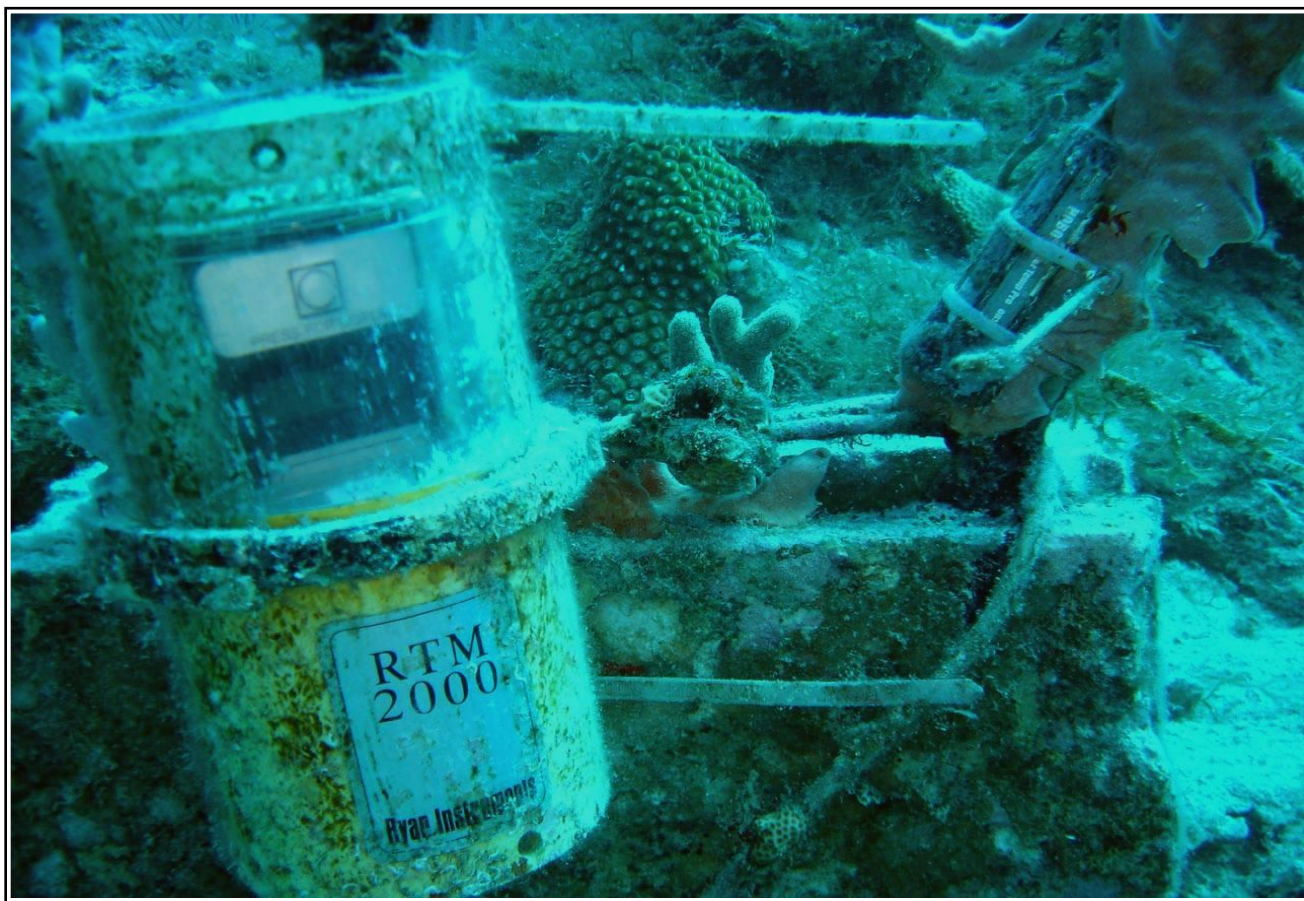




Coral Reef Ecosystem Water Temperature Monitoring Protocol, v. 1.00

Natural Resource Report NPS/SFCN/NRR—2013/679



ON THE COVER

Ryan Industries Thermisters and Onset Hobo Temperature Pro
Photograph by: Jeff Miller

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Natural Resource Report NPS/SFCN/NRR—2013/679

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Collaborative project of

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July 2013

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

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Please cite this publication as:

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.

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Summary

The Coral Reef Ecosystem Water Temperature Monitoring Protocol is a guide for the deployment, maintenance, and data management of South Florida/Caribbean Network (SFCN) temperature loggers. These loggers are currently deployed as part of a long-term coral reef monitoring program.

The three primary objectives for this monitoring protocol include:

1. Determine occurrence and duration of warm and cold water events that exceed thresholds known to cause stress (e.g., coral bleaching) to coral species for the purpose of interpreting trends in coral community metrics at sites established at Biscayne National Park (BISC), Buck Island Reef National Monument (BUIS), Dry Tortugas National Park (DRTO), Salt River National Historic Park and Ecological Reserve (SARI) and Virgin Islands National Park (VIIS).
2. Determine the status and trends in water temperatures at reef depth at coral monitoring sites established in BISC, BUIS, DRTO, SARI, and VIIS.
3. Assess any correlations of warm water events and/or cold water events with coral bleaching and/or disease outbreaks at sites established at BISC, BUIS, DRTO, SARI, and VIIS.

Temperature loggers are located at reef depth at a position generally representative of the site, typically at a centrally located coral reef monitoring transect pin. Most reefs are between 2-20m depth but can reach 30+m deep. Duplicate loggers are attached at the same point. The exception to this logger placement is SARI which has the greatest range of depths of any of the sites. In this case 2 locations were selected, one at a deep location and the second at a shallower location to better capture potential temperature differences.

Water temperature has been historically collected as a basic parameter of water quality monitoring efforts at coral reef sites throughout the world. There are numerous references in scientific literature suggesting a link between water temperature anomalies and coral colony survivorship. Coral bleaching occurs when the coral host loses zooxanthellae from its tissue due to physiological stress, most often associated with high water temperatures and/or high incidence of solar radiation. Additionally, unusual cold water temperatures have been found to affect the survivorship of corals and other reef dwelling organisms. The National Park Service (NPS) and United States Geological Survey (USGS) have collected water temperature data around St. John and VIIS since 1990. This effort has been expanded throughout the network, with 37 long-term *in-situ* water temperature monitoring sites presently managed by SFCN in BISC, BUIS, DRTO, SARI, and VIIS. The database developed with this protocol is a repository for SFCN parks water temperature data. Data collected under this protocol will also be useful to NPS efforts outside the network such as the Climate Change Response Program to help address climate change strategies. This data also complements *in situ* seawater temperature data information collected by several partners throughout the Florida reef tract.

List of Acronyms

AM = Amanda's Reef
BB = Ball Buoy
BKN = Bird Key Reef North
BK= Bird Key Reef
BISC = Biscayne National Park
BUIS = Buck Island Reef National Monument
DRTO = Dry Tortugas National Park
EVER = Everglades National Park
FWRI = Florida Fish and Wildlife Research Institute
HA = Haulover Reef
IRMA = Integration of Resource Management Applications
JHA = Job Hazard Analysis
MB = Mennebeck Reef
MOCC = Motor Boat Operations Certification Course
LH = Loggerhead Forest
NF = Newfound Reef
NOAA = National Oceanic and Atmospheric Administration
NRDT = Natural Resource Database Template
NPS = National Park Service
NPS RM4 = National Park Service, Reference Manual 4
SARI = Salt River Bay National Historical Park & Ecological Preserve
SFR = South Fore Reef
SFCN = South Florida/Caribbean Network
SOP = Standard Operating Procedure
STORET = Water Quality Storage and Retrieval Data Warehouse
SV = Santa's Village Reef
TK = Tektite Reef
USGS = United States Geological Survey
USVI = United States Virgin Islands
VIIS = Virgin Islands National Park
WS = Windspirit Reef
WSG = Western Spur and Grove
YZ = Yawzi Reef

Background and Objectives

Rationale and Background

The South Florida/Caribbean Network (SFCN) of the National Park Service (NPS) Inventory & Monitoring (I&M) program is responsible for monitoring natural resources in seven South Florida and Caribbean national parks (Figure 1). “Marine Benthic Communities” - were ranked as the highest priority “Vital Sign” for assessing the health and condition of SFCN parks (Patterson et al., 2008). The Coral Reef Ecosystem Water Temperature Protocol details the procedures for monitoring water temperature at coral monitoring sites, while a separate SFCN Coral Reef Monitoring Protocol (Miller et al., draft) describes coral communities monitoring in network parks. Although tied to the other protocol, the different technical equipment, field procedures, data management, QA/QC, and analysis procedures required are extensive enough to warrant this separate document. This protocol follows guidelines described in Oakley et al. (2003).

Water temperature has been historically collected as a basic parameter of water quality monitoring at coral reef sites throughout the world. Corals and many other marine organisms exist in a relatively narrow range of temperatures; coral stress and bleaching can occur outside this range. There are numerous references suggesting a link between water temperature anomalies and coral colony survivorship (e.g., Hoegh-Guldberg and Smith 1989, Glynn and D’Croz 1990, Brown 1997, Winter et al. 1998, Hoegh-Guldberg 1999, Rosenberg and Ben-Haim 2002, Miller et al. 2006, Whelan et al. 2007, Miller et al. 2009, Rogers et al. 2009, Lirman et al. 2011). Monitoring reef-depth temperature provides information on the intensity and duration of water temperature stress events, yielding better informed interpretation of trends in coral reef community metrics. In addition, such monitoring helps develop cause-and-effect hypotheses that allow management to better target research funding requests. For sites monitored during the summer (e.g., at Virgin Islands National Park), unusually warm temperatures may provide an early warning of potential bleaching events. This alerts park managers and can trigger additional, episodic monitoring. The significance of water temperature monitoring has recently taken on a new dimension in helping to understand ecological dynamics associated with global climate change (Sowder and Steel 2012).

Reef water temperature is a key factor when trying to analyze long-term coral reef monitoring results and explore the relationship between coral bleaching and survival. Zooxanthellae are algae that reside within coral tissue and give healthy coral its coloration. When zooxanthellae are lost, the underlying calcium carbonate skeletal structure is seen through the transparent tissue of the coral, giving it the “bleached” appearance characteristic of the phenomenon. This symbiotic relationship is important because the coral host receives most of its nutrients from zooxanthellae. Bleaching is associated with physiological stress, most-often related to high water temperatures and/or high incidence of solar radiation (Brown 1997, Hoegh-Guldberg 1999). Bleaching thresholds are species specific and also vary regionally; however, researchers consistently report that bleaching conditions occur at temperatures of 1°C above average maximum monthly temperatures (Hoegh-Guldberg 1999, Miller et al. 2009, Donner et al. 2005). SFCN utilizes theoretical bleaching thresholds of 29.5 °C in the USVI and 30.5 °C in Florida. This is consistent with Manzello et al. (2007), who report temperature bleaching thresholds of 29.4 °C for St. Croix

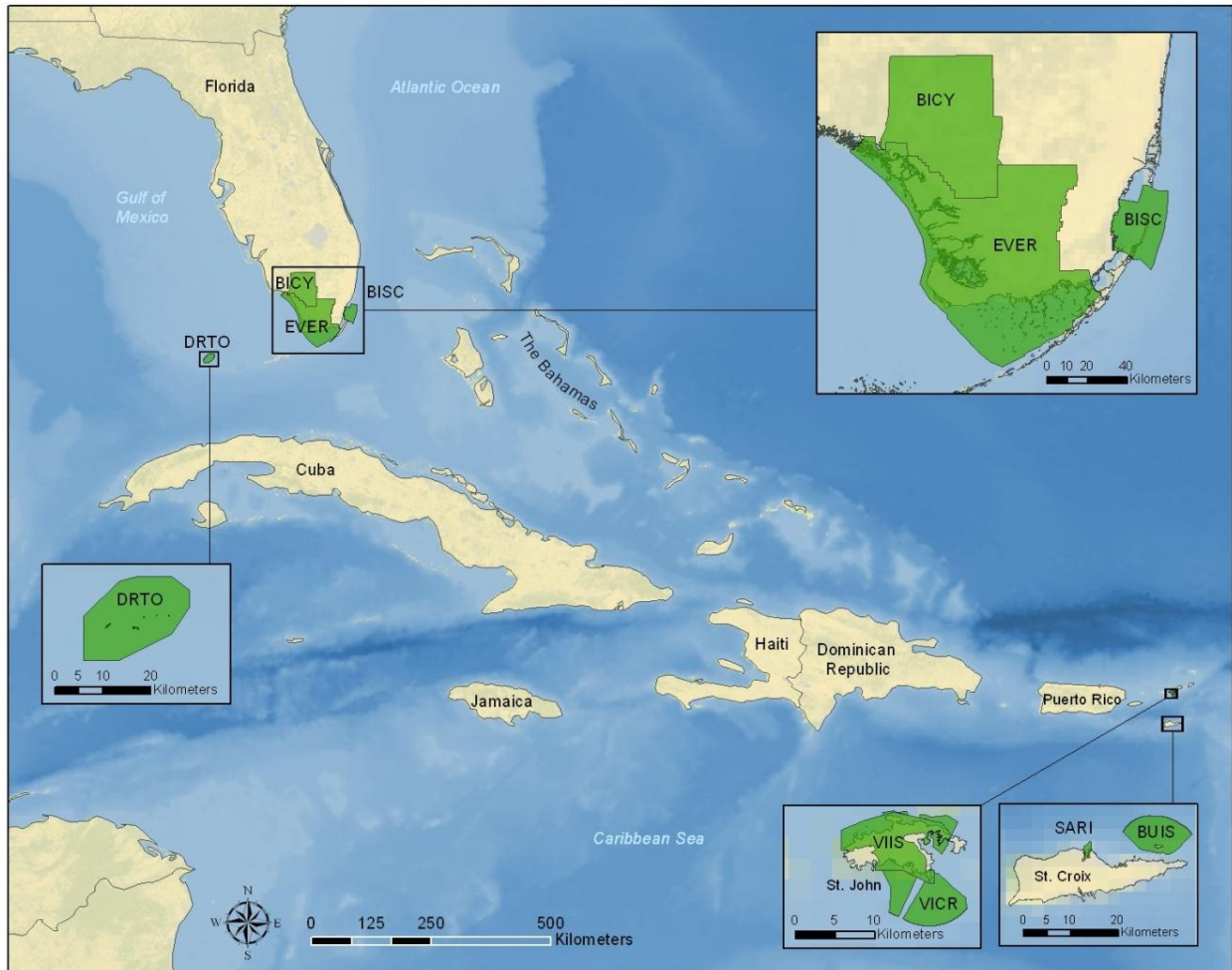


Figure 1. SFCN parks.

and 30.5 °C for the Florida Reef Tract. Personal (*in-situ*) observations along with these thresholds are used to guide monitoring activities with respect to potential bleaching events in SFCN parks. Additionally, unusually cold water temperature can cause bleaching and/or coral stress and has been found to affect the survivorship of corals, fish and other reef dwelling organisms (Mayer 1914, Davis 1982, Roberts et al. 1982, Jaap 1984, Lirman et al. 2011). SFCN uses the 16 °C threshold reported in Lirman et al. (2011) to guide monitoring activities during cold water events in South Florida parks. There is no historical evidence of cold-water bleaching events in the United States Virgin Islands (USVI).

Water temperature loggers are deployed at reef depth as part of a long-term reef monitoring program that originally began in VIIS in 1990. Reef depth is defined as the depth of the resource at a particular site. This contrasts with satellite Sea Surface Temperature (SST) measurements collected by the National Oceanic and Atmospheric Administration (NOAA) which measure the upper millimeters of the ocean. SFCN now conducts *in-situ* water temperature monitoring at 37 coral reef monitoring sites throughout network parks. SFCN monitors benthic conditions at “index” sites, which are moderate to high coral cover reefs selected due to management interest or previous research work. The network also monitors “extensive” sites, which are randomly distributed throughout the park in coral reef habitat of at least 5% live stony coral cover.

Currently the SFCN monitors temperatures at 13 index sites and 24 extensive sites in parks throughout the network. The Florida Fish and Wildlife Research Institute (FWRI) adopted a similar reef water temperature monitoring procedure that places loggers at reef depth in 2002. Partner institutions currently monitor water temperature throughout the Florida Reef Tract, including sites within both DRTO and BISC that are not reported in this protocol (<http://ocean.floridamarine.org/FLReefTractTemp/>).

National Park Service employee, Larry McLain, first started monitoring water temperature data at Yawzi Reef (VIIS) from 1/10/1988 – 4/12/1988 and then continuously from 12/27/1989. A temperature logger was installed at the Windspirit cruise ship grounding site on 2/26/1990. Data collection at Newfound Reef began 1/4/1991. Data has been collected nearly continuously at these three sites with occasional gaps, as the initial loggers had to be brought back to the office and downloaded before re-deployment. Water temperature monitoring increased concurrently with addition of new coral monitoring sites. Data collection began with Ryan[®] RTM2000 temperature loggers. In 2003, HOBO[®] water temp pro v1 data loggers replaced the Ryan[®] loggers and in 2005 HOBO[®] Water Temp Pro v2 data loggers replaced v1 sensors. In late 2005, loggers began to be deployed in pairs at each sample site to provide redundancy in case of logger malfunction.

Water temperature data has already proven useful in evaluating changes in coral communities by showing trends of thermal stress on reefs over time. In 2005, a coral bleaching event associated with abnormally high temperatures in the northeast Caribbean included SFCN USVI parks. Observations of wide-spread coral bleaching and elevated seawater temperatures triggered episodic monitoring that documented >60% loss in coral cover at the USVI index monitoring sites from 2005-2007 (Miller et al. 2006, Miller et al. 2009). Analysis of the temperature and benthic monitoring data revealed temperature was positively correlated with coral bleaching. However, the majority of coral mortality was caused by a post-bleaching disease outbreak (Whelan et al. 2007, Miller et al. 2009). In 2010, warm water temperature again triggered episodic benthic monitoring. Additionally, temperature data from these two events helped define the effect of tropical weather systems (tropical waves, storms and hurricanes) on water temperature. This reef water temperature data-set has been released and was used in multiple presentations. Several articles have also been published using this data-set (e.g., Miller et al. 2003, Miller and Patterson 2005, Miller et al. 2006, Miller et al. 2009).

In this protocol, SFCN researchers have established Standard Operating Procedures (SOPs) to ensure that data is collected, analyzed and stored properly, data consistency is maintained, and to provide for personnel safety.

Measurable Objectives

The three primary objectives for this monitoring protocol include:

1. Determine occurrence and duration of warm and cold water events that exceed thresholds known to cause stress (e.g., coral bleaching) to coral species for the purpose of interpreting trends in coral community metrics at sites established at BISC, BUIS, DRTO, SARI, and VIIS.
2. Determine the status and trends in water temperatures at reef depth at coral monitoring sites established in BISC, BUIS, DRTO, SARI, and VIIS.
3. Assess any correlations of warm water events and/or cold water events with coral bleaching and/or disease outbreaks at sites established at BISC, BUIS, DRTO, SARI, and VIIS.

Reef depth is defined as the depth of the resource at a particular site. SFCN coral reef monitoring sites are typically between 2-20m depth but can reach 30+ m deep.

Sampling Design

Rationale for selecting this sampling design over others

Monitoring water temperatures using data loggers placed *in situ* at reef depth provides data directly commensurate to documenting the stress experienced by coral reef ecosystem species. This approach is also efficient, cost-effective, and has low environmental impact.

Applicability to coral reef monitoring

Sea surface measurements that occur with standard water quality sampling and satellite generated data generally do not necessarily reflect benthic conditions. Satellites provide large area sea surface water temperatures and use passive multi-channel infrared measurements that correlate to water temperatures in the sea surface shallow water layer (0.1 mm depth). Satellite observations are generally less frequent (e.g., twice per week) when compared to *in-situ* loggers (every two hours). And satellite observations may be interrupted at critical times by atmospheric conditions such as storm clouds generated during tropical storms and hurricanes. Temperature measurements at reef depth are more representative of the water temperatures affecting the coral reef environment. Reef depth temperature monitoring is critical to connecting temperature changes with effects on benthic organisms. Co-locating data loggers at sites with benthic monitoring allows for combined analysis and establishment of potential linkages between water temperature and changes in these organisms. This monitoring provides efficient and relatively inexpensive data collection of a covariate that is important to understanding coral reef ecosystems.

Efficiency and cost effectiveness

Minimal person time is required for sensor deployment and retrieval as this occurs simultaneous with coral reef monitoring. Sensors have minimal cost (approximately \$120.00 per sensor). The data sensors used have adequate precision (± 0.2 °C), simple operating procedures, and low maintenance requirements.

Very low environmental impact

HOBO® Water Temp Pro loggers are made of inert material and only need to be downloaded periodically (typically annually), reducing the need for frequent site visits. Loggers are attached via cable ties to rebar, sand screws, or pins (used as part of the benthic monitoring protocol).

