research Natural Area in DRTO
		Rob Waara	Conducted additional episodic coral video and coral disease monitoring at I_05, I_50 in May and July.	Coral disease outbreak detected and triggered additional visit in DRTO.
		Ben Ruttenberg	Pilot testing of coral colony counts at BISC.	Other programs were reporting disease prevalence. SFCN Pilot tested coral colony counts to allow reporting disease prevalence.
1.10	March 2008	Jeff Miller	Began switch to High Definition (HD) video with 1 year overlap using both previous digital video camera (DV) and HD methods (at all index sites except AM).	Old camera was reaching point it needed replacement and high definition video would offer a greater resolution to increase identification and decrease unknowns and shadows. An overlap allowed a comparison of technologies to ensure any changes were captured and accounted for analyses and interpretation.
1.11	March 2009	Jeff Miller	Ended use of Digital Video and used HD exclusively.	HD video showed improved ability to identify benthos, reducing unknowns, and unidentified coral species.
1.12	2009	Andrea Atkinson, Jeff Miller	Initiated recording field in situ coral species lists at MB, TK, YZ, BK and some DRTO extensive sub-sites.	Increasing the ability to determine when a coral species has disappeared (rather than is momentarily undetected) improves the ability to describe the effect of an episodic event on the coral community in a timeframe useful to management.
		Matt Patterson	Beginning and terminal pins added to transects on all index sites.	Installed in case AquaMap ceased working, site could continue to be monitored.
		Jeff Miller	Underwater Range and bearing tables developed.	These tables allow divers to navigate to next transect without needing to return to surface and without need for AquaMap.
1.13	August 2009	Ben Ruttenberg	Expanded colony counts to remaining sites and began counting fire corals and stony corals separately; may or may not include coral < 4 cm as pilot SOP unclear.	Decided based upon pilot results to include colony counts at all sites but some confusion occurred between USVI vs. Florida sites as to whether colonies smaller than 4cm should be included.

Version #	Date	Revised by	Changes	Justification
1.14	2010	Jeff Miller	Use of AquaMap discontinued.	Manufacturer ceased producing AquaMap, device was failing, and SFCN discontinued use.
		Jeff Miller	Episodic coral monitoring conducted at TK, HA, MB, NF, SFR due to extensive bleaching.	Extensive bleaching triggered additional episodic monitoring at USVI sites in 2010.
		Jeff Miller	Conducted rugosity monitoring on most extensive sub-sites.	Completed rugosity monitoring at all current sites.
		Andrea Atkinson	Expanded collection of coral species lists in the field to all sites.	Change to protocol to improve detection of changes in species occupancy and species richness.
1.15	2012	Mike Feeley, Lee Richter, Jeff Miller	Installed 20 transect index coral monitoring site at Salt River (SR) in SARI.	Implemented monitoring at SARI.
		Mike Feeley, Andrea Atkinson	Installed 3 4-transect coral monitoring sub-sites at Loggerhead Forest in DRTO: LH01, LH02, LH03. Installed 3 4-transect coral monitoring sub-sites at Santa's Village in DRTO: SV01, SV02, SV03. Changed name of I-05 to LH-05 and I-50 to LH-04.	Expanded Index monitoring sites using extensive sub-site approach at two previously undocumented large high coral cover reefs in DRTO.
		Mike Feeley	Discontinued sampling at BKN, I_33, I_63, O_12, O_27, O_92.	5 sub-sites discontinued to allow time for other sampling. Initial coral cover using videography at these sites <3% which was not part of original sample frame. BKN discontinued as already had established BK site and wanted to reallocate effort to other sub-sites at Loggerhead Forest and Santa's Village.
		Jeff Miller	Pilot test conducted testing separating colony counts into < 4cm and >= 4 cm at VIIS sites and once at BK to examine time involved and variability of results.	Lesions are recorded on all colonies but disease prevalence in literature typically recorded only on colonies > 4cm. Only counting colonies > 4cm would likely reduce inter-observer variability in colony counts.
1.16	March 2014	Jeff Miller	Pilot test ends and so counts no longer include colonies < 4cm.	Reduced inter-observer variation in colony counts and is consistent with other research efforts.

Version #	Date	Revised by	Changes	Justification
1.17	June 2014	Mike Feeley	Starting at DRTO colony counts were conducted with 2 observers resulting in double counts.	Reduce inter-observer variation in colony counts.
		Mike Feeley	Switched to using 4-letter species codes.	This makes us more consistent with other monitoring groups and makes simple typos like DC vs DCA less likely.
2.00	Jan. 2015	Mike Feeley, Jeff Miller, Andrea Atkinson, All staff	Protocol re-written to meet I & M program, organization and format requirements.	Protocol re-written to meet I & M program, organization and format requirements.

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Standard Operating Procedures

The following Standard Operating Procedures accompany the *Coral Reef Monitoring: Protocol Narrative* and are published separately in:

Miller, J., C. S. Rogers, M. W. Feeley, A. J. Atkinson, A. D. Davis, M. E. Patterson, R. J. Waara, B. D. Witcher, J. M. Patterson, and E. M. Muller. 2017. Coral reef monitoring: Standard operating Procedures. South Florida/Caribbean Network. Miami, Florida. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2240897.

Standard Operating Procedure 1: *Using Videography to Monitor Coral Reefs*

Standard Operating Procedure 2: *Counting Long-Spined Sea Urchin, Diadema antillarum, on Coral Reefs*

Standard Operating Procedure 3: *Measuring Coral Disease*

Standard Operating Procedure 4: *Conducting Coral Colony Count*

Standard Operating Procedure 5: *Collecting Coral Species Diversity Data on Benthic Transects*

Standard Operating Procedure 6: *Measuring Rugosity on Coral Reefs*

Standard Operating Procedure 7: *Selecting and Locating Random Sampling Points using GPS*

Standard Operating Procedure 8: *Conducting Rapid Habitat Assessments*

Standard Operating Procedure 9: *Installing Monitoring Sites*

Standard Operating Procedure 10: *Video and Image Transfer, Capture, Catalog and Burning to a Blu-Ray Disk*

Standard Operating Procedure 11: *Dotting Captured Images with Adobe Photoshop Script* Standard Operating Procedure 12: *Conducting Analysis of HD Images*

Standard Operating Procedure 13: *Coral Reef Video Transect Database User's Guide*

Standard Operating Procedure 14: *Downloading Disease Photos and Uploading into Disease Species List Database*

Standard Operating Procedure 15: *Entering Disease Data, Coral Species List, Colony Counts, Diadema, and Rugosity*

Standard Operating Procedure 16: *Capture Images for Relocation of Transect Using Adobe Premiere CS3*

Standard Operating Procedure 17: *Rapid Habitat Assessment Database Data Entry and Verification*

Standard Operating Procedure 18: *Merging Coral database*

Standard Operating Procedure 19: *Merging ThumbsPlus Disease_Species_List database*

Standard Operating Procedure 20: *QA/QC Procedures*

Standard Operating Procedure 21: *Data Summaries, Analysis, and Reporting*

Standard Operating Procedure 22: *Archive of files*

Standard Operating Procedure 23: *Revising the Protocol*

Executive Summary

Coral reefs are among the most biologically rich and productive ecosystems on earth. This protocol guides the monitoring within the parks that comprise the National Park Service, South Florida/Caribbean Network (SFCN). The benthic marine communities of the SFCN are part of a complex and diverse ecological system that includes algae, corals, and other marine invertebrates. Reef-building corals are the primary architectural organisms and are sensitive to environmental degradation; therefore, they are good indicators of overall health for a park's reef ecosystem. Coral reefs face a wide and intensifying list of stressors, including disease, bleaching, sedimentation, overfishing, coastal development, eutrophication, storms, marine debris and global climate change. Coral reefs are often proposed as indicator systems for global climate change. For these reasons, coral reef ecosystems were ranked as the number one vital sign for SFCN implementation.

The coral reef monitoring protocol guides the monitoring of this globally imperiled system within five parks of the network: Biscayne National Park (BISC), Dry Tortugas National Park (DRTO), Virgin Islands National Park (VIIS), Buck Island Reef National Monument (BUIS) and Salt River Bay National Historical Park and Ecological Preserve (SARI). As funding becomes available, monitoring will expand to a sixth network park, Virgin Islands Coral Reef National Monument (VICR). Coral reef communities within the network represent some of the best Caribbean and Western Atlantic coral reefs within the National Park Service (NPS). The enabling legislation and/or presidential proclamations for VIIS, BUIS and DRTO specifically mention coral reefs within these park units as significant environmental communities. These reefs support incredible diversity, including corals, hundreds of fish species, conchs, lobsters, and endangered sea turtles. Reefs also play a vital role for humans by supporting fisheries, fish nursery areas, tourism, pharmaceutical bio-prospecting and shoreline protection, to name a few. Monitoring coral reefs was identified as a national priority in 1989 through President Clinton's Executive Order 13089 for Coral Reef Protection.

The objectives for this protocol include to:

- Determine whether percent cover of stony coral as well as other major taxonomic groups (e.g., algae [turf, calcareous, macroalgae], gorgonians, sponge, and substrate), coral species diversity, coral community structure, and rugosity are changing through time within selected coral reef sites.
- Determine how the above mentioned response variables vary in space within park reefs and how these variables, which describe coral reef health and composition, are changing through time in parks with different management zones (e.g., DRTO).
- Track trends in occurrence and severity in reef condition-associated variables such as coral bleaching and coral disease.
- Track trends in abundance of the regionally important herbivorous sea urchin, *Diadema antillarum*, within selected coral reef sites.

- Evaluate effects of unusual events on stony coral cover such as coral bleaching or hurricanes through episodic monitoring, within constraints of program resources.
- Provide a visual comparison of change through time and allow future analyses of benthic components not identified in this protocol by archiving and maintaining the video and photographic record of transects.

To achieve these objectives, the coral reef monitoring described in this protocol involves the following components: (1) selection of the reef study site, or identification and mapping of the habitat zones of interest, (2) selection of the arrangement and location of approximately twenty ten-meter transects within the study site, (3) filming the benthic community with a digital video camera in an underwater housing, and, in the office (4) quantification of benthic organisms and components found under random "dots" applied to the captured still images created from the video. This reef monitoring is supplemented by the simultaneous collection of data on presence and size of disease lesions, disease prevalence, presence and severity of coral bleaching, presence of *Diadema antillarum*, listing of scleractinian species, and rugosity along the transects. Additionally, water temperature data at reef-depth is collected at these sites. Monitoring is conducted annually and episodically, as necessary. The network analyzes and archives all data and videotapes, and prepares an annual report detailing the status and trends of the coral cover and selected variables at the sampled sites.

The developmental work for this protocol was conducted by the U.S. Geological Survey under the NPS Inventory & Monitoring prototype program and the core methods have been in use throughout the South Florida/Caribbean Network for over 15 years. The complete Coral Reef Monitoring Protocol consists of this narrative with appendices, and Standard Operating Procedures (SOPs; published separately). The other SOPs in this protocol were developed by the network and have been used within SFCN parks for nearly a decade. An overview of all SOPs is found beginning on page xxiii. Any changes in this narrative will be entered in the Change History Log found on page iii, and follow SOP 23: *Revising the Protocol*.

Standard operating procedures are published separately in *Coral Reef Monitoring: Standard Operating Procedures* (South Florida / Caribbean Network 2017) and are available at https://irma.nps.gov/DataStore/Reference/Profile/2240897

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This monitoring protocol and associated SOPs were developed from and expanded upon the Inventory &Monitoring (I&M) prototype protocols produced by the US Geological Survey (USGS). The authors acknowledge the significant contributions to this protocol from Andy Estep, Christy McManus, Jim Petterson, Alexandra Wright, Lee Richter, Julia Dileo, Meagan Murdock, and Kelley Peebles.

Selected Acronyms

AM	Amanda's Reef monitoring site in BISC
BB	Ball Buoy Reef monitoring site in BISC
BISC	Biscayne National Park
BK	Bird Key Reef monitoring site in DRTO
BKN	Bird Key North monitoring site in DRTO
BUIS	Buck Island Reef National Monument
CV	Coefficient of Variation
DOI	U.S. Department of Interior
DRTO	Dry Tortugas National Park
DV	Digital Video
ESA	Endangered Species Act
FMRI	Florida Marine Research Institute
GPS	Global Positioning System
GRTS	Generalized Random Tessellation Stratified
HA	Haulover Reef monitoring site in VIIS
HD or HDV	High Definition, or High Definition Video
I&M	NPS Inventory and Monitoring Program
IEEE	Institute of Electrical or Electronics Engineers
LH	Loggerhead Forest Reef monitoring site in DRTO
LTEM	Long-term ecological monitoring
MB	Mennebeck Reef monitoring site in VIIS
MOCC	Motor Boat Operation Certification
NCRMP	National Coral Reef Monitoring Program
NF	Newfound Reef monitoring site in St. John outside VIIS
NOAA	U. S. National Oceanic and Atmospheric Administration

NPS	U. S. National Park Service
NRDS	Natural Resource Data Series
QA/QC	Quality Assurance/Quality Control
REC/STBY	Record/Standby
RHA	Rapid Habitat Assessment
RNA	Dry Tortugas National Park Research Natural Area
SARI	Salt River Bay National Historical Park and Ecological Preserve
SE	Standard error
SFCN	NPS South Florida / Caribbean Network
SFL	South Florida
SFR	South Fore Reef monitoring site in BUIS
SONAR	Sound Navigation and Ranging
SOP	Standard Operating Procedure
SR	Salt River monitoring site in SARI
SV	Santa's Village monitoring site in DRTO
TK	Tektite Reef monitoring site in VIIS
TRACTS	Tortugas Reef Atoll Continuing Transect Studies
USGS	U. S. Geological Survey
USVI	U. S. Virgin Islands
UTM	Universal Transverse Mercator
VICR	Virgin Islands Coral Reef National Monument
VIIS	Virgin Islands National Park
WSG	Western Spur & Groove monitoring site in BUIS
YZ	Yawzi Reef monitoring site in VIIS

Background and Objectives

Background and History—from Prototype to Operational Program

Knowing the condition of natural resources in national parks is fundamental to the National Park Service's (NPS) ability to protect and manage parks. National park managers across the country are confronted with increasingly complex and challenging issues, and they are increasingly being asked to provide scientifically credible data to defend management actions. In the early 1990s, the National Park Service provided funding and technical assistance to parks with significant natural resources. The short-term goal was to acquire twelve natural resource inventory datasets for each park needed by park managers to deal effectively with park planning, management, and protection. The long-term goal is to implement monitoring of critical natural resource indicators, termed “vital signs,” in more than 270 parks with significant natural resources.

Beginning in 1992, the National Park Service established a network of experimental or “prototype” long-term ecological monitoring (LTEM) programs in an attempt to learn how to design scientifically credible and cost-effective monitoring programs in ecological settings of major importance to a number of NPS units. Long-term monitoring is a repeated information-gathering effort to better understand how to track changes in ecosystems (Likens 1988; Magnuson 1990; Rogers et al. 1994). Parks vary greatly in ecological conditions, sizes and management capabilities, and any attempt to institutionalize ecological monitoring within the National Park System poses substantial challenges. To develop monitoring expertise throughout this range of ecological diversity and types of parks, natural resource park units were grouped into 10 major biogeographic areas, or biomes, and one park from each major biome was selected to serve as a prototype LTEM program for that biome.

The first four prototype monitoring programs (Channel Islands National Park, Denali National Park, Great Smoky Mountains National Park and Shenandoah National Park) were funded in 1992 and were chosen because considerable monitoring design work had already been accomplished. In 1993, the National Park Service issued a call for proposals to competitively select seven additional prototype monitoring programs. To address the needs of smaller parks, three of these prototype programs were designed as "cluster" programs, i.e., a grouping of three to six parks, each of which lacked the full range of staff and resident expertise needed to conduct a long-range monitoring program on its own. In the same year, the three-park cluster consisting of Virgin Islands National Park (VIIS), Buck Island Reef National Monument (BUIS), and Dry Tortugas National Park (DRTO) was selected as the prototype for the tropical/subtropical biome. Initial funding for this Virgin Islands/South Florida (USVI/SFL) prototype program was provided in fiscal year (FY) 1996. After submittal of the proposal, NPS scientists based in VIIS were transferred first to the National Biological Survey, and then to the Biological Resources Division of the U.S. Geological Survey (USGS). The prototype program was a collaborative effort between the National Park Service and the U.S Geological Survey, with USGS scientists responsible for the design of long-term monitoring programs and development of sampling protocols (see Miller and Rogers 2002; and Miller 2002). Once protocols were developed, the operational monitoring tasks (including data analysis and reporting) were assumed by NPS staff.

In FY 2000, as part of the Natural Resource Challenge, the park service implemented an expanded strategy for natural resource monitoring in parks with significant natural resources, whereby parks were organized into 32 networks linked by geography and shared natural resource characteristics (Fancy et al. 2009). The network approach was intended to facilitate collaboration, information sharing, and economies of scale in natural resource monitoring, and to provide parks with a minimum infrastructure for initiating natural resource monitoring that could be built upon in the future. In October 2003, the prototype I&M program based in Virgin Islands National Park (VIIS) was transferred to the South Florida/Caribbean Network (SFCN). Two positions, fisheries biologist and biologist technician, remain located in VIIS, however programmatic and financial obligations for those positions and additional SFCN staff are in Palmetto Bay, Florida.

The NPS I&M program monitoring goals (Fancy et al. 2009) include:

- Determine the status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources.
- Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management.
- Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments.
- Provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment.
- Provide a means of measuring progress towards performance goals.

This protocol primarily focuses on the first three goals, and specifically on detection of trends in tropical marine ecosystems.

Ecological Context of USVI and Florida Parks

It is important to consider the SFCN parks with significant coral reef resources (VIIS, VICR, BUIS, SARI, BISC, and DRTO) within the biogeographical and ecological context of the wider Caribbean. The Caribbean Sea is relatively small, only 1200 nautical miles (nm) by 500 nm. Marine systems can be adversely and beneficially affected by upstream events and conditions. For example, areas within the wider Caribbean are “connected” via transport of fish and coral larvae in currents that generally move from east to west. Roberts (1997) examined the connectivity of Caribbean coral reefs by assuming passive dispersal of larvae and mapping what he called “transport envelopes” showing potential arrival of larvae from upstream sources and export of locally produced larvae downstream over one and two month time frames. While he acknowledges that larvae of many species exhibit some mobility resulting in greater local retention, his analysis highlights the potential linkages within the Caribbean and serve as a reminder that coral reefs far from each other are not isolated (Rogers et al. 2007). For example, USVI reefs can receive larvae from several upstream sources, including the British Virgin Islands, St. Martin, Anguilla and Saba (Baums et al. 2005).

Currents can transport harmful pollutants as well as larvae of fishes and other reef organisms. A dramatic example occurred in 1991 when oil began showing up on British and US Virgin Island beaches two weeks after a barge sank off Eustatia Island, a location 25 miles (mi; 40 kilometers [km] away from VIIS. Under certain wind and current conditions, the Orinoco River plume extends from the coast of Venezuela to the USVI, producing visible phytoplankton blooms (Muller-Karger et al. 1989) and bringing seeds and perhaps pollutants from South America. In another example, ash from the eruption of the volcano on Montserrat Island (200 miles [322 km] south of the USVI) fell on the islands the next day.

Kourafalou et al. (2009) and Roberts (1997, and references within) describe surface current patterns within the Caribbean through the Gulf of Mexico. South Florida reefs are downstream from larvae source areas in Central America and the Gulf of Mexico. The Caribbean current sweeps northward along the western edge of the Caribbean Sea, moving both water and larvae towards south Florida. The Caribbean current diverges as it passes the Yucatan peninsula, where it becomes the Yucatan Current feeding into both the Florida Current and the Loop Current of the Gulf of Mexico. The islands of the Bahamas, Cuba, Hispaniola, and Puerto Rico provide a southern and eastern boundary creating a narrow fast moving trough of water through the Straits of Florida that eventually feeds the Gulf Stream. Water typically moves from west to east and then north as it follows the Florida reef tract. There is also an inshore countercurrent associated with the Florida Current frontal features that moves from the north to the southwest close to shore along the reef platform (Lee and Williams 1999; e.g., Hawk Channel Current). The Gulf of Mexico Loop Current flows north first running along the Mexico and Texas coast before shifting to the East along the northern Gulf of Mexico. At this point, it receives outflows off the Mississippi River and continues east across the west Florida shelf. The Loop Current continues southward along the west coast of Florida and joins the Florida Current in the Straits of Florida (Ocean surface current data are available on-line at Ocean Surface Current Analysis Real-time: http://www.esr.org/oscar_index.html).

Rationale for Monitoring Coral Reefs

The National Park Service has clear responsibilities for monitoring and management of natural resources as stated in the founding legislation (National Park Service Organic Act of 1916). Coral reefs under U.S. jurisdiction were specifically targeted on 11 July 1998 when President Clinton signed Executive Order (EO) 13089—Coral Reef Protection (Clinton 1998). This executive order mandated all federal agencies to provide for implementation of measures needed to research, monitor, manage, and restore affected coral reef ecosystems, including, but not limited to, measures reducing impacts from pollution, sedimentation, and fishing. The U.S. Coral Reef Task Force, co-chaired by the Secretary of Interior and the Secretary of Commerce, was created, and they wrote a Coral Reef Action Plan (CRTF 2000) to address the federal agencies' responses to EO 13089. The SFCN coral reef monitoring protocol is one of the ways that National Park Service is responding to this executive order.

The importance of coral reefs in SFCN parks makes these ecosystems the primary focus of monitoring efforts. Coral reef ecosystems were ranked as the most important vital sign for the SFCN (Patterson et al. 2008). "Vital signs" as defined by the NPS, are a subset of physical, chemical, and

biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources or elements that have important human values (Fancy et al. 2009). The importance of coral reefs was well conveyed by Dr. John Ogden (then Director of the Florida Institute of Oceanography) in a presentation at Capitol Hill Oceans Week, in June 2002 (Ogden 2002): "Coral reefs are not remote, exotic systems, but rather a significant percentage of our national ocean patrimony." He noted approximately 40% of the 200 nautical mile Exclusive Economic Zone of the US encompasses areas where coral reefs are the dominant ecosystem. He drew attention to the precarious condition of coral reefs today, stating that "There is no reef, indeed no coastal ecosystem, that hasn't already been extensively changed and damaged by the activities of human beings…" with the disturbances categorized as: (1) careless land-use practices, (2) fishing, and (3) alterations of global climate.

The declines in coral reefs over the last 20-30 years are attributable to many factors including coral bleaching (e.g., Brown 1990), coral diseases (e.g., Weil 2002), tropical storms & hurricanes (e.g., Rogers et al. 1982), overfishing (e.g., Jackson et al. 2001), sedimentation (e.g., Rogers 1990) and nutrification (e.g., Szmant 1997), and climate change (Hoegh-Guldberg 1999), which are described in more detail below. Coral reefs within national parks have been strongly affected by these stresses. The severity and rapid degradation being experienced by coral reefs today makes the need for monitoring more critical.

Stressors to Coral Reefs

Coral Bleaching

Severe coral bleaching has been reported on reefs in the South Florida/Coastal Network in 1987, 1997-99, 2005-06, 2010, 2013 and 2014. These bleaching episodes are due primarily to elevated water temperatures, with their severity being linked to the level and duration of warming. In 2005, record warm water temperatures in the US Virgin Islands caused more than90% of coral cover to bleach at SFCN sites (Miller et al. 2006b). This event marked the first observation of bleaching of *Acropora palmata* (elkhorn coral) in the territory.

During the 1998–1999 event in the Florida Keys, the combination of a hurricane and bleaching caused extensive mortality (Banks et al. 2005) whereas in the Virgin Islands mortality due to bleaching was more limited (Nemeth and Sladek-Nowlis 2001; Nemeth et al. 2003). Coral bleaching also occurred in the USVI in 2010, but was less severe than 2005–2006, due to the influence of Hurricane Earl; the storm passed 40 miles (64.4 km) north of the Virgin Islands in August 2010 lowering water temperatures, thereby reducing thermal stress to the corals. In late summer 2014, extreme and prolonged thermal stress produced severe bleaching throughout the Florida Keys, including the reefs of BISC and DRTO.

Bleaching in conjunction with coral disease has proven to be a deadly combination. Bleaching was followed by a massive disease outbreak in the Virgin Island in 2005–2006. Bleaching-induced coral mortality was observed, primarily on *Agariciids*; however, the disease outbreak that followed bleaching caused extreme mortality for many coral species (see coral diseases below).

Coral Diseases

The variety and extent of coral diseases have increased dramatically in the past three decades, and are now a problem world-wide. As one of the most destructive stresses within SFCN parks, coral diseases are of great concern to park managers. The links between human activities and coral diseases are not well-understood although Patterson et al. (2002) claimed that bacteria in human feces caused "white pox" disease in the Florida Keys. Very few coral diseases have confirmed causative agents. (For this protocol, we have limited our discussion of coral diseases below to those that do not affect *Acropora* spp., as this protocol does not address *Acropora* monitoring.)

Beginning in 1997, coral diseases began to increase in severity and incidence in Florida and the Caribbean (Weil 2002). A survey of 30 sites from Key Biscayne to Dry Tortugas conducted in August 2000 recorded diseases throughout the Florida Keys reef tract (Santavy et al. 2005) with nearly 30% of corals surveyed at two Bird Key Reef (DRTO) sites showing signs of the coral disease "white plague." Most regional disease surveys conducted in the Florida Keys take place annually, in either spring or summer. A connection between disease prevalence and temperature is suggested but may be a factor of monitoring schedule and frequency.

Tektite Reef, a high coral cover reef within VIIS off the south shore of St. John, was selected for a pilot coral disease monitoring project in 1997 after exhibiting very conspicuous white plague. Miller et al. (2003) conducted disease surveys nearly every month between December 1997 and May 2001, and reported coral disease was present during every sampling, and the area killed by disease was not correlated to temperature for temperatures below levels that caused coral bleaching.

Episodic monitoring (increased frequency after an event) conducted at five SFCN monitoring sites in the Virgin Islands throughout and following the coral bleaching event in 2005 recorded catastrophic outbreaks of coral disease (Miller et al. 2006b). The monitoring showed that while record-breaking seawater temperatures caused the bleaching, it was coral disease that led to the mortality of over 60% of the live coral cover (Miller et al. 2009).

Tropical Storms and Hurricanes

Storms are a part of natural weather patterns in SFCN parks and can be a major force in shaping reef communities through direct processes such as physical impact to reefs, wave action, scouring by sand; and indirect processes such as increased terrestrial runoff, sedimentation, and pollution. Monitoring of reefs has provided quantitative data on the effects of these storms. Hurricanes Hugo (1989) and Marilyn (1995) have had the most devastating effects on USVI reefs. In 2004, four major hurricanes impacted the Florida coastline. Five storms in 2005 impacted DRTO reefs, and two affected BISC that same year. However, it was the lack of storms in 2005 in the USVI that contributed to the substantial increase in water temperatures that led to the bleaching and disease outbreak (Manzello et al. 2007). While these weather systems are obviously beyond the control of resource managers, the significant effects they have had on NPS resources cannot be ignored. The challenge is to address stresses caused by humans and human activities within the context of such natural stresses.

Overfishing and Destructive Fishing Methods

Coral reefs provide the ecological foundation for the south Florida tourism-based economy and fisheries that combined generate an estimated 71,000 jobs and $6 billion of economic activity in 2001 (Johns et al. 2001). Rogers and Beets (2001) state intensive fishing may be the single most damaging stress of all to USVI coral reefs. The intensity of fishing pressure and the process of grazing of macroalgae on coral reefs may be strongly linked. Removal of parrotfishes (grazers) may reduce grazing rates on macroalgae, which compete for available substrate with corals, and highlights the potential impact of fishing on the resilience of coral reefs (Mumby et al. 2006).

Sedimentation, Nutrification, and Run-off

Excessive sedimentation is a cause of reef decline worldwide. Sediments smother marine organisms and reduce the light available for photosynthesis by corals and reef algae (Rogers 1979; Rogers 1990). In the Virgin Islands, because of the islands' steep terrain, shallow soil and accelerating rate of development, sedimentation has been of great concern (Ramos-Scharrion et al. 2005). Sedimentation is not as major a factor at DRTO and BUIS, because there are no streams on these islands and no development. However, coastal development and runoff are of concern at BISC. Sediment and other pollutants can be carried large distances by oceanic currents on large regional scales with harmful results (Muller-Karger et al. 1989).

Nonpoint sources of pollution, in the form of storm water runoff, ground water seeps and surface water runoff can negatively affect reefs. Navigational inlets and passages can be direct conduits to reefs, and the porous limestone substrate underlying Florida can allow seepage of pollutants to reefs and coastal waters (BISC).

Nutrient loading from numerous land-based (e.g., failed septic systems [VIIS, SARI], agriculture [BISC] and boat-based sources [e.g., vessel waste in all SFCN parks]) can cause increases in macroalgal blooms. Nitrogen from land-based sewage has been linked to macroalgal blooms in southeast Florida (Lapointe 1997; Lapointe and Barile 2001). An increase in nutrients can lead to a degradation of the water quality necessary for coral reef survival and growth and may result in physiological stress to corals and deterioration of coral reef systems.

The effects of sediments can be more difficult to disentangle from the effects of other more obvious stresses such as coral diseases. Chronic input of terrigenous (land-derived) sediments and other pollutants is presumably having an adverse effect on reefs. Carbonate, reef-derived sediments can also abrade or bury reef organisms during storms. The effects of these impacts may be masked by more conspicuous stresses such as coral diseases.

In the 1980s, when VIIS began its coral reef monitoring, reefs protected within the parks were thought to serve as useful benchmarks for comparison with unprotected reefs. Now, after observing the combined effects of hurricanes, bleaching and coral diseases, it is apparent that stresses affecting reefs are more complex than originally thought and less tractable to management. At international meetings in 1993 (Ginsburg 1993) and 1996 (Lessios and Macintyre 1997), stressors such as sedimentation and nutrification were identified as the most critical problems affecting reefs. However, scientist couldn't predict the worldwide bleaching episode in 1998, the catastrophic losses

from disease following the bleaching event in the northwest Caribbean, the increase in incidence and severity of coral diseases since 1997, and the increase in the frequency of hurricanes, all of which caused a different perspective for reef scientists and managers. Clearly some of these stresses cannot be controlled by resource managers. However, park managers have the opportunity to minimize threats to already degraded reefs maximize the chances for recovery.

Climate Change

Human activities such as burning fossil fuels, deforestation and changing land use practices have increased atmospheric concentrations of carbon dioxide and methane (termed greenhouse gasses). The warming climate poses threats to coral reefs through increased thermal stress and ocean acidity producing increased frequency and severity of mass bleaching events, and declining calcification rates (Hoegh-Guldberg; 2011). There is little evidence that reef-building corals will adapt to these changes leading to the conclusion that reef ecosystems are under significant stress from a changing climate. Burke (2011) states:

> *The combined impacts of ocean warming and acidification will increase the threat levels on more than half of all reefs by 2030, pushing the percentage of threatened reefs to more than 90 percent by 2030. By 2050, nearly all reefs will be affected by warming and acidification and almost all reefs will be classified as threatened, assuming there is no change in local pressure on reefs.*

While sea-level rise, another factor of climate change, does not necessarily pose a problem for coral reefs *if coral growth remains vigorous*, increased water temperatures and ocean acidity are likely to reduce coral growth rate, thereby reducing the coral's ability to keep up with rising sea level. Other factors such as changing weather patterns (e.g., drought and storm activity) are likely to interact with coral reefs through mechanisms described in sections above.

History of Monitoring Coral Cover within SFCN Parks

The current I&M work in SFCN parks was built upon previous NPS programs and partnerships. For example, the National Park Service provided funding to support the NPS Coral Reef Assessment Program for a five-year period beginning in 1988. The overall goal was to establish effective long-term research and monitoring sites at the four NPS units (existing at that time) with coral reef ecosystems: BISC, BUIS, DRTO, and VIIS. Seven cooperating institutions participated in this program including the University of Georgia, Florida Department of Natural Resources, and the Southeast Fisheries Center (NOAA). Below are brief summaries of research and monitoring highlights describing the evolution of monitoring at each of the SFCN parks.

Biscayne National Park (BISC)

Federal agencies, universities, non-governmental organizations, and students have all contributed to the knowledge and research on coral reefs which has occurred throughout the Florida Keys. Early descriptions of the reefs can be found in 1852 (see Jaap 1984). However, within BISC, there are few monitoring projects lasting longer than three years. Jaap (1980) monitored eight patch reef sites in Biscayne National Park from 1977–1980. Porter and Meyer (1992, 1995) monitored two sites within the park from 1989–1994, one at Ball Buoy reef and the other at Triumph reef, using photostations

and chain transects. Dupont et al. 2008 cited significant declines in BISC coral cover in a retrospective analysis of studies conducted from 1977 to 2000 including Miller et al. 2000 and Moulding and Patterson 2002.

Ongoing coral monitoring activities (other than those conducted by the network) include the annual coral bleaching and disease monitoring by The Nature Conservancy (Study #: BISC-00024) and post-vessel grounding coral reef restoration monitoring by BISC staff since 2006. A distribution map of *Acropora cervicornis* (staghorn coral) and *A. palmata* (elkhorn coral) was completed in 2004 in preparation for *Acropora* spp. monitoring program development (Dickman 2004), and monitoring was initiated in 2010 by the Florida Fish and Wildlife Conservation Commission (Study #: BISC-10019).

Dry Tortugas National Park (DRTO)

Research and expeditions into the Dry Tortugas occurred in 1850 and 1851 by Louis and Alexander Agassiz. In 1881, Agassiz made one of the first attempts to quantify the marine biotopes in Dry Tortugas (Agassiz 1883). Nearly a century later, Gary Davis (NPS) conducted a mapping survey within DRTO, and published the comparison of his map with Agassiz's 1881 map (Davis 1982). In 1975–1976, the Tortugas Reef Atoll Continuing Transect Studies (TRACTS) research program was implemented. This project coordinated numerous federal, state, and private agencies and university scientists, and published findings on geology, fish assemblages and mapping (see Jaap et al. 1989). TRACTS established monitoring transects from the fore reef shelf edge to the back reef on Bird Key Reef. Monitoring increased in 1989 when NPS contracted Florida Marine Research Institute (FMRI) which installed five 2.5 square meter (m^2; 10.8 square feet [ft^2]) quadrats at Bird Key Reef for monitoring species composition and percent cover. Monitoring expanded again at this site in 1999 when FMRI installed four groups of three parallel transects (each about 22 mi [35.4 m] long) at Bird Key Reef and White Shoals Reef (see Ruzicka et al. 2010). These sites are monitored annually using digital video or still images and point count similar to Miller and Rogers (2002) and SOP 1 of this protocol (SFCN 2017). Other monitoring conducted at DRTO including investigating coral disease outbreaks (Brandt et al. 2012 and a collaborative multiagency disease outbreak cruise [Study #: DRTO-00007]), Florida FWC mapping and monitoring endangered corals (Study #: DRTO-00087) and USGS monitoring coral calcification rates (Study #: DRTO-00071). An annotated bibliography of scientific studies conducted in DRTO, including those monitoring activities listed above can be found in Schmidt and Pikula (1997).

Salt River Bay National Historical Park and Ecological Reserve (SARI)

This park unit was created in 1992 and is co-managed by NPS and the Government of the Virgin Islands. Between 1978 and 1989, two submerged manned undersea habitats were placed at the apex of Salt River Canyon, in the middle of what is now SARI. Numerous marine studies were conducted in Salt River Canyon prior to it being established as a park. For example, Boulon (1978) conducted benthic surveys along transects on the walls of Salt River Canyon during a saturation mission staged from the Hydrolab habitat. Saturation missions from the Aquarius Habitat evaluated coral recruitment (Rogers et al. 1984) and changes in the canyon's benthic community after the passing of Hurricane Hugo (Coulston et al. 1990).

Virgin Islands National Park (VIIS)

Monitoring in the USVI parks began in the 1970s and 1980s and provides some of the Caribbean's longest coral data sets. In a 1997 review of quantitative studies of trends in coral abundance, Dr. Joseph Connell was able to find only 23 studies of four or more years in duration, and data were available for only three locations from the Eastern Caribbean: the US Virgin Islands (including data from VIIS and BUIS), the Netherlands Antilles, and Barbados (Connell 1997). Most of these studies were conducted on a very small spatial scale.

In St. John, long-term transects were established at Yawzi Reef in Great Lameshur Bay in 1989 (Rogers 1991; Rogers 1997) and on Newfound Reef (offshore Newfound Bay) in 1990. Chain transects have been used at both sites (described in Rogers et al. 1994). The chain transect method is used by the Caribbean Coastal Marine Productivity Program (CARICOMP), a regional Caribbean monitoring program, and in many other locations throughout the Caribbean.

Additionally, from 1969–1970, Tektite Reef, on the south side of St. John was the location of the submerged laboratory/habitat programs, Tektite I and Tektite II. Several marine science research projects were conducted at this site (Collette 1972), and included the adoption into the Tektite Aquanaut program of the then NPS scientist, Gary Davis. The area (Lameshur Bay) of this site is also the location of the Virgin Islands Environmental Research Station (VIERS) which is a facility of the University of the Virgin Islands and is operated by Clean Islands International. This station supports a large number of undergraduate, graduate, post-doc, and local school groups. For example, Dr. Pete Edmunds (California State University, Northridge) has been conducting research and monitoring on Tektite and in Lameshur Bay for nearly 20 years (Edmunds 2002).

Development of the USGS/NPS legacy protocol "Using Videography to Monitor Coral Reefs" (Miller and Rogers 2002) began in 1997 with the initiation of the prototype program and was based in VIIS (Rogers 1993, 1997). Initially the linear chain transect method was used. After the development of the videography SOP, both techniques were used concurrently on the same transects at Yawzi and Newfound Reefs from 1998-2002. Results of this pilot study revealed remarkable similarity in coral cover, but some differences in cover by macroalgae (Rogers and Miller 2001). Although the transect placement (haphazard) limited the area of inference for the results of this study, these monitoring projects provide useful data over a long time period and were instrumental in providing a basis for the creation of VICR. The chain transect data from Yawzi Reef have been highlighted in the 1998 and 2002 DOI brochures on "Protecting the Nation's Coral Reefs" (see also Rogers and Miller 2006).

Additionally, a new approach to sampling was developed. On the advice of a USGS statistician (C. Rogers, pers. comm.), it was decided to invest a considerable amount of time to ensure that transects selected for video monitoring were truly independent of each other, rather than "haphazardly" chosen as is the case in most other reef monitoring projects (see Lewis 2004). This change resulted in the development, testing, and refinement of the legacy SOP "Using the AquaMap™ System at a Study Site" (Miller 2002).

Virgin Islands Coral Reef National Monument (VICR)

Established by Executive Order of President Clinton on January 17, 2001, this monument was created under the Antiquities Act of 1906. Very little was known of the benthic composition prior to becoming a managed unit of NPS. Since establishment, efforts to characterize the area have focused on the two major features of the monument: the Mid-Shelf Ridge (MSR) and Hurricane Hole. The MSR is a relatively deep (17–35 meters [55.7–114.8 ft]) coral reef ecosystem with relatively high coral cover and topographic complexity. NPS and NOAA collaborations [Monaco et al. (2007), Menza et al. (2007), and Boulon et al. (2008)] describe benthic composition along the MSR. Hurricane Hole consists of four connected bays with mangrove-fringed shorelines. This unique area, where scleractinian corals are found in high abundance and diversity growing on, and within the mangrove prop roots (Rogers and Herlan 2012) may provide corals a refuge from climate change (Yates et al. 2014).

Buck Island Reef National Monument (BUIS)

At Buck Island Reef NM, Dr. John Bythell, University of Newcastle upon Tyne, set up a coral colony monitoring program in 1988 which tracked approximately 480 colonies of three species for weekly and monthly monitoring (see Bythell et al. 1993). This project continued with annual monitoring and was the driver for the development of a USGS/NPS protocol on coral colony monitoring (Rogers and Catanzaro 2002, Phillips 2002). BUIS also conducted chain transect monitoring on four reef sites (unpublished data). These sites were monitored through 2005 with video method monitoring (described in SOP 1— "Using Videography to Monitor Coral Reef") added in 2000.

Measurable Objectives

The objectives for this protocol include:

- Determine whether percent cover of stony coral as well as other major taxonomic groups [e.g., algae (turf, calcareous, macroalgae), gorgonians, sponge, and substrate], coral species diversity, coral community structure, and rugosity are changing through time within selected coral reef sites.
- Determine how the above mentioned response variables vary in space within park reefs and how these variables, which describe coral reef health and composition, are changing through time in parks with different management zones (e.g., DRTO).
- Track trends in occurrence and severity in reef condition-associated covariates such as coral bleaching and coral disease.
- Track trends in abundance of the regionally important herbivorous sea urchin, *Diadema antillarum*, within selected coral reef sites.
- Evaluate effects of unusual events on stony coral cover such as coral bleaching or hurricanes through episodic monitoring, within constraints of program resources.
- Provide a visual comparison of change through time and allow for future analyses of benthic components not identified in this protocol by archiving and maintaining the video and photographic record of transects.

Sampling Design

Overview

This monitoring protocol and sampling design is adapted from the original protocol developed as part of the I&M prototype program which has been in use by SFCN parks since 1999 (Miller 2002; Miller and Rogers 2002). The protocol uses permanent 10-meter (32.8 ft) transects which are filmed underwater by a diver with a digital camera. In the lab, the videos are broken into sequential still image "frames" and 10 dots (per image) are randomly placed upon each image and identified to major category [coral (by species), algae (macroalgae, turf, or crustose coralline), gorgonians (sea fans, etc.), sponges, and substrate]. Other in situ collected field data have been gradually added to the protocol including coral disease type, number of lesions, area of disease mortality, and prevalence; coral species presence; coral bleaching; site rugosity; and *Diadema antillarum* (long spined sea urchin) density. Water temperature is collected at reef depth every two hours with data loggers (described separately in Davis et al. 2013) and began under a previous coral chain transect monitoring protocol at Yawzi and Newfound reefs in VIIS (Rogers et al. 2004). The Standard Operating Procedures (SOPs) referenced below are found in *Coral Reef Monitoring: Standard Operating Procedures* (South Florida/Caribbean Network 2017)."

Sample Design Decision Tree

The sampling design varies depending on the type of resource to be monitored, the size of the resource area to be monitored, the question to be answered, the level of knowledge about the resource, and spatial stratification.

The first decision is the type of resource to be monitored, i.e.,

- A selected reef ("Index Site" in this protocol)—these are typically a single reef or reef area with high coral cover, complexity and diversity, and often encompass high-relief, rugose habitat (reef terrace, patch reef or linear reef).
- A management zone—this study area is typically large well developed reef(s) with management rather than ecological boundaries.

The second decision involves the size of the resource and whether to use

- One-stage sampling ("Intensive sampling design" in this protocol)—this design is used with small study areas and involves 20 randomly selected permanent transects. The size of these areas has been less than five hectares (50,000 m^2; 12.4 acres [ac]) in SFCN parks to date.

- Two-stage sampling ("Extensive sampling design" in this protocol)—If the study area is too large (10's to 100's of hectares) for 1-stage sampling to be logistically cost effective, a two-stage sampling design is recommended. In this design two to four transects are clustered into sub-sites (referred to as "extensive" sub-sites). Within these sub-sites, transects are laid out in a systematic design. The sub-sites are randomly selected across the resource. To date SFCN has used extensive sub-sites consisting of four transects.

The third decision involves the level of knowledge about the resource:

- Boundaries of the well-defined complex reefs are easily identifiable—If the boundaries of the desired study area are readily identifiable, i.e. a good map exists or can be created during the preliminary investigation from field work and/or mapping from imagery, the habitat within those boundaries is all considered part of the sampling frame. A randomly selected transect is only excluded if it falls on more than 50% sand or for some reason is unfeasible to sample [e.g., too deep (> 33meters [108 ft]), excessive current, too steep a wall (~70°)]. Randomly selected extensive sub-sites are only excluded for the same criteria.
- Boundaries of the well-defined complex reef(s) are difficult to identify (only possible in a two-stage sampling scenario)—If the locations and ecological boundaries of focal reefs in the study are only partially known, e.g., maps exist that show hard-bottom areas but not necessarily high live coral cover reefs, the area is too large to completely map via field investigations, and discriminating imagery is not available, then a field investigation step using a Rapid Habitat Assessment (RHA) procedure (SOP 8) is added to first determine whether a potential sub-site location randomly chosen within possible habitat actually qualifies as part of the sample frame (e.g., high coral cover [> 5%], complexity, diversity, and high relief rugose habitat such as reef terrace, patch reef or linear reef). If the RHA reveals, for example, that a sub-site has < 5% live stony coral cover or the habitat is pavement rather than reef, the sub-site is excluded and investigation continues to the next randomly chosen sub-site. Once a sub-site is determined to be part of the desired sample frame reef habitat, then individual transects are evaluated for being greater than 50% sand or otherwise unfeasible as described above.

The fourth decision involves whether to spatially stratify the sampling domain.

- Area small and homogenous. If the area is small and fairly homogenous, e.g., no obvious reason that one section might be affected by stressors more than another or that a transect would be rejected as unfeasible in one area more than another, there is no need to stratify. Not stratifying can keep future analyses and adjustments to the design simpler.
- Large enough area that a spatial balance is desirable. If the area is large enough for a two- stage sampling design, then stratifying to force a spatial balance is recommended. The sampling frame can be broken into areas of approximately equal size and an equal number of randomly selected sub-sites placed within each (i.e., divide the sampling frame into 5 blocks of equal habitat and randomly place 1 sub-site in each block). Note: this design has the restriction that if there is a desire in the future to increase sampling, then two sub-sites must be placed in each block to maintain a balanced design; otherwise a weighted analysis must be employed. A Generalized Randomized Tessellation Stratified (GRTS) sampling design can also be employed which is an alternate way of achieving a spatial balance, provided that there are not greatly different probabilities of selection/rejection in different portions of the sampling domain (SFCN has found GRTS to be problematic if this is true).
- Different probabilities of selection and/or rejection. If there is a possibility that different areas of the sampling domain may have different selection or rejection probabilities, then stratifying can help maintain a spatial balance.

- Different levels of effort in different blocks. If there is a desire to put different levels of sampling effort into different blocks or areas and still combine the results into a single weighted answer, a stratified design is advisable coupled with dividing the habitat with a finite sampling grid to allow easy calculation of weighting factors.

Index Site Sampling Design

Index sites examine coral communities on specifically selected reefs and their sampling is designed to answer the question "What are the changes in the benthic community within a selected coral reef?" These reefs have been chosen for a variety of reasons, including high coral cover, management interest, historical work, etc. Because these sites were specifically chosen at each park, their trends and patterns apply only to those sites and are not statistically representative of other reefs in the park. In many cases, these sites have among the highest coral cover and diversity in the park, are the type generally referred to in park enabling legislation, are special enough to be named, are popular with divers and snorkelers, and/or their health and status is of high importance to management.

The selection of index sites within each park is based on several factors including: current state of knowledge of coral reefs within the park, management interest/needs, type, size, environmental context, research history, depth, location, and safety during sampling. In the legacy version of this protocol, sites were established that focused primarily on the fore reef zones because these zones are found on most reefs in SFCN parks, and they are zones of active reef-building. They usually have high substrate relief and relatively high coral cover, both of which have been correlated with higher diversity and abundance of reef fishes and other marine invertebrates. These areas are also affected by the stresses of significant concern to NPS managers.

Once an area has been identified as a study area of interest, investigations into historical monitoring and/or research conducted at the site are made. Field surveys to determine the type of reef, ecological structure, depth gradients, and extent of homogeneity were conducted. (See Current monitoring sites within SFCN parks section for details.)

Once an "index site" study area has been selected, the remainder of the sampling design decision-tree is followed.

Index Site with One-Stage Sampling (no stratification)

This approach is adapted from the original legacy protocol developed in 1999 as part of the I&M prototype program (Miller 2002; Miller and Rogers 2002) and is particularly useful if the resource to be monitored is a specific reef or feature that is easy to define and is small enough that twenty 10-meter (32.8 ft), randomly-placed, non-overlapping, permanent transects can be installed and easily navigated among using a range and bearing table. The site is typically small enough that several transects can be monitored during a single dive before returning to the surface (e.g., five), preferably with little to no movement of the boat required. The largest site monitored by SFCN in this fashion is South Fore Reef in Buck Island Reef NM with an area of 40,753 square meters (10 ac). Although developed for fore reefs, this protocol has also been successfully applied on a patch reef site in Biscayne NP.

Steps for establishing an Index Site with one-stage sampling

1) Choose site to monitor. These sites are chosen for a variety of reasons, including management interest, historical work, area of high stony coral cover (i.e., > 5% and preferably > 20%), etc.
2) Define boundary of area to be monitored in field (sampling frame) using diver towing a GPS float (see SOP 7). Boundaries of the site are typically set at the natural boundaries of the reef and/or safe dive depth limits. During this site evaluation determine the transect bearing based on depth contours and reef type. For example, transect bearings should be run to avoid dramatic changes in depth (along depth contours), or along spurs (as opposed to across spur and groove features).
3) Use GPS data and imagery to create a shapefile of the boundaries of the site (SOP 7).
4) Randomly select at least 40 points within the boundary with a requirement that they be at least 10 meters (32.8 ft) from another point to minimize the possibility of overlap (see SOP 7). Selecting twice the number of possible transects provides sufficient alternates if a transect is rejected in the field during the next step.
5) Investigate and install 20 transects. Transects are typically oriented to follow the reef contour with little change in depth along each transect, which in most cases results in parallel transects. This makes filming of transects easier and more consistent. If a randomly-selected transect is > 50% sand, overlaps another transect, is too steep to allow consistent filming, or is not feasible for safety concerns (e.g., is found to have high currents or is too deep for diver safety), then reject and proceed to next randomly chosen transect. If transects overlap, the higher numbered one is discarded and the next randomly selected transect is used (see SOP 9).
6) Install transect end points using copper clad stakes ("pins") to mark beginning and ends of transects (see SOP 9).
7) Develop range and bearing table, photos for pin relocation, and site maps (see SOP 7).

Current sites and/or reefs monitored in this method (Table 1)

BISC—Amanda's Reef (AM), Ball Buoy Reef (BB)

DRTO—Bird Key Reef (BK)

BUIS—South Fore Reef (SFR), Western Spur & Groove (WSG)

VIIS—Haulover Reef (HA), Mennebeck Reef (MB), Newfound Reef (NF), Tektite Reef (TK), Yawzi Reef (YZ)

Changes from Legacy Protocol

Most index sites using a one-stage sampling design were established with legacy version of this protocol which was developed as part of the I&M prototype program and implemented in SFCN parks beginning in 1999. The legacy version was developed as a result of numerous workshops and meetings attended by statisticians, reef ecologists, biologists and technicians during the USGS prototype protocol development. At the time, benthic maps were of poorer resolution than at present

and the decision was to focus monitoring on known reefs of high coral cover of which management was aware. The legacy version of this protocol follows approximately the same steps above but instead of using a towed GPS, an AquaMap™ System (an underwater SONAR based system that provided locations to the diver similar to a GPS system) was used to delineate the study site boundaries and then to randomly select 20 permanent 10-meter (32.8 ft) transects within the site (Miller 2002; Miller and Rogers 2002). Boundaries of the site were typically set at the natural boundaries of the reef, depth limits, and/or limits of the AquaMap™ system. This sample design for monitoring specific reefs was identified as one of only four protocols of 119 evaluated that met the requirements of random sampling and replication within habitats of a mosaic nature such as coral reefs (Lewis 2004).

In 2008–2009, filming at sites was switched from digital video (DV) to high definition video (HDV) with a one year overlap to allow a comparison of results (Appendix E). Also in 2008–2009, permanent pins were placed in the origin and terminus of all transects. The expense and difficulty of maintaining the AquaMap system, which the manufacturer had discontinued, led to the phasing out of the AquaMap SONAR system in 2010 and use of a diver towed GPS unit to delineate the survey area (SOP 7). Monitoring for long-spined sea urchins (*Diadema antillarum*) (i.e., diver count in 2 × 10 meter [6.5 × 32.8 ft]) belt transect centered on videography transect) was added in 2004 to BK and YZ and then expanded to all sites. In 2005, in response to the massive disease outbreak after the bleaching event, the National Park Service collaborated with the USGS to collect data on coral disease (type, size and number of lesions, coral species affected). Disease monitoring was implemented thereafter, first as a pilot project at Virgin Island sites, and then incorporated at all SFCN sites in 2007. As long-term monitoring of coral disease had not been previously considered or attempted, several iterations and modifications were conducted as pilot procedures prior to adaption within the network. Various methods of conducting colony counts (to calculate disease prevalence) were tested in 2008–2013 and became a standardized part of the protocol in 2014. A species list within the 10 × 2 meter (6.5 × 32.8 ft) transect was added as a pilot project in 2009 and became a standard part of the protocol in 2010. Finally, although the legacy protocol limited diver depth to 20 meters (65.6 ft), for Salt River the current protocol increased the depth to 33 meters (108.3 ft). For a more detailed timeline of the history of the protocol see Appendix C.

Table 1. SFCN monitoring sites.

Park	Site	Site Code	Extensive design sub-site code	Area (m^2)	Resource Type	Design	Design Details	Video Transects Initiated	Planned Revisit Frequency	Timing	Initial coral cover (%)
BISC	Amanda's Reef	AM	--	20,240	Index	1 stage	20 transects	2004	1 yr	Oct/ Nov	7.3
	Ball Buoy Reef	BB	--	14,136	Index	1 stage	20 transects	2004	1 yr	Oct/ Nov	6.6
BUIS	S. Fore Reef	SFR	--	40,753	Index	1 stage	20 transects	2002	1 yr	Jan/ Feb	17.2
	W. Spur & Groove	WSG	--	26,365	Index	1 stage	20 transects	2000	1 yr	Mar/ Apr	5.8
DRTO	Bird Key Reef	BK		19,765	Index	1 stage	20 transects	2004	1 yr	June	13.2
	Loggerhead Forest	LH	I05,I50,LH01, LH02,LH03	596,637	Index	2 stage, stratified	5 4-transect sub-sites	2012	1 yr	June	26.4
	Santa's Village	SV	SV01,SV02, SV03	371,763	Index	2 stage, stratified	3 4-transect sub-sites	2012	1 yr	June	16.2
	Inside RNA	I	I05,I26,I36,I38, I41,I44,I50	119,988,000	Mgmt Zone	2 stage, GRTS, reefs poorly known	7 4-transect sub-sites	2008	3 yrs	June	9.6
	Outside RNA	O	O42,O56, O72,O82, O84,O94	142,301,000	Mgmt Zone	2 stage, GRTS, reefs poorly known	6 4-transect sub-sites	2008	3 yrs	June	5.0
	Inside RNA	I	I33,I63	119,988,000	Mgmt Zone	2 stage, GRTS, reefs poorly known	2 4-transect sub-sites	2008	Last yr 2011	Discon-tinued	1.3

Table 1 (continued). SFCN monitoring sites.

Park	Site	Site Code	Extensive design sub-site code	Area (m^2)	Resource Type	Design	Design Details	Video Transects Initiated	Planned Revisit Frequency	Timing	Initial coral cover (%)
DRTO	Outside RNA	O	O12,O27, O92	142,301,000	Mgmt Zone	2 stage, GRTS, reefs poorly known	3 4-transect sub-sites	2008	Last yr 2011	Discon-tinued	0.8
	Bird Key North	BKN	--	24,944	Index	1 stage	20 transects	2005	Last yr 2011	Discon-tinued	11.0
SARI	Salt River	SR	--	26,026	Index	1 stage, stratified	20 transects	2012	1 yr	Apr	10.6
VIIS	Haulover Reef	HA	--	13,568	Index	1 stage	20 transects	2003	1 yr	Jan	22.1
	Mennebeck Reef	MB	--	12,495	Index	1 stage	20 transects	2000	1 yr	Oct	22.9
	Tektite Reef	TK	--	18,711	Index	1 stage	20 transects	2005	1 yr	Sep	24.7
	Yawzi Reef	YZ	--	7,125	Index	1 stage	20 transects	1999	1 yr	Sep	7.1
St. John (Out-side VIIS)	Newfound Reef	NF	--	13,768	Index	1 stage	20 transects	1999	1 yr	Mar	17.9

Index Site with One-Stage Sampling and Stratification

If there is a possibility that different areas of the sampling domain may have different selection or rejection probabilities or be affected strongly by different stressors, then stratifying can help maintain a spatial balance. An example is the approach used at the Salt River (SR) site. That "site" consists of three different mapped areas of high, complex coral cover inside and immediately outside the Salt River underwater canyon which were labeled "West Wall", "East Wall", and "Spur and Groove". Due to the steepness of the canyon in the West Wall and East Wall areas, the probability that a randomly chosen transect would be rejected was presumed to be higher than in the Spur and Groove area on the outside lip of the canyon. Calling these three areas strata and assigning them the number of transects equal to their proportion of area meant that if a transect was rejected as too deep or too steep to be feasible to sample in the West Wall, it would be replaced by another transect in the West Wall, rather than in one of the other areas. This prevented a disproportionately high number of transects (or even all transects) from being allocated to the Spur and Groove area. If selection probabilities in the different areas are grossly different, then selection probabilities my need to be incorporated into the analysis. In the case of the Salt River Site, selection probabilities were still roughly equivalent, thus this site is analyzed similar to an Index Site with One-Stage Sampling. Note: During the prototype protocol development, a pilot study was conducted to evaluate differences among depth zones within the fore reef at one study site. Results showed it was not necessary to stratify transect allocation by depth within this zone.

<u>Steps for establishing an Index Site with one-stage sampling and stratification</u>

1) Follow steps 1–3 above in "Index Site with One-Stage Sampling" (no stratification)
2) Clearly articulate the purpose for stratifying the site, e.g.,
    a) To maintain a spatial balance despite differing selection/rejection probabilities across the site (e.g., SARI)
    b) To make sure enough transects are in different portions of a site that may be affected differently by a stressor or management allowing future analysis of that effect if needed. For example, although not originally stratified in the design phase (the boundary didn't exist), the Bird Key Reef in DRTO has eight transects inside and twelve transects outside the Historical Adaptive Use Zone which would allow each area of that site to be analyzed separately if desired. If such a boundary did exist during the design phase, then this could be a reason for stratification.
    c) To force a spatial balance for some other concern. Generally these sites are small enough that unless there is a clearly articulated concern, stratification should be avoided.
3) Determine the number and size of strata. Break up the site so that each stratum is as consistent (homogeneous) as possible regarding the factor of concern and maximizes the difference among strata. If the factor of concern is different selection/rejection probabilities across the site, then create strata where each individual stratum has similar probabilities and maximize the differences among the strata.
4) Divide the shapefile into desired strata, e.g., for SARI this was "West Wall," "East Wall," "Spur and Groove."

5) Calculate the proportion of the total area in each stratum.
6) Multiply 20 transects by the proportion of area in each stratum to determine the number of transects to assign to each stratum.
7) Randomly select twice the number of transects within each stratum with a requirement that they be at least 10 meters (32.8 ft) from another point to minimize the possibility of overlap (see SOP 7).
8) Investigate and install transects in each stratum as described under Index Site with one-stage sampling (no stratification). However if a transect is rejected, then proceed to the next randomly chosen transect within that same stratum (see SOP 9).

Current sites and/or reefs monitored in this method (Table 1)
SARI—Salt River (SR)

Index Site with Two-Stage Sampling and Stratification

Some reefs are too large to feasibly monitor using the 20 random transect approach as described above. An example is Loggerhead Forest reef in DRTO with an area of 596,637 square meters (147.4 ac or 59.6 hectares [ha]), over 14 times the size of the largest one-stage design index site. Twenty random transects would result in 20 separate dives and difficulties in locating each transect. A cost-benefit analysis of travel time versus sample size found that sub-sites of two to four transects were optimal. Note: Sub-sites that are part of two-stage sampling are also referred to as "extensive" sub-sites in this protocol. South Florida/Caribbean Network chose to use four transect sub-sites in Dry Tortugas NP as these would logistically be easier to implement and also allowed some power to detect change at the individual extensive sub-site level as well as at the larger index site level. Typically three to five four transect sub-sites are used per feature of interest, with five sites recommended.

Steps for establishing an Index Site with two-stage sampling and stratification

1) Carefully define the desired sampling frame (e.g., a specific reef like Loggerhead Forest in DRTO). Field reconnaissance is necessary to validate or revise existing maps in order to accurate define and locate what is and is not included within the sampling frame. For example, the sample frame for Loggerhead Forest includes high relief reef terrace, linear reef, and spur and groove formations that are continuous and part of an overall reef formation, but does not include sand, coral patches in sand, pavement, or uncolonized hardbottom. The study area may contain small patches of low-relief reef within the larger high relief matrix, but otherwise habitat that transitions to low relief reef is no longer part of the sample frame.
2) Define the index site boundary using maps with field verification of boundaries and type of habitat present (see SOP 8).
3) Clearly articulate the purpose for stratifying the site and determine stratification approach. This could be one or some combination of the following, e.g.,
    a) To force a spatial balance across the site to better assess trends in the resource as a whole (a purely random design may cluster sub-sites in one corner of the resource)

i) Break the study area into sections of approximate equal size and then randomly select one extensive sub-site per section to force some spatial balance in the sites monitored. This approach was applied to Loggerhead Forest reef in Dry Tortugas NP. (NOTE: A drawback of this design is if there is a desire to increase sampling effort, then the number of sub-sites must be increased to two per section across all sections to maintain a balanced design. For example, Loggerhead Forest would increase from five sub-sites to ten sub-sites).

ii) An alternate method of creating spatial balance is by using a Generalized Random Tessellation Stratification (GRTS) sampling design which has grown in popularity in recent years as a way to provide a spatially distributed yet random set of points. The design allows additional sub-sites to be easily added without having to double the entire number of points as is required in the approach 3ai above. However, SFCN has tried this approach and has found that if there is a different probability of some sites being thrown out as not part of the sampling frame habitat in some portions of the study area than in others (e.g., part of the map is more accurate than another), then a GRTS design will tend to cluster points in areas where there is a high probability of site selection on the first visit. As there is always some uncertainty in such large two-stage sampling designs involving an underwater resource, the network has discontinued using GRTS in any near-future coral monitoring designs.

b) To maintain a spatial balance despite differing selection/rejection probabilities across the site.

i) Create strata where each individual stratum has similar probabilities and maximize the differences among the strata. Assign the number of sub-sites in proportion to the amount of area in the strata. If desired, further stratify to force a spatial balance.

c) To make sure enough sub-sites are in different portions of a site that may be affected differently by a stressor or management allowing future analysis of that effect if needed.

i) Break up the site so that each stratum is as consistent (homogeneous) as possible regarding the factor of concern and maximizes the difference among strata. Assign the number of sub-sites in proportion to the amount of area in the strata. If desired, further stratify to force a spatial balance.

4) Randomly choose sub-site center points within each stratum of the sample frame.

5) If sub-site does not meet criteria (reef habitat is part of described sample frame, feasible to visit safely with boat, within depth range and otherwise safe for sampling), go to next randomly selected sub-site within stratum.

6) Investigate and install two to four 10 meter (32.8 ft) transects per sub-site (i.e., install pins and collect data) that meet criteria, e.g., transect > 50% hardbottom. Four transect sub-sites are preferred in areas < 20 meters (65.6 ft) deep, but deeper areas may require restricting sub-sites to 2 transects in order to allow a sub-site to be completed on a single dive. Each extensive sub-site is organized in a systematic pattern with transects going North, South, East, and West, unless a transect is < 50% hardbottom in which case the set of alternate transects are investigated in order (see SOP 8).

7) Develop a detailed sub-site map with locations of all pins, important features to assist in relocating pins, location of water temperature loggers, and photos for pin relocation (See Appendix H).

Current features monitored using this method (Table 1)
Loggerhead Forest in Dry Tortugas NP (Five extensive sub-sites within a 596,637 square meter [147.4 ac] feature)

Santa's Village in Dry Tortugas NP (three extensive sub-sites within a 371,763 square meter [91.9 ac] feature)

Management Zones

Monitoring management zones involves a slightly different question than monitoring index sites. As described above, the index site sampling design was created to detect changes within a single or relatively small group of index reefs that were chosen for specific reasons (e.g., reef structure, coral cover, coral complexity, coral diversity, management interest, historical work, etc.). The fact that index sites were specifically selected limits the inferences one can draw from those data to that specific reef. In a management zone, the question involves whether well-developed, complex coral reefs, with at least 5% live stony coral cover and between 2–33 meters (6.5–108.3 ft) deep within the zone are showing change, often in comparison with similar areas outside the zone.

One challenge with implementing a management zone-wide monitoring design for high coral cover reefs is identifying where such reefs exist. Benthic habitat mapping is a new and rapidly developing field that uses aerial imagery or remotely sensed data (e.g., LiDAR—Light Detection and Ranging). Benthic maps are good at distinguishing the geological structures, e.g., hard/soft bottom interface. However map class designations of "reef terrace," "spur and groove," "linear reef," and "patch reef" are actually descriptions of the rugosity and patterning of the hard-bottom and don't necessarily indicate the quantity of live stony coral cover present (although it may have been present in the past). As corals die, their skeletal remains erode with processes that can be rapid (e.g., hurricanes) or prolonged (e.g., boring sponges). Structurally complex reefs don't always have abundant live coral cover. This protocol focuses on extant living reefs at time of implementation. Thus the sampling design must account for the uncertainty of the locations of well-developed, complex coral reefs with living stony coral cover. *(Note: Coral reefs develop slowly while established coral reefs can die quickly. If substantial coral growth begins in new/unmonitored places, other protocols [e.g., NOAA's National Coral Reef Monitoring Program (NCRMP) will detect it and trigger discussions for a targeted monitoring design. However, the current trend within SFCN parks is loss of live stony coral cover especially at higher coral cover reefs]).*

To monitor a management zone, potential extensive two- to four-transect sub-sites are randomly chosen from mapped complex reefs throughout a managed area (e.g., reef terrace, spur and groove, linear reef, and patch reefs). These sub-sites are then investigated using the RHA procedure to determine if the potential sub-site has enough live stony coral cover to be considered part of the sampling frame.

Steps for Establishing a Management Zone with Two-Stage Sampling and Stratification

1) Follow steps 1–4 above under "Steps for establishing an Index Site with two-stage sampling and stratification." *Note: If applying the design to sampling patch reefs (e.g., BISC), then some adjustments may need to be considered such as restricting random selection to patch reefs of 800 square meters (.19 ac) or larger (this is the minimum size an extensive four-transect sub-site will fit within) or switching to only two transects/sub-site.*
2) Investigate sub-sites using Rapid Habitat Assessment (RHA) method with line point intercept transect (see SOP 8). If a sub-site does not meet criteria (i.e., linear reef, reef terrace, spur & groove, and/or patch reef habitat, > 5% live stony coral cover [> 8% using RHA method], feasible to visit safely with boat, within 2–33 meter [6.6–108 ft] depth range and otherwise safe for divers to sample), go to next randomly selected extensive sub-site within same stratum. *NOTE: the RHA line point intercept methodology has been determined to estimate live stony coral cover about 3% higher than the videography method (unpublished comparison of SFCN videography results with SCREAM team line-intercept results on same transects in Dry Tortugas NP), so the minimum acceptable stony coral cover must be 8% in the RHA method to compensate.*
3) Continue to follow steps 6–7 above (Index Site with two stage sampling and stratification).

Current Features Monitored Using this Method (Table 1)

Dry Tortugas NP—Inside RNA (seven sites)

Dry Tortugas NP—Outside RNA (six sites)

Incorporating Different Selection Probabilities in Different Strata

If there is a desire to have different selection probabilities in different strata, then use a finite grid approach to make the math easy to calculate. For example in Dry Tortugas NP, the network initially chose to have nine sub-sites inside and nine sub-sites outside the Research Natural Area (RNA) to allow comparisons inside and outside this management zone, while also combining the results into an overall park trend. South Florida/Caribbean Network overlaid a 40 × 40 meter (131.2 ×131.2 ft) grid across the park (an extensive sub-site fits neatly into that grid cell size), selected cells that contained at least 70% of the desired map classes, and then randomly chose grid cell center points using a GRTS sample draw. This allowed calculation of the selection probabilities in each area. *NOTE: the network started with this approach in Dry Tortugas NP. However, subsequently it was determined that reporting by the different areas was both easier to calculate and more intuitive to park management and the public and thus the different index sites and management zones are more simply presented on the same graph rather than combined statistically into a single park-wide answer, e.g., Inside RNA, Outside RNA, Bird Key Reef, Loggerhead Forest, Santa's Village are each included on graphs rather than a single combined answer. Consequentially the details of analyzing using the weighted finite sample frame are extensive, they are not provided in this protocol and the user is instead referred to Brandt et al. (2009) for analysis details. ALSO NOTE: The RNA is closed to fishing and anchoring.*

Rationale for Focusing on Well-Developed Reefs with High Stony Coral Cover

The reef criteria for monitoring under this protocol include structurally complex/rugose reefs between depths of 2–33 meters (6.6–108.3 ft) with 5% minimum coral cover. A true coral reef is a "rigid skeletal structure in which stony corals are major framework constituents" (Hallock 1997) and is the product of primarily biological and ecological processes that exert some amount of physical control over nearby oceanographic processes (Hubbard 1997). Coral reefs cover a small percent of the sea bottom within the SFCN parks, yet they are of disproportionate importance as sinks and sources of the larvae of fish, coral, and other reef organisms that replenish or draw from areas far beyond the park (NPS 2009). Coral reefs are "special places" within "special places" (i.e., National Parks) that have been set aside precisely because of their ecological significance; these coral reefs were a driving force behind the establishment of several SFCN parks. These reefs take centuries to grow but can die quickly and degrade within a few decades. The reasons why high coral cover areas develop in some areas but not others are still unclear and are an area for research.

The legacy version of the protocol was originally developed for fore reef areas with higher coral cover dominated by *Orbicella* spp. (formerly *Montastraea* spp. e.g., star coral) with > 20% coral cover, but has also been successfully applied to patch reefs and low relief spur and groove with approximately 5–6% coral cover. However, while the ecologically important and federally protected (Endangered Species Act [ESA]) *Acropora palmata* (elkhorn coral) tends to dominate in shallow areas (e.g., < 2 meters [6.5 ft] deep), monitoring for that species is better addressed with methods which focus on individual colony monitoring.

The network's coral reef monitoring protocol using permanent sites and videography is well-designed for these rarer high coral cover areas, but is less well-suited for monitoring low coral cover areas with < 2% coral cover. Note that NOAA is developing their National Coral Reef Monitoring Program (NCRMP) to monitor hard-bottom benthic communities in conjunction with fish monitoring in hard-bottom habitats. The NCRMP design applies a stratified random sampling design to all hard-bottom habitats that is re-randomized each sampling period and uses an in situ line-point intercept approach. The NCRMP approach is designed to capture large scale change in hard-bottom communities but will likely have limited ability to detect change in high coral cover sites which are relatively rare (e.g., less than 5% of hard bottom). These two approaches complement each other and will provide managers with a good balance of information, with the SFCN Coral Reef Monitoring Protocol detecting change in the rarer but important high coral cover sites while the NCRMP protocol provides a coarser big picture of overall change across all hard-bottom habitats. The NCRMP protocol is in development by NOAA and is not discussed further in this document.

Rationale for Selecting "Coral Cover" as Primary Parameter to be Monitored

Several parameters can be used to describe reefs including coral cover, density of colonies, condition of colonies and size frequency distributions. This protocol emphasizes monitoring of coral cover (as well as algal cover, gorgonian cover, and sponge cover) for several reasons. Corals are the primary architects of the reef, providing shelter and habitat for many other organisms. Most of the stresses that affect coral reefs within this network cause loss of coral tissue. If the corals fail to recover, the affected areas will be rapidly colonized by algae, changing the function of the structure. Increasing

algal cover can inhibit the recovery and growth of coral as the algae out-compete the coral for available space. Changes in the amount of living coral recorded with still photography or video are changes in the amount of living coral tissue visible in planar (two-dimensional) view. Although these planar techniques will under-represent colonies with a more vertical morphology (e.g., *Dendrogyra cylindrus*—pillar coral), they are suitable for monitoring the encrusting and hemispherical morphologies of the species that dominate in the fore reef zones that are frequently a focus of this protocol.

While density and size distribution of coral colonies can be useful community descriptors in low coral cover reefs and are used in some other coral monitoring efforts, determining where one colony ends and another begins is often difficult in high coral cover reefs, especially in areas with *Orbicella annularis* (star coral, the dominant coral species on St. John reefs) or branching species like *Acropora cervicornis* (staghorn coral). Also, stresses to coral reefs that could lead to fragmentation of colonies, further complicate counts and interpretation. In this protocol, the density of coral colonies is used to calculate disease prevalence rather than being used as a primary focal metric.

Rationale for Using Permanent Transects

A pilot project was implemented during protocol development in 2000 in an effort to quantify potential differences between permanent random transects and annually re-randomized transects. At two index sites, 20 newly-chosen, random transects were identified and sampled in addition to sampling the permanent transects. This dual sampling was conducted in St. John at Newfound Reef from 2000–2003, and at Yawzi Reef in 2004–2005.

Results indicated considerable increased statistical power and reduction in sample size when using permanent transects (Miller et al. 2006a). A power analysis comparing 20 permanent transects versus 20 annually re-randomized transects showed that it would take at least seven times the number of re-randomized transects to have the same power to detect a 25% change in live coral cover as the permanent transects. The ability to detect substantial or significant coral cover change through focused and repeatable effort in SFCN parks is critical—enabling limited park resources to obtain maximum understanding of reef changes throughout monitoring periods.

A drawback of using permanent transects is the reduced ability to assess the wide spatial variability in hard-bottom habitat across the parks. However, as described above, the NCRMP led by NOAA is designed to randomize sampling of hard-bottom habitat each year, thus providing information on the spatial distribution of coral in the park while the SFCN protocol focuses on trends in the relatively rare high coral cover sites.

Sampling Frequency and Timing

Frequency

Sampling of sites generally occurs annually, although once a baseline is established (approximately three to five years depending on level of inter-annual variability), this frequency can be reduced to once every three years. This reduction is based upon coral cover values, sampling design and overall sampling effort within a park. Annual monitoring allows establishment of a baseline, early detection of problems, and potential identification of linkages to coral mortality. Frequent monitoring has been

shown to be essential in revealing the causes of some coral declines (Miller et al. 2009). Most corals grow very slowly (mm/yr.; see Gladfelter 1978), so detecting growth or increases in coral cover can take several years if not decades. Coral mortality on the other hand occurs very fast (i.e., weeks or months). Benthic components (coral, sponges, etc.) can overgrow the copper clad stakes, so visiting at least once every three years is advised to maintain an ability to relocate transects.

All current SFCN index sites are monitored annually. The SFCN extensive sub-sites at DRTO were monitored annually for the first five years and are now monitored every three years.

Rugosity (SOP 6) is measured only once every five years (six years for Dry Tortugas NP extensive sub-sites). All other variables are monitored during each regular field visit.

Timing

Sampling is conducted throughout the year, with each site visited in the same month each year (see Table 1). While coral usually shows little inter-annual variability, algae cover can change quickly and dramatically due to storms, swell conditions, wave action, currents or changes in nutrient regime. Monitoring each site about the same time of year provides the best opportunity for accurate comparisons across years for all taxonomic groups. However, comparison of percent cover of algal communities across sites should be treated with caution if monitored during different seasons.

Episodic Monitoring

Supplemental "episodic" monitoring can be conducted to capture the effect of extreme events such as hurricanes, prolonged warm water temperatures resulting in extensive bleaching, disease outbreaks or large-scale spills (e.g., Deep Water Horizon oil spill). The network's intention is to conduct annual monitoring; however given that rapid mortality can occur, an increased monitoring frequency (episodic monitoring) may be implemented at a subset of sites during periods of undue stress (e.g., a hurricane, elevated water temperature or disease outbreaks) to allow better interpretation of the cause of a decline in coral cover. This type of monitoring is not a requirement, but instead is an option that may be undertaken after discussion with the park managers, and evaluation of available resources.

As an example, episodic monitoring of Virgin Islands index sites was conducted after elevated water temperatures caused substantial coral bleaching in the summer of 2005. After consultation with park managers and evaluation of available resources, a monitoring sampling schedule (bi-monthly and quarterly at a subset of sites) was developed for selected parameters (video and disease). This schedule continued for a year due to the coral disease outbreak that followed the bleaching event. Evaluation of only the annual data collected would have suggested declines in coral cover were correlated with bleaching. However, when including the data collected episodically over the same time period, it was determined that coral disease was overwhelmingly the source of mortality, not bleaching. In addition, having at least two sampling visits before and after this event greatly improved the statistical power to detect changes, allowing earlier reporting that the changes occurring were statistically significant and establishing a previously little-understood relationship between bleaching, disease outbreaks, and coral mortality (Miller et al. 2009).

Level of Change that can be Detected in Live Coral Cover

The absolute change and percent change detectable in stony coral cover with the differing sampling designs (one-stage design 20 transect index site, two-stage design with multiple extensive sub-sites, and a single four transect extensive sub-site) is provided in Figure 1 for a simple paired t-test and in Figure 2 for a 10 year repeated measures analysis of covariance. Greater detail about calculating the level of change detectable is provided in Appendix D. Only data using high definition (HD) videography were used in the calculations. The change detectable is related to the site's average coral cover. As sudden drops in coral cover can occur as exemplified by the US Virgin Islands 2005–2006 die-off, maintaining sample sizes sufficient to detect changes at low coral cover sites, even if coral cover is initially high, is important to the sustainability of a long-term program.

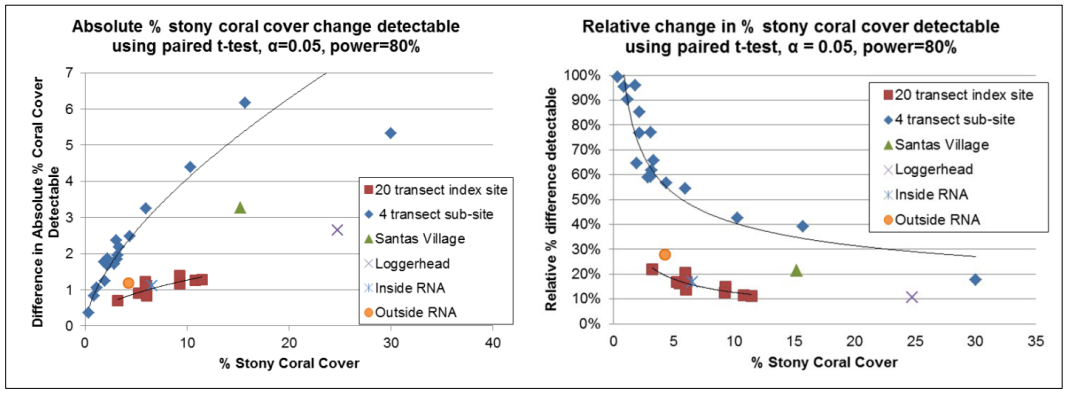


Figure 1. Differences detectable with varying amounts of initial stony coral using a paired t-test, a=0.05 and 80% power displayed as: (left) absolute % difference in coral cover, and (right) relative % difference in coral cover.

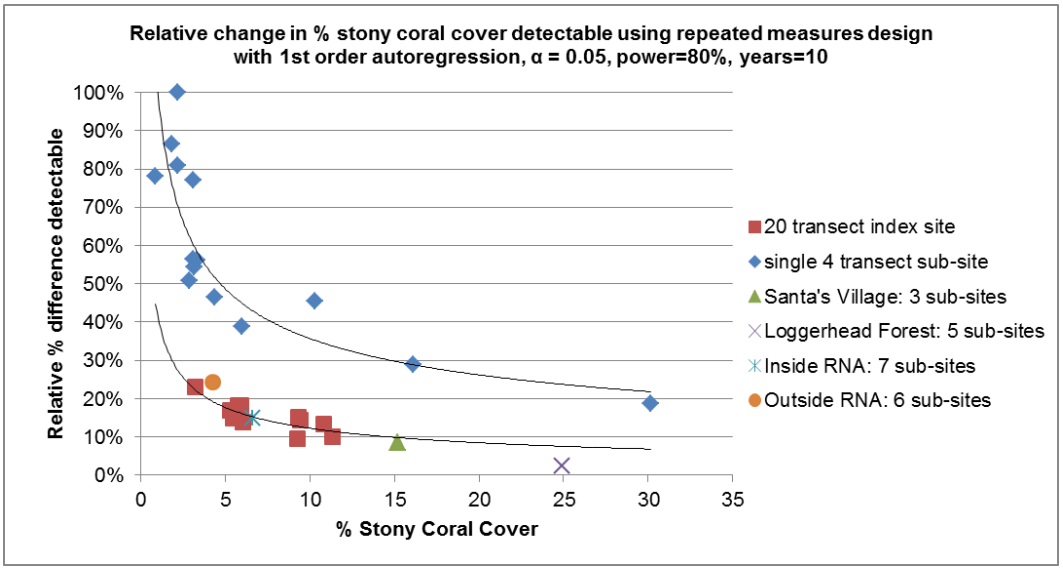


Figure 2. Relative percent change detectable in average coral cover after 10 years using a repeated measures analysis of covariance estimated using SFCN data for 20 transect sites, a single four-transect sub-site, and multiple extensive sub-site sites. Data were backtransformed before graphing.