Site selection and history

Water temperature is measured as a covariate indicator of reef stress at monitored reefs and site selection is dependent on the coral monitoring sampling design as described in SFCN's Coral Reef Monitoring Protocol (Miller et al., draft). Water temperature data is collected at:

- a) "Index sites" ranging in size from 7,125 – 40,753 m², between 2-20m deep, which are selected based upon management interest, historical work, or otherwise of considerable reef structure, coral cover, complexity and diversity. Index sites consist of 20 randomly placed, permanently installed coral monitoring transects.
- b) "Extensive sites" are smaller sites around 1600 m² in size typically consisting of 4 permanent coral monitoring transects. Sites are randomly selected from a larger zone, area, or reef of interest that is too large to effectively monitor using an index site approach.
- c) A temperature monitoring only site called "Windspirit" was established in 1990 in VIIS at the site of a cruise ship grounding.

The population of interest for water temperature measurement is the water that comes in contact with the benthic community at the coral reef sites. At this scale of interest, one temperature sampling location per coral reef site is considered adequate to make this generalization, as differences in water temperature across the site are expected to be small relative to the daily and seasonal range of temperatures. Most monitoring sites have minimal depth change across the site; however at Tektite Reef the bottom slopes from 6 m at the shallower end to 19 m at the deepest transect. At SARI the site transects range from 9 – 29 m deep.

Initially one data logger was installed per monitoring site. From late 2005 onwards, a second logger was gradually added to sites at the exact same position to provide data redundancy in case one logger is lost or malfunctions.

The loggers are located at reef depth at a position generally representative of the site. Historically, this involved attaching the loggers to a transect pin, Aquamap station attachment, or buoy station anchor. As part of the current protocol, loggers at extensive sites are attached to the center pin, or alternate pin when necessary (e.g., center pin is driven too deep into substrate to allow attachment). At index sites, loggers are placed at a transect pin that is generally of average site depth. Duplicate loggers are attached at the same point and the location recorded. The exception is SARI which has the greatest range of depths of any of the sites. In this case 2 locations were selected, one at a deep location and the second at a shallower location to better capture potential temperature differences.

Number and location of sampling sites

Two loggers per site are located at the following locations: VIIS (5 index, 1 Windspirit), BUIS (2 index), SARI (2 locations at 1 index site), DRTO (2 index, 24 extensive) and BISC (2 index). HOBO[®] Water Temp Pro v2 loggers are currently installed at all sites. Sites, locations, depths, and deployment dates are given in Table 1.

Virgin Islands National Park (VIIS):

Ryan[®] RTM2000 temperature loggers were installed at reef depth in Yawzi Point (YZ) in Dec. 1989 with some preliminary data collection in 1988, Windspirit (WS) in Feb. 1990, Newfound Bay (NF) in Jan. 1991, and Haulover Bay (HA) in Aug. 1998 (Figure 2). These loggers were later replaced with HOBO[®] loggers. Eventually two more sites were added: Tektite (TK) in Aug. 2005 and Mennebeck (MB) in Oct. 2005, using HOBO[®] loggers. In 2005, a duplicate logger was attached to the same mounting location as the original sensor.

In addition to SFCN monitoring, USGS scientists have deployed temperature loggers at locations around VIIS specific to their studies, not covered or managed by this protocol (e.g., Elkhorn coral studies at Hawksnest, Haulover Bay; coral monitoring in Hurricane Hole).

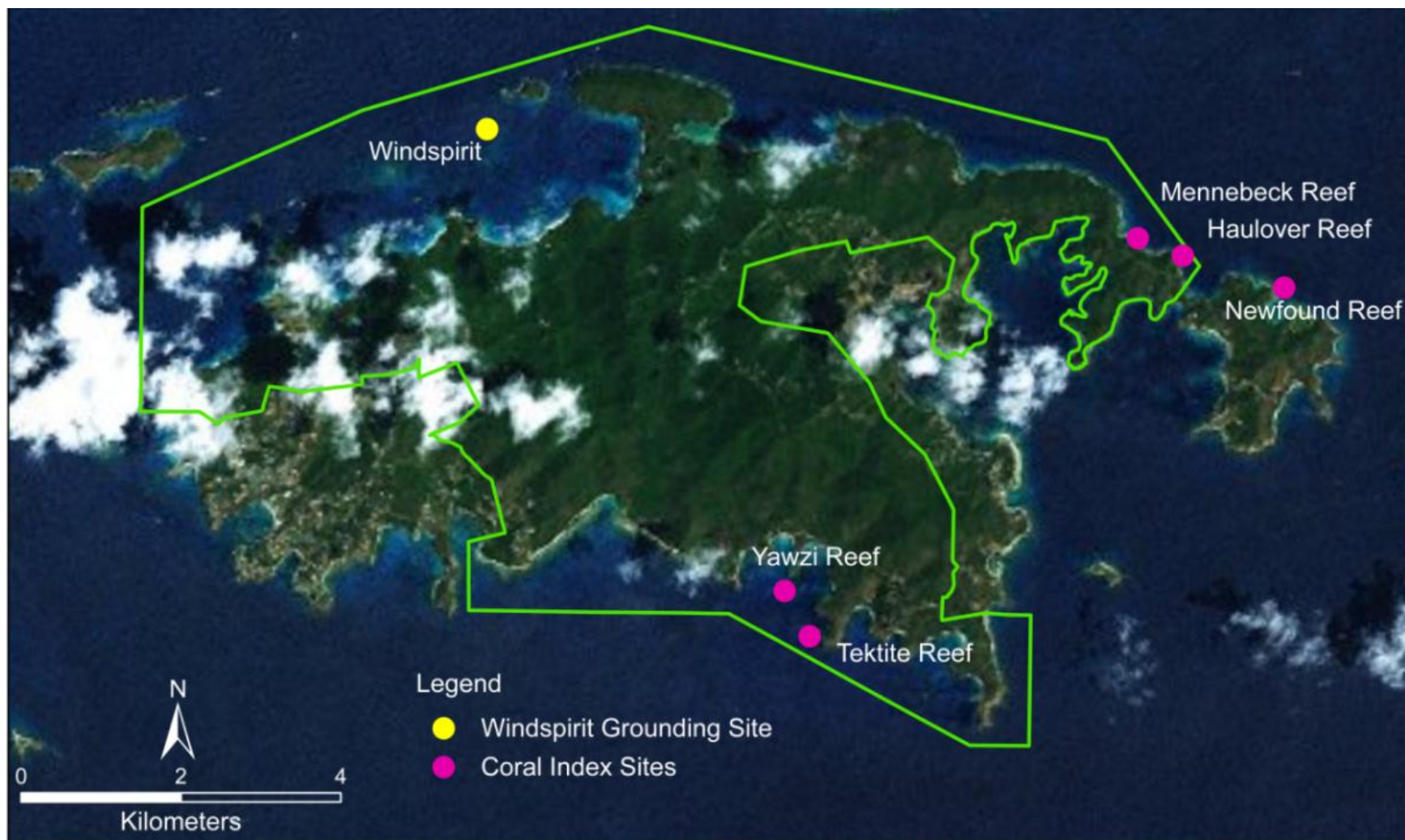


Figure 2. VIIS and St. John index sites, and Windspirit grounding site.

Buck Island Reef National Monument (BUIIS)

Two HOBO® Water Temp Pro v1 loggers were installed per site in BUIIS (Figure 3) at Western Spur and Groove (WSG) and South Fore Reef (SFR).

In addition to SFCN monitoring, a Ryan® RTM2000 temperature logger was deployed at the eastern forereef slope in 1991, and was replaced with two HOBO® Water Temp Pro v1 data loggers in 2003. An additional monitoring site was established at this time on the backreef at an approximate depth of two meters. BUIIS personnel maintain these loggers and record the data. These data are currently not included in this protocol or database.



Figure 3. BUIIS index sites.

Salt River Bay National Historic Park & Ecological Preserve (SARI)

Four HOBO® Water Temp Pro v2 loggers were installed in 2012, two at Spur and Groove (depth = 11 m) and two at West Wall (depth = 28 meters; Figure 4). These loggers can help detect water temperatures variance due to the unique submarine canyon feature at SARI.



Figure 4. SARI index site showing locations for both sets of loggers.

Biscayne National Park (BISC)

Two HOBO® Water Temp Pro v1 loggers per site were installed at BISC in 2005 (Figure 5) at Amanda's Reef (AM) and Ball Buoy (BB). These were replaced with two HOBO® Water Temp Pro v2 loggers per site in 2006.

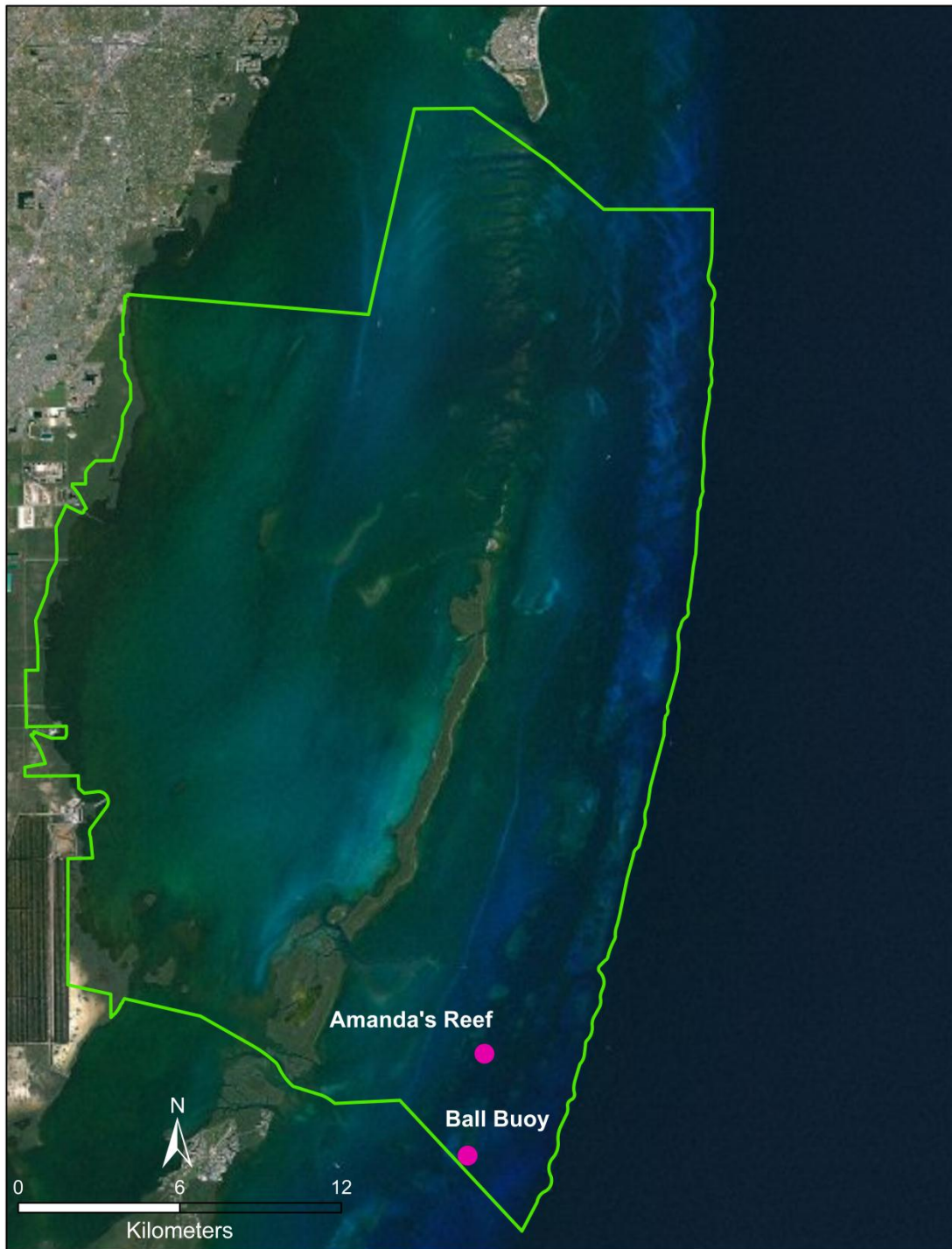


Figure 5. BISC index sites.

Dry Tortugas National Park (DRTO)

One HOBO® Water Temp Pro v1 logger per site was installed in 2005 at Bird Key (BK) and Bird Key North (BKN) (Figure 6). These were replaced with two HOBO® Water Temp Pro v2 loggers per site in 2006. The SFCN established 18 park wide coral reef monitoring sites in 2008. Nine of those are located inside the Research Natural Area and 9 outside. Researchers placed two HOBO® Water Temp Pro v2 loggers at each of the 18 extensive sites. The network also established six more extensive sites in 2012 to better monitor Loggerhead Reef (LH) and the northeastern Santa's Village reef (SV), with two temperature loggers installed at each of those sites. Loggerhead Reef also includes I-05 and I-50 extensive sites.

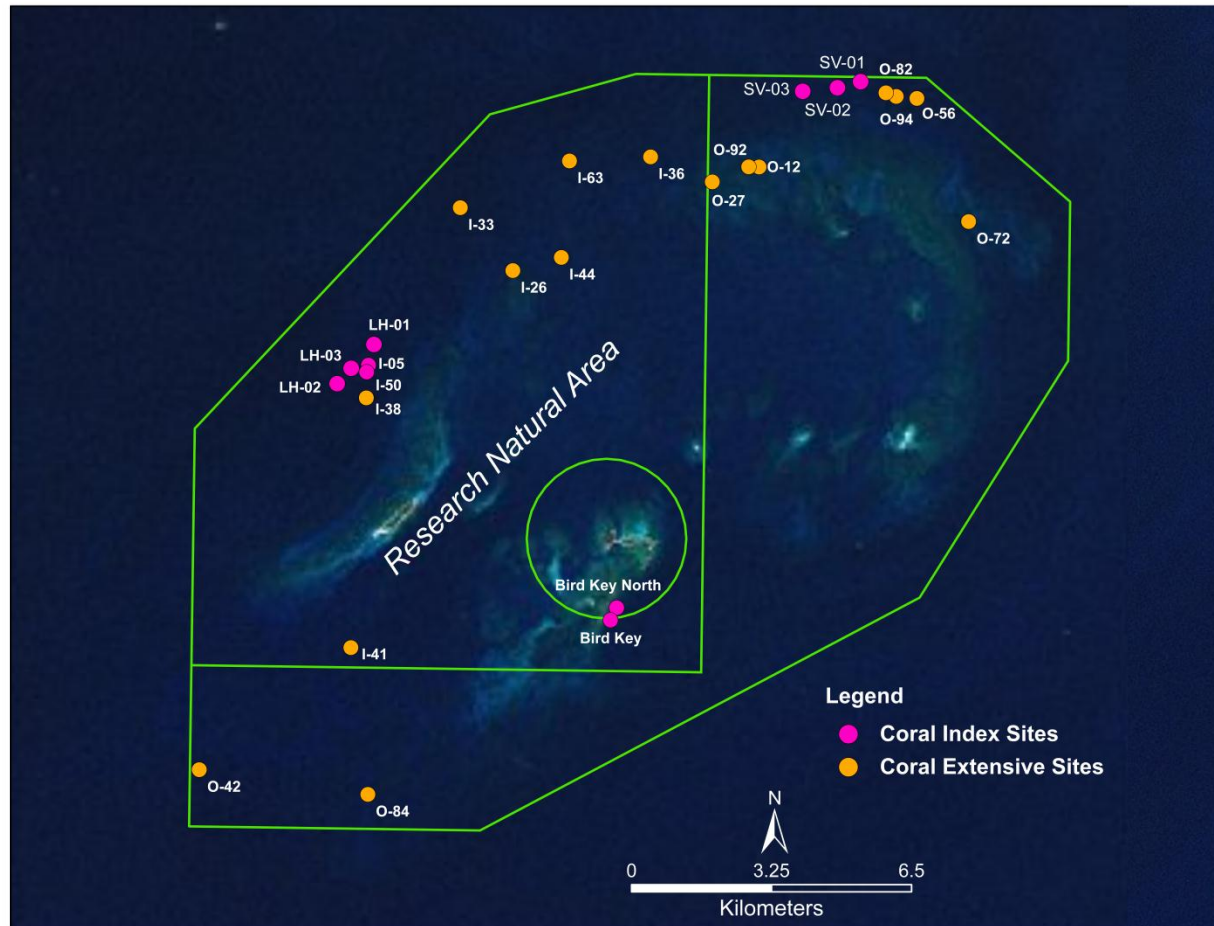


Figure 6. DRTO extensive and index sites.

Table 1. Site locations and descriptions.

Park	Location Name	Station Name	1st deployment	Depth (m)	UTM Zone	Easting	Northing	Location Details	Data Gaps*
VIIS	Yawzi Reef	VIIS_YZ	Jan. 1988	11	20	317605	2025783	On concrete block/pin station, in reef, near chain transect pin #7	4/12/1988 – 12/27/1989 6/3/1991 – 6/12/1991 4/13/1997 – 10/2/1997 8/12/1999 – 5/18/2001 11/18/2004 – 9/13/2005 11/30/2010 – 3/1/2011
VIIS	Windspirit Grounding	VIIS_WS	Feb. 1990	12	20	313855	2031537	On dedicated pin in reef for loggers	4/11/1991 – 4/16/1991 11/25/1998 – 12/16/1999 12/13/2001 – 6/26/2003 8/15/2006 – 8/30/2006
VIIS	Newfound Reef	VIIS_NF	Jan. 1991	8	20	323744	2029627	On Pin 1 of chain transect pin series, in reef	6/3/1991 – 8/1/1991 8/12/1999 – 8/29/2000 3/18/2004 – 4/2/2004 1/8/2009 – 6/4/2009
VIIS	Haulover Reef	VIIS_HA	Aug. 1998	8	20	322557	2029877	On dedicated pin in reef for loggers	8/12/1999 – 9/23/2000 11/3/2001 – 3/27/2002 3/18/2004 – 4/2/2004
VIIS	Tektite Reef	VIIS_TK	Aug. 2005	18	20	317870	2025305	Base Station 1 (B1); off reef edge in sand/seagrass	
VIIS	Mennebeck Reef	VIIS_MB	Oct. 2005	14	20	322020	2030198	Base Station 1 (B1); off reef edge in sand/seagrass	
BUIS	Western Spur & Groove	BUIS_WSG	May 2001	9	20	326617	1968704	Base Station 1 (B1)	5/2001 - 6/2/2003
BUIS	South Fore Reef	BUIS_SFR	Feb. 2002	12	20	329328	1967164	Base Station 1 (B1)	2/2002 – 3/14/2006
SARI	Salt River Canyon	SARI_SG	April 2012	11	20	313539	1967267	Transect #01, terminal pin – spur and groove	
SARI	Salt River Canyon	SARI_WW	April 2012	28	20	313366	1967302	Transect #15, terminal pin – west wall	
BISC	Ball Buoy	BISC_BB	June 2004	6	17	582099	2800441	Transect #19, origin pin	6/8/2004 – 6/15/2006
BISC	Amanda's Reef	BISC_AM	June 2004	3	17	582710	2804159	Stainless Steel ring on bottom near mooring ball	6/15/2005 – 6/15/2006

Table 1 (Continued).

Park	Location Name	Station Name	1st deployment	Depth (m)	UTM Zone	Easting	Northing	Location Details	Data Gaps*
DRT0	Bird Key Reef	DRT0_BK	Oct. 2004	11	17	310622	2723243	Base Station 3 (B3)	
DRT0	Bird Key North Reef	DRT0_BKN	June 2005	12	17	310741	2723436	Base Station 1 (B1)	6/7/2006 – 6/9/2007
DRT0	Inside RNA 05	DRT0_I05	May 2008	17	17	304993	2729092	Center Pin	
DRT0	Inside RNA 26	DRT0_I26	May 2008	4	17	308343	2731286	Center Pin	
DRT0	Inside RNA 33	DRT0_I33	May 2008	12	17	307123	2732743	Center Pin	
DRT0	Inside RNA 36	DRT0_I36	May 2008	10	17	311540	2733923	Center Pin	
DRT0	Inside RNA 38	DRT0_I38	May 2008	14	17	304943	2728332	Center Pin	
DRT0	Inside RNA 41	DRT0_I41	May 2008	14	17	304584	2722537	Center Pin	
DRT0	Inside RNA 44	DRT0_I44	May 2008	11	17	309468	2731591	Center Pin	
DRT0	Inside RNA 50	DRT0_I50	May 2008	16	17	304951	2728932	Center Pin	
DRT0	Inside RNA 63	DRT0_I63	May 2008	12	17	309658	2733828	Center Pin	
DRT0	Outside RNA 12	DRT0_O12	May 2008	3	17	314057	2733689	Center Pin	
DRT0	Outside RNA 27	DRT0_O27	May 2008	3	17	312972	2733343	Center Pin	
DRT0	Outside RNA 42	DRT0_O42	May 2008	20	17	301065	2719704	Center Pin	
DRT0	Outside RNA 56	DRT0_O56	May 2008	13	17	317719	2735279	Pin #2	
DRT0	Outside RNA 72	DRT0_O72	May 2008	3	17	318920	2732422	Pin #3	
DRT0	Outside RNA 82	DRT0_O82	May 2008	14	17	317000	2735409	Center Pin	
DRT0	Outside RNA 84	DRT0_O84	May 2008	13	17	304978	2719131	Pin #4	
DRT0	Outside RNA 92	DRT0_O92	May 2008	5	17	313817	2733692	Center Pin	
DRT0	Outside RNA 94	DRT0_O94	May 2008	13	17	317239	2735325	Center Pin	
DRT0	Loggerhead Forest 1	DRT0_LH1	June 2012	16	17	305119	2729569	Center Pin	
DRT0	Loggerhead Forest 2	DRT0_LH2	June 2012	17	17	304592	2729016	Center Pin	
DRT0	Loggerhead Forest 3	DRT0_LH3	June 2012	16	17	304267	2728661	Center Pin	
DRT0	Santa's Village Reef	DRT0_SV1	June 2012	17	17	315071	2735442	Center Pin	
DRT0	Santa's Village Reef	DRT0_SV2	June 2012	16	17	315877	2735527	Center Pin	
DRT0	Santa's Village Reef	DRT0_SV3	June 2012	16	17	316417	2735666	Center Pin	

* See tblMissingDataRanges in MSAccess database for notes.

** An initial pilot data collection at Yawzi Reef ran from 1/10/1988-4/12/1988.

Sampling frequency, timing and replication

HOBO® Water Temp Pro v2 sensors are continuously deployed, sampling at two hour intervals. Two sensors are synchronized and deployed together at each site to provide redundancy. Temperature data from the two sensors are considered sub-samples and are averaged for analyses. Sensors are inspected and downloaded once a year, before impending hurricanes, or more frequently when a potential thermal stress event occurs.

Level of change that can be detected for the type of sample being instituted

HOBO® Water Temp Pro v1 and v2 operation range is -20° to 50 °C in water ± 0.2 °C with a resolution of 0.02 °C at 25 °C. Typical analysis includes detection of unusual temperature patterns and comparison of mean seasonal or monthly temperatures to a baseline.

Field Methods

Field preparations and equipment setup

Water temperature monitoring sites are co-located with coral monitoring sites (currently SFCN monitors 37 sites). Access to the sample sites are addressed in the SFCN coral reef monitoring protocol. No permits are required for SFCN staff to collect temperature data in any of the SFCN parks.

Field crews will review the field log before commencing field operations. A field log is maintained with specific information pertaining to each data logger. Serial number, date, time of deployment, logger program launch time, site identification, and any comments are recorded in this log. Depth and coordinates are recorded the first time the loggers are installed.

Replacement loggers will be available in case the deployed loggers fail or are missing. The HOBO[®] waterproof shuttle should be time-synchronized before going into the field.

When new loggers are to be deployed either at new sites or replacing those at existing sites, the accuracy of each logger is tested prior to field deployment as described in “SOP 1 –Testing the precision of HOBO[®] data loggers in a Cold Bath” (see also Sowder and Steel 2012). Loggers with $> 0.15^{\circ}\text{C}$ difference from the average of the other loggers will not be deployed in the field. Most loggers tested will record values well within the error range, but any logger that records average values outside $\pm 0.15^{\circ}\text{C}$ should not be used, as deploying a logger with initial readings so close to an unacceptable threshold is not worth the loss of precision and the consequent QA/QC personnel time needed for the resulting data. Loggers with average values outside $\pm 0.2^{\circ}\text{C}$ can be returned to the manufacturer as faulty.

Field operations

The loggers are placed in plastic boots and caps (provided by manufacturer) and installed at reef depth (2-30 m); thus, direct sunlight should not bias temperature readings (see Sowder and Steel 2012). Loggers are installed/downloaded/retrieved by a dive team and are attached to a coral community monitoring center pin, transect pin, Aquamap station attachment, or buoy station with zip ties. Monitoring occurs concurrently with coral reef community monitoring (Miller et al Draft) and other member(s) of the dive team are implementing aspects of that protocol. Locations of loggers are provided in Table 1 with GPS coordinates stored in the SFCN Water Temperature database. Three different types of operations typically occur: deploying loggers at a new site, data retrieval, and replacement of loggers. SOPs relating to each operation are shown in Table 2.

Deploying loggers at a new site

Tested loggers (see above) are prepared for deployment in the field following the steps described in “SOP 2 – Launch HOBO[®] Temperature Pro v2 Logger.” The deployment time should be set to midnight. For example, if the logger is deployed on October 5, the first temperature should be taken on October 6 at 12:00 am. Details of deploying the loggers are described in “SOP 4 – Deploying/retrieving loggers and using the HOBO Optic[®] USB Base Station – BASE-U-4.” The loggers are located at reef depth, at a position generally representative of the site and attached to

a center pin, transect pin, Aquamap station attachment, or buoy station that will remain attached to the bottom in the case of storms and is easy to re-locate. The field log notebook is updated to

Table 2. Linking field tasks to related SOPs.

Standard Operating Procedure	Deploy loggers at new site	Data retrieval		Replacing loggers at existing site
		Underwater Shuttle (preferred)	USB base station (alternate)	
SOP 1 – Testing the Precision of HOBO® Loggers in a Cold Bath	X			X
SOP 2 – Launch HOBO® Temperature Pro v2 Logger	X			X
SOP 3 – HOBO® Temperature Pro v2 Field Data Collection using the HOBO® Waterproof Shuttle - U-DTW-1		X		
SOP 4 – Deploying/retrieving loggers and using the HOBO® Optic USB Base Station – BASE-U-4	X		X	X
SOP 5 – *.hobo File Renaming Procedure, Conversion and Storage		X	X	X
SOP 6 – Entering Data into the Access Database Field Log.	X	X	X	X
SOP 7 – Import *.csv Files into Access Database.		X	X	X
SOP 8 – QA/QC of Newly Imported HOBO® Data Files into Water Temperature Database		X	X	X
SOP 9 – Reports, Graphing and Web Page Data		X	X	X

include the new site’s specific GPS coordinates, depth, and notes. This information is also entered into the HOBO® field log form in the Water Temperature Database (SOP 6).

Data retrieval

There are two methods for downloading the data from the loggers: a HOBO® waterproof shuttle is used to download the temperature data while submerged, or the logger is brought to the surface, and connected with the HOBO® launcher/reader (attached to a laptop computer). The preferred method is to use the shuttle, as it prevents potential temperature spikes when the sensor is brought to the surface and reduces QA/QC time. When it is determined that data from the loggers should be downloaded, typically during annual coral reef monitoring, or episodically (during thermal stress event), the HOBO® waterproof shuttle is used to transfer the data from the logger to the shuttle. This process involves unfastening the logger from the pin or other mounting structure, removing the protective boot and cap, inserting the logger into the shuttle and depressing a handle on the shuttle. When the data transfer is complete (generally <1 min.), the logger is placed back in the boot and cap, and re-attached to the mounting structure. This process is repeated for each of the paired loggers (See “SOP 3 – HOBO® Temperature Pro v2 Field Data Collection using the HOBO® Waterproof Shuttle – U-DTW-1” for more information and specific details on how to use the HOBO® waterproof shuttle). When data is transferred to the shuttle from the logger, it is no longer contained on the logger. The logger will begin recording again at the next scheduled interval leaving no gap in the data stream. Care must be

used with the shuttle as it is positively buoyant and can easily float away from divers, and until data is transferred from the shuttle to another device (laptop or server) it is the only location where the data exists.

Data can also be downloaded from the loggers by bringing them to the surface and downloading them via the HOBO Optic[®] USB Base Station, then re-deploying them. Procedures are detailed in “SOP 4 – Deploying/retrieving loggers and using the HOBO Optic[®] USB Base Station – BASE-U-4.” The deployment time should be set to the following midnight.

The field log notebook is maintained with information recorded during every visit, and this information is also entered into the HOBO[®] field log form in the Water Temperature Database. If a logger is lost, e.g. disappears during a hurricane, this is noted in the field log notebook and a replacement logger is deployed.

Replacement of loggers

Replacement of loggers involves a combination of the data retrieval from the old logger and deployment steps for new loggers outlined above. Steps are detailed in “SOP 4 – Deploying/retrieving loggers and using the HOBO Optic[®] USB Base Station – BASE-U-4.” When retrieving loggers either for replacement with new loggers or because of a need to update software, they should preferably be downloaded with the HOBO[®] waterproof shuttle before retrieving them to the surface. This will save QA/QC time by preventing post-deployment temperature records and minimize the loss of data if a logger accidentally floats away. However in the event the logger must be downloaded out of the water, the HOBO Optic[®] USB Base Station can be used.

Data Handling, Analysis and Reporting

Data storage, entry, verification and editing

The data life cycle is described in Table 3.

Table 3. Data life cycle.

Activity	Date
Field data collection	Coincides with coral monitoring site schedule
File storage on server Scanning of field logbook	Afternoon or day after field data collection
Data conversion & import into database	Week after field data collection
Data QA/QC'd	Month after field data collection
Data summary report Data made publicly available Archiving	December

Data that is downloaded in the field with the shuttle can be stored temporarily on the shuttle, or transferred to a field laptop computer (e.g., when in remote locations such as DRTO), until transferred to the SFCN Florida server.

Original and exported data files are stored under their appropriate Park_Site name folder in:
..\Marine_benthic_communities\Water_Temperature\data\Sites

In the VIIS office data is stored in: Y:\Projects\Vital_signs\Water_Temperature\data.

The database is located in:

..\Marine_benthic_communities\Water_Temperature\data\SFCN_Water_Temperature.mdb

Data import will only occur in the database on the SFCN server in Florida.

Data are exported using HOBOWare[®] Pro software, then converted to *.csv file format for uploading into the Water Temperature database using “SOP 5 – *.hobo File Renaming Procedure, Conversion, and Storage”. Data from the Field Log Book is entered into the database using “SOP 6 - Entering Data into the Access Database Field Log.” Files are uploaded into the database using “SOP 7 - Import *.csv Files into Access Database.”

Once data have been uploaded into the database, the *.hobo and *.csv files are moved to an Archive folder within that park site folder, making it easy to see files that remain to be uploaded.

QA/QC procedures are performed once data is uploaded into the server database as described in “SOP 8 – QA/QC of Newly Imported HOBOWare[®] Data Files into Water Temperature Database”.

When data do not meet QA/QC standards, steps are described to invalidate that data. The following errors are checked for:

- The logger was collecting data pre-deployment in the water or post-retrieval and this data is invalidated.
- Logger malfunctions such as time drift, temperature drift, missing data, sensor gives same value continuously,, or data out of range.
- Data gaps where data is missing, possibly because a file was not uploaded.

The database automatically checks for the following errors:

- Duplicate uploads
- Uploads to the wrong site name.

All data are reviewed for QA/QC and proper data storage. Procedures developed for this step are consistent with recommendations in Sowder and Steel (2012). Once data has been validated it is submitted to the network data manager for archiving and storage as outlined below in the Data Handling, Analysis, and Reporting section. Only data that are reviewed for QA/QC are transferred to outside databases such as DataForEVER.

The logbook will be scanned and the copies will be placed in the following location:
..\Marine_benthic_communities\Water_Temperature\data\Field_logbook
This should occur before the next field trip to avoid loss of data in case a logbook is misplaced or lost in the field.

Metadata procedures

Metadata for each sensor deployment is stored in the database in the “tblFieldLog” table. Metadata for each file imported into the database is stored in the “tblOperationLog” table during the data upload procedure. Metadata for the spatial location of the sample sites is stored within the “tblStations” table in the database. Metadata requirements are further discussed in section 8.3 of the network data management plan (Witcher, 2007).

Overview of database design

The database design is based off the structure of the original USGS/NPS 1988-2003 database that has been migrated into the Natural Resource Database Template (NRDT) format. The current MS Access design view is shown in Figure 7. Details of this database are provided in “Appendix A – Coral Reef Water Temperature Monitoring Database Documentation”.

Recommendations for routine data summaries and reporting

The data will be used in several different types of reports and analyses such as:

- a) Annual summaries included as part of the SFCN Coral Reef Monitoring Protocol data summary reports and “Connect the Dots” reporting
- b) Early warning reports of a coral bleaching episode
- c) Data posted to IRMA and linked to SFCN web page
- d) Data made available through the Everglades DataForEVER online database

Annual data summary included in coral reef monitoring data summary reports

An annual data summary by park across and within sites for mean, variance, maximum and minimum water temperature will be completed coupled with graphs for the past two years and the entire data series. The number of days with average temperatures above the regional bleaching threshold as well as occurrence and duration of any abnormal cold-water events are reported.

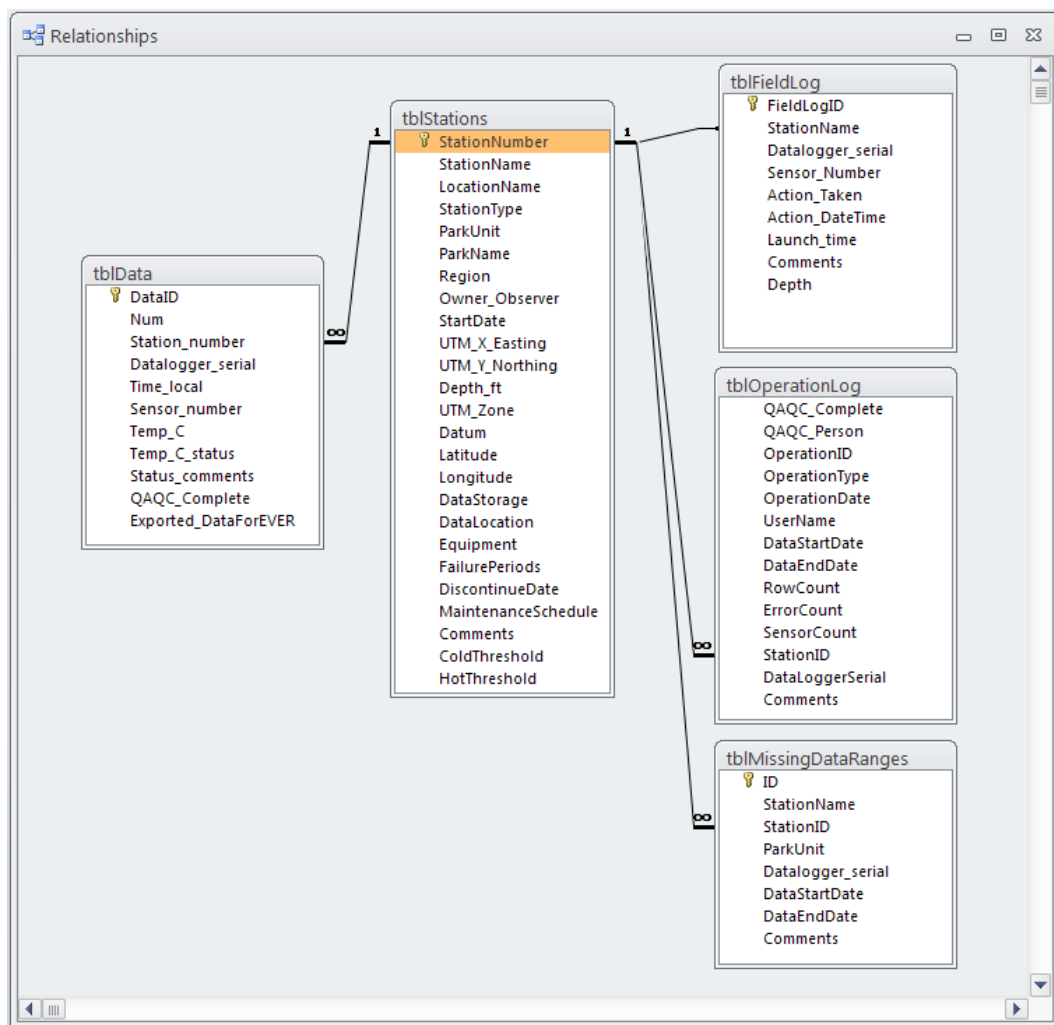


Figure 7. Database design.

This data is tied to the coral reef monitoring protocol reporting schedule and will be reported as part of the SFCN Coral Reef Monitoring Protocol park data summary reports. “SOP 9 – Reports, Graphing, and Web Page Data” describes the procedures for exporting data from the database into park specific graphing templates to create data summaries to be completed by December of each sampling year. Sample graphs are provided in Appendix B.

Early warning of temperature related stress

When conditions develop suggesting that coral bleaching or other stress may occur (e.g., Figure 8), the loggers may be downloaded more frequently to determine if surface level temperatures measured by satellite and surface buoys are also occurring at reef depth. Current logger data can easily be compared against historical data. If bleaching seems likely, park staff can be alerted to report signs of bleaching and additional monitoring may be triggered. In such cases data may be used to better assess associations between temperatures and severity/duration of coral bleaching, disease and other signs of stress on reefs. Well informed park staff can readily answer questions from the public. The graphing templates used in the annual summary report can be used, and results rapidly shared with the parks involved.

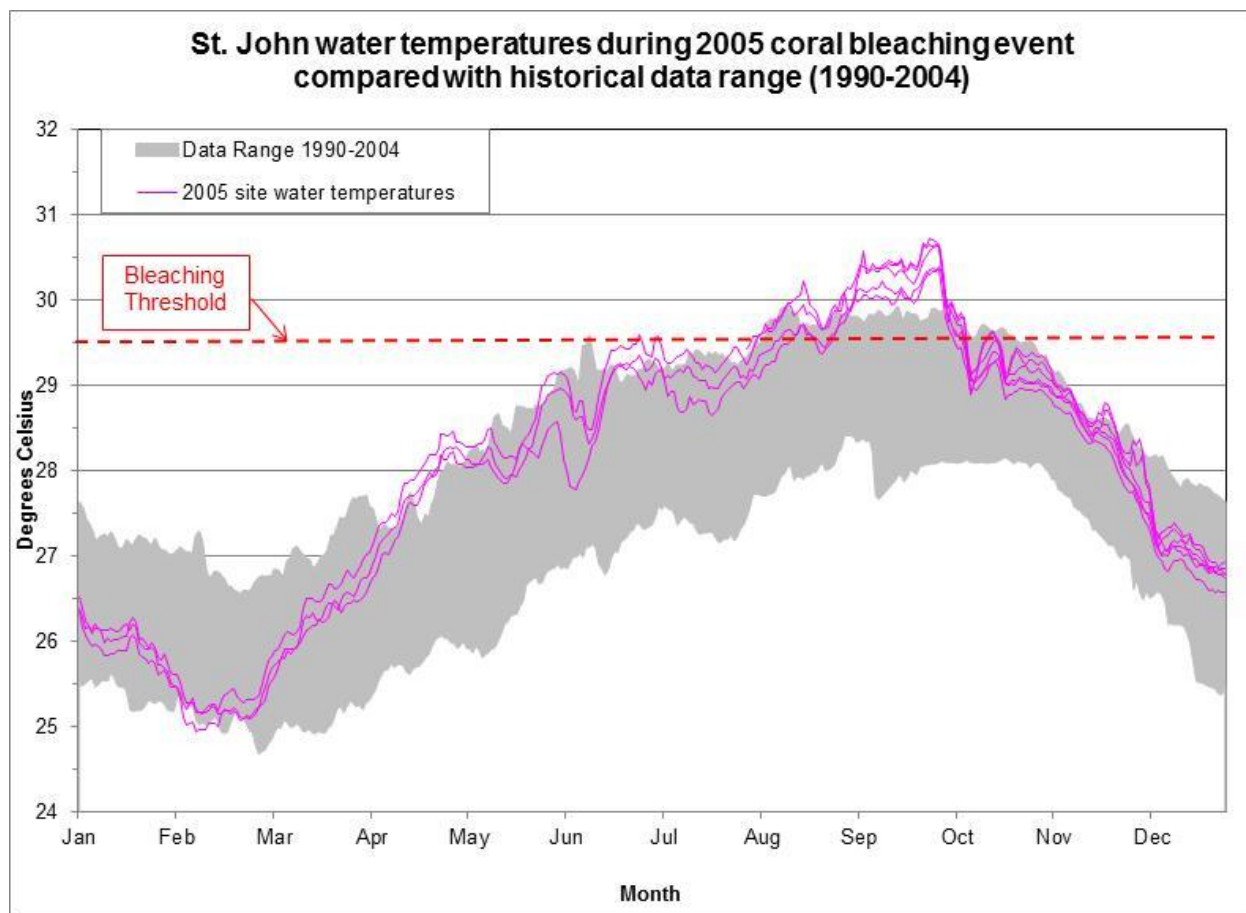


Figure 8. St. John, U.S. Virgin Islands water temperatures during 2005 coral bleaching event compared with historical data range (1990-2004). Data collected during spring and summer showed water temperatures at or exceeding historical maximums, triggering additional field visits and logger data downloads to determine if a coral bleaching event was likely to occur.

Data posted to IRMA.nps.gov and linked to SFCN web page

After data are uploaded into the database and reviewed for QA/QC, the data is updated in IRMA.nps.gov, the NPS web-based one stop online data and reports information portal where it is made publicly available. Water temperature data is not considered sensitive and thus will be made publicly available. The SFCN Marine Benthic Communities web page maintains links to the appropriate record page in IRMA. Details are described in the “SOP 9 – Reports, Graphing, and Web Page Data.”

Data posted to Everglades DataForEVER database

After data are uploaded into the SFCN database and reviewed for QA/QC, the data will be uploaded into the Everglades DataForEVER database. This also makes the data publicly available while ensuring it is also submitted to STORET as described in “SOP 10 – Exporting Data to Everglades DataForEVER Database”.

Data archival procedures

Initial archiving is started once the project manager has conducted the appropriate QA/QC procedures for a specific field season and has notified the network data manager that the dataset

is ready for archiving. This occurs concurrently with the production of the SFCN annual report in the fall and will occur no later than December 31. At this point the network data manager places a copy of the dataset into the appropriate folder within the archive directory on the network server. For example, the Water Temperature database and version of protocol used that year are copied onto the network server under:

Z:\SFCN_Archive\Vital_Signs\Marine_Benthic_Communities\Water_Temperature\yyyy
where yyyy is the relevant year.