A single stage 20 transect index site is initially a little more powerful at detecting change than a design consisting of five four-transect sub-sites (e.g., able to detect a 13% versus 17% change at a site with 10% coral cover). Even this difference will diminish over time as the increasing number of sampling events increase the effective sample size. However, this underscores that an index site small enough to allow randomization of all 20 transects will benefit by this design. However for a large area the tradeoff of a small decrease in power for increased logistical feasibility, reduced travel costs, and an ability to extrapolate changes to a larger area supports use of the four-transect extensive sub-sites. Large area here means an area large enough that it would not be practical to swim and navigate from one transect to another. The switching point between methods is probably a reef between 50,000 to 100,000 square meters (12.4–24.7 ac). In addition, a four-transect extensive sub-site with 10% cover can individually be assessed for a change of about 42%. Thus change can be evaluated at both the index site and individual sub-site level, increasing the flexibility of the design.

Five extensive sub-sites are recommended for a large index site or management zone although three sub-sites are possible. The number of sub-sites used also affects the amount of change detectable. Using a pairwise t-test, three extensive sub-sites will detect a change of about 28% versus the 17% of 5 extensive sub-sites. However this difference will likewise diminish through time with repeated sampling (see Appendix D).

The decision to use permanent transects was supported by an older analysis using digital videography data from Yawzi and Newfound reefs (before high-definition video implementation) that found that non-permanent transects require over seven times the sample size of permanent transects to detect a 25% trend with equivalent power (Miller et al. 2006a).

The switch from digital video to high-definition digital video in 2008 increased the power of this protocol to detect change and is now the preferred technology in this protocol. Although the width of the video field remains the same, the number of digital sample frames that are captured increased from about 27 to about 34 causing an increase in the average number of points identified per transect from about 270 to 340 resulting in an increased precision of estimate. In addition, the percent of "unknown" points was reduced. Other minor differences are shown in Appendix E.

Current Monitoring Sites within SFCN Parks

The name, location and size of current SFCN coral monitoring sites (by park) are listed in Table 1. Expansion of monitoring is being considered for Biscayne NP depending upon overall SFCN workload. If Virgin Islands Coral Reef NM is added to the SFCN, then monitoring may be expanded into this park.

Virgin Islands National Park (VIIS)

Development of the USGS/NPS legacy protocol "Using Videography to Monitor Coral Reefs" (Miller and Rogers 2002) began in 1997 with the initiation of the I&M prototype program and was based in Virgin Islands NP (Rogers 1993, 1997). This evolution of monitoring techniques was piloted at Virgin Islands NP (Rogers and Miller 2006), therefore at this time more study sites are monitored there than in other SFCN parks (Figure 3).

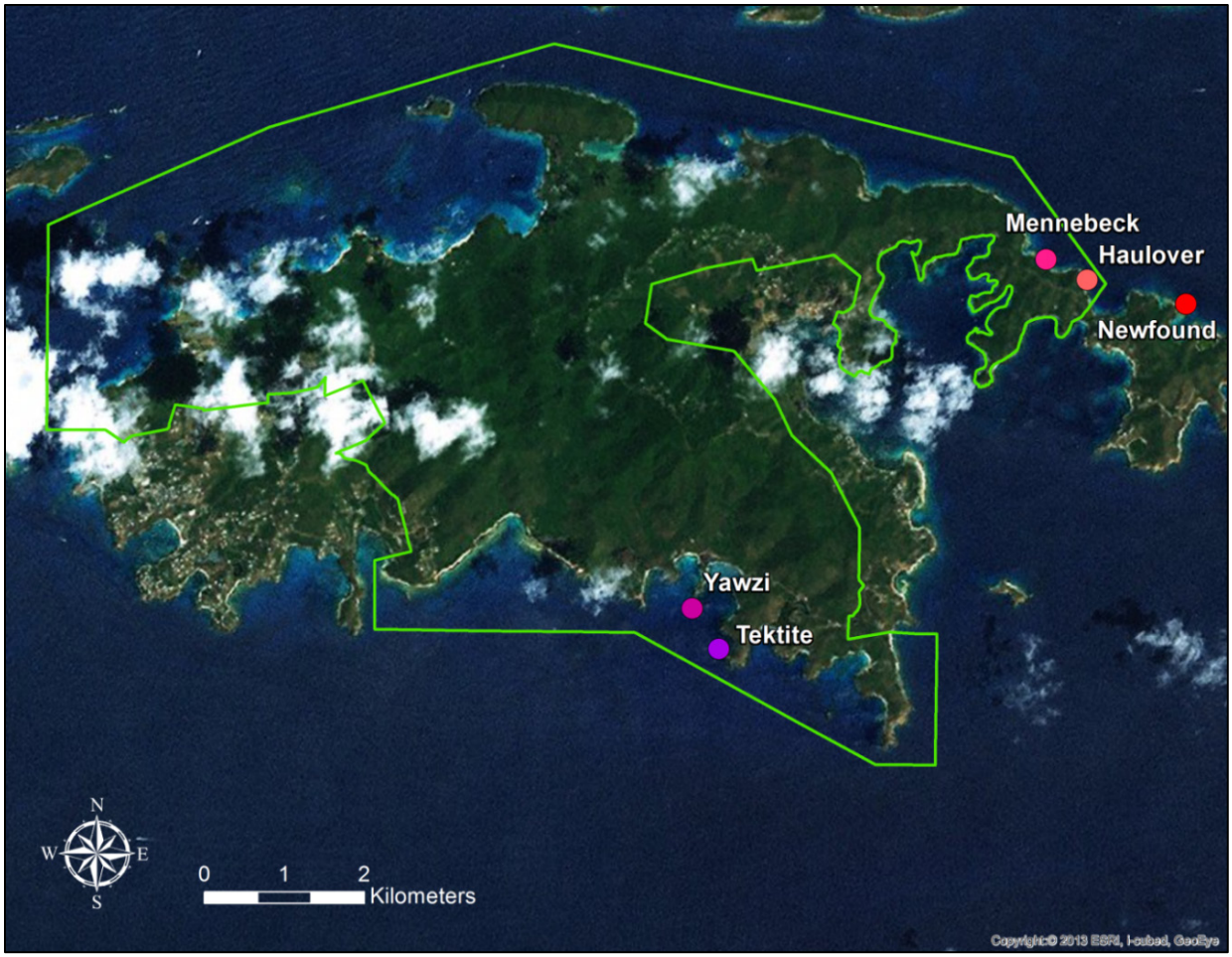


Figure 3. Map of St. John, boundary of VIIS and the location of SFCN index sites.

The sites are detailed below in the chronological order of SFCN monitoring.

- Yawzi Reef is located near Tektite Reef on the south side of St. John (Figure 4) between Great and Little Lameshur Bays. The study site is the smallest monitored by SFCN at 7,125 square meters (1.7 ac). It is defined by a sand plateau on all sides except the north, where the reef boundary is defined by a change in habitat from scattered corals to a mixed boulder and gorgonian community. Following the pilot testing of the "SOP 1—Using Videography to Monitor Coral Reefs" in 1999, SFCN monitoring began with the establishment of 20, 10-meter (32.8-ft) transects with annual and episodic monitoring since that time.

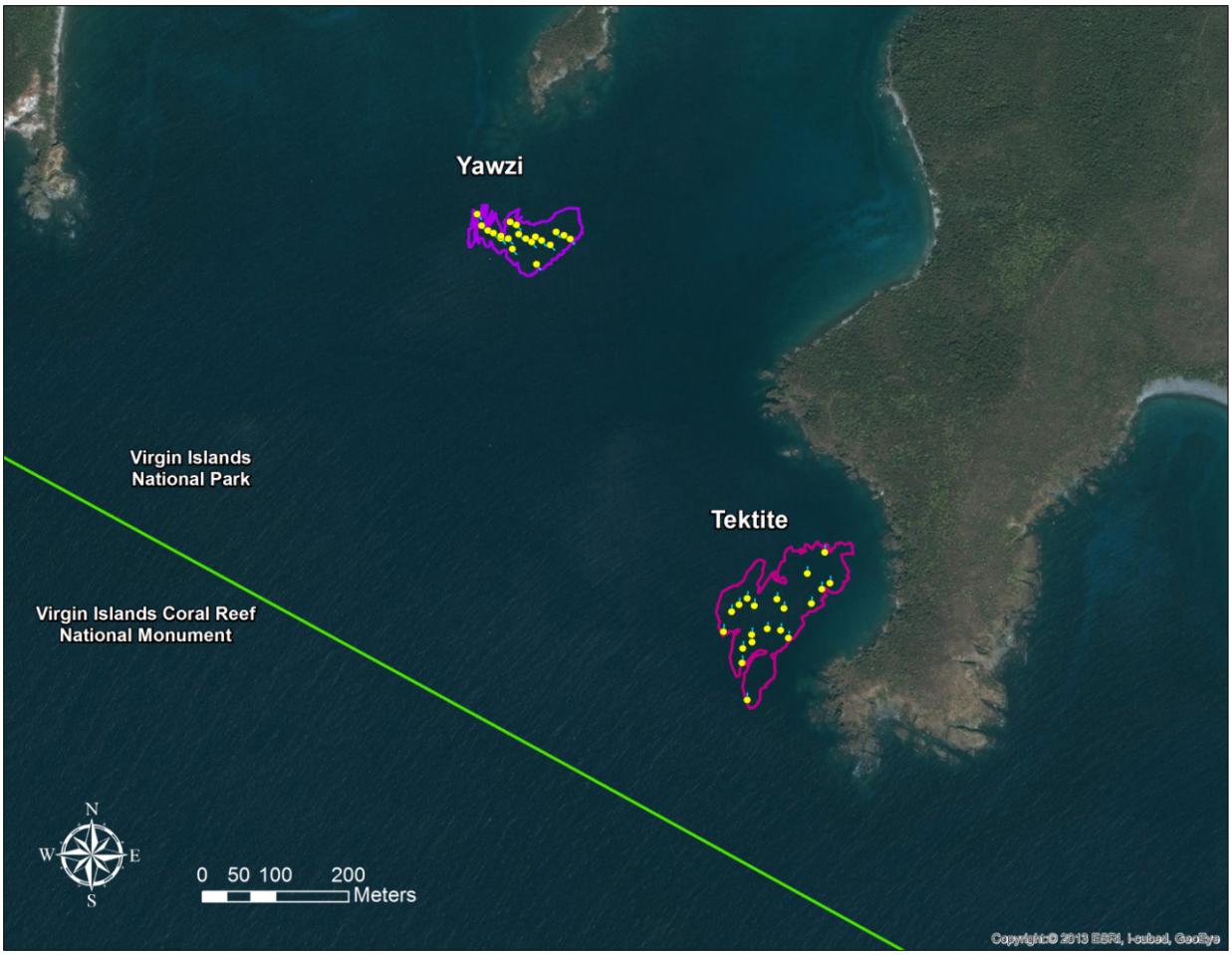


Figure 4. Location of SFCN index sites on south side of St. John, Yawzi Reef and Tektite Reef. Site boundaries are shown with transect locations and yellow circles representing start pins.

- Newfound Reef study site is a 13,768 square meter (3.4 ac) site located on the east end of St. John (Figure 5), outside the boundary of Virgin Islands National Park. The site is within a watershed that is privately owned, but undeveloped at this time. The fore reef site is defined by a four-meter (13.4 ft) depth contour (west), an imaginary line offshore and perpendicular to a rocky outcropping (north), the sand channel that enters Newfound Bay back reef (south), and the edge of the fore reef slope (east). Shoreward of the study site is a back reef lagoon, which is a popular anchorage for day-charter boats bringing visitors to this reef.

  I&M involvement at this site began in 1997, as part of the USGS prototype protocol development program, and once pilot testing was completed, permanent monitoring began in 1999. Sampling the 20 randomly placed permanent transects has been conducted annually since 1999 through the I&M program, now under the auspices of SFCN. Episodic monitoring was also conducted here during the 2005–2006 bleaching/disease outbreak.

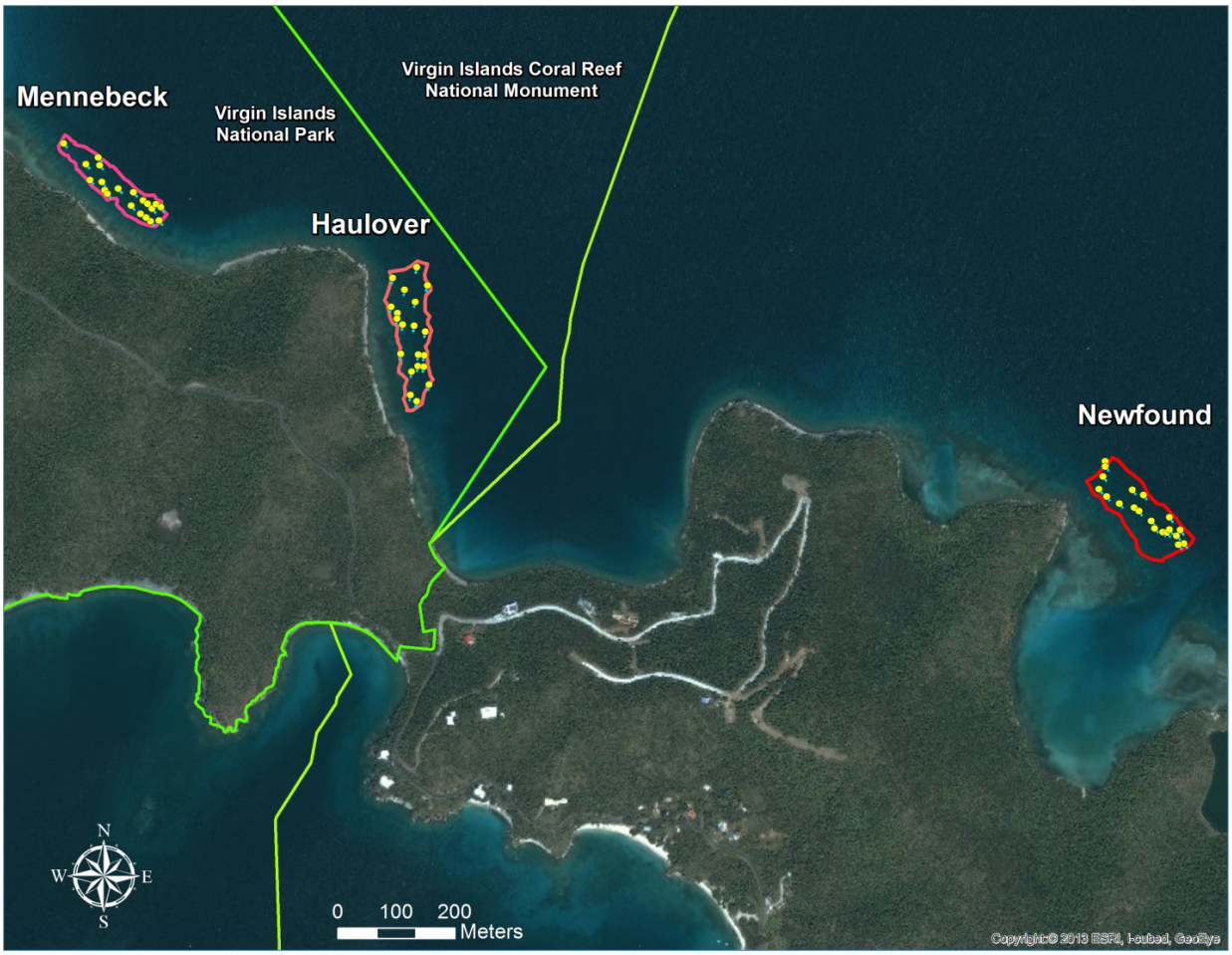


Figure 5. Locations of SFCN index sites in northeast St. John with boundaries of VIIS and VICR. Yellow circles represent transect start pins.

- Mennebeck Reef study site (Figure 5) is 12,495 square meters (3.1 ac) and is located within a completely undeveloped watershed within the VIIS boundary. There are no roads or trails to this site and it is not marked or known as a destination for divers or snorkelers, therefore it receives very little visitation (R. Boulon pers. comm.). However, it is directly "downstream" of the majority of islands that comprise the British Virgin Islands. The site is defined by a depth contour of four meters (13.1 ft; south), fragmentation of the reef structure with increased sand channels (both in frequency and size) to the east and west, and the fore reef slope to the sand base at 18 meters (59 ft; north). The network has been monitoring annually and episodically at this site since 2000.
- Haulover Reef study site is located on the northeastern end of St. John, within Virgin Islands NP (Figure 5). The site is on the north side of Haulover Bay, a bay that is bisected by the boundary of the park and monument. Currently, development is progressing on the southern shore of the bay and plans have been approved for 35 home sites on a very steep slope. The proximity of this well-developed reef to the park boundary and the development pressures from adjacent non-park land makes this site of particular interest to VIIS/VICR resource managers.

The study site is an approximately rectangular fore reef site, measuring 13,568 square meters (3.4 ac) and located on the outer edge of the fore reef along the north side of the bay. The site is defined by a 10 meter (32.8 ft) depth contour (west), rocky outcroppings (north and south), and the fore reef slope (east). It is similar in size, structure and composition to Mennebeck Reef, which is located approximately 2 kilometers (1.2 mi) south. However, this site receives substantial visitation, primarily from snorkelers who access the area from the shore. Their impacts are minimal at the depths of the monitoring transects. The network has been monitoring this site since 2003, both annually and episodically.

- Tektite Reef is located on the south side of St. John, in a bay to the north and west of Cabritte Horn Point. The study site is 18,711 square meters (4.6 ac; Figure 4). Its boundary was determined on the north, east, and south by the determination of where the linear reef gave way to a patch reef habitat. The site is bounded by deep sand to the west. The depth at this site varies from 4 to 20 meters (13.1–65.6 ft).

  This site is in a relatively undeveloped watershed, but has two day-use dive moorings maintained by Virgin Islands NP, so visitation by scuba divers is frequent. The reef was originally comprised of very high coral cover areas dominated by *Orbicella* spp., which has suffered significant mortality since 1997 from the coral disease, white plague (Miller et al. 2003). Monitoring by the South Florida/Caribbean Network began in September 2005 with the installation of 20 permanent transects, then continued bi-monthly during the bleaching/disease outbreak. Monitoring is conducted on an annual frequency.

Buck Island Reef National Monument (BUIS)

In June 1999, SFCN scientists collaborated with Buck Island Reef NM resource managers to conduct preliminary investigations in five habitats (spur and groove, fore reef slope, *Acropora palmata* (elkhorn coral) "haystack" complex, lagoon, and back reef). After these initial investigations, park managers indicated that their highest priorities for long-term monitoring were the Western Spur and Groove Reef and the South Fore Reef (Figure 6). These habitats were selected based on the depth, size of the reef area, composition, and complexity of the reef structures. These sites were established using the legacy version of this protocol (Miller 2002; Miller and Rogers 2002).

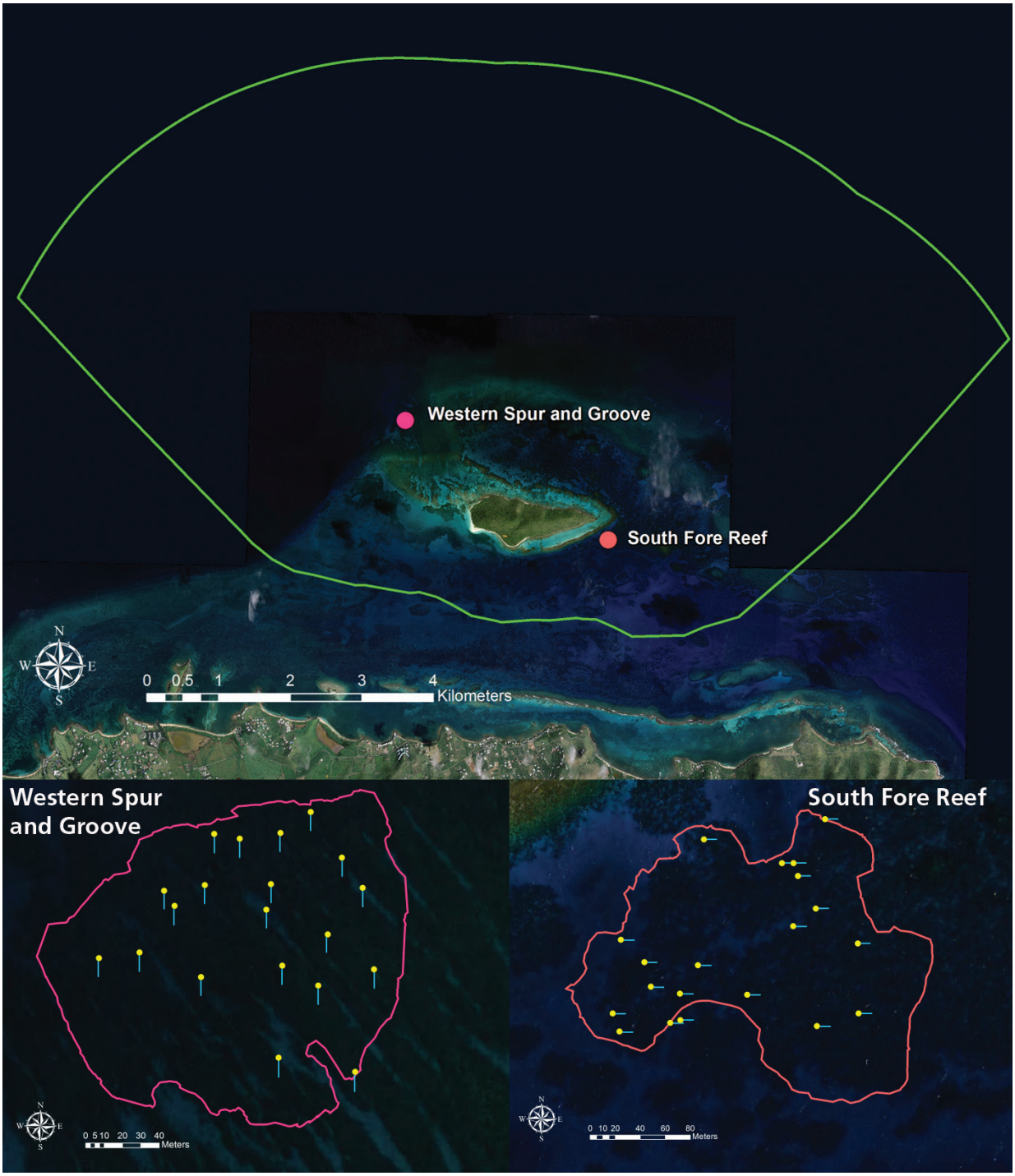


Figure 6. Top: Buck Island Reef National Monument showing location of SFCN index sites and park boundary (green line). The St. Croix USVI is to the south. Bottom left: Western Spur and Groove (WSG) site showing transect locations. Bottom Right: South Fore Reef (SFR) site. Yellow circles represent the start pin. Length of transect and location within polygon are approximate due to conversion errors from a 3D AquaMap SONAR system to a 2D GIS system.

- The Western Spur and Groove Reef study site is 26,365 square meters (6.6 ac), located within this reef type that comprises a substantial portion of the park's northwest waters. The "spurs" are

low relief features with shallow sand channels between. Depths range from 9–13 meters (29.5–42.7 ft). The area is subjected to large sea swells from the north, especially during winter "cold" fronts that approach the area. Coral cover is relatively low, and made up of low, "mounded" type corals (e.g., *Diploria* spp. and *Pseudodiploria* spp. [brain corals] and *Orbicella* spp. [star corals]) which survive well in the high surge environment. Monitoring began in 2000 with the establishment of 19 permanent transects (on-site logistics dictated this number). A twentieth transect was installed in 2003 with monitoring continuing annually.

The South Fore Reef study site encompasses over 40,000 square meters (9.9 ac) of the fore reef that typifies the southern waters of Buck Island Reef NM. The site was selected as representative of a highly complex, high coral cover reef, dominated by *Orbicella* spp. (star corals). This type of reef is typically found extending into the fore reef on the south side of Buck Island. Depths range from 11–14 meters (36.1 –45.9 ft). The site is bordered by sand on the west, and north; the south and east boundaries are defined by the limitations of the mapping equipment as the habitat characterized by this site extends beyond the east and south boundaries. Monitoring began at this site in 2003 with the installation and sampling of 20 permanent transects and has continued annually. Additionally, episodic monitoring was conducted at this site during the bleaching/disease event in 2005–06.

Biscayne National Park (BISC)

South Florida/Caribbean Network has been annually monitoring two coral reef sites at Biscayne National Park since 2004 (Figure 7), "Ball Buoy" and "Amanda's Reef". Selection of the study sites was made after consultation and field investigations led by the Biscayne NP resource management staff.

- Ball Buoy reef was selected due in part to the historical monitoring done at this site. Furthermore, the reef formation and coral reef habitat at this site are very similar to that of sites monitored by the state and located within the upper Florida Keys reef tract. Dr. Jim Porter (University of Georgia, Athens, Georgia) has conducted photo monitoring at this site, and other similar reefs in the upper Florida Keys. The site contains a substantial population of the federally threatened *Acropora palmata* (elkhorn coral) and while this coral species is not a priority target of this protocol, it is an additional feature of interest to park resource managers.

  Ball Buoy reef study site (Figure 7) is located at the southern end of the park south-east of Old Rhodes Key. The study site is 14,136 square meters (3.5 ac) and defined by the reef crest to the west, sand to the east, and a narrowing of the fore reef habitat to the north and south. The site is shallow near the reef crest and extends to a depth of 12 meters (39.4 ft) on the offshore (east) side.

- Amanda's Reef study site (Figure 7) is one of several thousand patch reefs found in Biscayne NP and was selected to represent patch reef structure. It is a shallow feature, with average depth less than 3 meters (9.8 ft), with some corals found within 0.3 meters (1.2 inches [in]) of the surface. The edges slope to seagrass/sand community at a depth of 6 meters (19.7 ft). This reef was also selected due to a boat grounding that occurred, and the population of *A. palmata* (elkhorn coral) it contains, one of the few remaining in the park. These components are not selection criteria for an index site but are features of interest to the BISC resource management staff. While this site

was established during the legacy version of this protocol when the AquaMap™ System was still in use, the shallow depth of this site would not allow for the use of that SONAR-based mapping system for transect location selection used at the other sites (SONAR signals were blocked by in the shallow water environment). A modified procedure was created using a hand-held GPS device in a water proof bag, and towed by a diver/snorkeler on the surface. (See SOP 7). Communication between the divers and surface personnel aided navigation to sample points.

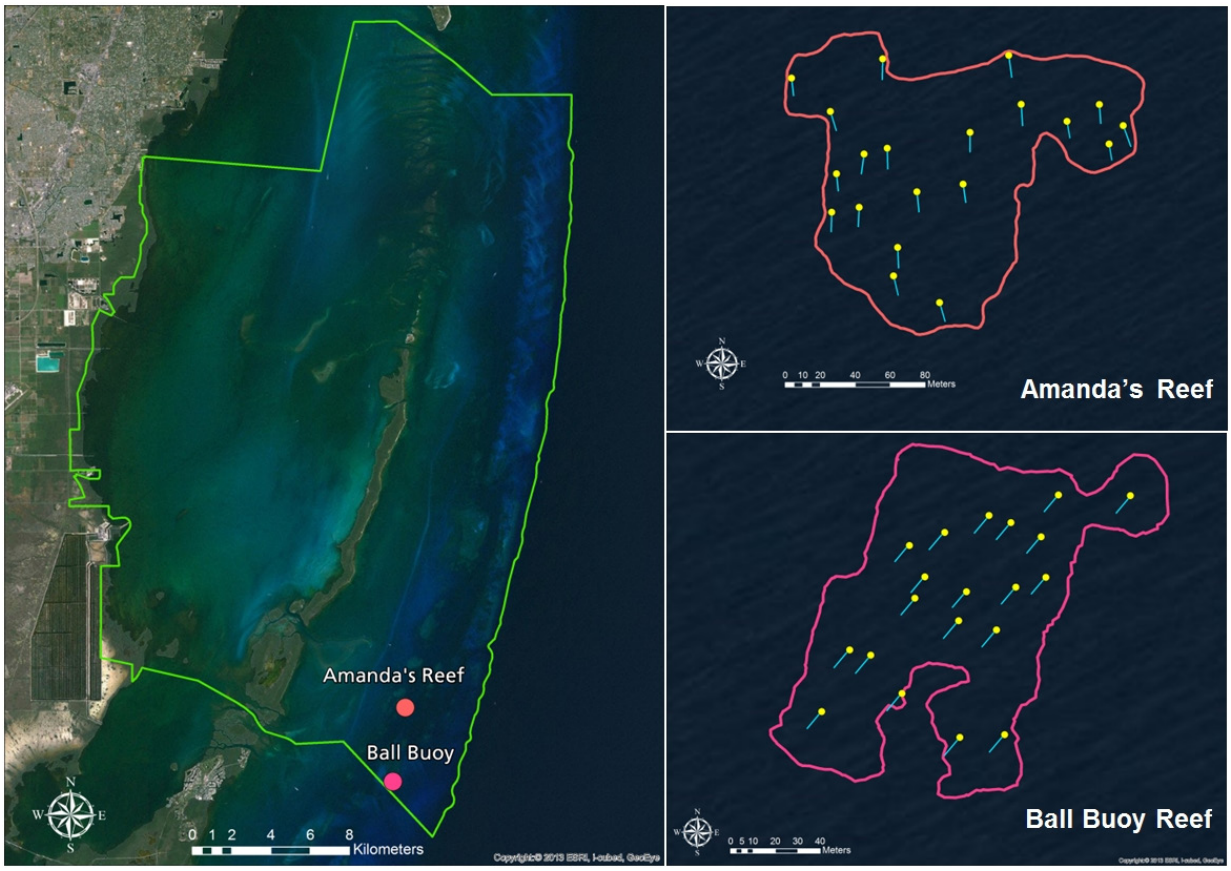


Figure 7. Biscayne National Park boundary showing the locations of SFCN index sites. Larger images of Amanda's Reef (top right) and Ball Buoy Reef (bottom right) show site perimeters and transect locations. Length of transect and location within polygon are approximate due to conversion errors from a 3D AquaMap SONAR system to a 2D GIS system.

Dry Tortugas National Park (DRTO)

- Bird Key Reef was selected for long-term monitoring due to the extensive historical monitoring data existing for the location and after consultation with park managers. Bird Key Reef is one of the most well-developed reefs in Dry Tortugas NP. Lying southeast of Garden Key, this linear reef extends for over 2 kilometers (1.2 mi) and is approximately 360–400 meters (1,181–1,312 ft) wide. A shallow reef crest is emergent during low tide.

  Jaap et al. (1989) describes the reef zones:

- A rubble and fleshy algae zone 0–3 meters (0–9.8 ft) deep, extending approximately 100 meters (328 ft) from the reef crest;
- Octocoral-dominated hardgrounds 3–6 meters (9.8–19.7 ft) deep, extending 100 to 150 meters (328–492 ft) from the reef crest;
- Mixed hardgrounds and sediments 6–9 meters (19.7–29.5 ft) deep, extending 150–250 meters (492–820 ft) from the reef crest, and
- A spur and groove zone 9–23 meters (29.5–75.5 ft) deep, extending 250 to 400 meters (492–1,312ft) from the reef crest.

The Bird Key Reef study site established by the network (Figure 8) encompasses the locations of the historical work (see Jaap 1989) and transects monitored by the Florida State government (FMRI/FWC) beginning in 1999 through the present day (Ruzicka et al. 2013) and includes 19,765 square meters (4.9 ac) of reef. The area is a well-developed spur and groove reef with the deep buttresses in about 25 meter (82 ft) depth, and the shallow (west) end terminating in a gorgonian hardbottom and sand community at about 6 meters (19.7 ft). Twenty permanent 10-meter transects were established and sampled in 2004 and are monitored annually.

The Bird Key Reef feature is much larger than what could be surveyed with one deployment of the AquaMap. In 2005, in an effort to extend the area of knowledge around this large reef tract, an adjacent Bird Key North (BKN) study site was added to the north of the existing SFCN Bird Key study site. The site was mapped with similar characteristics as the existing Bird Key site, and is 25,642 square meters (6.3 ac) in size. Twenty permanent, 10-meter transects were established and sampled beginning in 2005 with annual monitoring occurring through 2011. However in 2012, to free up resources to expand monitoring in Loggerhead Forest and Santa's Village reefs, the network discontinued BKN benthic monitoring.

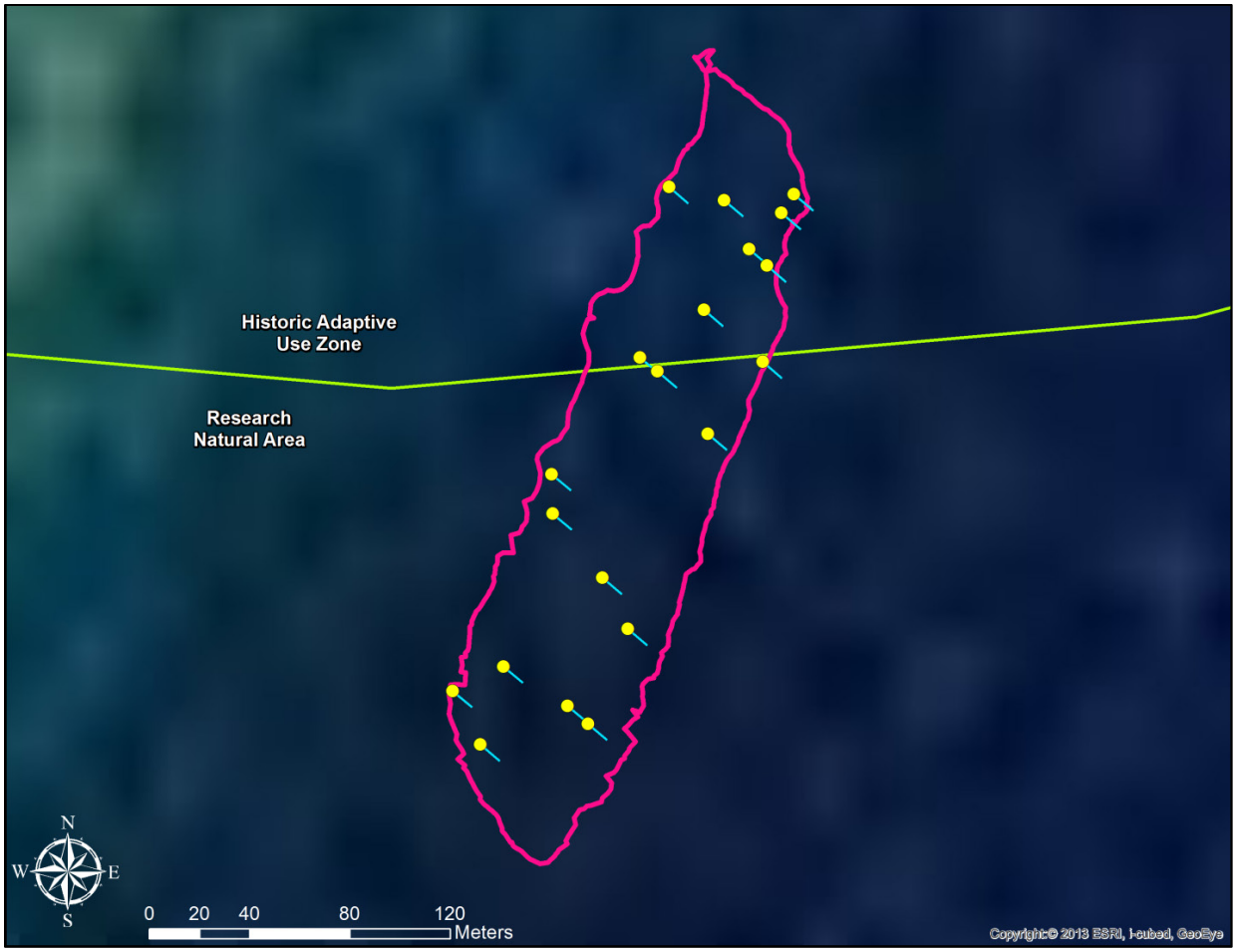


Figure 8. Expanded map of Bird Key Reef (BK) site in DRTO in relation to the Research Natural Area and Historic Adaptive Use Zone. SFCN sample transects are shown as blue lines with yellow start pins. Length of transect and location within polygon are approximate due to conversion errors from a 3D AquaMap SONAR system to a 2D GIS system.

- The "2 stage extensive sub-sites" approach was used to select and monitor four-transect sub-sites inside and outside the new RNA in DRTO. The desired sampling frame was coral reef communities between 2–20 meters (6.5–65.6 ft) depth, with greater than 5% stony coral cover inside and outside the RNA. To accomplish this goal:
    - First, a 40 × 40 meter (131.2 ×131.2 ft) grid was overlaid on the 1998 NOAA benthic habitat map of Florida Keys and Biscayne Bay (restricted first to DRTO boundaries) and grid cells were labeled with the habitat category that comprised at least 50% of the area in that cell. Cells were further restricted using bathymetry to depths between 2–20 meters (6.5–65.6 ft) to ensure boat and diver safety. As the accuracy of hardbottom habitat mapping categories was unknown at first, all cells in the park that had greater than 50% hardbottom habitat were initially included in the sampling frame, plus the "Coral Patches in Bare Sand" and "Unknown" categories, as it was uncertain whether they contained enough hardbottom habitat to warrant inclusion. Site selection was accomplished using the program S-DRAW to provide a Generalized Random Tessellation Stratified (GRTS) Sampling Design (Stevens and

Olsen 2004). A GRTS sampling design provides a random, yet spatially balanced sampling design while maintaining flexibility for future sampling effort changes. The sample draw was performed separately inside the RNA and outside the RNA. 500 sites were selected in both areas to allow for sites to be dropped if some mapped habitat classes were determined to be unsuitable.

- Three rounds of sampling were conducted in May, June, and August 2007 using the Rapid Habitat Assessment procedure (see SOP 8) in which four 20-meter (65.6 ft) line-intercept transects were laid out North, South, East, and West from a central point and the benthos identified every 0.5 meter (1.6 ft). Differences between the initial procedures and the current SOP 8 include a recommendation to sample points every 0.25 meter (0.8 ft) and to secure the transect ends before proceeding with identification. These revisions will reduce variability in the estimates.
- During round two and three of RHA sampling, all grid cells labeled as "Coral patches in Bare Sand" and "Unknown" were dropped from further sampling as they were determined in the first round to be primarily sand habitat.
- Sampling continued until nine extensive sub-sites per stratum were located that met the pre-defined sampling frame criteria (a preliminary sample size analysis had suggested nine extensive sub-sites as a conservative approach). Over 75% of the sampled sites did not meet the initial sampling frame criteria, e.g., at least 50% hardbottom, 5% live stony coral cover, between 2–20 meter (6.5–65.6 ft) depth, and safe to sample. In addition, some areas of the park had a greater probability of an extensive sub-site being "accepted" as part of the sampling frame than others. As a consequence of this analysis, it is recommended to use a simple random design error structure rather than a GRTS error structure as it is no longer clear that a true spatial balance was maintained. However, the randomness of the selection was maintained.
- The 18 extensive sub-sites were installed using procedures described in SOP 9 and monitored annually from 2008–2012.
- After four years of very low coral cover values obtained using the videography method (less than 2% stony coral cover) the following five extensive sub-sites were discontinued from annual monitoring: O-12, O-27, O-92, I-33, and I-63. Areas of less than 2-3% cover have lower power to detect changes using videography and were not part of the initial described sample frame for Dry Tortugas NP. *NOTE: It was determined that the RHA method tends to estimate higher coral cover values than the videography method (on average 3%) and this difference should be accounted for in future applications of this approach. The power analysis described in the previous section suggested that the remaining sites will provide sufficient power to detect trends.*
- Beginning in 2012, the remaining 13 extensive sub-sites will be resampled every three years (See Figure 9).

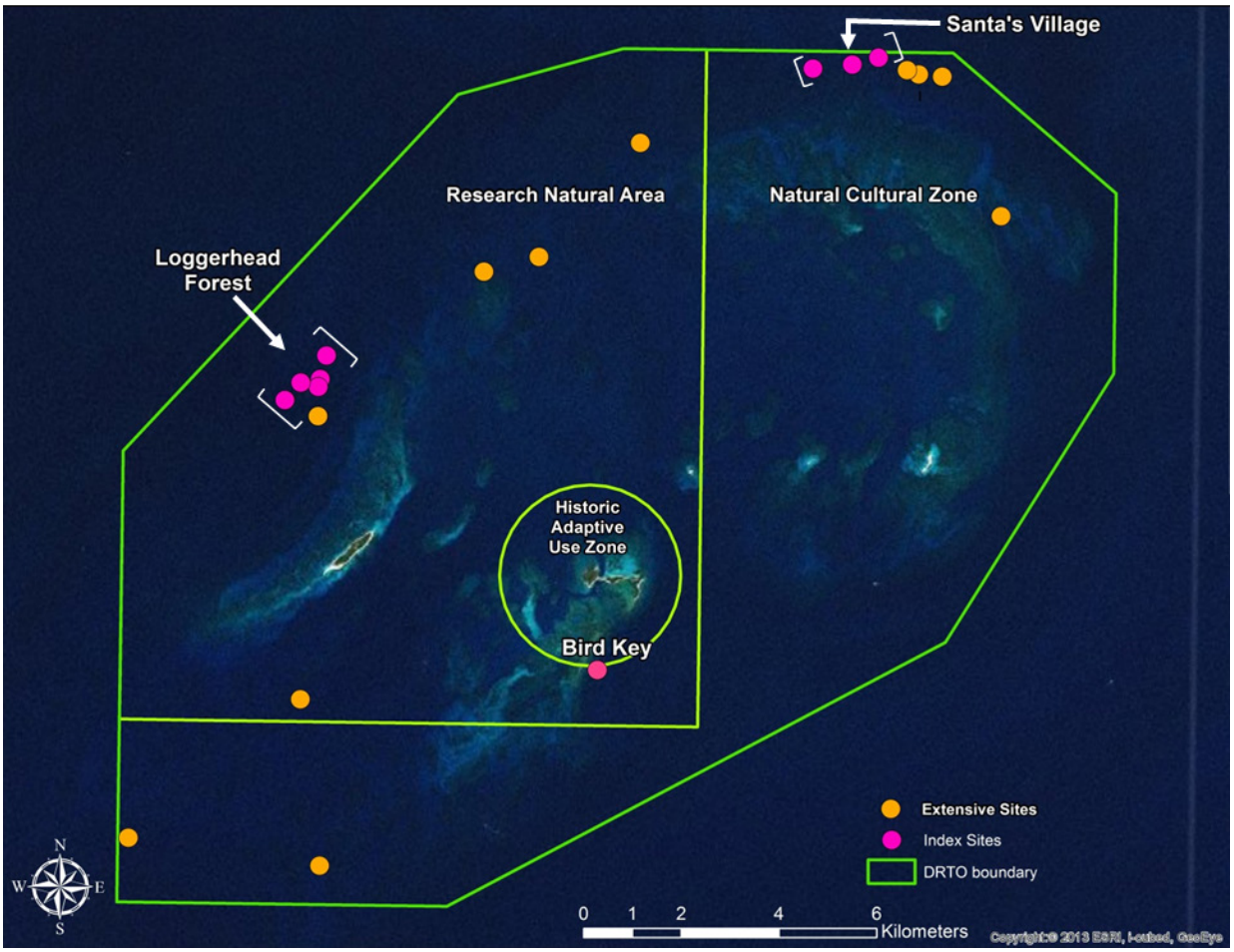


Figure 9. Dry Tortugas National Park, the location of the SFCN index sites, and the boundaries of the Research Natural Area and Historic Adaptive Use Zone.

Loggerhead Forest and Santa's Village Index Sites were added in 2012 based on the improved Dry Tortugas NP Benthic Habitat map (Waara et al. 2011). This map identified features that were previously undefined, but proved to be extensive reef terrace communities with high coral cover, diversity, and complexity within the depth range of 15–20 meters (49.2–65.6 ft; see Figure 9–11). Therefore, the extensive sample design was expanded to include well-developed reef habitat in the northern part of the park (sites called Santa's Village), and expanded the boundaries of reef terrace habitat known as Loggerhead Forest. Three sites (four transects each) were added in Loggerhead forest (LH1, LH2, LH3) and two were added in the northern reef (SV1, SV2). Monitoring is conducted at these sites annually. LH-04 and LH-05 sites (originally labeled I-50 and I-05 respectively) are analyzed as part of the Loggerhead Forest sites as well as part of the Inside-RNA sites.



Figure 10. *Orbicella* spp. dominated reef terrace at Loggerhead Forest (Photo credit: Rob Waara).

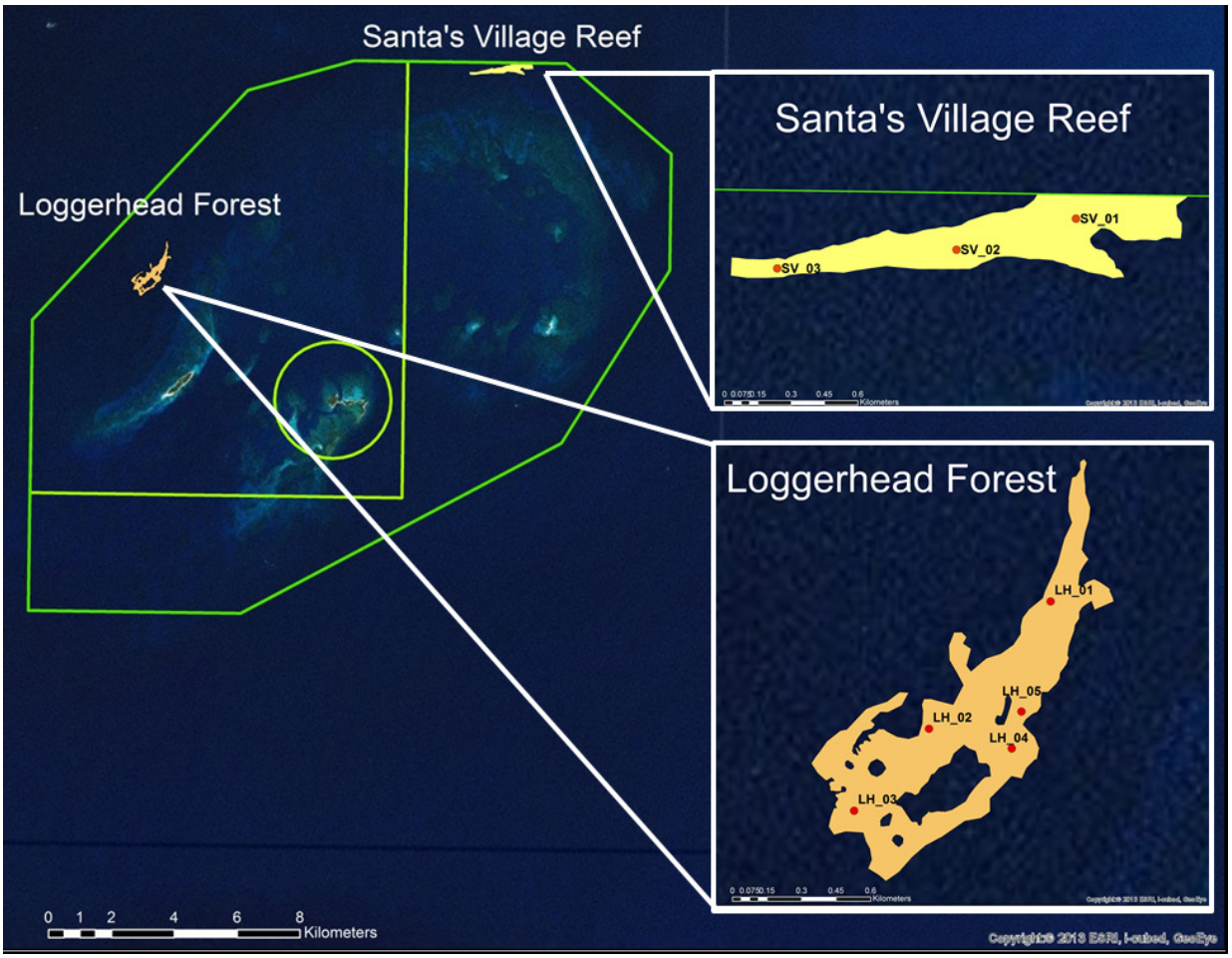


Figure 11. Loggerhead Forest and Santa's Village delineated reefs and sub-sites added for monitoring in 2012.

Salt River Bay National Historical Park and Ecological Preserve (SARI)

Created in 1992, this 1,015 acre (410.8 ha) park is jointly managed by the National Park Service and Government of the Virgin Islands, Department of Planning and Natural Resources (DPNR). It contains some of the largest remaining mangrove forests in the Virgin Islands (Kendall et al. 2005) as well as well-developed coral reefs and a unique marine feature, the submarine canyon. The South Florida/Caribbean Network began benthic monitoring in Salt River Bay NHP&EP in 2012. Three polygons were identified from aerial imagery and field reconnaissance as habitats of relatively high coral cover, reef complexity, and historical significance: Spur and Groove—16,538 square meters (4.1 ac), West Wall—5,233 square meters (1.3 ac) and East Wall—4,664 square meters (1.2 ac). Given the unique submarine canyon with nearly vertical walls dropping to greater than180 meters (590 ft) within, depths were constrained to less than 33 meters (108.3 ft). The total area from which transects were randomly chosen (26,435 square meters, or 6.5 ac) is consistent with an index site approach. Twenty 10 meter (65.6 ft) transects were allocated, proportional to each polygon area, and randomly placed in each polygon following SOP 7 (Figure 12). Sampling followed the SOPs 1–6 described in this protocol.

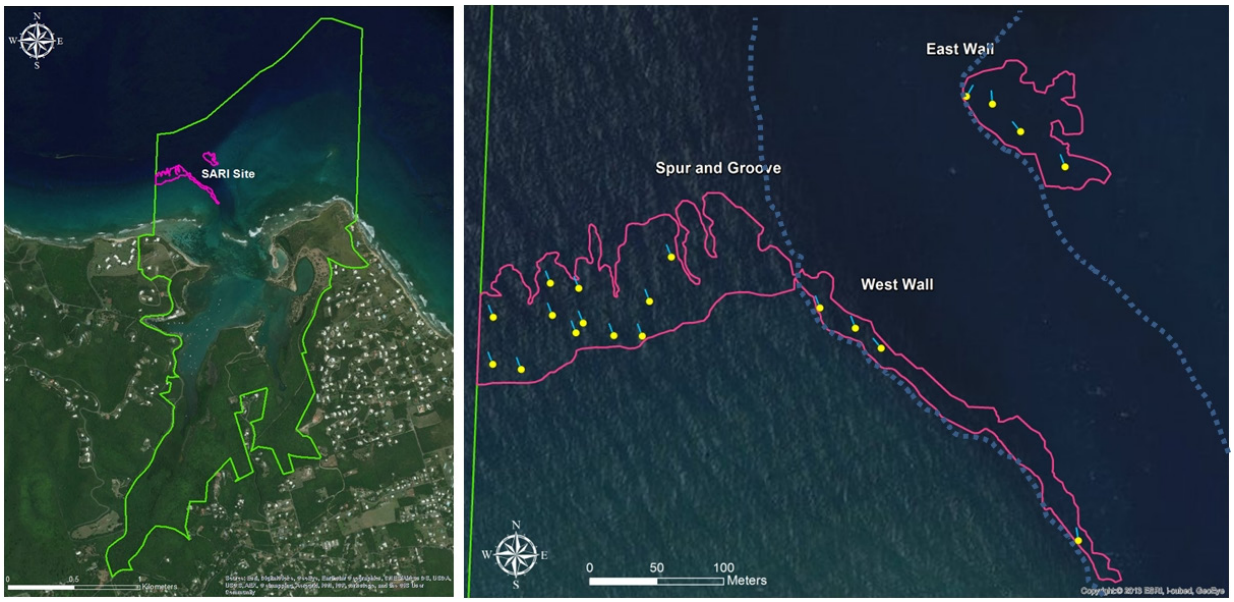


Figure 12. Outline of SARI on St. Croix, US Virgin Islands with break-out map showing the details of the three polygons (Spur and Groove, West and East Walls) that combined constitute the SARI index monitoring site (SR). SFCN sample transects are shown as blue lines with yellow start pin locations. (The submarine canyon is highlighted by the dashed blue line in the right picture.)

Virgin Islands Coral Reef National Monument (VICR)

VICR reefs are not currently monitored by SFCN since this park was established in 2001 after the formation of this I&M network.

Field Methods

Field monitoring is conducted throughout the year at SFCN parks (see annual monitoring schedule header "Timing" Table 1). Before monitoring in the park, SFCN marine team staff makes contact with the host park Resource Management division to coordinate the upcoming activities. Through agreements reached at SFCN Science and Technical Committee/Board of Director Meetings, monitoring activities described within this protocol do not require NPS Research permits. Salt River Bay NHP & EP is co-managed between the National Park Service and the US Virgin Islands Department of Planning and Natural Resources (DPNR) and as such, a research permit for establishing the monitoring site was obtained from the VI Government, Division of Fish and Wildlife prior to the start of field work. (http://dpnr.vi.gov/).

In preparation for field monitoring, all participants will review and follow procedures outlined in this narrative and all attached SOPs, appendices and data sheets. If water temperature data are to be collected during benthic monitoring, participants will review and follow procedures outlined in the Coral Reef Water Temperature Monitoring Protocol (Davis et al. 2013). All divers participating in monitoring will review and follow policies found in Reference Manual #4—Diving Management (RM-4) and submit applicable plans (e.g., float and dive plans). All participants will be briefed on their roles and responsibilities before going out in the field, and be qualified and competent in completing those tasks.

At least two people are required to conduct benthic monitoring, but more people can be used to facilitate data collection. Checklists for each field SOP are contained in Appendix G. The fieldwork flow begins with finding pins and laying and confirming the location of the transect. At an extensive sub-site, typically the four transect tapes are laid before filming and data collection begins. At an index site, one transect tape is laid, all data is collected, at which time the transect tape is rolled up and the team navigates to the next transect.

The two person dive team begins data collection with one diver filming the transect, while the second diver collects disease, coral species lists, *Diadema* and colony counts. The diver filming may collect any of these data depending upon abilities, and timing to expedite completion. When rugosity is scheduled to be measured, divers perform this activity together. Water temperature data is collected as described by Davis et al. 2013. All diver assignments are reviewed as part of the pre-dive plan. Variations in air consumption or benthic conditions (e.g., currents, disease outbreaks, etc.) require divers to communicate effectively to be assured all data has been collected before removing a transect tape from the bottom.

Nine SOPs were written to guide the user through benthic data collection. A brief overview of each is provided below and detailed in the SOP section of this protocol.

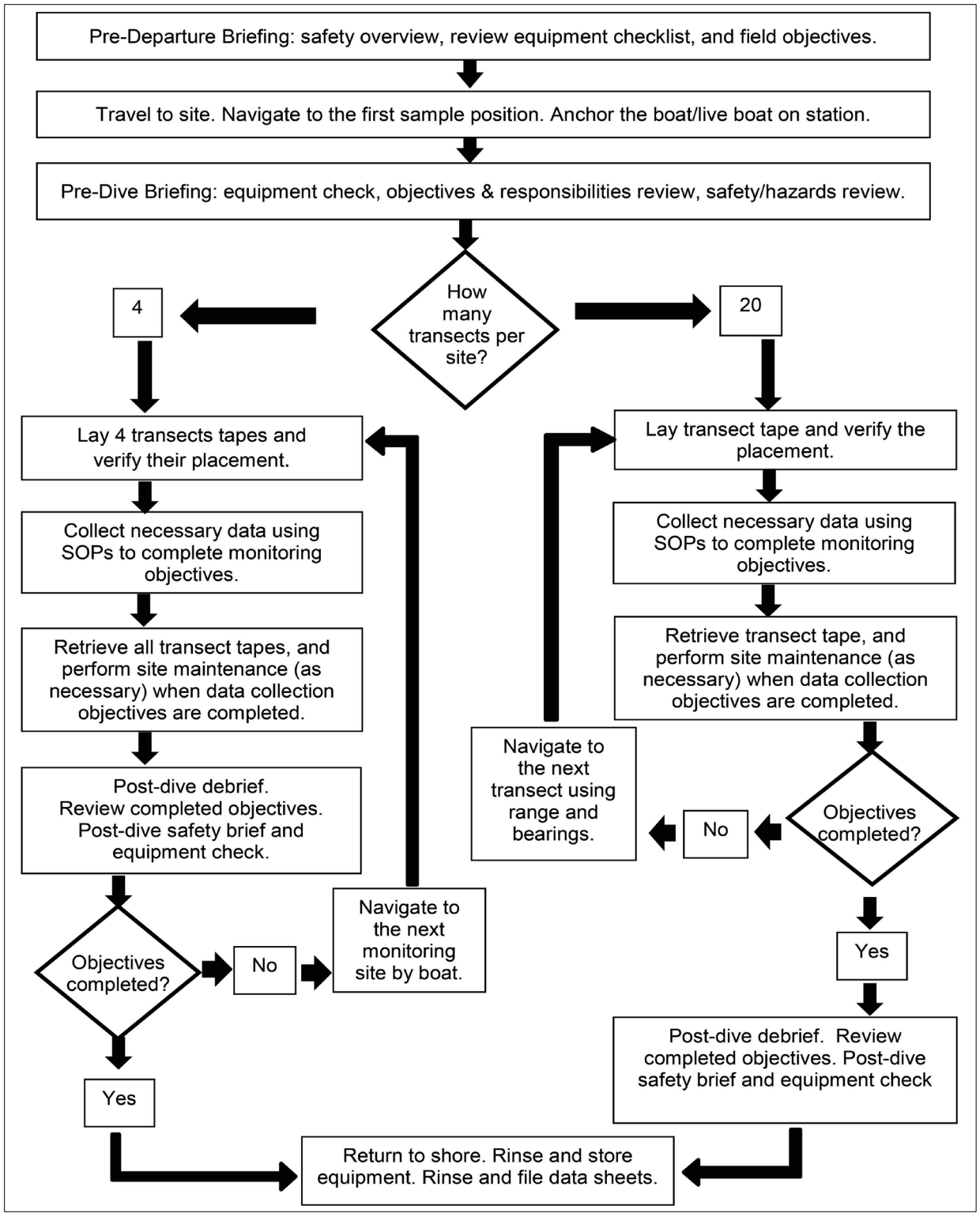


Figure 13. Diagram of field operations steps.

Overview of Field SOPs

Listed below are overviews of the nine SOPs that are used when conducting the field portion of this protocol. The detailed steps are within the SOPs in *Coral Reef Monitoring: Standard Operating Procedures*(South Florida/Caribbean Network 2017).

SOP 1. Videography to Monitor Coral Reefs

As mentioned above, videography monitoring was selected over the chain transect method because comparisons between the methods showed that the coral data were comparable; the video monitoring method did not require touching the corals, thus minimizing risk of damaging the resource; the video can be archived creating a permanent visual record; video requires less dive-time; because the corals are identified on the videotape in the office, the level of coral expertise required by the field crew is reduced; and error-checking of coral species identification is possible.

Given the constraints of scuba diving, photography provides the most practical means of sampling large areas underwater. A proficient videographer can obtain large amounts of data with little or no impact to the surrounding resource. However, a diver needs to be adept at buoyancy control to produce quality video images.

Since the development of this method, video technology has progressed from analog video, to digital video (DV) to high-definition video (HDV). The network switched from DV to HDV in 2008 based on a year comparison with DV (see Appendix E for details of HDV/DV comparison). Whichever format is selected, the objectives remain the same; however, the exact details of the camera preparation and settings may differ. The advent and refinement of digital still cameras in the past decade has added yet another option. The SOPs attached provide a step by step outline for using video equipment, underwater housings, computers, and software that are both commonly available and affordable.

For this protocol, the diver uses a digital video camera fitted with a wide-angle lens and an underwater housing. The diver videotapes while swimming slowly (~30 seconds per meter) along the transect holding the camera perpendicular to the substratum from a height of ~40 centimeters (15.8 in), producing a “swath” or belt transect that is ~40 centimeters (15.8 in) wide.

The videotape is viewed to make sure that the clarity and resolution are satisfactory, then catalogued to archive the raw footage. A computer is connected to either the camera or a separate videotape player and the tape is played to "capture" 30–35 (HDV) adjacent, non-overlapping frames as still images. In this way, each transect is depicted by a number of unique frames, or video “quadrats," which are converted to photo files and saved in a computer folder. Ten random dots are placed on each frame during a process that uses Adobe Photoshop. After the images have been processed (dotted), an analyst identifies the benthic components under the random dots while viewing the frames in Adobe Photoshop. The resulting 300-350 (HDV) points per transect are identified and used to calculate percent cover of substratum categories. Additionally, special coral conditions are identified when occurring under dots (e.g., four different severity levels of bleaching or coral diseases) for quantification within transects and sites.

SOP 2. Counting Long-Spined Sea Urchin, Diadema antillarum, on Coral Reefs

The abundance of *Diadema antillarum* are monitored along each transect. This invertebrate is a significant marine herbivore and can have substantial effects on the macroalgal cover on coral reefs. Abundant macroalgal cover interferes with larval settlement, thus inhibiting the coral recruitment process. During the 1980's, this sea urchin suffered Caribbean-wide mortality at levels approaching 90% (Lessios et al. 1984). Recent information suggests numbers of *Diadema* are increasing (e.g., Edmunds and Carpenter 2001). Using this procedure, the number of all long-spined sea urchins, *Diadema antillarum* (adult and juvenile) found within 1 meter (3.3 ft) on both sides of the sample transect are counted when the transects are filmed. The data will be used to look for associations between *Diadema* recovery and cover by algae and other benthic organisms.

SOP 3. Measuring Coral Disease

Coral diseases can have devastating effects on coral reef communities (Rogers and Miller 2013). Pathogenesis for most coral diseases are still unknown, so field observations remain the most effective way of documenting coral diseases. Identification of the type of disease, measurements and digital photographs are taken of disease "lesions," bright white areas of coral skeleton (recently killed = not encrusted with any algae, turf or otherwise) within 1 meter (3.3 ft) on both sides of the sample transect. Diseased coral tissue or mucous sampling is not covered under this SOP and is not included in this protocol.

Coral disease on corals that occupy one meter (3.3 ft) on either side of the video transect is photographed and described during each sampling event. The following are recorded:

- Type of coral disease
- Coral species affected
- Location along transect
- Approximate distance from transect
- Maximum length of recent disease lesion
- Maximum dimension perpendicular to measurement above

SOP 4. Conducting Coral Colony Count

Another widely used measure of disease is prevalence; defined as the percent of diseased individuals in a population at a point in time (Stedman 1976). Thus, the "population" needs to be determined first, in order to calculate this value. Coral morphology, reproductive strategy (asexual reproduction), and the ability to fragment and have partial mortality all complicate the calculation of individuals within a given population (reef or transect) (Rogers 2010). This SOP details a standardized approach for counting coral colonies greater than 4 centimeters (1.6 in) along a transect. It is not the only method to conduct a colony count; however by using this standardized SOP, we reduce variability and produce a population value consistent over time.

SOP 5. Collecting Coral Species Diversity Data on Benthic Transects

Evaluating the long term presence (or absence) of coral species provide vital information to managers regarding the conditions of park reefs. Especially critical is the tracking of species that are

listed as Threatened or Endangered under the US Endangered Species Act. This SOP details the method for creating a scleractinian coral species list on the transects as part of this protocol. Standardizing this procedure allows greater precision in occupancy measures and increases that ability of the protocol to provide species-specific change information.

SOP 6. Measuring Rugosity on Coral Reefs

Coral reefs are three dimensional structures. The overall structure of the reef supports a high diversity of fishes and other organisms which depend on it for shelter, food, etc. (Connell et al. 1997). Generally, greater reef structure equates to higher numbers of fishes (Friedlander and Parrish 1998) and mobile invertebrates (Aronson et al. 1994; Rogers et al. 1997). Changes in the structure can occur through long-term growth of the corals, hurricane damage and coral colony movement ("bowling ball" effect), ocean acidification, visitation damage (anchors, kicking reefs), and erosion, as areas no longer covered by live coral tissue are gradually lost.

Rugosity measures of each transect are taken once every five years or after a major event such as a hurricane or ship grounding. The diver takes a lightweight chain and lays it along the transect, following the bottom hard structure. The length of chain required divided by10 meters straight length is the measure of rugosity.

SOP 7. Selecting and Locating Random Sampling Points using GPS

This SOP was developed to augment the transect selection at an Index Site. After 2008, with the advent of improved benthic maps, and increased accuracy of GPS, this is now the primary procedure used. In such cases, a handheld GPS unit in a waterproof container can be used by a snorkeler or a diver on the surface in much the same way the AquaMap™ system works underwater. (Note that even the slightest film of water over the antenna portion of the GPS unit will disrupt satellite reception.) The surface person can swim the perimeter of the index site to obtain the bounds and record that track in the GPS unit. In the office, using ArcGIS™ or similar software, scripts can be used to meet the objectives of the random sample selection design including:

- calculate the site area in square meters,
- define the population of sample points within that site,
- randomly select a number of points from that population, and then
- create a range and bearing between selected sampling points
- locate those points during initial and subsequent sample events.

Accuracy is another factor to be considered with this procedure. Fixing a location on the surface may not translate simply to an exact location even a few feet underwater. Range and bearings calculated in ArcView™ or similar software will contain error, and the precise navigation underwater is not easily accomplished. Rough sea states, current, surge, and poor visibility (above and below water) can complicate this procedure and compromise safety rapidly. However, given appropriate conditions and with user experience, an index site can be successfully sampled following this SOP.

For RHAs and extensive sub-sites, GPS units are used to locate/relocate points. The potential sample points should be uploaded onto a handheld GPS unit and/or the GPS unit on the boat. To find the point, the field team should navigate the boat as close to the point as possible, ideally no more than 10 feet (3 m) from the point, and lower a soft-weighted line attached to a cave reel and float to mark the point. Divers should tie off transects for the RHA as close to the weight as possible.

SOP 8. Conducting Rapid Habitat Assessments

Rapid Habitat Assessments (RHAs) are designed to provide rapid and quantitative information about the benthic composition of a large number of sites. They are used to rapidly investigate an area for inclusion in either the index site with large well-defined boundaries or extensive sub-site approach. RHAs are conducted using four 20 meter (65.6 ft) transects laid in cardinal directions. Divers record benthic cover every 0.25 meter (0.8 ft; Note: 0.5 meter [1.6 ft] was initially used in Dry Tortugas NP but was changed to the 0.25 meter interval to provide more data) using the point intercept method noting the species/group that occupies the benthos directly under the transect tape, for a total of 320 points.

RHAs are expected to perform best when characterizing moderate to high coral cover reefs; at low coral cover, small numerical changes in the number of points of live coral can lead to large changes in the calculated percent cover. For example, even when recording points every 0.25m (320 points in 4 transects), recording an additional 4 points of live coral will add greater than 1% coral to the total, which can signify a difference of 33% for a 3% live coral cover site.

SOP 9. Installing Monitoring sites

This SOP describes the procedures for installing extensive and index sites including the in-water selection criteria for the transects (greater than 50% hardbottom), installation of the transect start and end pins within the extensive or index sites, creation of range and bearing tables, and creation of site maps.

Videography Analysis Procedures

This protocol uses a form of remote sensing where HD video is collected in the field, then manipulated before data collection can begin. Steps involved in this process and discussed in the SOPs10–12 include: transfer video to computer, capture, dot, rename, and store images, archive video and images, and enter sample event and data entry placeholders into database. At this point, image analysis and data entry can begin. Data and pictures associated with coral disease are renamed, stored and linked to the software program, ThumbsPlus. Image processing, analysis, and data entry take place at the analyst computer workstation with video, images and data ultimately being stored on a server. Brief overviews of SOPs 10–12 that detail these processes are provided below.

SOP 10. Video and Image Transfer, Capture, Catalog and Burning to a Blu-Ray Disk

During the sampling year 2008 the network integrated the use of HD video cameras, replacing the DV cameras. This SOP details the procedures to be used to transfer the HD video tape to the server/computer workstation, then catalog and capture the images (in HD) from that video. Users must follow all settings in the SOP to assure true high-definition images are captured for dotting and

analysis. Projects are created in Adobe Premiere to display and allow capture of the images. Procedures for archiving the transferred HD video to Blu-Ray disks are also described in this SOP.

SOP 11. Dotting Captured Images with Adobe Photoshop Script

This SOP describes how to use an Adobe Photoshop script to apply dots to the captured HD images in Adobe Photoshop. The script (written in javascript), uses the original (Source) BMP image, applies a layer of 10 randomly-placed, hollow squares (aka: "dots"- labeled A-J) upon the original (Source) image, then flattens the layers together, eventually saving the dotted image as a JPG of the same name (as the Source) but stored in a separate transect folder. The script gives the user options to run automated image adjustments (adding red tones) with the level of that adjustment selected by the user based on the depth of the transects. The script has been tested to work in Adobe Photoshop CS2, CS3, CS4, and CC. However, as Adobe Photoshop evolves, continued vigilance is needed to assure compatibility and true HD quality image flow-through with subsequent versions.

SOP 12. Conducting Analysis of HD Images

This SOP details the programs and steps necessary to analyze the captured and dotted HD images. The analyst views dotted HD images (displayed in Adobe Photoshop CS4 on a HD computer monitor) and enters codes for substrate identified under the "dots" into a second computer monitor screen displaying a data entry form for the CoralVideo Database (displayed in Microsoft Access). Additionally displayed on the second monitor is the Adobe Premiere CS3 project containing the video and positioned to the transect where the analysis is taking place. In this manner, the analyst may obtain views of the benthic area surrounding a "dot" to provide cues or context from which to make the benthic identification. The steps outlined in this procedure help ensure consistency among analysts.

Data Assimilation, Analysis and Reporting

Overview of Data Life Cycle

The coral monitoring data has a complicated data life that involves two separate databases and three data entry portals. Figure 14 describes the data life cycle while Table 2 provides an overview of the file storage locations and naming conventions. A third database exists for the rapid habitat assessment data collected during the sampling design phase of the protocol.

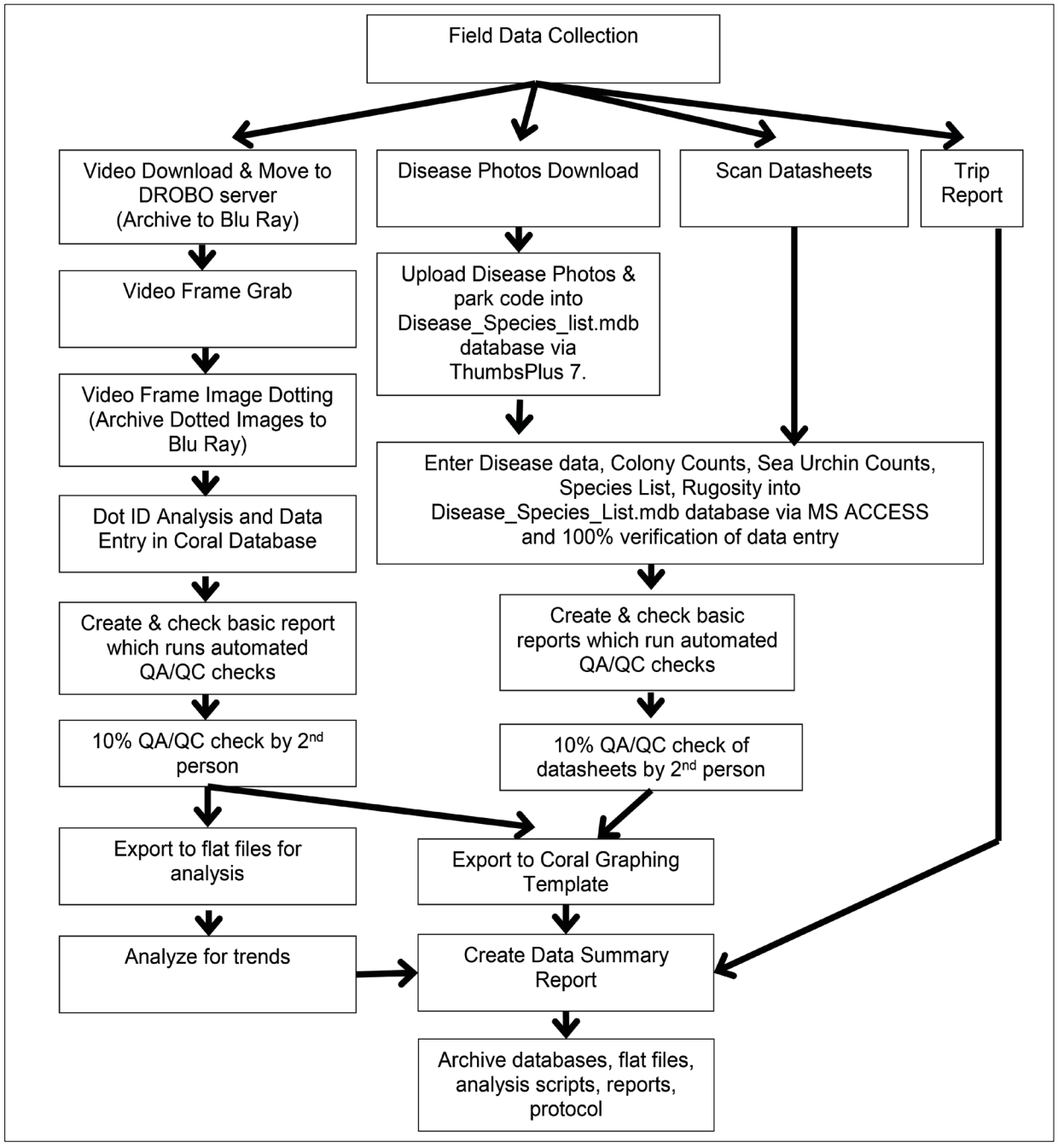


Figure 14. Data life cycle.

Table 2. Storage locations for SFCN datasheets, photos, video, data, analysis scripts, exports, and reports.

Category	File Type	Folder	Filename
Field Files	Blank Field Datasheets Disease/Diadema/Rugosity Colony Count/Species List RHA Habitat w/transect	…\documents\Field_Documents\Datasheet_templates	DDR template.pdf Colony_count_&_spp_list_template.pdf RHA_Datasheet_with_Transect.pdf
	Site maps	…\documents\Field_Documents\PARK\Site_Maps\	Park_Site.pdf
	Range and bearing tables	…\documents\Field_Documents\PARK\Site_Maps\	Park_Site_RB.pdf
	Relocation photos	…\documents\Field_Documents\PARK\Relocation_Photos\	Park_Site_Transect.pub
	Waypoint Files to Sites	…\documents\Field_Documents\PARK\Garmin_Waypoints\	Park.gdb
	Equipment Checklist	…\documents\Field_Documents\	Equipment_Checklist.docx
	Field Return Checklist	…\documents\Field_Documents\	Field_Return_Checklist.docx
Raw Data Storage & Video Analysis	Trip reports	…\documents\trip_reports\YYYY\	Park_Year_TripReport.docx
	Scanned Data Sheets	…\data\scanned_dataSheets\PARK\	Park_Year_DataSheetType.pdf
	Photos - Disease	...\images\disease\PARK\Site\YYYY\Disease_pics\	YYYYMM_Park_T##_dis##.jpg
	Photos - Other	...\images\disease\PARK\Site\YYYY\Misc_pics\	YYYYMM_PARK_T##_Desc.jpg
	Video Files – Initial	Local hard drive	YYYYMMDD_PARK_SITE(s).mpeg;
	Video Files - Analysis	DROBO\Video\PARK_Sitetype\YYYYMM_annual\SITE_HDV\	YYYYMMDD_PARK_SITE_Tape_1.mpeg
	Video Files - Archive	Blue Ray Disks & Tapes stored in SFCN Conference Room	--
	Dotting scripts	…\images\general\tools\	SFCN_Dotting_Script_v1.5.jsx
	Frame Grab - Archive	…\images\PARK_Sitetype\YYYYMM_annual\archive\SITE\	Tran_Site_YYYYMM_HD_Frame.bmp
	Frame Dotting - Destination	…\images\PARK_Sitetype\YYYYMM_annual\destination\SITE\Tran_Site_YYYYMM	Tran_Site_YYYYMM_HD_Frame.jpg
	Frame Dotting - Archive	Blue Ray Disks stored in SFCN Conference Room	--

Table 2 (continued). Storage locations for SFCN datasheets, photos, video, data, analysis scripts, exports, and reports.

Category	File Type	Folder	Filename
Databases	Coral	…\data\	SFCN_CoralVideo.mdb
	Disease/Sp/Diadema/Rug/Col Ct	…\data\	SFCN_CoralDisease_Species_List.mdb
	RHA - Database	…\data\	RHA_Sites.mdb
	RHA - LPI transect data entry form	…\data\	RHA.xls
Data Summaries	Exports – Coral all parks	…\data\Exports\csv\	Site_export.csv, Transect_export.csv, Bleaching_export.csv
	Exports - Disease/Sp/Diadema/ Rug/Col Ct, all parks	…\data\Exports\csv\	Coral_Species.csv, Disease.csv, Diadema.csv, Disease_Prevalence.csv, Rugosity.csv
	Graphing Template – Coral	…\data\Graphs\	CoralGraphTemplate.xlsm
	Analysis scripts	…\Analysis\Annual\Scripts\	*.SAS,
	Data Summary Report Template	…\documents\summaries_&_reports\NRDS\PARK\	--
	Data Summary Reports	…\documents\summaries_&_reports\NRDS\PARK\	PARK_NRDS_Report_YYYY.docx
Other	Protocol	…\documents\protocol\	SFCN_Coral_Protocol.docx, .pdf
	Backup templates, forms, scripts	…\documents\protocol\backups\	--
	Archives – database, protocol, reports, export flat files	Z:\SFCN_Archive\Vital_Signs\Marine_benthic_communities\CoralMonitoring\YYYY\ http://irma.nps.gov	(see above; add _YYYY as needed)

Overview of SFCN Databases

This protocol requires three databases:

- Coral Database
- Disease/Species List/Diadema/Rugosity/Colony Count database
- Rapid Habitat Assessment database

Coral Database

The coral database (Coral_SFCN_GUID.mdb) design is a legacy dataset that was originally designed using the Natural Resource Database Template (NRDT) Phase 2 format. Implementation of any future changes to the database will follow published IMD (NPS Inventory and Monitoring Division) database standards. The current design of the database is shown in Figure 15.