Once the data are archived, any changes made to the data are documented in an edit log. Secure data archiving is essential for protecting data files from corruption.

Backup copies of the data are maintained at the South Florida office and at the Southeast Regional office in Atlanta, GA. For further detail of the archiving procedure please refer to the SFCN Data Management Plan (Witcher 2007).

Data Analyses

Annual data summaries consist of calculating the following:

- Average, maximum, and minimum annual temperature
- Average of cold months (December of previous year – March)
- Average of warm months (July – October)
- # days average daily temperature $\geq$ bleaching threshold (29.5°C in USVI, 30.5 °C in S. Florida)
- # days average daily temperature $\leq$ cold stress threshold (16°C in S. Florida; not recorded in USVI)
- $\sum$ (average daily temperature - bleaching threshold) for all days above the threshold.
- # consecutive days where average daily temperature is $\geq$ bleaching threshold.

Graphical summaries show annual water temperatures compared with previous years and overlaid on the historical data range of temperatures in non-bleaching years (e.g., Figure 8). Examples of tables and graphs are provided in Appendix B.

Additional analyses

In the future a redundancy analysis may be used to evaluate whether water temperature monitoring at any of the extensive sites can be eliminated if their temperatures are highly correlated with nearby sites. However, given current equipment costs, any cost savings may be minimal.

With a 22+ year data set at St. John, long-term trends in annual, summer, and winter water temperatures are possible. However these methods are not described in this protocol. Users for this purpose should be aware there are data gaps at the various sites. Table *tblOperationLog* in the database shows all the datasets imported and *tblMissingDataRanges* summarizes the data gaps. Most data gaps are short and have at least one other St. John site collecting data and thus most gaps (but not all) can be filled using data interpolation. However there is a gap from 8/13/1999 – 12/15/1999 during which no temperature data exists. Users should also be aware of the Atlantic Multidecadal Oscillation (AMO) phenomenon when making any interpretations.

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. These procedures can be implemented by any dive team member. The SFCN Marine Ecologist is responsible for overseeing the entering of the data into the MS Access database and conducting the QA/QC, but this task is typically delegated to one of the Florida-based Biological Science Technicians. 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.

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. It is the responsibility of each individual to be familiar with such rules and regulations.

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.

- NPS Blue Card Diver (Ref NPS RM4, 485 DM 27)
- MOCC (ref 36 CFR part 3, 485 DM 22) (necessary if driving an NPS boat)

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 for divers and at least one person on the boat must have Motor Boat Operations Certification (MOCC).

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 and subject to pertinent regulations.

Operational Requirements

Annual workload and field schedule

Field visits shall coincide with concurrent coral reef monitoring efforts unless periodic events dictate otherwise. Monitoring is conducted throughout the year with suggested months for field activities listed as target dates (Table 4). Some flexibility is allowed for logistics, safety, and to provide good field conditions for coral videography. If time and safety permit, additional logger downloads may occur before and during coral thermal stress events (early warning and event reporting) and before approach of tropical storms (to prevent data loss).

Table 4. Annual monitoring schedule.

Month	Park	Site
January	VIIS	Haulover
February	BUIS	S. Fore Reef
March	VIIS	Newfound
May	BUIS	W. Spur & Groove
June	DRTO	All sites
August	BISC	Ball Buoy
August	BISC	Amanda's Reef
September	VIIS	Yawzi
September	VIIS	Tektite
October	VIIS	Mennebeck

The SFCN Marine Ecologist is responsible for the implementation of this protocol but may delegate tasks as needed. 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.) The additional workload to implement this protocol, in conjunction with the SFCN coral reef protocol monitoring is not expected to exceed one person hour per site including both office and field time. The personnel required to implement this protocol include a team member from the Marine Ecology team with a corresponding effort by the Data Management, Analysis and Reporting Team. The SFCN Data Manager is responsible for maintaining the database.

Equipment needs

Equipment

- HOBO[®] underwater shuttle and/or launcher/reader connected to a laptop or workstation
- HOBO[®] Logger with removable rubber boot/cap
- Cable ties
- Knife or shears for cutting cable ties
- Field log book

Support Equipment

- Standard dive equipment and accessories
- Boat with dive and boating safety equipment
- Navigation equipment and accessories (e.g., GPS, maps, charts)

Software

- HOBO® software
- MS Access®
- MS Excel®

A HOBO® underwater shuttle or launcher/reader connected to a laptop or workstation allows data transfer from the loggers. Each logger is encased in a removable rubber boot/cap (Figure 9), and loggers are attached with cable ties to pins or stakes. All sites are accessible by boat, but logger installation or removal at each site must be done using SCUBA equipment.

HOBO® Water Temp Pro v2 has 12-bit measurement resolution and a precision sensor with $\pm 0.2^{\circ}\text{C}$ over a wide range. The logger has a streamlined case for extended deployment in fresh or salt water, and equipped with an optic interface for data offload in the field.

Measurement Range: -20° to 50°C (-4° to 122°F) in water; -20° to 70°C (-4° to 158°F) in air

Waterproof: To 120 m (400 ft.)

Accuracy: $\pm 0.2^{\circ}\text{C}$ at 0 to 50°C ($\pm 0.36^{\circ}\text{F}$ at 32° to 122°F)

Resolution: 0.02°C at 25°C (0.04°F at 77°F)

The manufacturer estimates the battery life for the HOBO® data loggers at approximately 6 years based on the logging interval of two hours under this protocol. However, The SFCN protocol suggests replacement after 3-4 years.

Initially data loggers were physically removed from the water for downloading of data. However in 2009, SFCN started using a HOBO® waterproof shuttle to download the data at reef depth without the need to remove the loggers from the water.

Startup costs and budget considerations

The only costs in addition to those described in the SFCN Coral Monitoring Protocol are described below. Equipment costs are as follows:

- HOBO® Water Temp Pro v2 logger: \$123.00
- Rubber boot/cap: \$19.00
- HOBO® Optic USB Base Station: \$115.00
- HOBO® Waterproof Shuttle: \$230.00

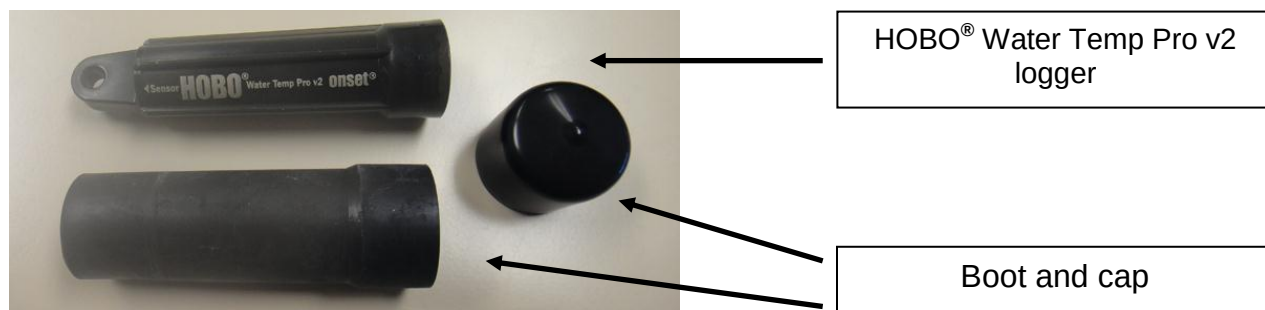


Figure 9. HOBO® Water Temp Pro v2 logger, boot and cap.

Table 5. SFCN Budget. *Note: these are only additional expenses and do not include other operational expenses necessary to maintain a functional marine monitoring and dive program, e.g., boat, trailer, tow vehicle, equipment and maintenance, dive equipment, dive physicals, training, gas, computers, software, travel, etc. Costs are estimates (2013 dollars).*

Category	Expense	Amount
Equipment replacement every 4 years	HOBO Optic USB Base Station (2 @ \$115)	\$230
	HOBO Waterproof Shuttle (2 @ \$230)	\$460
	HOBO Water Temp Pro v2 logger (76 @ \$123)	\$9,348
	HOBO Rubber boot/cap (76 @ \$19)	<u>\$1,444</u>
		\$11,482
Salary & benefits/yr	Marine Ecology team member (GS-7) 5 days (75% data management, QA/QC, reporting)	\$1193/yr
	Data Manager (GS12)/Quantitative Ecologist (GS-12) 5 days	\$1,996/yr
Periodic Data Management costs	Salary for updating database analysis and graphing tools with major software changes	\$5,000

Safety

Personnel must review the respective SOP associated with operation of each SFCN vessel, Float Plan Safety Sheet, and any other SOPs associated with this protocol. They must also review and sign all Job Hazard Analyses (JHA) associated with this protocol. These SOPs and JHAs are located in the SFCN Safety SOP & JHA Binder. Electronic versions are available on the SFCN server at Z:\Safety\ with filenames given by protocol in SFCN_Safety_SOP_and_JHA_Binder.pdf.

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. It is the responsibility of each individual to be familiar with such rules and regulations. Personnel must follow all rules, regulations, requirements, policies, and procedures from the NPS Dive Program, any park specific requirements, and any other requirements of the National Park Service not otherwise specified herein. All NPS-SFCN personnel will follow the Safe Practices Manual and Emergency Operations Plan specific to the respective park they are operating within. Dive team roles and responsibilities as predicated in NPS Resource Manual 4 (National Park Service 2011) will be reviewed in a safety briefing before each dive trip.

Completion of the Department of Interior's Motorboat Operator Certification Course (MOCC) is required for the solo operation of an NPS vessel. Non-certified MOCC personnel may drive a park boat under the supervision of an MOCC certified operator. All SFCN vessels operate using state-of-the-art GPS chart plotters to ensure safe and efficient navigation.

Literature Cited

- 36 C. F. R. § 3. 2007. Boating and Water Use Activities. Title 36 Code of Federal Regulations, Part 3. Government Printing Office, Washington, D.C.
- 485 D. M. § 22. 2011. Watercraft Safety. Department of Interior Departmental Manual, Part 485, Chapter 22. Office of Occupational Safety and Health, Washington, D.C.
- 485 D.M. § 27. 1999. Underwater Diving Safety. Department of the Interior Departmental Manual, Part 485, Chapter 27. Office of Managing Risk and Public Safety, Washington, D.C.
- Brown, B. E. 1997. Coral Bleaching: Causes and consequences. *Coral Reefs* 16:S129-S138.
- Davis, G. E. 1982. A century of natural change in coral distribution at the Dry Tortugas: a comparison of reef maps from 1881 and 1976. *Bulletin of Marine Science* 32(2):608-623.
- Donner, S. D., W. J. Skirving, C. M. Little, M. Oppenheimer and O. Hoegh-Guldberg. 2005. Global assessment of coral bleaching and required rates of adaptation under climate change. *Global Change Biology* 11:1-15.
- Glynn, P. W. and L. D'Croz. 1990. Experimental evidence for high temperature stress as the cause of El-Niño coincident coral mortality. *Coral Reefs* 8:181-191.
- Hoegh-Guldberg, O. 1999. Climate change, coral bleaching and the future of the world's coral reefs. *Journal of Marine and Freshwater Resources* 50:939-866.
- Hoegh-Guldberg, O. and G. J. Smith. 1989. The effect of sudden changes in temperature, light and salinity on the population density and export of zooxanthellae from the reef corals *Stylophora pistillata* Esper and *Seriatopora hystrix* Dana. *Journal of Experimental Marine Biology and Ecology* 129:279-303.
- Jaap, W. C. 1984. The ecology of the South Florida coral reefs: a community profile. FWS/OBS – 82/08. MMS 84-0038. Minerals Management Service, Metairie, Louisiana.
- Lirman, D., S. Schopmeyer, D. Manzello, L. J. Gramer, W. F. Precht, F. Muller-Karger, K. Banks, B. Barnes, E. Bartels, A. Bourque, J. Byrne, S. Donahue, J. Duquesnel, L. Fisher, D. Gilliam, J. Hendee, M. Johnson, K. Maxwell, E. McDevitt, J. Monty, D. Rueda, R. Ruzicka and S. Thanner. 2011. Severe 2010 cold-water event caused unprecedented mortality to corals of the Florida Reef tract and reversed previous survivorship patterns. *Public Library of Science One*. 6(8): e23047. doi:10.1371/journal.pone.0023047.
- Manzello, D. P., R. Berkelmans and J. C. Hendee. 2007. Coral bleaching indices and thresholds for the Florida Reef Tract, Bahamas, and St. Croix, US Virgin Islands. *Marine Pollution Bulletin* 54(12):1923-1931.
- Mayer, A. G. 1914. The effects of temperature on tropical marine animals. *Papers from the Tortugas Laboratory of the Carnegie Institution of Washington* 6:1-24.

- Miller, J., C. Rogers, A. Atkinson, E. Muller, A. Davis, C. Loomis, M. Patterson, R. Waara, B. Witcher, A. Wright, J. Patterson, M. Feeley and A. Estep. Draft. Coral reef monitoring protocol. Natural Resource Report NPS/SFCN/NRR—2011/XXX. National Park Service, Fort Collins, Colorado.
- Miller, J., C. Rogers, and R. Waara. 2003. Monitoring the coral disease, plague type II, on coral reefs in St. John, U.S. Virgin Islands. *Revista de Biología Tropical* 51(Sup 4):47-55.
- Miller, J., R. Waara, E. Muller, and C. Rogers. 2006. Coral Bleaching and disease combine to cause extensive mortality on reefs in US Virgin Islands. *Coral Reefs* 25:418.
- Miller, J., and M. Patterson. 2005. Coral bleaching and coral disease: A damaging combination for reefs in Virgin Islands National Park. Pages 88-89 in J. Selleck, editor. Natural Resource Year in Review-2005: A portrait of the year in natural resource stewardship and science in the National Park System. National Park Service. Denver, Colorado, and Washington, DC.
- Miller, J., E. Muller, C. Rogers, R. Waara, A. Atkinson, K. R. T. Whelan, M. Patterson, and B. Witcher. 2009. Coral disease following massive bleaching in 2005 causes 60% decline in coral cover on reefs in the US Virgin Islands. *Coral Reefs* 28:925-937.
- National Park Service. 2011. Diving Management Reference Manual RM4. National Park Service, Fort Collins, Colorado.
- Oakley, K. L., L. P. Thomas and S. G. Fancy. 2003. Guidelines for long-term monitoring protocols. *Wildlife Society Bulletin* 31(4):1000-1003.
- Patterson, M. E., A. J. Atkinson, B. D. Witcher, K. R. T. Whelan, W. J. Miller, R. J. Waara, J. M. Patterson, B. I. Ruttenberg, A. D. Davis, R. Urgelles, R. B. Shamblin. 2008. South Florida / Caribbean Network vital signs monitoring plan. Natural Resource Report NPS/SFCN/NRR—2008/063.
- Roberts, H. H., L. J. Rouse, N. D. Walker and J. H. Hudson. 1982. Cold-water stress in Florida Bay and northern Bahamas; a product of winter cold-air outbreaks. *Journal of Sedimentary Research* 52(1):145-155.
- Rogers, C. S., E. Muller, T. Spitzack and J. Miller. 2009. Extensive coral mortality in the US Virgin Islands in 2005/2006: A review of the evidence for synergy among thermal stress, coral bleaching and disease. *Caribbean Journal of Science* 45(2-3):204-214.
- Rosenberg, E. and Y. Ben-Haim. 2002. Microbial diseases of corals and global warming. *Environmental Microbiology* 4(6):318-326.
- Sowder, C. and E. A. Steel. 2012. A note on the collection and cleaning of water temperature data. *Water* 4:597-606.
- Whelan, K. R.T., J. Miller., O Sanchez., and M. Patterson. 2007. Impact of the 2005 coral bleaching event on *Porites porites* and *Colpophyllia natans* at Tektite Reef, US Virgin Islands. *Coral Reefs* 26:689-693.

- Winter, A., R. S. Appeldoorn, A. Bruckner, E. H. Williams Jr., and C. Goenaga. 1998. Sea Surface temperatures and coral reef bleaching off La Pargera, Puerto Rico (northeastern Caribbean Sea). *Coral Reefs* 17:377-382.
- Witcher, Brian, 2007. South Florida/Caribbean Network Data Management Plan. Natural Resource Report NPS/SER/SFCN/NRR—2008/064. National Park Service, Ft. Collins, CO.

Standard Operating Procedure 1 – Testing the Precision of HOBO® Loggers in a Cold Bath

Version 1.0

Revision History Log

Version #	Date	Revised by	Changes	Justification

Purpose

This SOP describes the testing procedures for HOBO® water temperature loggers in the office before field deployment. By definition pure water changes phase from the liquid to the solid state at precisely 0 °C, thus one can check the accuracy of a temperature measuring device against a standard consisting of a pure (distilled) water and ice slurry. The objective is to verify that the loggers record the temperature of the slurry to within the +/- 0.2 °C accuracy range reported for the device (note that this is NOT a calibration procedure - there is no way to adjust the calibration of the loggers against the pure water standard). It is not necessary to perform a warm water test for these devices. Although it is possible to perform such a test, a controlled laboratory setting and high precision instruments would be necessary to provide appropriately accurate and reliable results, and such a test would be time consuming and prohibitively costly.

Procedures

A. Establishing accuracy of HOBO® Water Temp Pro v2 loggers:

1. Freeze one or two gallons of distilled water (note that fresh water is not as precise but can be used if distilled water is not available; however, if fresh water is used, recordings just outside of the accuracy range could occur and still be accurate, since fresh water contains impurities and does not freeze at precisely 0°C).
2. Break the gallon ice block into smaller pieces while still inside the plastic container, preferably with a rubber mallet; as long as the container is not breached the distilled water will not be contaminated, but if some cracks occur in the container this should not significantly change the accuracy of the test. Keep in mind that some water will likely spill, thus avoid wetting any sensitive equipment.
3. Place the pieces of ice into a clean, sealable container large enough to receive all loggers. Fill the container with distilled water to make an ice and water slurry.
4. Open the current version of HOBOware® Pro program
5. Plug in the HOBO® Optic USB Base Station
6. Perform a delayed launch for all loggers to be tested to a time in which all loggers will already be sealed inside the container. Confirm that the units are set to record at 1 minute intervals, (consult the “Standard Operating Procedure 2 – Launch HOBO® Temperature Pro v2 Logger” for guidance).
7. Allow the loggers to record temperature data for at least one hour.

8. Refer to “Standard Operating Procedure 4 - HOBO[®] Temperature Pro v2 Field Data Collection using the HOBO[®] Optic USB Base Station” and follow steps 1-10 in part B for instructions on how to retrieve and view data. Be sure to record the serial number, date tested, and error range for each logger in the field notebook where all HOBO[®] information is recorded.
9. Once the loggers have reached temperature equilibrium in the slurry, all loggers should record consistent values close to 0°C until removed. Any logger that records a value outside the reported +/- 0.2 °C accuracy range must be rejected and returned to the manufacturer for replacement. Most loggers tested will record values well within the error range, but any logger that records average values outside +/- 0.15 °C should not be used, as deploying a logger with initial readings so close to an unacceptable threshold is not worth the loss of precision and the consequent QA/QC personnel time needed for the resulting data.

Standard Operating Procedure 2 – Launch HOBO® Temperature Pro v2 Logger

Version 1.0

Revision History Log

Version #	Date	Revised by	Changes	Justification

Purpose

This SOP describes the steps to be taken to launch the HOBO® loggers. After a logger has passed the cold water bath test (SOP1), it may be stored before deployment in the field. Spare loggers that have passed the tests in SOP1 are often taken along in the field kit when visiting a site to be deployed if a replacement logger is needed. Such a situation may arise if a field logger is missing or if there is a problem or error in the data transfer. Prior to deployment the logger must be launched. These procedures can be performed with the loggers connected to either the base station or the waterproof shuttle. These devices can be connected to a laptop or desktop computer; therefore, this procedure can be conducted in the office or in the field.

Procedures

1. Open HOBOWare® (latest version- update as necessary)
2. Plug in the HOBO® Optic USB Base Station or the HOBO® waterproof shuttle into the computer; attach the logger to the HOBO® device.

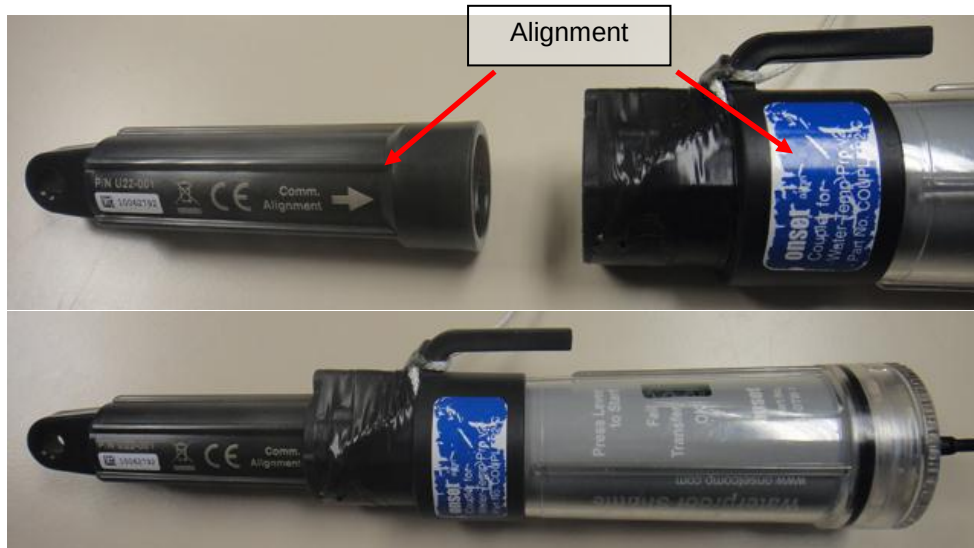


Figure SOP 2-1. HOBO® Water Temp Pro v2 logger and shuttle.