This database contains all videography analysis transect data including:

- Index site transect data
- Extensive sub-site transect data
- Legacy data sets
    - Re-randomized transects pilot data sets
    - Discontinued sites transect data (e.g., BKN)
    - Chain transects (not videography)
- Training data sets for video transects
- QA/QC data for transects

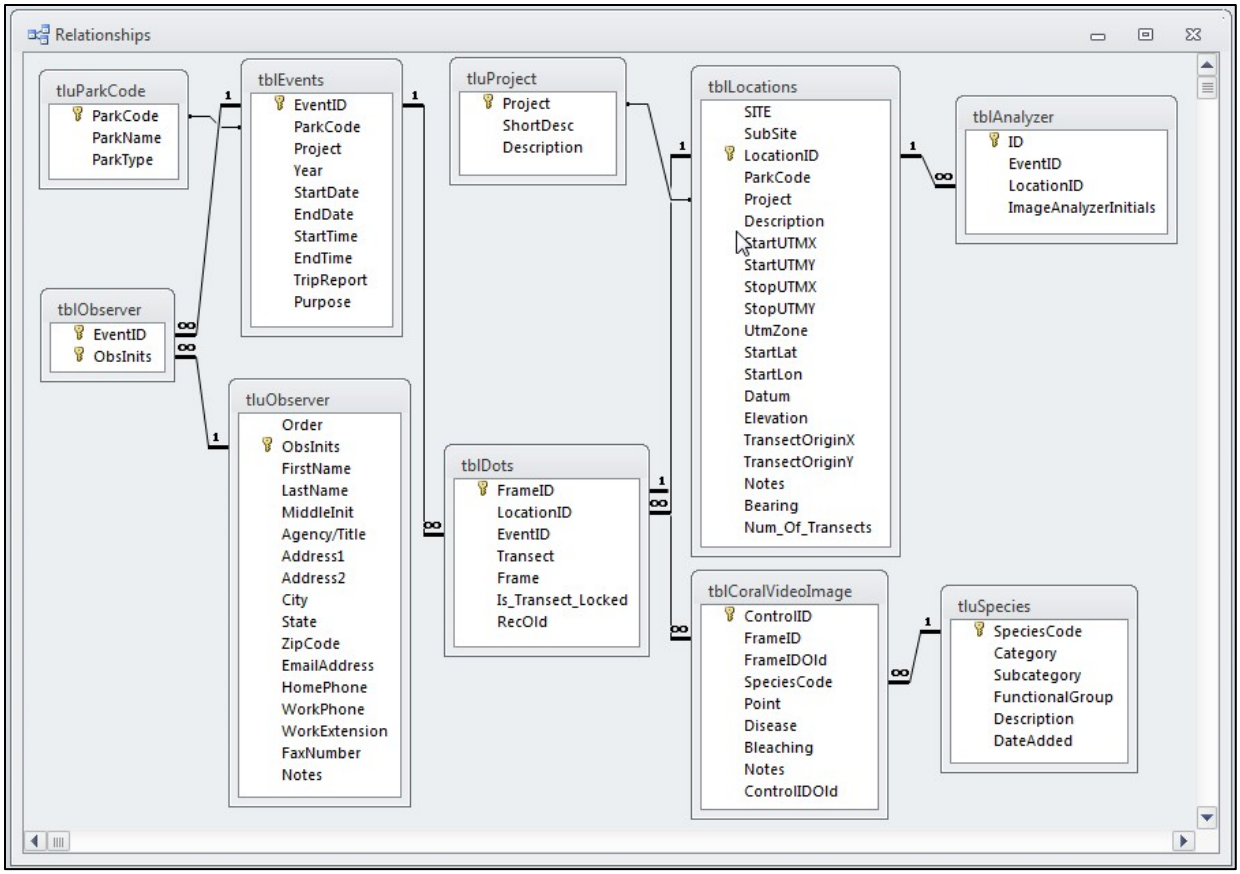


Figure 15. Overview of coral database design.

Disease/Species List/Diadema/Rugosity/Colony Count database

The Disease_Species_List.mdb (Figure 16) database is a Microsft Access database linked to ThumbsPlus 7.0 for the purpose of storing the coral disease photos linked with transect data. The data stored in this database includes:

- Coral disease data with links to photos
- Coral species list
- Coral colony counts
- Sea urchin counts
- Rugosity

Coral disease data is entered via a ThumbsPlus 7.0 interface which allows easy linkage to the relevant photos. The coral species list, coral colony counts, sea urchin counts, and rugosity are entered via data entry forms in Microsoft Access as this allows restricted drop-down lists and additional automated error checking not available in ThumbsPlus.

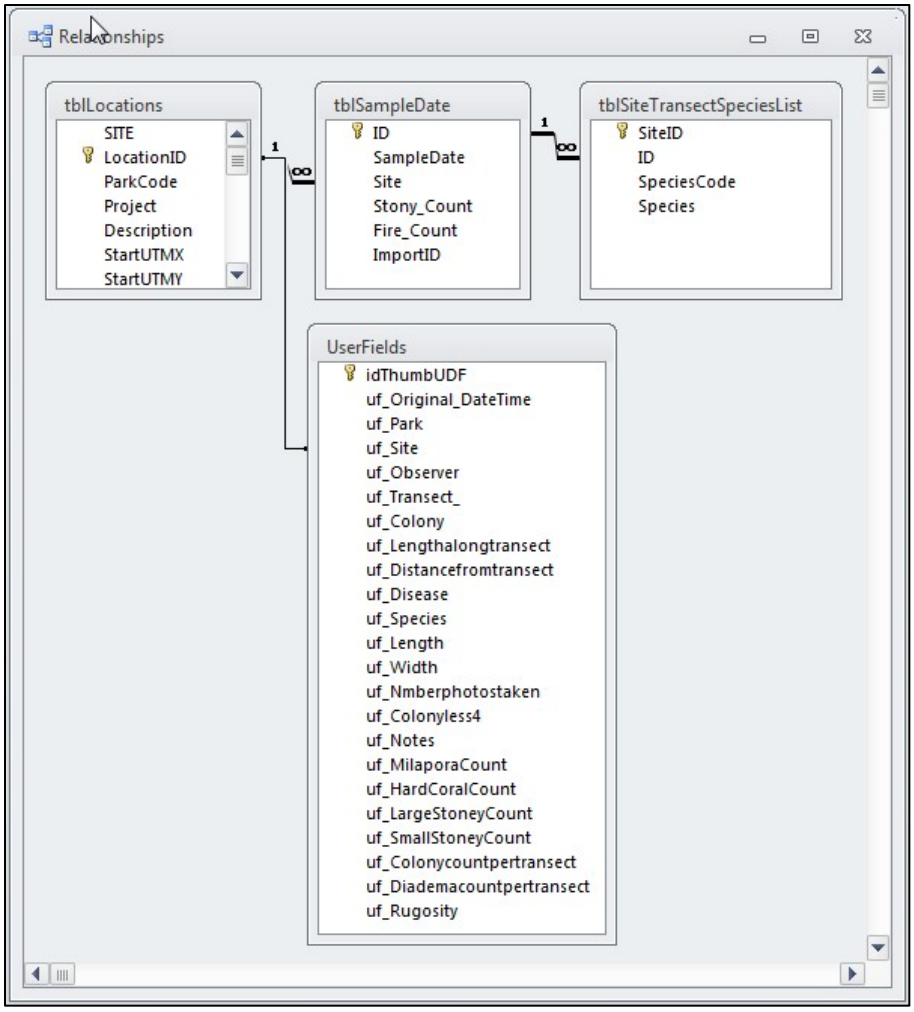


Figure 16. Overview of Disease Database design. This database contains coral disease data and links to photos via ThumbsPlus 7.0, as well as Diadema counts, coral species lists, colony counts, and rugosity.

Rapid Habitat Assessment Database

The Rapid Habitat Assessment database (RHA_Sites.mdb) is a Microsoft Access database that is used during the sampling design phase of the extensive sub-site monitoring design which involves a site exploration phase (Figure 17). This database contains:

- RHA site evaluation data
- RHA line point intercept transect data

Site evaluation data is entered through a form in the database. Once all sampling design is complete, this database will become static. However the data collected from such a wide number of sites has proven useful to other projects such as benthic mapping and distribution of various coral species.

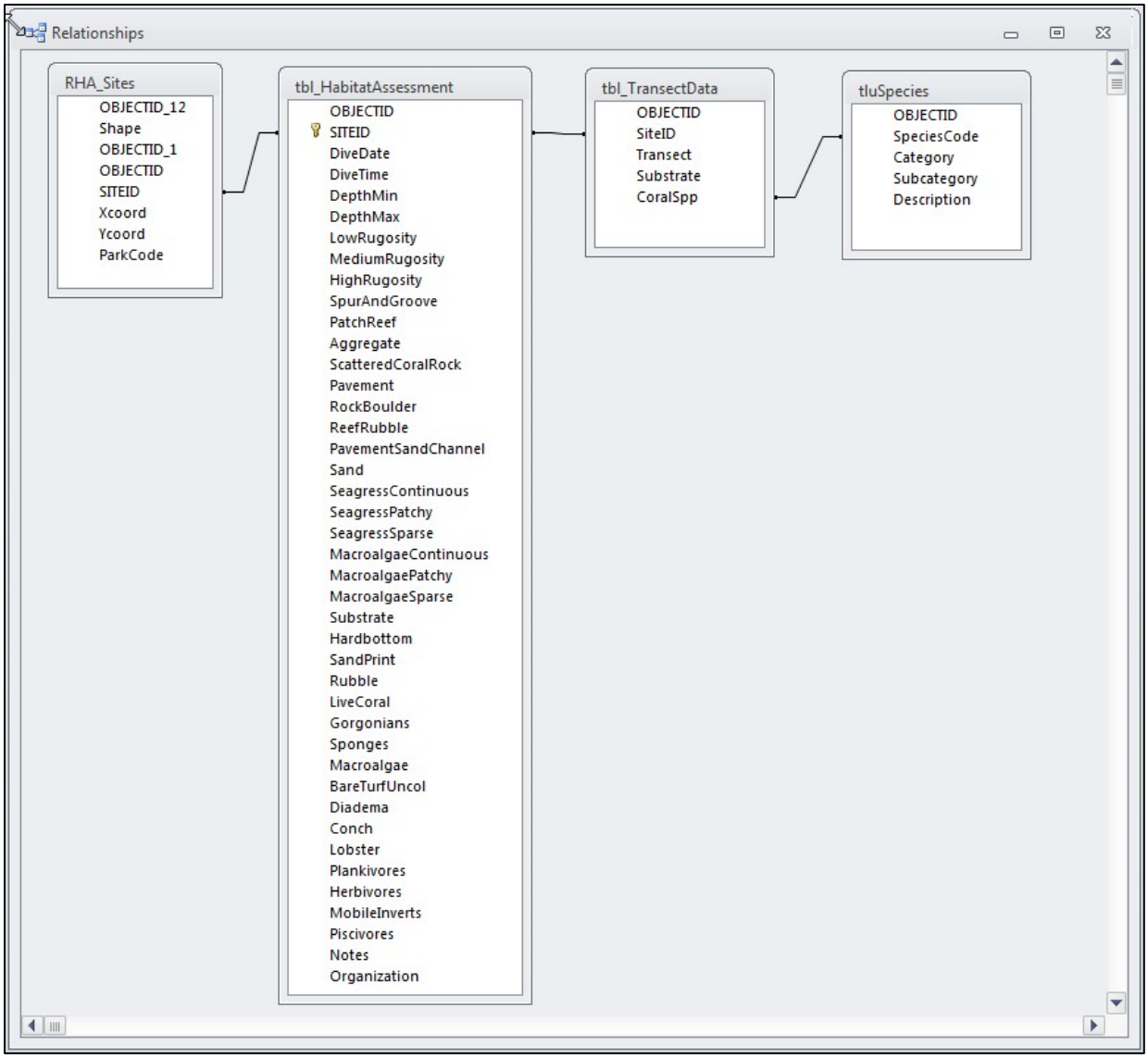


Figure 17. Overview of Rapid Habitat Assessment database design.

Data Entry, Verification and Editing

Eight SOPs (13–18, 20, 21) were written to guide the user through the databases, and describe the methods for entering data from the covariate data sources collected in this protocol. A brief overview of each is provided below. The SOPs are found in *Coral Reef Monitoring: Standard Operating Procedures* (South Florida/Caribbean Network 2017).

SOP 13. Coral Reef Video Transect Database User's Guide

This SOP describes the process of entering data from the coral transects image analysis into the Coral Reef Monitoring Database. The process for creating events, locations, entering the spaces for the data entry within the database then locking (securing) those entries is described. Additionally, information on how the database is structured, including the structure and function of the queries is explained.

The database only allows entry of pre-determined species codes and site codes. Transect number, site names, and sampling date are double-entered both directly and as part of a unique location code and unique event code. This allows cross-verification of entries through automated error checking routines in the database.

SOP 14. Downloading Disease Photos and Uploading into Disease Species List Database

Coral disease monitoring efforts as part of this protocol collect photographic and tabular data documenting the incidents of diseased corals at the sample sites. In an effort to both catalog images and ensure an accurate relationship between the original photo and tabular data collected at the time of monitoring, a program called ThumbsPlus 7.0 is used to upload links to the photos into the Disease_Species_List.mdb MS Access database and create initial records and fill in the park code. Subsequent data entry occurs via MS Access as described in SOP 15.

SOP 15. Entering Disease Data, Coral Species List, Colony Counts, Diadema and Rugosity

Disease data, coral species list data, the abundance of the long-spined sea urchin, *Diadema antillarum*, and the number of scleractinian coral colonies (greater than 4 centimeter [1.6 in]) on each transect are collected on field datasheets as covariates of benthic conditions. These data are entered into the Disease_Species_List MS Access database. Disease photos are linked to their associated data, e.g., transect, sample date, disease type, lesion size, colony number. Additionally, rugosity data (when collected) is entered into this same database.

SOP 16. Capture of Images for Relocation of Transect Using Adobe Premiere CS3

The more precisely the transect can be re-laid each year in the same way, the lower the sampling variance will be. SOP 16 describes the process of capturing images from the video and assembling them on a single laminated page for use underwater to precisely reposition the sample transect tape during subsequent sampling.

SOP 17. Rapid Habitat Assessment Database Data Entry and Verification

The data collected during the sampling design phase using the rapid habitat assessment procedure is stored in the rapid habitat assessment database (rha.mdb). The procedures for data entry and verification are described in SOP 17. This data has proven useful for other projects such as habitat mapping or species distribution mapping and is valuable to retain.

SOP 18. Merging Coral Database and SOP 19. Merging ThumbsPlus Disease_Species_List Database

Data entry into the Coral database (Coral_SFCN_GUID.mdb) and the Disease_Species_List database (Disease_Species_List.mdb) occurs in both the S. Florida office and the USVI office. These SOPs describes the procedures for merging the two copies of these databases. This merge process is conducted at least on a quarterly basis with additional merges being conducted during reporting periods.

SOP 20. QA/QC Procedures

Quality Assurance/Quality Control (QA/QC) evaluations are done at several levels depending upon the type of data generated. Written data (such as rugosity measurements, urchin and coral colony counts, disease observations) receive the following QA/QC checks:

- 100% verification by checking all data entries with information recorded on datasheets.
- 10% check by second observer of data entered.

In the case of video analysis, where data is entered after image interpretation, there are some automated levels of QA/QC checks:

- 100% verification that data is entered for all points on all images,
- 100% verification that data entered is an appropriate benthic code, and
- 100% verification of sites, transects, and dates via the double-entry of these variables into the system,
- 100% verification that coral species codes entered are listed on field coral species diversity list,
- 10% of transects are analyzed by second observer.

Both field data collected on data sheets and video data also have two additional checks:

- Verification that data is entered for all sites, transects, and sampling periods monitored.
- Graphing of data to check for suspicious data (unusual spikes or changes) in an ecological context that may have made it past the above checks.
- If the 10% checks yield errors, these are reviewed by the project leader who determines if there is a systematic problem that must be addressed with training and whether video analysis or data entry must be redone for the site.

SOP 21. Data Summaries and Reporting

- Analysis and reporting involve the following main steps:
- Data are summarized in Microsoft Access and exported into a graphing template (Microsoft Excel) that automatically generates updated graphs and tables for all parks. An Excel graphing template is used as it provides a wider range of users with the ability to modify graphing formats to suit the needs of various presentations/talks/reports/briefs than creating the same graphs in the statistical program R or SAS.
- Site level and transect level *.csv files are exported to allow easy statistical analysis and are coupled with updated metadata to allow sharing with partners.
- Coral cover and other metrics are tested for trends.

Routine annual data summary reports are produced for each park each survey year in the NPS Natural Resource Data Series (NRDS). A sample summary data report template can be found in Appendix K.

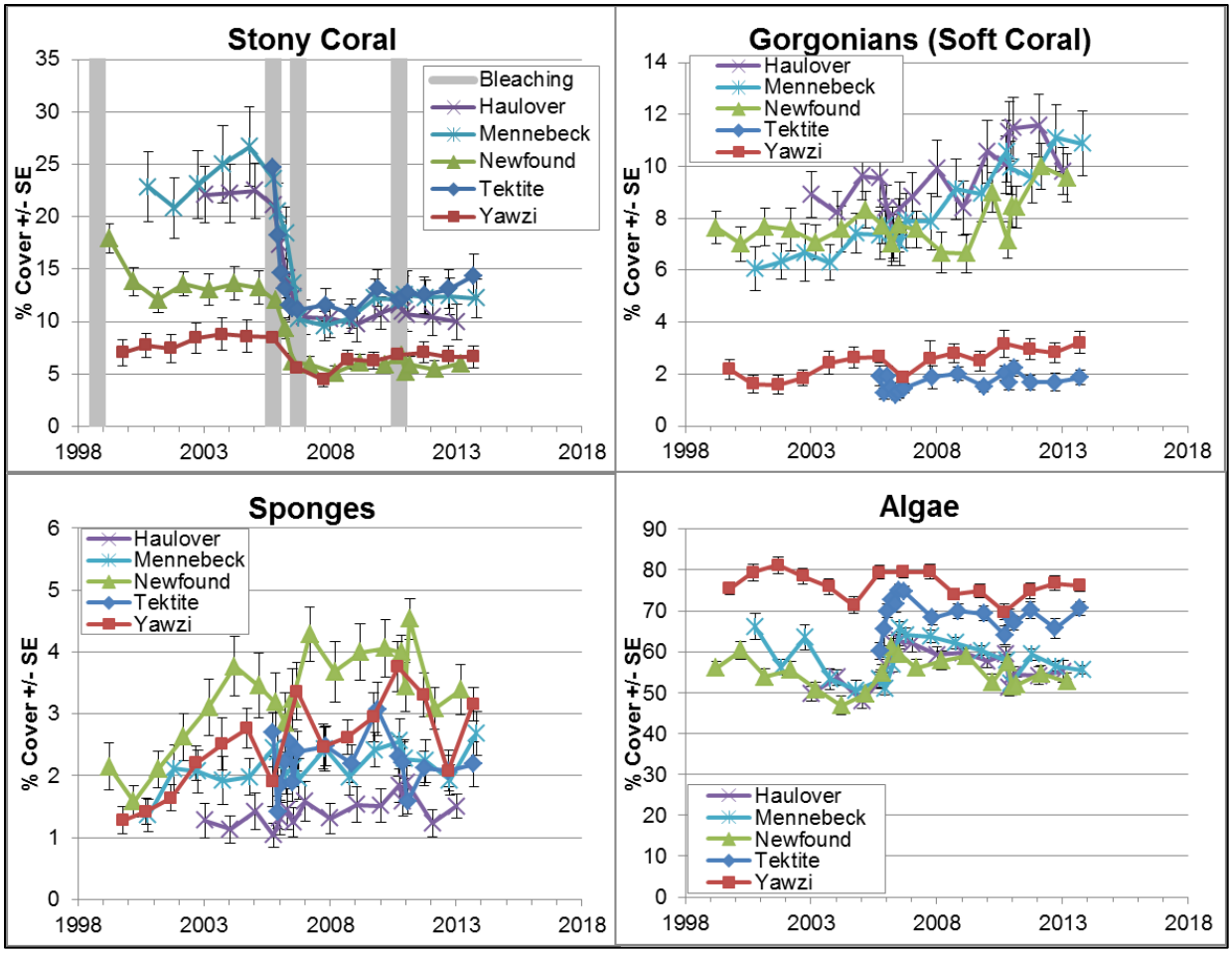


Figure 18. Sample graphs showing percent cover for Virgin Islands National Park coral monitoring sites for stony coral (top left), gorgonians (top right), sponges (bottom left), and algae (bottom right). Grey lines indicate coral bleaching years on coral graph. Large stony coral dieoff occurred in 2005–2006.

Basic Metrics Reported

A wide variety of metrics are possible with the large data set generated by this protocol. However, below are some fundamental metrics that should be generated after each sampling season that are outlined in SOP 21- "Data Analysis and Reporting".

1) Benthic Community—Average percent cover by major benthic groups
    a) Corals
    b) Gorgonians
    c) Sponges
    d) Zoanthids
    e) Algae
        i) Macroalgae
        ii) crustose coralline algae
        iii) dead coral with turf algae

f) Bare substrate (sand, rubble, and pavement)

g) Other (live components – e.g., fish, but not benthic)

h) Unknown

2) Coral Community

a) Absolute average percent cover of major coral species or genera. Suggested groups for this analysis are listed below:

i) *Orbicella* spp.

ii) *Colpophyllia natans*

iii) *Pseudodiploria* and *Diploria* spp.

iv) *Montastraea cavernosa*

v) *Siderastrea siderea*

vi) *Agaricia* spp.

vii) *Porites* spp.

viii) *Millepora* spp.

ix) *Acropora palmata*

x) *Acropora cervicornis*

b) Relative abundance of coral using same groupings in 2a.

c) Coral species richness

i) Average coral species richness per transect

ii) Coral species richness per site

d) Coral bleaching

i) Average percent of coral cover bleached by bleaching category (BL1, BL2, BL3, BL4, unbleached)

e) Coral disease

i) Site-wide # diseased colonies and # of hard coral colonies (Note: fire coral is counted separately)

ii) Disease prevalence (100 * # diseased colonies / # hard coral colonies)

iii) Average disease area/transect by disease type

iv) Average disease lesion count/transect by disease type

3) Other covariates by site

a) Long spined sea urchins

i) Average # urchins/transect

ii) Proportion of transects occupied

b) Rugosity

i) Average difference from initial rugosity

c) Water Temperature

i) Daily average water temperature

ii) # days > Bleaching stress threshold (29.5°C in USVI, 30.5°C in S. Florida)

Both for calculations of species richness and for individual species trends analysis, the species in the *Orbicella* species are combined together and considered one species as they cannot be reliably differentiated when small. This includes the species *Orbicella annularis* (OANN), *Orbicella faveolata* (OFAV), *Orbicella franksi* (OFRA) and undetermined *Orbicella* sp. (ORBI).

Recommended Methods for Statistical Analysis

This protocol produces a great deal of information and many different analyses are possible both for detection of change and for detection of associations with covariates. Only a few of the more important analyses are discussed below.

Statistical analyses have primarily been conducted on % live coral cover. Because variance in percent live coral cover increases with the mean (and Coefficient of Variation (CV) decreases), a binomial distribution is assumed in the analysis. Use of the statistical program SAS 9.2 is detailed in SOP 21. However SFCN plans to switch to the statistical program R in the near future provided similar analyses can be programmed.

One-stage design analyses for index sites

1) *Repeated Measures Analysis of Variance* to assess changes among different sampling periods. Time (i.e., sampling period) and transect are both treated as discrete classification or "class" variables rather than as numeric variables. A binomial distribution is assumed and a standard variance component (default) is used. A Tukey-Kramer mean separation test is used to look for which specific sampling periods are significantly different provided that the overall test is statistically significant.
2) *Repeated Measures Analysis of Covariance* to assess gradual trend increases or decreases. Time is treated as regression variable and transect as a class variable. A binomial distribution is assumed. As time is a repeated measure which may not meet the assumptions of a typical regression variable, at present a 1st order autoregression variance structure is used except in a few cases where the model cannot be fitted in which case standard variance component structure is used. However, the network will continue to evaluate appropriate variance structures in the future as the time series of the data becomes long enough make evaluations such as compound symmetry, 1st order autoregression, Toeplitz, 1st order autoregression with moving average, and unstructured variance structures.
3) *Repeated measures analysis of variance* using a contrast analysis to assess changes before and after an event such as coral bleaching/disease events, major hurricanes, and harmful algal blooms. Time is treated as class variable and transect as a class variable. A contrast analysis compares data before versus after the event. A binomial distribution is assumed. With time treated as a class variable, only a standard variance component (default) structure is used.

Examination of graphs is performed to look for general trends and spikes in other variables. Not all variables are assessed for statistical significance at this time but are still presented graphically with standard error bars. This can then suggest the need for more rigorous statistical analyses.

Interpretation of changes in gorgonian cover should be made cautiously as heavy wave action can cause normally upright sea fans to lie flat and thus temporarily increase their exposed surface area during filming. Thus small but statistically significant changes should be evaluated in the light of the conditions during filming. Analysis methods for rugosity will primarily be conducted as a paired t-test. Analyses for *Diadema antillarum* are still to be developed but will likely be similar to analyses described above for coral. Analyses for coral disease data are still to be developed. However coral disease tends to occur in outbreaks (e.g., spikes) and thus is most useful simply as an explanatory co-variate when trends are detected in coral cover.

Two-stage design analyses (extensive sub-site design)

Coral cover at index sites with multiple four-transect sub-sites are analyzed by first taking the percent cover average of each extensive sub-site, and then using those averages in the analyses. From that point computations on those sub-site averages are similar to what is described above for one-stage analyses of coral cover at index sites.

Coral cover data for multiple 20-transect index sites can also be combined as long as the statistical inference is only to those sites. As an example, data were combined from multiple index sites to analyze the response of each coral species to the 2005 bleaching/disease outbreak event in the US Virgin Islands. Some individual coral species had many transects with zero percent cover, which is problematic for statistical analyses. By averaging the data at the index site level and then using each index site as a replicate, the problem of zero-inflated data was avoided.

Combining of multiple 20-transect index site data for analysis of algal variables should be approached with caution as algal cover changes seasonally and 20-transect index sites are typically monitored during different months of the year. A combined variable of algae + bare substrate may be used instead to avoid this problem.

Multi-site analyses with unequal probability of selection in different strata

The initial sampling design for Dry Tortugas NP assumed a desire to assess both trends inside and outside the RNA as well as trends in the park as a whole. Thus sub-sites were initially established both inside and outside the RNA using a grid approach with the intent of calculating each sub-site's probability of selection and using that probability as an inverse weighting factor in the park-wide analysis. Subsequently, the network has decided to report separately for Inside the RNA, Outside the RNA, Loggerhead Forest, Santa's Village, and Bird Key reef, rather than trying to combine all results together into a single park-wide trend. This approach is both simpler to calculate and more intuitive to explain to park management and the public. As SFCN is not currently calculating the park-wide trend using the weighted probability statistics based upon the grid design, and as the statistics are lengthy to explain, users who decide upon this approach are referred to Bryan et al. 2013 where the steps are well-described.

Rapid Habitat Assessment Analysis

The primary metric calculated from the Rapid Habitat Assessment (RHA) database is percent live stony coral cover. The data are not being used to calculate changes through time, but rather as a step in development of sampling designs (i.e., see Sampling Design, Sample frame boundaries are difficult to define and SOP 8).

Analysis and Review of Effectiveness of Sampling Design

The power of the sample design to detect change should be revisited after major technical changes in how the protocol is implemented, e.g., when the video was switched from Digital Video to High Definition Video.

In addition, the use of the four-transect extensive sub-sites method is a new variant of this protocol, and the power of this design to detect change should be revisited after five years.

From a big picture viewpoint, this protocol is designed to assess changes in higher coral cover reefs (e.g., > 5% coral cover and preferably > 20% cover). However, knowledge of the coral reefs in SFCN parks is limited and is dependent upon the accuracy of the maps available to SFCN at time of sampling design. If better maps become available indicating that major portions of this type of habitat were not considered for sampling, then the design may need to be revisited and these additional areas added, perhaps as an additional stratum or index site.

The South Florida/Caribbean Network is not currently monitoring reefs deeper than 33 meters (108.2 ft) as this creates an overhead constraint (decompression) using open circuit SCUBA for extended periods of time. However, such reefs exist in Buck Island Reef NM, Salt River Bay NHP&EP, and Virgin Islands Coral Reef NM, and their health may become increasingly important as climate change and overfishing affect shallower reefs. The network has recently started using Closed Circuit Rebreather (CCR) technology and feasibility of monitoring these deeper reefs may be revisited.

Newer statistical analysis tools and procedures are becoming available as increases in computing power make the previously impossible approaches feasible. In upcoming years, alternative methods such as Bayesian Analysis methods or bootstrapping of results should be explored.

Stoplight Indicators

The SFCN staff members may summarize the results into a “stoplight” indicator symbol (Table 3) if desired by park management. This will likely require an additional appropriate level of review before such results can be published. The indicator color (i.e., status – red, yellow, green) and shape (i.e., trend = arrow up, sideways, down) is based upon a qualitative or quantitative assessment of all the data with a primary focus on the current live stony coral cover. However for many sites, current coral cover values can only be compared with initial estimates of coral cover and trends since the beginnings of data collection or from a major event (e.g., major bleaching disease event in USVI in 2005) to provide temporal context. The network is working to find old coral monitoring data sets to better assess current reef status against historical reef conditions. Data are already available for Yawzi Reef, Newfound Reef, Bird Key Reef, and Salt River. A more complete description of the use of stoplight indicators is in SOP 21.

Table 3. Summary condition of Haulover Reef in Virgin Islands National Park.

Indicator of Condition	Specific Measure	Condition Status/ Trend*	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source
Haulover Coral Reef Condition	Primary= % live stony coral cover; Secondary= algal, sponge, & soft coral cover, sea urchin density, disease area, disease prevalence and water temp.		Live stony coral cover = 10.0%. Condition is degraded after the decrease in coral cover between 2005–2007 Bleaching/Disease event. No trend has occurred in live stony coral cover since 2007. (SFCN data analysis 2013.)	Pre 2005 bleaching event coral cover= 22.5% (sampled 1/11/2005; SFCN database)

Data Summary Report

The data summary report will focus on

- a summary of the data collected that year by park and by site,
- updating multi-year graphs,
- updating trend analysis results from initiation of monitoring or from previous stress event (e.g., 2005 bleaching disease event in USVI), and
- if desired by parks, may include stoplight condition assessments for each reef or zone monitored with appropriate level of review.

Once the data summary report has received its report number from the Natural Resource Data Summary report series, the report will be uploaded to Integrated Resource Management Applications (IRMA.nps.gov), linked to from the SFCN webpage, an associated resource brief will be updated, and the results included in other reports as appropriate.

SOP 22. Archive of Files

Secure data archiving is essential for protecting data files from corruption. Several different types of archiving are involved with this protocol which are summarized in Table 4.

Annual archiving for these files starts once the marine ecologist or designated project lead has affirmed that the appropriate QA/QC procedures for the current year's data are complete and has notified the network data manager that the calendar year's data is ready for archiving. This is expected to be in December or January. At this point the network data manager places a copy of the databases, exported flat files, scanned datasheets, disease photos, protocol, and associated analysis scripts into the appropriate folder within the archive directory on the network server.

Once the data are archived, any changes made to the databases must be documented in an edit log, and the electronic version of the data set is maintained in a read-only format on the network server.

Copies of the databases are loaded to IRMA (http://irma.nps.gov) and made available to "NPS ONLY." Backup copies of the server data are maintained at the south Florida office and at the Southeast Regional office in Atlanta, Georgia.

Upon publication, PDF versions of data summary reports and exported flat files are copied to the archive folder and loaded to IRMA and made available to "PUBLIC." The current protocol, even in draft form, will be archived in the archive folder together with the database each year.

Detailed steps are provided in SOP 22: Archive of Files. For further detail of the archiving procedure please refer to the SFCN Data Management Plan (http://www1.nrintra.nps.gov/im/units/sfcn/docs/phase/appq.pdf).

Table 4. File types and method of archiving.

File Type	Tape	Blu-ray Disk or other network storage	Server Archive Folder	IRMA
Video files	X	X	—	—
Video frame image files w/ dotting	—	X	—	—
Disease photos	—	—	X	X (NPS only)
Datasheets	—	—	X	X (NPS only)
Databases	—	—	X	X (NPS only)
Exported flat files	—	—	X	X
Protocol	—	—	X	X
Analysis scripts	—	—	X	X
Data summary reports	—	—	X	X

* SFCN will continue to update long-term storage with the best available affordable technology.

Sensitive Information

The only sensitive information that requires special attention is location of black coral (*Antipatharia*) and submerged cultural resources. Data sets made available to the general public will have black corals presence replaced with UNK (unknown). At time of publication, no black coral has been detected on SFCN transects after 18 years of monitoring. Listed ESA coral species such as *Acropora palmata* (elkhorn coral), *A. cervicornis* (staghorn coral), *Dendrogyra cylindricus* (pillar coral), *Mycetophyllia ferox* (rough cactus coral) and *Orbicella* spp. (star corals) do not tend to be poached, so their location is not considered sensitive. If submerged cultural resources are observed or captured on video, this will be brought to the attention of the relevant park management and a decision will be made on how to protect the information from public release.

Metadata Procedures

Metadata (such as date, location, observers) for each event are stored within the database. Metadata for the spatial location of the sample sites are stored with each park's coral monitoring shapefile.

A Federal Geographic Database Committee (FGDC) compliant metadata file is maintained that requires minimal updates and that will accompany flat file data exports in a .zip file in response to data requests.

For further discussion concerning metadata requirements please see section 8.3 of the SFCN data management plan (http://www1.nrintra.nps.gov/im/units/sfcn/docs/phase/appq.pdf).

SOP 23. Revising the Protocol

The protocol is a living document and changes will be ongoing, especially with regards to changes in technology. Changes will be made and tracked as described in SOP 23. SOPs and the entire document are versioned and each have a change history tracking table. Upon publication the protocol will be uploaded to IRMA and linked to via the SFCN web page.

Personnel Requirements and Training

Roles and responsibilities

The field portion of this protocol falls under the overall responsibility of the SFCN marine ecologist, although in the Virgin Islands it is managed regionally by the SFCN fisheries biologist. The procedures described in this protocol can be implemented by any qualified dive team member. The SFCN marine ecologist is responsible for overseeing the entering of the data into the Microsoft Access database and conducting the QA/QC. The SFCN data manager is responsible for managing the database and archiving annual data sets. The SFCN quantitative ecologist is responsible for maintaining the graphing templates and assisting with analysis and reports. The SFCN marine ecologist is responsible for producing the SFCN coral reef monitoring reports which include the water temperature results collected under the guidelines of the *Coral Reef Water Temperature Protocol* (Davis et al. 2013).

Personnel assigned to data collection, analysis and storage shall be properly trained in the procedures relevant to the assigned tasks. Responsibility of proper adherence to procedure, quality control and quality assurance rests with all pertinent personnel.

Rules and regulations applicable to the performance of these tasks shall be observed, with particular note to individual park policies.

Nothing in this protocol implies or is meant to imply deviations from established federal, departmental or local safety rules and regulations applicable to the performance of assigned tasks. Familiarity and compliance with such rules and regulations is the responsibility of each individual team member.

Qualifications

The following qualifications are accepted minimum standards to perform relevant procedures. Tasks may be performed by personnel in training status under the supervision of properly qualified persons. Specific guidelines and applicable regulations shall be strictly adhered to at all times. This list is not meant to be all inclusive and may be supplemented by individual park regulations and qualification requirements.

Personnel involved in field data collection must have the following training:

- NPS Blue Card Diver (Ref NPS RM4, 485 DM 27) or equivalent reciprocity
- Motor Boat Operations Certification (MOCC - ref 36 CFR part 3, 485 DM 22) (necessary if driving an NPS boat)

Personnel must be not only qualified but extremely proficient in science diving; diving is the means to collect the data, not the objective itself. Personnel must have a high level of comfort with multiple tasks while diving, in addition to excellence in buoyancy control. Image analysis and subsequent data collection and results can be compromised if filming was not done in a controlled manner.

The videography performed for this protocol requires superior diving skills and a thorough understanding of the procedures described herein. Videographers should be trained and closely monitored until they acquire the necessary skills and experience to perform this task properly. For video analysis, knowledge and familiarity of marine invertebrate taxonomy is required. Further, as this is a "remote sensing" method, the analyst needs sufficient in-water "coral reef" experience to interpret the video imagery and make correct identifications. All analysts are required to review and become familiar with this protocol especially SOPs 10–14 and Appendix A. Personnel are qualified to perform image analysis during an evaluation period in which an experienced taxonomist (i.e., designated by the marine ecologist) conducts a duplicate analysis. Qualification implies a high confidence in the ability of the analyst to accurately identify the required benthic taxa, consistently following the guidelines described in this protocol.

Training Procedures

Personnel should thoroughly review this protocol before implementing procedures under the supervision of experienced staff. In addition to the protocol, personnel must complete the necessary requirements to maintain NPS Blue Card (or approved equivalent) for divers and at least one person on the boat must have an MOCC (See safety section under operational requirements).

Training takes place under the supervision or designee of the marine ecologist in the use of protocol SOPs. Filming of transects in a controlled manner that produces quality images for analysis requires buoyancy control and practice.

Image analysis by new personnel is completely checked during an evaluation period (e.g., two to three analyzed sites) by an experienced taxonomist until there is consistent concurrence in species identification. Continued review of literature regarding taxonomy is recommended. Knowledge of these benthic communities is also necessary for the Rapid Habitat Assessment procedure (See SOP 8).

As the sampling for this protocol takes place throughout the year, field and office skills (data analysis and entry) are continually honed. All trainees should have ready access to this protocol for reference.

There are no restrictions to training in any procedure that does not entail diving or boating activities by the trainee. Nevertheless, trainees shall not be allowed to perform tasks unless under supervision. Divers in training and boat operator trainees shall perform under the supervision of qualified personnel, subject to pertinent regulations.

Operational Requirements

Annual Workload and Field Schedule

Monitoring is conducted throughout the year with suggested months for field activities listed (Table 1) as target dates. Some flexibility is allowed, but if the scheduled month is altered, effort should be made to conduct the work within the same season (e.g., summer, spring, fall, winter). Weather, sea conditions and in-water visibility are major factors in scheduling sampling, as good field conditions allow for better video images which result in more accurate analyses. Field work is conducted out of the Virgin Islands and South Florida offices, with the exception of Dry Tortugas NP where staging from the RV Ft. Jefferson or NPS quarters within the park are preferable due to the remote location.

A two person dive team is the minimum required for field work; for both boat and diving safety, and data collection. (The NPS does not require a 'top-side' person on vessels during diving operations.) Generally, a site can be sampled in two to three days, typically consecutive, but in all cases as close together as possible. When conducting monitoring in SFCN parks, invitations are extended to qualified personnel in the host park to partner or collaborate where, either as an observer or data collector (where skills permit). This partnership fosters camaraderie among staff and can increase staff skills.

Videotaping requires approximately five minutes of bottom time per 10-meter (32.8-ft) transect, plus the time needed for transect location and set-up. An additional 5–10 minutes per transect is needed for the collection urchin density, disease, coral species list data. Six to ten, 10-meter transects can be filmed during a typical dive day (two dives, 60 to 75 minutes bottom time). See "SOP 1–Using Videography to Monitor Coral Reefs" for additional details.

Facility and Equipment Needs

Field and office equipment are detailed in Miller and Rogers (2002). The equipment lists are specific to the Sony DCR-VX 1000 digital camera and Light and Motion housing. A more generic list of suggested videography and diving equipment is as follows:

- Video camera and accessories (batteries, tapes, lens, battery chargers)
- Camera housing and accessories (O-rings, O-ring grease, cotton swabs, distance aiming mechanism)
- Boat
- Standard dive equipment and accessories
- Miscellaneous underwater equipment (slate, survey tapes, underwater paper, pencils, rubber bands)
- Laminated transect relocation photos and map for the site being sampled
- Navigation equipment and accessories (e.g., GPS, waterproof bag, misc. lines, floats)
- Dive and boating safety equipment.

Software needed includes:

- Adobe Premiere (image capture)
- Adobe Photoshop (dotting of images)
- Adobe InDesign (creating fact sheets)
- Adobe Acrobat (creating PDFs of documents)
- Microsoft Office—Access, Excel, Word
- ThumbsPlus 7.0 (coral disease photo data entry)
- ArcGIS (mapping of sites, site selection, creating field logistic plans)
- DNR GPS (transferring data between GPS devices and GIS software)
- MapSource (manage field trip data on a Garmin)
- SAS statistical software (regression analysis; will be replaced by R)
- R statistical software (will replace SAS code soon for statistical analysis)

Startup Costs and Budget Considerations

The HD video camera equipment, housing and accessories cost about $5,000. Standard dive equipment costs about $1000 per diver. Equipment to set up sites includes copper-clad stakes for marking transect endpoints, lines, floats and miscellaneous hardware costs between $750 for an index site (twenty transects) or $200 extensive sub-site (four transects).

The network already has a SAS statistical software 9.2 license (approximate cost $10,000) and plans to switch to R statistical software (free) rather than upgrading SAS. ThumbsPlus is approximately $120. DNR GPS and R are free. ArcGIS and Microsoft Office products are purchased government-wide with no additional costs at the network level. The government is negotiating software costs for Adobe products but prices are expected to range between $300 - $600/year for all four software packages per machine. These software packages are used by multiple monitoring protocols. Boat and vehicle maintenance costs and time are not included here.

Each index site takes a team of two to three divers approximately 2.5 days to sample including filming, collecting coral species, urchin and disease data, and performing site maintenance. Extensive sub-sites are most efficiently sampled by three to four divers in approximately three hours. Non-video data entry can be accomplished in approximately four hours. The time required for components of the video protocol including data capture, entry and analyses (SOP 1—Using Videography to Monitor Coral Reefs) takes about two hours of technician time per transect.

The total costs of data entry/proofing, data management, analysis and reporting are approximately 40% of project costs (Table 5).

Table 5. SFCN monitoring budget for installed sites. Note: These costs are approximate based upon 2014 salary, travel cost, and equipment estimates for annual monitoring of sites. New site setup costs include considerable additional work and are not included. Episodic monitoring costs are not included but can be generally calculated from the table below. Maintenance costs of boats, vehicles, computers, etc. are not included as these are spread across monitoring for multiple vital signs.

Category	Expense	Amount
BISC Budget (2 sites)	Fuel ($400/week @$4/gal)	$400
	Field work salary incl. hazard pay ($28/hr/per @2.5 days per site)	$4200
	Data entry/proofing salary ($28/hr @ 2 hrs / transect)	$2464
BUIS Budget (2 sites)	Travel ($1000/wk except housing)	$2000
	Housing ($187/night if can't get park housing)	$1496
	Fuel ($400/week including roundtrip to St. Croix)	$1000
	St. Croix Dockspace ($25/day)	$150
	Nitrox fills ($20/tank)	$720
	Field work salary incl. hazard pay ($28/hr + hazard)	$3360
	Data entry/proofing salary ($28/hr @ 2 hrs / transect)	$2464
DRTO Budget (3 sites)	Travel (Includes staying on MV Fort Jefferson)	$12000
	Fuel ($400/week)	$500
	Field work salary incl. hazard pay	$16800
	Data entry/proofing salary ($28/hr @ 2 hrs / transect)	$3360
SARI Budget (1 site)	Travel ($1000/wk except housing)	$3000
	Housing ($187/night if can't get park housing)	$1496
	Fuel ($400/week including roundtrip to St. Croix)	$425
	St. Croix Dockspace ($25/day)	$50
	Nitrox fills ($20/tank))	$540
	Field work salary incl. hazard pay	$2100
	Data entry/proofing salary ($28/hr @ 2 hrs / transect)	$1232
VIIS Budget (5 sites)	Fuel ($400/week)	$800
	Air fills ($10/tank)	$900
	Field work salary incl. hazard pay	$8400
	Data entry/proofing salary ($28/hr @ 2 hrs / transect)	$6160
Add'l Project Costs	Data management, analysis, reporting (Quant. Ecol. 7 days, Data Mgr 10 days, GIS spec. 5 days, Outreach/Data Mgmt tech 15 days, Fisheries Biologist 10 days, Marine Ecologist 10 days)	$14384
Equipment	Dive equipment ($200/diver/year)	$1000
	Survey equipment ($500/season)	$500
Total	–	$91,901
Additional Periodic Costs	• Dive training (8 annual and 40 hours every three years) • Computers, GPS devices, etc. • Salary for updating database analysis and graphing tools with major software changes • Boat and vehicle maintenance • Software	–

Safety

Diving requires considerable safety training and then mission specific caution and care. Network personnel must follow all rules, regulations, requirements, policies, and procedures from the NPS Dive Program, any park, network, and I&M Division specific requirements, and any other requirements of the National Park Service not otherwise specified herein. In general an attitude of a "culture of safety" and "operational leadership" should prevail in which problems are considered proactively and each person must feel empowered to think about potential problems and speak up early about safety concerns regardless of their position and those concerns must be addressed seriously and respectfully by the rest of the team.

All DOI personnel participating in SFCN dive missions for this monitoring project must be NPS Blue Card Divers (or approved equivalent) with an appropriate depth rating. Tasks may be performed by personnel in training status (NPS Diver in Training) under the supervision of properly qualified persons.

Persons independently driving SFCN boats must complete a DOI MOCC for solo operation of a NPS vessel. Non-certified MOCC personnel may drive a park boat under the close supervision of someone whom is MOCC certified.

All SFCN vessels will be operated using state-of-the-art GPS chart plotters to ensure safe and efficient navigation.

SFCN personnel must also review and implement the respective SOPs associated with operation of each SFCN vessel, Float Plan Safety Sheet, and any other SOPs associated with this protocol and must review and sign all Job Hazard Analyses (JHAs) associated with this protocol. These SOPs and JHAs are located in the SFCN Safety folder Z:\Safety\ with guidance to their location in the Final_SFCN_Safety_Plan.doc. A summary of these SOPs and JHAs are provided in Table 6. These forms may be updated individually and the SFCN Safety Plan updated as a whole, so personnel should check the Z:\Safety\ folder for the most recent versions of these files and any additional requirements.

All SFCN personnel will follow the Program Specific Dive Supplement/ Diver Emergency Evacuation Plan and Safety Operations Plan specific to the respective park they are operating within. Dive team roles and responsibilities as predicated in NPS Resource Manual 4 (Diving Management Reference Manual) will be reviewed in a safety briefing before each dive trip.

Table 6. Safety SOPs and JHAs. For most recent version of files see Z:\Safety\SFCN_SOPs\.

Type	Category	File Name
SOPs	Safety Signout – Float plan	20120914_SFCN_Float_Plan.doc
	Motorboats • Twin Vee – Large • Twin Vee – Small • Acropora - USVI	• SOP_11_Twin_vee_Maintenance_Operation.docx • SOP_11_Acropora_Maintenance_Operation.docx • Minimum safety requirements for SFCN Motorboats.docx • Twin Vee protocol for boat break down in BISC.docx • 2013 Vessel Operations and Safety Plan.pdf (EVER & DRTO) • Risk_Assessment_Motorboating_BISC.docx • 2016 DRAFT DRTO Boating Safety Plan.docx • MOCC-StudentManualwCover-v2015-9-2.pdf
	Dive	• NPS Resource Manual 4 (Diving Safety and Operations Manual) • Updated DEEPs for each park are located in "Z:\SAFETY\Section 2Q - Diving Safety\Network Parks DEEP's. Latest DEEPS are downloadable for NPS Blue Card divers from http://inpniscvdive/pdologin1.cfm (password protected) • 20130801_NPS_DIVE_SAFE_PRACTICES_WORKSHEET_Scooters_for SFCN.docx • 20130801_NPS_DIVE_SAFE_PRACTICES_WORKSHEET_Underwater_Visual_Surveys_for SFCN.docx
	Radio	• Radio_Channels.xlsx • Virgin Islands Diver Emergency Call Sheet.docx
JHAs	Diving	Diving_SFCN_Diving_from_park_boats_JHA_for_all_marine_monitoring_5_10_2013.pdf
	Motorboats • Twin Vee • Acropora	• Boats_Twin_Vee_JHA_5_15_13.pdf • Boat_Acropora_JHA_5_18_2016.xls

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Appendix A. Species / Database Codes

Species Category	Species Name	Code
General Coral Species	*Acropora cervicornis*	ACER
	Acropora palmata	APAL
	Acropora prolifera	APRO
	Agaricia spp.	AGAR
	Agaricia fragilis	AFRA
	Agaricia grahamae	AGRA
	Agaricia lamarcki	ALAM
	Agaricia undata	AUND
	Colpophyllia natans	CNAT
	Dendrogyra cylindrus	DCYL
	Dichocoenia stokesii	DSTO
	Diploria labyrinthiformis	DLAB
	Eusmilia fastigiata	EFAS
	Favia fragum	FFRA
	Helioseris cucullata	HCUC
	Isophyllia rigida	IRIG
	Isophyllia sinuosa	ISIN
	Madracis spp.	MADR
	Madracis aurentenra	MAUR
	Madracis decactis	MDEC
	Madracis formosa	MFOR
	Madracis pharensis	MPHA
	Madracis senaria	MSEN
	Manicina areolata	MARE
	Meandrina jacksoni	MJAC
	Meandrina meandrites	MMEA
	Montastraea cavernosa	MCAV
	Mussa angulosa	MANG
	Mycetophyllia spp.	MYCE
	Mycetophyllia aliciae	MALI
	Mycetophyllia danaana	MDAN
	Mycetophyllia ferox	MFER
	Mycetophyllia lamarckiana	MLAM
	Oculina diffusa	ODIF
	Orbicella spp.	ORBI
	Orbicella annularis	OANN
	Orbicella faveolata	OFAV
	Orbicella franksi	OFRA
	Porites astreoides	PAST

Species Category	Species Name	Code
	Porites branching spp.	PORI
	Porites branneri	PBRA
	Porites divaricata	PDIV
	Porites furcata	PURF
	Porites porites	PPOR
	Pseudodiploria spp.	PSEU
	Pseudodiploria clivosa	PCLI
	Pseudodiploria strigosa	PSTR
	Scolymia spp.	SCOL
	Scolymia cubensis	SCUB
	Scolymia lacera	SLAC
	Siderastrea spp.	SIDE
	Siderastrea radians	SRAD
	Siderastrea siderea	SSID
	Solenastrea spp.	SOLE
	Solenastrea bournoni	SBOU
	Solenastrea hyades	SHYA
	Stephanocoenia intersepta	SINT
	Tubastraea aurea	TAUR
	Undaria spp.	UNDA
	Undaria agaricites	UAGA
	Undaria humilis	UHUM
	Undaria tenuifolia	UTEN
Other Coral Codes	*Antipatharia* (Black coral)	ANTI
	Millepora spp.	MILL
	Millepora alcicornis	MALC
	Millepora complanata	MCOM
	Millepora squarrosa	MSQU
	Stylaster roseus	SROS
	Unknown coral juvenile spp.	CORJU
	Unknown adult coral spp.	CORALU
	Diseased coral	DCOR
Gorgonian Species and Forms	*Briareum asbestinum*	BASB
	Encrusting gorgonian	ENGO
	Erythropodium caribaeorum	ECAR
	Plume form	PLUME
	Rod form	ROD
	Sea fan	FAN
	Whip form	WHIP
	All other and unknown gorgonians	GO
	Ball sponge	BALL

Species Category	Species Name	Code
Sponge Species and Forms	Barrel/vase sponge	BASP
	Boring sponge	BOSP
	Clionia spp.	CLIO
	Encrusting sponge	ENSP
	Rope sponge	ROPE
	Tube sponge	TUBE
	All other and unknown sponges	SPO
Zoanthid Species and Generic Codes	*Palythoa* spp.	PALY
	Zoanthus spp.	ZOAN
	Other zoanthids	ZO
Macroalgal Species, Genus, and Generic Codes	*Amphiroa* spp.	AMPH
	Cladophora spp.	CLAD
	Cyanobacteria	CYAN
	Dictyota spp.	DICT
	Halimeda spp.	HALI
	Liagora spp.	LIAG
	Lobophora variegata	LVAR
	Microdictyon spp.	MICRO
	Sargassum spp.	SARG
	Other macroalgae	MACA
Other Algae	*Coralline algae*	CALG
	Dead coral with turf algae	DCA
Seagrass Species, Genus, and Generic Codes	*Halodule wrightii*	HWRI
	Halophila spp.	HALOP
	Halophila stipulacea	HSTI
	Syringodium filiforme	SFIL
	Thalasia testudinum	TTES
	Other seagrass	SEAG
Inorganic substrate components	Boulder	B
	Sand	S
	Rubble	R
	Pavement	P
Non-substrate entities	Shadow	SHADOW
	Equipment	EQUIP
	Tape	TAPE
	Wand	WAND
	Slate	SLATE
Other live organisms	Anemones	ANEM
	Corallimorpharians	CMOR
	Tunicates	TUN
	Worms	WORM

Species Category	Species Name	Code
	Other organisms	O
	Unknown benthic entities	UNK
Coral Diseases	Black band disease	BB
	White band disease	WB
	White Plague	WPL
	White Pox	WPX
	Yellow Band	YB
	Dark Spot	DS
	Dark Spot – Type 1	DS1
	Dark Spot – Type 2	DS2
	Dark Spot – Type 4	DS4
Coral Bleaching	Bleaching Level 1	BL1
	Bleaching Level 2	BL2
	Bleaching Level 3	BL3
	Bleaching Level 4	BL4

Appendix B. Key Products Associated with this Protocol

Video has been used to monitor coral cover on transects at reef sites in the SFCN since 1999. To date, video monitoring has expanded to over 30 reefs encompassing more than 200 separate sampling events (annual and episodic) and resulted in the filming and analyzing over 4000 transect videos. Two fundamental modifications of the protocol occurred in 2008: the change from digital video to High Definition video (see SOP 12—Conducting Analysis of HD Images and Appendix E), and the incorporation of extensive sub-sites (see Sample design). Data from this protocol have been used in numerous written documents such as annual reports, technical publications, NPS publications, professional meeting proceedings/posters and peer-reviewed scientific journals. Data and results have been used for community outreach including local newspaper articles, informative articles in trade books, local newspapers and NPS interpretative materials. Presentations have been given to government senators, state and territorial officials, as well as local schools, hotels and resorts, university and civic groups. Briefings were given to the Director of the National Park Service, Southeast Regional Director, numerous superintendents, division chiefs, park staff, and members of the US Coral Reef Task Force committee. Methods, results and images have been used around the world, over the internet, radio, and on national and public television networks. Workshops have been given to teach this approach to several Caribbean governments and non-governmental organizations.

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Appendix C. Timeline of Legacy and Current Protocol Implementation

Table C-1. Timeline of Legacy and current protocol implementation showing year and what took place.

Year	Action
1999	Initiated annual coral videography index site monitoring transects at Newfound (NF) and Yawzi (YZ) reef sites in VIIS with Digital Video.
2000	Initiated annual coral videography index site monitoring transects at Mennebeck (MB) in VIIS and Western Spur and Groove (WSG) in BUIS (19 transects only installed at WSG).
2003	Initiated annual coral videography index site monitoring transects at Haulover (HA) in VIIS and South Fore Reef (SFR) in BUIS; added 20th transect to WSG.
2004	Initiated annual coral videography index site monitoring transects at Amanda's Reef (AM) and Ball Buoy reef (BB) in BISC (origins marked with brass survey pin) and Bird Key Reef (BK) at DRTO. Initiated sea urchin (*Diadema antillarum*) monitoring at BK and YZ sites.
2005	Initiated annual coral videography index site monitoring transects at Tektite (TK) in VIIS and Bird Key North (BKN) in DRTO. Initiated coral disease monitoring at VIIS and BUIS sites including the type of disease, number and area of lesions, and coral species affected. Expanded annual sea urchin (*Diadema antillarum*) monitoring to all sites.
2005–2006	Conducted episodic monitoring at HA, MB, NF, TK, SFR sites in response to Bleaching / Disease event.
2006	Initiated disease monitoring at BK site.
2007	Gradually expanded annual coral disease monitoring to remaining coral monitoring sites. Conducted rugosity monitoring on most index sites (1 year only). Investigated potential extensive coral monitoring sub-sites inside / outside DRTO Research Natural Area.
2008	Installed 18 extensive coral monitoring sub-sites in DRTO: I_26, I_33, I_36, I_38, I_41, I_44,I_63, I_05, I_50, O_12, O_27, O_42, O_56, O_72, O_82, O_84, O_92, O_94. Conducted additional episodic coral video and coral disease monitoring at I_05, I_50 in May and July. Initiated coral colony counts at BISC.
2008–2009	Switch to HD video with 1 year overlap using both methods (at all index sites except AM)
2009	Initiated recording field in situ coral species lists at MB, TK, YZ, BK and some DRTO extensive sub-sites.
2009-2010	Expanded colony counts to remaining sites and began counting fire corals and stony corals separately; may or may not include coral < 4 cm as pilot SOP unclear.
2010	Episodic coral monitoring conducted at TK, HA, MB, NF, SFR due to extensive bleaching. Conducted rugosity monitoring on most extensive sub-sites. Expanded collection of coral species lists in the field to all sites.
2012	Installed 3 4-transect coral monitoring sub- sites at Loggerhead Forest in DRTO: LH01, LH02, LH03. Installed 3 4-transect coral monitoring sub-sites at Santa's Village in DRTO: SV01, SV02, SV03. Installed 20 transect index coral monitoring site at Salt River (SR) in SARI. Discontinued sampling at BKN, I_33, I_63, O_12, O_27, O_92.

Table C-1 (continued). Timeline of Legacy and current protocol implementation showing year and what took place.

Year	Action
2012–2013	Pilot test conducted testing separating colony counts into < 4cm and > 4 cm at VIIS sites and once at BK to examine time involved and variability of results
2014	In March pilot test discontinued and colony counts changed so that dropped counting colonies < 4cm; Starting at DRTO in June, colony counts were conducted with 2 observers resulting in double counts

Appendix D. Change Detectable with Protocol

As the primary focus of this protocol is the percent cover of stony coral, this analysis focuses on that metric and only using data collected since the switch to high definition video in 2008. The following analyses are only intended to provide a rough estimate of the minimum change detectable with this protocol. It is important to note that following the 2005-06 bleaching/disease outbreak, the average coral cover in the USVI SFCN sites was only 7.0 % (see Figures D-1a and D-1b). Thus maintaining sample sizes sufficient to detect changes at low coral cover sites (about 5%) as well as high coral cover (>20%) sites is important to maintain an ability to detect change despite declines.

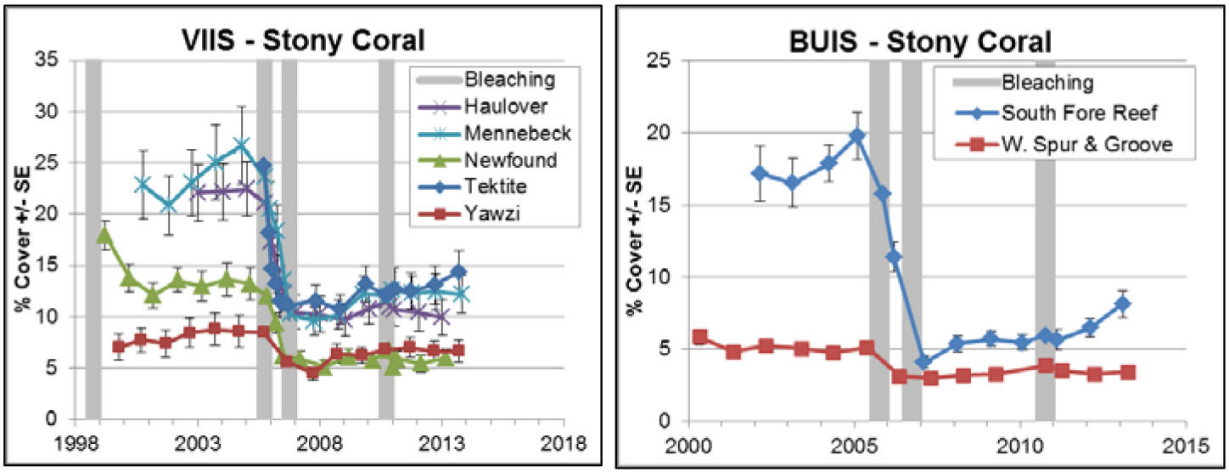


Figure D-1. Graphs showing sharp decline in stony coral cover following 2005–2006 bleaching/disease outbreak at SFCN monitored sites in VIIS and BUIS.

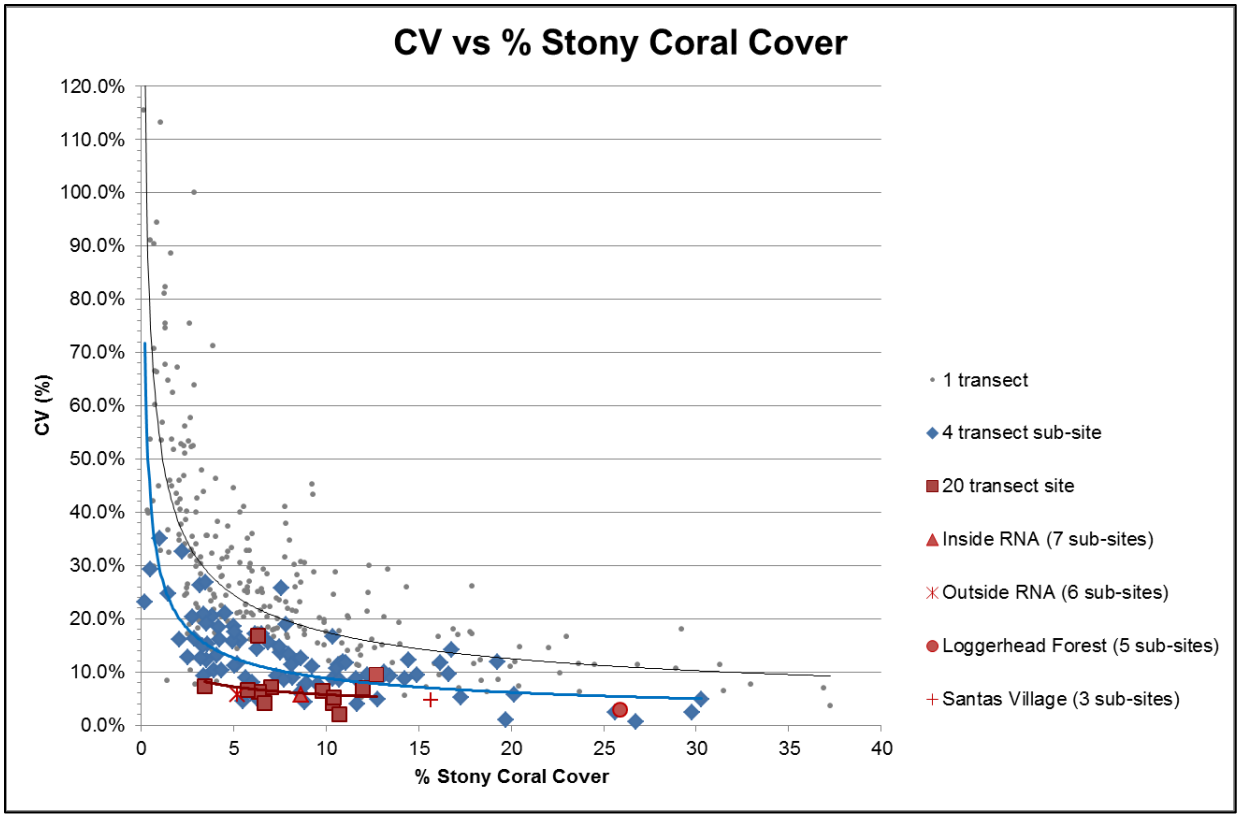


Figure D-2. CV% vs. % Stony Coral Cover at numbers of transects. Results based upon data collected with high definition video only from 2008–2013. Results represent CV through time of single transects, four-transect extensive sub-sites, twenty-transect index sites, and multiple extensive sub-site sites. Twenty-transect sites were also broken into four-transect groups for the purpose of graphing. All sites are included. However the CVs of some sites are likely inflated as trends have been detected at those sites.

Figure D-2 shows a graph of the coefficient of variation (CV) vs. % stony coral cover.

$$CV\ (\%) = 100 * \frac{s}{\bar{x}}$$

Where s = standard deviation of mean through time

$\bar{x}$ = average of mean through time

Some points of note from the graph:

- CV is not constant. Instead it decreases with percent stony coral cover ($CV \propto 1/\sqrt{\bar{x}}$). This suggests a binomial distribution which may require a square root transformation or a binomial data structure in the analysis.
- Below two to three percent stony coral cover, the CV sharply increases indicating the ability to detect change below 2-3% cover is sharply reduced without other modifications to the protocol or large increases in number of transects and/or sub-sites sampled.
- Sites showing strong trends from 2008–2013 have artificially inflated CVs (e.g., SFR and TK). These sites are removed from paired t-test calculations below or detrended from the regression calculations.

Although the statistical trend analyses described in SOP 21 use a binomial error structure, using this approach to determine the difference detectable would have required more complicated programming than it was felt was necessary to provide a general estimate of the change detectable. Instead the following analyses were conducted using square root transformed data to produce estimates of s2 that were useable in the equations. Separate estimates were created for each site or 4-transect extensive sub-site where possible in the hope of generating a better overall estimate of the change detectable by different versions of the sampling design presented.

At the most basic analysis level, the sampling design can be analyzed as paired t-tests between 2 years. This approach has the fewest assumptions about how a change can occur, e.g., suddenly versus a gradual trend. Data were first transformed using a square root transformation. Results are presented in Figures D-3a and b below. The Minimum Detectable Difference was calculated on the square root transformed data using the following equation:

$$minimum\ detectable\ difference = \sqrt{\frac{s^2}{n}} * (t_{\alpha(2),(n-1)} + t_{\beta,(n-1)}) \quad \text{Zar (1999)}$$

Where s^2 = sampling variance estimated from the variance through time (2008-2013) for each transect or each extensive sub-site.

n = the number of transects in the case of 4 transect sub-sites or 20 transect sites

or n = number of extensive sub-sites for index sites or managed zones.

$\alpha = 0.05$

$\beta = 0.20$

power = $1 - \beta = 80\%$.

Minimum detectable percent difference was calculated by back transforming the difference using the following equation:

$$\text{min. detect. \% difference} = \frac{(\text{Transformed data average})^2 - (\text{Transformed data average} - \text{Difference})^2}{}$$

(Transformed data average)^2

The difference detectable depends upon the initial average coral cover at the site (see Figure D-3 a and b). In general a 20 transect site with 10% coral cover can detect a relative change of approximately 13% and a four-transect extensive sub-site can detect a change of approximately 41%. If all twenty-transect sites are broken into four-transect groups and added to the DRTO four-transect extensive sub-sites, the change detectable at 10% cover for five four-transect groups is about 17%. Thus, the twenty-transect design is a little more powerful at detecting change than a site using five four-transect extensive sub-sites. The difference is due to the first having a sample size of twenty and the latter having a sample size of five (the four transects of each extensive sub-site are considered

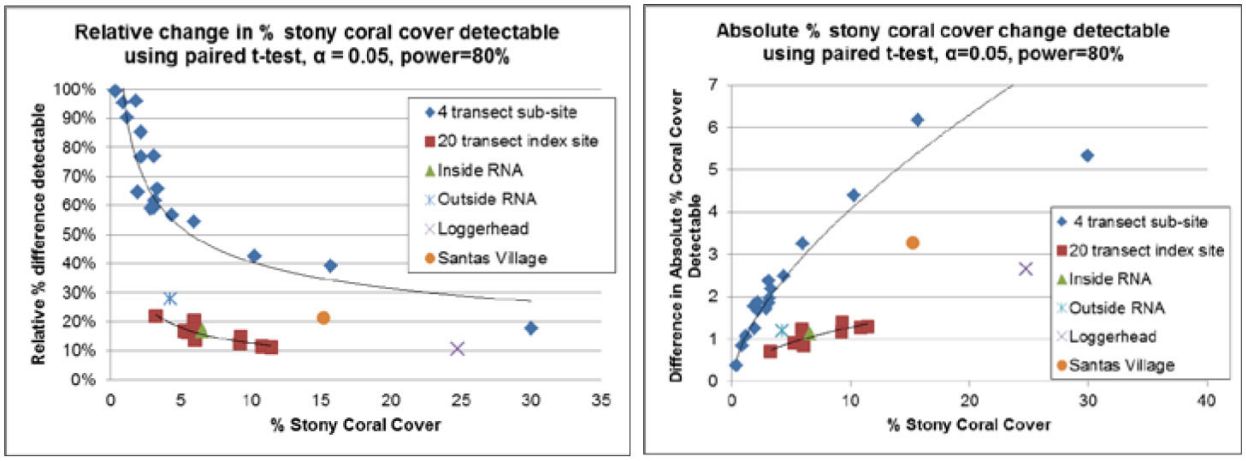


Figure D-3. Absolute and relative change detectable in percent stony cover vary with the initial percent stony coral cover.

sub-samples). The difference is small and should gradually disappear as the number of years monitored increases. However, this underscores that a site small enough to allow randomization of all 20 transects will benefit by this design. However for a large area, the tradeoff of a small decrease in power for increased logistical feasibility, reduced travel costs, and an ability to extrapolate changes to a larger area supports use of the four-transect extensive sub-sites.

A regression analysis yielded similar results to the pairwise t-test (see Figure D-4). The analysis was based upon Gerrodette (1987)'s approximated equation for sample size determination:

$$r^2y^3 \geq 12\ CV^2(Z_{\alpha/2} + Z_{\beta})^2$$

where r = % change / time step

y = # time steps = # years

This equation was modified as follows:

$$d \geq \sqrt{12 * \frac{SS_{resid}}{n * y} * (t_{\frac{\alpha}{2},n*(y-2)} + t_{\beta,n*(y-2)})^2}$$

where d = min. detectable difference between first and last time step = r * y

$CV^2 = SE^2 / \bar{x}^2 = (ss_{resid} / n) / \bar{x}^2$

ss_{resid} = residual sum of squares from repeated measures analysis of covariance with 1st order autoregressive covariance structure using SAS 9.2.

$\bar{x}$ = average of transformed data

n = number of samples/year (this can be transects=20 or sub-sites=5)

y = number of years = 10

$\alpha = 0.05$

β = 1- power = 0.2

The results are given in Figure D-4.

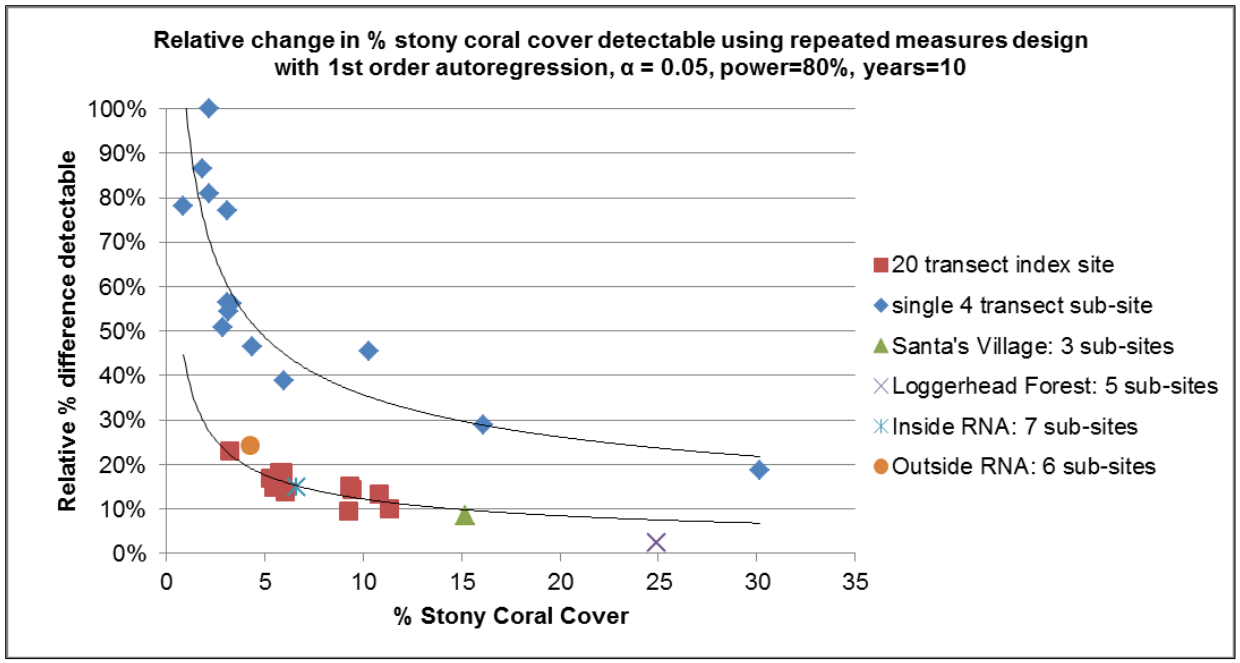


Figure D-4. Relative % change detectable in average coral cover after 10 years using a repeated measures analysis of covariance estimated using SFCN data for 20 transect sites, 4 transect extensive sub-sites, and multiple extensive sub-site sites. Data were backtransformed before graphing.

To estimate the level of change detectable with differing numbers of four-transect extensive sub-sites, all twenty transect sites were divided into five four-transect groupings. Those results were combined with the DRTO extensive sub-sites to estimate the percent change detectable with differing numbers of four transect extensive sub-sites after 10 years of data collection. Results are graphed in Figure D-5. At 10% coral cover five extensive sub-sites can detect a 16% change in coral cover, three extensive sub-sites a 28% change, and two extensive sub-sites a 70% change. However after 10 years, the difference detectable is increasingly reduced as the sampling through time increases the degrees of freedom in the test (14%, 18%, and 23% respectively, see Figure D-6).

A previous analysis on digital videography data from Yawzi and Newfound reefs (before high-definition video implementation) found that non-permanent transects require over 7 times the sample size of permanent transects to detect a 25% trend with equivalent power (Miller et al. 2006a).

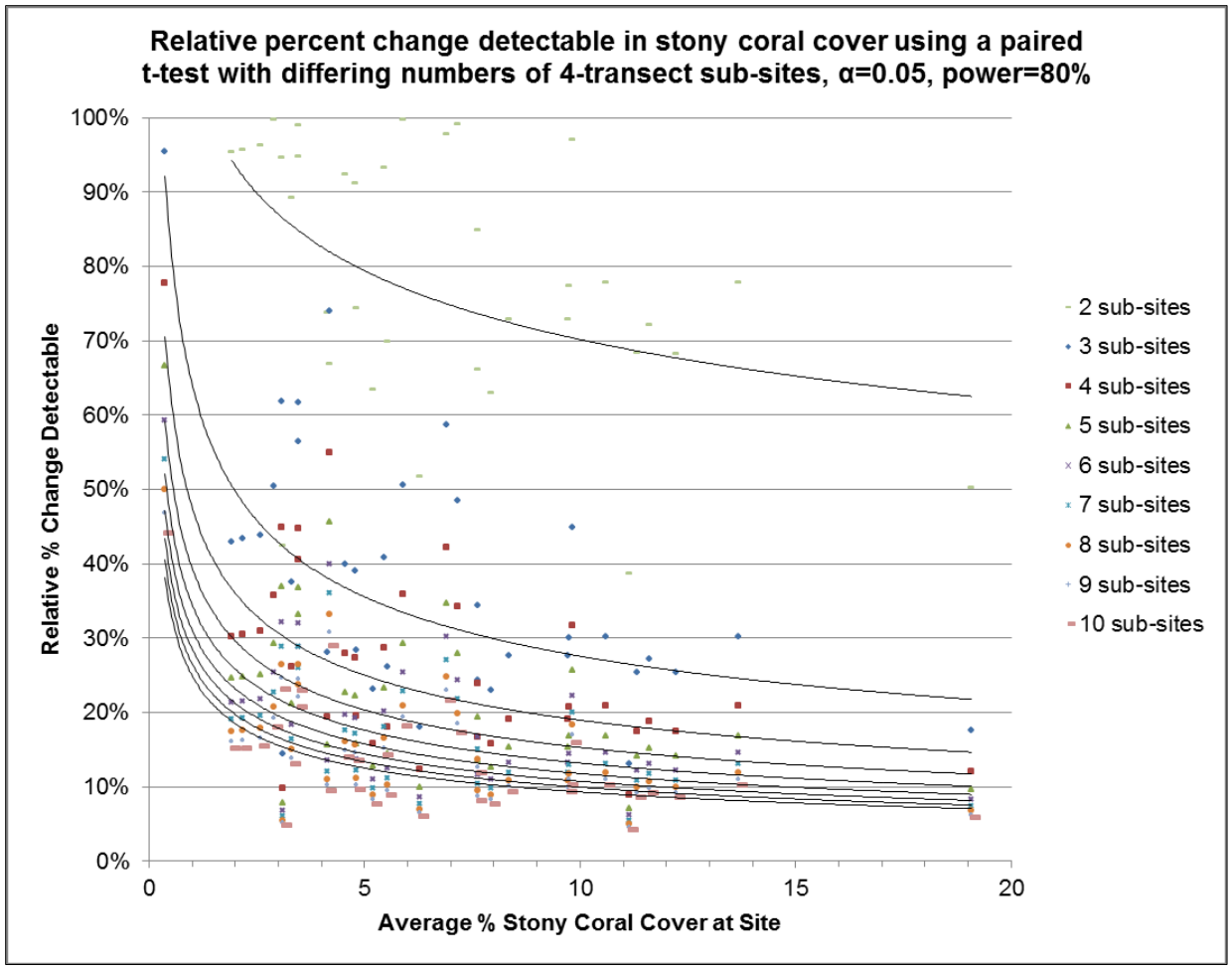


Figure D-5. Relative % change detectable in average coral cover using a paired t-test with differing number of extensive sub-sites. Twenty transect sites were broken into four-transect groupings and combined with DRTO extensive sub-sites for the analysis. Data were backtransformed before graphing.

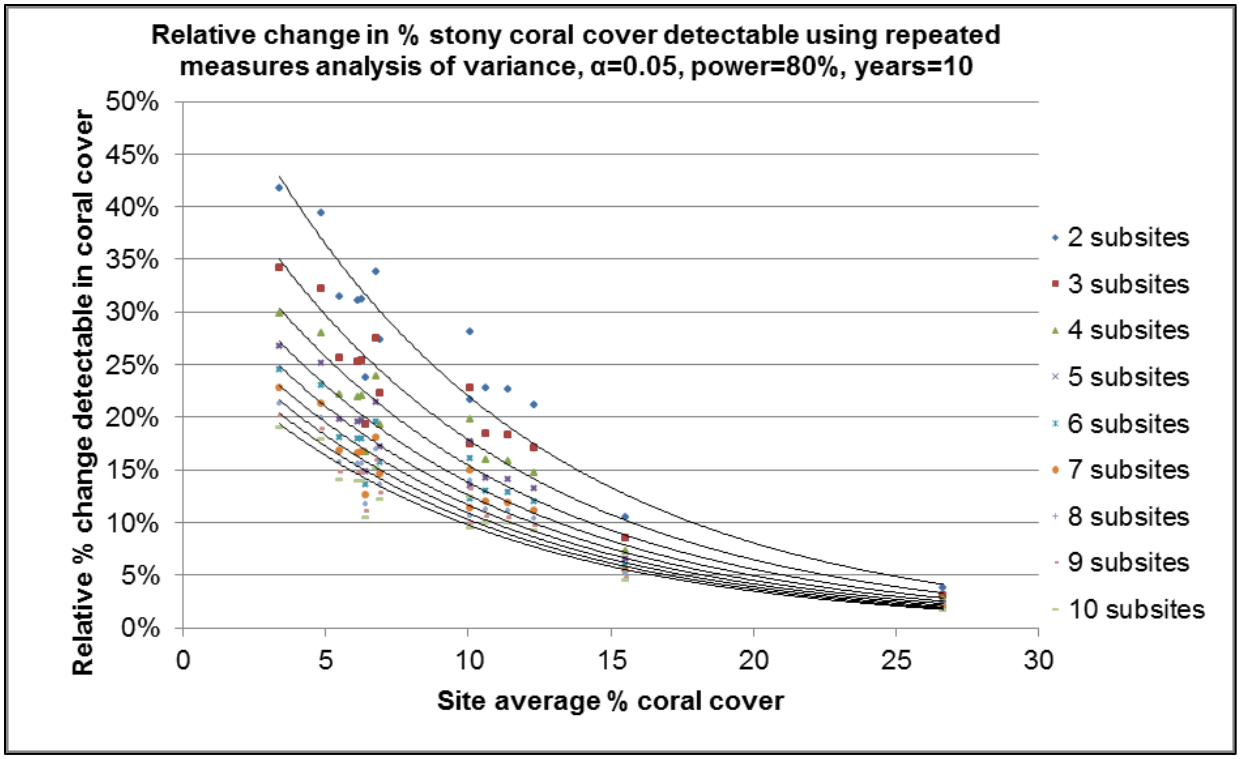


Figure D-6. Relative % change detectable in average coral cover after 10 years using a repeated measures analysis of covariance with differing number of extensive sub-sites. Twenty transect sites were broken into four-transect groupings and combined with DRTO extensive sub-sites for the analysis. Data were backtransformed before graphing.

Appendix E. Conversion from Digital Video (DV) to High Definition Digital Video (HD)

Introduction

Since 1997, the South Florida/ Caribbean Network has been using underwater video transects collected using Digital Video (DV) cameras in underwater housings for the monitoring of the coral reefs in its network National Parks and Monuments. Advancements in technology have produced additional tools to be used in coral reef monitoring. The development of High Definition Video (HDV) is one of these new tools. The increased image quality, through higher resolution and contrast of the HDV format raises the question of whether the transition to HDV videography for monitoring coral reefs will produce different results from DV.