3. When using the shuttle, squeeze the plastic lever on the shuttle **ONCE** so that the software can interact with the logger.

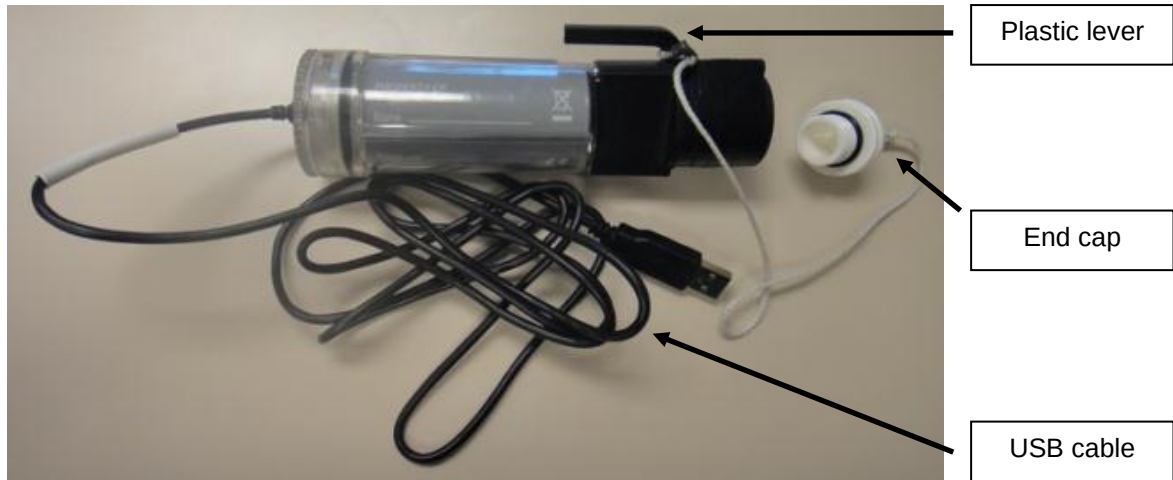


Figure SOP 2-2. HOBOT® Water Temp Pro v2 shuttle and USB cable.

4. Click on “Device” drop down menu.
5. Click on “Launch”.
6. In the dialog box, type in park, site code, and sensor number (e.g., VIIS_YZ_1)
7. Set the launch time for midnight of the day after the logger is deployed in the field.
8. Confirm that the unit is set to record at 2 hour intervals, delayed start.
9. Inset each logger into a rubber boot and cap.
10. Disconnect the device. Replace the end cap immediately.
11. Record the date, time and location of deployment along with the logger serial number in the temperature log book.

Standard Operating Procedure 3 – HOBO® Temperature Pro v2 Field Data Collection using the HOBO® Waterproof Shuttle - U-DTW-1

Version 1.0

Revision History Log

Version #	Date	Revised by	Changes	Justification

Purpose

This SOP describes the process for collecting temperature data from the HOBO® loggers using the waterproof shuttle. The HOBO® waterproof shuttle is a standalone device used to obtain data from the HOBO® loggers. This process is done while diving and does not require bringing the HOBO® loggers to the surface. When the data is transferred from the logger to the shuttle, the data no longer resides on the logger. The logger will continue collecting data at the next scheduled interval.

Procedures

A. Office Preparation - synchronize the shuttle clock to the computer clock

At each site, two loggers are deployed in case one logger fails or is lost. It is important that internal clock within the loggers are synchronized as closely as possible. This will assure that data is collected by each logger at the same time. When the data is transferred to the shuttle, the clock time of the logger is updated to that of the shuttle.

1. Update the time on your laptop or desktop computer using www.time.gov.
2. Connect the shuttle to a laptop or desktop computer using the USB cable.
3. Open HOBOWare® Pro (latest version – update as necessary).
4. Select “Device” from the drop down menu, then select “Manage Shuttle”.
5. In the Waterproof Shuttle Management dialog box, click the box “Sync Shuttle Clock”.
6. Check the shuttle memory. There are 63 “banks” to store data in the shuttle. If data has been transferred off the shuttle to a laptop, or server, it may be deleted. Do not delete data unless you are sure that the data has been transferred. Once data is transferred from the logger to the shuttle, it no longer is stored on the logger.
7. Evaluate the battery life in the shuttle as indicated in the display within the dialog box. If battery life is <50% remaining, replace batteries.
8. Close the dialog box, and shut down HOBOWare® Pro.
9. Disconnect the shuttle. Replace the end cap immediately.

B. Field Activities

1. The following equipment will be needed (along with standard dive equipment):
 - a. GPS coordinates and/or laminated map showing the specific locations of the loggers
 - b. Underwater shuttle – **handle with care while diving. The shuttle is positively buoyant and will easily float away from a diver.**
 - c. Two 12 inch long cable ties per logger
 - d. Dive knife or shears
 - e. Water temperature field log and pen
 - f. Field notebook
 - g. Extra loggers in case one is missing or has failed.
2. Dive to the specific location where the loggers are attached. Use knife or shears to remove one logger at a time from mounting device remembering to retrieve the used cable ties from the bottom for disposal. **Use caution as the loggers are positively buoyant.**



Figure SOP 3-1. HOBO® Water Temp Pro v2 logger inside boot and cap.

3. Remove the protective rubber boot and cap from the logger. **Use caution as the rubber boot is positively buoyant.**
4. Align the mark on the logger with the line on the shuttle, inserting the logger completely into the shuttle (Figure SOP 2-1). Complete insertion minimizes space between the logger and shuttle providing the best chance for a complete download.
5. Squeeze the plastic handle on the shuttle **ONCE** to begin data transfer. The yellow “Transfer” light will blink when downloading. The green “OK” light will blink when the transfer is complete. Take care to only depress the lever once. **Depressing the lever again after the transfer has started will cause data to be unreadable.**
6. Upon successful transfer, remove the logger from the shuttle and replace the protective boot/cap on the logger. If the transfer fails the logger may have to be replaced, in which case the instrument may have to be returned to the manufacturer for data retrieval.
7. Attach the loggers (in rubber boots and caps) to the appropriate location with two cable ties. One cable tie goes through the eye of the logger; the second goes around the logger body. Assure the cable ties are very snug (loggers should withstand hurricanes that may pass over the site). The loggers are positioned vertically, and inverted with respect to each other.
8. When removing the second logger for data transfer, ensure that the correct logger is retrieved. New cable ties attach the reinstalled logger, thus remove the logger with the old ties.

9. Return to the surface with the shuttle and the old cable ties. **REMEMBER to use care with the shuttle. It is positively buoyant and easily floats away from divers. When the data is transferred to the shuttles from the loggers, it no longer exists on the loggers; only in the shuttle. If the shuttle is lost, so is the data!**
10. At completion of the dive record the following information in the field log book:
 - a. Date
 - b. Site Name
 - c. Number of loggers transferred
 - d. Comments: Any pertinent information not mentioned above shall be recorded here

C. Transferring Files from the waterproof shuttle

1. Rinse with fresh water and dry the shuttle.
2. Unscrew the back port of the shuttle and connect the USB cable to the computer.
3. Open HOBOWare[®] Pro program (Program is under “Onset Computer Corporation” file)
4. Open the “Device” drop down menu, click on “readout”
5. At the Select Device dialog box, click “ok” when the program recognizes the shuttle
6. In the dialog box “Waterproof Shuttle Management”, put a check in each “save” box in front of the files to be saved to the computer.
7. Click on the “choose” box and browse to the appropriate storage file for temperature data.
8. Click on the “Save checked” box – you will not need to rename the files at this time. Allow the files to be downloaded with the name that comes from the shuttle. The file extension will be “*.hobo”.
9. Open the downloaded files to make sure they have been saved properly, then close the files
10. Once the files have been downloaded and checked, go to the “Device” drop down menu and select “Manage Shuttle”.
11. Put a check in the box in front of the files that have been transferred then click “Delete checked” box. This removes the files from the shuttle. The files now only exist where they were placed in the step C8 above.

Standard Operating Procedure 4 – Deploying/retrieving loggers and using the HOBO[®] Optic USB Base Station – BASE-U-4

Version 1.0

Revision History Log

Version #	Date	Revised by	Changes	Justification

Purpose

This SOP describes the process for collecting data from loggers using the HOBO[®] Optic USB Base Station. The base station is a device used to connect the HOBO[®] loggers directly to a PC or laptop and transfer data between the computer and the data logger. The base station is typically used as an alternative to the HOBO[®] waterproof shuttle to launch or retrieve data from loggers on the surface; **the base station can't be used underwater.**

NOTE: When retrieving loggers, it is preferred that they are downloaded with the HOBO[®] waterproof shuttle before retrieving them to the surface (See SOP 3 - HOBO[®] Temperature Pro v2 Field Data collection using the HOBO[®] Waterproof Shuttle - U-DTW-1). This will save QA/QC time by preventing post-deployment temperature spikes and minimizes the loss of data if a logger accidentally floats away or otherwise is lost.

Procedures

A. Deploying and retrieving loggers

1. The following equipment will be needed (along with standard dive equipment):
 - a. GPS coordinates and/or laminated map showing the specific locations of the loggers
 - b. Underwater shuttle – **handle with care while diving. The shuttle is positively buoyant and will easily float away from a diver.**
 - c. Two 12 inch long cable ties per logger
 - d. Dive knife or shears
 - e. Water temperature field log and pen
 - f. Field notebook
2. Prior to field work, any new loggers should be tested using SOP 1 – Testing the Precision of HOBO[®] Loggers in a Cold Bath and launched using SOP 2 – Launch HOBO[®] Temperature Pro v2 Logger.
3. Dive to the specific location where the current loggers are attached.
4. Use knife or shears to remove both loggers from mounting device remembering to retrieve the used cable ties from the bottom for disposal. **Use caution as the loggers are positively buoyant.**
5. Download the loggers using the underwater shuttle (see SOP 3 – HOBO[®] Temperature Pro V2 Field Data Collection using the HOBO Waterproof Shuttle U-DTW-1). If shuttle is not working, then data will be downloaded from the logger using Section B below.

6. Secure the new loggers to the mounting pin at this time. Attach the loggers (in rubber boots and caps) to the appropriate location with two cable ties. One cable tie goes through the eye of the logger; the second goes around the logger body. Assure the cable ties are very snug (loggers should withstand hurricanes that may pass over the site). The loggers are positioned vertically and inverted with respect to each other.
7. Bring old loggers to boat.
8. At completion of the dive, record the following information in the field log book:
 - a. Date
 - b. Site Name
 - c. Number of loggers transferred
 - d. Comments: Any pertinent information not mentioned above shall be recorded here
 - e. If first time deployment at a site, also record:
 - i. Depth (in ft)
 - ii. GPS coordinates (in UTM)

B. Downloading data from a logger with the base station and re-launching logger

1. When re-launching rather than replacing loggers, take them to the surface at the completion of your dive.
2. Assure that the base station is plugged into the laptop by the USB cable, and that HOBOWare[®] Pro opened properly.
3. Remove the logger from the rubber boot and cap. Don't get water or dirt from inside the boot on the laptop!
4. Align the mark on the logger with the mark on the coupler and insert the logger completely into the coupler. This will activate the base station and it will be "found" by HOBOWare[®] Pro software.
5. Select "Device" drop down menu.
6. Click "readout".
7. At the Select Device dialog box, click "ok" when the program recognizes the shuttle.
8. Select the "stop Logger" dialog box to stop and transfer the data from the logger at this time.
9. In the Save dialog box, browse to the appropriate storage file for temperature data. Select "save" once you are in the proper location. You will not need to rename the files at this time. Allow the files to be downloaded with the name that comes from the shuttle. The file extension will be "*.hobo".
10. If desired, one can view the plot at this time, in that the Plot Setup window is open. Select PLOT.
11. If you are deploying this logger back to the site, you need to launch it. Follow the steps outlined in SOP 2.
12. When you have completed transferring (readout) and launching all loggers at this site, record the following information in the field log book:
 - a. Station name (location where deployed)

- b. Serial number for each of the two loggers
 - c. Sensor number (1 or 2)
 - d. Date and time of data retrieval
 - e. Comments: Any pertinent information not mentioned above shall be recorded in this section.
13. Repeat Steps 1-12 for each logger retrieved at the site.
14. Make additional relevant notes, such as:
- a. Damage observed
 - b. Difficulty downloading data
 - c. Discrepancies with name, serial # or data
 - d. Length of time the logger has been deployed. NOTE: The loggers will be switched out every 4 years or as needed.

Standard Operating Procedure 5 – *.hobo File Renaming Procedure, Conversion and Storage

Version 1.0

Revision History Log

Version #	Date	Revised by	Changes	Justification

Purpose

This SOP describes the process for renaming *.hobo files and converting them into *.csv format and the archival procedure for these files.

Procedures

A. Renaming the *.hobo files.

1. Browse to the location where the files are stored. Keep this Windows Explorer window open. You will be coming back to it in step 7.
2. Double-click on the *.hobo file. This will open the file in HOBOWare[®] Pro.
3. In the 'Plot Setup' screen, put a check in Series 1, for "Temp" measurement, and set units to °C.
4. Remove the check in Series 2, Battery.
5. Click the 'Plot' button in the lower-right, Plot Setup dialog box. You should see a graph of the data.
6. Click the 'Show All' button on the left side of the screen to reveal metadata details. This will provide all the information you need to rename the *.hobo file.
7. Return to the Windows Explorer window where the *.hobo files are located.
8. Use the data provided in HOBOWare[®] Pro to rename the file with the following sections, each separated by an underscore.
 - a. Park Code (e.g., DRTO)
 - b. Site Name (e.g., I33)
 - c. Logger Number (1 or 2)
 - d. Serial Number (e.g., 2011222)
 - e. Original Sample Date (e.g., 20080512)
 - f. Last Sample Date (e.g., 20090615)

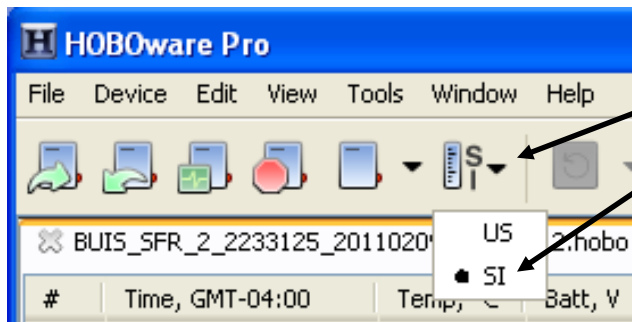
Example filename: DRTO_I33_2_2011222_20080512_20090615.hobo

9. This needs to be repeated for each *.hobo file.
10. As each file is renamed, close the file in HOBOWare[®] Pro.
11. Do not close the Windows Explorer window showing the renamed files.

B. Creating the *.csv file from the *.hobo file in HOBOWare® Pro.

1. In Windows Explorer window showing the renamed *.hobo files, double-click on a file. This will open the Plot dialog box in HOBOWare® Pro.
2. Check that “Temp” units are °C and change if necessary. If the units displayed are in °F, see note below on how to change default to metric settings.
3. Select “Plot” from the “Plot” setup dialog box.
4. In HOBOWare® Pro, click the ‘File’ menu and then select ‘Export Table Data’ or the icon .
5. In the Export Option dialog box, select ‘Export to a single file’ and click ‘Export’.
6. Browse to the desired output location (usually same place the *.hobo file is stored).
7. This will create the *.csv file with the same naming structure as the *.hobo file.

Note: To change to metric units, open HOBOWare® Pro and click the units button and select “SI”



This should cause the program to default to °C in the future.

Standard Operating Procedure 6 – Entering Data into the Access Database Field Log.

Version 1.0

Revision History Log

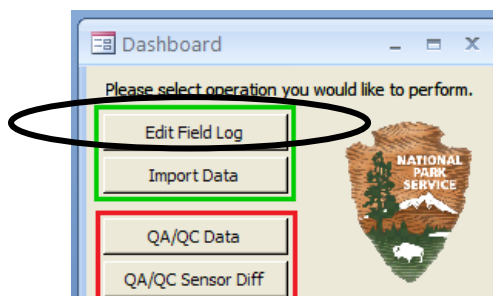
Version #	Date	Revised by	Changes	Justification

Purpose

This SOP describes the procedures for entering data into the “Field Log” within the water temperature database in Microsoft Access. The Field Log documents the details of the deployment and retrieval of each logger including station, sensor number, data logger serial number, type of action, time and dates of deployment and launch time, and depth upon first installation. The Field Log also contains comments or notes of sensor problems such as lost sensors or when sensors are removed from water to the boat. This provides a useful record during QA/QC procedures and a history of sensor deployment at a site from 2012 onwards.

Procedures

1. Scan the field logbook and place the copies in the following location:
..\\Marine_benthic_communities\\Water_Temperature\\data\\Field_logbook
This should occur before the next field trip to avoid loss of data in case a logbook is misplaced or lost in the field. Files should be named as:
TripStartDate(YYYYMMDD)_TempLogBook_Pages
(e.g., 20120130_TempLogbook_p31_33)
2. Append the most recently scanned pages to the master field log book pdf using Adobe Acrobat Professional
(..\\Marine_benthic_communities\\Water_Temperature\\data\\Field_logbook\\FieldLogBook.pdf)
3. Open the database, ‘SFCN_Water_Temperature.mdb’
The location of the database is:
..\\Marine_benthic_communities\\Water_Temperature\\data\\
4. This database requires the use of macros, so ensure macros are enabled. (Click the Office Button Icon at the upper left of MS Access. Click the ‘Access options’ in lower right corner; select ‘trust center’ and click the ‘trust center settings’ button; select macro settings and turn on the ‘Enable all macros’ button. Then select, OK and close all Office Button windows.)
5. On the Dashboard window that opens, click on “Edit Field Log” button.



6. Enter the data from the field log book into the appropriate fields in the database “Field Log”.

NOTE: New stations must be entered in tblStations table before they will appear in the drop down list. To enter new stations see Data Management Team for assistance.

For “Action_Taken” there are 4 options:

- Underwater Download w/shuttle
- Sensor Deployment
- Sensor Retrieval
- Other (lost sensor, damage, etc.)

If “Other” please enter a comment such as “Sensor lost after Hurricane Marilyn”, “Sensor found on beach”, “Sensor Missing”, etc.

“Action_DateTime” is entered Month/Day/Year Hour:Min AM/PM, e.g., 11/3/2009 3:30 PM.

Upon deployment, sensors are typically launched at 10 PM or Midnight. This should be entered under “Launch_Date/Time”. Note: if launch time is midnight, time does not need to be entered as this is the default.

If this is the first time a sensor has been installed at a site, record depth (ft.) of sensor deployment.

The screenshot shows a Windows application window titled "frmFieldLog". The main content area is titled "Field Log" and contains a note: "Note: New stations must be entered in tblStations before they will appear in drop down list. To enter new stations see Data Management Team for assistance." Below the note are several input fields: "StationName:" with a dropdown menu showing "BISC_AM"; "Sensor_Number:" with a text box containing "1"; "Datalogger_serial:" with a text box containing "500032"; "Action_Taken:" with a dropdown menu showing "Sensor Deployment"; "Action_DateTime:" with a text box containing "11/3/2009 3:30:00 PM". Below these fields is a section titled "If Sensor Deployment then also fill in:" containing a "Launch_date/time:" text box with "11/3/2009 10:00:00 PM" and a "Comments:" text box. At the bottom, there is a section titled "Enter upon first installation:" with a "Depth (ft):" text box containing "10". The bottom status bar shows "Record: 1 of 1", "No Filter", and a "Search" button.

StationName:	BISC_AM
Sensor_Number:	1
Datalogger_serial:	500032
Action_Taken:	Sensor Deployment
Action_DateTime:	11/3/2009 3:30:00 PM
If Sensor Deployment then also fill in:	
Launch_date/time:	11/3/2009 10:00:00 PM
Comments:	
Enter upon first installation:	
Depth (ft):	10

Standard Operating Procedure 7 – Import *.csv Files into Access Database.

Version 1.0

Revision History Log

Version #	Date	Revised by	Changes	Justification

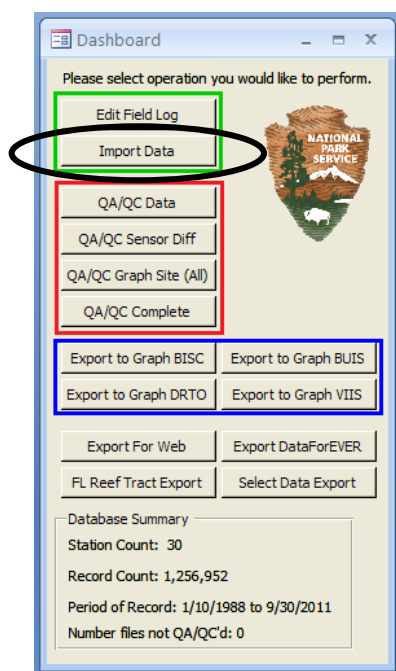
Purpose

This SOP describes the procedures for importing data into the Access database. The ultimate destination of the logger data is to import *.csv files into the Access water temperature database. Files should have already been named using “SOP 5 – *.hobo File Renaming Procedure, Conversion and Storage”

Procedures

A. Import into Water Temperature Database:

1. Open the database, ‘SFCN_Water_Temperature.mdb’
 - a. The location of the database is:
..\Marine_benthic_communities\Water_Temperature\data\
 - b. This database requires the use of macros, so ensure macros are enabled. (Click the Office Button Icon at the upper left of MS Access. Click the ‘Access options’ in lower right corner; select ‘trust center’ and click the ‘trust center settings’ button; select macro settings and turn on the ‘Enable all macros’ button. Then select, OK and close all Office Button windows.)
2. In the Dashboard dialog box, click on the “Import Data” button.



3. In the 'Data Import Wizard' which opens, browse to and select the appropriate data file. If the filename is formatted properly, the station name, serial number and sensor number will be extracted from the filename automatically. If the filename is not formatted correctly, it must be modified in Windows Explorer before data entry can proceed (refer to SOP 5 - *.hobo File Renaming Procedure, Conversion and Storage).
4. Click the 'Import Data' button.
5. Enter your name in the dialog box (FirstName LastName, e.g., Andrea Atkinson), click OK.
6. Review the information in the confirm dialog box, press OK or cancel as appropriate.
7. When import completes, a "DATA IMPORT COMPLETED SUCCESSFULLY!" status message will appear near the bottom of the screen.
 - a. If duplicate data is detected, the status message will change to "IMPORT FAILURE!" and data import will stop.
 - b. If a new serial number is detected, a message will be displayed. If this data file is from a new HOBO[®] device, click "Yes" to proceed. Otherwise, click "No" to cancel and correct the filename before retrying import.
8. Repeat steps 4-8 for each additional data file that needs to be imported.
9. When all files have been imported, close the Data Import Wizard window.

Standard Operating Procedure 8 – QA/QC of Newly Imported HOBO® Data Files into Water Temperature Database

Version 1.0

Revision History Log

Version #	Date	Revised by	Changes	Justification

Purpose

This SOP is designed to assist basic QA/QC for water temperature data. Once the files are in the database, QA/QC tests are conducted to assure the validity of the imported data. When data do not meet QA/QC standards, steps are described to invalidate that data. The following errors are checked for:

- The logger was collecting data pre-deployment in the water or post-retrieval and this data must be invalidated.
- Logger malfunctions such as time drift, temperature drift, missing data, stuck sensor, or data out of range.
- Data gaps where data is missing, possibly because a file was not uploaded.

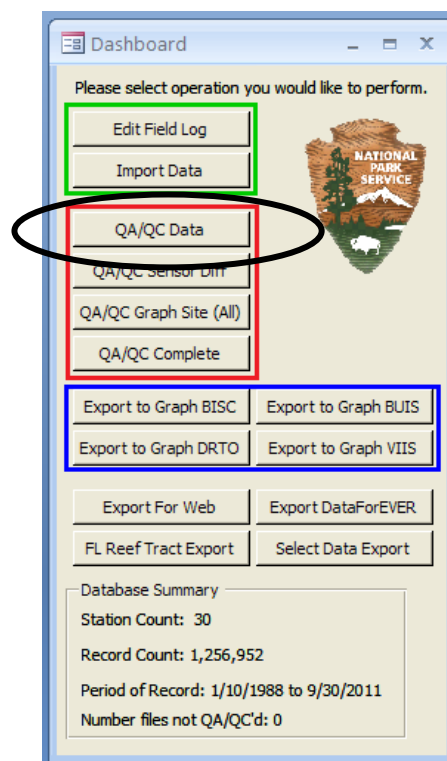
Although the database automatically checks for the following errors, these are still included in the QA/QC check for the present:

- Duplicate uploads
- Uploads to the wrong site name.

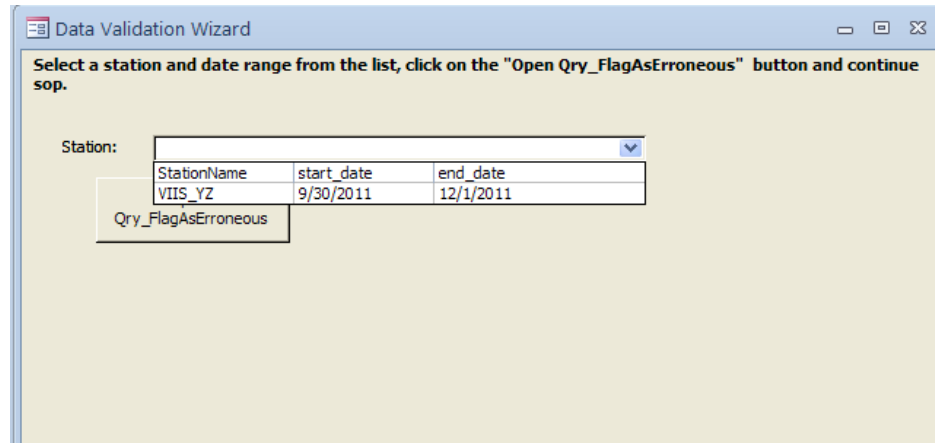
Procedures

A. Investigate a newly uploaded data logger data series

1. Click “QA/QC Data”. Once data from a pair of sensors at a site have been imported into the database, click the “QA/QC Data” button on the “Dashboard” form.



2. Select station and dates. Select the appropriate station name and data range and click “**Open Qry_FlagAsErroneous.**” Data for both sensors will be retrieved for the date range.



Station:

StationName	start_date	end_date
VIIS_YZ	9/30/2011	12/1/2011

Qry_FlagAsErroneous

3. Check for duplicate uploads. In the query window that opens, check for doubles of the temperature readings (**Temp_C**) and time stamps (**Time_local**) for the same sensor (**Sensor_number**). This occurs if a logger file is uploaded twice, which can happen when data is not entered according to the “SOP 6 - Entering Data into the Access Database Field Log”. Typically you only need to look at the first 10 entries to determine if a duplicate upload has occurred. A duplicate upload should be deleted (ask for help from Data Management Team).
4. Check for odd data. Check if there are any odd data at the beginning and ending of the data series such as abrupt changes in temperature of 1°C or more within 2 hours or greater than 2°C within 24 hours that may indicate that the logger was taking readings while out of the water.
 - a. Loggers that are taking readings on board a ship will frequently show a sudden spike over 30°C or show temperature swings of several °C within a 24 hour period which is very unusual for BUIS and VIIS and is a very characteristic pre-deployment or post-retrieval temperature signature. DRTO and BISC have greater temperature variance and abrupt natural swings are possible. However abrupt swings within 1-2 days of logger reading deployment or retrieval should still be considered suspicious and should be compared with field notes.
 - b. If found, look at graphs and compare with field notes for when a logger was deployed and/or retrieved from the water.
 - c. Typically if the time a logger starts is 10PM to midnight, it was correctly set to start after deployment (i.e., under water) and no further changes are needed.
 - d. If a logger was downloaded via underwater shuttle, there usually are no problems as the logger is not brought to the surface. Check anyway in case of a logger malfunction.
 - e. Note: Blank Temp_C cells at the end of an upload are the result of the Hobo logging off and do not need to be edited (automatically receives a Temp_C_status of -1).

qry_FlagAsErroneous - Microsoft Access

StationName	Num	Datalogger_serial	Time_local	Sensor_number	Temp_C	Temp_C_status	Status_comments
VIIS_YZ		901110.001	1/10/1988 11:45:00 AM	1	31.9	-1	pre-deployment data. Andrea Atkinson
VIIS_YZ		901110.001	1/10/1988 12:45:00 PM	1	27.7	-1	pre-deployment data. Andrea Atkinson
VIIS_YZ		901110.001	1/10/1988 1:45:00 PM	1	26.2	-1	pre-deployment data. Andrea Atkinson
VIIS_YZ		901110.001	1/10/1988 2:45:00 PM	1	25.8	0.0	
VIIS_YZ		901110.001	1/10/1988 3:45:00 PM	1	25.8	0.0	
VIIS_YZ		901110.001	1/10/1988 4:45:00 PM	1	25.8	0.0	
VIIS_YZ		901110.001	1/10/1988 5:45:00 PM	1	25.8	0.0	
VIIS_YZ		901110.001	1/10/1988 6:45:00 PM	1	25.8	0.0	
VIIS_YZ		901110.001	1/10/1988 7:45:00 PM	1	25.8	0.0	
VIIS_YZ		901110.001	1/10/1988 8:45:00 PM	1	25.8	0.0	
VIIS_YZ		901110.001	1/10/1988 9:45:00 PM	1	25.8	0.0	
VIIS_YZ		901110.001	1/10/1988 10:45:00 PM	1	25.8	0.0	
VIIS_YZ		901110.001	1/10/1988 11:45:00 PM	1	25.7	0.0	
VIIS_YZ		901110.001	1/11/1988 12:45:00 AM	1	25.7	0.0	
VIIS_YZ		901110.001	1/11/1988 1:45:00 AM	1	25.7	0.0	
VIIS_YZ		901110.001	1/11/1988 2:45:00 AM	1	25.6	0.0	
VIIS_YZ		901110.001	1/11/1988 3:45:00 AM	1	25.7	0.0	
VIIS_YZ		901110.001	1/11/1988 4:45:00 AM	1	25.6	0.0	
VIIS_YZ		901110.001	1/11/1988 5:45:00 AM	1	25.5	0.0	
VIIS_YZ		901110.001	1/11/1988 6:45:00 AM	1	25.5	0.0	
VIIS_YZ		901110.001	1/11/1988 7:45:00 AM	1	25.6	0.0	
VIIS_YZ		901110.001	1/11/1988 8:45:00 AM	1	25.6	0.0	
VIIS_YZ		901110.001	1/11/1988 9:45:00 AM	1	25.7	0.0	
VIIS_YZ		901110.001	1/11/1988 10:45:00 AM	1	25.7	0.0	
VIIS_YZ		901110.001	1/11/1988 11:45:00 AM	1	25.6	0.0	
VIIS_YZ		901110.001	1/11/1988 12:45:00 PM	1	25.7	0.0	
VIIS_YZ		901110.001	1/11/1988 1:45:00 PM	1	25.8	0.0	
VIIS_YZ		901110.001	1/11/1988 2:45:00 PM	1	25.8	0.0	
VIIS_YZ		901110.001	1/11/1988 3:45:00 PM	1	25.8	0.0	
VIIS_YZ		901110.001	1/11/1988 4:45:00 PM	1	25.8	0.0	
VIIS_YZ		901110.001	1/11/1988 5:45:00 PM	1	25.8	0.0	

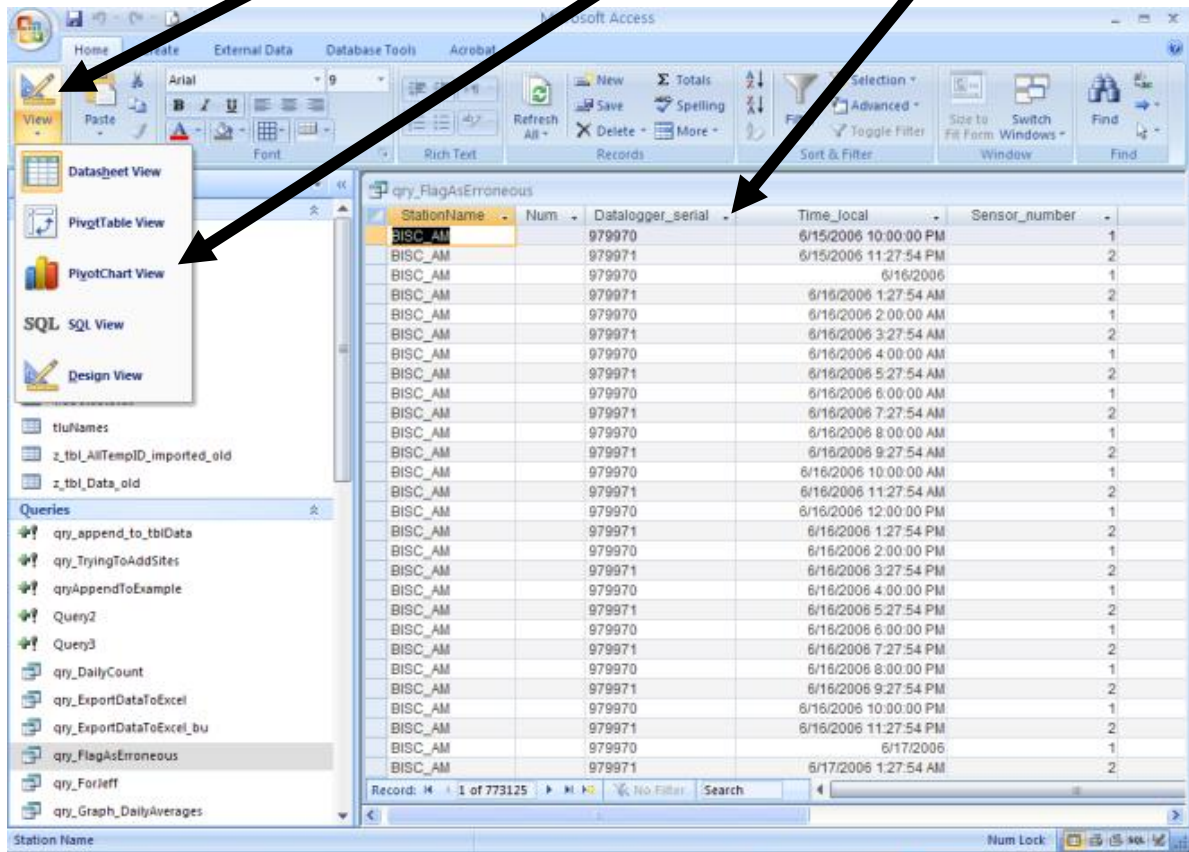
5. Check for time drift on the sensors. Check the time of the 1st records of Sensor 1 and Sensor 2 (usually are the same/synchronized). Then click the “Last Record button” and check that the last record of Sensor 1 and Sensor 2 are still synchronized.

StationName	Num	Datalogger_serial	Time_local	Sensor_number	Temp_C	Temp_C_status	Status_comments
BUIS_SFR	4118	2233125	1/27/2010 2:00:01 AM	1	27.186		
BUIS_SFR	4119	2233124	1/27/2010 4:00:01 AM	1	27.112		
BUIS_SFR	4119	2233125	1/27/2010 4:00:01 AM	2	27.161		
BUIS_SFR	4120	2233124	1/27/2010 6:00:01 AM	1	27.063		
BUIS_SFR	4120	2233125	1/27/2010 6:00:01 AM	2	27.087		
BUIS_SFR	4121	2233124	1/27/2010 8:00:01 AM	1	26.989		
BUIS_SFR	4121	2233125	1/27/2010 8:00:01 AM	2	27.014		
BUIS_SFR	4122	2233124	1/27/2010 10:00:01 AM	1	27.014		
BUIS_SFR	4122	2233125	1/27/2010 10:00:01 AM	2	27.038		
BUIS_SFR	4123	2233124	1/27/2010 12:00:01 PM	1	27.161		
BUIS_SFR	4123	2233125	1/27/2010 12:00:01 PM	2	27.186		
BUIS_SFR	4124	2233124	1/27/2010 2:00:01 PM	1	27.235		
BUIS_SFR	4124	2233125	1/27/2010 2:00:01 PM	2	27.259		

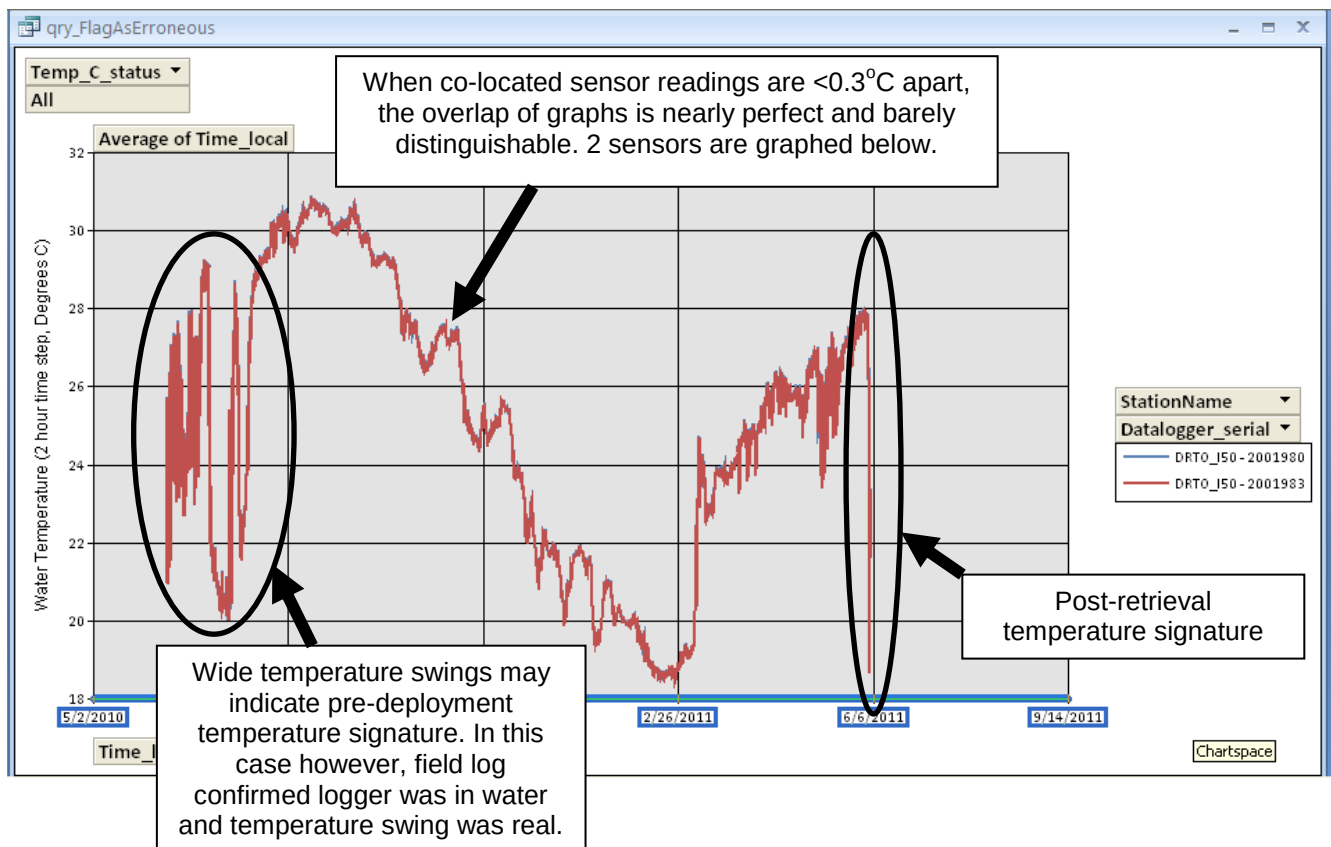
If they are no longer synchronized, consult with the HOBO[®] company as one of the sensors may be malfunctioning and need replacement. Minor time drifts of a few minutes do not invalidate the temperature data, so catching this problem early means the data is still valid. If times are not synchronized in the first record, then see if time difference remains the same in the last records.

6. Graph the data. **Before graphing the data make sure that less than 32,000 data records are showing.** Attempts to graph more than 32,000 data records will cause MS ACCESS to crash and shut down. A single logger should still have <32,000 records after six years. However two loggers will acquire >32,000 records after only 3.5 years. If >32,000 data records, click on arrow to right of **Datalogger_serial** column and select only 1 of the 2 loggers you wish to graph and then graph them individually.

Under <Views> menu select <**PivotChart View**>



Once the graph is viewable, look for unusual spikes or flat lines, missing data, suspicious temperature swings that might indicate a problem, or differences between the two loggers at the same site.



If problems are found, click on the graph at the point of the problem to get an approximate date, then Click on **<View>** menu and select **<Datasheet View>** to view the data once again, investigate problems, and invalidate data if necessary (see Step 7). Usually this requires looking at the field log for exact deployment and retrieval dates and times and any other comments (e.g., evidence of hurricane damage). Re-graph the data once corrections are made. See a member of the Data Management Team if tediously large numbers of data records need to be invalidated or otherwise fixed.