In the fall of 2007 SFCN began evaluating the use of HDV cameras for use in its coral monitoring program. A side-by-side comparison between DV and HDV was conducted to evaluate the ability to produce a similar image "footprint" with HDV to historical DV format, and determine whether enhanced image quality of HDV translated into increased benthic identifications. The following are the results that have been acquired.

Video equipment

The original DV camera and housing were:

- Camera Sony DCR-VX 1000
- Underwater Housing Light and Motion Stingray
- The current HDV camera and housing:
- Camera Sony HDR-FX1
- Underwater Housing Light and Motion Blue Fin FX1

This is the current technology we are using, but as improvements in video equipment occur there may be a need to upgrade to the most effective technology available.

Video Quality

The difference in quality between a DV and HDV image can be seen in the two captured images (Figures E-1 and E-2). The DV image is 0.31 Mega pixels and the HDV image is 2.1 Mega pixels. A size comparison between these two sizes is shown here in Figure E-3. This increased resolution produces a higher quality image, which helps in habitat identification.



Figure E-1. Digital Video image capture.



Figure E-2. High Definition Video capture. Note: The wand is no longer in the picture frame.

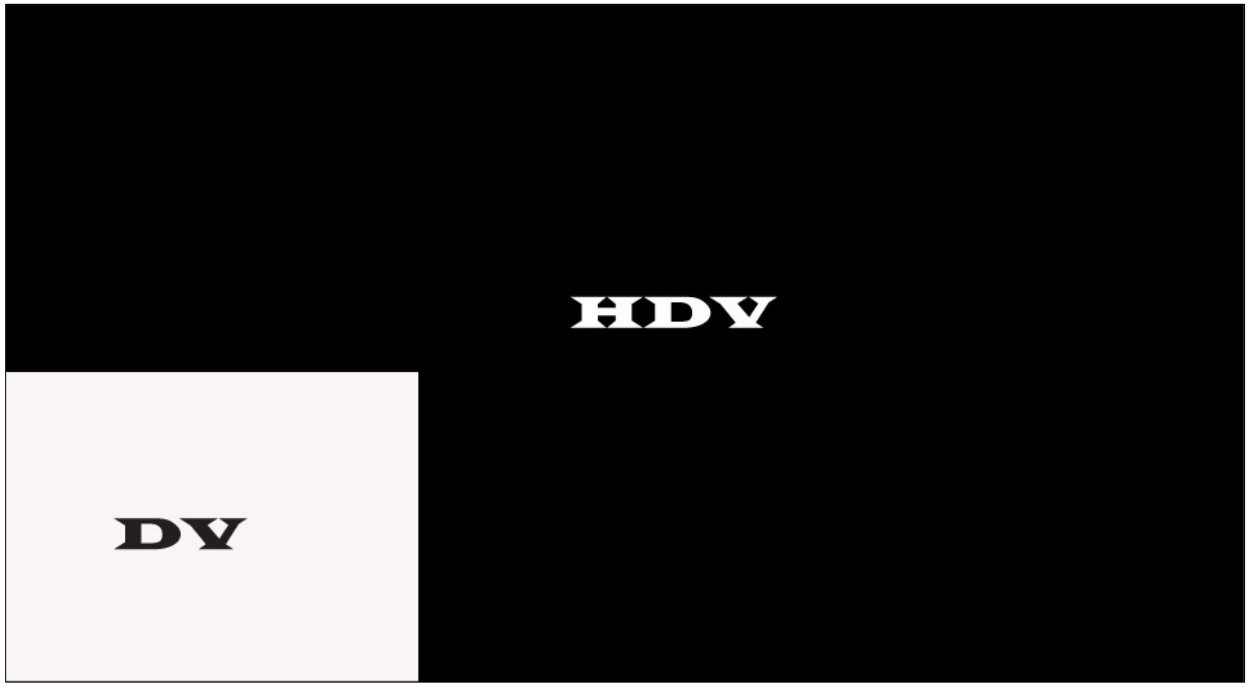


Figure E-3. Comparative sizing between High Definition Video image and Digital Video image.

Coverage Area

To establish the same coverage area a comparison video was filmed between the two cameras and underwater housings along intersecting transect lines along the bottom of a swimming pool. Then to maintain the same focal distance of 40cm an aluminum rod was attached to each of the housings. The resulting captured video images showed a 0.8 cm difference in width between the two formats, but a much more significant difference in length (Figures E-1 and E-2). The difference in width was found to be slight enough so not to affect the repeatability of filming of the already established long term video monitoring sites. The difference in length has increased the number of captured images by an average of 5 per transect for a ten meter transect. This also increased the number of points/dots for identification by an average of 74 more per transect for the HDV.

Data Comparison

The following are the results of the side by side comparison between DV and HDV from the coral video monitoring method used by SFCN (Figure E-4). Comparisons were made upon the differences between the two methods using a Signed Rank test in SAS 9.2. Only variables with statistically significant results are included in Figure E-4. Note: A description of the categories used in the point count identification process is located in Rogers and Miller (2002).

Table E-1a. Summary of differences in results for 7 different sites where HDV and DV were shot at the same time. A signed rank test was conducted on the paired differences between the two methods.

Statistic	Usable points	% Unknown or unidentifiable cover type	% Shadow, but not an unidentifiable cover type	% Equipment - wand	% Stony coral cover	% Coral - unidentified	% Coral - *Colpophyllia natans*	% Coral - *Orbicella franksi*	% Coral - *Porites porites*	# Coral species
Probability		<0.0001	<0.0001	<0.0001	0.0060	<0.0001	0.0384	0..0026	0.0188	<0.0001
HDV avg.	340.6[a]	1.49	0.60	0	7.98[a]	0.07	0.25[a]	0.61[a]	0.57[a]	4.78[a]
DV avg.	266.4	2.17[a]	1.21[a]	0.43[a]	7.63	0.19[a]	0.17	0.45	0.46	4.01
Avg. Diff.	74.2	-0.68	-0.61	-0.043	0.35	-0.12	0.08	0.16	0.11	0.77
Median Difference	70.5	-0.75	-0.42	-0.37	0.50	0	0	0	0	1.00

[a]The higher average (also highlighted in yellow).

Table E-4b. Summary of differences in results for 7 different sites where HDV and DV were shot at the same time. A signed rank test was conducted on the paired differences between the two methods.

Statistic	% Dead coral w/ turf algae	% Macroalgae	% Macroalgae - *Dictyota* spp.	% Macroalgae - *Lobophora variegata*	% Cyano-bacteria	% Gorgonian - *Briareum asbestinum*	% Other organisms	% Bare substrate	% Sand
Probability	<0.0001	<0.0001	<0.0001	<0.0001	0.0173	0.0172	0.0029	0.0035	0.0047
HDV avg.	38.81	26.41[a]	7.78[a]	2.97[a]	2.55[a]	0.09[a]	0.12[a]	13.24[a]	13.20[a]
DV avg.	41.09[a]	24.14	6.30	2.41	2.05	0.05	0.05	12.57	12.55
Avg. Diff.	-2.28	2.26	1.48	0.56	0.50	0.05	0.06	0.66	0.6469
Median Difference	-2.53	1.58	1.31	0	0	0	0	0.32	0.3018

[a]The higher average (also highlighted in yellow).

The analysis exhibited a slight increase in % live coral cover with a median difference of 0.5%. This difference appears to be due to the decrease in the categories of Unknown, Shadow and Wand. This is important because during the identification of the points/dots if the point cannot be confidently identified the Unknown category is chosen. In addition many times a dot may land on an area where there is a shadow or the resolution of the image is too dark to pull in what the image may be and the Shadow category is chosen. The increased resolution of the HDV has given a much clearer image for identification, thereby helping lower the number of points/dots identified as Unknowns and Shadows. In addition the Wand category has been eliminated from the HDV format since the HDV image does not pick up the wand in the image. This allows for an increase dots landing on substrate instead of the wand. Additional changes that occurred were the increased ability to identify macro algae and sponges to species and the increased identification of unknown corals.

Conclusion

After the conducting the comparison between the DV and HDV formats, the HDV format not only physically demonstrated a difference in image quality and resolution, but statistically showed an increase in identification of important reef structures such as coral and macro algae and helped identify categories that were hard to identify in the DV format. The overall conclusion is that the HDV has increased our ability to monitor the benthic habitat and was a worthwhile investment.

Appendix F. Datasheets

Note: Field versions of the datasheets are also available in Z:\SFCN\Vital_Signs\Marine_benthic_communities\CoralMonitoring\documents\Field_Documents\Datasheet_templates

SITE:	DATE:	OBSERVER:

Disease data: **BB**=black band, **CWS**=Carib. white syndrome, **DS**=dark spots, **WB**=white band, **WPL**=white plague, **WPX**=white pox, **YB**=yellow band

Transect: _____ Species List				Transect: _____ Species List			
Stony Count		Fire Count		Stony Count		Fire Count	
Notes:				Notes:			

Transect: _____ Species List				Transect: _____ Species List			
Stony Count		Fire Count		Stony Count		Fire Count	
Notes:				Notes:			

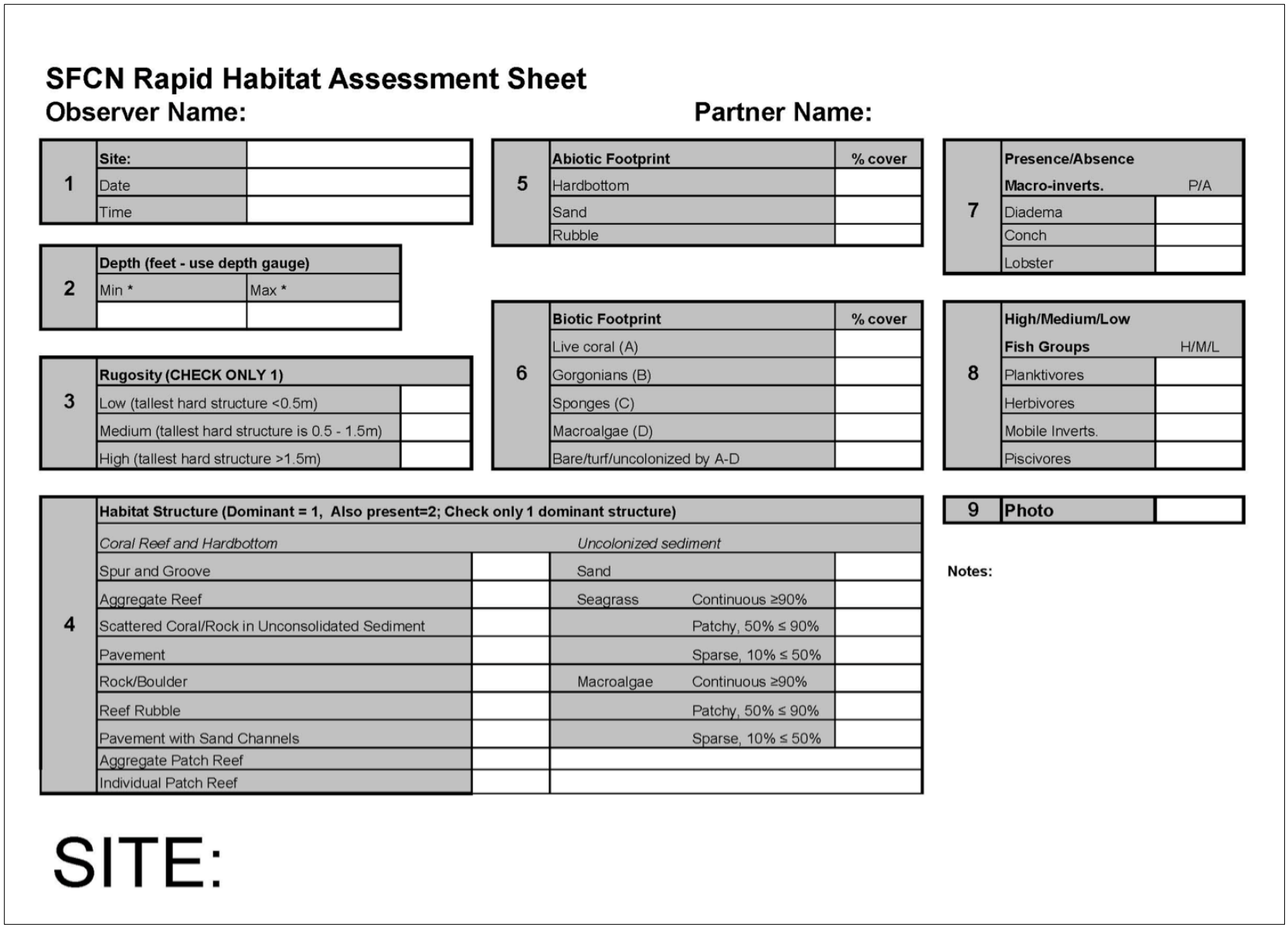
Transect #											
Colony #											
Length along transect (m)											
Distance from transect (cm)											
Is the colony < 4 cm (Y/N)?											
Disease											
Species											
Length (cm)											
Width (cm)											
% discolored tissue											
# of DS blemishes; >30=30											
Number of pictures taken											
TRANSECT NOTES:											

Transect #	1	2	3	4	5	6	7	8	9	10	11
Rugosity (m)											
Diadema											

Figure F-1. Example of Coral disease, species list, diadema, rugosity datasheet, page 1 of 2.

SITE:							DATE:				OBSERVER:									
Disease data: BB=black band, CWS=Carib. white syndrome, DS=dark spots, WB=white band, WPL=white plague, WPX=white pox, YB=yellow band																				
Transect #																				
Colony #																				
Length along transect (m)																				
Distance from transect (cm)																				
Is the colony < 4 cm (Y/N)?																				
Disease																				
Species																				
Length (cm)																				
Width (cm)																				
% discolored tissue																				
# of DS blemishes; >30=30																				
Number of pictures taken																				
TRANSECT NOTES:																				
SITE NOTES																				

Figure F-2. Example of Coral disease, species list, diadema, rugosity datasheet, page 2 of 2.



SFCN Rapid Habitat Assessment Sheet

Observer Name: **Partner Name:**

1	**Site:**	
	Date	
	Time	

2	**Depth (feet - use depth gauge)**	
	Min *	Max *

3	**Rugosity (CHECK ONLY 1)**	
	Low (tallest hard structure <0.5m)	
	Medium (tallest hard structure is 0.5 - 1.5m)	
	High (tallest hard structure >1.5m)	

4	**Habitat Structure (Dominant = 1, Also present=2; Check only 1 dominant structure)**	
	Coral Reef and Hardbottom	
	Spur and Groove	
	Aggregate Reef	
	Scattered Coral/Rock in Unconsolidated Sediment	
	Pavement	
	Rock/Boulder	
	Reef Rubble	
	Pavement with Sand Channels	
	Aggregate Patch Reef	
	Individual Patch Reef	

5	**Abiotic Footprint**	**% cover**
	Hardbottom	
	Sand	
	Rubble	

6	**Biotic Footprint**	**% cover**
	Live coral (A)	
	Gorgonians (B)	
	Sponges (C)	
	Macroalgae (D)	
	Bare/turf/uncolonized by A-D	

	Uncolonized sediment			
	Sand			
	Seagrass	Continuous ≥90%		
		Patchy, 50% ≤ 90%		
		Sparse, 10% ≤ 50%		
	Macroalgae	Continuous ≥90%		
		Patchy, 50% ≤ 90%		
		Sparse, 10% ≤ 50%		

7	**Presence/Absence Macro-inverts.**	P/A
	Diadema	
	Conch	
	Lobster	

8	**High/Medium/Low Fish Groups**	H/M/L
	Planktivores	
	Herbivores	
	Mobile Inverts.	
	Piscivores	

9	**Photo**	

Notes:

SITE:

Figure F-3. Example of an SFCN Rapid Habitat Assessment Sheet, page 1 of 2.

RHA TRANSECT DATA SHEET

Observer Name: **Partner Name:**

Site:	

Date/Time:

Transect (N,S,E,W):			
Meter	Cover	Meter	Cover
0.25		10.25	
0.5		10.5	
0.75		10.75	
1		11	
1.25		11.25	
1.5		11.5	
1.75		11.75	
2		12	
2.25		12.25	
2.5		12.5	
2.75		12.75	
3		13	
3.25		13.25	
3.5		13.5	
3.75		13.75	
4		14	
4.25		14.25	
4.5		14.5	
4.75		14.75	
5		15	
5.25		15.25	
5.5		15.5	
5.75		15.75	
6		16	
6.25		16.25	
6.5		16.5	
6.75		16.75	
7		17	
7.25		17.25	
7.5		17.5	
7.75		17.75	
8		18	
8.25		18.25	
8.5		18.5	
8.75		18.75	
9		19	
9.25		19.25	
9.5		19.5	
9.75		19.75	
10		20	

Transect (N,S,E,W):			
Meter	Cover	Meter	Cover
0.25		10.25	
0.5		10.5	
0.75		10.75	
1		11	
1.25		11.25	
1.5		11.5	
1.75		11.75	
2		12	
2.25		12.25	
2.5		12.5	
2.75		12.75	
3		13	
3.25		13.25	
3.5		13.5	
3.75		13.75	
4		14	
4.25		14.25	
4.5		14.5	
4.75		14.75	
5		15	
5.25		15.25	
5.5		15.5	
5.75		15.75	
6		16	
6.25		16.25	
6.5		16.5	
6.75		16.75	
7		17	
7.25		17.25	
7.5		17.5	
7.75		17.75	
8		18	
8.25		18.25	
8.5		18.5	
8.75		18.75	
9		19	
9.25		19.25	
9.5		19.5	
9.75		19.75	
10		20	

Figure F-4. Example of an SFCN Rapid Habitat Assessment Data Sheet, page 2 of 2.

Appendix G. Printable Checklists

FIELD CHECKLIST FOR SFCN FIELD STATIONS

Standard equipment:

1) Boat keys
2) Emergency O_2 Kit
3) Dive cylinders - number depends upon # divers and tasks; add 2 for emergency.
4) Standard personal dive equipment (mask, fins, snorkel, BCD, weights/belt, knife, exposure suit, compass).
5) Save-a-dive kit: O_2 analyzer, spare o-rings, zip-ties, etc.
6) Boat Dive management folder containing: boat log, dive log, Navy Dive Tables, RM4, and park Emergency Evacuation Plan.
7) Data management folder containing: spare datasheets (DDR and coral colony and species list etc.), site maps, relocation photos and blank underwater paper.
8) Clipboards with attached pencils, rubberbands, spare pencils and 1m transect tape segments.
9) HD Video camera
    a) Tape in camera
    b) Battery in camera
    c) Spare tape and spare charged battery
10) HD Video housing
    a) Lenses cleaned
    b) O-rings inspected and cleaned
    c) Airplane pressure port **CLOSED** on back plate of housing
    d) Aiming wand with method for attachment to the housing
11) Transect tapes with metal "claw" end removed and string leader attached.
    a) 30 m tapes marked at the 10 m point
    b) One 50 m and/or 100 m tape
12) One or two mesh bags and/or weight belt straps for carrying transect tapes.
13) Sledge hammer/mallet
14) Extra copper clad pins
15) Point and shoot camera in housing. O-rings/groove inspected and cleaned and battery charged.
16) SD card in camera.
17) Weighted line with cave reel and float.
18) Rugosity chain marked with pieces of flagging tape every 1m (if needed).
19) Drinking fluids
20) Sunscreen

Additional Equipment for Remote SFCN Field Stations (BUIS, SARI AND DRTO)

1) Hobo base station
2) Hobo boots and caps
3) Hobo USB cable
4) Mini HDV player
5) USB - I.E.E.E. cable
6) Powerstrip
7) Laptop computers
8) USB cable
9) Box of rubber bands
10) Cotton swabs
11) Pens
12) Sharpies
13) Spool of line
14) Black folder
15) Site location floats
16) Duct tape
17) Electrical tape
18) Kimwipes
19) Toothpaste
20) Silicone grease

Additional equipment for SOP7—Selecting Random Sampling Points using GPS

1) GPS in waterproof bag.
2) Flotation device; kickboard, life-jacket etc.
3) Elastic shock cords to secure GPS to floatation device.

Remote SFCN Field Stations (BUIS, SARI AND DRTO)
Coral Field Return Checklist

Trip: _____

Return Date: _____

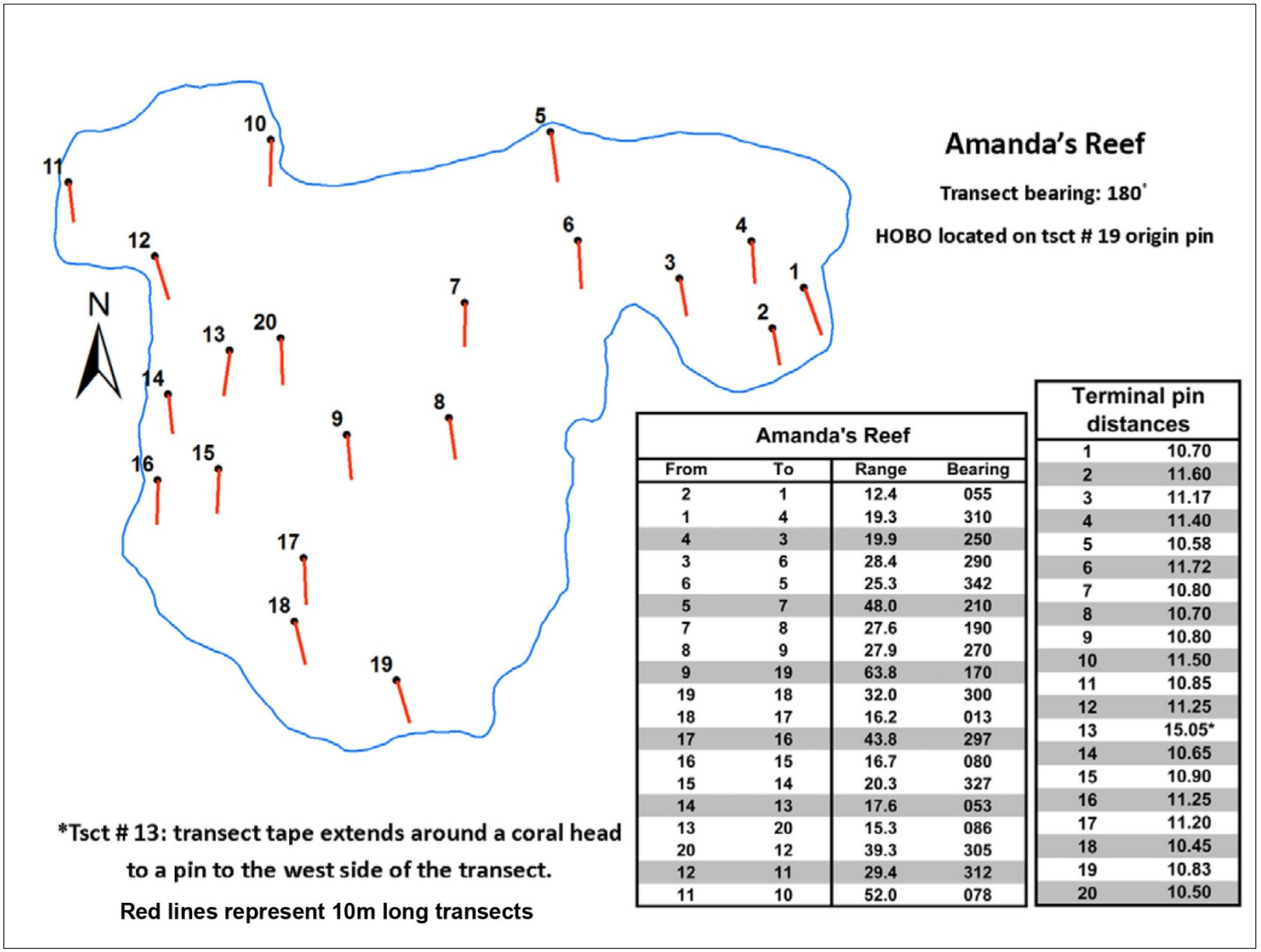
Task	Date Completed	Initials
Download photographs from all cameras *Z:\Photos\Marine\Disease\DRTO\YYYY*		
Format camera memory cards and recharge batteries		
Download waypoints and tracks from each GPS unit *Z:\GIS\GPS\#GPS Unit#*		
Extract relevant waypoints/tracks to new shapefiles *Z:\SFCN\Vital_Signs\Marine_benthic_communities\CoralMonitoring\spatial_info*		
Transfer any files stored on laptop(s) *Z:\SFCN\Vital_Signs\Marine_benthic_communities\CoralMonitoring\data\Archive All files should have YYYYMMDD_ affix to the start of their file name.*		
Scan the disease & colony count datasheets & convert to PDF *Z:\SFCN\Vital_Signs\Marine_benthic_communities\CoralMonitoring\data\DataSheets\DRTO*		

Comments:

Return completed sheet to Data Management

Figure G-1. Example of Remote SFCN Field Stations (BUIS, SARI, and DRTO) Coral Field Return Checklist.

Appendix H. Field Site Maps, Range & Bearing Tables



Amanda's Reef			
From	To	Range	Bearing
2	1	12.4	055
1	4	19.3	310
4	3	19.9	250
3	6	28.4	290
6	5	25.3	342
5	7	48.0	210
7	8	27.6	190
8	9	27.9	270
9	19	63.8	170
19	18	32.0	300
18	17	16.2	013
17	16	43.8	297
16	15	16.7	080
15	14	20.3	327
14	13	17.6	053
13	20	15.3	086
20	12	39.3	305
12	11	29.4	312
11	10	52.0	078

Terminal pin distances	
1	10.70
2	11.60
3	11.17
4	11.40
5	10.58
6	11.72
7	10.80
8	10.70
9	10.80
10	11.50
11	10.85
12	11.25
13	15.05*
14	10.65
15	10.90
16	11.25
17	11.20
18	10.45
19	10.83
20	10.50

Figure H-1. Amanda's Reef field site map, range and bearing tables.

Table H-1. Range table for Amanda's Reef Site, transects 1–10.

Distance	1	2	3	4	5	6	7	8	9	10
1	--	14.4	28.3	12	77	60.6	95.2	93.1	120	144
2	14.4	--	25.6	20	77.3	57.3	86.1	81.3	109	140
3	28.3	25.6	--	19.4	51.7	32.6	68.7	70.8	96.2	116
4	12	20	19.4	--	65.3	50.4	88.1	88.8	115	134
5	77	77.3	51.7	65.3	--	25.3	59.5	78.1	90.2	73.1
6	60.6	57.3	32.6	50.4	25.3	--	45.5	58.1	76.4	83.7
7	95.2	86.1	68.7	88.1	59.5	45.5	--	24.7	31.2	67.9
8	93.1	81.3	70.8	88.8	78.1	58.1	24.7	--	29	91.4
9	120	109	96.2	115	90.2	76.4	31.2	29	--	78.4
10	144	140	116	134	73.1	83.7	67.9	91.4	78.4	--
11	191	186	163	181	122	131	105	124	101	49.4
12	165	159	137	156	102	106	75.3	93.3	70.7	35.4
13	151	142	123	143	97.4	94.9	56	69.6	44.4	49
14	165	156	139	158	116	112	70	78.8	50.5	66.1
15	158	148	133	152	118	110	64.9	67.3	38.3	79.9
16	174	163	149	168	133	125	80.5	82.7	53.9	88.2
17	145	133	124	142	123	108	63.8	53	33.1	105
18	158	144	138	155	140	124	80.5	67.2	50.3	121
19	146	132	130	145	145	124	87.6	66.8	63.8	142
20	135	126	107	127	83.6	79.4	40.1	55.5	33.6	47.4

Table H-2. Bearing table for Amanda's Reef Site, transects 1–10.

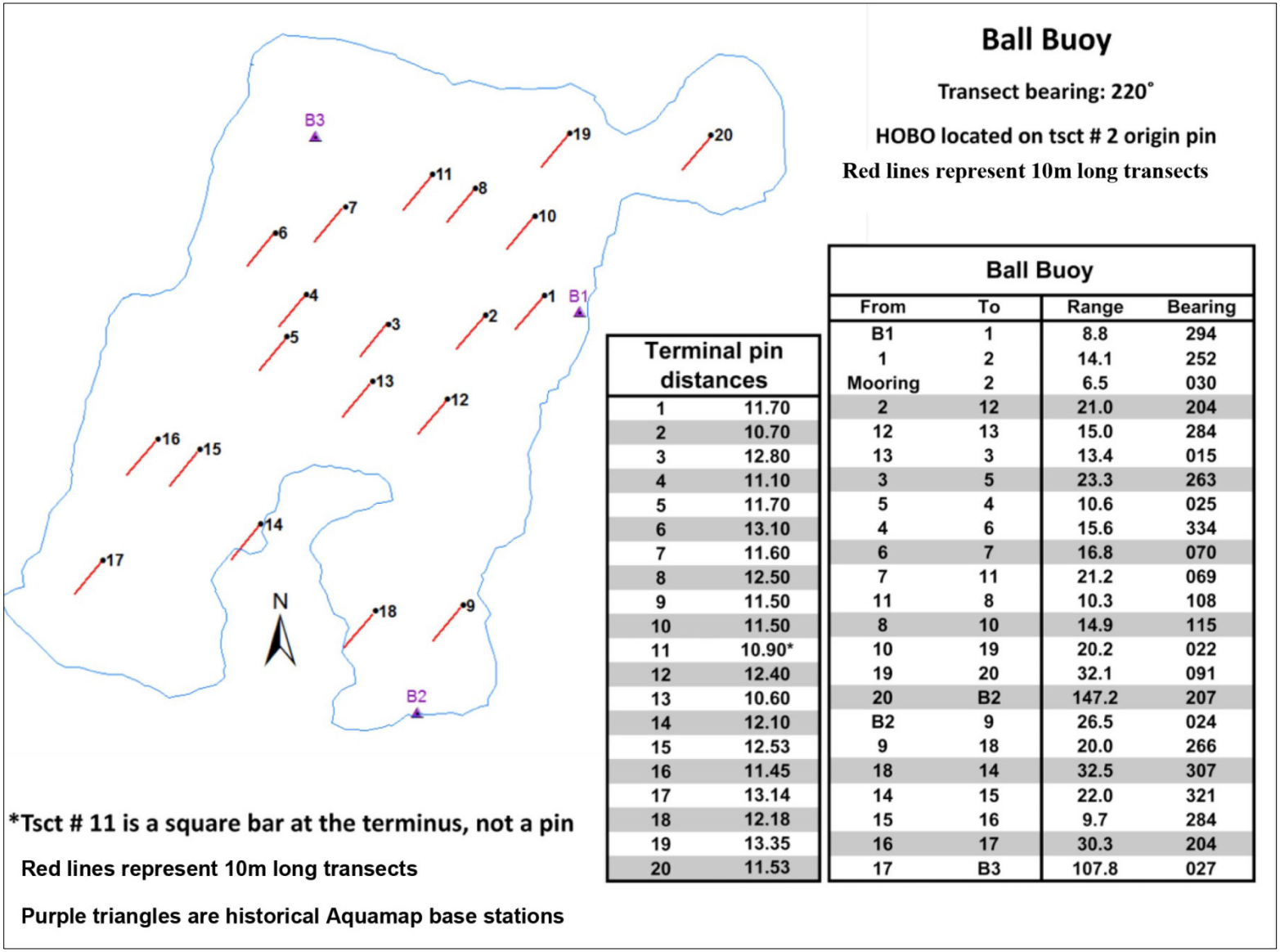
Bearing	1	2	3	4	5	6	7	8	9	10
1	--	214	278	312	300	283	261	246	251	284
2	34	--	309	357	310	297	268	251	256	290
3	98	129	--	78	311	288	254	234	243	285
4	132	177	258	--	297	277	255	239	246	282
5	120	130	131	117	--	162	207	193	211	268
6	103	117	108	97	342	--	230	207	226	285
7	81	88	74	75	27	50	--	159	220	317
8	66	71	54	59	13	27	339	--	268	323
9	71	76	63	66	31	46	40	88	--	341
10	104	110	105	102	88	105	137	143	161	--
11	99	103	99	97	86	97	115	123	132	83
12	93	98	93	91	74	88	109	121	134	45
13	85	90	82	82	58	73	92	111	126	12
14	81	84	77	77	56	68	80	98	104	20
15	74	77	69	70	46	58	63	85	83	9
16	74	77	69	70	49	60	65	82	79	18
17	62	65	54	57	30	40	32	54	25	353
18	57	59	49	53	28	36	28	44	21	356
19	46	47	36	41	15	21	7	17	351	345
20	85	90	81	81	53	71	94	118	143	353

Table H-3. Range table for Amanda's Reef Site, transects 11–20.

Distance	11	12	13	14	15	16	17	18	19	20
1	191	165	151	165	158	174	145	158	146	135
2	186	159	142	156	148	163	133	144	132	126
3	163	137	123	139	133	149	124	138	130	107
4	181	156	143	158	152	168	142	155	145	127
5	122	102	97.4	116	118	133	123	140	145	83.6
6	131	106	94.9	112	110	125	108	124	124	79.4
7	105	75.3	56	70	64.9	80.5	63.8	80.5	87.6	40.1
8	124	93.3	69.6	78.8	67.3	82.7	53	67.2	66.8	55.5
9	101	70.7	44.4	50.5	38.3	53.9	33.1	50.3	63.8	33.6
10	49.4	35.4	49	66.1	79.9	88.2	105	121	142	47.4
11	--	30.6	57.3	61.7	81.8	81	115	128	156	68.6
12	30.6	--	27.5	37.1	55.5	59	87.2	102	128	38
13	57.3	27.5	--	19.1	31.1	39.8	60.2	75.2	100	16
14	61.7	37.1	19.1	--	20.3	22.4	54.7	66.7	95.4	32.6
15	81.8	55.5	31.1	20.3	--	15.8	34.7	46.5	75.3	36.7
16	81	59	39.8	22.4	15.8	--	43.8	50.9	82.3	49.6
17	115	87.2	60.2	54.7	34.7	43.8	--	17.5	40.8	57.3
18	128	102	75.2	66.7	46.5	50.9	17.5	--	32.3	74
19	156	128	100	95.4	75.3	82.3	40.8	32.3	--	94.9
20	68.6	38	16	32.6	36.7	49.6	57.3	74	94.9	--

Table H-4. Bearing table for Amanda's Reef Site, transects 11–20.

Bearing	11	12	13	14	15	16	17	18	19	20
1	279	273	265	261	254	254	242	237	226	265
2	283	278	270	264	257	257	245	239	227	270
3	279	273	262	257	249	249	234	229	216	261
4	277	271	262	257	250	250	237	233	221	261
5	266	254	238	236	226	229	210	208	195	233
6	277	268	253	248	238	240	220	216	201	251
7	295	289	272	260	243	245	212	208	187	274
8	303	301	291	278	265	262	234	224	197	298
9	312	314	306	284	263	259	205	201	171	323
10	263	225	192	200	189	198	173	176	165	173
11	--	128	137	155	153	164	148	154	147	127
12	308	--	147	177	166	182	155	161	151	125
13	317	327	--	223	184	205	159	166	153	86
14	335	357	43	--	147	190	140	152	142	63
15	333	346	4	327	--	252	136	155	140	29
16	344	2	25	10	72	--	117	137	130	42
17	328	335	339	320	316	297	--	193	144	354
18	334	341	346	332	335	317	13	--	120	358
19	327	331	333	322	320	310	324	300	--	342
20	307	305	266	243	209	222	174	178	162	--



Terminal pin distances	
1	11.70
2	10.70
3	12.80
4	11.10
5	11.70
6	13.10
7	11.60
8	12.50
9	11.50
10	11.50
11	10.90*
12	12.40
13	10.60
14	12.10
15	12.53
16	11.45
17	13.14
18	12.18
19	13.35
20	11.53

Ball Buoy			
From	To	Range	Bearing
B1	1	8.8	294
1	2	14.1	252
Mooring	2	6.5	030
2	12	21.0	204
12	13	15.0	284
13	3	13.4	015
3	5	23.3	263
5	4	10.6	025
4	6	15.6	334
6	7	16.8	070
7	11	21.2	069
11	8	10.3	108
8	10	14.9	115
10	19	20.2	022
19	20	32.1	091
20	B2	147.2	207
B2	9	26.5	024
9	18	20.0	266
18	14	32.5	307
14	15	22.0	321
15	16	9.7	284
16	17	30.3	204
17	B3	107.8	027

Figure H-2. Ball Buoy Reef field site map, range and bearing tables.

Table H-5. Range table for Ball Buoy Reef site, transects 1–10.

Distance	1	2	3	4	5	6	7	8	9	10
1	--	14.1	36	54	59.3	62.6	49.4	29	72.7	18.2
2	14.1	--	22.2	41	45.4	51.1	40.2	28.9	66.1	25.2
3	36	22.2	--	19.8	23.3	32.9	28.3	36.8	66.1	41.5
4	54	41	19.8	--	10.6	15.6	21.8	45.5	79.1	55
5	59.3	45.4	23.3	10.6	--	23.7	32.3	54.6	73	62.8
6	62.6	51.1	32.9	15.6	23.7	--	16.8	46.5	94.7	59
7	49.4	40.2	28.3	21.8	32.3	16.8	--	29.9	94.3	43.2
8	29	28.9	36.8	45.5	54.6	46.5	29.9	--	94.8	14.9
9	72.7	66.1	66.1	79.1	73	94.7	94.3	94.8	--	90
10	18.2	25.2	41.5	55	62.8	59	43.2	14.9	90	--
11	37.5	34.2	35.6	39.7	49.7	38	21.2	10.3	98.2	25.2
12	32.2	21	21.6	39.8	39.1	54.2	49.4	48.4	47	46.2
13	43.5	29.6	13.4	24.8	22	40.2	40	49.7	54.9	52.6
14	82.6	69.6	53.8	53.2	43	66.3	74.5	90.6	49.4	93.7
15	85.6	71.6	51.3	42.6	32.2	52	64.1	86.2	69.5	92.7
16	93.4	79.4	58.3	46.9	37.2	53.8	67.6	91.8	78.9	99.4
17	117	103	84	75.9	65.6	84	97.2	120	82.4	125
18	81.2	71.7	65.2	73.5	65.4	88.7	91.9	98.7	20	96.8
19	37.3	45.4	59.7	70	79.1	70.3	53.5	24.6	110	20.2
20	52.6	65.5	84.9	98.8	107	101	84.6	54.7	121	43.9

Table H-6. Bearing table for Ball Buoy Reef site, transects 1–10.

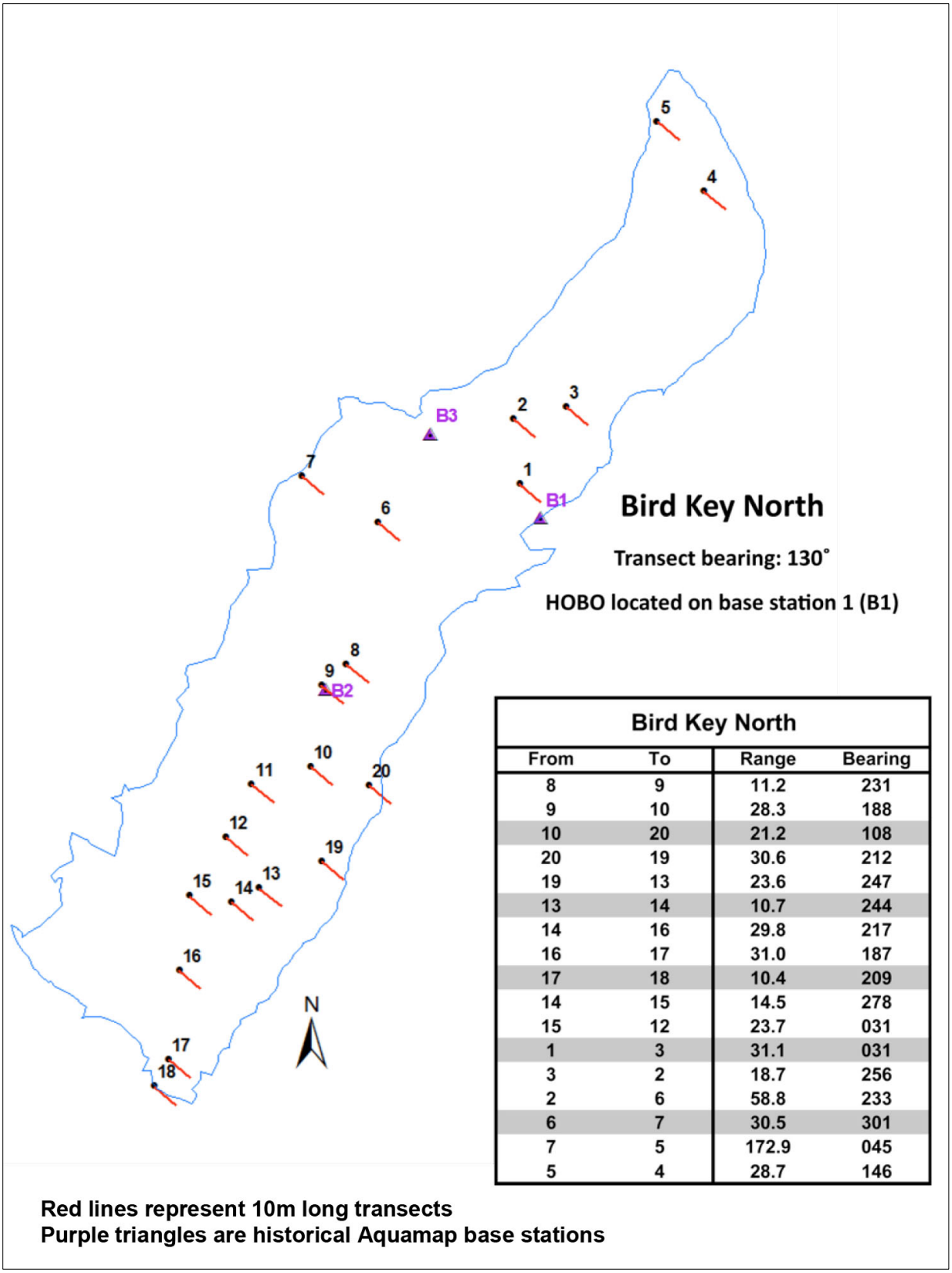
Bearing	1	2	3	4	5	6	7	8	9	10
1	--	252	260	270	261	283	294	327	195	353
2	72	--	265	277	264	291	308	356	184	27
3	80	85	--	290	263	309	340	33	165	54
4	90	97	110	--	205	334	24	58	153	71
5	81	84	83	25	--	354	24	52	147	64
6	103	111	129	154	174	--	70	77	153	86
7	114	128	160	204	204	250	--	82	164	93
8	147	176	213	238	232	257	262	--	182	115
9	15	4	345	333	327	333	344	2	--	10
10	173	207	234	251	244	266	273	295	190	--
11	137	159	196	226	222	249	249	108	176	112
12	43	24	322	307	291	314	332	8	176	26
13	63	60	15	322	297	327	351	28	158	44
14	51	47	32	11	8	3	15	33	112	42
15	66	65	56	35	38	19	31	47	121	55
16	70	69	64	46	51	30	39	52	119	59
17	59	57	50	37	39	28	34	45	97	51
18	28	20	3	348	342	345	356	13	86	22
19	189	205	223	238	234	251	252	240	193	202
20	226	231	240	248	245	257	259	257	208	245

Table H-7. Range table for Ball Buoy Reef site, transects 11–20.

Distance	11	12	13	14	15	16	17	18	19	20
1	37.5	32.2	43.5	82.6	85.6	93.4	117	81.2	37.3	52.6
2	34.2	21	29.6	69.6	71.6	79.4	103	71.7	45.4	65.5
3	35.6	21.6	13.4	53.8	51.3	58.3	84	65.2	59.7	84.9
4	39.7	39.8	24.8	53.2	42.6	46.9	75.9	73.5	70	98.8
5	49.7	39.1	22	43	32.2	37.2	65.6	65.4	79.1	107
6	38	54.2	40.2	66.3	52	53.8	84	88.7	70.3	101
7	21.2	49.4	40	74.5	64.1	67.6	97.2	91.9	53.5	84.6
8	10.3	48.4	49.7	90.6	86.2	91.8	120	98.7	24.6	54.7
9	98.2	47	54.9	49.4	69.5	78.9	82.4	20	110	121
10	25.2	46.2	52.6	93.7	92.7	99.4	125	96.8	20.2	43.9
11	--	51.2	48.9	88.6	81.8	86.5	115	100	32.4	63.8
12	51.2	--	17.4	50.9	57.3	66.2	86.2	50.8	66.4	84.8
13	48.9	17.4	--	41.2	42.2	50.4	73.5	52.2	71.8	94.9
14	88.6	50.9	41.2	--	22	30.4	36.8	32.5	113	135
15	81.8	57.3	42.2	22	--	9.72	33.4	54.2	110	136
16	86.5	66.2	50.4	30.4	9.72	--	30.3	62.9	116	143
17	115	86.2	73.5	36.8	33.4	30.3	--	62.8	143	168
18	100	50.8	52.2	32.5	54.2	62.9	62.8	--	117	132
19	32.4	66.4	71.8	113	110	116	143	117	--	32.1
20	63.8	84.8	94.9	135	136	143	168	132	32.1	--

Table H-8. Bearing table for Ball Buoy Reef site, transects 11–20.

Bearing	11	12	13	14	15	16	17	18	19	20
1	317	223	243	231	246	250	239	208	9	46
2	339	204	240	227	245	249	237	200	25	51
3	16	142	195	212	236	244	230	183	43	60
4	46	127	142	191	215	226	217	168	58	68
5	42	111	117	188	218	231	219	162	54	65
6	69	134	147	183	199	210	208	165	71	77
7	69	152	171	195	211	219	214	176	72	79
8	288	188	208	213	227	232	225	193	60	77
9	356	356	338	292	301	299	277	266	13	28
10	292	206	224	222	235	239	231	202	22	65
11	--	176	196	206	220	226	220	187	73	82
12	356	--	284	236	259	262	245	199	25	45
13	16	104	--	218	249	255	236	179	38	54
14	26	56	38	--	321	310	257	127	38	49
15	40	79	69	141	--	284	221	133	49	58
16	46	82	75	130	104	--	204	128	53	61
17	40	65	56	77	41	24	--	101	48	55
18	7	19	359	307	313	308	281	--	22	35
19	253	205	218	218	229	233	228	202	--	91
20	262	225	234	229	238	241	235	215	271	--



Bird Key North			
From	To	Range	Bearing
8	9	11.2	231
9	10	28.3	188
10	20	21.2	108
20	19	30.6	212
19	13	23.6	247
13	14	10.7	244
14	16	29.8	217
16	17	31.0	187
17	18	10.4	209
14	15	14.5	278
15	12	23.7	031
1	3	31.1	031
3	2	18.7	256
2	6	58.8	233
6	7	30.5	301
7	5	172.9	045
5	4	28.7	146

Figure H-3. Bird Key North Reef field site map, range and bearing table.

Table H-9. Range table for Bird Key North Reef site, transects 1–10.

Distance	1	2	3	4	5	6	7	8	9	10
1	--	22.2	31.1	119	133	50.7	74.9	86.4	97.5	121
2	22.2	--	18.7	103	114	58.8	75.5	102	113	139
3	31.1	18.7	--	88.2	103	76.3	94.1	117	128	152
4	119	103	88.2	--	28.7	160	170	205	216	241
5	133	114	103	28.7	--	168	173	216	226	252
6	50.7	58.8	76.3	160	168	--	30.5	50.3	59.5	87.4
7	74.9	75.5	94.1	170	173	30.5	--	66.8	72.4	100
8	86.4	102	117	205	216	50.3	66.8	--	11.2	37.3
9	97.5	113	128	216	226	59.5	72.4	11.2	--	28.3
10	121	139	152	241	252	87.4	100	37.3	28.3	--
11	139	155	170	257	268	100	108	52.6	41.8	21.2
12	159	175	189	277	288	121	127	72.7	62	38.1
13	166	184	197	285	298	133	143	82.7	73.2	45.5
14	175	193	206	294	306	140	149	90.8	80.9	54
15	182	199	213	301	312	144	150	96.3	85.7	61
16	205	222	236	324	336	169	176	120	110	83.6
17	233	251	264	352	365	199	207	149	140	112
18	243	261	274	362	375	209	217	160	150	123
19	147	166	178	266	280	118	133	68.3	60.7	32.9
20	117	136	147	236	250	90.9	109	42.4	38.3	21.2

Table H-10. Bearing table for Bird Key North Reef site, transects 1–10.

Bearing	1	2	3	4	5	6	7	8	9	10
1	--	355	31	32	21	255	272	224	224	216
2	175	--	76	40	26	233	255	214	216	210
3	211	256	--	32	18	238	255	220	221	215
4	212	220	212	--	326	224	235	217	218	214
5	201	206	198	146	--	215	225	210	211	208
6	75	53	58	44	35	--	301	192	199	195
7	92	75	75	55	45	121	--	167	175	178
8	44	34	40	37	30	12	347	--	231	199
9	44	36	41	38	31	19	355	51	--	188
10	36	30	35	34	28	15	358	19	8	--
11	42	36	40	37	31	26	9	38	35	73
12	40	35	38	36	31	26	12	35	32	50
13	33	28	32	32	27	18	6	21	17	23
14	35	30	34	34	29	21	9	26	23	30
15	39	34	38	36	31	27	15	34	32	43
16	35	31	34	34	29	24	14	29	26	33
17	31	28	31	32	27	21	13	24	22	26
18	31	28	31	31	27	22	14	24	23	26
19	28	23	28	30	24	9	357	7	360	353
20	26	22	27	29	23	2	348	350	335	288

Table H-11. Range table for Bird Key North Reef site, transects 11–20.

Distance	11	12	13	14	15	16	17	18	19	20
1	139	159	166	175	182	205	233	243	147	117
2	155	175	184	193	199	222	251	261	166	136
3	170	189	197	206	213	236	264	274	178	147
4	257	277	285	294	301	324	352	362	266	236
5	268	288	298	306	312	336	365	375	280	250
6	100	121	133	140	144	169	199	209	118	90.9
7	108	127	143	149	150	176	207	217	133	109
8	52.6	72.7	82.7	90.8	96.3	120	149	160	68.3	42.4
9	41.8	62	73.2	80.9	85.7	110	140	150	60.7	38.3
10	21.2	38.1	45.5	54	61	83.6	112	123	32.9	21.2
11	--	20.4	36	41.1	44.1	68.9	99.3	109	36.1	40.4
12	20.4	--	21.1	22.3	23.7	48.6	79.2	89.3	34.3	52.5
13	36	21.1	--	10.7	24.1	39.6	66.9	77.3	23.6	51.7
14	41.1	22.3	10.7	--	14.5	29.8	58.7	69	34.2	62
15	44.1	23.7	24.1	14.5	--	26	57	66.8	47.2	72.5
16	68.9	48.6	39.6	29.8	26	--	31	40.9	62	91.2
17	99.3	79.2	66.9	58.7	57	31	--	10.4	86.5	117
18	109	89.3	77.3	69	66.8	40.9	10.4	--	96.8	127
19	36.1	34.3	23.6	34.2	47.2	62	86.5	96.8	--	30.6
20	40.4	52.5	51.7	62	72.5	91.2	117	127	30.6	--

Table H-12. Bearing table for Bird Key North Reef site, transects 11–20.

Bearing	11	12	13	14	15	16	17	18	19	20
1	222	220	213	215	219	215	211	211	208	206
2	216	215	208	210	214	211	208	208	203	202
3	220	218	212	214	218	214	211	211	208	207
4	217	216	212	214	216	214	212	211	210	209
5	211	211	207	209	211	209	207	207	204	203
6	206	206	198	201	207	204	201	202	189	182
7	189	192	186	189	195	194	193	194	177	168
8	218	215	201	206	214	209	204	204	187	170
9	215	212	197	203	212	206	202	203	180	155
10	253	230	203	210	223	213	206	206	173	108
11	--	206	176	190	209	201	197	198	138	91
12	26	--	146	175	211	199	194	196	104	70
13	356	326	--	244	264	224	208	208	67	47
14	10	355	64	--	278	217	202	203	66	50
15	29	31	84	98	--	188	187	191	75	58
16	21	19	44	37	8	--	187	192	53	46
17	17	14	28	22	7	7	--	209	38	36
18	18	16	28	23	11	12	29	--	37	35
19	318	284	247	246	255	233	218	217	--	32
20	271	250	227	230	238	226	216	215	212	--

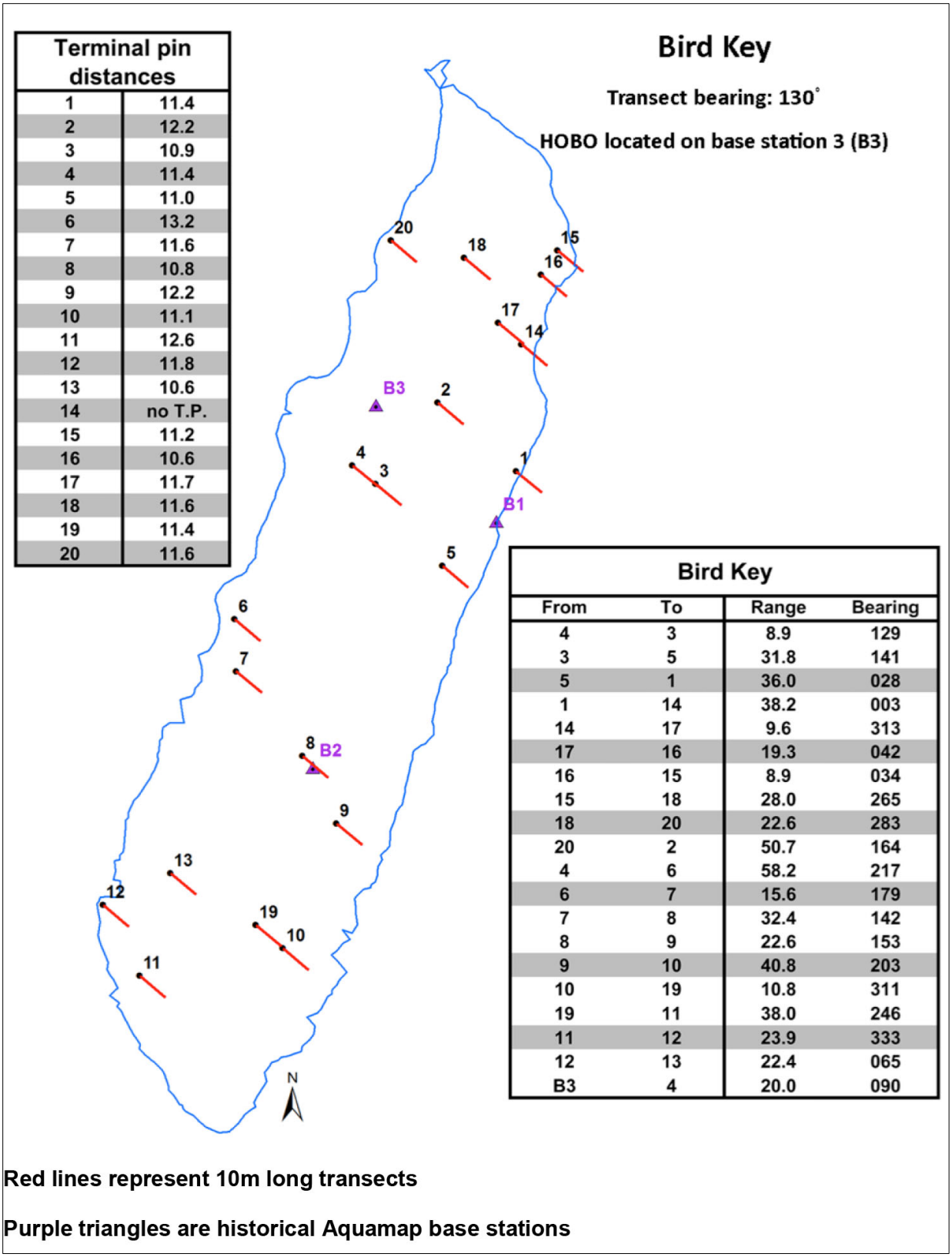


Figure H-4. Bird Key Reef field site map, range and bearing tables.

Table H-13. Range table for Bird Key Reef site, transects 1–10.

Distance	1	2	3	4	5	6	7	8	9	10
1	--	31.2	42.1	49	36	95.3	103	107	119	160
2	31.2	--	30.6	31.7	49.1	89.1	101	114	130	170
3	42.1	30.6	--	8.91	31.8	58.7	70.2	84.8	103	142
4	49	31.7	8.91	--	40.5	58.2	71.1	88.7	108	147
5	36	49.1	31.8	40.5	--	64.3	69.5	70.9	83.7	125
6	95.3	89.1	58.7	58.2	64.3	--	15.6	45.8	68.5	100
7	103	101	70.2	71.1	69.5	15.6	--	32.4	54.7	84.5
8	107	114	84.8	88.7	70.9	45.8	32.4	--	22.6	58.1
9	119	130	103	108	83.7	68.5	54.7	22.6	--	40.8
10	160	170	142	147	125	100	84.5	58.1	40.8	--
11	189	194	164	166	153	111	96	82.1	74.6	43.7
12	180	181	151	152	144	94.6	80.8	74.7	74.1	55.4
13	159	162	132	134	123	78.7	63.8	52.9	51.8	40.6
14	38.2	30.7	60.5	62.3	70.7	119	130	140	154	195
15	67.5	58.2	88.8	89.2	101	147	159	170	185	225
16	59.5	49.3	79.9	80.4	92.3	138	150	161	176	217
17	44.9	30.1	60.7	61.1	75	119	131	143	158	199
18	65.9	44.2	72.9	70.8	92.8	129	142	157	174	215
19	157	166	137	141	122	92.1	76.5	52.6	38.9	10.8
20	78.7	50.7	73.3	68.6	99	123	138	157	176	215

Table H-14. Bearing table for Bird Key Reef site, transects 1–10.

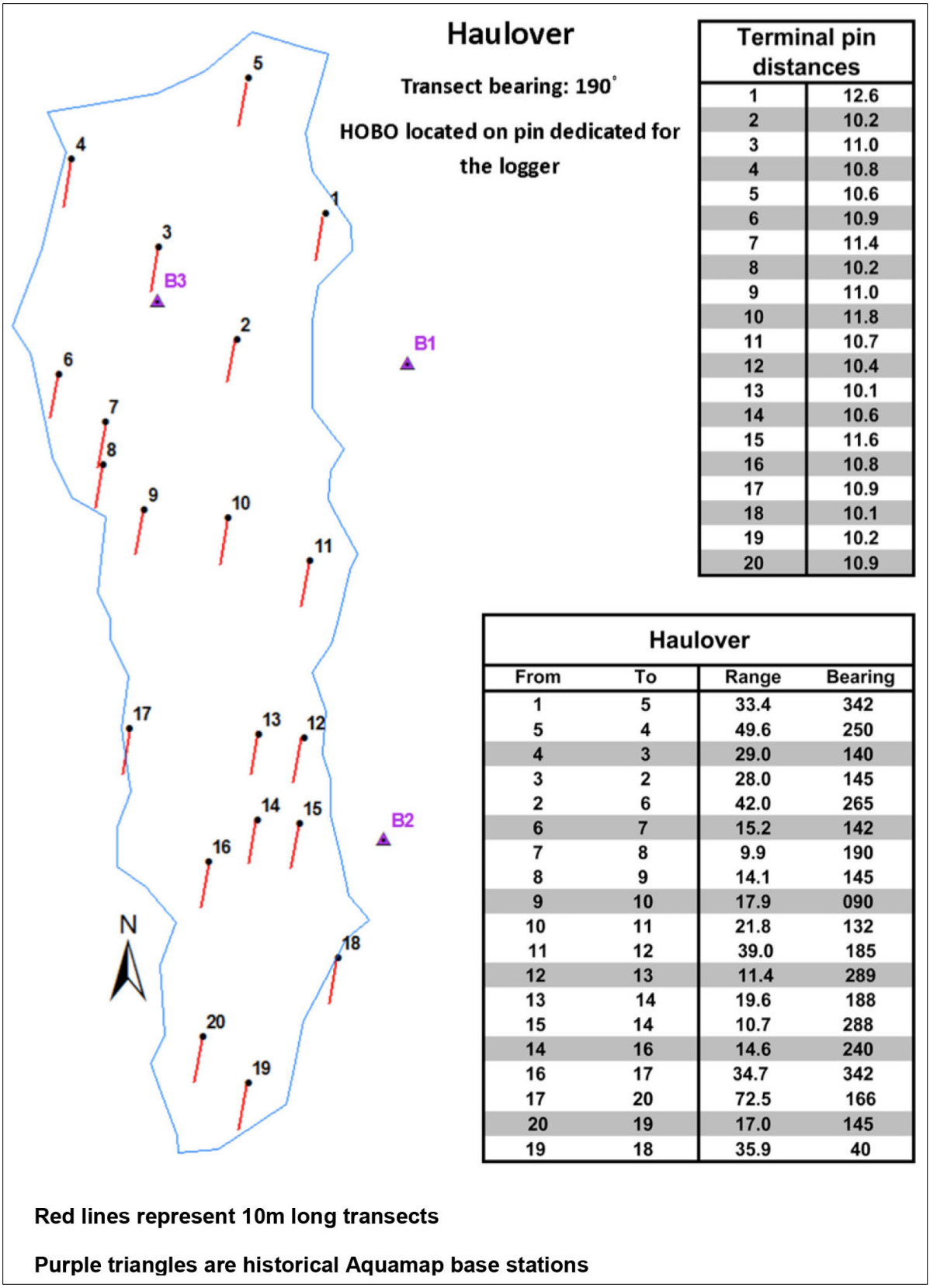
Bearing	1	2	3	4	5	6	7	8	9	10
1	--	311	265	272	218	242	234	217	207	206
2	131	--	217	234	178	223	217	201	193	196
3	85	37	--	309	141	226	217	195	187	191
4	92	54	129	--	138	217	209	190	183	188
5	38	358	321	318	--	256	243	216	202	203
6	62	43	46	37	76	--	179	154	154	172
7	54	37	37	29	63	359	--	142	147	170
8	37	21	15	10	36	334	322	--	153	186
9	27	13	7	3	22	334	327	333	--	203
10	26	16	11	8	23	352	350	6	23	--
11	37	27	26	23	36	15	17	36	52	79
12	43	34	33	29	45	25	30	53	71	104
13	41	29	28	24	41	14	18	48	73	124
14	183	235	226	234	200	226	221	208	201	201
15	191	218	218	224	200	221	217	207	201	201
16	187	219	218	225	199	222	217	206	200	201
17	173	217	217	225	193	221	217	204	198	199
18	166	190	201	208	184	212	209	198	193	195
19	30	19	15	12	27	356	356	15	38	131
20	152	164	184	190	171	202	200	190	185	189

Table H-15. Range table for Bird Key Reef site, transects 11–20.

Distance	11	12	13	14	15	16	17	18	19	20
1	189	180	159	38.2	67.5	59.5	44.9	65.9	157	78.7
2	194	181	162	30.7	58.2	49.3	30.1	44.2	166	50.7
3	164	151	132	60.5	88.8	79.9	60.7	72.9	137	73.3
4	166	152	134	62.3	89.2	80.4	61.1	70.8	141	68.6
5	153	144	123	70.7	101	92.3	75	92.8	122	99
6	111	94.6	78.7	119	147	138	119	129	92.1	123
7	96	80.8	63.8	130	159	150	131	142	76.5	138
8	82.1	74.7	52.9	140	170	161	143	157	52.6	157
9	74.6	74.1	51.8	154	185	176	158	174	38.9	176
10	43.7	55.4	40.6	195	225	217	199	215	10.8	215
11	--	23.9	32.2	222	251	243	224	237	38	234
12	23.9	--	22.4	210	239	230	211	223	46.2	218
13	32.2	22.4	--	191	220	211	192	205	29.9	201
14	222	210	191	--	30.2	21.7	9.55	31.1	192	50
15	251	239	220	30.2	--	8.91	28.1	28	222	49.9
16	243	230	211	21.7	8.91	--	19.3	23.5	213	46
17	224	211	192	9.55	28.1	19.3	--	21.9	195	40.5
18	237	223	205	31.1	28	23.5	21.9	--	210	22.6
19	38	46.2	29.9	192	222	213	195	210	--	210
20	234	218	201	50	49.9	46	40.5	22.6	210	--

Table H-16. Bearing table for Bird Key Reef site, transects 11–20.

Bearing	11	12	13	14	15	16	17	18	19	20
1	217	223	221	3	11	7	353	346	210	332
2	207	214	209	55	38	39	37	10	199	344
3	206	213	208	46	38	38	37	21	195	4
4	203	209	204	54	44	45	45	28	192	10
5	216	225	221	20	20	19	13	4	207	351
6	195	205	194	46	41	42	41	32	176	22
7	197	210	198	41	37	37	37	29	176	20
8	216	233	228	28	27	26	24	18	195	10
9	232	251	253	21	21	20	18	13	218	5
10	259	284	304	21	21	21	19	15	311	9
11	--	333	17	31	30	30	29	24	66	19
12	153	--	65	37	35	35	34	29	97	23
13	197	245	--	33	32	32	31	25	121	19
14	211	217	213	--	21	16	313	327	205	309
15	210	215	212	201	--	214	219	265	204	273
16	210	215	212	196	34	--	222	282	204	283
17	209	214	211	133	39	42	--	333	202	308
18	204	209	205	147	85	102	153	--	197	283
19	246	277	301	25	24	24	22	17	--	11
20	199	203	199	129	93	103	128	103	191	--



Terminal pin distances	
1	12.6
2	10.2
3	11.0
4	10.8
5	10.6
6	10.9
7	11.4
8	10.2
9	11.0
10	11.8
11	10.7
12	10.4
13	10.1
14	10.6
15	11.6
16	10.8
17	10.9
18	10.1
19	10.2
20	10.9

Haulover			
From	To	Range	Bearing
1	5	33.4	342
5	4	49.6	250
4	3	29.0	140
3	2	28.0	145
2	6	42.0	265
6	7	15.2	142
7	8	9.9	190
8	9	14.1	145
9	10	17.9	090
10	11	21.8	132
11	12	39.0	185
12	13	11.4	289
13	14	19.6	188
15	14	10.7	288
14	16	14.6	240
16	17	34.7	342
17	20	72.5	166
20	19	17.0	145
19	18	35.9	40

Figure H-5. Haulover Reef field site map, range and bearing tables.

Table H-17. Range table for Haulover Reef site, transects 1–10.

Distance	1	2	3	4	5	6	7	8	9	10
1	--	35.5	39.7	60.6	35.8	72.2	70	77.4	79.9	73.1
2	35.5	--	27.9	56.4	59.8	42.2	36	42.3	44.5	40.8
3	39.7	27.9	--	28.6	43.9	37.2	41.7	51.4	60.1	64
4	60.6	56.4	28.6	--	45.2	49.2	60.4	70.2	81.9	89.7
5	35.8	59.8	43.9	45.2	--	80.8	85.2	94.6	102	101
6	72.2	42.2	37.2	49.2	80.8	--	15.2	23	36.8	51.3
7	70	36	41.7	60.4	85.2	15.2	--	9.91	22.2	36.2
8	77.4	42.3	51.4	70.2	94.6	23	9.91	--	14.1	31.7
9	79.9	44.5	60.1	81.9	102	36.8	22.2	14.1	--	19.8
10	73.1	40.8	64	89.7	101	51.3	36.2	31.7	19.8	--
11	79.5	53.4	80	107	111	72.4	57.5	53	40.4	21.4
12	120	92.4	117	143	151	101	85.9	78.1	64.1	53.3
13	120	90.4	114	139	150	94.6	80	71.6	57.9	50
14	139	110	133	157	169	112	97.7	88.8	75.6	69.3
15	140	112	136	161	171	117	103	94.1	80.5	72
16	151	120	141	164	179	117	104	94.1	81.9	78.8
17	126	92.3	110	131	151	82.5	70.4	60.5	50	53.3
18	170	143	168	193	202	148	134	125	112	104
19	200	170	192	215	230	168	155	145	133	129
20	190	159	181	203	219	155	142	133	121	119

Table H-18. Bearing table for Haulover Reef site, transects 1–10.

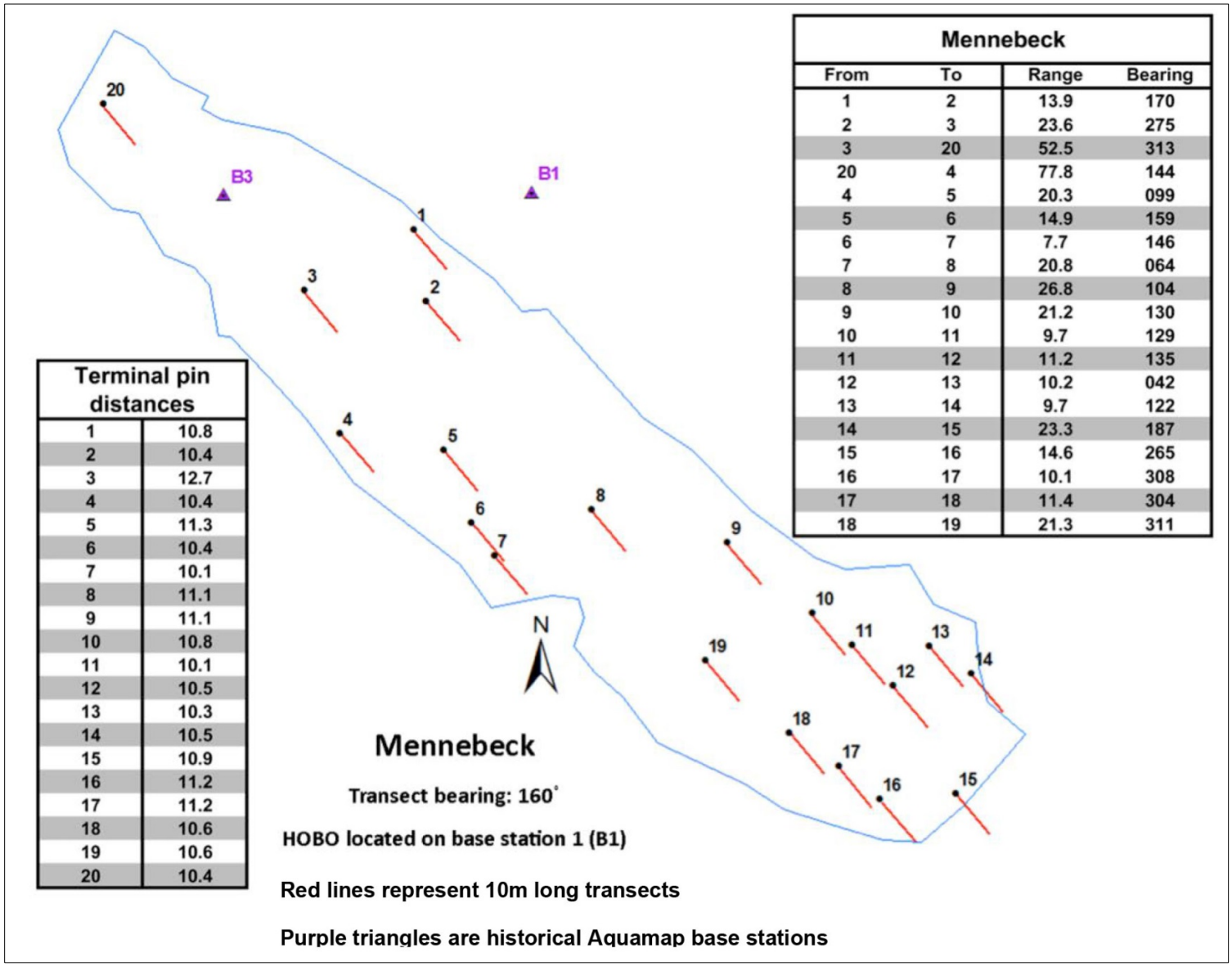
Bearing	1	2	3	4	5	6	7	8	9	10
1	--	216	259	282	330	239	227	222	212	198
2	36	--	319	317	3	259	239	228	209	183
3	79	139	--	315	28	219	197	195	183	165
4	102	137	135	--	66	183	173	174	168	156
5	150	183	208	246	--	213	203	201	194	183
6	59	79	39	3	33	--	135	154	147	130
7	47	59	17	353	23	315	--	183	156	127
8	42	48	15	354	21	334	3	--	137	113
9	32	29	3	348	14	327	336	317	--	95
10	18	3	345	336	3	310	307	293	275	--
11	3	341	334	329	353	306	304	295	287	298
12	3	350	343	338	355	326	327	323	325	341
13	8	357	348	342	359	331	333	330	333	352
14	7	358	350	344	359	336	339	336	340	354
15	2	352	346	341	356	331	334	331	333	347
16	10	3	355	349	3	343	346	345	349	3
17	21	16	4	354	11	349	355	354	4	26
18	359	351	346	341	354	334	336	334	336	346
19	5	359	354	349	0	345	348	347	350	358
20	9	3	357	351	3	348	351	350	354	3

Table H-19. Range table for Haulover Reef site, transects 11–20.

Distance	11	12	13	14	15	16	17	18	19	20
1	79.5	120	120	139	140	151	126	170	200	190
2	53.4	92.4	90.4	110	112	120	92.3	143	170	159
3	80	117	114	133	136	141	110	168	192	181
4	107	143	139	157	161	164	131	193	215	203
5	111	151	150	169	171	179	151	202	230	219
6	72.4	101	94.6	112	117	117	82.5	148	168	155
7	57.5	85.9	80	97.7	103	104	70.4	134	155	142
8	53	78.1	71.6	88.8	94.1	94.1	60.5	125	145	133
9	40.4	64.1	57.9	75.6	80.5	81.9	50	112	133	121
10	21.4	53.3	50	69.3	72	78.8	53.3	104	129	119
11	--	40.5	41.4	60.4	60.1	72.6	56.7	90.8	120	111
12	40.5	--	10.5	21.5	19.6	35.8	40.6	50.7	79.9	72.1
13	41.4	10.5	--	19.5	22.6	31.3	30.1	54.2	79.7	70.3
14	60.4	21.5	19.5	--	10.1	14.8	36.3	36.7	60.3	51.2
15	60.1	19.6	22.6	10.1	--	22.9	45.4	31.7	60.4	53.6
16	72.6	35.8	31.3	14.8	22.9	--	35.7	37.1	51.4	39.9
17	56.7	40.6	30.1	36.3	45.4	35.7	--	71.4	85.7	72.5
18	90.8	50.7	54.2	36.7	31.7	37.1	71.4	--	35.6	36.4
19	120	79.9	79.7	60.3	60.4	51.4	85.7	35.6	--	15
20	111	72.1	70.3	51.2	53.6	39.9	72.5	36.4	15	--

Table H-20. Bearing table for Haulover Reef site, transects 11–20.

Bearing	11	12	13	14	15	16	17	18	19	20
1	183	183	188	187	182	190	201	179	185	189
2	161	170	177	178	172	183	196	171	179	183
3	154	163	168	170	166	175	184	166	174	177
4	149	158	162	164	161	169	174	161	169	171
5	173	175	179	179	176	183	191	174	180	183
6	126	146	151	156	151	163	169	154	165	168
7	124	147	153	159	154	166	175	156	168	171
8	115	143	150	156	151	165	174	154	167	170
9	107	145	153	160	153	169	184	156	170	174
10	118	161	172	174	167	183	206	166	178	183
11	--	182	197	192	182	199	228	176	187	193
12	2	--	275	210	182	218	273	171	189	199
13	17	95	--	181	155	202	273	160	182	191
14	12	30	1	--	96	229	305	149	182	194
15	2	2	335	276	--	248	299	164	192	205
16	19	38	22	49	68	--	329	126	170	182
17	48	93	93	125	119	149	--	137	161	166
18	356	351	340	329	344	306	317	--	216	240
19	7	9	2	2	12	350	341	36	--	315
20	13	19	11	14	25	2	346	60	135	--



Terminal pin distances	
1	10.8
2	10.4
3	12.7
4	10.4
5	11.3
6	10.4
7	10.1
8	11.1
9	11.1
10	10.8
11	10.1
12	10.5
13	10.3
14	10.5
15	10.9
16	11.2
17	11.2
18	10.6
19	10.6
20	10.4

Mennebeck			
From	To	Range	Bearing
1	2	13.9	170
2	3	23.6	275
3	20	52.5	313
20	4	77.8	144
4	5	20.3	099
5	6	14.9	159
6	7	7.7	146
7	8	20.8	064
8	9	26.8	104
9	10	21.2	130
10	11	9.7	129
11	12	11.2	135
12	13	10.2	042
13	14	9.7	122
14	15	23.3	187
15	16	14.6	265
16	17	10.1	308
17	18	11.4	304
18	19	21.3	311

Figure H-6. Mennebeck Reef field site map, range and bearing tables.

Table H-21. Range table for Mennebeck Reef site, transects 1–10.

Distance	1	2	3	4	5	6	7	8	9	10
1	--	13.9	24	41.7	42.8	57.4	64.6	63.7	85.1	106
2	13.9	--	23.6	30.5	28.9	43.5	50.7	51.1	74.1	95.4
3	24	23.6	--	28.4	40.9	55.1	62.8	69.5	94.6	116
4	41.7	30.5	28.4	--	20.3	30.6	37.9	50.6	77.3	97.1
5	42.8	28.9	40.9	20.3	--	14.9	22.4	30.5	57.2	77.3
6	57.4	43.5	55.1	30.6	14.9	--	7.72	23.2	49.2	67.7
7	64.6	50.7	62.8	37.9	22.4	7.72	--	20.8	44.8	62.1
8	63.7	51.1	69.5	50.6	30.5	23.2	20.8	--	26.8	46.8
9	85.1	74.1	94.6	77.3	57.2	49.2	44.8	26.8	--	21.2
10	106	95.4	116	97.1	77.3	67.7	62.1	46.8	21.2	--
11	116	105	125	106	86.7	76.6	70.7	56.3	30.9	9.7
12	127	116	136	117	97.4	86.8	80.5	67.1	42.1	20.9
13	127	117	138	120	100	90.9	85.2	69.8	43.5	23.2
14	137	127	148	130	110	100	94.3	79.4	53.1	32.6
15	150	139	158	137	118	106	99.6	88.6	65.1	44.2
16	141	129	148	125	107	94.7	87.6	78.5	57.4	38.1
17	132	119	138	115	97.1	84.6	77.5	68.5	48.1	29.9
18	121	108	126	104	85.7	73.2	66.1	57.4	38.6	23.6
19	100	87.5	105	82.7	64.4	52.1	45.2	36.4	23.1	22.6
20	64.2	72.6	52.5	77.8	93.3	107	115	122	146	168

Table H-22. Bearing table or Mennebeck Reef site, transects 1-10.

Bearing	1	2	3	4	5	6	7	8	9	10
1	--	170	241	200	172	169	166	148	135	134
2	350	--	275	213	173	168	165	142	129	129
3	61	95	--	166	139	144	144	127	121	122
4	20	33	346	--	99	124	128	107	106	111
5	352	353	319	279	--	159	155	112	108	114
6	349	348	324	304	339	--	146	84	94	105
7	346	345	324	308	335	326	--	64	87	100
8	328	322	307	287	292	264	244	--	104	115
9	315	309	301	286	288	274	267	284	--	130
10	314	309	302	291	294	285	280	295	310	--
11	314	309	303	292	296	288	284	298	310	309
12	314	310	304	295	298	291	288	300	311	312
13	309	305	300	290	292	285	282	292	297	286
14	309	304	300	291	293	287	284	293	298	291
15	316	313	308	300	304	299	297	308	318	322
16	321	318	312	304	309	304	302	315	329	340
17	322	319	312	304	309	304	302	316	334	350
18	323	320	313	304	309	304	301	319	342	11
19	326	322	313	302	309	301	297	323	11	66
20	112	121	133	144	135	139	139	130	125	126

Table H-23. Range table for Mennebeck Reef site, transects 11–20.