7. Invalidate suspect data. If any data needs to be marked as invalidated, change **Temp_C_status** to **-1** and give the reason and your name under **Status_comments**, e.g., “Pre-deployment data”, “Post-retrieval data”, “Data upload error”, “Found on beach after Hurricane Marilyn”, etc. In case the logger was not appropriately delay launched, invalidate all readings to **midnight** of the deployment date.

qry_FlagAsErroneous - Microsoft Access

StationName	Num	Datalogger_serial	Time_local	Sensor_number	Temp_C	Temp_C_status	Status_comments
VIIS_YZ		901110.001	1/10/1988 11:45:00 AM	1	31.9	-1	pre-deployment data. Andrea Atkinson
VIIS_YZ		901110.001	1/10/1988 12:45:00 PM	1	27.7	-1	pre-deployment data. Andrea Atkinson
VIIS_YZ		901110.001	1/10/1988 1:45:00 PM	1	26.2	-1	pre-deployment data. Andrea Atkinson
VIIS_YZ		901110.001	1/10/1988 2:45:00 PM	1	25.8	0	
VIIS_YZ		901110.001	1/10/1988 3:45:00 PM	1	25.8	0	
VIIS_YZ		901110.001	1/10/1988 4:45:00 PM	1	25.8	0	
VIIS_YZ		901110.001	1/10/1988 5:45:00 PM	1	25.8	0	
VIIS_YZ		901110.001	1/10/1988 6:45:00 PM	1	25.8	0	
VIIS_YZ		901110.001	1/10/1988 7:45:00 PM	1	25.8	0	
VIIS_YZ		901110.001	1/10/1988 8:45:00 PM	1	25.8	0	
VIIS_YZ		901110.001	1/10/1988 9:45:00 PM	1	25.8	0	
VIIS_YZ		901110.001	1/10/1988 10:45:00 PM	1	25.8	0	
VIIS_YZ		901110.001	1/10/1988 11:45:00 PM	1	25.7	0	
VIIS_YZ		901110.001	1/11/1988 12:45:00 AM	1	25.7	0	
VIIS_YZ		901110.001	1/11/1988 1:45:00 AM	1	25.7	0	
VIIS_YZ		901110.001	1/11/1988 2:45:00 AM	1	25.6	0	
VIIS_YZ		901110.001	1/11/1988 3:45:00 AM	1	25.7	0	
VIIS_YZ		901110.001	1/11/1988 4:45:00 AM	1	25.6	0	
VIIS_YZ		901110.001	1/11/1988 5:45:00 AM	1	25.5	0	
VIIS_YZ		901110.001	1/11/1988 6:45:00 AM	1	25.5	0	
VIIS_YZ		901110.001	1/11/1988 7:45:00 AM	1	25.6	0	
VIIS_YZ		901110.001	1/11/1988 8:45:00 AM	1	25.6	0	
VIIS_YZ		901110.001	1/11/1988 9:45:00 AM	1	25.7	0	
VIIS_YZ		901110.001	1/11/1988 10:45:00 AM	1	25.7	0	
VIIS_YZ		901110.001	1/11/1988 11:45:00 AM	1	25.6	0	
VIIS_YZ		901110.001	1/11/1988 12:45:00 PM	1	25.7	0	
VIIS_YZ		901110.001	1/11/1988 1:45:00 PM	1	25.8	0	
VIIS_YZ		901110.001	1/11/1988 2:45:00 PM	1	25.8	0	
VIIS_YZ		901110.001	1/11/1988 3:45:00 PM	1	25.8	0	
VIIS_YZ		901110.001	1/11/1988 4:45:00 PM	1	25.8	0	
VIIS_YZ		901110.001	1/11/1988 5:45:00 PM	1	25.8	0	

Record: 1 of 92476

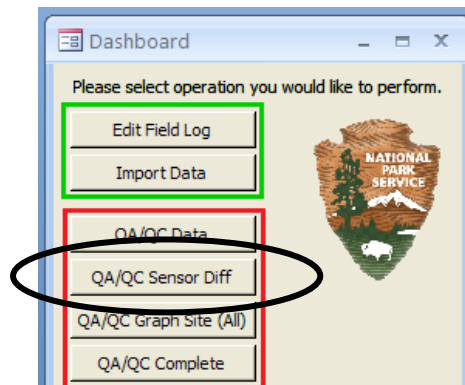
Navigation Pane

Pre-deployment temperature spike. Temp_C_status is set to -1, and rationale and name provided in Status_comments

8. When finished, close query.

B. Comparing differences between two co-located loggers in Datasheet View

1. Click on “QA/QC Sensor Diff” on Dashboard



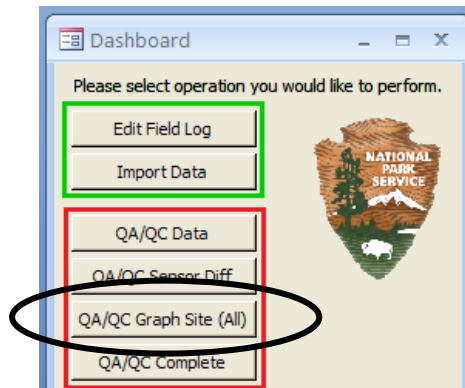
2. Check if sensor difference $>0.3^{\circ}\text{C}$. Check to see if the StationName and dates in the date range are flagged with a warning. This query calculates the difference in the daily average temperatures for the two data loggers at all sites and displays the greatest differences on top (so you only need to look at the top of the table). Differences in daily average temperature $>0.3^{\circ}\text{C}$ are flagged with the message “Warning >0.3 ”.

StationName	Date	1	2	Difference	Warning
DRT0_BK	6/6/2006	27.9047555555556	28.6422222222222	0.737466666666666	WARNING >0.3
DRT0_BK	7/2/2010	28.5878333333333	29.078	0.490166666666666	WARNING >0.3
DRT0_BK	6/9/2010	27.556	27.9259166666667	0.369916666666666	WARNING >0.3
DRT0_BK	6/18/2010	29.14025	29.4936666666667	0.353416666666666	WARNING >0.3
DRT0_BK	7/5/2010	28.6356666666667	28.9699166666667	0.334250000000001	WARNING >0.3
VIIS_YZ	5/19/2006	28.297	28.6166666666667	0.319666666666666	WARNING >0.3
VIIS_YZ	5/20/2006	28.2333333333333	28.55	0.316666666666666	WARNING >0.3
BISC_AM	1/11/2010	16.8185	17.12825	0.309750000000001	WARNING >0.3
DRT0_BK	6/17/2010	28.6836666666667	28.9905833333333	0.306916666666666	WARNING >0.3
DRT0_BK	7/12/2010	28.0586666666667	28.362	0.303333333333331	WARNING >0.3
VIIS_YZ	10/9/2005	29.6000833333333	29.9	0.299916666666672	
VIIS_YZ	8/5/2006	28.2269166666667	28.525	0.298083333333338	
VIIS_YZ	5/21/2006	28.1715	28.4666666666667	0.295166666666667	
VIIS_YZ	4/15/2006	27.0055833333333	27.3	0.294416666666674	
VIIS_YZ	10/5/2005	29.8150833333333	30.1083333333333	0.293250000000004	
VIIS_YZ	8/4/2006	28.2745833333333	28.5666666666667	0.292083333333327	

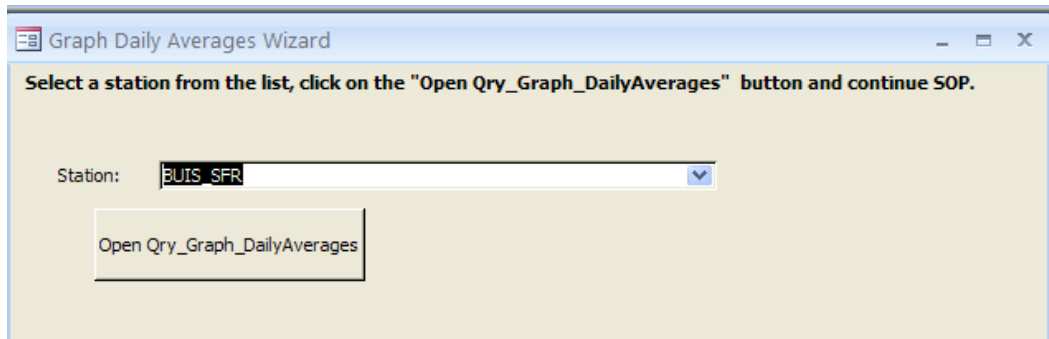
3. For readings $>0.3^{\circ}\text{C}$ apart, investigate. The source of the problem may either be a data logger was uploaded with the wrong StationName, one of the loggers may be faulty, or some legitimate differences have occurred during a rapid cold water event in cases where the time readings of the loggers are not synchronized (e.g., an hour apart). To determine which sensor is faulty, suggestions include looking at and graphing the data, checking that StationName is appropriate, compare with loggers at same site prior to and after the current data range, compare data with nearby sites, and check the logger test data for anomalies.
4. Determine whether data needs to be invalidated and whether the logger needs to be replaced. If the data from the loggers is for the most part $<0.3^{\circ}\text{C}$ apart with only a few readings greater than the threshold, then the decision will likely be to treat the data as valid. This may especially occur during cold water events with rapid changes in temperature, particularly if the temperature reading times are not synchronized between the two loggers. If one logger is frequently $>0.3^{\circ}\text{C}$ from the other logger or is gradually increasing the difference from its paired logger, then it will need to be invalidated.
5. If data must be invalidated, see Step 7. If large data ranges must be invalidated, see a member of the Data Management, Analysis and Reporting Team for assistance.
6. When completed with evaluation, close the query.

C. Graph data to check it in context of all data from site

7. On “Dashboard”, click “QA/QC Graph Site (ALL)”.



8. Select station, then click “Open Qry_Graph_DailyAverages”

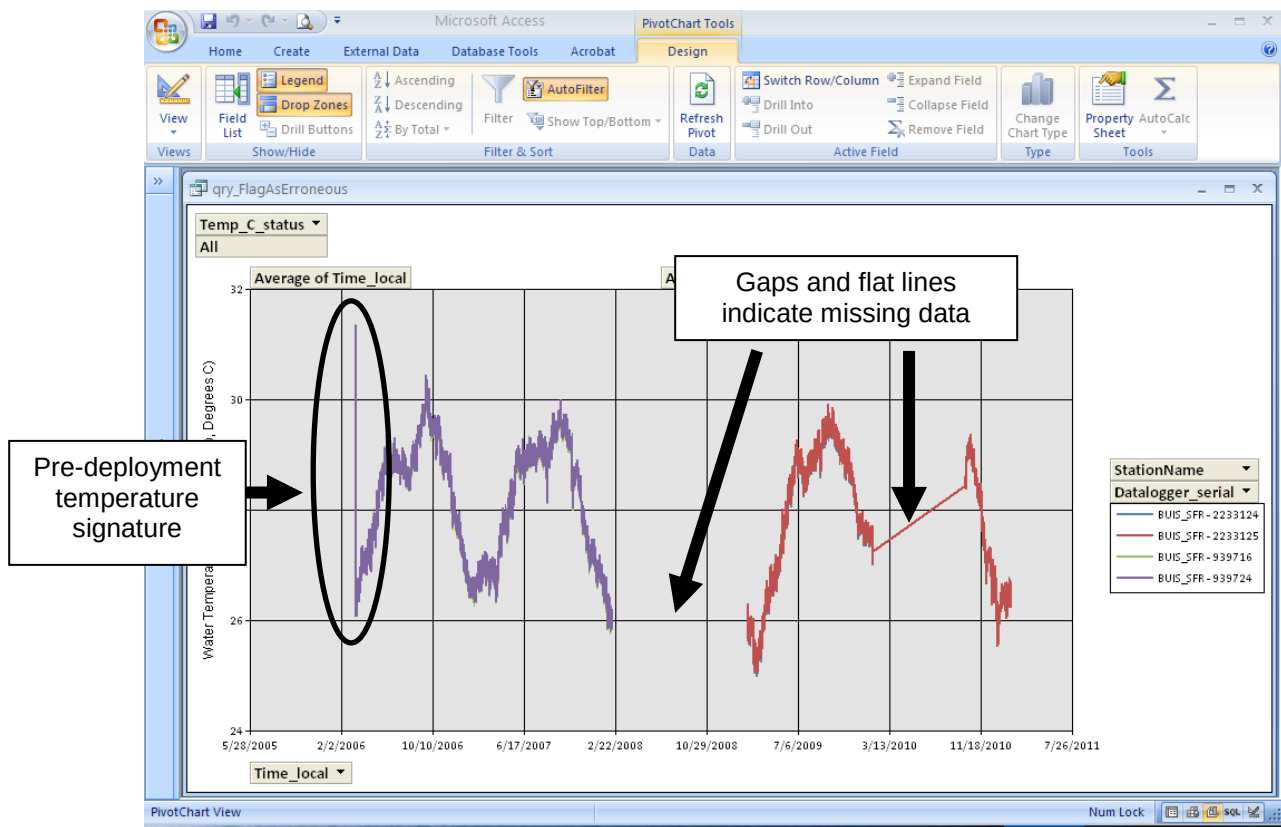


9. Resize X-axis if necessary. If you are looking at VIIS_NF, VIIS_WS, or VIIS_YZ, you may need to resize the X-axis (this is a discrepancy in MSAccess).
- Left click on the X-axis until it highlights,
 - Right click and select **<Properties>**.
 - Select **<Scale>** tab
 - Select **<Custom min>** and set to 32143 (Jan 1, 1988)

10. Look for odd or missing data. Once the graph is viewable, look for

- unusual spikes or flatlines, missing data, or suspicious temperature swings that might indicate a problem.
- data that doesn't match with rest of site which may indicate an upload to an incorrect filename.

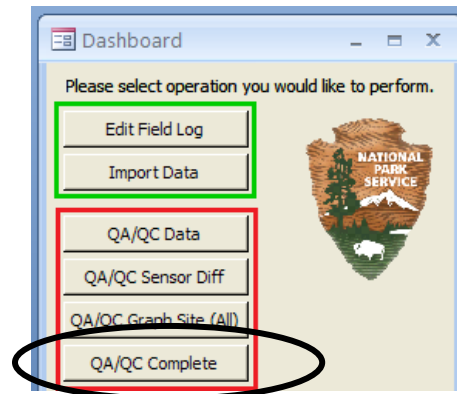
You can select specific loggers by selecting “**Datalogger_serial**” list on the right of the graph. Similarly you can also select specific **StationName** and even specific years. TblMissingDataRanges lists known missing data ranges and associated comments (i.e., these data sets are not findable). Add to this list if all efforts have been made to find a missing data set and it remains unfound.



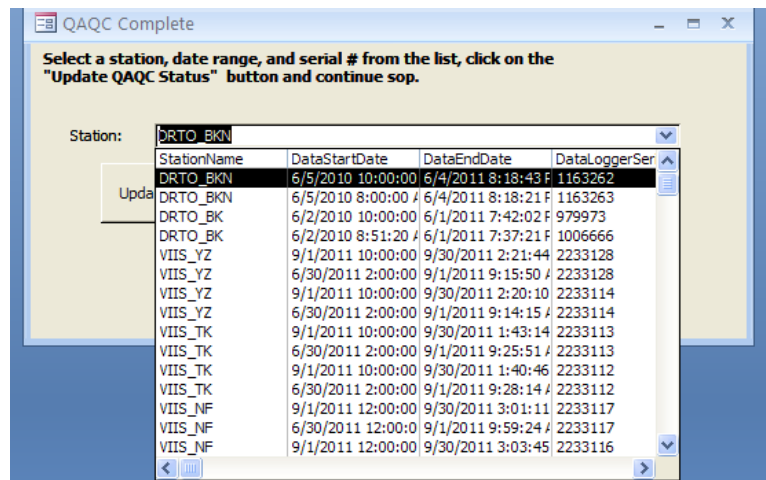
11. Investigate and resolve problems. If a problem is found, take corrective action, e.g., investigate and invalidate pre-deployment data, find missing data sets, or ask Data Management Team for assistance with data uploaded with wrong sitename.

D. Checking off that QA/QC is complete

12. QA/QC Complete Step. *Important: This must be done through the “Dashboard” form to trigger the routine that will mark all associated data with this data range as “validated” and allow it to be exported to graphs and other files. When QA/QC is complete, click “QA/QC Complete” on Dashboard form.*



13. Select station and date range and click “Update QAQC Status”



14. Add your initials.
15. Click “Update QAQC Status.”
16. Archive original files. When QA/QC is complete, move the original *.hobo and *.csv files to the Archive sub-folder within the respective Site folder.

Standard Operating Procedure 9 – Reports, Graphing and Web Page Data

Version 1.0

Revision History Log

Version #	Date	Revised by	Changes	Justification

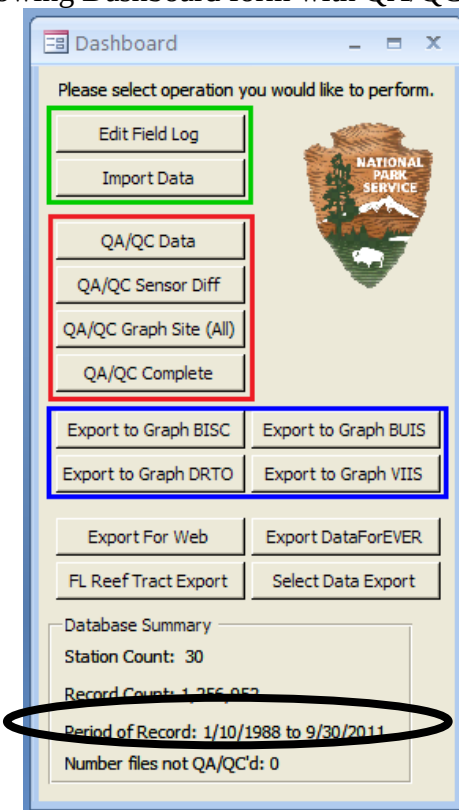
Purpose

This SOP describes how to export water temperature data for upload to the SFCN web page and export data to a graphing template to create summary graphs and tables for use with the Coral Reef Monitoring Protocol data summary reports. Temperature data collected under this protocol will be reported with the Coral Reef Monitoring Protocol, as water temperature data is critical for interpreting coral status and trends.

Procedures

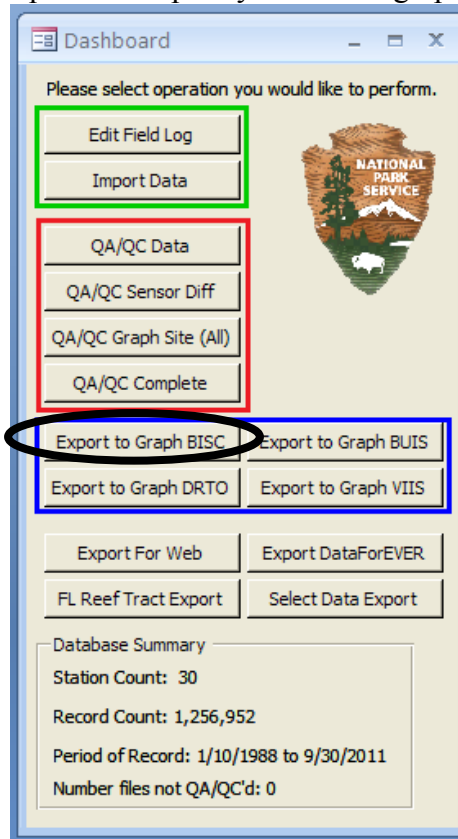
A. First check that all QA/QC is complete.

1. On Dashboard form check that “Number files not QA/QC’d” = 0.
Screen capture showing Dashboard form with QA/QC Sensor Diff circled.



B. Export of daily average temperatures to park graphing templates

1. Select “Export to Graph <park>” for park you wish to graph.



Nothing will appear to happen for about 30 seconds.