Distance	11	12	13	14	15	16	17	18	19	20
1	116	127	127	137	150	141	132	121	100	64.2
2	105	116	117	127	139	129	119	108	87.5	72.6
3	125	136	138	148	158	148	138	126	105	52.5
4	106	117	120	130	137	125	115	104	82.7	77.8
5	86.7	97.4	100	110	118	107	97.1	85.7	64.4	93.3
6	76.6	86.8	90.9	100	106	94.7	84.6	73.2	52.1	107
7	70.7	80.5	85.2	94.3	99.6	87.6	77.5	66.1	45.2	115
8	56.3	67.1	69.8	79.4	88.6	78.5	68.5	57.4	36.4	122
9	30.9	42.1	43.5	53.1	65.1	57.4	48.1	38.6	23.1	146
10	9.7	20.9	23.2	32.6	44.2	38.1	29.9	23.6	22.6	168
11	--	11.2	14.8	23.6	34.8	30.2	23.5	20.8	28.3	177
12	11.2	--	10.2	15.2	23.9	22	18.7	22	36.4	188
13	14.8	10.2	--	9.65	28.7	30.8	28.9	31.6	43	190
14	23.6	15.2	9.65	--	23.3	29.9	31.2	36.8	51.1	199
15	34.8	23.9	28.7	23.3	--	14.6	23	34	54.4	210
16	30.2	22	30.8	29.9	14.6	--	10.1	21.5	42.8	200
17	23.5	18.7	28.9	31.2	23	10.1	--	11.4	32.7	190
18	20.8	22	31.6	36.8	34	21.5	11.4	--	21.3	179
19	28.3	36.4	43	51.1	54.4	42.8	32.7	21.3	--	157
20	177	188	190	199	210	200	190	179	157	--

Table H-24. Bearing table for Mennebeck Reef site, transects 11–20.

Bearing	11	12	13	14	15	16	17	18	19	20
1	134	134	129	129	136	141	142	143	146	292
2	129	130	125	124	133	138	139	140	142	301
3	123	124	120	120	128	132	132	133	133	313
4	112	115	110	111	120	124	124	124	122	324
5	116	118	112	113	124	129	129	129	129	315
6	108	111	105	107	119	124	124	124	121	319
7	104	108	102	104	117	122	122	121	117	319
8	118	120	112	113	128	135	136	139	143	310
9	130	131	117	118	138	149	154	162	191	305
10	129	132	106	111	142	160	170	191	246	306
11	--	135	91	103	145	170	186	215	264	306
12	315	--	42	81	150	187	214	245	278	306
13	271	222	--	122	170	198	217	238	266	303
14	283	261	302	--	187	216	235	252	273	303
15	325	330	350	7	--	265	283	290	298	309
16	350	7	18	36	85	--	308	306	308	312
17	6	34	37	55	103	128	--	304	308	312
18	35	65	58	72	110	126	124	--	311	313
19	84	98	86	93	118	128	128	131	--	313
20	126	126	123	123	129	132	132	133	133	--

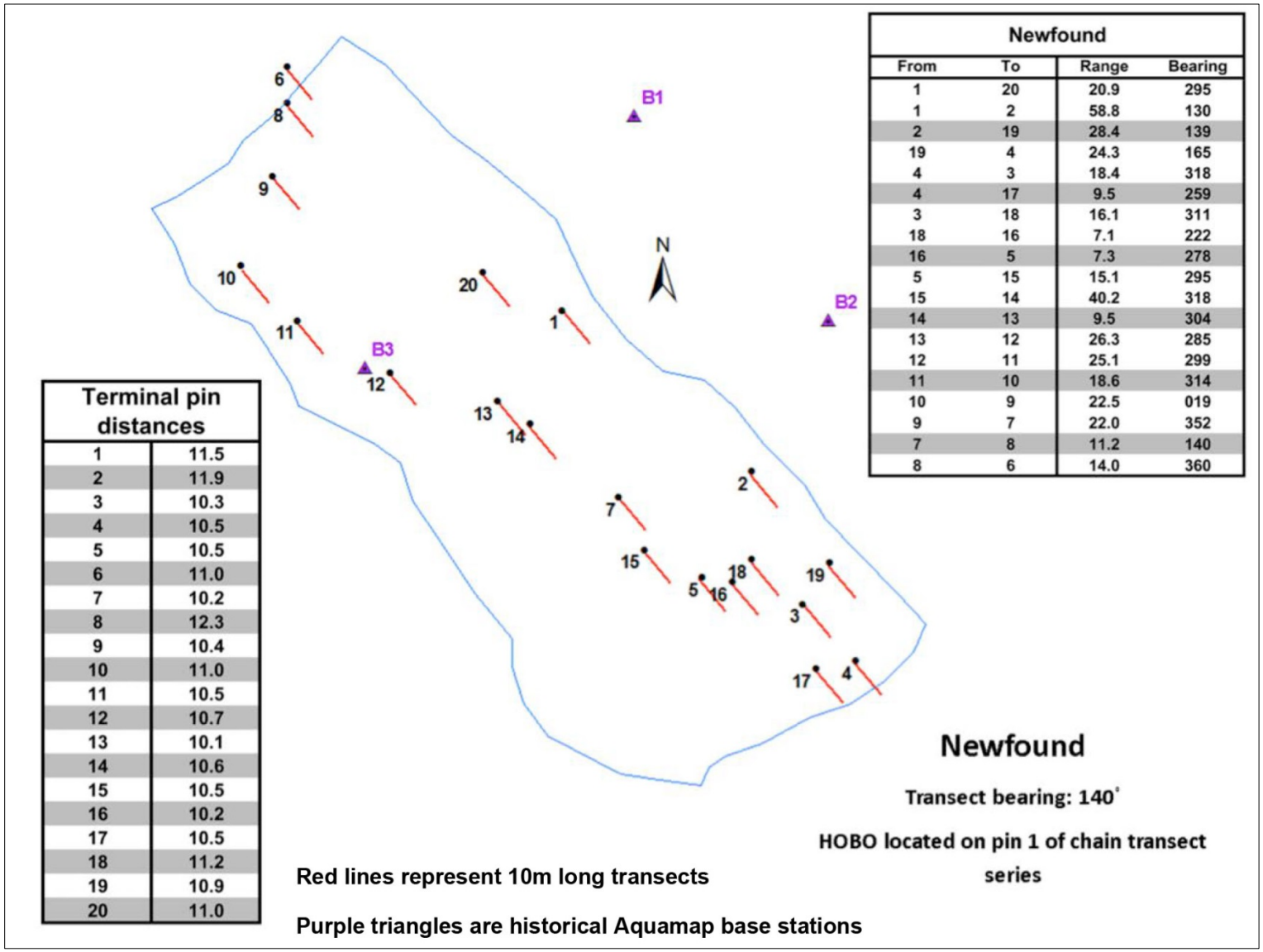


Figure H-7. Newfound Reef field site map, range and bearing tables.

Table H-25. Range table for Newfound Reef site, transects 1–10.

Distance	1	2	3	4	5	6	7	8	9	10
1	--	58.8	90	108	71.3	87.1	46.2	81.7	75.7	76.9
2	58.8	--	33.8	51.4	27.7	146	31.9	140	133	130
3	90	33.8	--	18.4	24.8	177	50.5	170	162	156
4	108	51.4	18.4	--	41.5	195	68.3	189	180	173
5	71.3	27.7	24.8	41.5	--	156	27.4	149	139	132
6	87.1	146	177	195	156	--	129	8.7	26.3	48.6
7	46.2	31.9	50.5	68.3	27.4	129	--	122	112	105
8	81.7	140	170	189	149	8.7	122	--	17.7	40.1
9	75.7	133	162	180	139	26.3	112	17.7	--	22.5
10	76.9	130	156	173	132	48.6	105	40.1	22.5	--
11	62.8	113	137	155	114	60.2	86.8	51.6	34.7	18.6
12	43.4	88.7	112	130	88.4	76.4	61.7	68.3	54.2	43.4
13	26.5	62.4	86.9	105	63.9	93.6	36.6	86.5	75.4	68.7
14	28	53.5	77.4	95.4	54.5	102	27.1	95.4	84.8	78.2
15	60	31.5	39.8	56.6	15.1	142	13.9	136	125	117
16	75.8	26.6	17.6	34.8	7.3	161	33.5	155	145	138
17	104	49.4	15.7	9.5	34.8	190	62.1	184	174	167
18	74.2	20.9	16.1	34.4	12.7	161	34.9	154	146	140
19	87	28.4	11.7	24.3	30.4	174	52.2	168	161	156
20	20.9	79.1	109	128	88.9	67.2	62.2	61.3	54.8	57.4

Table H-26. Bearing table for Newfound Reef site, transects 1–10.

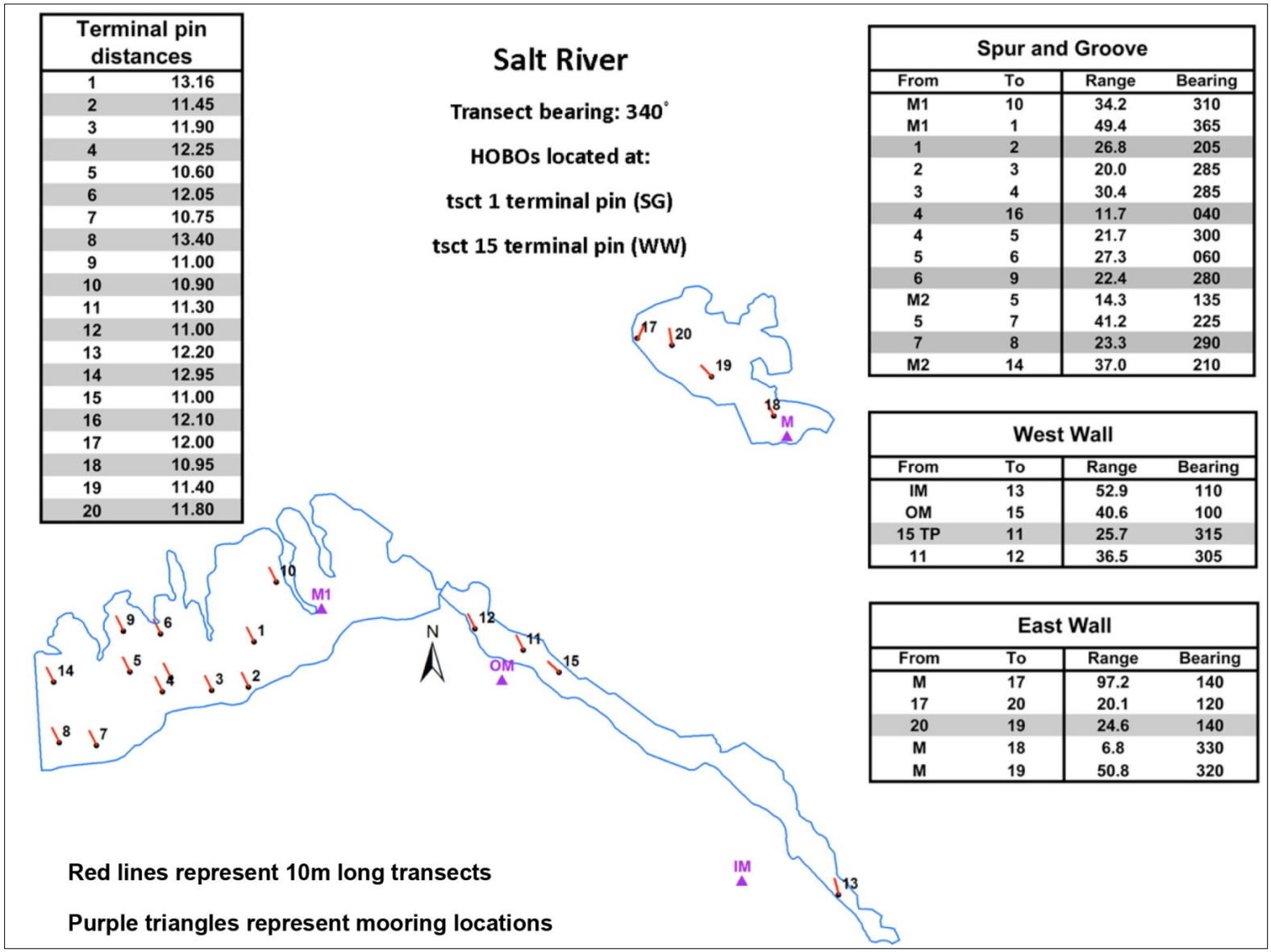
Bearing	1	2	3	4	5	6	7	8	9	10
1	--	130	141	140	152	312	163	307	295	278
2	310	--	159	151	205	311	259	308	302	292
3	321	339	--	138	285	316	300	314	309	301
4	320	331	318	--	299	316	305	314	310	303
5	332	25	105	119	--	321	314	319	313	304
6	132	131	136	136	141	--	142	181	188	193
7	343	79	120	125	134	322	--	320	313	301
8	127	128	134	134	139	1	140	--	191	196
9	115	122	129	130	133	8	133	11	--	199
10	98	112	121	123	124	13	121	16	19	--
11	88	108	119	121	122	358	119	357	350	314
12	70	105	119	122	123	341	119	339	329	305
13	36	105	124	126	131	328	128	325	315	298
14	16	102	123	126	132	326	129	323	314	299
15	341	54	109	118	115	324	335	321	315	305
16	328	10	108	123	278	319	307	317	311	303
17	325	342	349	79	309	319	311	317	312	305
18	323	359	131	135	251	317	295	314	309	300
19	313	319	212	165	263	312	287	310	305	297
20	115	127	136	136	144	317	149	311	295	272

Table H-27. Range table for Newfound Reef site, transects 11–20.

Distance	11	12	13	14	15	16	17	18	19	20
1	62.8	43.4	26.5	28	60	75.8	104	74.2	87	20.9
2	113	88.7	62.4	53.5	31.5	26.6	49.4	20.9	28.4	79.1
3	137	112	86.9	77.4	39.8	17.6	15.7	16.1	11.7	109
4	155	130	105	95.4	56.6	34.8	9.5	34.4	24.3	128
5	114	88.4	63.9	54.5	15.1	7.3	34.8	12.7	30.4	88.9
6	60.2	76.4	93.6	102	142	161	190	161	174	67.2
7	86.8	61.7	36.6	27.1	13.9	33.5	62.1	34.9	52.2	62.2
8	51.6	68.3	86.5	95.4	136	155	184	154	168	61.3
9	34.7	54.2	75.4	84.8	125	145	174	146	161	54.8
10	18.6	43.4	68.7	78.2	117	138	167	140	156	57.4
11	--	25.1	51.1	60.4	98.5	120	148	122	138	45.3
12	25.1	--	26.3	35.5	73.4	95	123	96.6	113	32.3
13	51.1	26.3	--	9.5	49.5	70.1	98.6	71	87.4	30.7
14	60.4	35.5	9.5	--	40.2	60.7	89.2	61.5	78	37.6
15	98.5	73.4	49.5	40.2	--	22.2	49.6	25.7	44	76
16	120	95	70.1	60.7	22.2	--	28.7	7.1	23.5	94.1
17	148	123	98.6	89.2	49.6	28.7	--	30.1	25.5	123
18	122	96.6	71	61.5	25.7	7.1	30.1	--	18.3	93.2
19	138	113	87.4	78	44	23.5	25.5	18.3	--	107
20	45.3	32.3	30.7	37.6	76	94.1	123	93.2	107	--

Table H-28. Bearing table for Newfound Reef site, transects 11–20.

Bearing	11	12	13	14	15	16	17	18	19	20
1	268	250	216	196	161	148	145	143	133	295
2	288	285	285	282	234	190	162	179	139	307
3	299	299	304	303	289	288	169	311	32	316
4	301	302	306	306	298	303	259	315	345	316
5	302	303	311	312	295	98	129	71	83	324
6	178	161	148	146	144	139	139	137	132	137
7	299	299	308	309	155	127	131	115	107	329
8	177	159	145	143	141	137	137	134	130	131
9	170	149	135	134	135	131	132	129	125	115
10	134	125	118	119	125	123	125	120	117	92
11	--	119	112	114	124	121	124	118	114	75
12	299	--	105	110	125	121	125	117	113	43
13	292	285	--	124	135	128	130	122	116	354
14	294	290	304	--	138	128	131	121	115	343
15	304	305	315	318	--	110	125	95	94	330
16	301	301	308	308	290	--	136	42	79	321
17	304	305	310	311	305	316	--	330	7	320
18	298	297	302	301	275	222	150	--	92	317
19	294	293	296	295	274	259	187	272	--	310
20	255	223	174	163	150	141	140	137	130	--



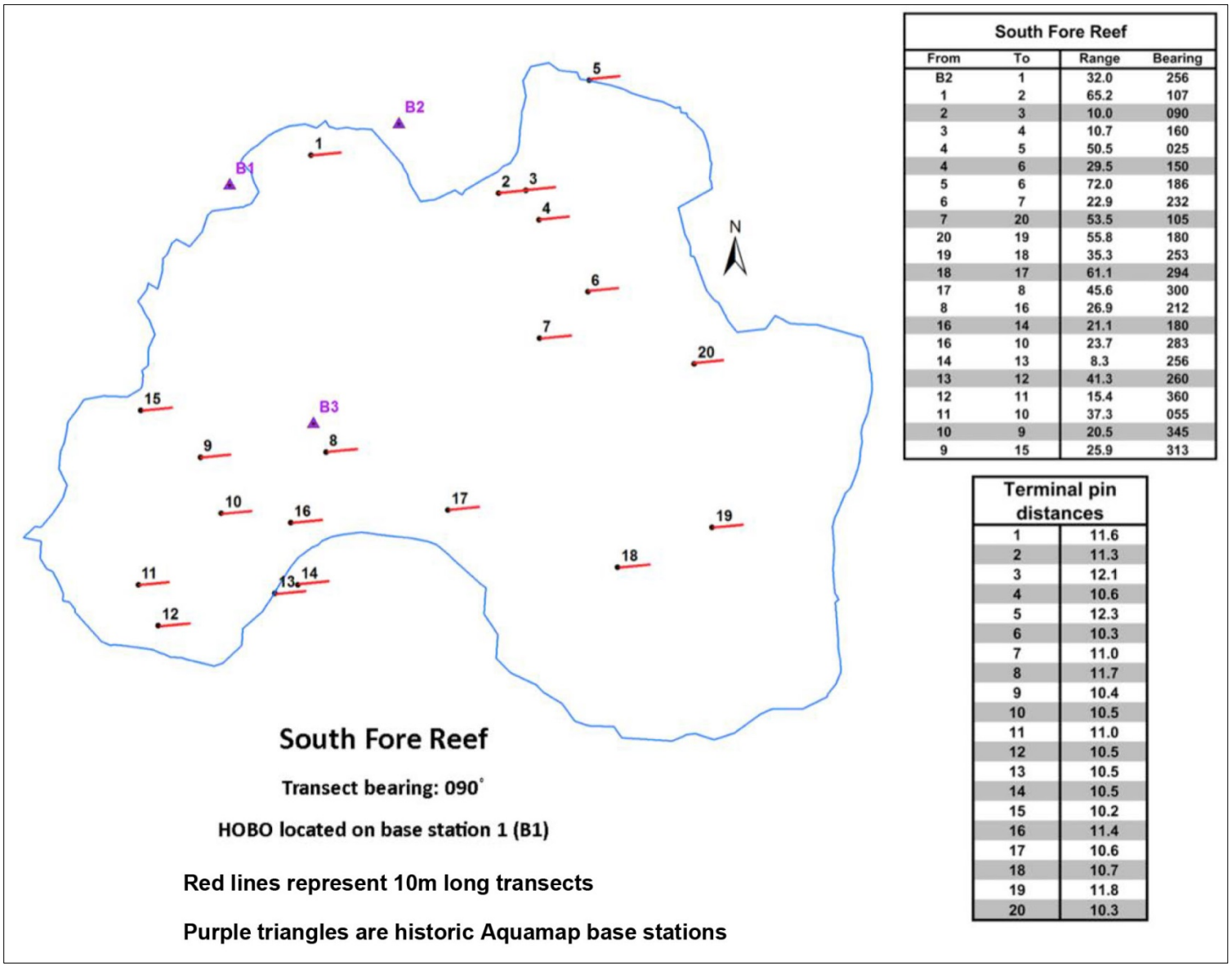
Terminal pin distances	
1	13.16
2	11.45
3	11.90
4	12.25
5	10.60
6	12.05
7	10.75
8	13.40
9	11.00
10	10.90
11	11.30
12	11.00
13	12.20
14	12.95
15	11.00
16	12.10
17	12.00
18	10.95
19	11.40
20	11.80

Spur and Groove			
From	To	Range	Bearing
M1	10	34.2	310
M1	1	49.4	365
1	2	26.8	205
2	3	20.0	285
3	4	30.4	285
4	16	11.7	040
4	5	21.7	300
5	6	27.3	060
6	9	22.4	280
M2	5	14.3	135
5	7	41.2	225
7	8	23.3	290
M2	14	37.0	210

West Wall			
From	To	Range	Bearing
IM	13	52.9	110
OM	15	40.6	100
15 TP	11	25.7	315
11	12	36.5	305

East Wall			
From	To	Range	Bearing
M	17	97.2	140
17	20	20.1	120
20	19	24.6	140
M	18	6.8	330
M	19	50.8	320

Figure H-8.Salt River field site map, range and bearing tables.



South Fore Reef			
From	To	Range	Bearing
B2	1	32.0	256
1	2	65.2	107
2	3	10.0	090
3	4	10.7	160
4	5	50.5	025
4	6	29.5	150
5	6	72.0	186
6	7	22.9	232
7	20	53.5	105
20	19	55.8	180
19	18	35.3	253
18	17	61.1	294
17	8	45.6	300
8	16	26.9	212
16	14	21.1	180
16	10	23.7	283
14	13	8.3	256
13	12	41.3	260
12	11	15.4	360
11	10	37.3	055
10	9	20.5	345
9	15	25.9	313

Terminal pin distances	
1	11.6
2	11.3
3	12.1
4	10.6
5	12.3
6	10.3
7	11.0
8	11.7
9	10.4
10	10.5
11	11.0
12	10.5
13	10.5
14	10.5
15	10.2
16	11.4
17	10.6
18	10.7
19	11.8
20	10.3

Figure H-9. South Fore Reef field site map, range and bearing tables.

Table H-29. Range table for South Fore Reef site, transects 1–10.

Distance	1	2	3	4	5	6	7	8	9	10
1	--	65.3	74.2	80.8	98.2	105	99.6	101	109	125
2	65.3	--	9.26	16.5	49.1	45.2	51.1	106	135	144
3	74.2	9.26	--	10.9	43.2	40.3	50.3	112	143	151
4	80.8	16.5	10.9	--	50.2	29.5	40.2	107	141	147
5	98.2	49.1	43.2	50.2	--	71.6	89.1	155	184	193
6	105	45.2	40.3	29.5	71.6	--	22.9	105	144	146
7	99.6	51.1	50.3	40.2	89.1	22.9	--	82.4	122	124
8	101	106	112	107	155	105	82.4	--	42.9	41.3
9	109	135	143	141	184	144	122	42.9	--	20.2
10	125	144	151	147	193	146	124	41.3	20.2	--
11	157	181	188	184	230	183	160	78.3	48.2	37.3
12	167	187	193	189	236	185	162	82.1	58.8	43.7
13	149	156	161	155	204	148	125	51	52.7	32.8
14	145	149	155	149	198	140	117	46	54.5	35.7
15	104	143	151	151	190	158	138	64.8	25.9	44.3
16	125	132	138	133	181	128	105	26.8	37.9	23.9
17	129	109	111	103	153	88	66	46	86.3	77.4
18	174	133	131	121	165	93.8	81.9	107	147	137
19	186	135	131	120	157	90.4	87	134	176	168
20	149	88.3	82.2	72	102	43.7	53.5	129	171	169

Table H-30. Bearing table for South Fore Reef site, transects 1–10.

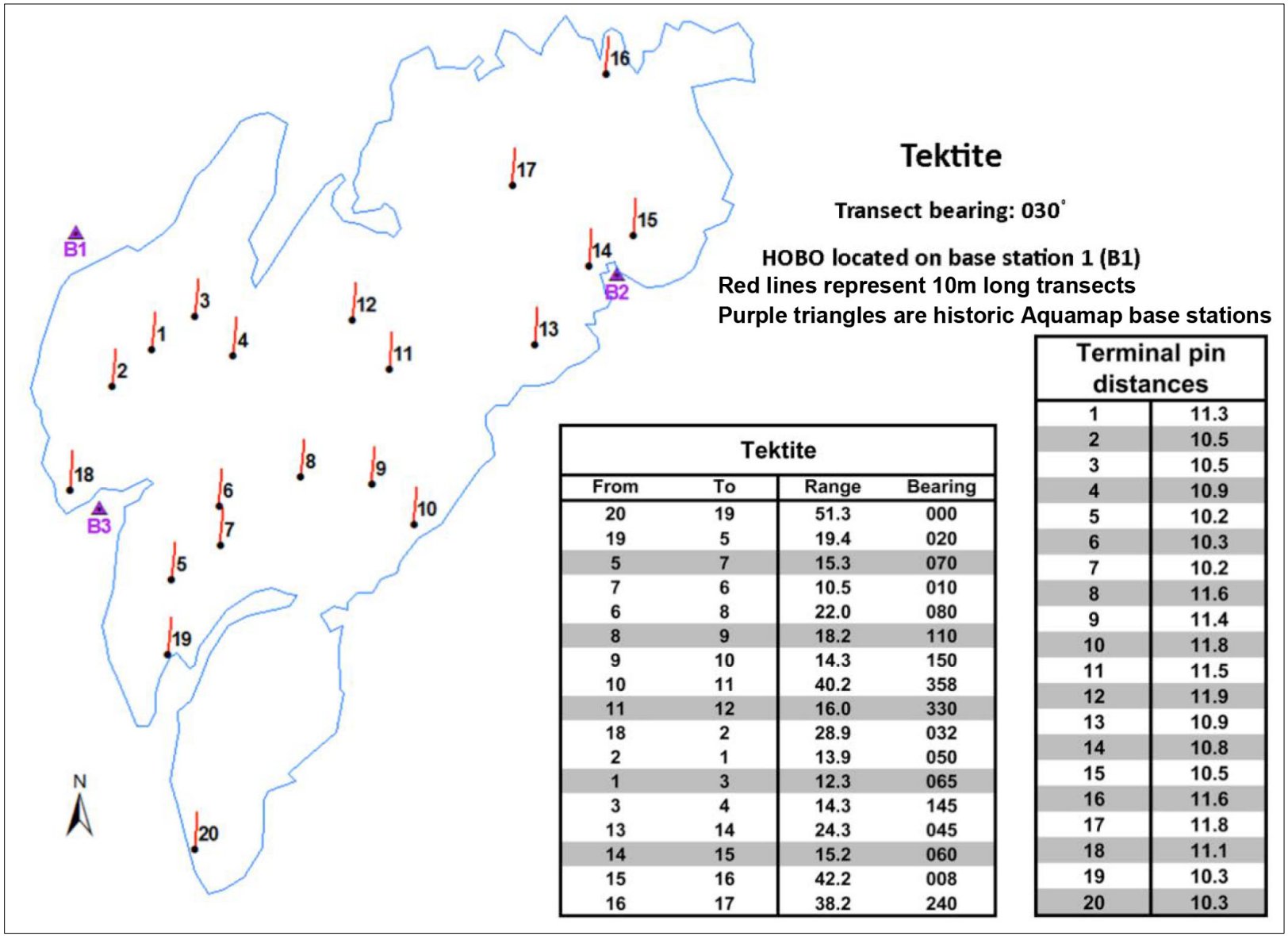
Bearing	1	2	3	4	5	6	7	8	9	10
1	--	107	105	111	81	122	134	183	206	200
2	287	--	90	129	45	143	170	220	234	227
3	285	270	--	161	36	154	180	223	236	229
4	291	309	341	--	26	151	185	228	241	233
5	261	225	216	206	--	186	197	221	232	226
6	302	323	334	331	6	--	232	244	253	245
7	314	350	0	5	17	52	--	248	256	247
8	3	40	43	48	41	64	68	--	273	246
9	26	54	56	61	52	73	76	93	--	165
10	20	47	49	53	46	65	67	66	345	--
11	28	48	50	54	48	63	64	61	32	55
12	24	44	46	49	44	58	59	50	20	35
13	10	35	38	41	37	52	52	26	337	332
14	7	33	36	39	36	51	50	18	328	319
15	40	65	66	70	59	81	85	108	133	147
16	9	38	41	45	40	58	59	32	311	284
17	344	15	19	23	24	39	34	301	288	275
18	329	348	352	353	2	359	347	297	290	283
19	318	333	336	336	350	338	323	287	283	277
20	304	317	321	318	345	310	285	262	265	258

Table H-31. Range table for South Fore Reef site, transects 11–20.

Distance	11	12	13	14	15	16	17	18	19	20
1	157	167	149	145	104	125	129	174	186	149
2	181	187	156	149	143	132	109	133	135	88.3
3	188	193	161	155	151	138	111	131	131	82.2
4	184	189	155	149	151	133	103	121	120	72
5	230	236	204	198	190	181	153	165	157	102
6	183	185	148	140	158	128	88	93.8	90.4	43.7
7	160	162	125	117	138	105	66	81.9	87	53.5
8	78.3	82.1	51	46	64.8	26.8	46	107	134	129
9	48.2	58.8	52.7	54.5	25.9	37.9	86.3	147	176	171
10	37.3	43.7	32.8	35.7	44.3	23.9	77.4	137	168	169
11	--	15.4	46.8	54.4	59.1	56.1	109	164	197	204
12	15.4	--	41.3	49.6	73.1	57	106	158	192	203
13	46.8	41.3	--	8.3	77.1	24.6	65.5	117	151	163
14	54.4	49.6	8.3	--	79.8	21.2	57.2	109	143	155
15	59.1	73.1	77.1	79.8	--	63.8	110	171	199	190
16	56.1	57	24.6	21.2	63.8	--	53.9	113	144	148
17	109	106	65.5	57.2	110	53.9	--	61.1	90.4	97.6
18	164	158	117	109	171	113	61.1	--	34.9	73.6
19	197	192	151	143	199	144	90.4	34.9	--	55.8
20	204	203	163	155	190	148	97.6	73.6	55.8	--

Table H-32. Bearing table for South Fore Reef site, transects 11–20.

Bearing	11	12	13	14	15	16	17	18	19	20
1	208	204	190	187	220	189	164	149	138	124
2	228	224	215	213	245	218	195	168	153	137
3	230	226	218	216	246	221	199	172	156	141
4	234	229	221	219	250	225	203	173	156	138
5	228	224	217	216	239	220	204	182	170	165
6	243	238	232	231	261	238	219	179	158	130
7	244	239	232	230	265	239	214	167	143	105
8	241	230	206	198	288	212	121	117	107	82
9	212	200	157	148	313	131	108	110	103	85
10	235	215	152	139	327	104	95	103	97	78
11	--	159	99	96	6	74	82	94	90	74
12	339	--	80	80	1	58	74	88	86	70
13	279	260	--	75	329	18	70	91	87	67
14	276	260	255	--	323	359	69	92	88	67
15	186	181	149	143	--	132	113	114	107	91
16	254	238	198	179	312	--	91	103	96	74
17	262	254	250	249	293	271	--	114	99	65
18	274	268	271	272	294	283	294	--	73	26
19	270	266	267	268	287	276	279	253	--	359
20	254	250	247	247	271	254	245	206	179	--



Tektite			
From	To	Range	Bearing
20	19	51.3	000
19	5	19.4	020
5	7	15.3	070
7	6	10.5	010
6	8	22.0	080
8	9	18.2	110
9	10	14.3	150
10	11	40.2	358
11	12	16.0	330
18	2	28.9	032
2	1	13.9	050
1	3	12.3	065
3	4	14.3	145
13	14	24.3	045
14	15	15.2	060
15	16	42.2	008
16	17	38.2	240

Terminal pin distances	
1	11.3
2	10.5
3	10.5
4	10.9
5	10.2
6	10.3
7	10.2
8	11.6
9	11.4
10	11.8
11	11.5
12	11.9
13	10.9
14	10.8
15	10.5
16	11.6
17	11.8
18	11.1
19	10.3
20	10.3

Figure H-10. Tektite Reef field site map, range and bearing tables.

Table H-33. Range table for Tektite Reef site, transects 1–10.

Distance	1	2	3	4	5	6	7	8	9	10
1	--	13.9	14.2	21.1	60	44.3	54	50.9	66.9	81.6
2	13.9	--	28.1	32.3	52.7	41.8	50.2	54.3	71.9	85.9
3	14.2	28.1	--	14.1	68.8	49.9	60.1	50	63.3	78.3
4	21.1	32.3	14.1	--	60.5	39.5	49.7	36.2	49.2	64.2
5	60	52.7	68.8	60.5	--	22.7	15.3	42.9	57.5	64.3
6	44.3	41.8	49.9	39.5	22.7	--	10.3	22.6	39.9	50.6
7	54	50.2	60.1	49.7	15.3	10.3	--	27.6	42.4	50.4
8	50.9	54.3	50	36.2	42.9	22.6	27.6	--	18.4	31.6
9	66.9	71.9	63.3	49.2	57.5	39.9	42.4	18.4	--	15
10	81.6	85.9	78.3	64.2	64.3	50.6	50.4	31.6	15	--
11	61.7	71.9	52.1	40.6	78.6	56.7	63.5	36.1	30.3	40.8
12	52.6	64.5	40.8	32.2	82.2	59.5	68	42.9	43	55.4
13	99.2	110	88.2	78.1	112	92	96.9	69.7	55.8	56.4
14	115	127	103	94.8	135	114	120	92.4	79.8	81
15	128	140	115	108	149	128	134	107	93.8	94.4
16	138	151	124	121	173	151	158	131	123	127
17	103	116	89	84.8	135	113	121	93.7	86.1	92
18	42.4	29.4	55.8	55.1	35	38.8	41.4	59.9	78.2	89.4
19	79.5	71.5	88.4	79.8	19.6	40.9	31.5	57.8	69	72.1
20	131	123	139	129	70.7	89.7	79.5	101	106	102

Table H-34. Bearing table for Tektite Reef site, transects 1–10.

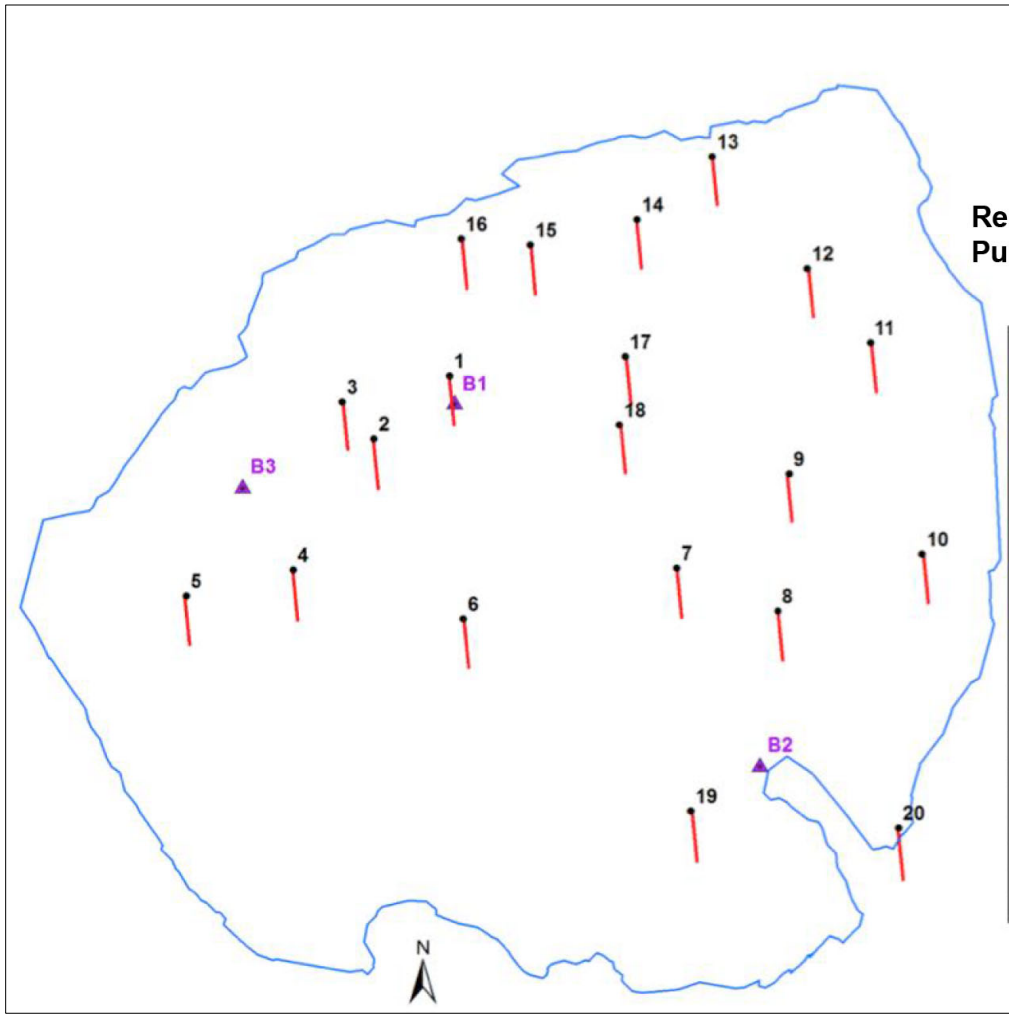
Bearing	1	2	3	4	5	6	7	8	9	10
1	--	227	52	94	175	157	161	131	122	124
2	47	--	50	76	163	139	146	116	111	115
3	232	230	--	136	185	173	174	147	134	134
4	274	256	316	--	195	185	184	151	133	133
5	355	343	5	15	--	33	55	51	64	77
6	337	319	353	5	213	--	179	70	82	95
7	341	326	354	4	235	359	--	49	68	84
8	311	296	327	331	231	250	229	--	96	113
9	302	291	314	313	244	262	248	276	--	134
10	304	295	314	313	257	275	264	293	314	--
11	275	267	285	275	226	231	224	219	189	171
12	262	255	272	254	215	216	210	198	173	163
13	269	264	275	268	237	243	237	240	229	214
14	259	256	263	256	233	237	233	234	225	214
15	257	254	259	253	233	237	233	234	226	217
16	239	238	239	233	221	222	219	217	210	203
17	245	243	247	238	221	222	219	216	205	196
18	30	22	36	50	131	96	110	87	89	96
19	357	348	5	12	3	19	26	37	50	62
20	355	350	0	4	355	4	5	16	26	34

Table H-35. Range table for Tektite Reef site, transects 11–20.

Distance	11	12	13	14	15	16	17	18	19	20
1	61.7	52.6	99.2	115	128	138	103	42.4	79.5	131
2	71.9	64.5	110	127	140	151	116	29.4	71.5	123
3	52.1	40.8	88.2	103	115	124	89	55.8	88.4	139
4	40.6	32.2	78.1	94.8	108	121	84.8	55.1	79.8	129
5	78.6	82.2	112	135	149	173	135	35	19.6	70.7
6	56.7	59.5	92	114	128	151	113	38.8	40.9	89.7
7	63.5	68	96.9	120	134	158	121	41.4	31.5	79.5
8	36.1	42.9	69.7	92.4	107	131	93.7	59.9	57.8	101
9	30.3	43	55.8	79.8	93.8	123	86.1	78.2	69	106
10	40.8	55.4	56.4	81	94.4	127	92	89.4	72.1	102
11	--	15.9	38.2	58.1	72.2	95.2	57.7	88.5	93.9	135
12	15.9	--	47.5	62.6	76	91.8	54.4	85.6	99.4	144
13	38.2	47.5	--	24.5	38.2	72.8	41.9	126	125	158
14	58.1	62.6	24.5	--	14.2	50.4	29	146	149	183
15	72.2	76	38.2	14.2	--	42.6	33.9	160	163	196
16	95.2	91.8	72.8	50.4	42.6	--	37.7	176	189	228
17	57.7	54.4	41.9	29	33.9	37.7	--	140	151	192
18	88.5	85.6	126	146	160	176	140	--	49.7	98.9
19	93.9	99.4	125	149	163	189	151	49.7	--	51.3
20	135	144	158	183	196	228	192	98.9	51.3	--

Table H-36. Bearing table for Tektite Reef site, transects 11–20.

Bearing	11	12	13	14	15	16	17	18	19	20
1	95	82	89	79	77	59	65	210	177	175
2	87	75	84	76	74	58	63	202	168	170
3	105	92	95	83	79	59	67	216	185	185
4	95	74	88	76	73	53	58	230	192	184
5	46	35	57	53	53	41	41	311	183	175
6	51	36	63	57	57	42	42	276	199	184
7	44	30	57	53	53	39	39	290	206	185
8	39	18	60	54	54	37	36	267	217	196
9	9	353	49	45	46	30	25	269	230	206
10	351	344	34	34	37	23	16	276	242	214
11	--	323	80	63	61	36	34	249	218	202
12	143	--	97	77	73	46	50	239	209	197
13	260	277	--	35	42	15	352	252	230	214
14	243	257	215	--	55	5	317	247	227	214
15	241	253	222	235	--	350	293	245	228	215
16	216	226	195	185	170	--	220	232	217	208
17	214	230	172	137	113	40	--	235	216	205
18	69	59	72	67	65	52	55	--	149	161
19	38	29	50	47	48	37	36	329	--	172
20	22	17	34	34	35	28	25	341	352	--



Western Spur and Groove

Transect bearing: 180°

HOBO located on base station 1 (B1)

Red lines represent 10m long transects
Purple triangles are historic Aquamap base stations

Terminal pin distances	
1	11.4
2	12.1
3	11.3
4	11.9
5	12.1
6	11.8
7	10.7
8	11.1
9	10.7
10	11.5
11	11.9
12	10.8
13	13.1
14	10.4
15	11.3
16	11.3
17	11.3
18	11.8
19	10.6
20	10.4

Western Spur and Groove			
From	To	Range	Bearing
B1	1	5.2	356
1	2	20.0	235
2	3	10.0	325
3	4	36.1	202
4	5	22.4	262
5	6	56.6	100
6	19	60.8	136
19	20	42.4	100
20	B2	31.1	301
B2	7	43.6	342
7	8	22.4	119
8	10	31.6	074
10	9	31.6	307
9	11	31.6	037
11	12	20.0	325
12	13	30.0	325
13	14	20.0	235
14	15	22.4	262
15	16	14.1	280
16	17	41.2	131
17	18	14.1	190
18	B3	77.3	266

Figure H-11. Tektite Reef field site map, range and bearing tables.

Table H-37. Range table for Western Spur and Groove Reef site, transects 1–10.

Distance	1	2	3	4	5	6	7	8	9	10
1	--	20	22	51	70	50	61	82	72	103
2	20	--	10	32	50	41	67	89	85	114
3	22	10	--	36	51	51	76	98	92	122
4	51	32	36	--	22	36	78	99	103	128
5	70	50	51	22	--	57	100	120	125	150
6	50	41	51	36	57	--	45	64	73	94
7	61	67	76	78	100	45	--	22	30	50
8	82	89	98	99	120	64	22	--	28	32
9	72	85	92	103	125	73	30	28	--	32
10	103	114	122	128	150	94	50	32	32	--
11	86	103	108	126	149	101	61	58	32	45
12	76	95	98	122	143	101	67	71	42	63
13	70	90	91	120	140	108	85	94	67	92
14	50	70	71	100	120	89	72	85	61	90
15	32	51	50	82	100	78	73	91	71	102
16	28	45	41	76	92	78	81	100	82	114
17	36	54	58	81	102	63	45	61	41	73
18	36	50	57	73	95	51	32	50	36	67
19	102	100	110	95	112	61	50	45	72	71
20	130	133	143	134	153	98	70	51	76	57

Table H-38. Bearing table for Western Spur and Groove Reef site, transects 1–10.

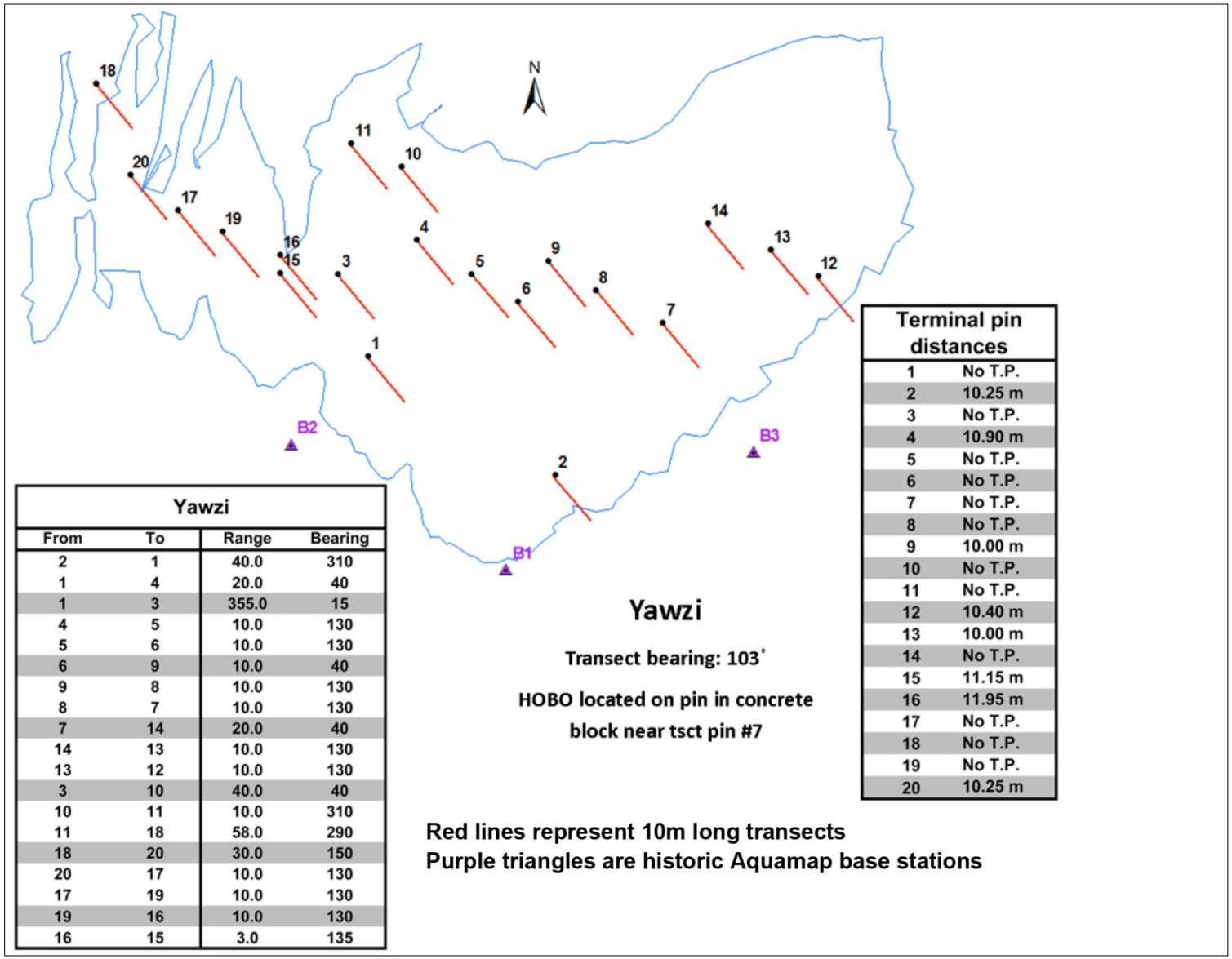
Bearing	1	2	3	4	5	6	7	8	9	10
1	--	235	262	224	235	182	136	131	112	116
2	55	--	325	217	235	160	119	119	100	108
3	82	145	--	202	224	157	122	122	105	110
4	44	37	22	--	262	112	95	100	85	94
5	55	55	44	82	--	100	92	97	84	92
6	2	340	337	292	280	--	82	94	71	87
7	316	299	302	275	272	262	--	119	55	92
8	311	299	302	280	277	274	299	--	10	74
9	292	280	285	265	264	251	235	190	--	127
10	296	288	290	274	272	267	272	254	307	--
11	271	265	269	254	255	241	226	205	217	172
12	259	254	259	245	248	230	209	190	190	164
13	235	235	242	231	235	214	190	177	172	158
14	235	235	244	230	235	209	179	166	155	145
15	217	224	235	221	230	196	161	152	137	134
16	190	209	221	212	223	185	153	145	131	130
17	269	257	266	243	247	217	172	155	131	130
18	292	272	280	251	254	224	164	145	112	119
19	337	325	325	307	299	316	2	29	22	47
20	321	312	313	299	294	302	325	337	349	10

Table H-39. Range table for Western Spur and Groove Reef site, transects 11–20.

Distance	11	12	13	14	15	16	17	18	19	20
1	86	76	70	50	32	28	36	36	102	130
2	103	95	90	70	51	45	54	50	100	133
3	108	98	91	71	50	41	58	57	110	143
4	126	122	120	100	82	76	81	73	95	134
5	149	143	140	120	100	92	102	95	112	153
6	101	101	108	89	78	78	63	51	61	98
7	61	67	85	72	73	81	45	32	50	70
8	58	71	94	85	91	100	61	50	45	51
9	32	42	67	61	71	82	41	36	72	76
10	45	63	92	90	102	114	73	67	71	57
11	--	20	50	54	72	86	50	54	103	100
12	20	--	30	36	57	71	41	50	114	117
13	50	30	--	20	41	54	45	58	135	143
14	54	36	20	--	22	36	28	42	122	136
15	72	57	41	22	--	14	30	41	121	141
16	86	71	54	36	14	--	41	50	126	150
17	50	41	45	28	30	41	--	14	94	112
18	54	50	58	42	41	50	14	--	81	101
19	103	114	135	122	121	126	94	81	--	42
20	100	117	143	136	141	150	112	101	42	--

Table H-40. Bearing table for Western Spur and Groove Reef site, transects 11–20.

Bearing	11	12	13	14	15	16	17	18	19	20
1	91	79	55	55	37	10	89	112	157	141
2	85	74	55	55	44	29	77	92	145	132
3	89	79	62	64	55	41	86	100	145	133
4	74	65	51	50	41	32	63	71	127	119
5	75	68	55	55	50	43	67	74	119	114
6	61	50	34	29	16	5	37	44	136	122
7	46	29	10	359	341	333	352	344	182	145
8	25	10	357	346	332	325	335	325	209	157
9	37	10	352	335	317	311	311	292	202	169
10	352	344	338	325	314	310	310	299	227	190
11	--	325	325	304	292	290	272	257	206	182
12	145	--	325	292	280	280	250	235	198	176
13	145	145	--	235	250	257	209	205	187	170
14	124	112	55	--	262	269	190	190	180	163
15	112	100	70	82	--	281	145	160	170	154
16	110	100	77	89	101	--	131	145	164	149
17	92	70	29	10	325	311	--	190	177	156
18	77	55	25	10	340	325	10	--	175	151
19	26	18	7	0	350	344	357	355	--	100
20	2	356	350	343	334	329	336	331	280	--



Yawzi			
From	To	Range	Bearing
2	1	40.0	310
1	4	20.0	40
1	3	355.0	15
4	5	10.0	130
5	6	10.0	130
6	9	10.0	40
9	8	10.0	130
8	7	10.0	130
7	14	20.0	40
14	13	10.0	130
13	12	10.0	130
3	10	40.0	40
10	11	10.0	310
11	18	58.0	290
18	20	30.0	150
20	17	10.0	130
17	19	10.0	130
19	16	10.0	130
16	15	3.0	135

Terminal pin distances	
1	No T.P.
2	10.25 m
3	No T.P.
4	10.90 m
5	No T.P.
6	No T.P.
7	No T.P.
8	No T.P.
9	10.00 m
10	No T.P.
11	No T.P.
12	10.40 m
13	10.00 m
14	No T.P.
15	11.15 m
16	11.95 m
17	No T.P.
18	No T.P.
19	No T.P.
20	10.25 m

Figure H-12. Yawzi Reef field site map, range and bearing tables.

Table H-41. Range table for Yawzi Reef site, transects 1–10.

Distance	1	2	3	4	5	6	7	8	9	10
1	--	39	15.5	22.3	23.3	28.1	52.2	41.7	35.9	33.8
2	39	--	52.1	48.1	38.4	31.1	32.7	33.2	37.7	60.5
3	15.5	52.1	--	15.1	23.5	32.1	57.9	45.5	37.1	21.8
4	22.3	48.1	15.1	--	11.4	21.1	45.8	32.8	23.5	13
5	23.3	38.4	23.5	11.4	--	9.6	34.8	22.1	13.7	22.4
6	28.1	31.1	32.1	21.1	9.6	--	25.7	13.8	9	31.4
7	52.2	32.7	57.9	45.8	34.8	25.7	--	13.2	23	53.6
8	41.7	33.2	45.5	32.8	22.1	13.8	13.2	--	9.9	40.5
9	35.9	37.7	37.1	23.5	13.7	8.96	23	9.9	--	30.6
10	33.8	60.5	21.8	13	22.4	31.4	53.6	40.5	30.6	--
11	37.5	68.4	23	20.3	31.1	40.5	63.3	50.2	40.3	10
12	80.5	57.9	84.5	71	61	53	28.5	39.3	47.6	75.8
13	73.3	54.8	76.3	62.4	52.8	45.4	23	31.6	39.2	66.6
14	64.4	51.9	65.9	51.5	42.7	36.3	19.3	23.2	29	55
15	21.3	60.1	10.2	24.8	33.7	42.3	68	55.7	47.3	28.4
16	23.6	62	10.7	24.1	33.8	42.7	68.4	55.9	47.1	26.4
17	42.2	81.1	30.3	42.3	52.8	62	87.6	74.8	65.7	40.1
18	67.9	106	54.2	62.8	74.2	83.8	108	95.3	85.5	55.8
19	33.9	72.7	21.8	34.3	44.6	53.6	79.3	66.6	57.7	33.6
20	52.7	91.6	40.6	51.7	62.6	71.9	97.4	84.5	75.2	47.9

Table H-42. Bearing table for Yawzi Reef site, transects 1–10.

Bearing	1	2	3	4	5	6	7	8	9	10
1	--	122	340	22	51	70	84	74	62	10
2	302	--	313	329	337	348	35	12	358	333
3	160	133	--	66	90	99	99	94	86	31
4	202	149	246	--	122	122	109	106	99	348
5	231	157	270	302	--	121	104	98	80	327
6	250	168	279	302	301	--	98	81	36	319
7	264	215	279	289	284	278	--	296	299	301
8	254	192	274	286	278	261	116	--	302	302
9	242	178	266	279	260	216	119	122	--	303
10	190	153	211	168	147	139	121	122	123	--
11	175	148	186	146	137	133	120	121	121	115
12	260	233	270	275	270	265	253	266	273	285
13	255	224	267	272	265	258	236	257	267	283
14	249	211	262	267	258	248	205	239	257	280
15	133	126	90	76	90	97	97	93	87	49
16	139	129	108	83	96	101	100	96	91	54
17	128	125	112	97	102	105	103	101	98	79
18	135	130	128	116	117	117	113	112	111	105
19	130	126	110	92	100	103	102	99	95	70
20	127	125	115	103	106	108	106	104	102	88

Table H-43. Range table for Yawzi Reef site, transects 11–20.

Distance	11	12	13	14	15	16	17	18	19	20
1	37.5	80.5	73.3	64.4	21.3	23.6	42.2	67.9	33.9	52.7
2	68.4	57.9	54.8	51.9	60.1	62	81.1	106	72.7	91.6
3	23	84.5	76.3	65.9	10.2	10.7	30.3	54.2	21.8	40.6
4	20.3	71	62.4	51.5	24.8	24.1	42.3	62.8	34.3	51.7
5	31.1	61	52.8	42.7	33.7	33.8	52.8	74.2	44.6	62.6
6	40.5	53	45.4	36.3	42.3	42.7	62	83.8	53.6	71.9
7	63.3	28.5	23	19.3	68	68.4	87.6	108	79.3	97.4
8	50.2	39.3	31.6	23.2	55.7	55.9	74.8	95.3	66.6	84.5
9	40.3	47.6	39.2	29	47.3	47.1	65.7	85.5	57.7	75.2
10	10	75.8	66.6	55	28.4	26.4	40.1	55.8	33.6	47.9
11	--	85.4	76.2	64.5	26	23.2	32.7	46.3	27.5	39.4
12	85.4	--	9.58	21.4	94.8	94.8	113	132	105	122
13	76.2	9.58	--	11.9	86.5	86.3	105	122	96.7	114
14	64.5	21.4	11.9	--	76	75.6	93.4	111	85.7	102
15	26	94.8	86.5	76	--	3.2	21	46.6	12.6	31.6
16	23.2	94.8	86.3	75.6	3.2	--	19.6	44.4	11.1	30
17	32.7	113	105	93.4	21	19.6	--	26.7	8.6	10.6
18	46.3	132	122	111	46.6	44.4	26.7	--	34.2	17.2
19	27.5	105	96.7	85.7	12.6	11.1	8.6	34.2	--	19
20	39.4	122	114	102	31.6	30	10.6	17.2	19	--

Table H-44. Bearing table for Yawzi Reef site, transects 11–20.

Bearing	11	12	13	14	15	16	17	18	19	20
1	355	80	75	69	313	319	308	315	310	307
2	328	53	44	31	306	309	305	310	306	305
3	6	90	87	82	270	288	292	308	290	295
4	326	95	92	87	256	263	277	296	272	283
5	317	90	85	78	270	276	282	297	280	286
6	313	85	78	68	277	281	285	297	283	288
7	300	73	56	25	277	280	283	293	282	286
8	301	86	77	59	273	276	281	292	279	284
9	301	93	87	77	267	271	278	291	275	282
10	295	105	103	100	229	234	259	285	250	268
11	--	106	104	103	209	213	249	283	236	262
12	286	--	299	296	270	272	276	285	274	278
13	284	119	--	293	267	269	274	284	272	277
14	283	116	113	--	263	266	271	283	269	275
15	29	90	87	83	--	1	302	316	306	303
16	33	92	89	86	181	--	294	313	292	298
17	69	96	94	91	122	114	--	327	116	306
18	103	105	104	103	136	133	147	--	140	160
19	56	94	92	89	126	112	296	320	--	301
20	82	98	97	95	123	118	126	340	121	--

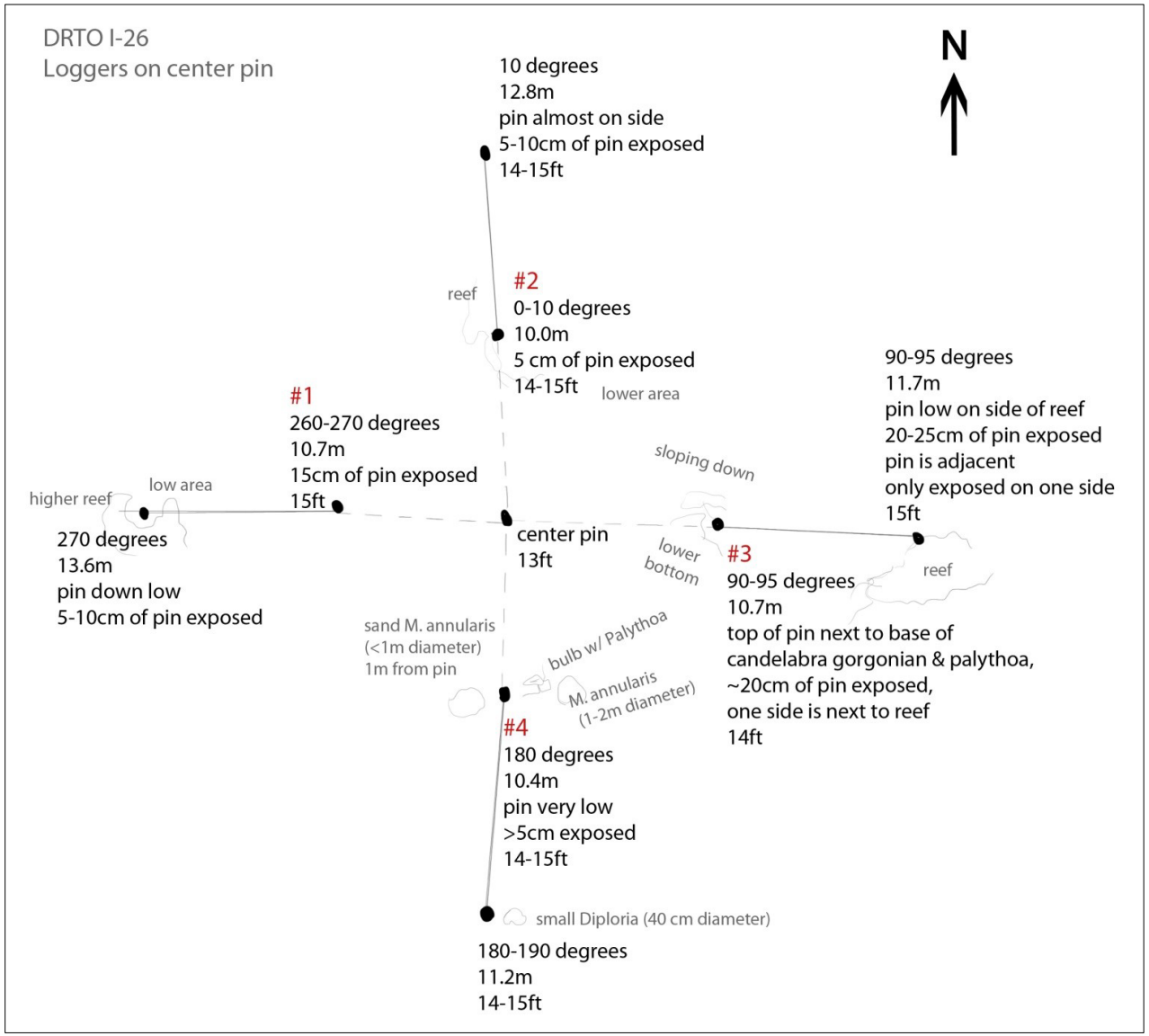


Figure H-13. Site map for DRTO I-26.

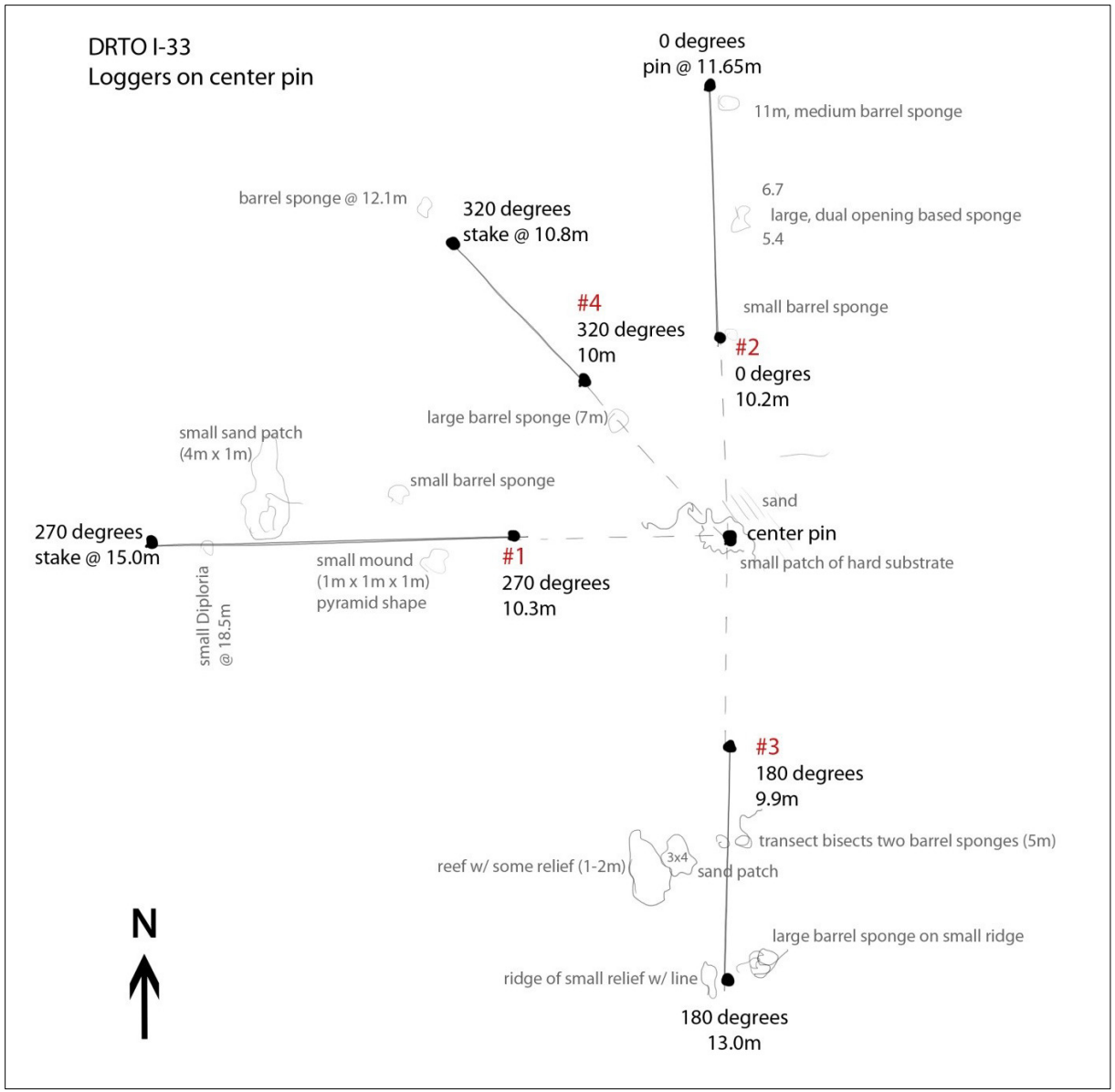


Figure H-14. Site map for DRTO I-33.

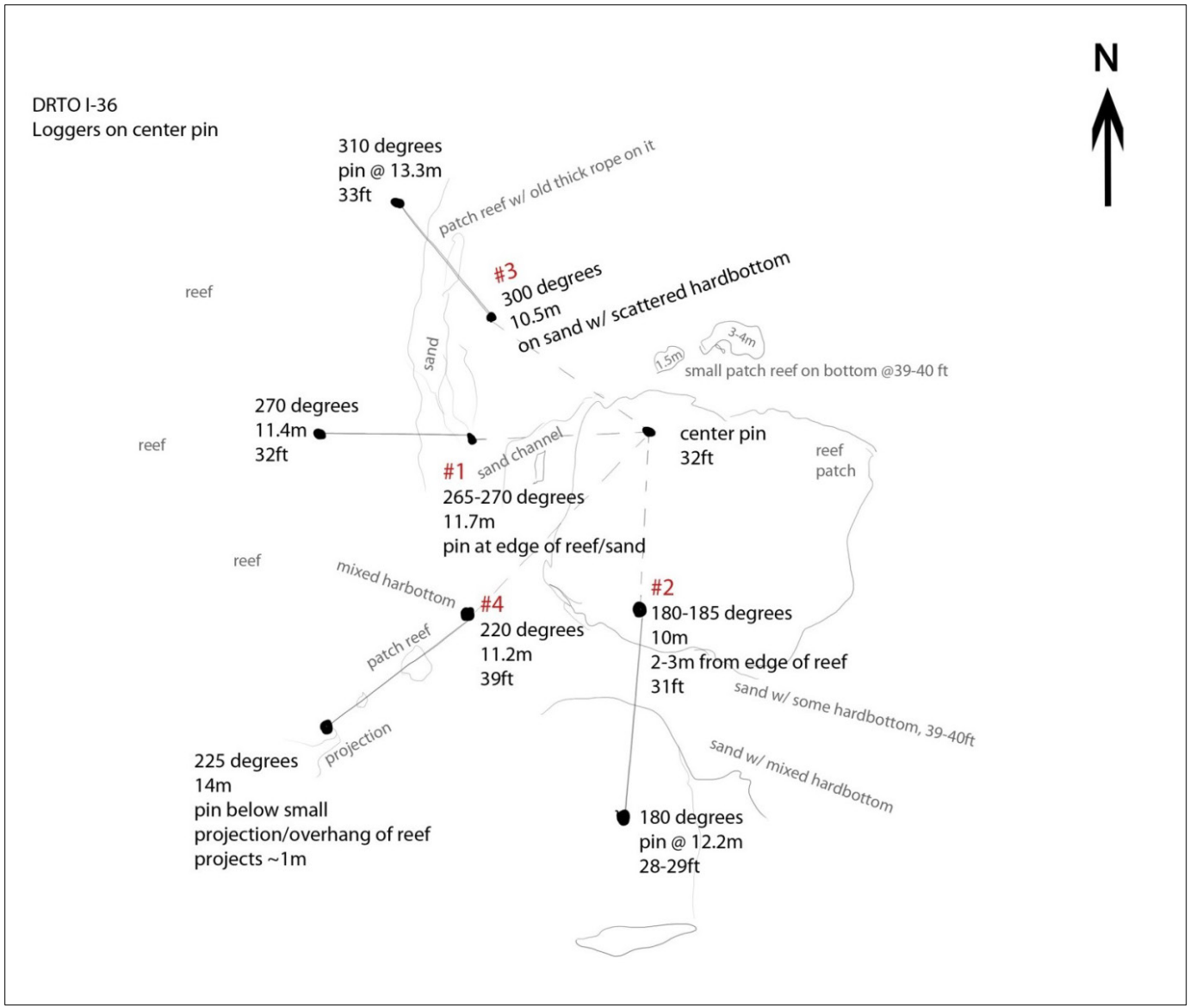


Figure H-15. Site map for DRTO I-36.

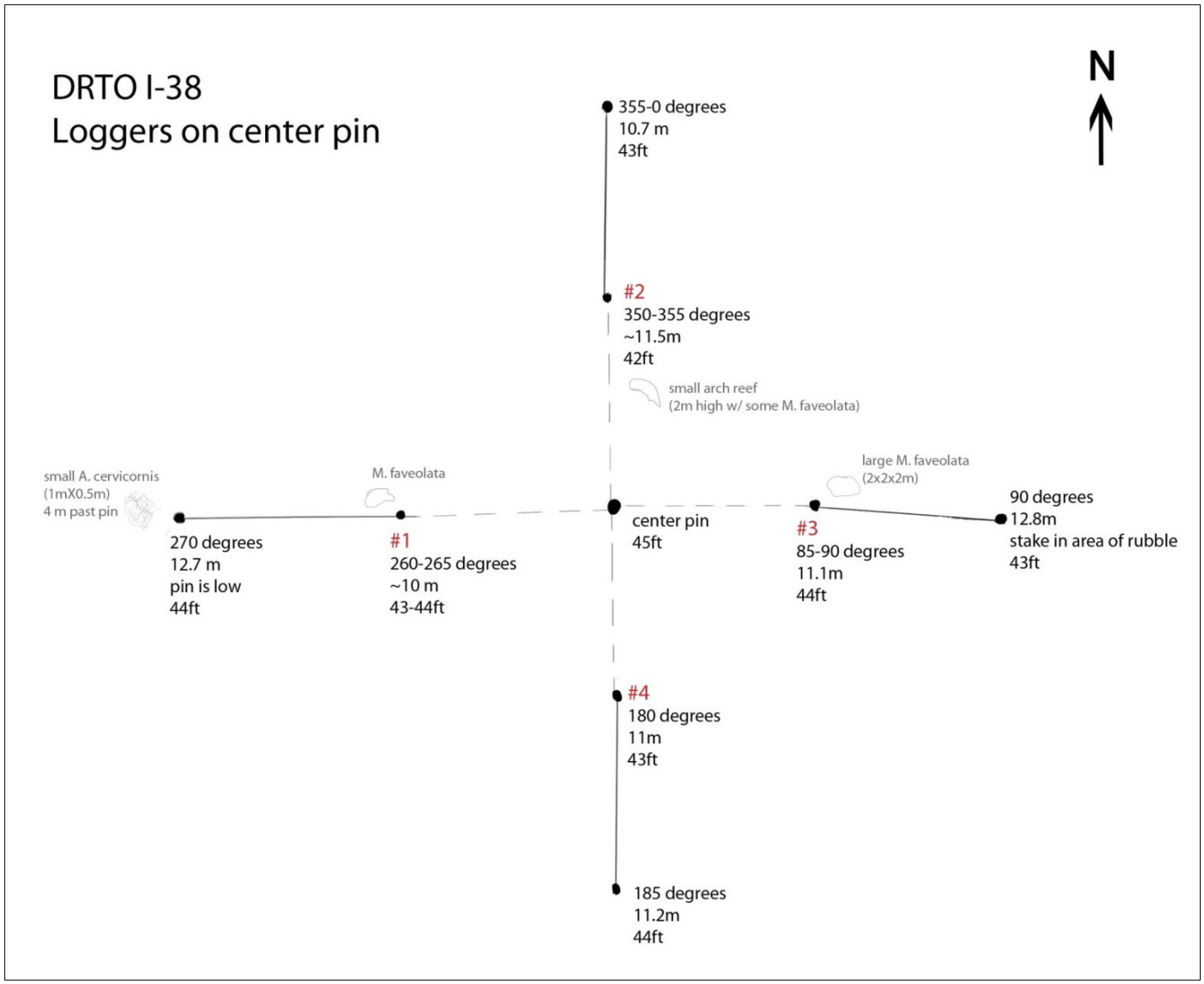


Figure H-16. Site map for DRTO I-38.

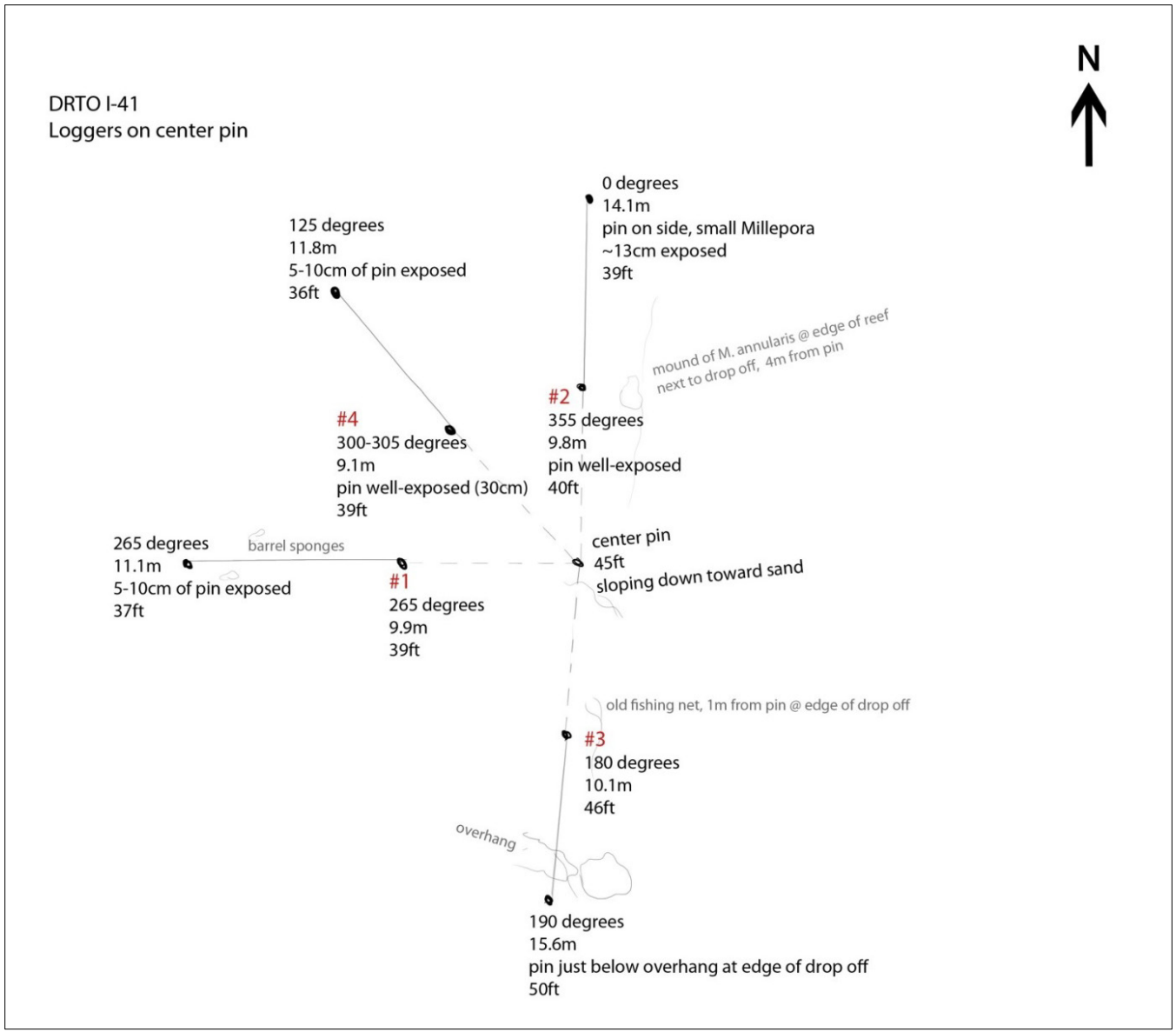


Figure H-17. Site map for DRTO I-41.

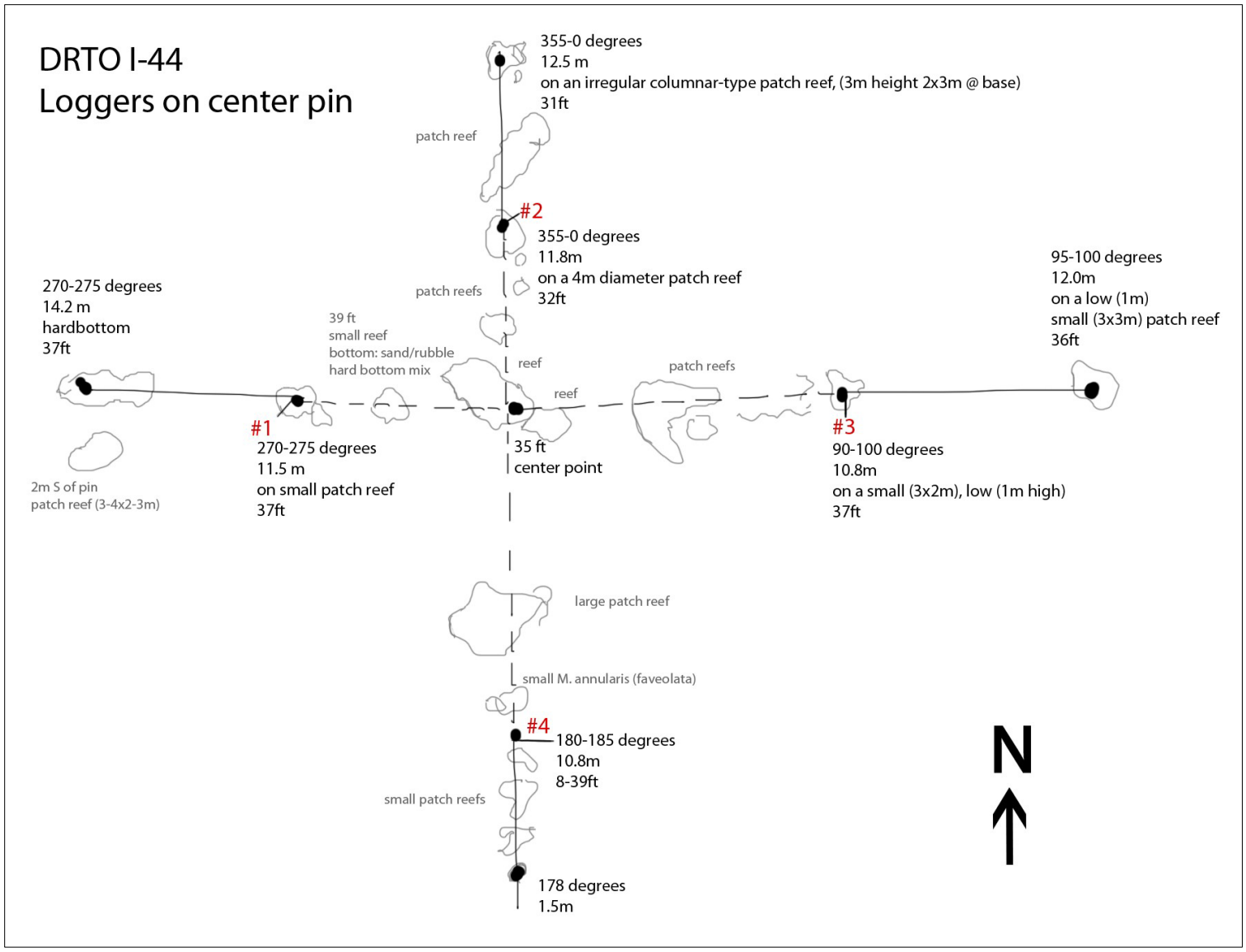


Figure H-18. Site map for DRTO I-44.

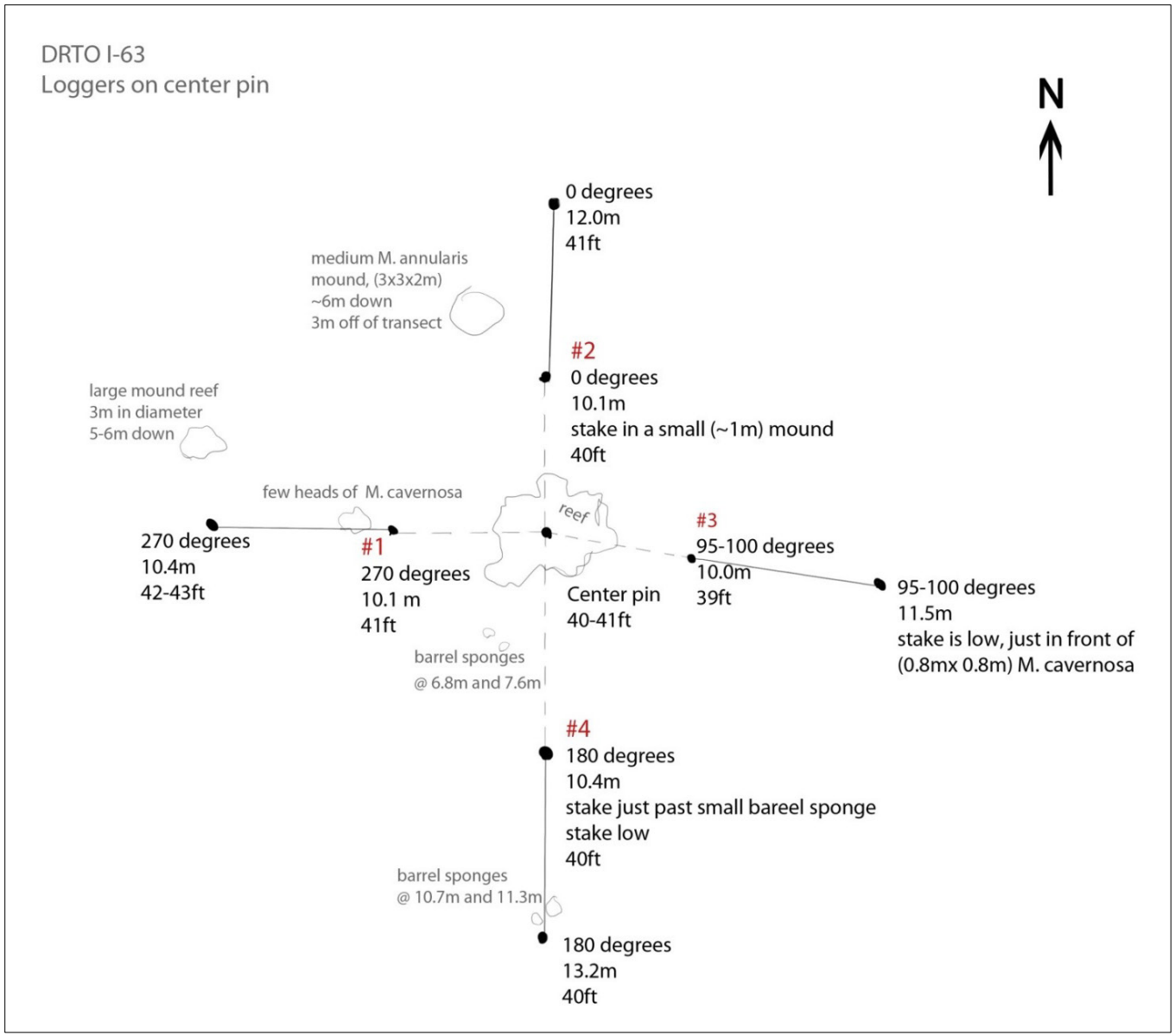


Figure H-19. Site map for DRTO I-63.

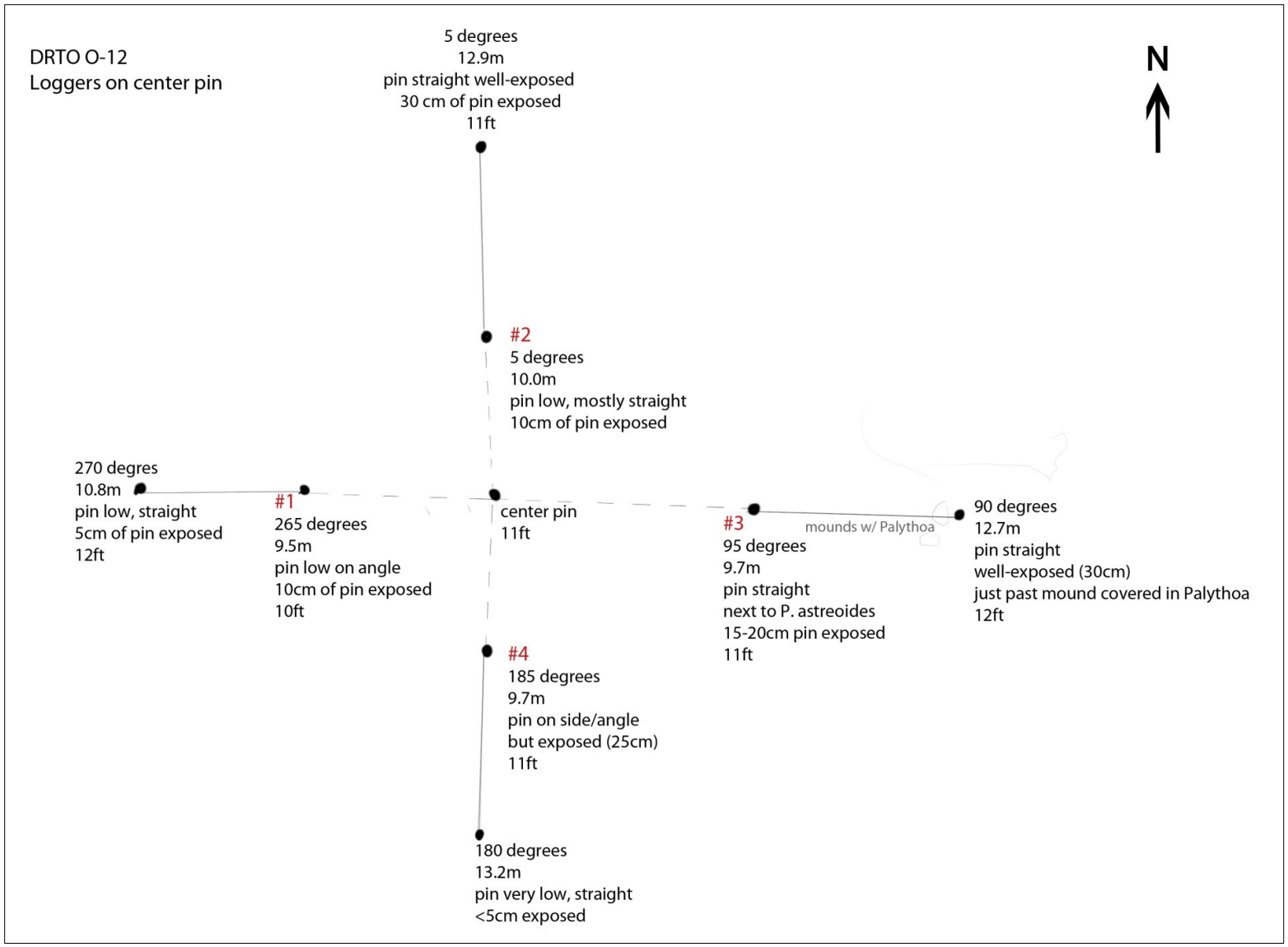


Figure H-20. Site map for DRTO O-12.

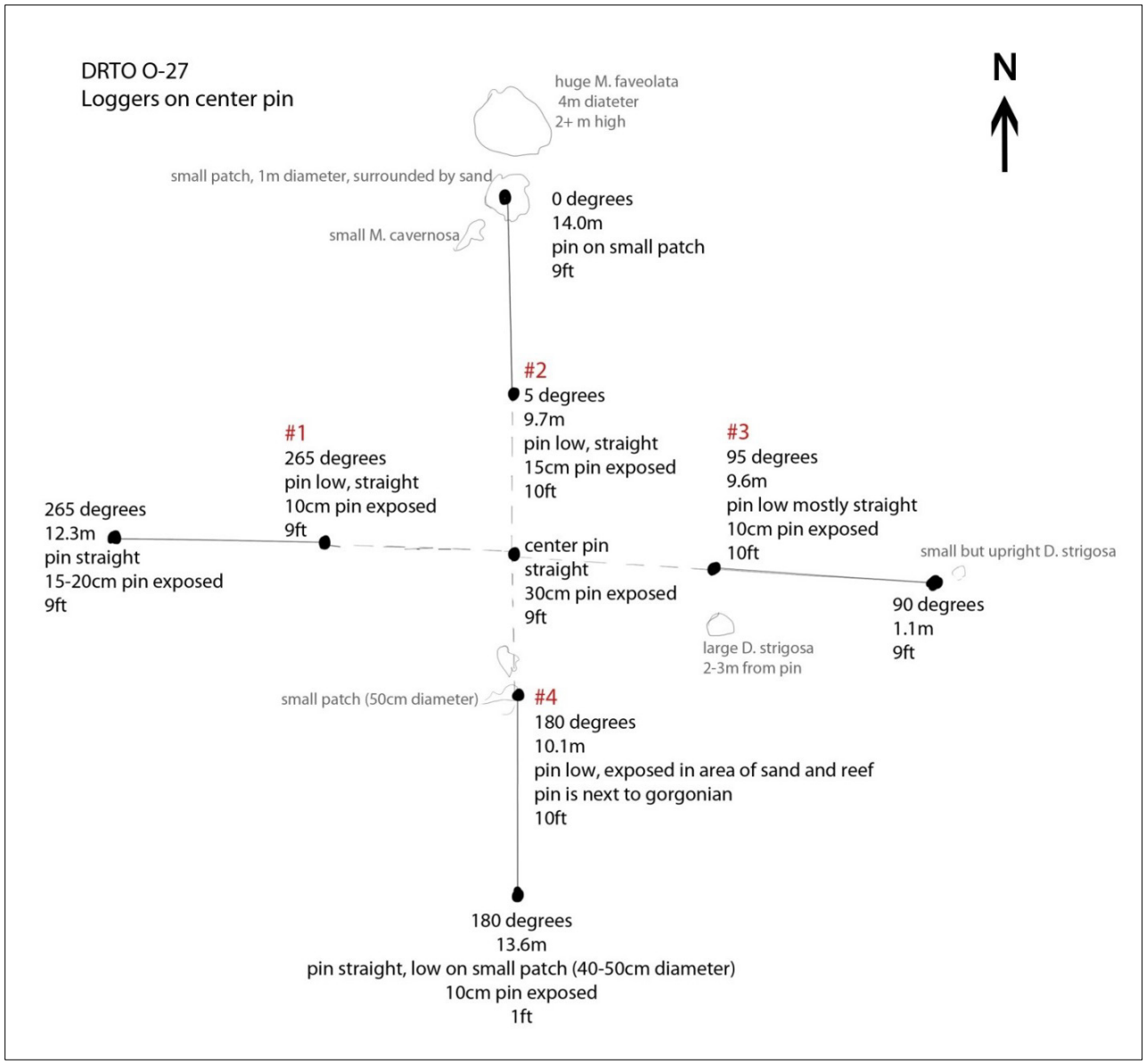


Figure H-21. Site map for DRTO O-27.

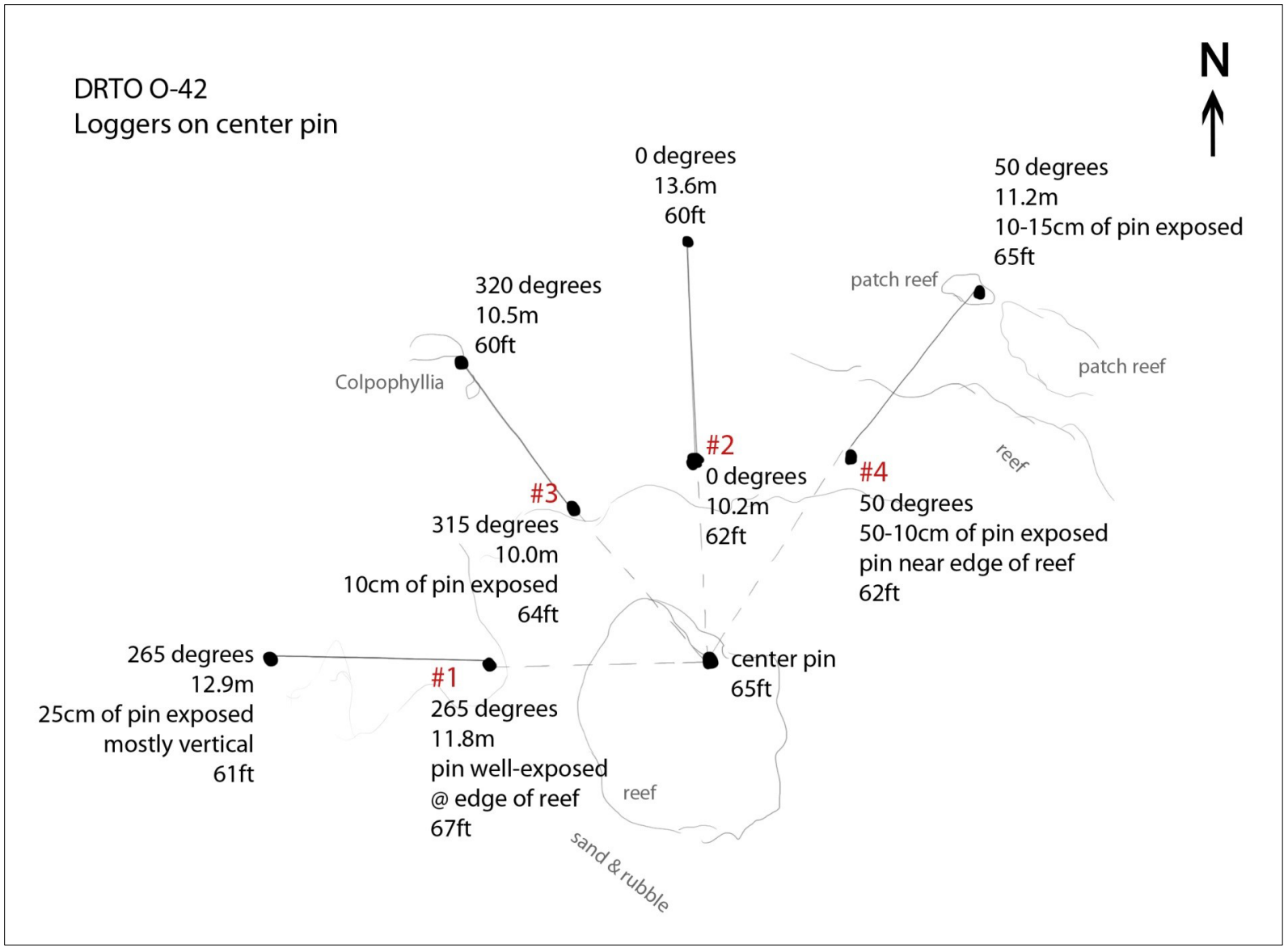


Figure H-22. Site map for DRTO O-42.

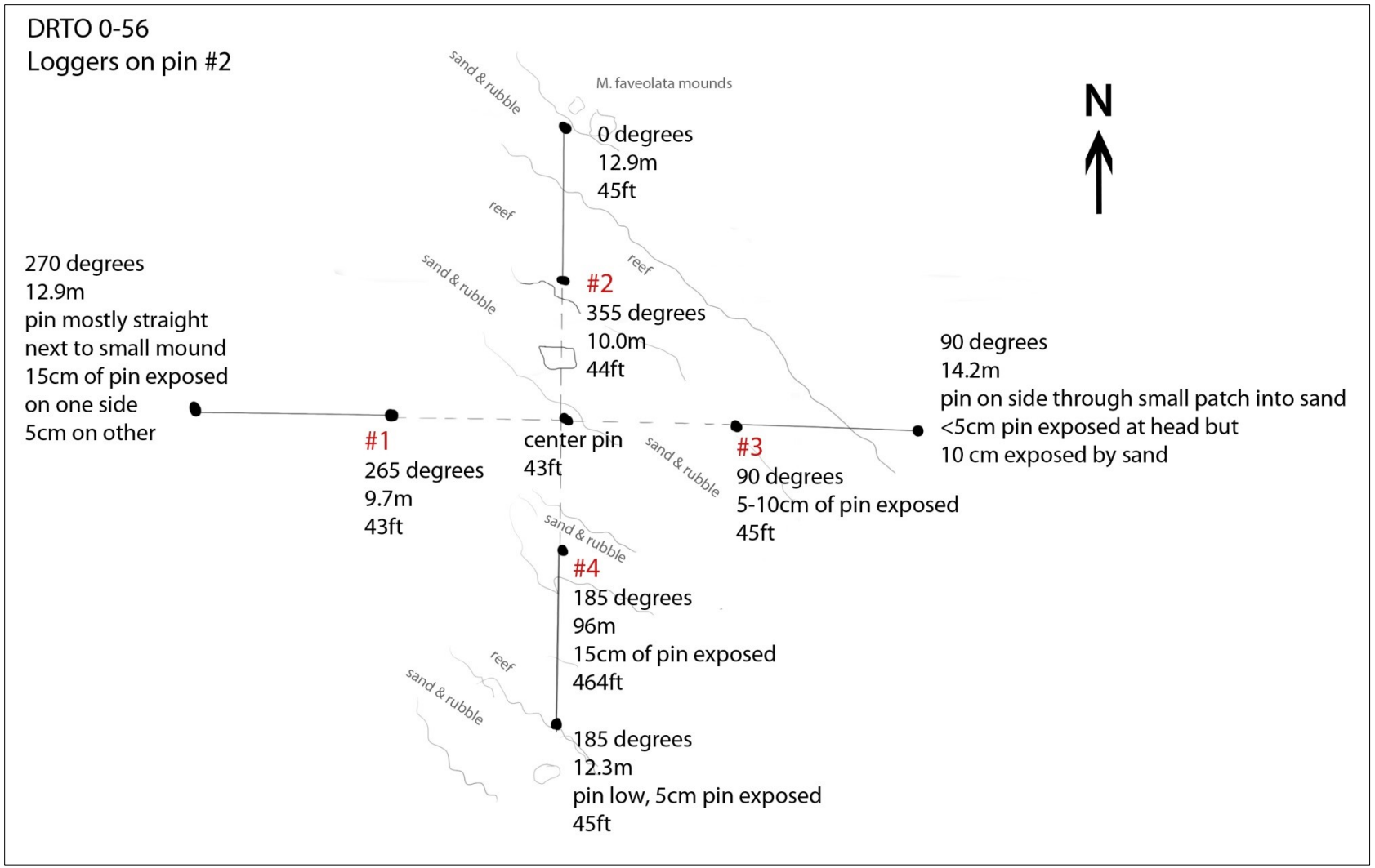


Figure H-23. Site map for DRTO O-56.

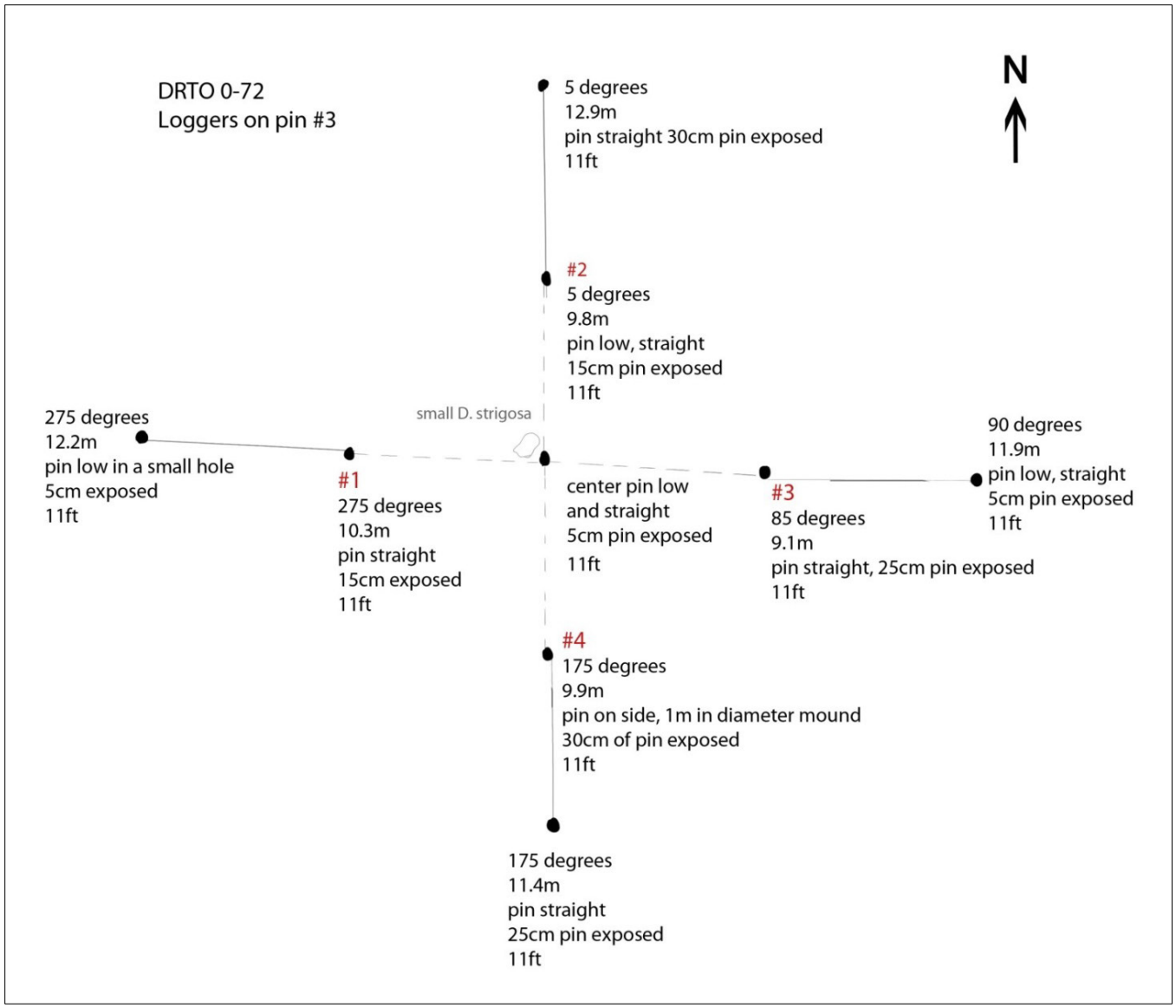


Figure H-24. Site map for DRTO O-72.

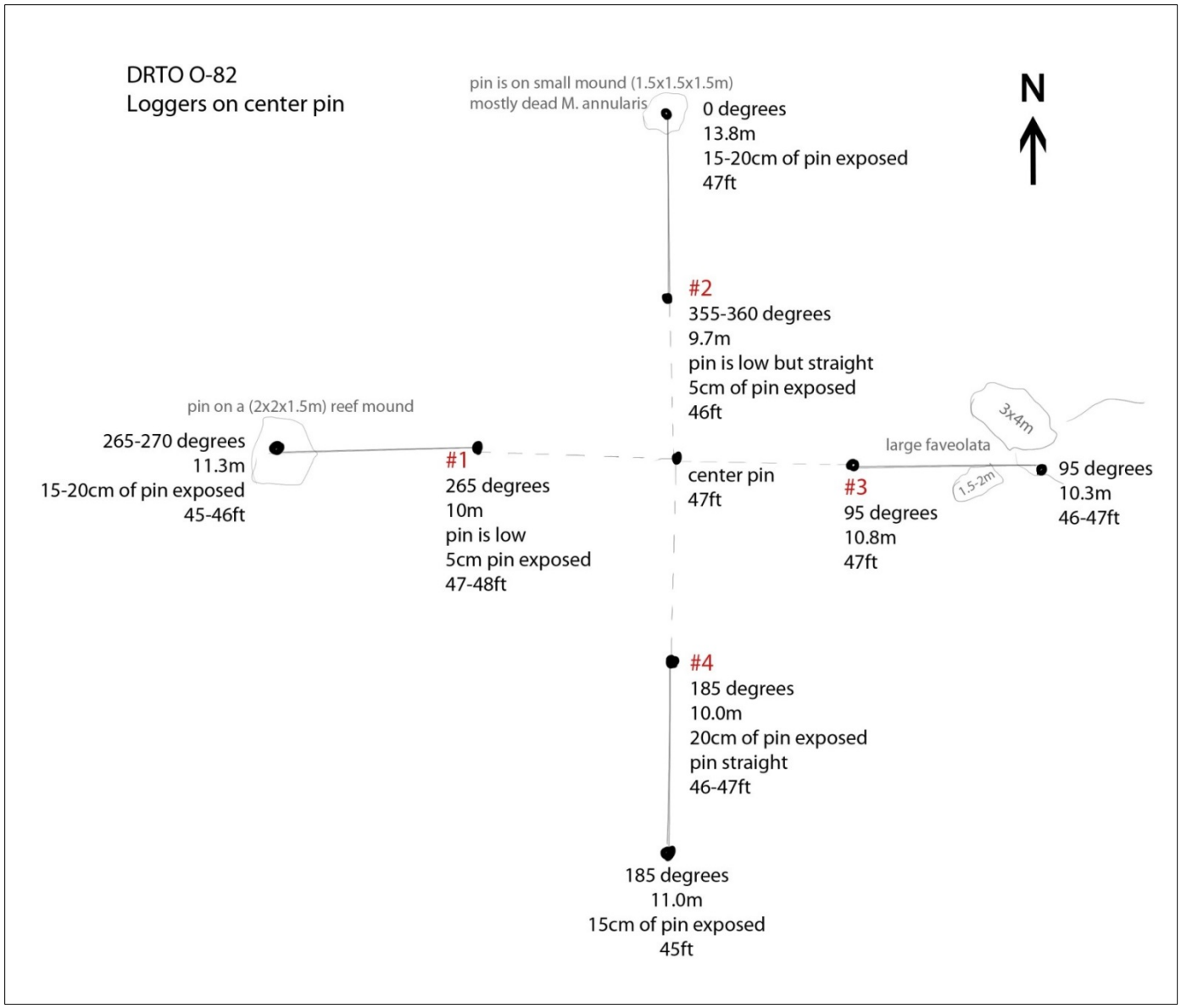


Figure H-25. Site map for DRTO O-82.

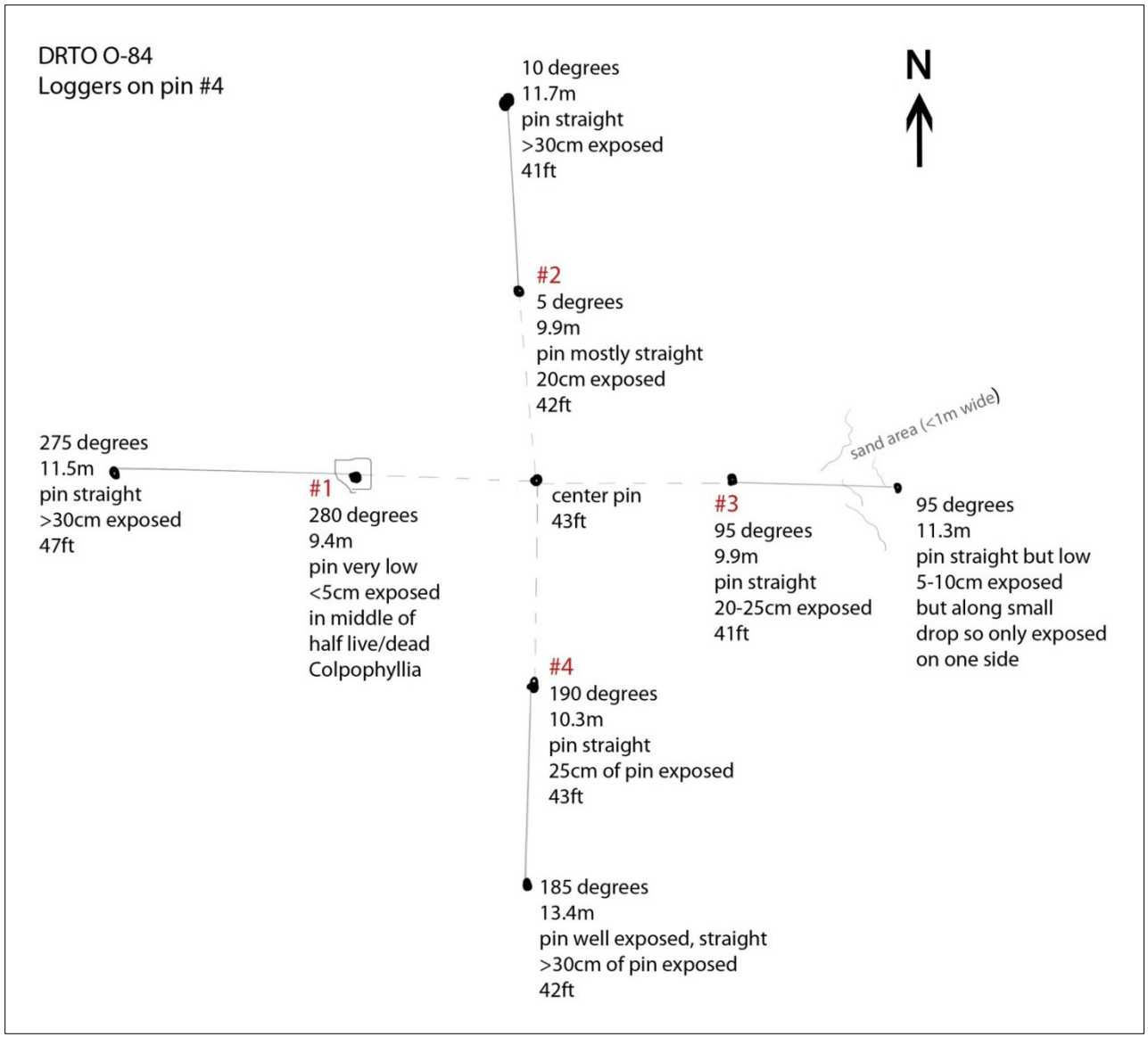


Figure H-26. Site map for DRTO-84.

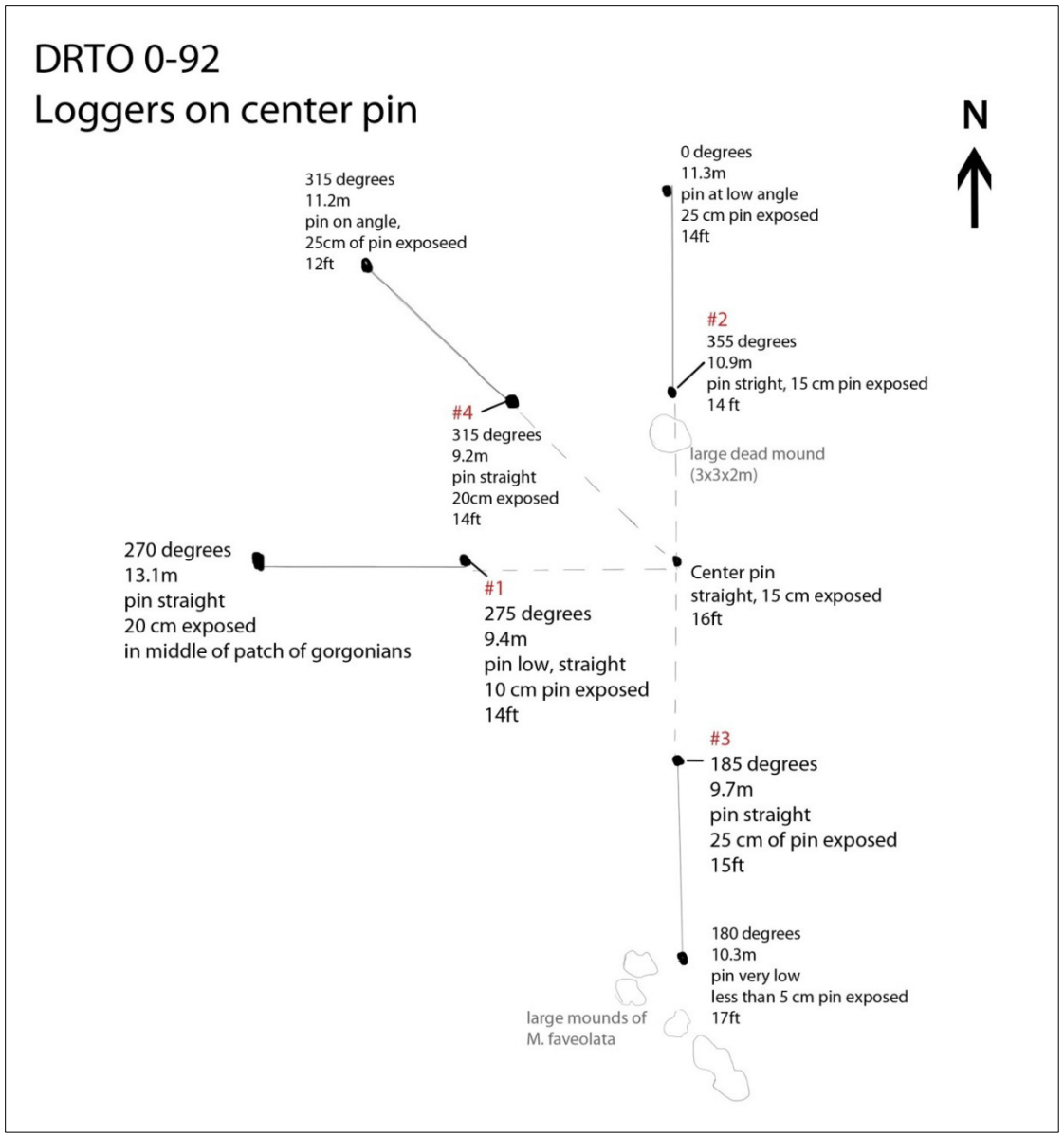


Figure H-27. Site map for DRTO O-92.

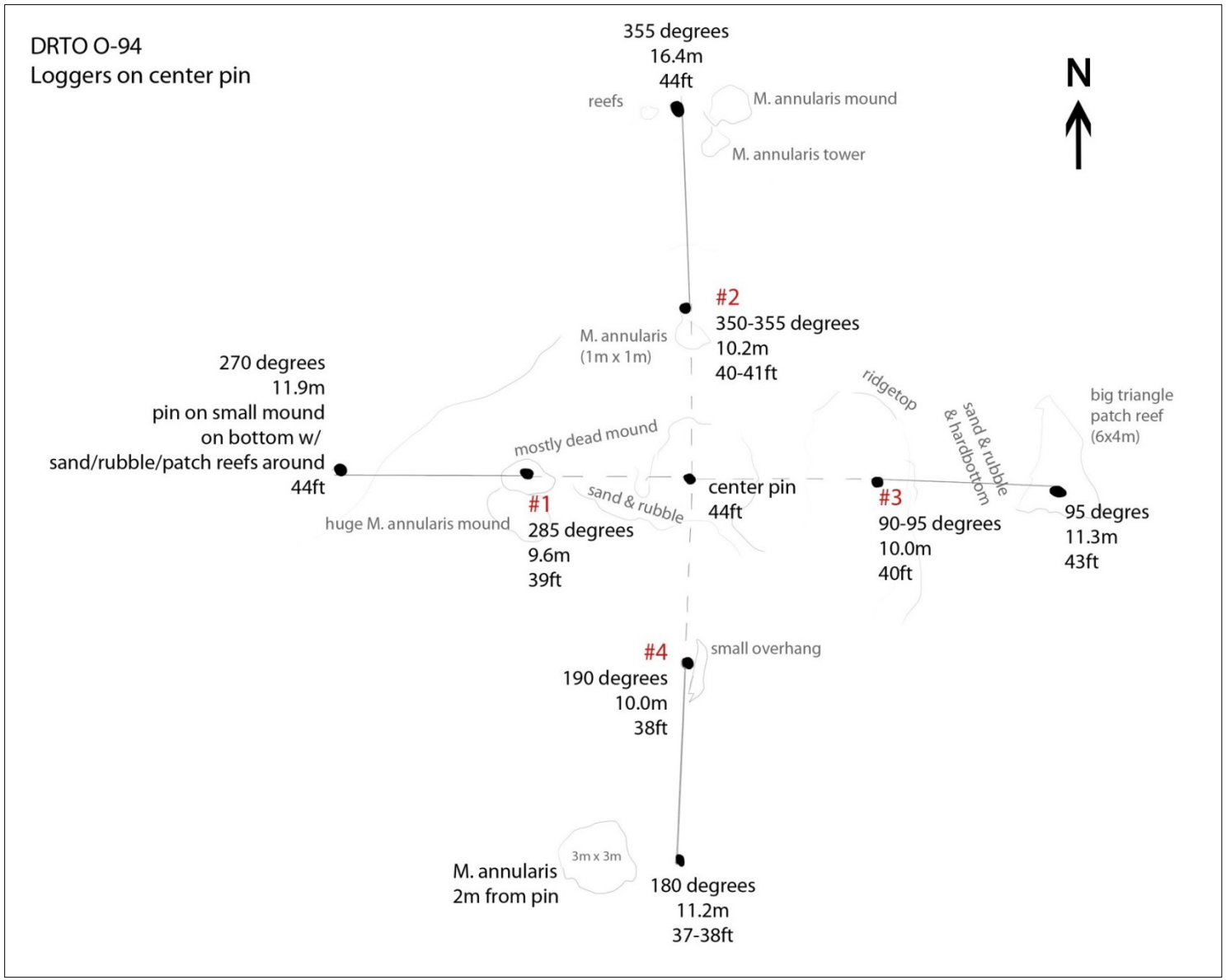


Figure H-28. Site map for DRTO O-94.

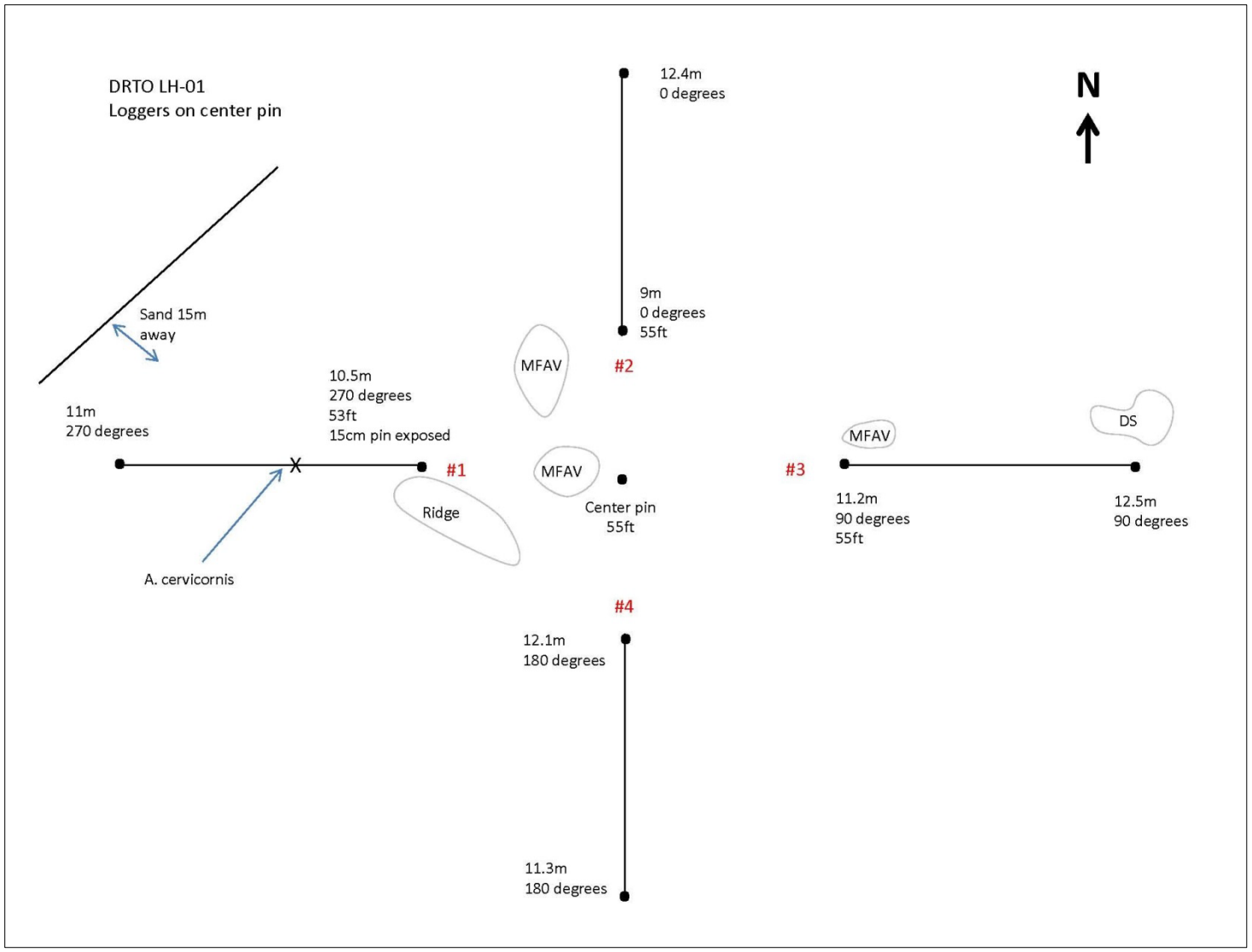


Figure H-29. Site map for DRTO LH-01.

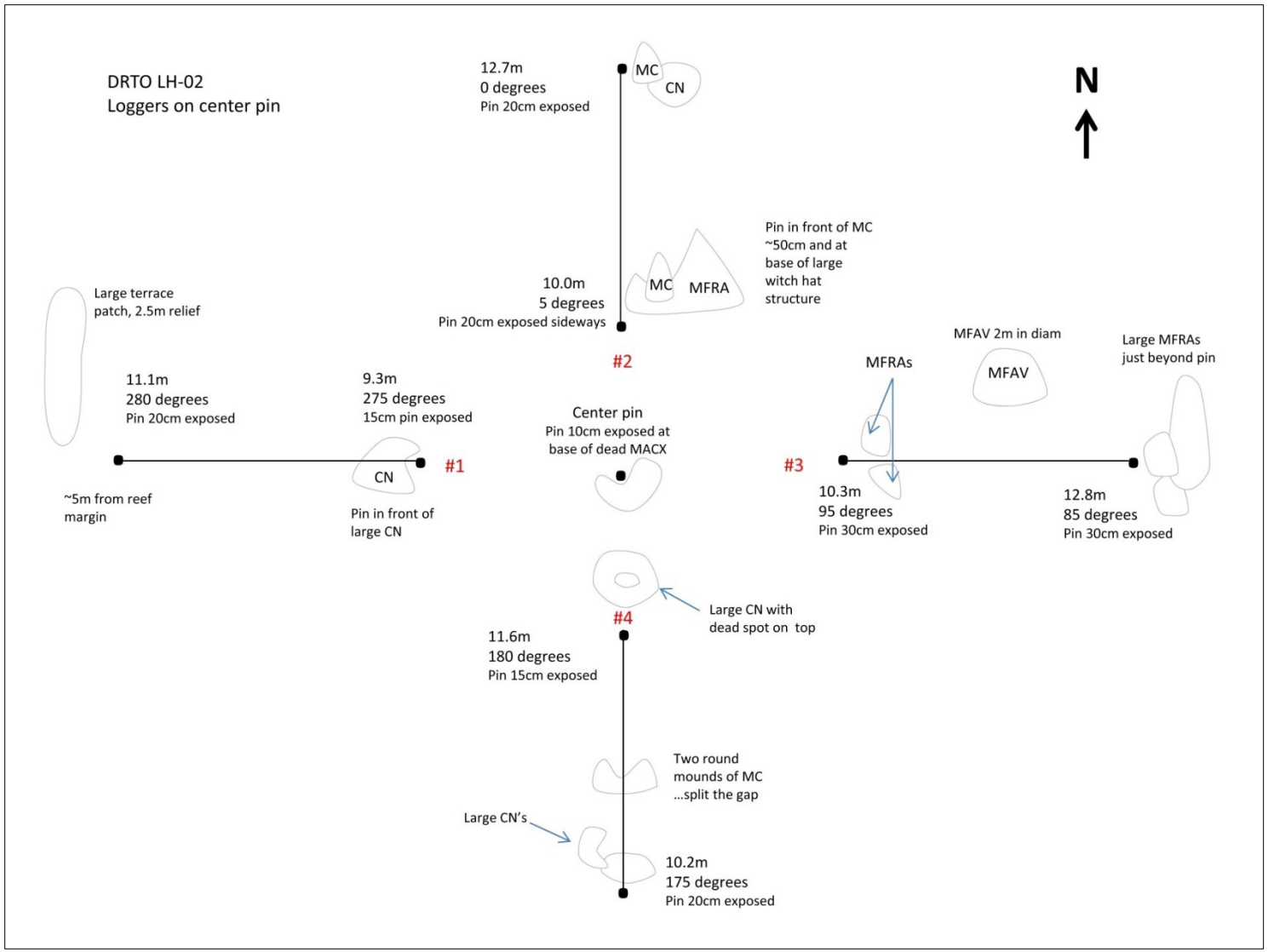


Figure H-30. Site map for DRTO LH-02.

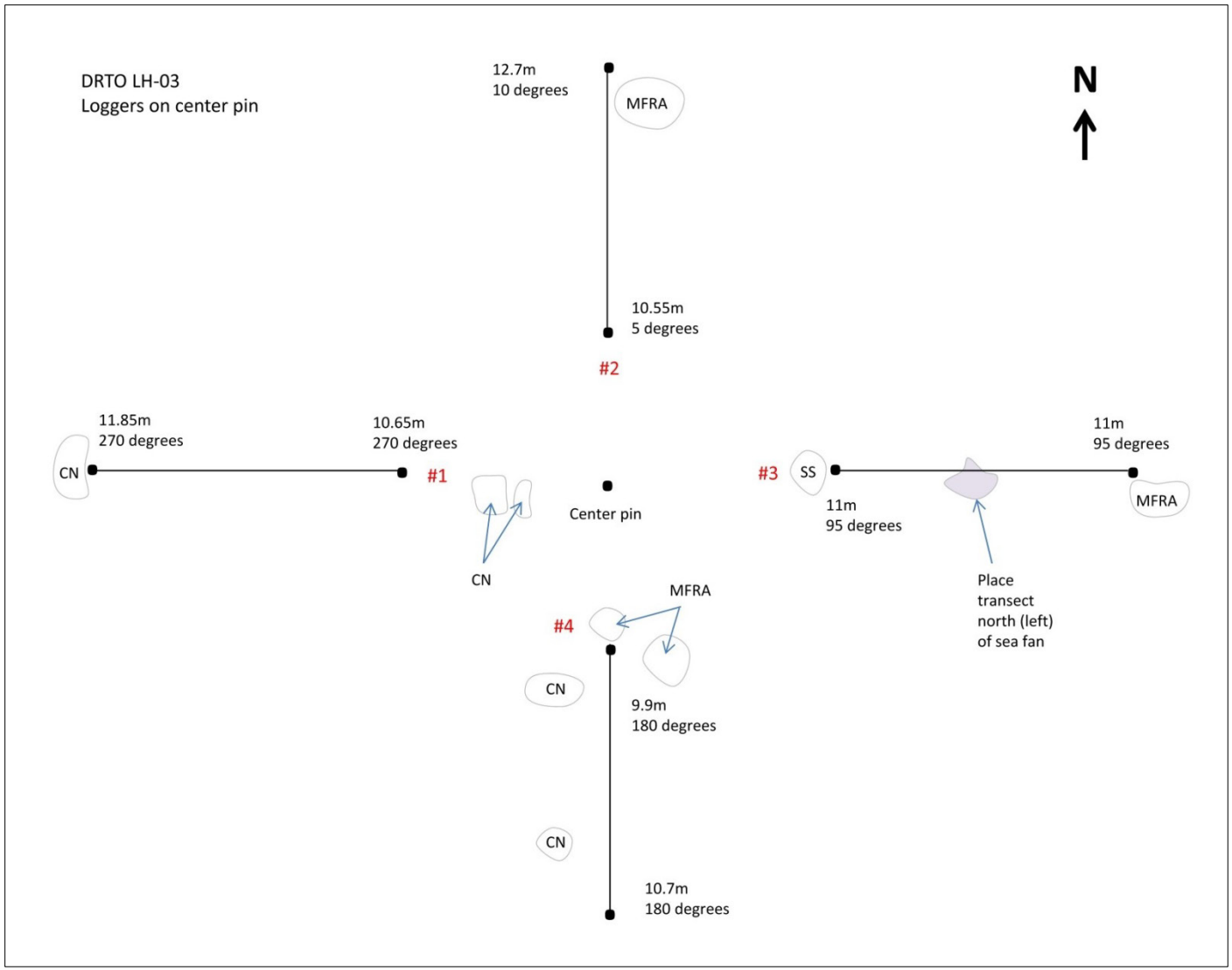


Figure H-31. Site map for DRTO LH-03.

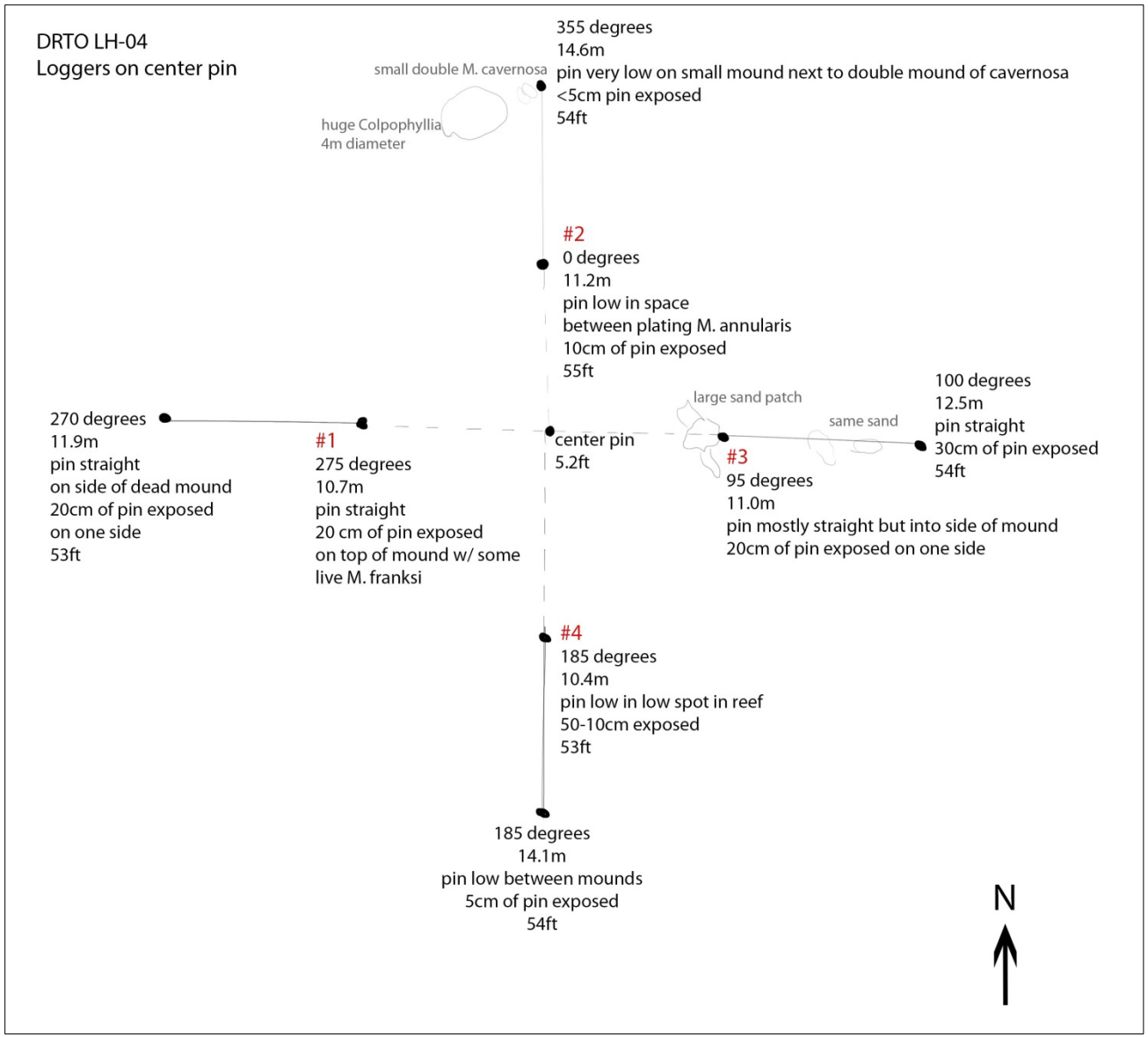


Figure H-32. Site map for DRTO LH-04.

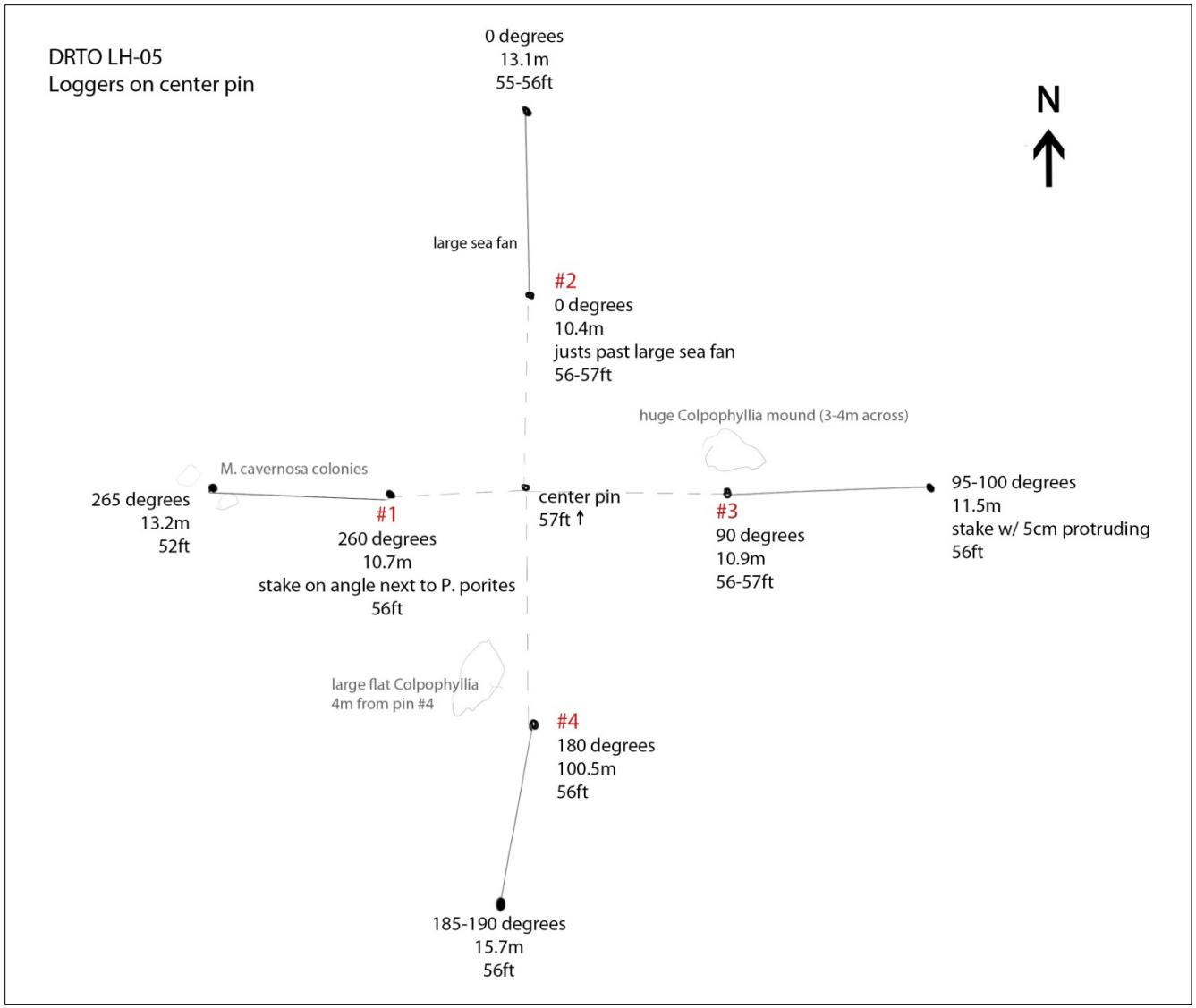


Figure H-33. Site map for DRTO LH-05.

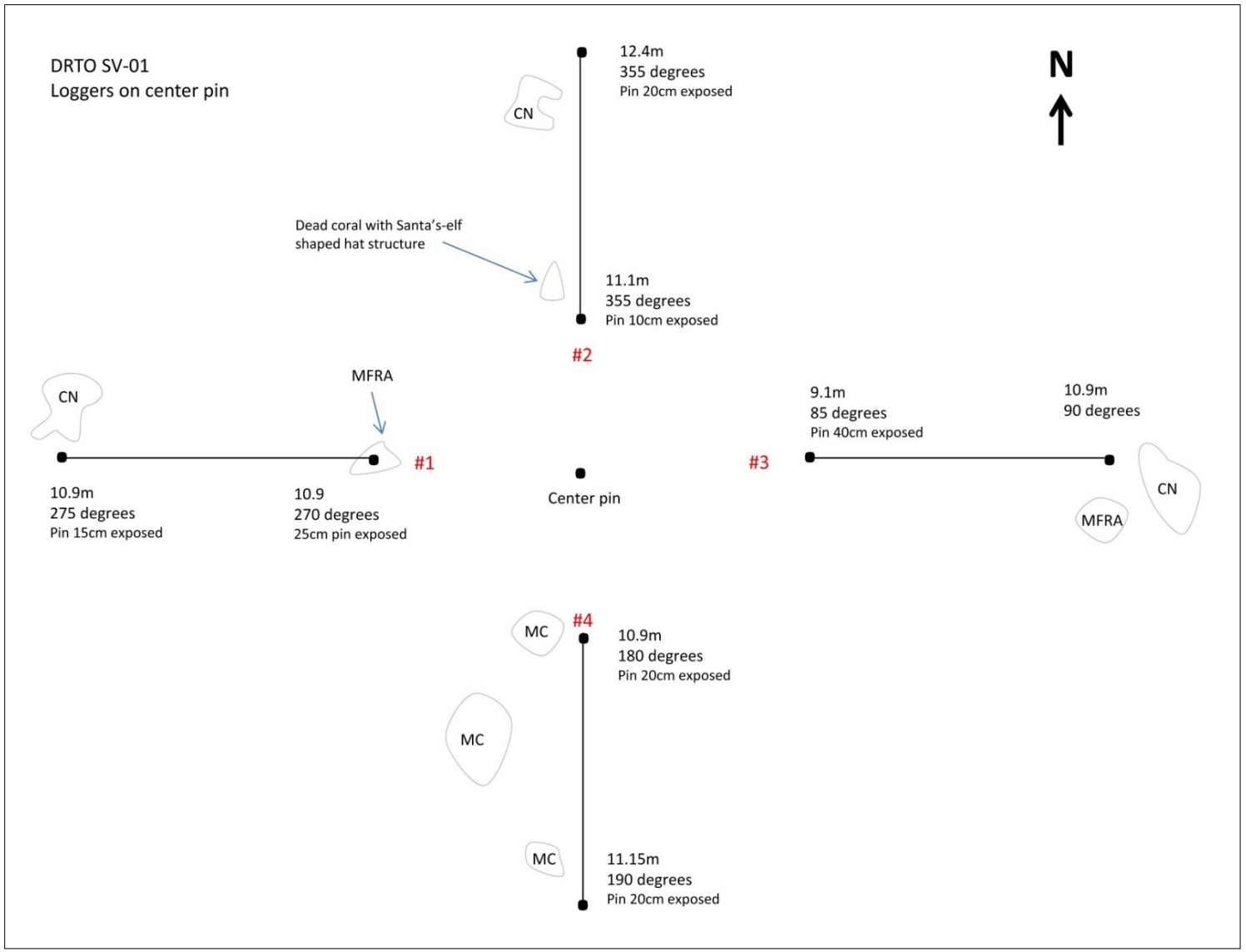


Figure H-34. Site map for DRTO SV-01.

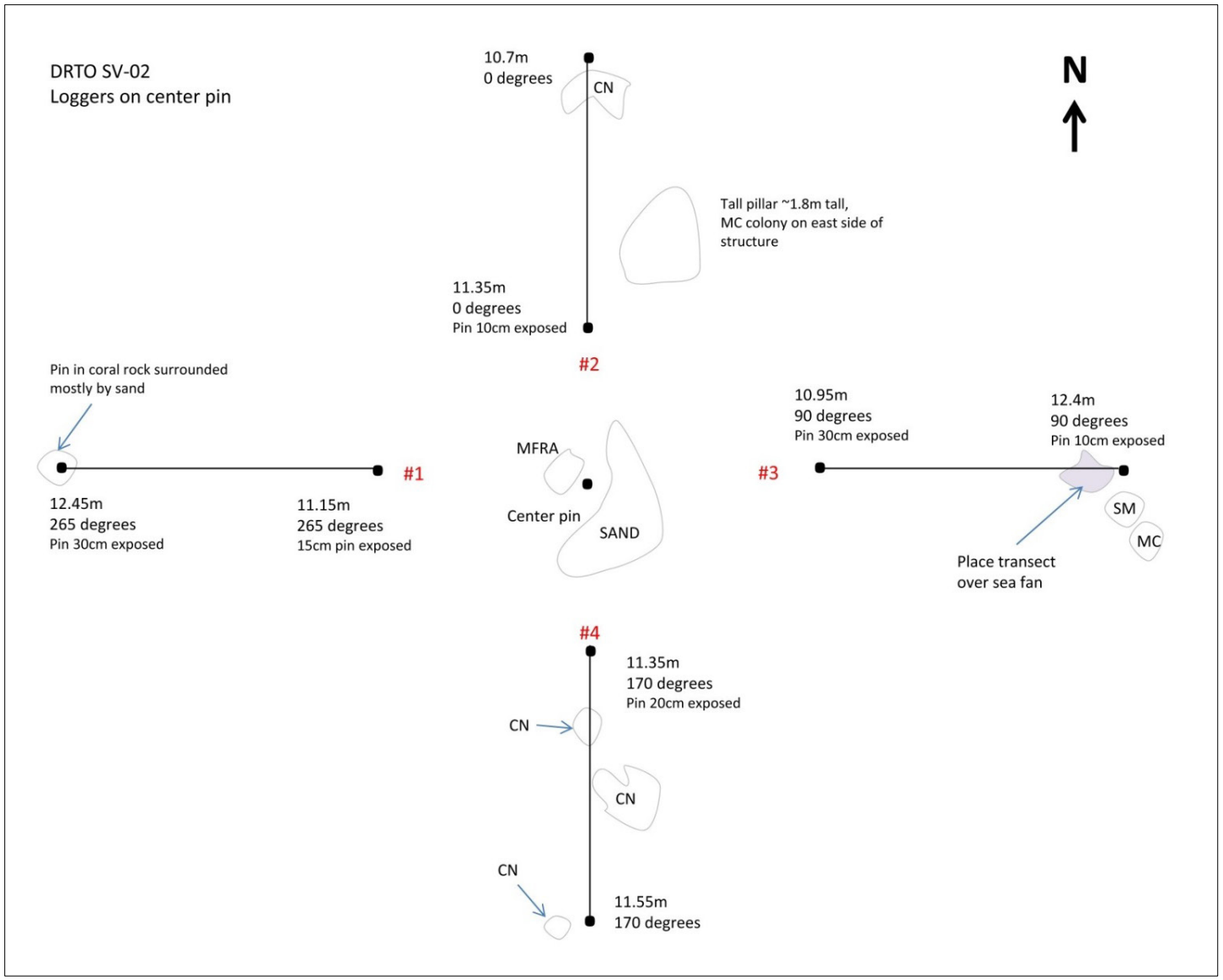


Figure H-35. Site map for DRTO SV-02.

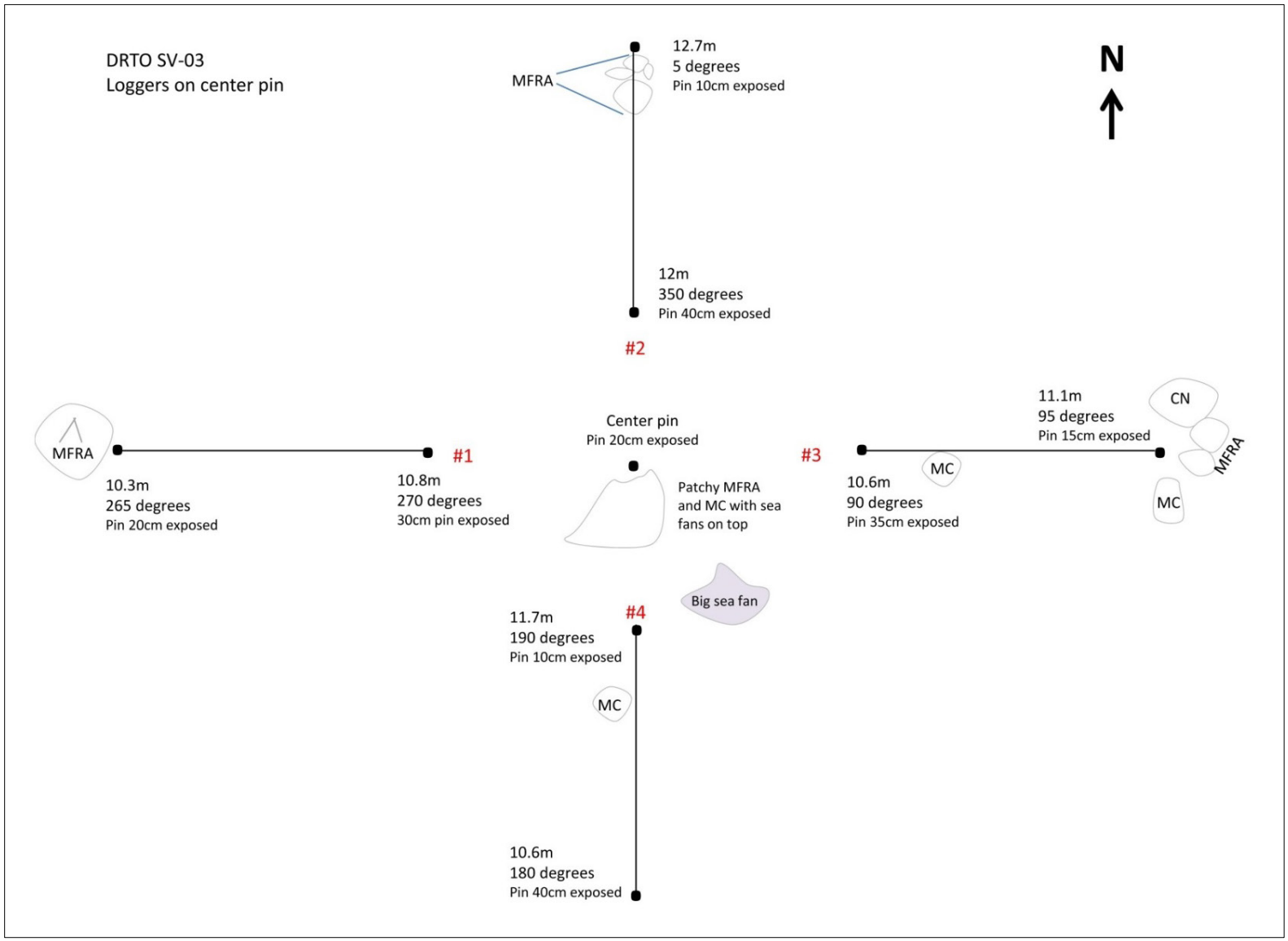


Figure H-36. Site map for DRTO SV-03.

Table H-45. Coordinates for start pins of SFCN coral reef monitoring transects and extensive sub-site center pins. Coordinates for discontinued sites are also provided. Depth is in feet. Active Sites.

Park	SITE	Type	Extensive sub-site Grouping	LocationID	UTM X	UTM Y	UTM Zone	Latitude	Longitude	Depth
BISC	AM	20 transect	—	BISC_CoralVideo_AM_01	582814	2804261	17	25.3527331	-80.1769785	16
BISC	AM	20 transect	—	BISC_CoralVideo_AM_02	582806	2804249	17	25.3526251	-80.1770588	13
BISC	AM	20 transect	—	BISC_CoralVideo_AM_03	582786	2804265	17	25.3527707	-80.1772565	9
BISC	AM	20 transect	—	BISC_CoralVideo_AM_04	582805	2804269	17	25.3528058	-80.1770675	8
BISC	AM	20 transect	—	BISC_CoralVideo_AM_05	582747	2804299	17	25.3530799	-80.177642	11
BISC	AM	20 transect	—	BISC_CoralVideo_AM_06	582755	2804275	17	25.3528628	-80.177564	7
BISC	AM	20 transect	—	BISC_CoralVideo_AM_07	582720	2804246	17	25.3526028	-80.1779136	7
BISC	AM	20 transect	—	BISC_CoralVideo_AM_08	582729	2804223	17	25.3523946	-80.1778255	7
BISC	AM	20 transect	—	BISC_CoralVideo_AM_09	582700	2804222	17	25.3523872	-80.1781138	6
BISC	AM	20 transect	—	BISC_CoralVideo_AM_10	582674	2804296	17	25.3530569	-80.1783676	10
BISC	AM	20 transect	—	BISC_CoralVideo_AM_11	582265	2804290	17	25.3530253	-80.1824324	11
BISC	AM	20 transect	—	BISC_CoralVideo_AM_12	582649	2804271	17	25.3528325	-80.1786176	10
BISC	AM	20 transect	—	BISC_CoralVideo_AM_13	582664	2804248	17	25.352624	-80.1784699	6
BISC	AM	20 transect	—	BISC_CoralVideo_AM_14	582651	2804234	17	25.3524983	-80.1786	8
BISC	AM	20 transect	—	BISC_CoralVideo_AM_15	582662	2804217	17	25.3523442	-80.1784917	8
BISC	AM	20 transect	—	BISC_CoralVideo_AM_16	582647	2804212	17	25.3522999	-80.1786411	9
BISC	AM	20 transect	—	BISC_CoralVideo_AM_17	582686	2804192	17	25.3521171	-80.1782547	6
BISC	AM	20 transect	—	BISC_CoralVideo_AM_18	582682	2804175	17	25.3519638	-80.1782955	8
BISC	AM	20 transect	—	BISC_CoralVideo_AM_19	582710	2804159	17	25.3518178	-80.1780182	7
BISC	AM	20 transect	—	BISC_CoralVideo_AM_20	582680	2804249	17	25.3526321	-80.1783109	5

Park	SITE	Type	Extensive sub-site Grouping	LocationID	UTM X	UTM Y	UTM Zone	Latitude	Longitude	Depth
BISC	BB	20 transect	—	BISC_CoralVideo_BB_01	582119	2800449	17	25.31835	-80.1841159	22
BISC	BB	20 transect	—	BISC_CoralVideo_BB_02	582106	2800444	17	25.3183056	-80.1842453	16
BISC	BB	20 transect	—	BISC_CoralVideo_BB_03	582084	2800442	17	25.3182888	-80.184464	13
BISC	BB	20 transect	—	BISC_CoralVideo_BB_04	582065	2800449	17	25.318353	-80.1846523	15
BISC	BB	20 transect	—	BISC_CoralVideo_BB_05	582061	2800439	17	25.3182629	-80.1846927	17
BISC	BB	20 transect	—	BISC_CoralVideo_BB_06	582058	2800463	17	25.3184798	-80.184721	11
BISC	BB	20 transect	—	BISC_CoralVideo_BB_07	582074	2800469	17	25.3185331	-80.1845617	11
BISC	BB	20 transect	—	BISC_CoralVideo_BB_08	582103	2800473	17	25.3185676	-80.1842734	14
BISC	BB	20 transect	—	BISC_CoralVideo_BB_09	582101	2800378	17	25.3177099	-80.184299	19
BISC	BB	20 transect	—	BISC_CoralVideo_BB_10	582117	2800467	17	25.3185127	-80.1841346	17
BISC	BB	20 transect	—	BISC_CoralVideo_BB_11	582094	2800476	17	25.3185952	-80.1843626	10
BISC	BB	20 transect	—	BISC_CoralVideo_BB_12	582097	2800425	17	25.3181345	-80.1843359	20
BISC	BB	20 transect	—	BISC_CoralVideo_BB_13	582080	2800429	17	25.3181716	-80.1845045	21
BISC	BB	20 transect	—	BISC_CoralVideo_BB_14	582055	2800397	17	25.317884	-80.1847548	19
BISC	BB	20 transect	—	BISC_CoralVideo_BB_15	582041	2800414	17	25.3180383	-80.1848929	10
BISC	BB	20 transect	—	BISC_CoralVideo_BB_16	582031	2800416	17	25.3180569	-80.1849921	8
BISC	BB	20 transect	—	BISC_CoralVideo_BB_17	582081	2800389	17	25.3178103	-80.184497	13
BISC	BB	20 transect	—	BISC_CoralVideo_BB_18	582081	2800377	17	25.317702	-80.1844977	15
BISC	BB	20 transect	—	BISC_CoralVideo_BB_19	582125	2800485	17	25.3186748	-80.1840541	18
BISC	BB	20 transect	—	BISC_CoralVideo_BB_20	582157	2800485	17	25.318673	-80.1837362	11
BUIS	SFR	20 transect	—	BUIS_CoralVideo_SFR_01	329357	1967172	20	17.7853668	-64.6098188	40
BUIS	SFR	20 transect	—	BUIS_CoralVideo_SFR_02	329419	1967153	20	17.7851999	-64.6092325	44

Park	SITE	Type	Extensive sub-site Grouping	LocationID	UTM X	UTM Y	UTM Zone	Latitude	Longitude	Depth
BUIS	SFR	20 transect	—	BUIS_CoralVideo_SFR_03	329429	1967153	20	17.7852007	-64.6091382	43
BUIS	SFR	20 transect	—	BUIS_CoralVideo_SFR_04	329432	1967142	20	17.7851015	-64.609109	40
BUIS	SFR	20 transect	—	BUIS_CoralVideo_SFR_05	329454	1967188	20	17.7855189	-64.6089052	42
BUIS	SFR	20 transect	—	BUIS_CoralVideo_SFR_06	329446	1967117	20	17.7848767	-64.6089749	38
BUIS	SFR	20 transect	—	BUIS_CoralVideo_SFR_07	329428	1967103	20	17.7847489	-64.6091436	41
BUIS	SFR	20 transect	—	BUIS_CoralVideo_SFR_08	329352	1967071	20	17.7844538	-64.6098577	47
BUIS	SFR	20 transect	—	BUIS_CoralVideo_SFR_09	329309	1967074	20	17.7844776	-64.6102635	47
BUIS	SFR	20 transect	—	BUIS_CoralVideo_SFR_10	329314	1967054	20	17.7842973	-64.6102147	46
BUIS	SFR	20 transect	—	BUIS_CoralVideo_SFR_11	329284	1967033	20	17.7841052	-64.610496	45
BUIS	SFR	20 transect	—	BUIS_CoralVideo_SFR_12	329289	1967018	20	17.7839701	-64.6104476	47
BUIS	SFR	20 transect	—	BUIS_CoralVideo_SFR_13	329330	1967025	20	17.7840365	-64.6100615	46
BUIS	SFR	20 transect	—	BUIS_CoralVideo_SFR_14	329338	1967027	20	17.7840552	-64.6099862	46
BUIS	SFR	20 transect	—	BUIS_CoralVideo_SFR_15	329290	1967092	20	17.7846388	-64.6104442	44
BUIS	SFR	20 transect	—	BUIS_CoralVideo_SFR_16	329338	1967049	20	17.784254	-64.609988	48
BUIS	SFR	20 transect	—	BUIS_CoralVideo_SFR_17	329391	1967048	20	17.784249	-64.6094881	43
BUIS	SFR	20 transect	—	BUIS_CoralVideo_SFR_18	329447	1967023	20	17.7840275	-64.6089579	41
BUIS	SFR	20 transect	—	BUIS_CoralVideo_SFR_19	329481	1967033	20	17.7841205	-64.608638	40
BUIS	SFR	20 transect	—	BUIS_CoralVideo_SFR_20	329480	1967089	20	17.7846264	-64.608652	40
BUIS	WSG	20 transect	—	BUIS_CoralVideo_WSG_01	326563	1968791	20	17.7997762	-64.6363024	37
BUIS	WSG	20 transect	—	BUIS_CoralVideo_WSG_02	326546	1968780	20	17.7996754	-64.6364618	33
BUIS	WSG	20 transect	—	BUIS_CoralVideo_WSG_03	326541	1968788	20	17.7997473	-64.6365096	34
BUIS	WSG	20 transect	—	BUIS_CoralVideo_WSG_04	326527	1968755	20	17.7994481	-64.636639	33

Park	SITE	Type	Extensive sub-site Grouping	LocationID	UTM X	UTM Y	UTM Zone	Latitude	Longitude	Depth
BUIS	WSG	20 transect	—	BUIS_CoralVideo_WSG_05	326505	1968752	20	17.7994192	-64.6368462	34
BUIS	WSG	20 transect	—	BUIS_CoralVideo_WSG_06	326561	1968741	20	17.7993243	-64.6363171	35
BUIS	WSG	20 transect	—	BUIS_CoralVideo_WSG_07	326605	1968748	20	17.799391	-64.6359027	27
BUIS	WSG	20 transect	—	BUIS_CoralVideo_WSG_08	326624	1968737	20	17.7992931	-64.6357226	29
BUIS	WSG	20 transect	—	BUIS_CoralVideo_WSG_09	326630	1968765	20	17.7995465	-64.6356683	28
BUIS	WSG	20 transect	—	BUIS_CoralVideo_WSG_10	326655	1968745	20	17.7993678	-64.6354309	27
BUIS	WSG	20 transect	—	BUIS_CoralVideo_WSG_11	326649	1968790	20	17.7997739	-64.6354912	33
BUIS	WSG	20 transect	—	BUIS_CoralVideo_WSG_12	326637	1968806	20	17.7999175	-64.6356057	34
BUIS	WSG	20 transect	—	BUIS_CoralVideo_WSG_13	326620	1968831	20	17.8001421	-64.6357681	32
BUIS	WSG	20 transect	—	BUIS_CoralVideo_WSG_14	326604	1968820	20	17.8000414	-64.6359181	32
BUIS	WSG	20 transect	—	BUIS_CoralVideo_WSG_15	326582	1968817	20	17.8000126	-64.6361253	32
BUIS	WSG	20 transect	—	BUIS_CoralVideo_WSG_16	326568	1968819	20	17.8000295	-64.6362575	34
BUIS	WSG	20 transect	—	BUIS_CoralVideo_WSG_17	326599	1968792	20	17.799788	-64.6359629	33
BUIS	WSG	20 transect	—	BUIS_CoralVideo_WSG_18	326596	1968778	20	17.7996613	-64.6359901	31
BUIS	WSG	20 transect	—	BUIS_CoralVideo_WSG_19	326603	1968698	20	17.7989391	-64.6359174	29
BUIS	WSG	20 transect	—	BUIS_CoralVideo_WSG_20	326645	1968690	20	17.7988701	-64.6355207	29
DRTO	BK	20 transect	—	DRTO_CoralVideo_BK_01	310664	2723223	17	24.6115447	-82.8702348	50
DRTO	BK	20 transect	—	DRTO_CoralVideo_BK_02	310640	2723244	17	24.6117313	-82.8704746	33
DRTO	BK	20 transect	—	DRTO_CoralVideo_BK_03	310622	2723219	17	24.6115035	-82.870649	33
DRTO	BK	20 transect	—	DRTO_CoralVideo_BK_04	310615	2723225	17	24.6115568	-82.8707189	31
DRTO	BK	20 transect	—	DRTO_CoralVideo_BK_05	310642	2723195	17	24.6112893	-82.8704483	41
DRTO	BK	20 transect	—	DRTO_CoralVideo_BK_06	310580	2723179	17	24.6111372	-82.8710583	32

Park	SITE	Type	Extensive sub-site Grouping	LocationID	UTM X	UTM Y	UTM Zone	Latitude	Longitude	Depth
DRTO	BK	20 transect	—	DRTO_CoralVideo_BK_07	310580	2723163	17	24.6109928	-82.8710562	32
DRTO	BK	20 transect	—	DRTO_CoralVideo_BK_08	310600	2723137	17	24.6107606	-82.8708552	34
DRTO	BK	20 transect	—	DRTO_CoralVideo_BK_09	310610	2723117	17	24.6105813	-82.8707538	41
DRTO	BK	20 transect	—	DRTO_CoralVideo_BK_10	310594	2723080	17	24.6102453	-82.8709068	40
DRTO	BK	20 transect	—	DRTO_CoralVideo_BK_11	310551	2723071	17	24.6101588	-82.8713301	31
DRTO	BK	20 transect	—	DRTO_CoralVideo_BK_12	310540	2723093	17	24.610356	-82.8714417	27
DRTO	BK	20 transect	—	DRTO_CoralVideo_BK_13	310560	2723102	17	24.6104397	-82.8712454	30
DRTO	BK	20 transect	—	DRTO_CoralVideo_BK_14	310665	2723261	17	24.6118879	-82.8702301	42
DRTO	BK	20 transect	—	DRTO_CoralVideo_BK_15	310676	2723290	17	24.612151	-82.8701253	41
DRTO	BK	20 transect	—	DRTO_CoralVideo_BK_16	310671	2723282	17	24.6120782	-82.8701736	41
DRTO	BK	20 transect	—	DRTO_CoralVideo_BK_17	310658	2723268	17	24.6119502	-82.8703001	39
DRTO	BK	20 transect	—	DRTO_CoralVideo_BK_18	310648	2723287	17	24.6121205	-82.8704014	34
DRTO	BK	20 transect	—	DRTO_CoralVideo_BK_19	310586	2723087	17	24.6103075	-82.8709867	35
DRTO	BK	20 transect	—	DRTO_CoralVideo_BK_20	310626	2723292	17	24.6121629	-82.8706193	32
DRTO	I-05b	4 transect	InsideRNA, LoggerheadForest	DRTO_Extensive_I-05b_01	304993	2729092	17	24.6638141	-82.9270404	57
DRTO	I-05b	4 transect	InsideRNA, LoggerheadForest	DRTO_Extensive_I-05b_02	304993	2729092	17	24.6638141	-82.9270404	57
DRTO	I-05b	4 transect	InsideRNA, LoggerheadForest	DRTO_Extensive_I-05b_03	304993	2729092	17	24.6638141	-82.9270404	57
DRTO	I-05b	4 transect	InsideRNA, LoggerheadForest	DRTO_Extensive_I-05b_04	304993	2729092	17	24.6638141	-82.9270404	57
DRTO	I-26	4 transect	InsideRNA	DRTO_Extensive_I-26_01	308343	2731286	17	24.6840392	-82.8942496	15
DRTO	I-26	4 transect	InsideRNA	DRTO_Extensive_I-26_02	308343	2731286	17	24.6840392	-82.8942496	15

Park	SITE	Type	Extensive sub-site Grouping	LocationID	UTM X	UTM Y	UTM Zone	Latitude	Longitude	Depth
DRTO	I-26	4 transect	InsideRNA	DRTO_Extensive_I-26_03	308343	2731286	17	24.6840392	-82.8942496	15
DRTO	I-26	4 transect	InsideRNA	DRTO_Extensive_I-26_04	308343	2731286	17	24.6840392	-82.8942496	15
DRTO	I-36b	4 transect	InsideRNA	DRTO_Extensive_I-36b_01	311540	2733923	17	24.7082378	-82.8630192	40
DRTO	I-36b	4 transect	InsideRNA	DRTO_Extensive_I-36b_02	311540	2733923	17	24.7082378	-82.8630192	40
DRTO	I-36b	4 transect	InsideRNA	DRTO_Extensive_I-36b_03	311540	2733923	17	24.7082378	-82.8630192	41
DRTO	I-36b	4 transect	InsideRNA	DRTO_Extensive_I-36b_04	311540	2733923	17	24.7082378	-82.8630192	40
DRTO	I-38	4 transect	InsideRNA	DRTO_Extensive_I-38_01	304943	2728332	17	24.6569477	-82.9274289	40
DRTO	I-38	4 transect	InsideRNA	DRTO_Extensive_I-38_02	304943	2728332	17	24.6569477	-82.9274289	40
DRTO	I-38	4 transect	InsideRNA	DRTO_Extensive_I-38_03	304943	2728332	17	24.6569477	-82.9274289	41
DRTO	I-38	4 transect	InsideRNA	DRTO_Extensive_I-38_04	304943	2728332	17	24.6569477	-82.9274289	40
DRTO	I-41	4 transect	InsideRNA	DRTO_Extensive_I-41_01	304584	2722537	17	24.6045943	-82.9301708	36
DRTO	I-41	4 transect	InsideRNA	DRTO_Extensive_I-41_02	304584	2722537	17	24.6045943	-82.9301708	36
DRTO	I-41	4 transect	InsideRNA	DRTO_Extensive_I-41_03	304584	2722537	17	24.6045943	-82.9301708	45
DRTO	I-41	4 transect	InsideRNA	DRTO_Extensive_I-41_04	304584	2722537	17	24.6045943	-82.9301708	36
DRTO	I-44	4 transect	InsideRNA	DRTO_Extensive_I-44_01	309468	2731591	17	24.6869322	-82.8831767	32
DRTO	I-44	4 transect	InsideRNA	DRTO_Extensive_I-44_02	309468	2731591	17	24.6869322	-82.8831767	33
DRTO	I-44	4 transect	InsideRNA	DRTO_Extensive_I-44_03	309468	2731591	17	24.6869322	-82.8831767	34
DRTO	I-44	4 transect	InsideRNA	DRTO_Extensive_I-44_04	309468	2731591	17	24.6869322	-82.8831767	33
DRTO	I-50	4 transect	InsideRNA, LoggerheadForest	DRTO_Extensive_I-50_01	304951	2728932	17	24.6623646	-82.9274331	54
DRTO	I-50	4 transect	InsideRNA, LoggerheadForest	DRTO_Extensive_I-50_02	304951	2728932	17	24.6623646	-82.9274331	51

Park	SITE	Type	Extensive sub-site Grouping	LocationID	UTM X	UTM Y	UTM Zone	Latitude	Longitude	Depth
DRTO	I-50	4 transect	InsideRNA, LoggerheadForest	DRTO_Extensive_I-50_03	304951	2728932	17	24.6623646	-82.9274331	50
DRTO	I-50	4 transect	InsideRNA, LoggerheadForest	DRTO_Extensive_I-50_04	304951	2728932	17	24.6623646	-82.9274331	51
DRTO	LH01	4 transect	LoggerheadForest	DRTO_Extensive_LH01_01	305120	2729570	17	24.668144	-82.925855	53
DRTO	LH01	4 transect	LoggerheadForest	DRTO_Extensive_LH01_02	305120	2729570	17	24.668144	-82.925855	55
DRTO	LH01	4 transect	LoggerheadForest	DRTO_Extensive_LH01_03	305120	2729570	17	24.668144	-82.925855	55
DRTO	LH01	4 transect	LoggerheadForest	DRTO_Extensive_LH01_04	305120	2729570	17	24.668144	-82.925855	55
DRTO	LH02	4 transect	LoggerheadForest	DRTO_Extensive_LH02_01	304592	2729017	17	24.663086	-82.930989	60
DRTO	LH02	4 transect	LoggerheadForest	DRTO_Extensive_LH02_02	304592	2729017	17	24.663086	-82.930989	55
DRTO	LH02	4 transect	LoggerheadForest	DRTO_Extensive_LH02_03	304592	2729017	17	24.663086	-82.930989	55
DRTO	LH02	4 transect	LoggerheadForest	DRTO_Extensive_LH02_04	304592	2729017	17	24.663086	-82.930989	54
DRTO	LH03	4 transect	LoggerheadForest	DRTO_Extensive_LH03_01	304267	2728661	17	24.659835	-82.934149	53
DRTO	LH03	4 transect	LoggerheadForest	DRTO_Extensive_LH03_02	304267	2728661	17	24.659835	-82.934149	53
DRTO	LH03	4 transect	LoggerheadForest	DRTO_Extensive_LH03_03	304267	2728661	17	24.659835	-82.934149	53
DRTO	LH03	4 transect	LoggerheadForest	DRTO_Extensive_LH03_04	304267	2728661	17	24.659835	-82.934149	53
DRTO	O-42	4 transect	OutsideRNA	DRTO_Extensive_O-42_01	301065	2719704	17	24.5785732	-82.9645137	60
DRTO	O-42	4 transect	OutsideRNA	DRTO_Extensive_O-42_02	301065	2719704	17	24.5785732	-82.9645137	61
DRTO	O-42	4 transect	OutsideRNA	DRTO_Extensive_O-42_03	301065	2719704	17	24.5785732	-82.9645137	62
DRTO	O-42	4 transect	OutsideRNA	DRTO_Extensive_O-42_04	301065	2719704	17	24.5785732	-82.9645137	61
DRTO	O-56	4 transect	OutsideRNA	DRTO_Extensive_O-56_01	317719	2735279	17	24.7212243	-82.8021372	41
DRTO	O-56	4 transect	OutsideRNA	DRTO_Extensive_O-56_02	317719	2735279	17	24.7212243	-82.8021372	46
DRTO	O-56	4 transect	OutsideRNA	DRTO_Extensive_O-56_03	317719	2735279	17	24.7212243	-82.8021372	46

Park	SITE	Type	Extensive sub-site Grouping	LocationID	UTM X	UTM Y	UTM Zone	Latitude	Longitude	Depth
DRTO	O-56	4 transect	OutsideRNA	DRTO_Extensive_O-56_04	317719	2735279	17	24.7212243	-82.8021372	41
DRTO	O-72	4 transect	OutsideRNA	DRTO_Extensive_O-72_01	318920	2732422	17	24.6955763	-82.7898992	11
DRTO	O-72	4 transect	OutsideRNA	DRTO_Extensive_O-72_02	318920	2732422	17	24.6955763	-82.7898992	12
DRTO	O-72	4 transect	OutsideRNA	DRTO_Extensive_O-72_03	318920	2732422	17	24.6955763	-82.7898992	11
DRTO	O-72	4 transect	OutsideRNA	DRTO_Extensive_O-72_04	318920	2732422	17	24.6955763	-82.7898992	11
DRTO	O-82	4 transect	OutsideRNA	DRTO_Extensive_O-82_01	317000	2735409	17	24.7223122	-82.8092599	42
DRTO	O-82	4 transect	OutsideRNA	DRTO_Extensive_O-82_02	317000	2735409	17	24.7223122	-82.8092599	42
DRTO	O-82	4 transect	OutsideRNA	DRTO_Extensive_O-82_03	317000	2735409	17	24.7223122	-82.8092599	42
DRTO	O-82	4 transect	OutsideRNA	DRTO_Extensive_O-82_04	317000	2735409	17	24.7223122	-82.8092599	42
DRTO	O-84	4 transect	OutsideRNA	DRTO_Extensive_O-84_01	304978	2719131	17	24.5739	-82.9258104	39
DRTO	O-84	4 transect	OutsideRNA	DRTO_Extensive_O-84_02	304978	2719131	17	24.5739	-82.9258104	39
DRTO	O-84	4 transect	OutsideRNA	DRTO_Extensive_O-84_03	304978	2719131	17	24.5739	-82.9258104	39
DRTO	O-84	4 transect	OutsideRNA	DRTO_Extensive_O-84_04	304978	2719131	17	24.5739	-82.9258104	39
DRTO	O-94	4 transect	OutsideRNA	DRTO_Extensive_O-94_01	317239	2735325	17	24.7215824	-82.8068869	38
DRTO	O-94	4 transect	OutsideRNA	DRTO_Extensive_O-94_02	317239	2735325	17	24.7215824	-82.8068869	38
DRTO	O-94	4 transect	OutsideRNA	DRTO_Extensive_O-94_03	317239	2735325	17	24.7215824	-82.8068869	38
DRTO	O-94	4 transect	OutsideRNA	DRTO_Extensive_O-94_04	317239	2735325	17	24.7215824	-82.8068869	37
DRTO	SV01	4 transect	SantasVillage	DRTO_Extensive_SV01_01	316416	2735667	17	24.724568	-82.815068	57
DRTO	SV01	4 transect	SantasVillage	DRTO_Extensive_SV01_02	316416	2735667	17	24.724568	-82.815068	58
DRTO	SV01	4 transect	SantasVillage	DRTO_Extensive_SV01_03	316416	2735667	17	24.724568	-82.815068	56
DRTO	SV01	4 transect	SantasVillage	DRTO_Extensive_SV01_04	316416	2735667	17	24.724568	-82.815068	57
DRTO	SV02	4 transect	SantasVillage	DRTO_Extensive_SV02_01	315878	2735527	17	24.723242	-82.820363	53

Park	SITE	Type	Extensive sub-site Grouping	LocationID	UTM X	UTM Y	UTM Zone	Latitude	Longitude	Depth
DRTO	SV02	4 transect	SantasVillage	DRTO_Extensive_SV02_02	315878	2735527	17	24.723242	-82.820363	54
DRTO	SV02	4 transect	SantasVillage	DRTO_Extensive_SV02_03	315878	2735527	17	24.723242	-82.820363	54
DRTO	SV02	4 transect	SantasVillage	DRTO_Extensive_SV02_04	315878	2735527	17	24.723242	-82.820363	54
DRTO	SV03	4 transect	SantasVillage	DRTO_Extensive_SV03_01	315072	2735443	17	24.722388	-82.828323	53
DRTO	SV03	4 transect	SantasVillage	DRTO_Extensive_SV03_02	315072	2735443	17	24.722388	-82.828323	54
DRTO	SV03	4 transect	SantasVillage	DRTO_Extensive_SV03_03	315072	2735443	17	24.722388	-82.828323	53
DRTO	SV03	4 transect	SantasVillage	DRTO_Extensive_SV03_04	315072	2735443	17	24.722388	-82.828323	54
SARI	SR	20 transect	—	SARI_CoralVideo_SR_01	313366	1967302	20	17.78525	-64.760633	37
SARI	SR	20 transect	—	SARI_CoralVideo_SR_02	313360	1967277	20	17.785017	-64.760683	31
SARI	SR	20 transect	—	SARI_CoralVideo_SR_03	313339	1967277	20	17.785017	-64.760883	32
SARI	SR	20 transect	—	SARI_CoralVideo_SR_04	313311	1967279	20	17.785033	-64.76115	35
SARI	SR	20 transect	—	SARI_CoralVideo_SR_05	313293	1967292	20	17.78515	-64.761317	41
SARI	SR	20 transect	—	SARI_CoralVideo_SR_06	313313	1967312	20	17.785333	-64.761133	46
SARI	SR	20 transect	—	SARI_CoralVideo_SR_07	313270	1967252	20	17.784783	-64.761533	34
SARI	SR	20 transect	—	SARI_CoralVideo_SR_08	313249	1967255	20	17.784817	-64.761733	36
SARI	SR	20 transect	—	SARI_CoralVIdeo_SR_09	313292	1967316	20	17.785367	-64.761333	55
SARI	SR	20 transect	—	SARI_CoralVideo_SR_10	313382	1967335	20	17.78555	-64.760483	51
SARI	SR	20 transect	—	SARI_CoralVideo_SR_11	313519	1967282	20	17.785083	-64.759183	83
SARI	SR	20 transect	—	SARI_CoralVideo_SR_12	313493	1967297	20	17.785217	-64.759433	60
SARI	SR	20 transect	—	SARI_CoralVideo_SR_13	313686	1967124	20	17.783667	-64.7576	58
SARI	SR	20 transect	—	SARI_CoralVideo_SR_14	313249	1967290	20	17.785133	-64.761733	51
SARI	SR	20 transect	—	SARI_CoralVideo_SR_15	313539	1967267	20	17.78495	-64.759	92

Park	SITE	Type	Extensive sub-site Grouping	LocationID	UTM X	UTM Y	UTM Zone	Latitude	Longitude	Depth
SARI	SR	20 transect	—	SARI_CoralVIdeo_SR_16	313316	1967286	20	17.7851	-64.7611	38
SARI	SR	20 transect	—	SARI_CoralVideo_SR_17	313602	1967455	20	17.78665	-64.758417	94
SARI	SR	20 transect	—	SARI_CoralVideo_SR_18	313676	1967403	20	17.786183	-64.757717	37
SARI	SR	20 transect	—	SARI_CoralVideo_SR_19	313643	1967429	20	17.786417	-64.758033	69
SARI	SR	20 transect	—	SARI_CoralVideo_SR_20	313622	1967449	20	17.7866	-64.758233	62
VIIS	HA	20 transect	—	VIIS_CoralVideo_HA_01	322562	2029953	20	18.3520358	-64.6792857	34
VIIS	HA	20 transect	—	VIIS_CoralVideo_HA_02	322541	2029924	20	18.351772	-64.6794818	24
VIIS	HA	20 transect	—	VIIS_CoralVideo_HA_03	322523	2029945	20	18.3519603	-64.679654	20
VIIS	HA	20 transect	—	VIIS_CoralVideo_HA_04	322503	2029965	20	18.3521393	-64.6798449	16
VIIS	HA	20 transect	—	VIIS_CoralVideo_HA_05	322544	2029984	20	18.3523144	-64.6794587	28
VIIS	HA	20 transect	—	VIIS_CoralVideo_HA_06	322500	2029916	20	18.3516964	-64.679869	12
VIIS	HA	20 transect	—	VIIS_CoralVideo_HA_07	322510	2029906	20	18.3516068	-64.6797736	13
VIIS	HA	20 transect	—	VIIS_CoralVideo_HA_08	322510	2029896	20	18.3515165	-64.6797727	13
VIIS	HA	20 transect	—	VIIS_CoralVideo_HA_09	322519	2029885	20	18.3514179	-64.6796866	15
VIIS	HA	20 transect	—	VIIS_CoralVideo_HA_10	322539	2029884	20	18.3514105	-64.6794973	17
VIIS	HA	20 transect	—	VIIS_CoralVideo_HA_11	322558	2029874	20	18.3513217	-64.6793166	30
VIIS	HA	20 transect	—	VIIS_CoralVideo_HA_12	322557	2029833	20	18.3509513	-64.6793225	29
VIIS	HA	20 transect	—	VIIS_CoralVideo_HA_13	322546	2029834	20	18.3509594	-64.6794267	19
VIIS	HA	20 transect	—	VIIS_CoralVideo_HA_14	322546	2029815	20	18.3507877	-64.679425	20
VIIS	HA	20 transect	—	VIIS_CoralVideo_HA_15	322556	2029814	20	18.3507795	-64.6793303	25
VIIS	HA	20 transect	—	VIIS_CoralVideo_HA_16	322535	2029805	20	18.3506965	-64.6795282	15
VIIS	HA	20 transect	—	VIIS_CoralVideo_HA_17	322516	2029836	20	18.3509749	-64.6797107	12

Park	SITE	Type	Extensive sub-site Grouping	LocationID	UTM X	UTM Y	UTM Zone	Latitude	Longitude	Depth
VIIS	HA	20 transect	—	VIIS_CoralVideo_HA_18	322565	2029783	20	18.3505002	-64.6792425	30
VIIS	HA	20 transect	—	VIIS_CoralVideo_HA_19	322544	2029754	20	18.3502365	-64.6794386	17
VIIS	HA	20 transect	—	VIIS_CoralVideo_HA_20	322533	2029765	20	18.3503349	-64.6795436	13
VIIS	MB	20 transect	—	VIIS_CoralVideo_MB_01	321999	2030172	20	18.3539673	-64.6846315	32
VIIS	MB	20 transect	—	VIIS_CoralVideo_MB_02	322002	2030159	20	18.3538501	-64.6846019	25
VIIS	MB	20 transect	—	VIIS_CoralVideo_MB_03	321978	2030161	20	18.3538662	-64.6848292	18
VIIS	MB	20 transect	—	VIIS_CoralVideo_MB_04	321985	2030133	20	18.3536138	-64.6847605	15
VIIS	MB	20 transect	—	VIIS_CoralVideo_MB_05	322005	2030130	20	18.3535884	-64.684571	18
VIIS	MB	20 transect	—	VIIS_CoralVideo_MB_06	322010	2030116	20	18.3534623	-64.6845225	17
VIIS	MB	20 transect	—	VIIS_CoralVideo_MB_07	322015	2030110	20	18.3534085	-64.6844746	15
VIIS	MB	20 transect	—	VIIS_CoralVideo_MB_08	322033	2030119	20	18.3534913	-64.6843051	21
VIIS	MB	20 transect	—	VIIS_CoralVideo_MB_09	322059	2030112	20	18.3534303	-64.6840585	23
VIIS	MB	20 transect	—	VIIS_CoralVideo_MB_10	322076	2030099	20	18.3533142	-64.6838966	25
VIIS	MB	20 transect	—	VIIS_CoralVideo_MB_11	322083	2030092	20	18.3532516	-64.6838297	22
VIIS	MB	20 transect	—	VIIS_CoralVideo_MB_12	322092	2030085	20	18.3531891	-64.6837439	23
VIIS	MB	20 transect	—	VIIS_CoralVideo_MB_13	322098	2030092	20	18.3532528	-64.6836878	24
VIIS	MB	20 transect	—	VIIS_CoralVideo_MB_14	322106	2030087	20	18.3532083	-64.6836117	27
VIIS	MB	20 transect	—	VIIS_CoralVideo_MB_15	322103	2030064	20	18.3530003	-64.683638	21
VIIS	MB	20 transect	—	VIIS_CoralVideo_MB_16	322089	2030063	20	18.3529901	-64.6837704	15
VIIS	MB	20 transect	—	VIIS_CoralVideo_MB_17	322081	2030069	20	18.3530436	-64.6838466	15
VIIS	MB	20 transect	—	VIIS_CoralVideo_MB_18	322071	2030075	20	18.353097	-64.6839418	17
VIIS	MB	20 transect	—	VIIS_CoralVideo_MB_19	322055	2030089	20	18.3532221	-64.6840944	19

Park	SITE	Type	Extensive sub-site Grouping	LocationID	UTM X	UTM Y	UTM Zone	Latitude	Longitude	Depth
VIIS	MB	20 transect	—	VIIS_CoralVideo_MB_20	322055	2030089	20	18.3532221	-64.6840944	21
VIIS	NF	20 transect	—	VIIS_CoralVideo_NF_01	323786	2029593	20	18.3488851	-64.6676741	34
VIIS	NF	20 transect	—	VIIS_CoralVideo_NF_02	323831	2029555	20	18.3485455	-64.667245	33
VIIS	NF	20 transect	—	VIIS_CoralVideo_NF_03	323843	2029524	20	18.3482665	-64.6671288	28
VIIS	NF	20 transect	—	VIIS_CoralVideo_NF_04	323855	2029510	20	18.348141	-64.6670141	27
VIIS	NF	20 transect	—	VIIS_CoralVideo_NF_05	323819	2029530	20	18.3483187	-64.6673564	26
VIIS	NF	20 transect	—	VIIS_CoralVideo_NF_06	323721	2029651	20	18.3494037	-64.6682941	27
VIIS	NF	20 transect	—	VIIS_CoralVideo_NF_07	323799	2029549	20	18.3484887	-64.6675473	25
VIIS	NF	20 transect	—	VIIS_CoralVideo_NF_08	323721	2029643	20	18.3493315	-64.6682934	25
VIIS	NF	20 transect	—	VIIS_CoralVideo_NF_09	323717	2029625	20	18.3491685	-64.6683297	21
VIIS	NF	20 transect	—	VIIS_CoralVideo_NF_10	323710	2029604	20	18.3489782	-64.6683941	17
VIIS	NF	20 transect	—	VIIS_CoralVideo_NF_11	323723	2029591	20	18.3488618	-64.6682699	17
VIIS	NF	20 transect	—	VIIS_CoralVideo_NF_12	323745	2029579	20	18.3487552	-64.6680608	20
VIIS	NF	20 transect	—	VIIS_CoralVideo_NF_13	323771	2029572	20	18.3486942	-64.6678142	24
VIIS	NF	20 transect	—	VIIS_CoralVideo_NF_14	323778	2029567	20	18.3486496	-64.6677475	24
VIIS	NF	20 transect	—	VIIS_CoralVideo_NF_15	323805	2029537	20	18.3483808	-64.6674895	23
VIIS	NF	20 transect	—	VIIS_CoralVideo_NF_16	323826	2029529	20	18.3483102	-64.6672901	26
VIIS	NF	20 transect	—	VIIS_CoralVideo_NF_17	323846	2029508	20	18.3481222	-64.667099	27
VIIS	NF	20 transect	—	VIIS_CoralVideo_NF_18	323831	2029534	20	18.3483558	-64.6672432	29
VIIS	NF	20 transect	—	VIIS_CoralVideo_NF_19	323849	2029534	20	18.3483573	-64.6670729	31
VIIS	NF	20 transect	—	VIIS_CoralVideo_NF_20	323767	2029602	20	18.3489649	-64.6678546	27
VIIS	TK	20 transect	—	VIIS_CoralVideo_TK_01	317890	2025274	20	18.3093699	-64.7230685	45

Park	SITE	Type	Extensive sub-site Grouping	LocationID	UTM X	UTM Y	UTM Zone	Latitude	Longitude	Depth
VIIS	TK	20 transect	—	VIIS_CoralVideo_TK_02	317879	2025265	20	18.3092877	-64.7231717	47
VIIS	TK	20 transect	—	VIIS_CoralVideo_TK_03	317901	2025283	20	18.3094522	-64.7229652	43
VIIS	TK	20 transect	—	VIIS_CoralVideo_TK_04	317911	2025273	20	18.3093627	-64.7228698	43
VIIS	TK	20 transect	—	VIIS_CoralVideo_TK_05	317895	2025214	20	18.3088283	-64.7230158	52
VIIS	TK	20 transect	—	VIIS_CoralVideo_TK_06	317907	2025233	20	18.309001	-64.722904	45
VIIS	TK	20 transect	—	VIIS_CoralVideo_TK_07	317907	2025223	20	18.3089107	-64.7229031	50
VIIS	TK	20 transect	—	VIIS_CoralVideo_TK_08	317928	2025241	20	18.3090751	-64.7227061	44
VIIS	TK	20 transect	—	VIIS_CoralVideo_TK_09	317946	2025239	20	18.3090585	-64.7225357	38
VIIS	TK	20 transect	—	VIIS_CoralVideo_TK_10	317957	2025229	20	18.3089691	-64.7224307	35
VIIS	TK	20 transect	—	VIIS_CoralVideo_TK_11	317951	2025269	20	18.30933	-64.7224911	38
VIIS	TK	20 transect	—	VIIS_CoralVideo_TK_12	317942	2025282	20	18.3094467	-64.7225773	40
VIIS	TK	20 transect	—	VIIS_CoralVideo_TK_13	317989	2025276	20	18.3093965	-64.7221323	27
VIIS	TK	20 transect	—	VIIS_CoralVideo_TK_14	318003	2025296	20	18.3095783	-64.7220016	26
VIIS	TK	20 transect	—	VIIS_CoralVideo_TK_15	318014	2025304	20	18.3096516	-64.7218983	25
VIIS	TK	20 transect	—	VIIS_CoralVideo_TK_16	318007	2025346	20	18.3100304	-64.7219683	30
VIIS	TK	20 transect	—	VIIS_CoralVideo_TK_17	317983	2025317	20	18.3097664	-64.7221927	36
VIIS	TK	20 transect	—	VIIS_CoralVideo_TK_18	317868	2025238	20	18.3090428	-64.7232733	57
VIIS	TK	20 transect	—	VIIS_CoralVideo_TK_19	317894	2025195	20	18.3086566	-64.7230236	60
VIIS	TK	20 transect	—	VIIS_CoralVideo_TK_20	317899	2025145	20	18.3082053	-64.7229718	62
VIIS	YZ	20 transect	—	VIIS_CoralVideo_YZ_01	317579	2025761	20	18.313743	-64.7260537	42
VIIS	YZ	20 transect	—	VIIS_CoralVideo_YZ_02	317612	2025740	20	18.3135561	-64.7257397	43
VIIS	YZ	20 transect	—	VIIS_CoralVideo_YZ_03	317574	2025776	20	18.3138781	-64.7261023	45

Park	SITE	Type	Extensive sub-site Grouping	LocationID	UTM X	UTM Y	UTM Zone	Latitude	Longitude	Depth
VIIS	YZ	20 transect	—	VIIS_CoralVideo_YZ_04	317588	2025782	20	18.3139335	-64.7259704	41
VIIS	YZ	20 transect	—	VIIS_CoralVideo_YZ_05	317597	2025776	20	18.3138801	-64.7258848	38
VIIS	YZ	20 transect	—	VIIS_CoralVideo_YZ_06	317606	2025771	20	18.3138357	-64.7257992	42
VIIS	YZ	20 transect	—	VIIS_CoralVideo_YZ_07	317631	2025767	20	18.3138017	-64.7255624	39
VIIS	YZ	20 transect	—	VIIS_CoralVideo_YZ_08	317619	2025773	20	18.3138549	-64.7256764	42
VIIS	YZ	20 transect	—	VIIS_CoralVideo_YZ_09	317611	2025778	20	18.3138994	-64.7257525	41
VIIS	YZ	20 transect	—	VIIS_CoralVideo_YZ_10	317585	2025795	20	18.3140507	-64.726	41
VIIS	YZ	20 transect	—	VIIS_CoralVideo_YZ_11	317576	2025799	20	18.3140861	-64.7260855	41
VIIS	YZ	20 transect	—	VIIS_CoralVideo_YZ_12	317658	2025775	20	18.3138763	-64.7253077	42
VIIS	YZ	20 transect	—	VIIS_CoralVideo_YZ_13	317650	2025780	20	18.3139208	-64.7253838	40
VIIS	YZ	20 transect	—	VIIS_CoralVideo_YZ_14	317639	2025785	20	18.313965	-64.7254883	39
VIIS	YZ	20 transect	—	VIIS_CoralVideo_YZ_15	317564	2025776	20	18.3138773	-64.7261969	42
VIIS	YZ	20 transect	—	VIIS_CoralVideo_YZ_16	317564	2025779	20	18.3139044	-64.7261972	43
VIIS	YZ	20 transect	—	VIIS_CoralVideo_YZ_17	317546	2025787	20	18.3139751	-64.7263682	45
VIIS	YZ	20 transect	—	VIIS_CoralVideo_YZ_18	317531	2025809	20	18.3141726	-64.726512	44
VIIS	YZ	20 transect	—	VIIS_CoralVideo_YZ_19	317553	2025783	20	18.3139396	-64.7263016	42
VIIS	YZ	20 transect	—	VIIS_CoralVideo_YZ_20	317537	2025793	20	18.3140285	-64.7264538	43

Table H-46. Coordinates for start pins of SFCN coral reef monitoring transects and extensive sub-site center pins. Coordinates for discontinued sites are also provided. Depth is in feet. Discontinued Sites.

Park	SITE	Type	Extensive sub-site Grouping	LocationID	UTM X	UTM Y	UTM Zone	Latitude	Longitude	Depth
DRTO	BKN	20 transect	—	DRTO_CoralVideo_BKN_01	310808	2723507	17	24.614126	-82.8688511	49
DRTO	BKN	20 transect	—	DRTO_CoralVideo_BKN_02	310806	2723529	17	24.6143243	-82.8688738	39
DRTO	BKN	20 transect	—	DRTO_CoralVideo_BKN_03	310824	2723534	17	24.6143717	-82.8686968	42
DRTO	BKN	20 transect	—	DRTO_CoralVideo_BKN_04	310871	2723608	17	24.6150454	-82.8682426	38
DRTO	BKN	20 transect	—	DRTO_CoralVideo_BKN_05	310855	2723632	17	24.6152601	-82.8684038	34
DRTO	BKN	20 transect	—	DRTO_CoralVideo_BKN_06	310759	2723494	17	24.6140026	-82.8693332	34
DRTO	BKN	20 transect	—	DRTO_CoralVideo_BKN_07	310733	2723509	17	24.6141348	-82.8695919	33
DRTO	BKN	20 transect	—	DRTO_CoralVideo_BKN_08	310748	2723444	17	24.6135499	-82.8694351	35
DRTO	BKN	20 transect	—	DRTO_CoralVideo_BKN_09	310740	2723437	17	24.6134858	-82.8695131	35
DRTO	BKN	20 transect	—	DRTO_CoralVideo_BKN_10	310736	2723409	17	24.6132325	-82.8695489	40
DRTO	BKN	20 transect	—	DRTO_CoralVideo_BKN_11	310716	2723403	17	24.6131759	-82.8697456	35
DRTO	BKN	20 transect	—	DRTO_CoralVideo_BKN_12	310707	2723385	17	24.6130123	-82.869832	34
DRTO	BKN	20 transect	—	DRTO_CoralVideo_BKN_13	310718	2723367	17	24.6128512	-82.869721	43
DRTO	BKN	20 transect	—	DRTO_CoralVideo_BKN_14	310709	2723363	17	24.612814	-82.8698093	43
DRTO	BKN	20 transect	—	DRTO_CoralVideo_BKN_15	310694	2723365	17	24.6128302	-82.8699577	37
DRTO	BKN	20 transect	—	DRTO_CoralVideo_BKN_16	310691	2723339	17	24.6125951	-82.8699838	40
DRTO	BKN	20 transect	—	DRTO_CoralVideo_BKN_17	310687	2723308	17	24.6123148	-82.8700191	46
DRTO	BKN	20 transect	—	DRTO_CoralVideo_BKN_18	310682	2723299	17	24.612233	-82.8700673	48
DRTO	BKN	20 transect	—	DRTO_CoralVideo_BKN_19	310740	2723377	17	24.6129442	-82.8695051	53
DRTO	BKN	20 transect	—	DRTO_CoralVideo_BKN_20	310756	2723403	17	24.6131808	-82.8693506	57

Park	SITE	Type	Extensive sub-site Grouping	LocationID	UTM X	UTM Y	UTM Zone	Latitude	Longitude	Depth
DRTO	I-33	4 transect	InsideRNA	DRTO_Extensive_I-33_01	307123	2732743	17	24.6970382	-82.9065025	41
DRTO	I-33	4 transect	InsideRNA	DRTO_Extensive_I-33_02	307123	2732743	17	24.6970382	-82.9065025	41
DRTO	I-33	4 transect	InsideRNA	DRTO_Extensive_I-33_03	307123	2732743	17	24.6970382	-82.9065025	41
DRTO	I-33	4 transect	InsideRNA	DRTO_Extensive_I-33_04	307123	2732743	17	24.6970382	-82.9065025	41
DRTO	I-63	4 transect	InsideRNA	DRTO_Extensive_I-63_01	309658	2733828	17	24.7071482	-82.881603	41
DRTO	I-63	4 transect	InsideRNA	DRTO_Extensive_I-63_02	309658	2733828	17	24.7071482	-82.881603	40
DRTO	I-63	4 transect	InsideRNA	DRTO_Extensive_I-63_03	309658	2733828	17	24.7071482	-82.881603	41
DRTO	I-63	4 transect	InsideRNA	DRTO_Extensive_I-63_04	309658	2733828	17	24.7071482	-82.881603	41
DRTO	O-12b	4 transect	OutsideRNA	DRTO_Extensive_O-12b_01	314057	2733689	17	24.7064324	-82.8381166	11
DRTO	O-12b	4 transect	OutsideRNA	DRTO_Extensive_O-12b_02	314057	2733689	17	24.7064324	-82.8381166	11
DRTO	O-12b	4 transect	OutsideRNA	DRTO_Extensive_O-12b_03	314057	2733689	17	24.7064324	-82.8381166	11
DRTO	O-12b	4 transect	OutsideRNA	DRTO_Extensive_O-12b_04	314057	2733689	17	24.7064324	-82.8381166	11
DRTO	O-27	4 transect	OutsideRNA	DRTO_Extensive_O-27_01	312972	2733343	17	24.7031774	-82.8487917	11
DRTO	O-27	4 transect	OutsideRNA	DRTO_Extensive_O-27_02	312972	2733343	17	24.7031774	-82.8487917	11
DRTO	O-27	4 transect	OutsideRNA	DRTO_Extensive_O-27_03	312972	2733343	17	24.7031774	-82.8487917	11
DRTO	O-27	4 transect	OutsideRNA	DRTO_Extensive_O-27_04	312972	2733343	17	24.7031774	-82.8487917	11
DRTO	O-92	4 transect	OutsideRNA	DRTO_Extensive_O-92_01	313817	2733692	17	24.7064304	-82.8404885	15
DRTO	O-92	4 transect	OutsideRNA	DRTO_Extensive_O-92_02	313817	2733692	17	24.7064304	-82.8404885	15
DRTO	O-92	4 transect	OutsideRNA	DRTO_Extensive_O-92_03	313817	2733692	17	24.7064304	-82.8404885	15
DRTO	O-92	4 transect	OutsideRNA	DRTO_Extensive_O-92_04	313817	2733692	17	24.7064304	-82.8404885	15

Appendix I. Database description and definitions

Coral database

Database name: Coral_SFCN_GUID.mdb

Description: MS Access 2010 database that contains coral transect data including bleaching data. Also contains historical coral chain transect data, re-randomized transect pilot project data, training data, and qa/qc data.

Key Database Relationships

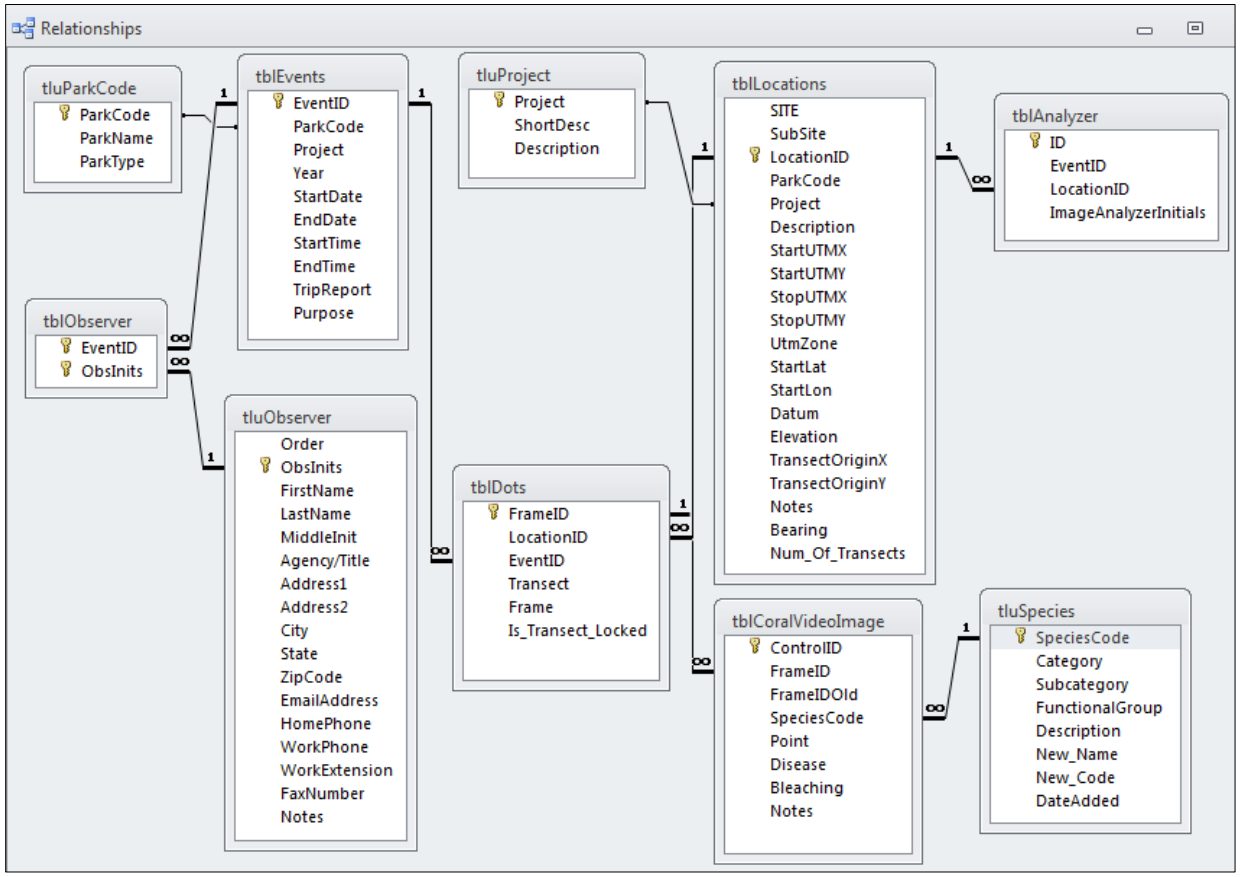


Figure I-1. Database relationships in Coral_SFCN_GUID.mdb.

Table I-1. tblAnalyzer—For each Location ID/Event ID combination provides the name of the individual who analyzed the dotted images and entered them into the database.

Field Name	Type	Size	Description
ID	Autonumber	4	Automatically generated unique ID
EventID	Text	255	Sampling event ID code
LocationID	Text	255	unique ID used to designate project and location
ImageAnalyzerInitials	Text	10	initials of the person (tluObserver) who viewed the dotted images and made the call on the contents

Table I-2. tblCoralVideoImage—Primary table that stores data such as the species detected and whether or not disease is present.

Field Name	Type	Size	Description
ControlID	Autonumber	16	Automatically generated unique ID
FrameID	Autonumber	16	Frame ID
FrameIDOld	Number	8	Old Frame ID
SpeciesCode	Text	8	Alphanumeric Species code
Point	Text	1	PointA-J
Disease	Yes/No	1	Disease present
Bleaching	Text	6	Bleaching level 1-5
Notes	Text	255	Notes

Table I-3. tblDots—Primary table that stores data about each individual frame.

Field Name	Type	Size	Description
FrameID	Autonumber	16	Automatically generated unique ID
LocationID	Text	255	Unique ID used to designate project and location
EventID	Text	255	Event including date
Transect	Number	8	Transect number
Frame	Number	8	Frame number
Is_Transect_Locked	Yes/No	1	Indicates whether or not the frame is locked from editing

Table I-4. tblEvents—Standardized table containing the starting and ending dates and times for period during which all the locations at a given site are monitored.

Field Name	Type	Size	Description
EventID	Text	255	Sampling event ID code
ParkCode	Text	50	Looks up Park code in tluparkcode
Project	Text	15	1-15 character Project Code
Year	Number	4	4-digit year when sampling occurred
StartDate	Date/Time	8	Date (mm/dd/yyyy) when sampling began
EndDate	Date/Time	8	Date (mm/dd/yyyy) when sampling ended
StartTime	Date/Time	8	Time (hh:mm) when sampling began
EndTime	Date/Time	8	Time (hh:mm) when sampling ended
TripReport	Hyperlink	0	Pathname to trip report in MS Word including protocol used and special circumstances
Purpose	Text	50	Purpose of monitoring event

Table I-5. tblLocations—Contains all coral monitoring locations by transect.

Field Name	Type	Size	Description
SITE	Text	10	site name
Extensive site	Text	25	an optional designation below the site level that may be used for some analyses
LocationID	Text	255	unique ID used to designate project and location
ParkCode	Text	255	4-letter park code
Project	Text	255	Project name
Description	Text	255	description of this project
StartUTMX	Number	4	UTM Easting coordinate (in meters) for the starting point of each transect
StartUTMY	Number	4	UTM Northing coordinate (in meters) for the starting point of each transect
StopUTMX	Number	4	UTM Easting coordinate (in meters) for the end point of each transect
StopUTMY	Number	4	UTM Northing coordinate (in meters) for the end point of each transect
UtmZone	Text	255	UTM zone for the coordinates provided
StartLat	Number	8	Latitude coordinate for the starting point of each transect
StartLon	Number	8	Longitude coordinate for the starting point of each transect
Datum	Text	255	Horizontal datum for the provided coordinates
Elevation	Text	255	Depth (in feet)
TransectOriginX	Text	255	Origin X coordinate for AquaMap
TransectOriginY	Text	255	Origin Y coordinate for AquaMap
Notes	Text	255	Notes
Bearing	Number	4	Transect bearing in degrees. All transects within a site have the same bearing.
Num_Of_Transects	Number	4	Total number of transects for this site

Table I-6. tblObserver—Links Initials of persons taking the field data to a specific event.

Field Name	Type	Size	Description
Observer_ID	AutoNumber	16	Unique Observer ID
EventID	Text	50	Sampling event ID code
ObsInits	Text	50	Initials of persons taking the field data,

Table I-7. tluObserver—Lookup table for observer initials. This was a default table in which some fields are not used.

Field Name	Type	Size	Description
Order	Number	4	Sort order
ObsInits	Text	50	Initials of persons taking the field data,2002-11-21 - ADDED LOOKUP FROM TLUOBSERVER
FirstName	Text	50	First name
LastName	Text	50	Last name
MiddleInit	Text	4	Middle Initial [Only used if two names are similar]
Agency/Title	Text	255	Agency
Address1	Text	255	[Not used]
Address2	Text	255	[Not used]
City	Text	50	[Not used]
State	Text	2	[Not used]
ZipCode	Text	10	[Not used]
EmailAddress	Text	50	[Not used]
HomePhone	Text	20	[Not used]
WorkPhone	Text	20	[Not used]
WorkExtension	Text	5	[Not used]
FaxNumber	Text	20	[Not used]
Notes	Hyperlink	0	Notes

Table I-8. tluParkCode Description: Lookup table for park codes and park names where sampling occurs.

Field Name	Type	Size	Description
ParkCode	Text	255	Four letter park code
ParkName	Text	255	Park name
ParkType	Text	255	Park type

Table I-9. tluProject—Lookup table for project codes and descriptions.

Field Name	Type	Size	Description
Project	Text	30	name of project
ShortDesc	Text	50	abbreviated description of project
Description	Text	255	description of this project

Table I-10. tluSpecies—Lookup table containing the 8-character species code, category, subcategory, description (includes scientific name).

Field Name	Type	Size	Description
SpeciesCode	Text	255	Alphanumeric Species code
Category	Text	50	Grouping of species into general types (coral, algae, etc)
Subcategory	Text	50	Smaller grouping within a specific category
FunctionalGroup	Text	50	Name of functional group
Description	Text	255	Description of benthic organisms
New_Name	Text	255	New scientific name 4/17/2014
New_Code	Text	8	New species code
DateAdded	Date/Time	8	Field season when code was added

Disease/Species List/Colony Count/Sea urchin/Rugosity database

Database name: Disease_Species_List.mdb

Description: MS Access 2010 database coupled with a ThumbsPlus 7.0 interface that contains coral species list data, disease data from belt transect and links to disease photos, coral colony count data, sea urchin count data and rugosity data.

Key Database Relationships

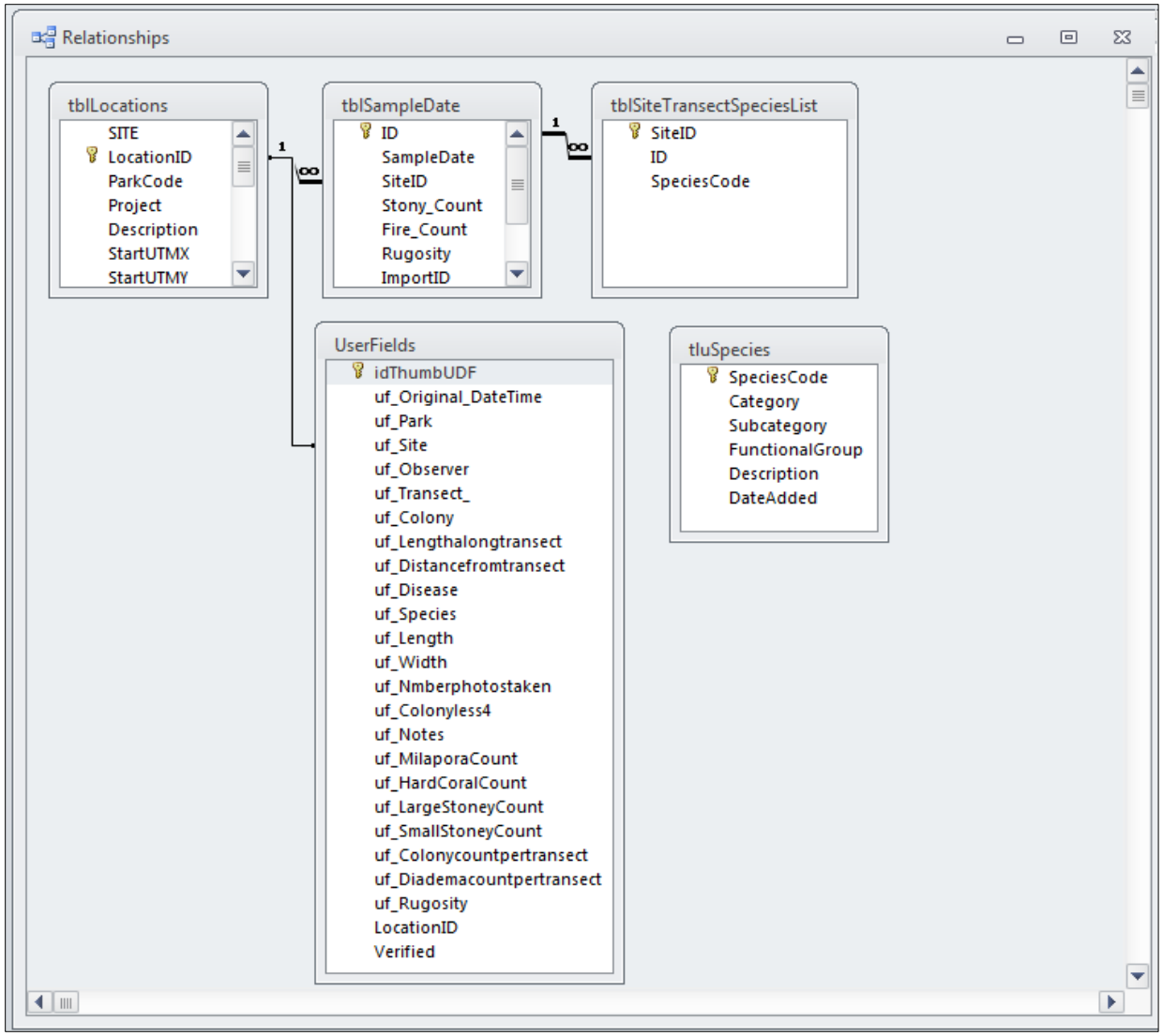


Figure I-2. Database relationships in Disease_Species_List.mdb.

Table Descriptions

Table I-11. tblLocations—Contains all coral monitoring locations by transect.

Field Name	Type	Size	Description
SITE	Text	255	site name
LocationID	Text	255	unique ID used to designate project and location
ParkCode	Text	255	4-letter park code
Project	Text	255	Project name
Description	Text	255	description of this project
StartUTMX	Text	255	UTM Easting coordinate (in meters) for the starting point of each transect
StartUTMY	Text	255	UTM Northing coordinate (in meters) for the starting point of each transect
StopUTMX	Text	255	UTM Easting coordinate (in meters) for the end point of each transect
StopUTMY	Text	255	UTM Northing coordinate (in meters) for the end point of each transect
UtmZone	Text	255	UTM zone for the coordinates provided
StartLat	Text	255	Latitude coordinate for the starting point of each transect
StartLon	Text	255	Longitude coordinate for the starting point of each transect
Datum	Text	255	Horizontal datum for the provided coordinates
Elevation	Text	255	Depth (in feet)
TransectOriginX	Text	255	Origin X coordinate for AquaMap
TransectOriginY	Text	255	Origin Y coordinate for AquaMap
Notes	Text	255	Notes
Bearing	Number	4	Transect bearing in degrees.
Num_Of_Transects	Number	4	Total number of transects for this site

Table I-12. tblSampleDate—Date when transect was sampled.

Field Name	Type	Size	Description
ID	AutoNumber	4	Automatically generated unique ID
SampleDate	Date/Time	8	Date site was sampled
SiteID	Text	50	Site ID
Stony_Count	Number	2	Stoney coral colony count
Fire_Count	Number	2	Fire coral colony count
Rugosity	Number	4	Rugosity in meters
ImportID	Number	4	Preserves original ID of imported data
Diadema	Number	4	Number of *Diadema*
Verified	Text	10	Data has been verified
Observer_Initals	Text	255	Observer initials

Table I-13. tblSiteTransectSpeciesList—Species list per transect from each sampling date.

Field Name	Type	Size	Description
SiteID	AutoNumber	4	Automatically generated unique ID
ID	Number	4	SampleDate ID
SpeciesCode	Text	10	Species Code

Table I-14. UserFields—ThumbsPlus table which contains critical data on disease, colony counts, sea urchins (Diadema) and rugosity.

Field Name	Type	Size	Description
idThumbUDF	AutoNumber	4	Automatically generated unique ID
uf_Original_DateTime	Text	23	date and time
uf_Park	Text	4	park code
uf_Site	Text	10	site code
uf_Observer	Text	20	observer
uf_Transect_	Number	4	transect number
uf_Colony	Number	4	colony number
uf_Lengthalongtransect	Number	8	length along transect
uf_Distancefromtransect	Number	4	distance from transect
uf_Disease	Text	6	disease species code
uf_Species	Text	6	coral species code
uf_Length	Number	8	length of disease lesion
uf_Width	Number	8	width of disease lesion
uf_Nmberphotostaken	Number	4	number of photos taken
uf_Colonyless4	Text	3	is coral colony less than 4cm in area
uf_Notes	Text	100	notes
uf_MilaporaCount	Number	4	milepora colony count
uf_HardCoralCount	Number	4	stony coral count
uf_LargeStoneyCount	Number	4	large stony coral count
uf_SmallStoneyCount	Number	4	small stony coral count
uf_Colonycountpertransect	Number	4	colony count per transect
uf_Diademacountpertransect	Number	4	*Diadema* count per transect
uf_Rugosity	Number	8	transect rugosity in meters
LocationID	Text	255	LocationID
Verified	Text	255	Data has been verified

Table I-15. tluSpecies—Lookup table containing the 8-character species code, category, subcategory, description (includes scientific name).

Field Name	Type	Size	Description
SpeciesCode	Text	255	Alphanumeric Species code
Category	Text	50	Grouping of species into general types (coral, algae, etc)
Subcategory	Text	50	Smaller grouping within a specific category
FunctionalGroup	Text	50	Name of functional group
Description	Text	255	Description of benthic organisms
DateAdded	Date/Time	8	Field season when code was added

Rapid Habitat Assessment Database

Database Name: RHA_Sites.mdb

Description: MS Access 2010 database that contains Rapid Habitat Assessment site data and line-intercept transect data.

Key Database Relationships

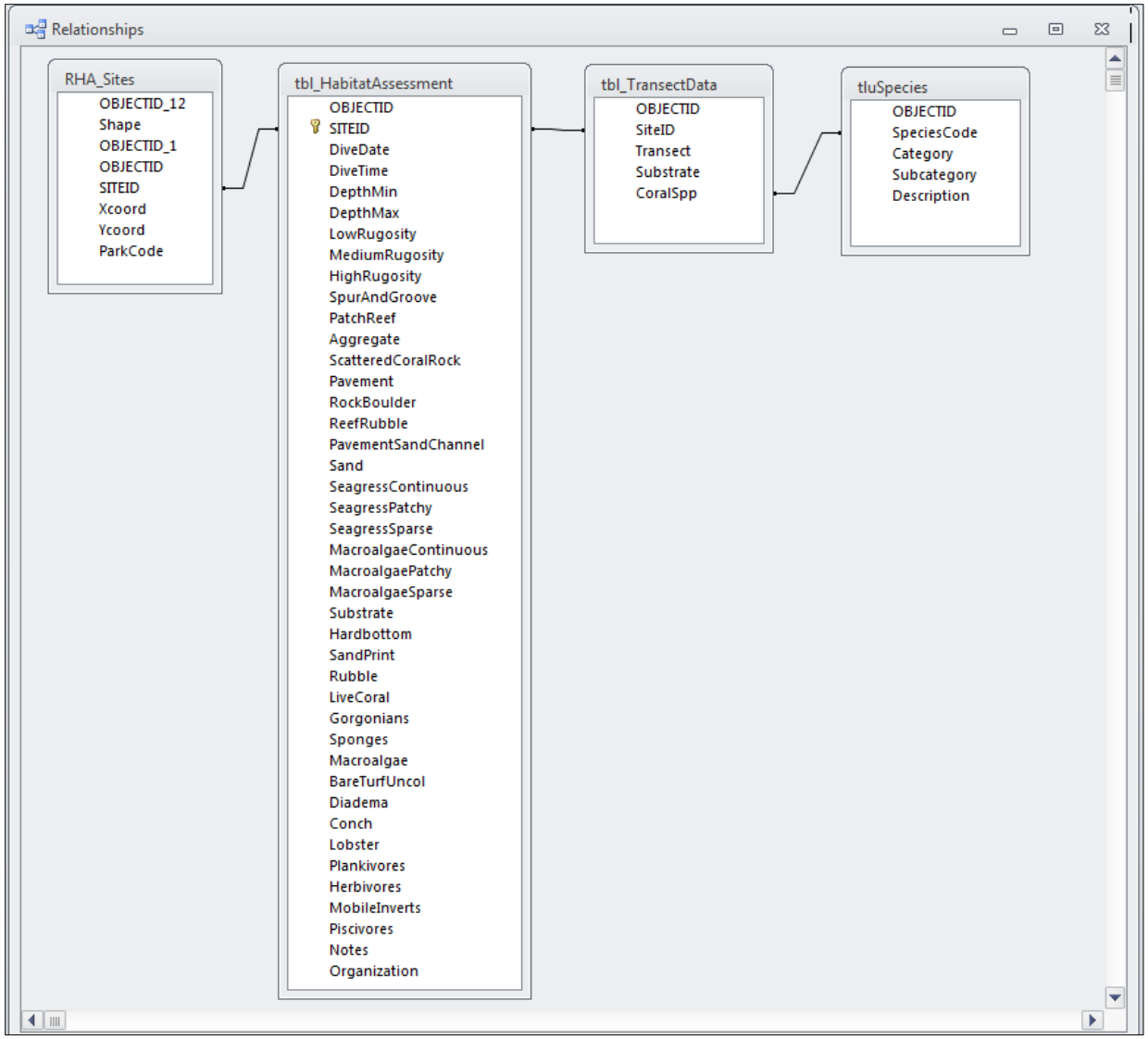


Figure I-3. Database relationships in RHA.mdb

Table Descriptions

Table I-16. RHA_Sites—Contains all RHA locations

Field Name	Type	Size	Description
OBJECTID_12	Autonumber	4	
Shape	OLE Object	0	ArcMap object ID
OBJECTID_1	Number	4	ArcMap object ID
OBJECTID	Number	4	ArcMap object ID
SITEID	Text	9	Site name
Xcoord	Text	254	UTM Easting coordinate (in meters) for the starting point of each transect
Ycoord	Text	254	UTM Northing coordinate (in meters) for the starting point of each transect
ParkCode	Text	4	4-letter park code

Table I-17.tbl_HabitatAssessment—General Site Data.

Field Name	Type	Size	Description
OBJECTID	Autonumber	4	
SITEID	Text	255	Site name
DiveDate	Date/Time	8	Date of dive
DiveTime	Date/Time	8	Time of dive
DepthMin	Number	4	Minimum depth at site (feet)
DepthMax	Number	4	Maximum depth at site (feet)
LowRugosity	Number	4	low relief (<0.5m)
MediumRugosity	Number	4	medium relief (0.5-1.5m)
HighRugosity	Number	4	high relief (>1.5m)
SpurAndGroove	Number	4	Spur and Groove is dominant= 1 or present= 2
PatchReef	Number	4	Patch reef is dominant= 1 or present= 2
Aggregate	Number	4	Aggregate reef is dominant= 1 or present= 2
ScatteredCoralRock	Number	4	Scattered Coral Rock is dominant= 1 or present= 2
Pavement	Number	4	Pavement is dominant= 1 or present= 2
RockBoulder	Number	4	Rock boulder is dominant= 1 or present= 2
ReefRubble	Number	4	Reef rubble is dominant= 1 or present= 2
PavementSandChannel	Number	4	Pavement Sand Channel is dominant= 1 or present= 2

Field Name	Type	Size	Description
Sand	Number	4	uncolonized sediment habitat type/ soft bottom
SeagressContinuous	Number	4	90% or greater seagrass coverage
SeagressPatchy	Number	4	50-90% seagrass coverage
SeagressSparse	Number	4	Less than 10% seagrass coverage
MacroalgaeContinuous	Number	4	90% or greater macroalgae coverage
MacroalgaePatchy	Number	4	50-90% macroalgae coverage
MacroalgaeSparse	Number	4	Less than 10% macroalgae coverage
Substrate	Number	4	descriptor
Hardbottom	Number	4	percent hardbottom cover
SandPrint	Number	4	percent sandcover
Rubble	Number	4	percent rubble cover
LiveCoral	Number	4	percent live coral of biotic footprint
Gorgonians	Number	4	percent gorgonians of biotic footprint
Sponges	Number	4	percent sponges of biotic footprint
Macroalgae	Number	4	percent macroalgae of biotic footprint
BareTurfUncol	Number	4	percent bare turf/uncolonized pavement of biotic footprint
Diadema	Text	50	presence/absence macro-inverts.
Conch	Text	50	presence/absence macro-inverts.
Lobster	Text	50	presence/absence macro-inverts.
Plankivores	Text	50	high/medium/low fish groups
Herbivores	Text	50	high/medium/low fish groups
MobileInverts	Text	50	high/medium/low mobile inverts
Piscivores	Text	50	high/medium/low fish groups
Notes	Memo	0	Notes
Organization	Text	50	Agency conducting work

Table I-18. tbl_TransectData—Raw line point intercept data.

Field Name	Type	Size	Description
OBJECTID	Autonumber	4	Autonumber
SiteID	Text	255	SiteID
Transect	Text	50	direction (north, south, east, west)
Substrate	Text	50	hard bottom/soft bottom descriptor (H/S) (example: DCA-dead coral algae, S-sand, GO-gorgonian all based off of TLU spp.)
CoralSpp	Text	50	coral species (MILA-Millepora, Siderastrea radians - all based off of TLU spp.)

Table I-19. tbl_Species—Species lookup table.

Field Name	Type	Size	Description
OBJECTID	Autonumber	4	Autonumber
SpeciesCode	Text	255	abbreviated species code
Category	Text	50	substrate description
Subcategory	Text	50	in depth descriptor of category
Description	Text	255	scientific name/name and acronym

Appendix J. SAS Analysis code

Coral_1_Transect_ANOVA_MeanComparison.sas

```
* Runs Repeated Measures Analysis of Variance by site using EventID
and SiteTran as class variables.
* A binomial distribution and a standard (default) covariance
structure is used.1st Order Autoregression is not used
* as each time step is calculated as an individual mean rather than as
a regression.
* Tukey is used as a mean separation test for the various EventID
sampling dates.;
* Imports dataset. Remember to put DummyLine at start so data will
read in correctly *;
proc import
datafile="Z:\SFCN\Vital_Signs\Marine_benthic_communities\CoralMonitori
ng\data\Exports\csv\Transect_Export.csv"
     dbms=csv
out=coraldata replace;
quit;
* Restricts data to total coral cover using 1_Sub Coral variable.
* Deletes DummyLine.
* Deletes Digital Video data from years when DV and HD were done
concurrently. Having both measured on same day
* in the analysis causes model fit problems.
* Deletes sites not currently monitored ;
Data coraldataonly;
set coraldata;
if speciescode= "1_Sub CORAL";
pct_coral=percent_cover/100;
if parkcode="XXXX" then delete;
if eventid IN('BISC_CoralVideo_20081021',
'BUIS_CoralVideo_20080415','BUIS_CoralVideo_20090215','DRTO_CoralVideo
_20080615','DRTO_CoralVideo_20080617','VIIS_CoralVideo_20080312',
'VIIS_CoralVideo_20080910','VIIS_CoralVideo_20081006','VIIS_CoralVideo
_20081105',
'VIIS_CoralVideo_20090120') then delete;
if site IN ('TR','PN','BKN','I-33','I-63','O-12b','O-27','O-92') then
delete;
run;
Proc sort;
by site sitetran EventID;
run;
title;footnote; options pageno=1;
*** Repeated Measures Analysis using standard variance components (vc)
***;
```

```
proc glimmix ;
   Title "ANOVA Mean Comparison of Time, Standard Variance Components,
Binomial Distribution,  subject=Transect";
   by SITE;
   class SITETRAN EventID;
   model pct_coral = SITETRAN EventID/ ddfm=satterth  dist=binomial
link=logit solution;
   random eventID / subject=sitetran type=vc residual;
   lsmeans EventID / pdiff adjust=tukey;
   Output pred=predglx2 resid=residglx2;
run;  quit;
```

Coral_2_Transect_ANCOVA_Regression.sas

```
* Runs Repeated Measures Analysis of Covariance by site using SiteTran
as class variables
* and DecimalYear as a regression variable.
* A binomial distribution is used with a 1st Order Autoregressive
Covariance structure and then a
* standard variance (default) structure . Generally the 1st Order
* Autoregressive covariance structure is preferred but in a few cases
the model has trouble fitting so in those
* cases, use the default standard variance structure results.

* Imports dataset. Remember to put DummyLine at start so data will
read in correctly *;
proc import
datafile="Z:\SFCN\Vital_Signs\Marine_benthic_communities\CoralMonitori
ng\data\Exports\csv\Transect_Export.csv"
     dbms=csv
out=coraldata replace;
quit;
* Restricts data to total coral cover using 1_Sub Coral variable.
* Deletes DummyLine.
* Deletes Digital Video data from years when DV and HD were done
concurrently. Having both measured on same day
* in the analysis causes model fit problems.
* For USVI sites, deletes data prior to 2007 to restrict data to post-
bleaching event.
* Makes decimalyear the number of years since 1999, the earliest year
sampled using this methodology.
* Deletes sites not currently monitored ;

Data coraldataonly;
set coraldata;
```

```
if speciescode= "1_Sub CORAL";
pct_coral=percent_cover/100;
if parkcode="XXXX" then delete;
if eventid IN('BISC_CoralVideo_20081021',
'BUIS_CoralVideo_20080415','BUIS_CoralVideo_20090215','DRTO_CoralVideo
_20080615','DRTO_CoralVideo_20080617','VIIS_CoralVideo_20080312',
'VIIS_CoralVideo_20080910',
'VIIS_CoralVideo_20081006',
'VIIS_CoralVideo_20081105',
'VIIS_CoralVideo_20090120') then delete;
if year<2007 and site in('SFR','WSG','HA','NF','TK','MB','YZ') then
delete;
Decimalyear=decimalyear-1999;
if site IN ('TR','PN','BKN','I-33','I-63','O-12b','O-27','O-92') then
delete;
run;
Proc sort;
by site sitetran EventID;
run;
title;  footnote; options pageno=1;
*** Repeated Measures ANCOVA using 1st order autoregression ***;
proc glimmix ;
 Title "Repeated Measures ANCOVA, 1st order autoregression variance
structure, binomial distribution, subject= transect";
   by SITE;
 class SITETRAN ;
 model pct_coral = SITETRAN DecimalYear/ ddfm=satterth dist=binomial
link=logit solution;
 random  _residual_ / subject=sitetran type=ar(1) residual ;
   Output pred=predglx resid=residglx;
run;
*** Repeated Measures ANCOVA using standard variance components (vc)
***;
proc glimmix ;
   Title "Repeated Measures ANCOVA, Standard Variance Components (vc),
binomial distribution, subject= transect";
   by SITE;
   class SITETRAN ;
   model pct_coral = SITETRAN DecimalYear/ ddfm=satterth dist=binomial
link=logit solution;
   random  _residual_ / subject=sitetran type=vc residual ;
   Output pred=predglx resid=residglx;
run;
```

Coral_3_Transect_ CONTRAST.sas

```
* Runs Repeated Measures Analysis of Variance by site using EventID
and SiteTran as class variables.
* A binomial distribution and a standard variance component (default)
structure is used.
* A "Contrast" statement is used to compare sets of means with other
sets of means. Because the sampling history for
* most sites is unique this program must be run separately for each
site. The Contrast statement is used to set up
* the comparison. With EventID sorted, set up the comparison starting
from oldest to newest sampling. The sum of all
* the contrasts must equal zero. In example below, SFR is set up to
contrast the 4 pre-bleach sampling events with
* 8 post-bleach sampling events. The two events during the bleaching
event receive a weight of zero so they are
* essentially dropped from the analysis.
* This is designed to be used with 20 transect sites or 4 transect
sites. Multiple extensive sub-site sites will require adding
* the contrast statement into Coral_4_Glimmix_MeanComparison.sas
program;

* Imports dataset. Remember to put DummyLine at start so data will
read in correctly *;
proc import
datafile="Z:\SFCN\Vital_Signs\Marine_benthic_communities\CoralMonitori
ng\data\Exports\csv\Transect_Export.csv"
     dbms=csv
out=coraldata replace;
quit;
* Restricts data to total coral cover using 1_Sub Coral variable.
* Deletes DummyLine.
* Deletes Digital Video data from years when DV and HD were done
concurrently. Having both measured on same day
* in the analysis causes model fit problems.
* Identifies site to be monitored;
Data coraldataonly;
set coraldata;
if speciescode= "1_Sub CORAL";
pct_coral=percent_cover/100;
if parkcode="XXXX" then delete;
if eventid IN('BISC_CoralVideo_20081021',
'BUIS_CoralVideo_20080415','BUIS_CoralVideo_20090215','DRTO_CoralVideo
_20080615','DRTO_CoralVideo_20080617','VIIS_CoralVideo_20080312',
'VIIS_CoralVideo_20080910',
'VIIS_CoralVideo_20081006',
```

```
'VIIS_CoralVideo_20081105',
'VIIS_CoralVideo_20090120') then delete;
if site='SFR';
run;
Proc sort;
by site sitetran EventID;
run;
title; footnote;  options pageno=1;
proc glimmix ;
   Title "Contrast analysis, Time is class variable, Repeated
measures, Standard variance component, Binomial Distribution,
Subject=Transect";
   class SITETRAN EventID;
   model pct_coral = SITETRAN EventID/ ddfm=satterth  dist=binomial
link=logit solution;
   random eventID / subject=sitetran type=vc residual;
   Contrast 'pre vs post bleach' eventid -2 -2 -2 -2 0 0 1 1 1 1 1 1 1
1;
   Output pred=predglx resid=residglx;
run;
```

Coral_4_Site_ANOVA_MeanComparison.sas

```
* Runs Repeated Measures Analysis of Variance for sites consisting of
extensive sub- sites using Year and Site as class variables.
* A standard variance structure is used.
* Tukey is used as a mean separation test for the various decimalyear
sampling dates.;

* Imports dataset. Remember to put DummyLine at start so data will
read in correctly *;
proc import
datafile="Z:\SFCN\Vital_Signs\Marine_benthic_communities\CoralMonitori
ng\data\Exports\csv\Site_Export.csv"
     dbms=csv
out=coralsite replace;
quit;
* Restricts data to total coral cover using 1_Sub Coral variable.
* Converts percent cover to a proportion
* Deletes DummyLine.
* Deletes Digital Video data from years when DV and HD were done
concurrently. Having both measured on same day
* in the analysis causes model fit problems.
* Restricts years analyzed. LH and SV began in 2011. In-RNA and Out-
RNA have years 2008-2012.
```

```
* Restricts lines to the specific extensive sub-sites of a site. Each
site must be analyzed separately. To turn on a site for
* analysis delete the * in front of the line.;

Data coralsiteonly;
set coralsite;
if speciescodepercent= "Pct Cov 1_Sub CORAL";
pct_coral=AvgOfPercent_Cover/100;
if parkcode="XXXX" then delete;
if eventid IN('BISC_CoralVideo_20081021', 'BUIS_CoralVideo_20080415',
'BUIS_CoralVideo_20090215','DRTO_CoralVideo_20080615','DRTO_CoralVideo
_20080617',
'VIIS_CoralVideo_20080312',
'VIIS_CoralVideo_20080910',
'VIIS_CoralVideo_20081006',
'VIIS_CoralVideo_20081105',
'VIIS_CoralVideo_20090120') then delete;
if year>2011;
 if site IN('LH01','LH02','LH03','I-05b','I-50');   * Loggerhead
forest;
* if site IN('SV01','SV02','SV03');   * Santas Village;
* if site IN('I-05b','I-50','I-26','I-36b','I-38','I-41','I-44';
* Inside RNA    ;
* if site IN ('O-42','O-56','O-72','O-82','O-84','O-94');
* Outside RNA ;
run;
Proc sort;
by site sitetran EventID;
run;
      title;
 footnote;
*** Repeated Measures ANOVA Analysis ***;
options pageno=1;
proc glimmix ;
 title "Repeated Measures ANOVA, Standard Variance Structure, Binomial
Distribution, Mean Comparison, Subject = Subsite";
   class SITE Year;
 model pct_coral = SITE Year/ ddfm=satterth  dist=binomial link=logit
solution;
   random Year / subject=site type=vc residual;
   lsmeans Year / pdiff adjust=tukey;
   Output pred=predglx resid=residglx;
run;
Quit;
```

Coral_5_Site_ANCOVA_Regression.sas

```
* Runs Repeated Measures Analysis of Co-Variance for sites consisting
of extensive sub-sites using Site and Year as regression variables.
* A binomial distribution is used with a 1st Order Autoregressive
Covariance structure as well as the
* default standard variance component structure. Generally the 1st
Order
* Autoregressive covariance structure is preferred but in a few cases
the model has trouble fitting so in those
* cases, use the default standard variance component (VC) structure
results while investigating the predicted vs residual plots for
unusual patterns.

* Imports dataset. Remember to put DummyLine at start so data will
read in correctly *;
proc import
datafile="Z:\SFCN\Vital_Signs\Marine_benthic_communities\CoralMonitori
ng\data\Exports\csv\Site_Export.csv"
     dbms=csv
out=coralsite replace;
quit;
Data coralsiteonly;
set coralsite;
if speciescodepercent= "Pct Cov 1_Sub CORAL";
pct_coral=AvgOfPercent_Cover/100;
if parkcode="XXXX" then delete;
if eventid IN('BISC_CoralVideo_20081021',
'BUIS_CoralVideo_20080415','BUIS_CoralVideo_20090215','DRTO_CoralVideo
_20080615','DRTO_CoralVideo_20080617','VIIS_CoralVideo_20080312',
'VIIS_CoralVideo_20080910',
'VIIS_CoralVideo_20081006',
'VIIS_CoralVideo_20081105',
'VIIS_CoralVideo_20090120') then delete;
if year>2011;
if site IN('LH01','LH02','LH03','I-05b','I-50'); * Loggerhead forest;
* if site IN('SV01','SV02','SV03');   * Santas Village;
* if site IN('I-05b','I-50','I-26','I-36b','I-38','I-41','I-44');
* Inside RNA    ;
* if site IN ('O-42','O-56','O-72','O-82','O-84','O-94');  * Outside
RNA ;
run;
Proc sort;
by site EventID;
run;
     title;
```

```
 footnote;
*** Repeated Measures ANCOVA Analysis ***;
options pageno=1;
proc glimmix ;
   title "Repeated Measures ANCOVA, 1st order Autoregression
Covariance Structure, Binomial Distribution, subject=sub-sites";
   class SITE ;
 model pct_coral = SITE DecimalYear/ ddfm=satterth dist=binomial
link=logit solution;
   random  _residual_ / subject=site type=ar(1) residual ;
 Output pred=predglx resid=residglx;
run;
proc glimmix ;
   title "Repeated Measures ANCOVA, Standard Variance Component
Structure, Binomial Distribution, Subject=sub-sites";
   class SITE ;
 model pct_coral = SITE DecimalYear/ ddfm=satterth dist=binomial
link=logit solution;
   random  _residual_ / subject=site type=vc residual ;
   Output pred=predglx2 resid=residglx2;
run;
quit;
```

Appendix K. Data Summary Template

Introduction

Coral reef communities within the National Park Service South Florida /Caribbean Network (SFCN) are among the best quality Caribbean and Western Atlantic Coral reefs protected by the National Park Service. The South Florida/Caribbean Network annually monitors five intensive coral reef sites: Newfound Reef (est. 1999); Yawzi Reef (est. 1999); Mennebeck Reef (est. 2000); Haulover Reef (est. 2003); and Tektite Reef (est. 2005) (Figure K-1). Monitoring enables detection of change over time at these reefs in major coral reef taxonomic groups (e.g., coral, algae [turf, calcareous, macroalgae], gorgonians, sponge, substrate), and community-level indicators of habitat condition (e.g., coral species diversity, coral community structure, rugosity); and tracking trends and severity in reef-associated covariates such as water temperature, coral bleaching, coral disease, and densities of the herbivorous sea urchin, *Diadema antillarum.* This report presents the data collected in Virgin Islands National Park at these five coral reefs through calendar year 2015.

Methods

Sites currently monitored include Newfound reef (NF), Yawzi reef (YZ), Haulover reef (HA), Mennebeck reef (MB), and Tektite reef (TK). Coral reef monitoring sites were selected through management recommendation, high initial reef coral cover, comparability with historic work, and

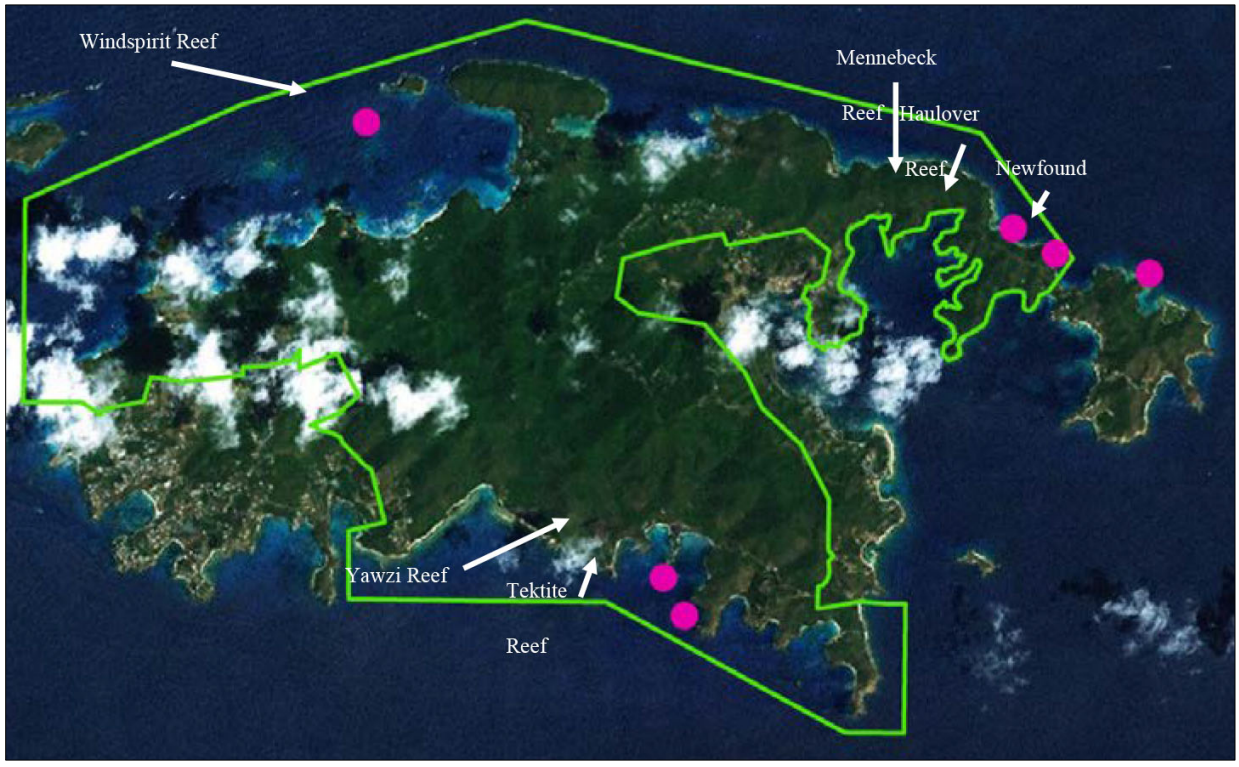


Figure K-1. Map of monitoring sites around St. John with the outline (green line) of Virgin Islands National Park. Windspirit Reef has water temperature monitoring only.

levels of stressors in differing watersheds. Each site consists of 20 permanent, randomly selected 10-meter (32.8 ft-) transects which are monitored using underwater high definition video. 300-350 random "dots" are applied to the video images and the benthic organisms found under each dot are identified. Coral community monitoring is conducted annually and episodically when feasible during or after unusual events such as bleaching events, disease outbreaks, or after hurricanes.

Coral reef community monitoring began inside and outside the park in 1988 on Newfound and Yawzi reefs using a chain transect methodology. SFCN's current videography monitoring protocol replaced the chain transects in 1999 and was gradually expanded to additional reefs through 2005. Reef-depth water temperature data have been collected almost continuously within the park since 1990.

The videography protocol was further expanded to include simultaneous field collection of data in a 2 × 10 meter (6.6 × 32.8 ft) belt transect centered on the video transect tape on presence and severity of coral bleaching (2005), type and size of disease lesions (2005), densities of *Diadema antillarum* (2010), listing of *scleractinian* species (2010), counting of coral colonies greater than 4 centimeters (1.6 in) in size (2013), disease prevalence (2013), and rugosity (2013). Rugosity is being measured along the transects every five years or after major events. Reef-depth water temperature data is collected at these sites every two hours using HOBO data loggers and at a sixth site called Windspirit which does not have benthic monitoring.

Coral cover data are analyzed for trends using a repeated measures analysis of covariance with a first-order autoregressive covariance structure using SAS 9.2. For further details on the protocols see "Coral Reef Monitoring Protocol" (Miller et al. 2016) and "Coral Reef Water Temperature Monitoring Protocol" (Davis et al. 2013).

All benthic monitoring in 2015 was conducted as described in the protocol with sampling dates provided in Table App. K-1. Rugosity was not collected. Water temperatures in 2015 are only provided through the most recent sampling date as the remaining months of data will not be downloaded until 2016 sampling occurs.

Results and Discussion

Table App. K-1 provides a brief summary of the data for the current year. Automated graphs and table summaries for coral communities are provided in

- Appendix K_A. Benthic Community Graphs
- Appendix K_B. Coral Community Composition
- Appendix K_C. Coral Bleaching
- Appendix K_D. Coral Disease
- Appendix K_E. Long spined sea urchins
- Appendix K_F. Water Temperature Graphs and Tables
- Appendix K_G. Transect level videography data summaries

Table App. K-2 is a synthesis of the data into a "stoplight" indicator symbol based upon the a qualitative assessment by SFCN staff of all the data with a primary focus on the current live stony coral cover compared with initial estimates of coral cover and trends since the 2005 bleaching/disease coral die off event. (*NOTE: Use of Stoplights in this data summary report is optional at the discretion of the Network Program Manager, Regional Program Manager and each park's Resource Management Chief and Superintendent. Applying the use of stoplights in a data summary report will likely trigger a requirement for additional "appropriate level of review" as hard thresholds for determining the different status have not been determined and assessments are still to some extent qualitative*).

Summary

Some key highlights include:

- Significant upward trends in stony coral cover since 2007 have occurred for Tektite, Mennebeck and Yawzi Reefs, but not Newfound Reef or Haulover Reef which remain unchanged (Tables App K-1 and K-2, Figure App K_A-1). Despite the gains in coral cover since 2007, the overall status of all five monitored reefs remains significantly less than pre-2005 levels (See Table 2).
- Although coral cover is increasing, all coral species are not increasing at the same rates. The star coral *Orbicella* spp. has remained the most dominant coral, and the percent cover of this species group has not changed since 2007. The increases in coral cover are predominately coming from the *Porites astreoides*, and *P. porites*, which have nearly doubled in percent cover since 2007 (see Figures App K_B-1 through App K_B-3).
- Water temperature loggers from Haulover, Newfound, Tektite, Windspirit, and Yawzi have been downloaded since January 2016 and have a complete 2015 dataset. Mennebeck 2015 data is only partially available at this time (see Figure App K_F-1). Water temperatures for 2015 exceeded the 1990-2004 data range during October (see Figure App K_F-3). The loggers recorded 23–52 days above the 29.5°C bleaching threshold depending on the site. Figure App K_F-2 graphs a proposed coral heating index consisting of the cumulative sum of the difference between the average daily temperature and 29.5°C for days above this threshold. The graph shows 2015 to have similar magnitude to 2010, a previous bleaching year (see Figure App K_F-2).
- Despite the warm water temperatures, less than 1% of stony coral bleached was bleached during monitoring in 2015 at USVI sites in September (see Table App K-1, Table App K_C-1 and Figure App K_C-1). However the warm temperatures were primarily in October 2015 after monitoring was completed so it's possible some bleaching happened after monitoring occurred. However SFCN staff did not receive and notifications of bleaching occurring.

Literature Cited

Davis, A. D., A. J. Atkinson, M. W. Feeley, J. Miller, J. M. Patterson, L. Richter, C. S. Rogers, R. J. Waara, K. R. T. Whelan, and B. Witcher. 2013. Coral reef ecosystem water temperature monitoring protocol, V. 1.00. Natural Resource Report NPS/SFCN/NRR—2013/679. National Park Service, Fort Collins, Colorado.

Miller, J., C. Rogers, A. Atkinson, E. Muller, A. Davis, M. Patterson, R. Waara, B. Witcher, M. Feeley, and J. Patterson. *DRAFT*. Coral reef monitoring protocol. Natural Resource Report NPS/SFCN/NRR—20XX/XXX. National Park Service, Fort Collins, Colorado.

Table K-1a. Coral monitoring summary table: Stony coral cover trends calculated from 2007-present. All other variables calculated from initial year to present. 2005-2006 were strong coral bleaching years accompanied by extensive disease outbreaks and extremely high coral mortality. Values are average percent (standard error) unless otherwise labeled. N/A = Not available

			Stony Coral % Cover Average (SE)			Stony Coral % Cover Trend (Prob)	Stony Coral Bleaching (% coral tissue)	Stony Coral Bleaching Dominant level	Coral Disease Prevalence (% colonies infected)	Coral Disease Dominant disease type	# Days Water Temp >29.5°C
Site	Date Sampled	Site Initiation	Current Year	Initial Year	2007	Current Year	Current Year	Current Year	Current Year	Current Year	Current Year
Haulover	2/6/2015	Jan 2003	10.4 (1.6)	22.1 (2.7)	10.4 (1.6)	0.5268	0%	No Bleaching	0.5%	White Plague	47
Mennebeck	9/25/2015	Oct 2000	11.4 (1.8)	23.0 (3.4)	9.6 (1.4)	0.0145	<1%	No Bleaching	0.7%	White Plague	N/A
Newfound	9/12/2015	Mar 1999	5.0 (0.8)	18.0 (1.4)	5.9 (0.8)	0.1117	0%	No Bleaching	N/A	N/A	48
Tektite	9/23/2015	Sep 2005	14.3 (2.3)	24.7 (2.5)	11.6 (1.5)	0.0001	<1%	No Bleaching	1.7%	White Plague	47
Yawzi	9/10/2015	Oct 1999	7.5 (1.2)	7.1 (1.3)	4.5 (0.6)	0.0001	<1%	No Bleaching	0.8%	White Plague	52

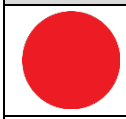
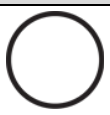
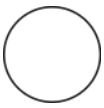
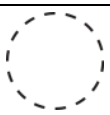
Table K-1b. Coral monitoring summary table: Stony coral cover trends calculated from 2007-present. All other variables calculated from initial year to present. 2005-2006 were strong coral bleaching years accompanied by extensive disease outbreaks and extremely high coral mortality. Values are average percent (standard error) unless otherwise labeled. N/A = Not available

	Gorgonians % Cover Average (SE)		Sponges % Cover Average (SE)		Coralline Algae % Cover Average (SE)		Substrate, Turf, & Macro Algae % Cover Average (SE)		*Diadema antillarum* No./20m^2 Average (SE)	
Site	Current Year	Initial Year	Current Year	Initial Year	Current Year	Initial Year	Current Year	Initial Year	Current Year	Initial Year
Haulover	10.6 (0.8)	8.9 (0.9)	1.7 (0.3)	1.3 (0.3)	3.8 (0.7)	1.7 (0.3)	73.5 (2.0)	63.8 (3.0)	0.1 (0.1)	0.3 (0.1)
Mennebeck	11.5 (1.2)	6.0 (0.8)	3.8 (0.3)	1.4 (0.3)	0.9 (0.2)	0.4 (0.2)	72.1 (2.2)	68.2 (3.2)	0.9 (0.3)	0.8 (0.3)
Newfound	10.8 (0.9)	7.6 (0.6)	4.3 (0.4)	2.2 (0.4)	0.4 (0.1)	0.2 (0.1)	78.6 (1.1)	70.5 (1.5)	N/A	0.2 (0.2)
Tektite	2.0 (0.4)	1.9 (0.4)	6.2 (0.5)	2.7 (0.3)	2.1 (0.4)	0.7 (0.2)	75.5 (2.2)	69.6 (2.6)	0.2 (0.1)	0.5 (0.2)
Yawzi	3.0 (0.3)	2.2 (0.4)	5.0 (0.4)	1.3 (0.2)	2.3 (0.3)	1.0 (0.2)	82.0 (1.5)	85.4 (1.5)	1.5 (0.3)	1.3 (0.4)

Table K-2. Summary condition five reef sites in and near Virgin Islands National Park. Symbols are described below (*). [NOTE: This table is optional at discretion of park management, SFCN Network Program Manager, and Regional I & M Program Manager.]

Specific Measure	Indicator of Condition	Condition Status/ Trend*	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source
Primary= % live stony coral cover; Secondary= algal, sponge, & soft coral cover, sea urchin density, disease area, disease prevalence and water temperatures.	Haulover Coral Reef Condition		Live stony coral cover = 10.4%. Condition is degraded after the decrease in coral cover between 2005-2007 Bleaching/Disease event. No trend has occurred in live stony coral cover since 2007. (SFCN data analysis 9/23/2016.)	Pre 2005 bleaching event coral cover= 22.5% (sampled 1/11/2005; SFCN database)
	Mennebeck Coral Reef Condition		Live stony coral cover = 11.4%. Condition is degraded after the decrease in coral cover between 2005-2007 Bleaching/Disease event. However a small upward trend has been detected since 2007. (SFCN data analysis 9/23/2016).	Pre 2005 bleaching event coral cover= 26.7% (sampled 10/19/2004; SFCN database)
	Newfound Coral Reef Condition		Live stony coral cover = 5.0%. Condition is degraded after the decrease in coral cover between 2005-2007 Bleaching/Disease event and prior decline. No trend has occurred in live stony coral cover since 2007. (SFCN data analysis 9/23/2016.)	3/23/1999 Coral Cover = 18.0%; Pre 2005 bleaching event coral cover = 13.2%. (sampled 3/2/2005; SFCN database)
	Tektite Coral Reef Condition		Live stony coral cover = 14.3%. Condition is degraded after the decrease in coral cover between 2005-2007 Bleaching/Disease event. However a small upward trend has been detected since 2007. (SFCN data analysis 9/23/2016.)	Pre 2005 bleaching event coral cover= 24.7%(sampled 9/26/2005; SFCN database)
	Yawzi Coral Reef Condition		Live stony coral cover = 7.5% which is > 1999's 7.1% and is the basis for changing the status from red to yellow. However shifts in corals species composition remain and overall stony coral cover remains lower than pre-1998 bleaching event levels. A small upward trend has been detected since 2007. (SFCN data analysis 9/23/2016.)	Pre 2005 bleaching event coral cover=8.6%.(sampled 9/14/2004; SFCN database)

* The Status and Trend symbols used above are summarized in the following key.

Condition Status		Trend in Condition		Confidence in Assessment	
	Warrants Significant Concern		Condition is Improving		High
	Warrants Moderate Concern		Condition is Unchanging		Medium
	Resource is in Good Condition		Condition is Deteriorating		Low

Appendix K_A. Benthic Community Graphs

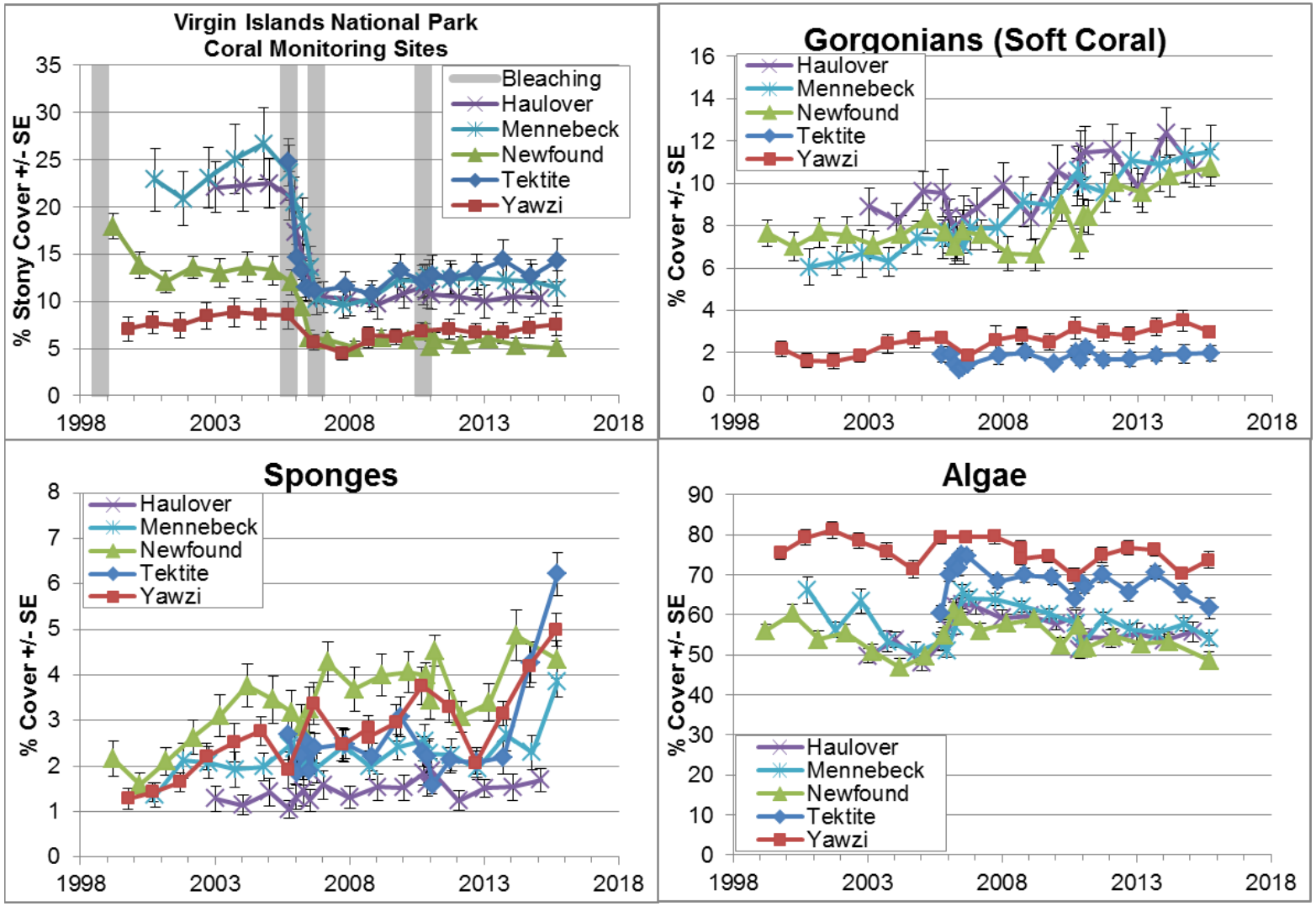


Figure App. K_A-1. Percent cover for Virgin Islands National Park coral monitoring sites for stony coral (top left), gorgonians (top right), sponges (bottom left), and algae (bottom right). Grey lines indicate coral bleaching years on coral graph. Large stony coral dieoff occurred in 2005-2006.

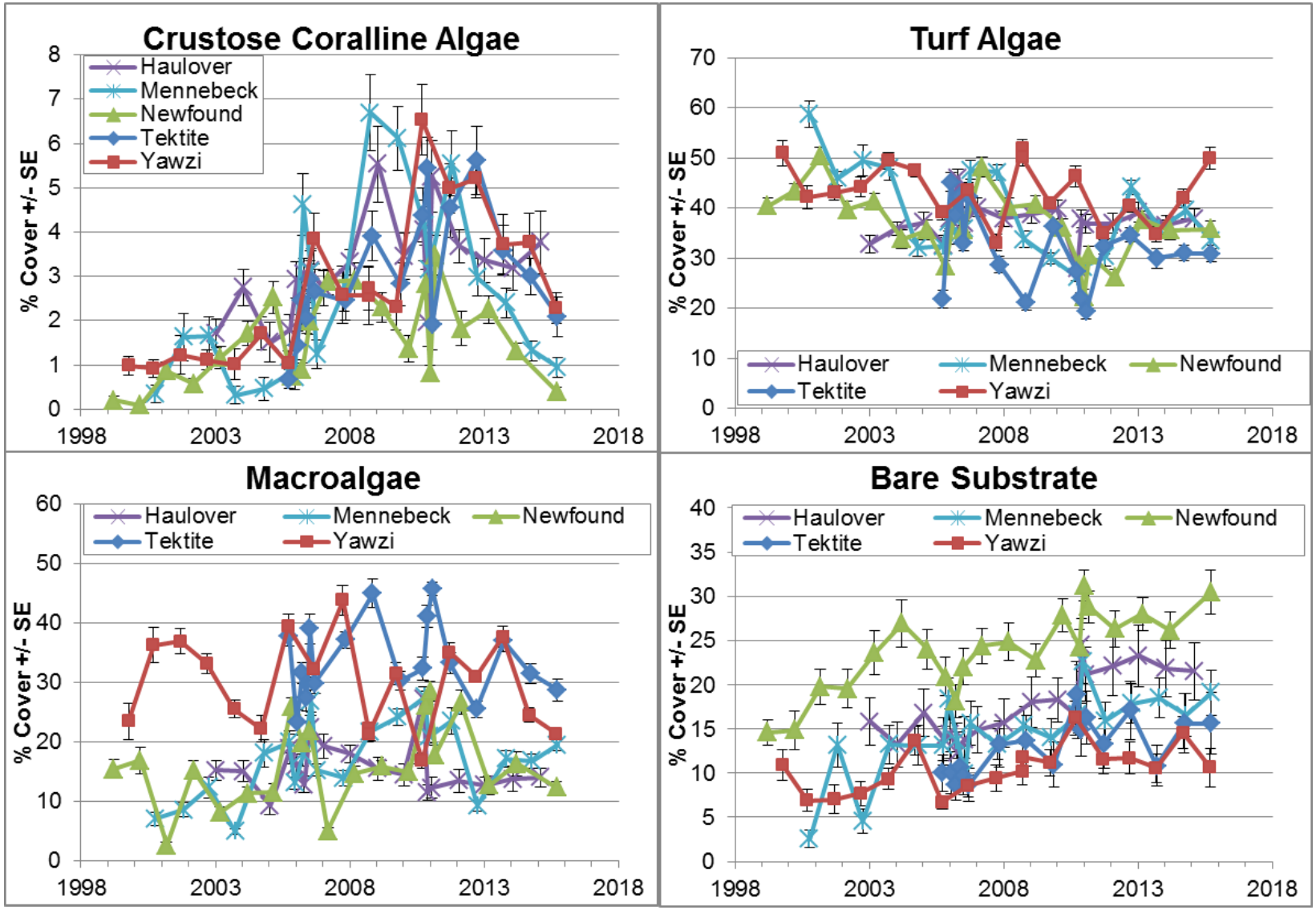


Figure App. K_A-2. Percent cover for crustose coralline algae (top left), turf algae (top right), macroalgae (bottom left), and bare substrate (bottom right).

Appendix K_B. Coral Community Composition

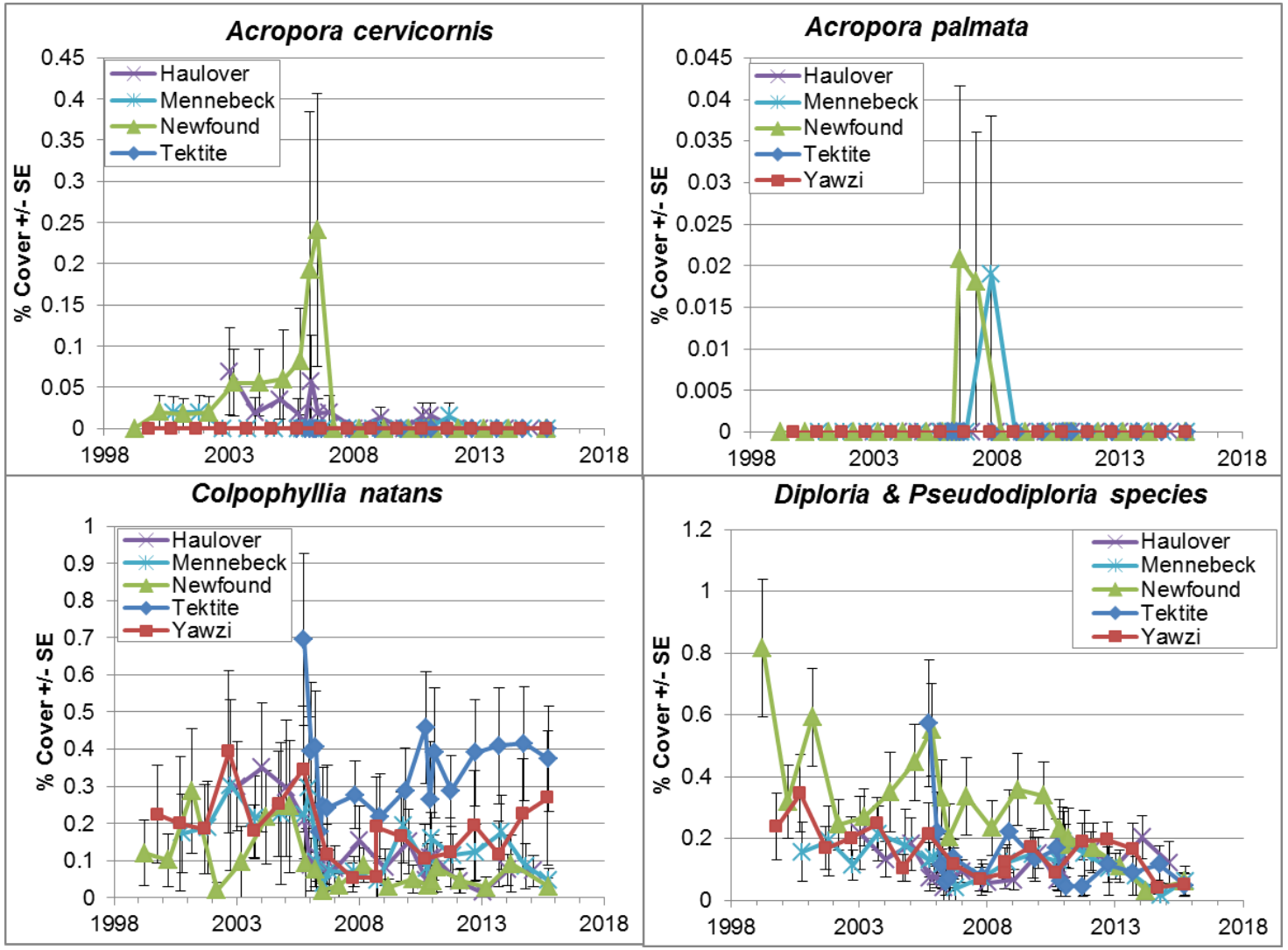


Figure App. K_B-1. Percent cover for major coral species and genera: *Acropora cervicornis* (top left), *Acropora palmata* (top right), *Colpophyllia natans* (bottom left), and Diploria and Pseudodiploria species (bottom right).

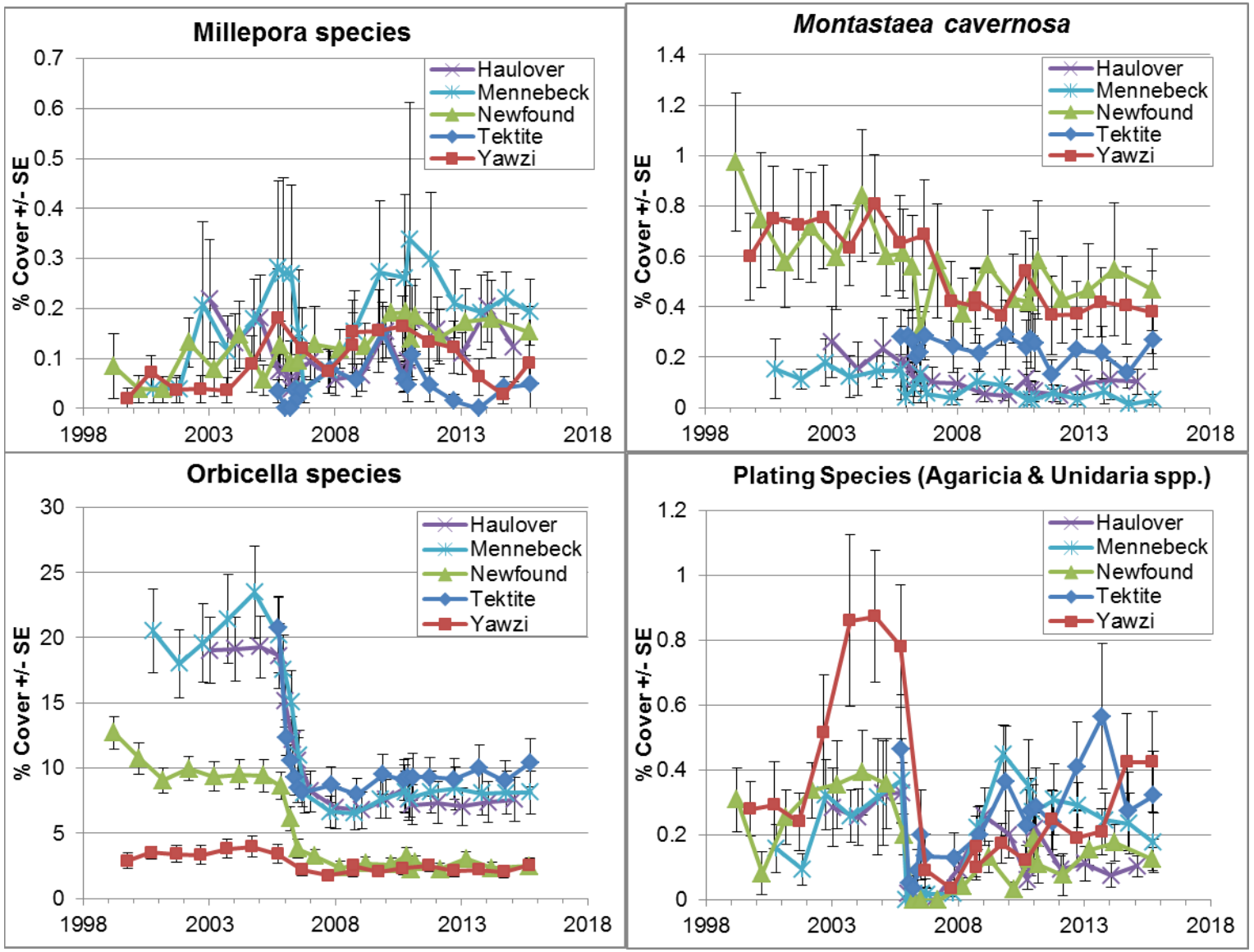


Figure App. K_B-2. Percent cover for major coral species and genera: Millepora species (top left), *Montastraea cavernosa* (top right), Orbicella species (bottom left), and plating species (Agaricia and Unidaria species) (bottom right).

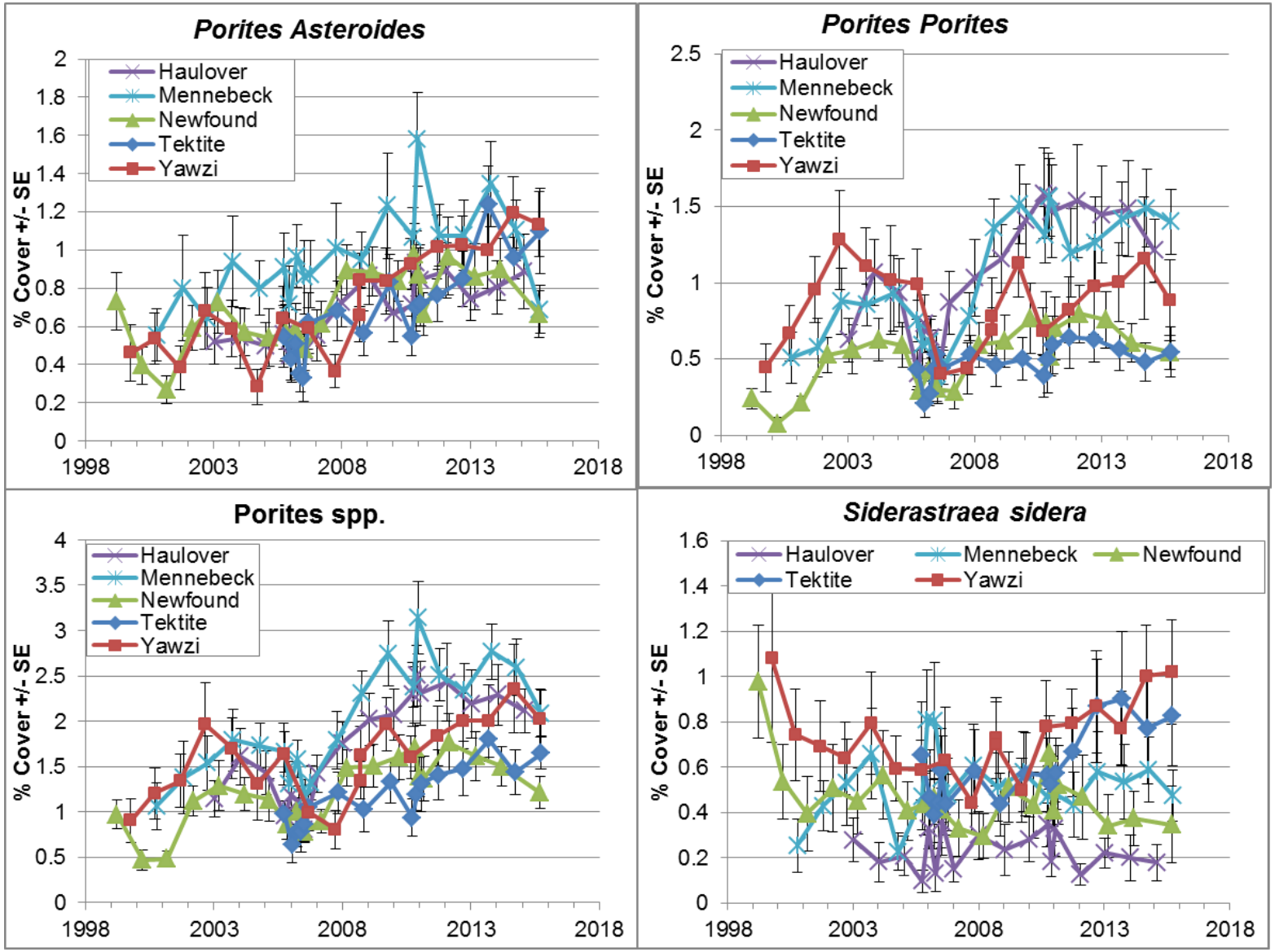


Figure App. K_B-3. Percent cover for major coral species and genera: *Porites asteroides* (top left), *Porites porites* (top right), Porites species (bottom left), and *Siderastrea sidera* (bottom right).

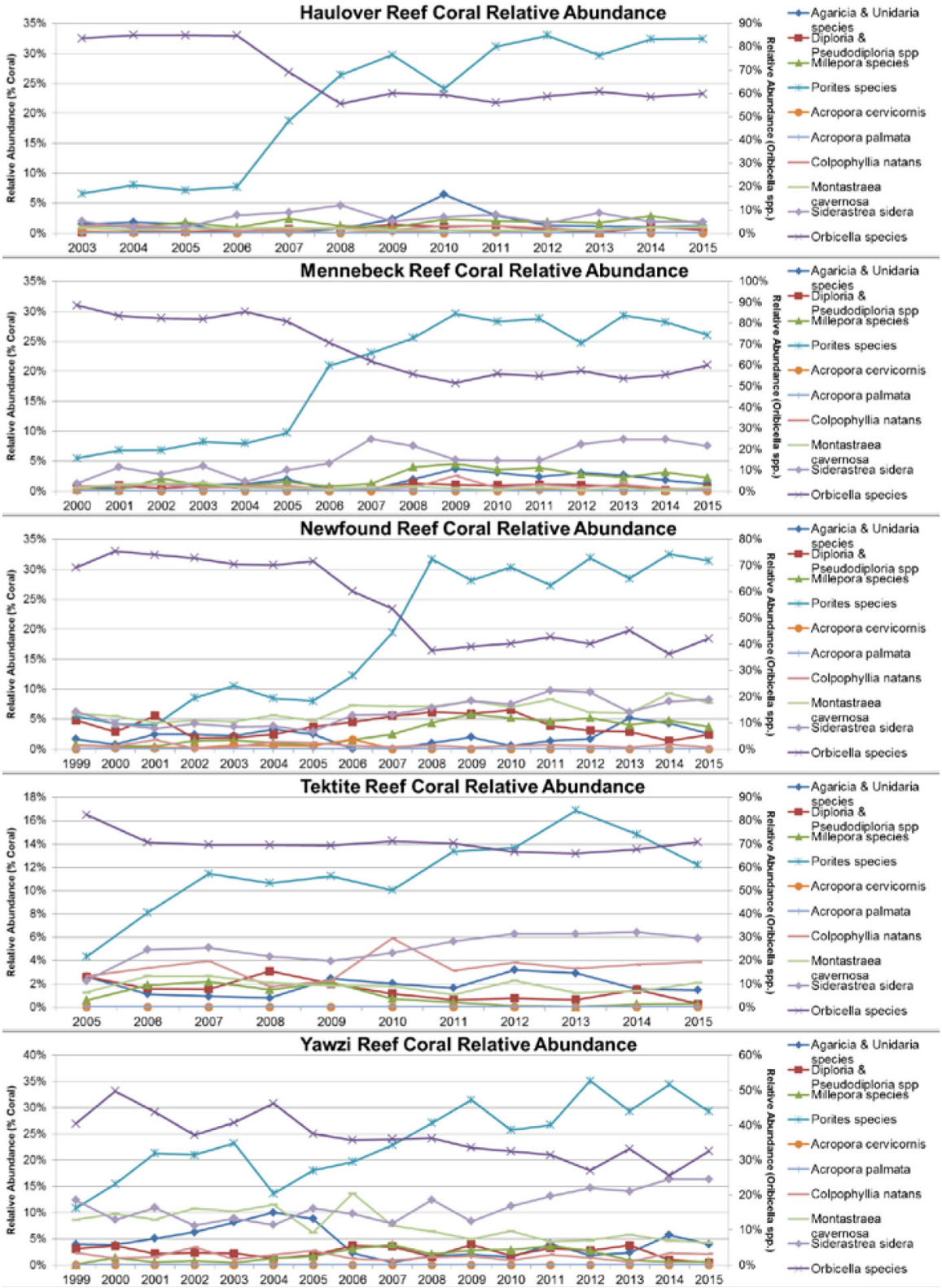


Figure App. K_B-4. Relative abundance of different major reef building corals for each of the five sites. *Orbicella* spp. is plotted along the right y-axis.

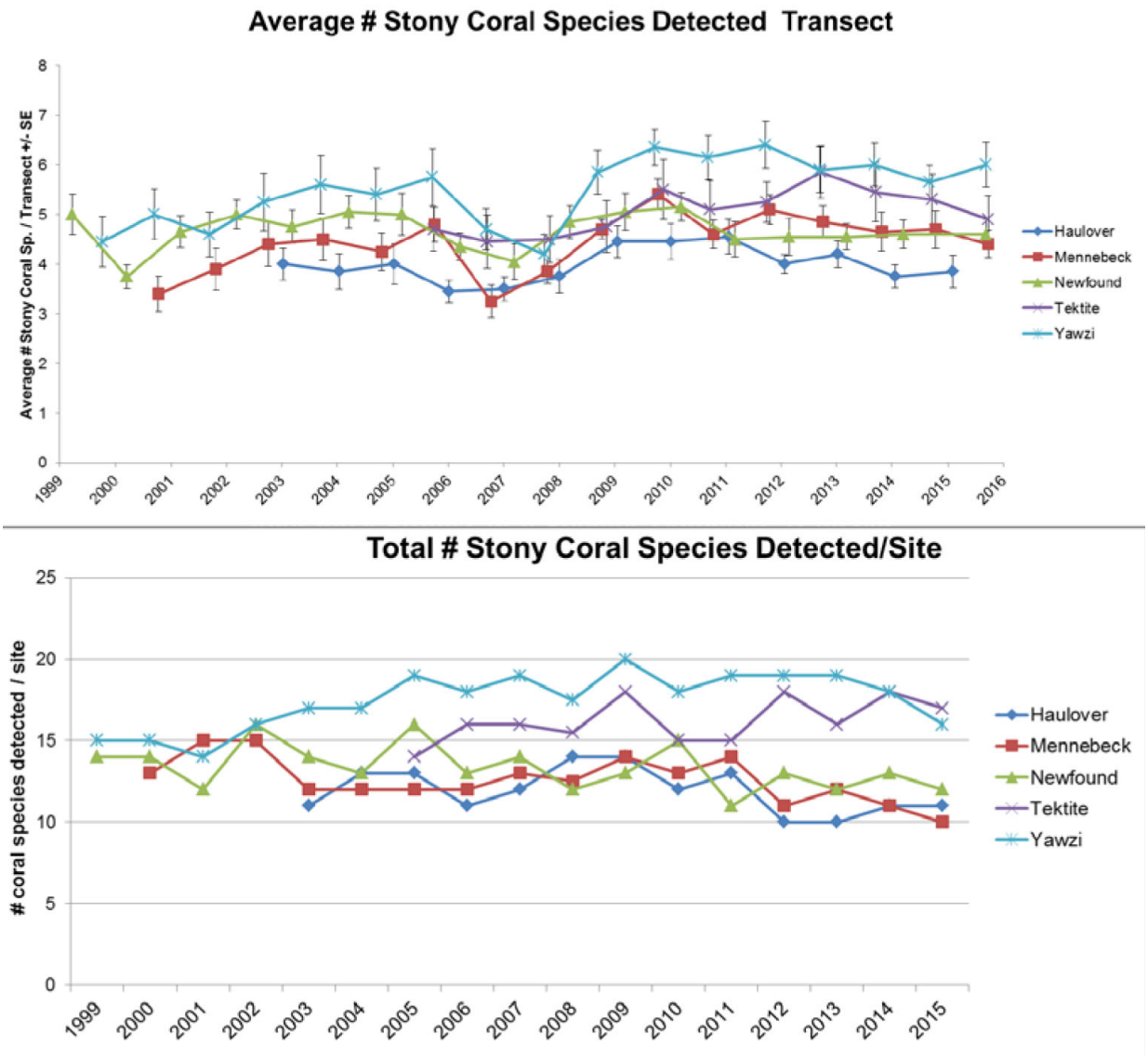


Figure App. K_B-5. Average # stony coral species detected per transect and detected by site using videography.

Appendix K_C. Coral Bleaching

Table App.K_C-1. Coral bleaching by 4 different bleaching levels in 2013. Level 4 (BL4) is minimal discoloration. Level 1 (BL1) is completely white. *[NOTE: 2013 results are shown to provide a demonstration of the results during a bleaching year]*

Sample Date	SITE	Unbleached	BL-4	BL-3	BL-2	BL-1
1/10/2013	HA	100.0	0.0	0.0	0.0	0.0
3/6/2013	NF	100.0	0.0	0.0	0.0	0.0
9/9/2013	YZ	81.0	10.7	6.8	1.4	0.0
9/16/2013	TK	51.2	34.3	12.1	2.2	0.2
10/23/2013	MB	20.2	30.7	35.9	11.9	1.3
Average	**–**	**70.5**	**15.1**	**11.0**	**3.1**	**0.3**

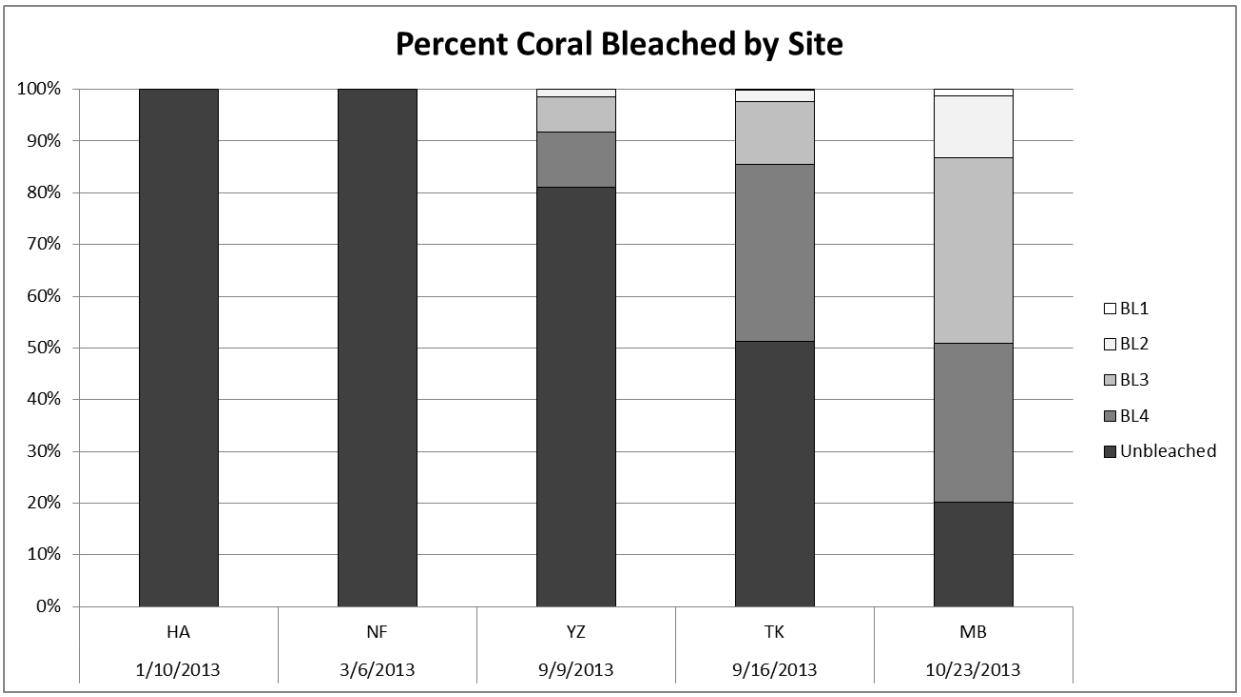


Figure App. K_C-1. Percent of coral bleached by 4 different bleaching levels by site. Sites are sorted by sampling date. (*NOTE: 2013 results are shown to provide a demonstration of the results during a bleaching year*).

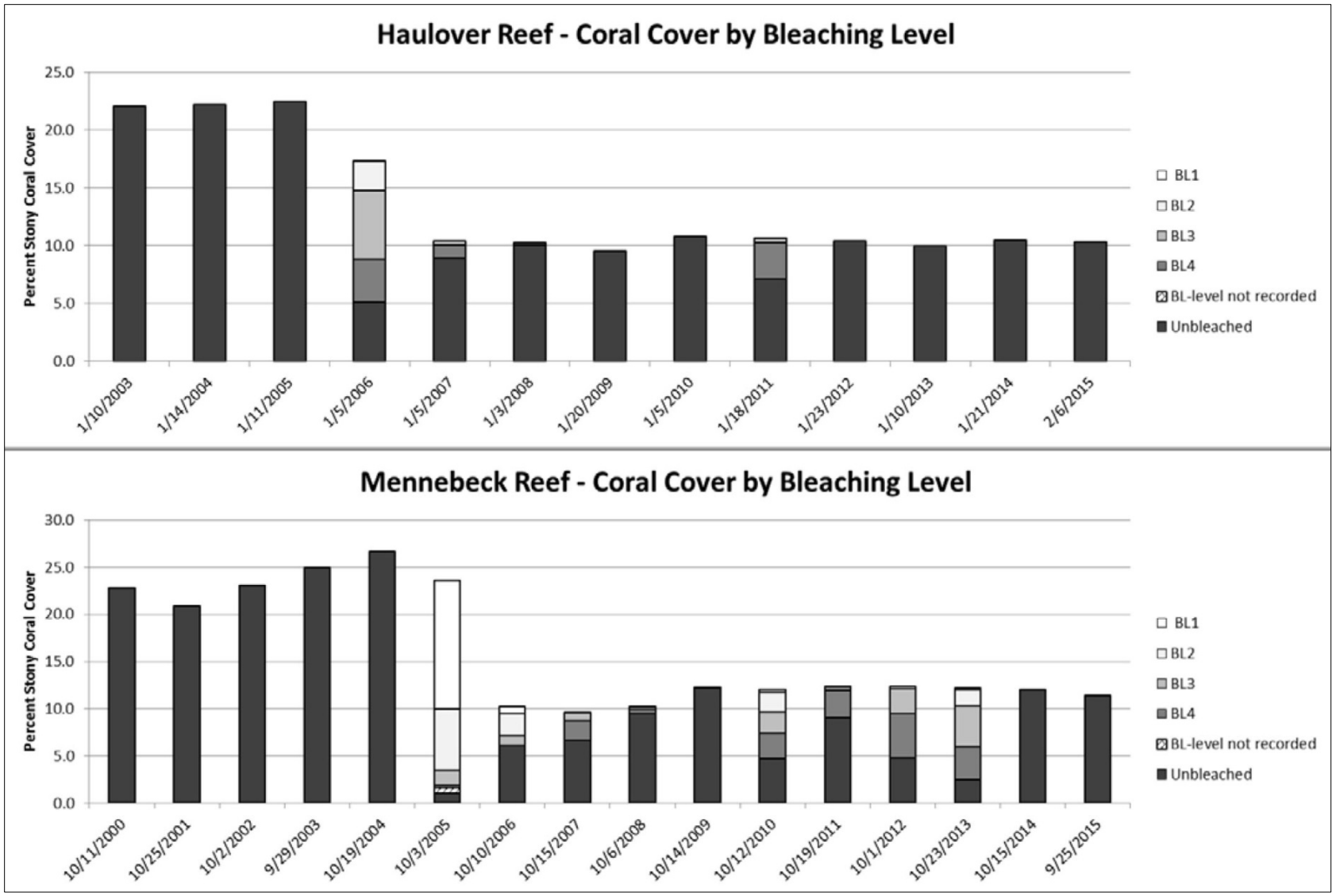


Figure App. K_C-2. Coral showing total percent coral cover partitioned by percent of coral bleached by year for Haulover (top) and Mennebeck reefs (bottom) from 2005-present.

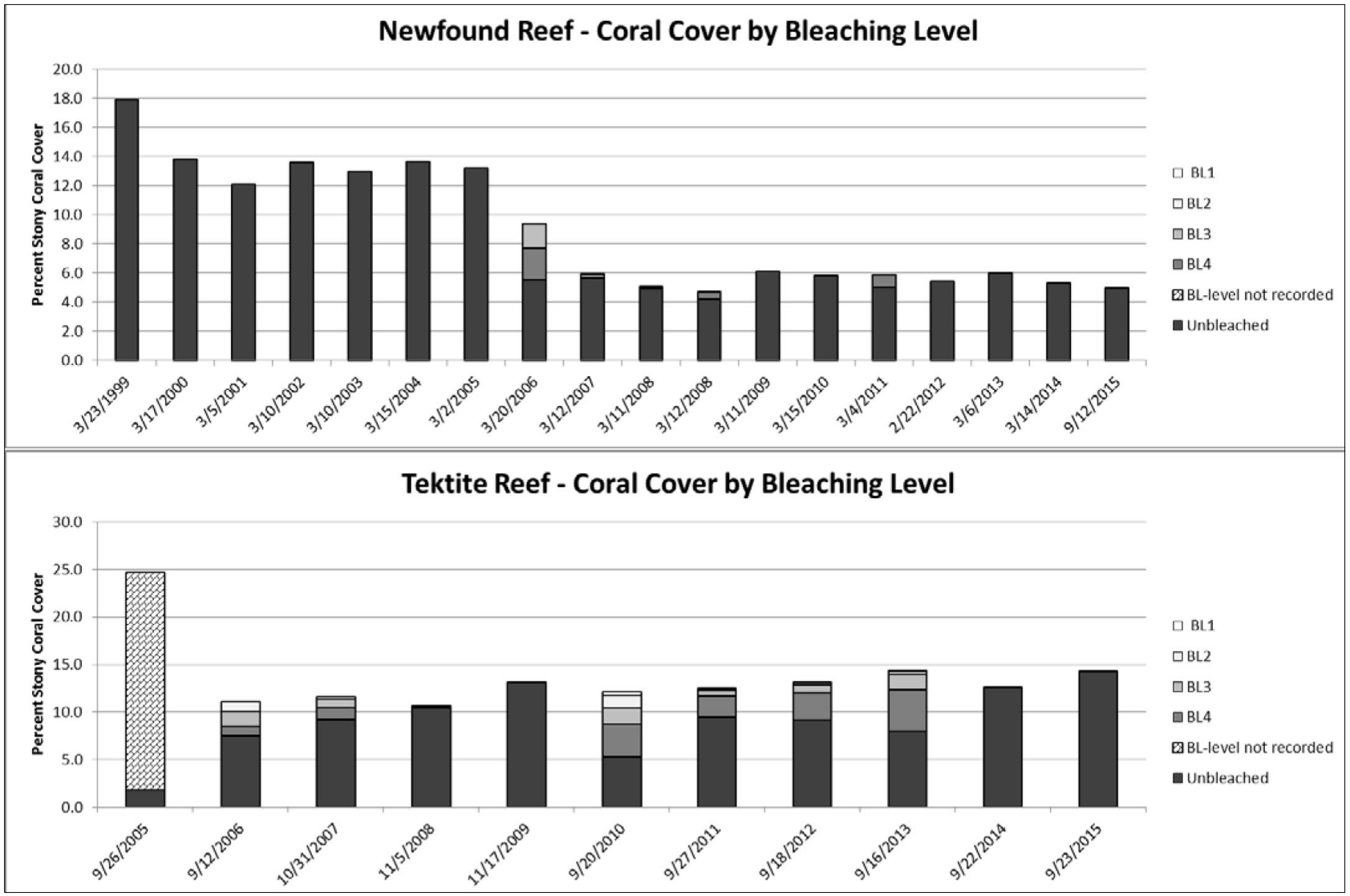


Figure App. K_C-3. Coral showing total percent coral cover partitioned by percent of coral bleached by year for Newfound (top) and Tektite reefs (bottom) from 2005-present.

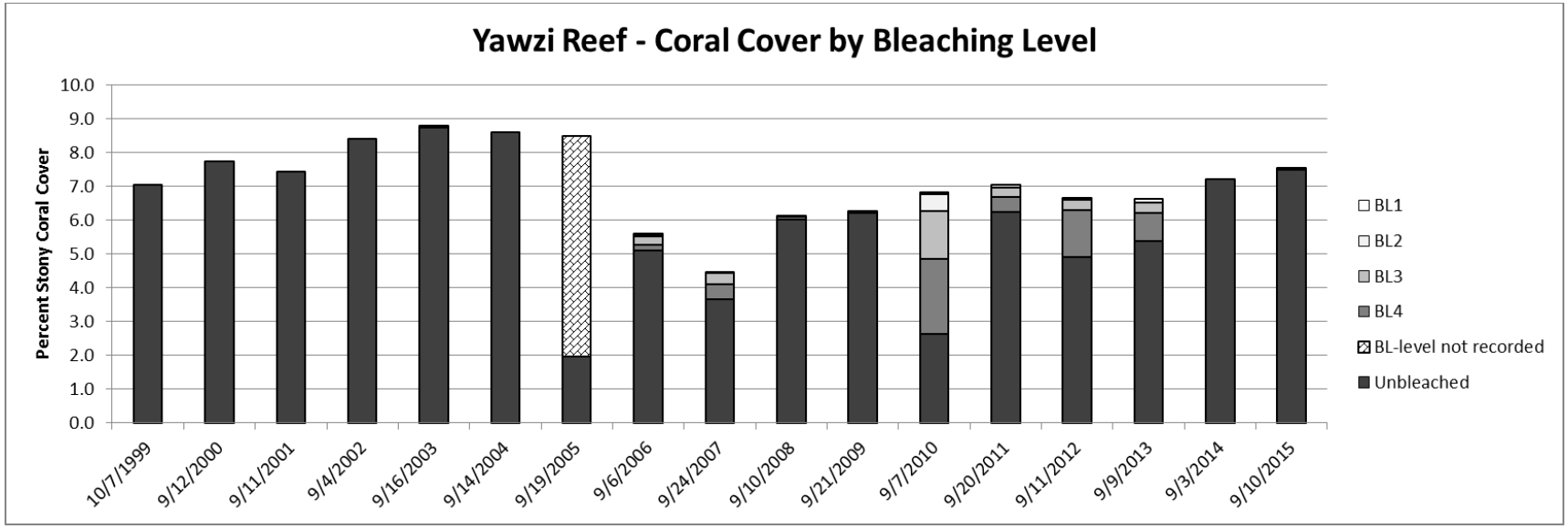


Figure App. K_C-4. Coral showing total percent coral cover partitioned by percent of coral bleached by year for Yawzi reef from 2005-present.

Appendix K_D. Coral Disease

Table App. K_D-1. Coral disease prevalence and colony counts averaged by site and year.

Site	Year	Month	Average Disease Colony Count	Average Stony Coral Colony Count	Average Fire Coral Colony Count	Average % Disease Prevalence
Haulover	2014	1	0.25	93.8	12.65	0.3%
	2015	2	0.8	139.625	15.7	0.5%
Mennebeck	2014	10	1.35	157.425	17.45	0.9%
	2015	9	0.7	114.4	18.9	0.7%
Newfound	2014	3	0.2	67.6	12.05	0.4%
Tektite	2014	9	1.95	160.925	9.2	1.1%
	2015	9	2.1	131.85	10.025	1.7%
Yawzi	2014	9	0.75	136.5	11.4	0.5%
	2015	9	1.35	172.075	13.225	0.8%

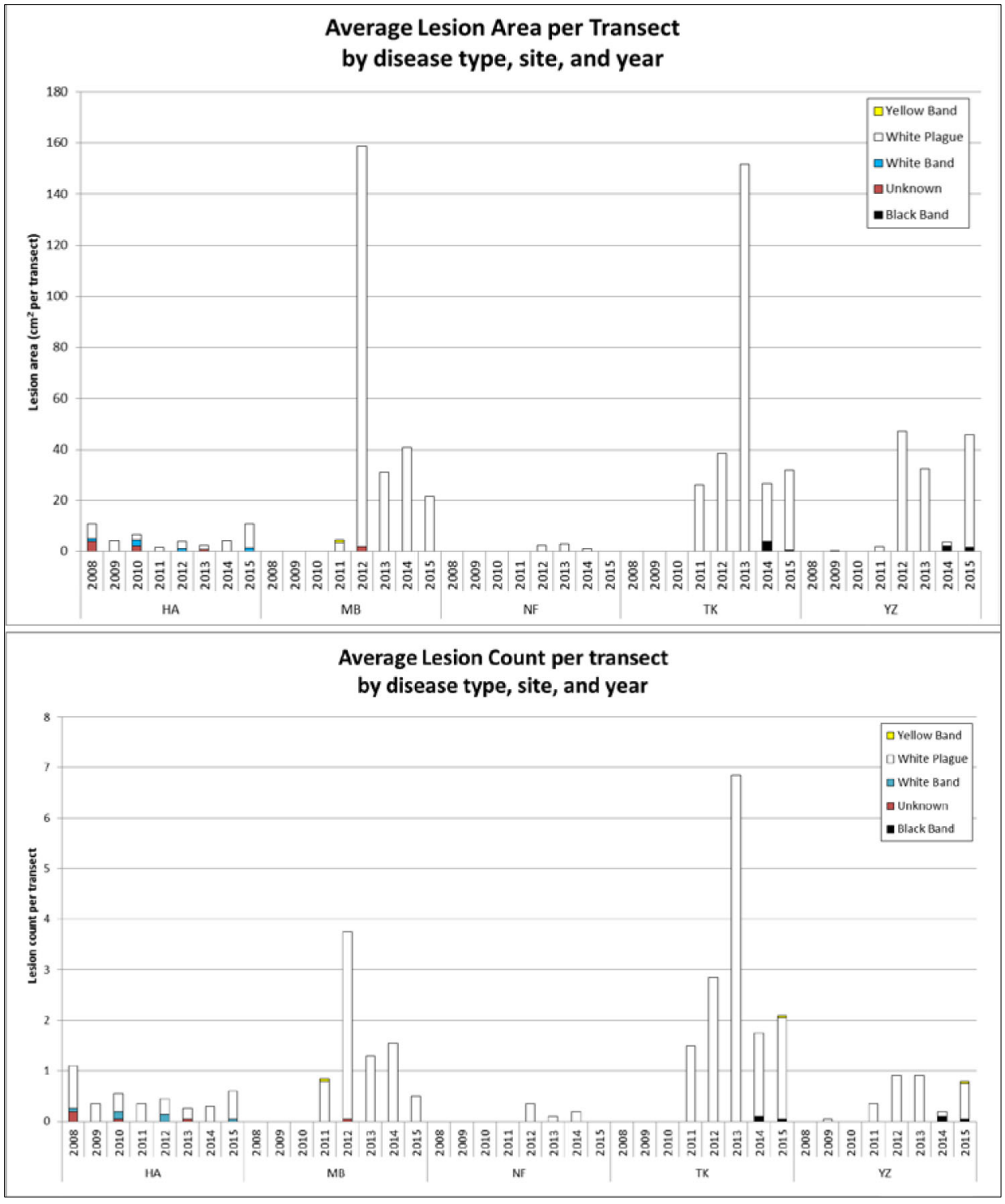


Figure App. K_D-1. Average lesions area (cm^2) by transect (top graph) and average # lesions by transect (bottom graph) by disease type, site, year and month sampled.

Appendix K_E. Long spined sea urchins

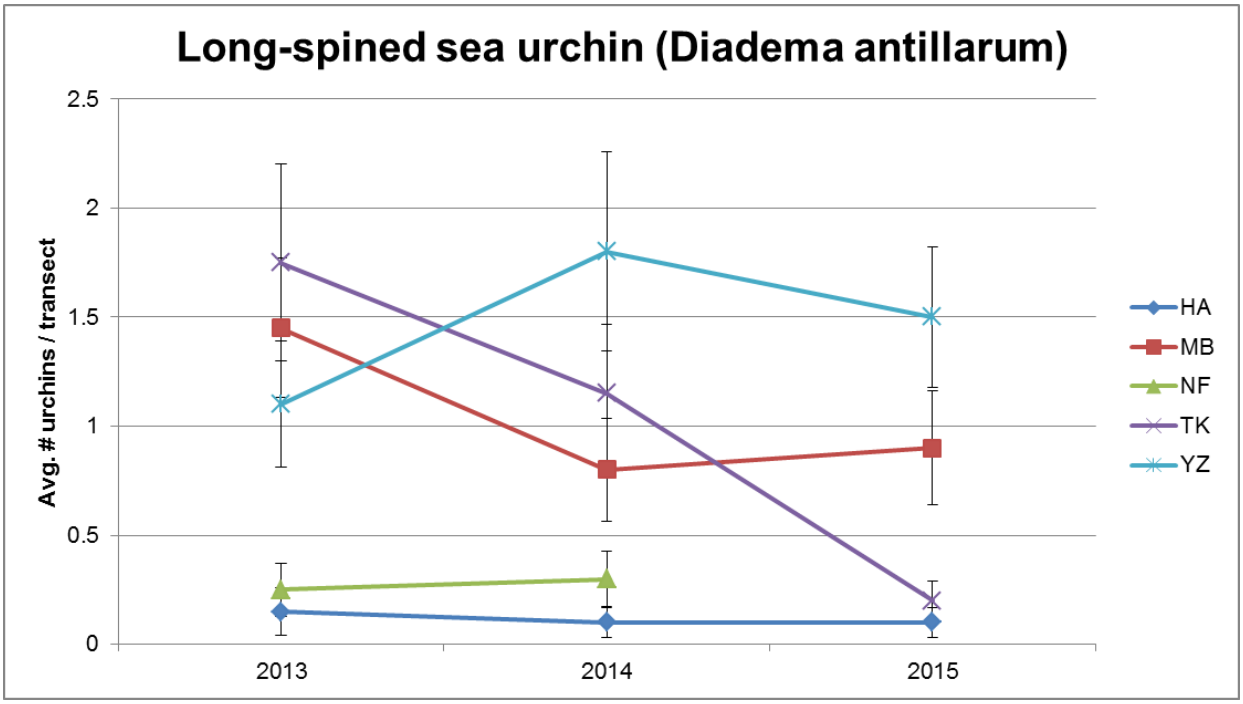


Figure App. K_E-1. Average # of *Diadema antillarum* / transect.

Appendix K_F. Water Temperature Graphs and Tables

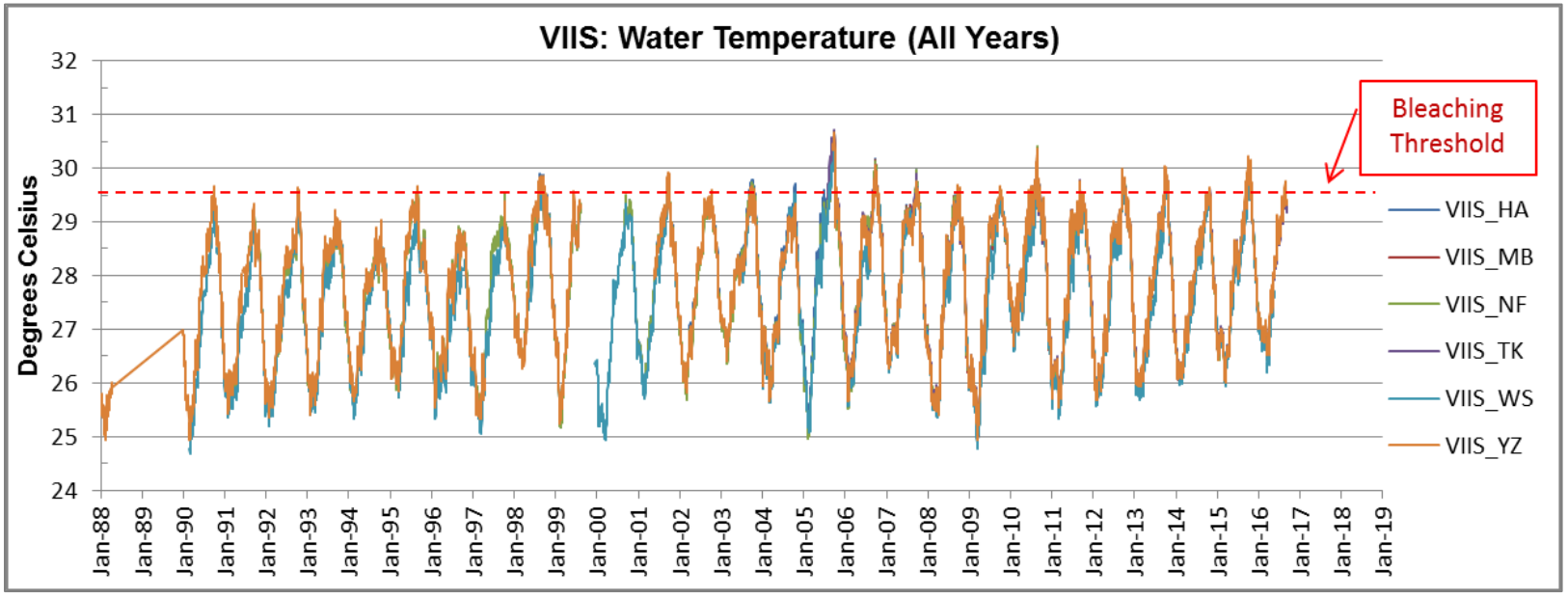


Figure App. K_F-1. St. John, USVI water temperature summary graphs. Graph of daily average of all water temperature data. Bleaching stress threshold of 29.5 °C is shown. Where multiple colors are not distinguishable, temperatures are similar across sites

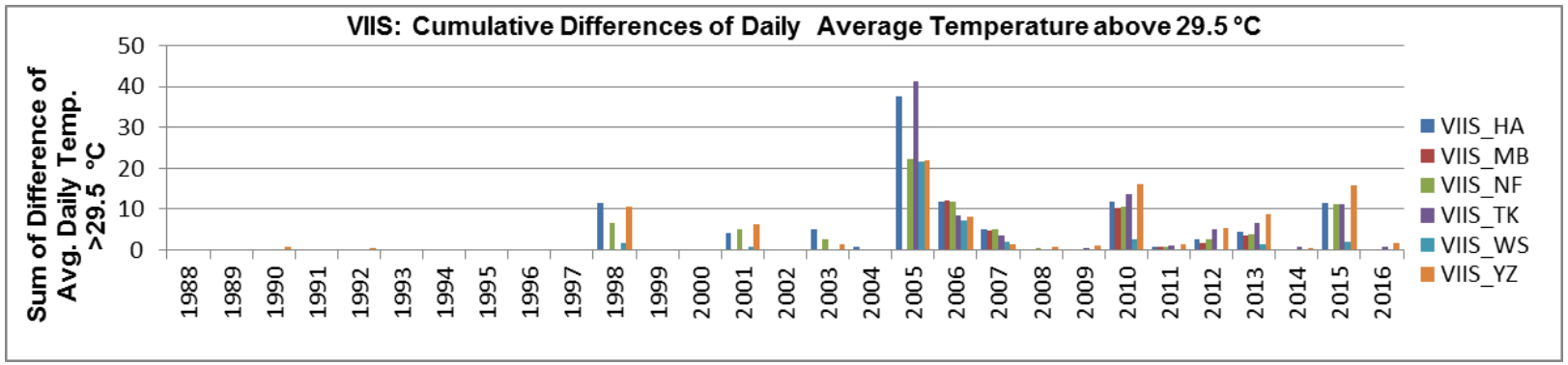


Figure App. K_F-2. Graph of cumulative sum of (daily average temperature – 29.5ºC) for days above the threshold.

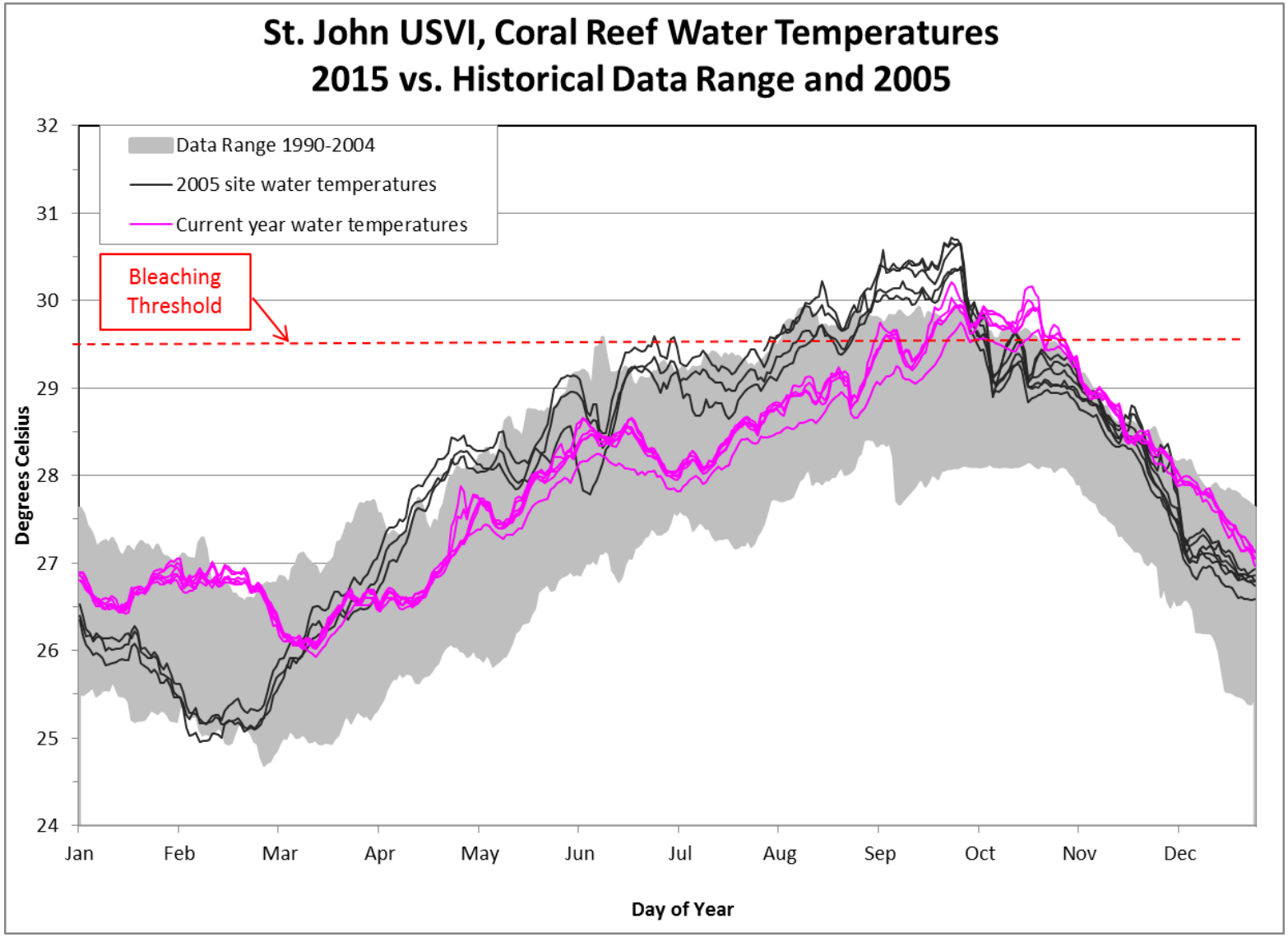


Figure App. K_F-3. The 2015 water temperature for Virgin Islands National Park compared with 2005 (a year with a major bleaching event) and the 1990-2004 range of daily average temperatures for all sites.

Appendix K_G. Transect level videography data

Table App. K_G-1. Haulover reef percent cover data by transect.

Category	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Mean	SD	SE
Coral	12.8	4.4	3.7	3.3	11.8	2.4	4.5	4.6	3.1	21.1	6.0	21.4	28.9	19.3	13.7	12.0	8.4	7.6	10.2	8.0	10.4	7.4	1.6
Coralline Algae	0.9	1.4	0.8	3.3	3.6	3.3	3.9	10.8	0.8	9.0	1.2	2.2	3.3	3.3	3.9	0.6	1.4	5.9	4.3	11.3	3.8	3.2	0.7
Dead Coral w/Turf Algae	35.4	39.5	36.4	52.7	42.7	24.4	43.5	48.5	24.6	27.9	37.3	35.6	38.4	49.2	48.3	45.9	31.5	23.2	33.3	40.8	38.0	8.7	2.0
Disease Coral	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gorgonians	4.5	11.5	14.4	14.6	16.7	10.7	10.3	12.0	9.2	13.2	8.4	6.8	12.5	10.6	4.7	11.8	3.2	10.3	12.7	14.7	10.6	3.6	0.8
Macroalgae	28.9	19.5	5.6	11.3	14.2	9.5	10.0	9.9	6.4	17.2	19.7	20.0	9.8	8.5	19.3	10.1	3.8	27.9	18.8	9.2	14.0	7.1	1.6
Unknown	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other (Live)	0.0	0.3	0.0	0.0	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Seagrass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sponge	2.1	2.7	1.7	1.8	2.7	1.2	0.6	0.9	4.5	1.1	2.7	1.4	0.3	0.3	2.8	3.1	0.0	2.1	1.5	0.3	1.7	1.2	0.3
Sand, Rubble, Pavement	15.5	20.8	37.3	13.1	7.9	48.5	26.9	13.3	51.3	10.4	24.8	12.6	6.8	8.8	7.3	16.5	51.2	23.2	19.1	15.6	21.5	14.5	3.2
Zoanthids	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.1	0.0

Table App. K_G-2. Mennebeck reef percent cover data by transect.

Category	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Mean	SD	SE
Coral	19.9	29.7	6.1	12.8	2.7	2.6	7.2	4.9	16.9	19.5	8.0	11.7	22.0	25.7	3.6	9.2	7.8	5.1	6.8	5.0	11.4	8.1	1.8
Coralline Algae	1.6	0.0	1.7	1.7	0.6	0.0	0.0	0.6	1.0	1.6	0.0	1.5	0.3	0.3	0.3	0.7	1.3	4.1	0.0	1.6	0.9	1.0	0.2
Dead Coral w/Turf Algae	42.4	34.7	41.3	38.6	21.3	35.1	37.5	32.7	34.8	41.6	33.8	31.5	41.7	27.0	22.4	35.6	28.2	30.4	41.8	19.2	33.6	7.1	1.6
Disease Coral	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gorgonians	2.9	14.7	16.7	23.4	15.9	10.8	17.8	10.1	10.1	7.8	3.5	10.2	8.4	10.6	3.6	12.5	18.8	5.4	12.0	14.8	11.5	5.5	1.2
Macroalgae	15.8	14.7	22.2	13.8	24.0	12.0	15.8	27.8	23.3	15.3	19.9	20.4	12.9	16.4	26.6	24.4	22.0	20.3	21.2	20.2	19.4	4.6	1.0
Unknown	0.6	0.0	0.0	0.7	0.0	0.3	0.0	0.0	1.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.1
Other (Live)	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Seagrass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sponge	3.9	5.0	3.8	2.1	5.4	2.6	2.6	2.1	4.1	5.8	5.1	5.4	5.8	5.8	1.2	2.6	2.6	2.8	3.1	5.0	3.8	1.5	0.3
Sand, Rubble, Pavement	12.9	1.3	8.2	6.9	30.2	36.5	18.8	21.4	8.8	8.1	29.6	19.2	8.7	13.8	42.4	14.9	19.4	32.0	15.1	34.1	19.1	11.5	2.6
Zoanthids	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table App. K_G-3. Newfound reef percent cover data by transect.

Category	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Mean	SD	SE
Coral	10.4	8.9	5.9	15.0	3.8	7.0	2.1	1.2	4.2	2.9	1.3	1.6	3.8	2.3	3.7	5.2	7.2	4.1	6.8	3.2	5.0	3.5	0.8
Coralline Algae	0.0	0.3	0.3	0.3	0.3	0.0	0.0	0.3	0.6	0.9	0.6	0.0	0.0	0.3	1.5	0.6	0.9	0.0	0.6	0.3	0.4	0.4	0.1
Dead Coral w/Turf Algae	42.0	49.4	36.8	36.9	38.5	35.8	33.2	26.5	35.4	37.1	31.7	21.3	42.1	41.5	29.1	41.9	22.6	38.2	40.4	36.3	35.8	6.9	1.5
Disease Coral	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gorgonians	5.2	12.7	16.3	7.8	9.8	6.6	15.1	6.4	8.9	14.7	19.1	12.2	11.7	12.4	7.4	11.9	8.8	7.3	13.7	6.9	10.8	3.8	0.9
Macroalgae	13.8	13.4	14.3	4.4	11.0	16.8	14.2	15.1	13.1	9.1	6.9	7.5	13.9	19.3	16.3	10.4	6.3	15.5	17.1	8.9	12.4	4.1	0.9
Unknown	0.3	0.6	0.0	0.3	0.0	0.3	0.0	0.3	0.0	0.3	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.3	0.0	0.2	0.2	0.0
Other (Live)	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.0	0.3	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.2	0.4	0.1
Seagrass	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	9.8	0.0	0.0	0.5	2.2	0.5
Sponge	3.7	1.9	3.3	9.4	3.5	3.2	4.5	4.4	4.8	4.7	2.2	2.5	4.4	4.9	5.8	7.0	6.3	4.1	4.3	2.0	4.3	1.8	0.4
Sand, Rubble, Pavement	24.5	12.7	22.8	25.3	33.1	30.4	30.9	45.9	32.7	30.0	37.9	54.9	23.4	19.0	36.2	22.9	47.5	19.6	16.8	42.4	30.4	11.1	2.5
Zoanthids	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table App. K_G-4. Tektite reef percent cover data by transect.

Category	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Mean	SD	SE
Coral	23.9	35.4	12.9	6.3	22.3	33.9	19.1	13.1	3.2	4.9	6.3	18.0	11.8	10.7	1.3	3.5	4.4	26.4	17.3	12.1	14.3	10.1	2.3
Coralline Algae	0.3	1.0	0.3	0.3	2.7	2.4	1.0	1.9	0.9	1.5	1.3	3.7	7.6	5.2	5.8	1.3	0.0	1.3	1.8	1.6	2.1	2.0	0.4
Dead Coral w/Turf Algae	26.5	22.9	25.7	31.1	36.3	24.3	33.0	30.8	31.5	29.6	23.0	26.0	41.2	44.2	43.5	30.6	14.5	36.3	37.4	28.9	30.9	7.5	1.7
Disease Coral	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gorgonians	3.6	1.9	0.3	0.9	1.5	0.3	1.9	1.9	0.6	1.2	0.7	1.0	0.6	4.6	6.4	3.2	0.6	2.6	0.6	4.9	2.0	1.7	0.4
Macroalgae	37.5	30.3	36.4	29.6	28.6	29.8	36.2	24.0	23.7	26.8	41.0	44.0	23.3	27.7	23.6	13.2	18.2	28.9	33.7	16.7	28.7	8.0	1.8
Unknown	0.0	0.0	0.0	0.3	0.6	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.3	0.6	0.3	0.0	0.2	0.2	0.1
Other (Live)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.3	0.0	0.3	0.0	0.0	0.0	0.1	0.0
Sponge	7.8	5.7	8.8	6.6	5.7	7.2	5.5	4.4	8.8	11.6	5.7	4.7	5.5	4.9	2.9	8.1	3.8	3.5	6.1	7.2	6.2	2.1	0.5
Sand, Rubble, Pavement	0.3	2.9	15.7	24.8	2.4	2.1	3.2	24.0	30.9	24.4	22.0	2.3	9.4	2.7	16.6	39.7	58.2	0.0	2.7	28.5	15.6	15.8	3.5
Zoanthids	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table App. K_G-5. Yawzi reef percent cover data by transect.

Category	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Mean	SD	SE
Coral	9.8	13.0	3.5	8.2	5.5	1.7	8.1	3.3	1.8	4.3	5.3	4.2	3.3	1.4	18.5	21.7	5.4	9.5	10.8	11.8	7.5	5.5	1.2
Coralline Algae	6.2	4.6	2.2	2.5	4.0	2.6	0.9	1.5	0.6	1.5	2.5	0.3	0.3	0.8	4.2	2.3	2.1	1.6	2.1	2.8	2.3	1.5	0.3
Dead Coral w/Turf Algae	44.6	59.9	33.8	45.0	46.0	66.7	49.9	56.7	53.0	42.9	52.2	61.5	59.2	67.7	46.5	41.1	51.6	34.0	47.1	41.2	50.0	9.7	2.2
Disease Coral	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.1	0.0
Gorgonians	3.0	2.8	1.6	1.6	1.7	3.4	5.5	3.0	2.1	2.5	1.2	2.4	2.4	1.1	3.6	2.8	4.8	3.9	4.8	5.3	3.0	1.3	0.3
Macroalgae	25.2	15.5	15.8	21.4	14.1	14.7	24.9	22.7	19.2	27.6	18.3	22.7	25.2	22.8	20.4	27.0	19.4	26.1	21.3	22.3	21.3	4.1	0.9
Unknown	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Other (Live)	0.7	0.4	0.3	0.6	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0
Sponge	5.6	2.1	2.2	4.1	5.2	6.6	2.6	5.1	4.9	6.4	6.8	7.8	6.3	4.5	3.4	2.8	5.1	6.5	5.7	6.2	5.0	1.7	0.4
Sand, Rubble, Pavement	4.9	1.8	40.7	16.4	23.3	4.0	8.1	7.8	18.3	14.7	13.7	1.2	3.0	1.7	2.8	2.3	11.6	18.3	8.1	10.2	10.6	9.7	2.2
Zoanthids	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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