2. All data for that park that has not been invalidated will have been exported to its corresponding graphing template “Graphing_Template_<park>.xslm” in
..\Marine_benthic_communities\Water_Temperature\data\Graphs\

For example:

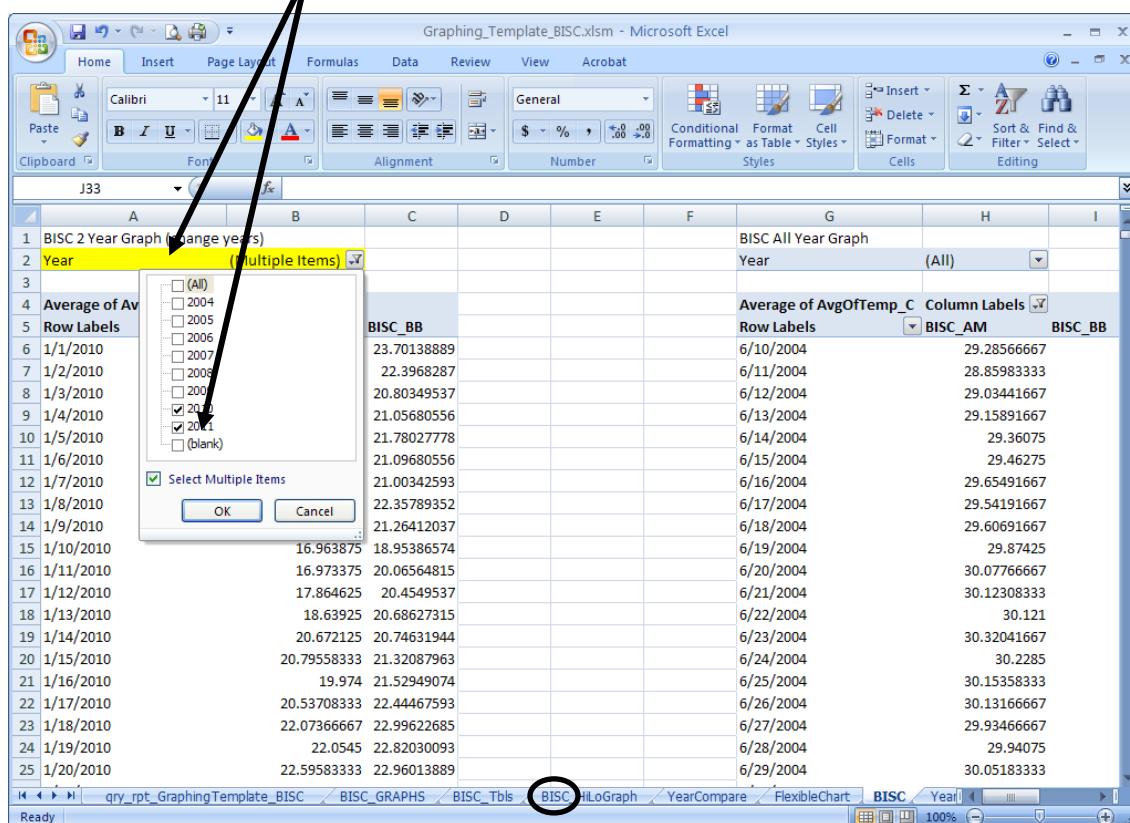
..\Marine_benthic_communities\Water_Temperature\data\Graphs\Graphing_Template_BISC.xslm”
..\Marine_benthic_communities\Water_Temperature\data\Graphs\Graphing_Template_BUIS.xslm”
..\Water_Temperature\data\Graphs\Graphing_Template_DRT0.xslm”
..\Water_Temperature\data\Graphs\Graphing_Template_VIIS.xslm”

3. The relevant park graph will open in Excel.

C. Using the Graphing Templates

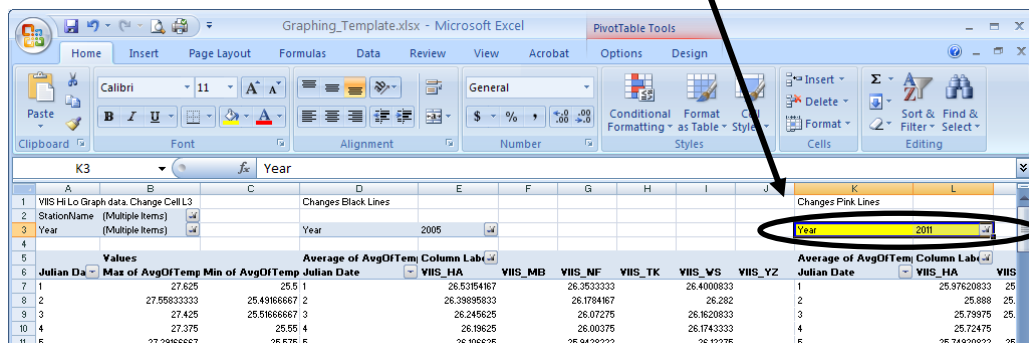
1. Once the graph opens in Excel you can begin updating.
2. Save to a new filename if you plan on making edits to the graph formats to meet special reporting needs.
3. Update <park> worksheet. All graphs and tables in the graphing template are designed to automatically update upon opening the file. **However the upper left hand graphs in BISC_Graphs, BUIS_Graphs, DRTO_Graphs, and VIIS_Graphs in their respective files, need to have the years updated to reflect the latest two years. Cells to change are highlighted in yellow.**

In “Graphing_Template_BISC” click on “BISC” worksheet to the far right. Where it says “BISC 2 Years (change years)” use the drop-down menu to select the latest 2 years to graph (or any years you want graphed). This will affect the top left graph in the BISC_Graphs worksheet.

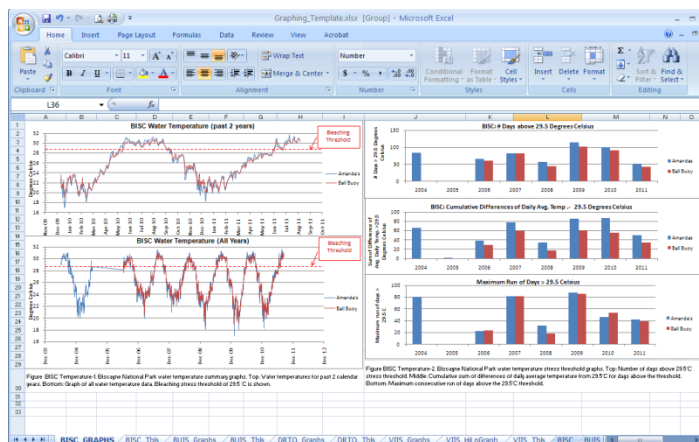


4. Do the same for the respective “BUIS”, “DRTO”, and “VIIS” worksheets when using the other park graphing templates.

- Update HiLoGraph. To select years in the VIIS_HiLoGraph, go to the HiLoPivot worksheet, use the drop-down menu in cell L3 to select the current year to compare. There is a similar procedure for BISC.



- Go through each of the graph and table pages to make sure they have updated appropriately and that the figure and table captions say what you need. Update as necessary.

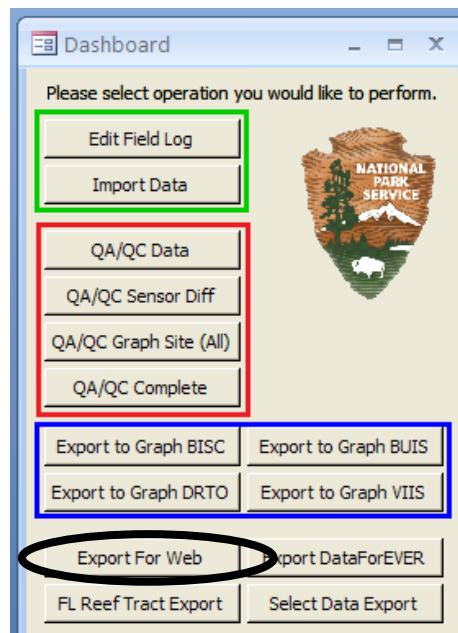


- “FlexibleChart” and “YearCompare” are flexible chart options with instructions on their respective pages.
- If you wish to edit graphs and tailor them to specific needs, save the file to a new name so as not to alter the original template. If a template does get modified, backup original templates are saved with the protocol.
- To print graphs as a PDF group, hold down the Ctrl Key, click on the tabs for each of the graph and table pages to print. Click “Office button”, Select “Print” and then “Print” again
- Make sure “Active Sheets” is selected, select the printer you want or Adobe PDF as appropriate, then Click “OK”
- When finished printing, click on “qrt_rpt_GraphingTemplate” so that the group of worksheets is unselected and the graphing template is ready for the next user.
- To export a graph to *.jpg format with best resolution
 - Left click on the graph to select it
 - Zoom in as high as possible to get the best resolution
 - Press CTRL-SHIFT-E
 - The graph will be exported to the same directory with the graph name as filename

- e. Go to the directory and immediately rename the file with the desired filename
 - f. If it does not work, look for message saying macros have been disabled underneath toolbars. Click it and turn on macros.
13. To change the file type exported
- a. Go to View Page
 - b. Under "Macros" click "View Macros"
 - c. Select "ExportChart" and click Edit
 - d. Replace .jpg with the desired file extension throughout document (.png, .tif, etc.)
 - e. Close
 - f. Test it out by pressing CTRL-SHIFT-E
14. To copy a graph to a MS Word document
- a. Left click on the graph to select it
 - b. Zoom in as high as possible to get the best resolution, then press "Copy" button
 - c. Go to location of document where you want to paste picture and click in that location
 - d. Select "Paste" Button then "Paste Special"
 - e. Usually selecting "Picture (Enhanced Metafile)" works best in Microsoft programs
 - f. Click OK

D. Exporting *.csv files for each of parks

1. Select "Export for Web" on Dashboard



2. Check that files exported appropriately to
`..\Marine_benthic_communities\Water_Temperature\data\Web_Reports`
3. Note: Export procedures will automatically write over existing files in the folder.
4. The Data Management/Outreach Technician should be notified that updated versions of these files are ready for upload to the web page.

Standard Operating Procedure 10 – Exporting Data to Everglades DataForEVER Database

Version 1.0

Revision History Log

Version #	Date	Revised by	Changes	Justification

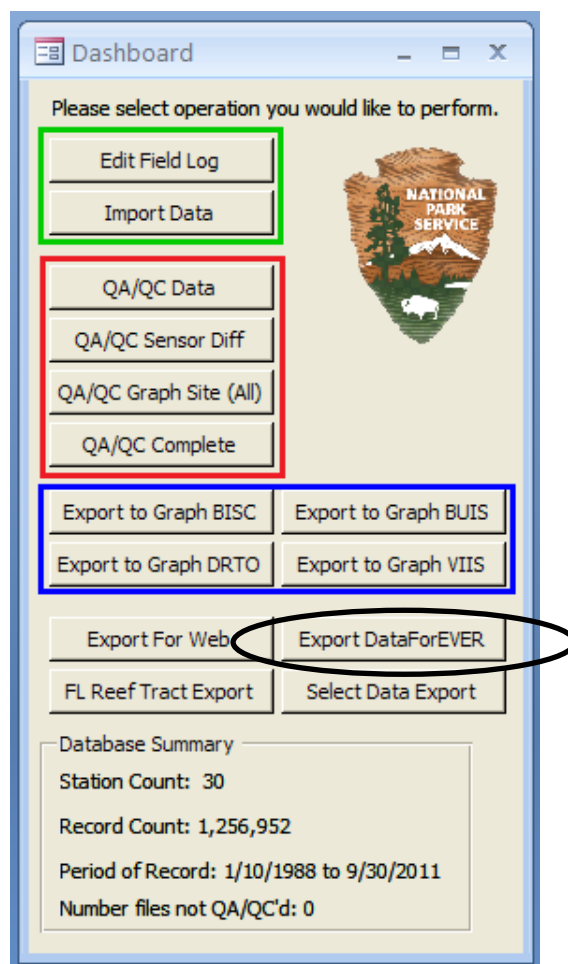
Purpose

This SOP describes how to export water temperature data for upload to DataForEVER and the steps to import data into DataForEVER. DataForEVER, developed and maintained by SFNRC, is a database system built on MySQL that provides for analysis and long-term storage of environmental observations.

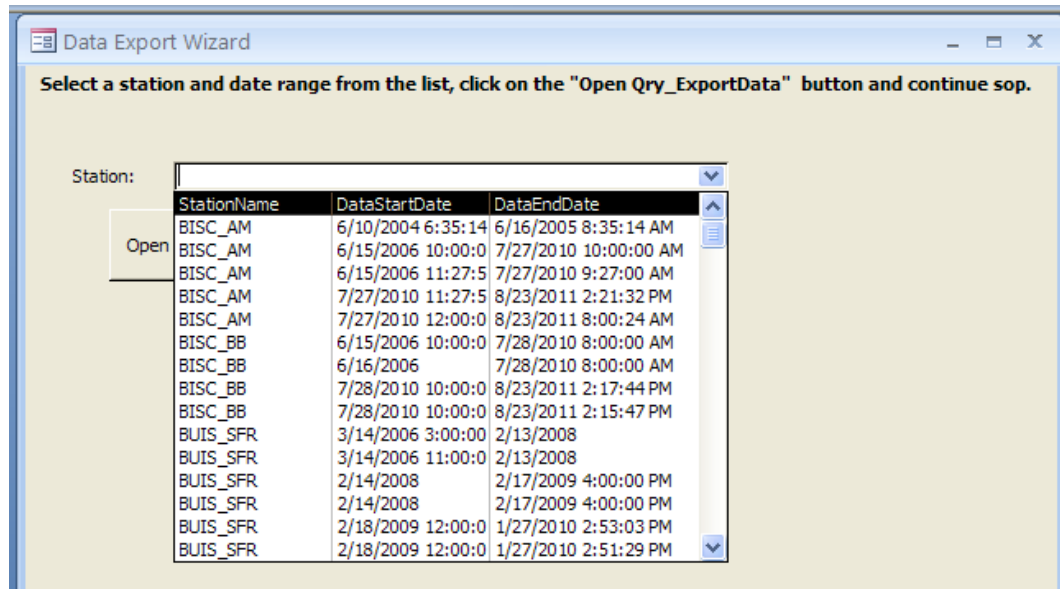
Procedures

A. Export data for uploading to DataForEVER

1. From the Dashboard form select “Export DataForEVER.”



2. Select the station and date range that you would like to export to DataForEVER.



3. Click the “Open Qry_ExportData” button. This will open the queries for both data loggers and create a csv export file for each logger. Please note that you must complete steps 1-9 before selecting a new date range and clicking the “Open Qry_ExportData” button.
4. Open a web browser and navigate to <http://10.146.112.34/hydrology/> and use the Member Login. Please contact the SFCN data manager to obtain a user login.
5. Select “Load”→”Generic Load”→Measurement
6. Browse to *..\Marine_benthic_communities\Water_Temperature\data\Web_Reports* and select the file with the appropriate station and sensor number, i.e., BISC_AM_1.csv.
7. Apply the following settings:
 - a. Delimiter = ,
 - b. Really vn = No
 - c. Station = Select the station you are loading
 - d. Datatype = Select Bottom Temperature if loading sensor 1 data or Bottom Temperature2 if loading sensor 2 data.
 - e. Measurement Date = Change Position to “6”
 - f. Measurement Time = Change Position to “7”
 - g. Measurement Value = Change Position to “9”
8. Ensure that you scroll to the bottom of the page and set all of the remaining values to “Ignore.”
9. Click “Submit.”
10. At the bottom of the screen there is a preview of data that will be posted. If all values are correct proceed to steps 11 – 13.

11. Apply the following settings:
 - a. Delimiter = ,
 - b. Really vn = Yes
 - c. Station = Select the station you are loading
 - d. Datatype = Select Bottom Temperature if loading sensor 1 data or Bottom Temperature2 if loading sensor 2 data.
 - e. Measurement Date = Change Position to “6”
 - f. Measurement Time = Change Position to “7”
 - g. Measurement Value = Change Position to “9”
12. Ensure that you scroll to the bottom of the page and set all of the remaining values to “Ignore.”
13. Click “Submit.”
14. This procedure exports a single time series for a single station. One may be required to follow the complete procedure to load additional data.

Standard Operating Procedure 11 – Revising the Protocol

Version 1.0

Revision History Log

Version #	Date	Revised by	Changes	Justification

Purpose

Define how changes in the protocol will occur and how they will be tracked.

When used

Changes can be suggested at any time following the procedures outline below.

Procedures

Once published in the Natural Resource Report Series, the protocol “Coral Reef Ecosystem Water Temperature Monitoring Protocol” can only be modified through the use of a versioning system and will follow the guidance below:

1. In the event the Coral Reef Ecosystem Water Temperature Monitoring Protocol requires editing, all edits must be reviewed for technical merit. Minor changes to the protocol and/or changes in the mechanics of equipment or software functioning will only require in-house review by network staff. Major changes in the protocol affecting the science and interpretation of the protocol may require external review by subject matter experts.
2. Protocols edits and versioning are tracked in the Revision History Log attached to the entire protocol and each individual SOP. Major changes results in an update by whole numbers (i.e., version 1.0, version 2.0, etc.) and minor changes by hundredths (e.g., version 1.01, version 1.02, etc.) Record the new version number, date of revision, author of the revision, describe the change, and provide a rationale for the change.
IMPORTANT: Any changes to an individual SOP must also be tracked in the protocol’s Revision History Log and the version number of the protocol **MUST** be updated, even if the change is editorial and only to one SOP.
3. Inform the data manager about the changes to the protocol narrative or SOPs, so the new version number can be incorporated in the project database metadata, reports, etc.
4. Post new protocol versions on NPS-IRMA (<http://irma.nps.gov>), the network website and National Inventory and Monitoring Program protocol database and forward copies to all individuals with a previous version of the protocol.

Appendix A. Coral Reef Water Temperature Monitoring Database Documentation

Version 1.0

Revision History Log

Version #	Date	Revised by	Changes	Justification

Purpose

Provide clear documentation of the database tables and relationships.

Documentation of Database Tables

The following section shows the overall relationships between each of the database tables as well as the specific design for each table. The main key that links the various tables together is StationNumber (or StationID in some tables).

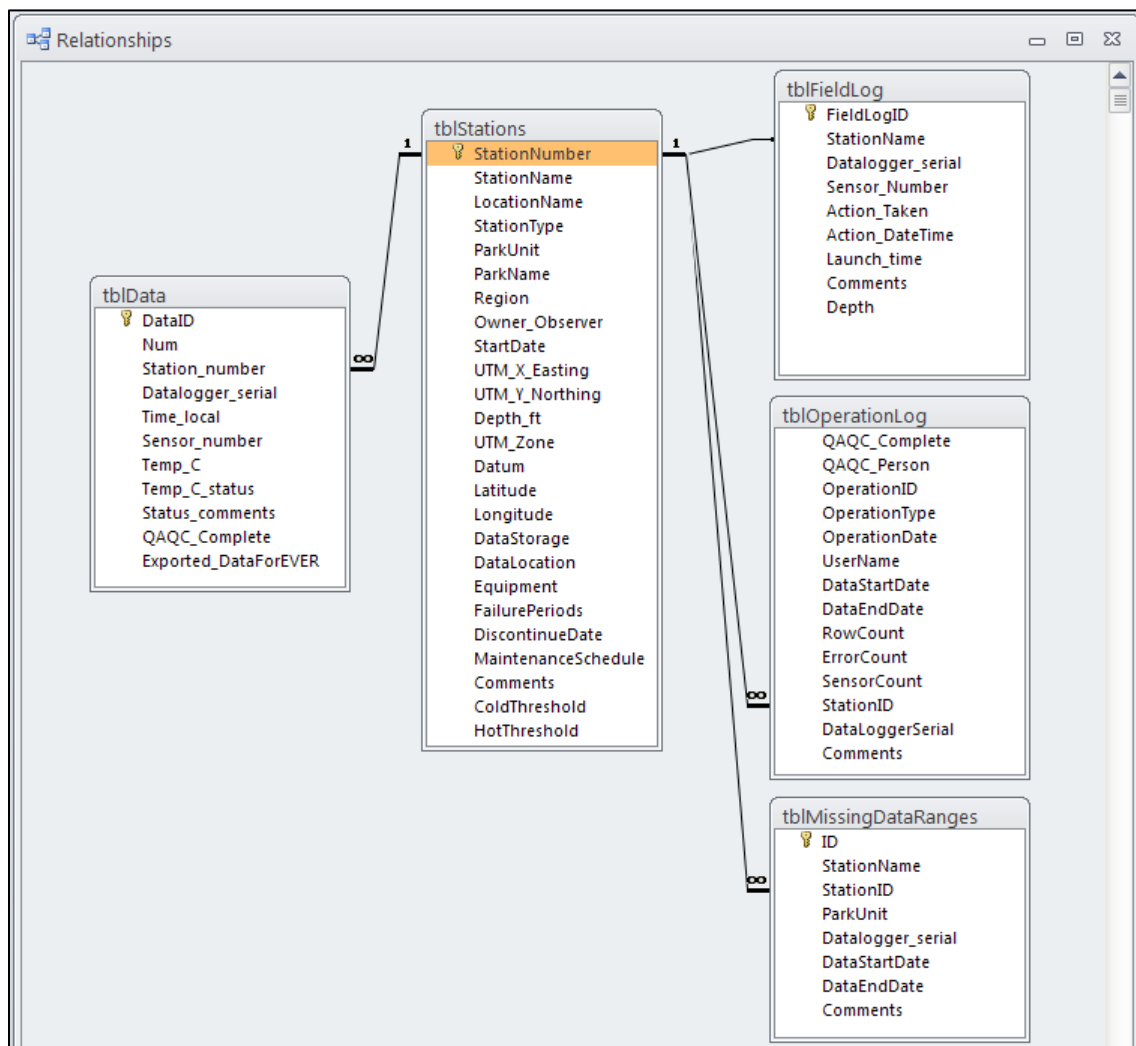


Table: tblStations

Description: Data logger monitoring station table containing station names, locations, and depths of monitoring stations

Field Name	Type	Size	Description
StationNumber	Text	50	Station Number / Designation
StationName	Text	50	Station Name
LocationName	Text	255	Full station location name
LocationDetails	Text	255	Additional details on where the temperature probe is located
StationType	Text	255	Type of station (e.g. weather station, rain guage, crest guage, etc.)
ParkUnit	Text	50	4-letter park abbreviation
ParkName	Text	255	Full park name
Region	Text	100	Geographic region where station/sensor is located
Owner_Observer	Text	50	Owner/Observer of Station
StartDate	Time/Local	8	Date Data Collection Began (month/year) OR date archiving began for designated location of information
UTM_X_Easting	Number	8	UTM X (northing) coordinate for the center of the plot or location
UTM_Y_Northing	Number	8	UTM Y (easting) coordinate for the center of the plot or location
Depth_ft	Text	255	Depth of datalogger in feet
UTM_Zone	Number	8	UTM zone
Datum	Text	5	Datum of mapping ellipsoid
Latitude	Number	8	Latitude in decimal degrees for the center of the plot or location to two decimal places
Longitude	Number	8	Longitude in decimal degrees for the center of the plot or location to two decimal places
DataStorage	Text	100	Type of Data Storage (Digital, Hard copy)
DataLocation	Text	250	Where the data is stored (physical location, digital address, etc)
Equipment	Memo	0	Types of Instruments
FailurePeriods	Memo	0	Periods of time where data may be inaccurate or missing
DiscontinueDate	Time/Local	8	date when the station data collection was permanently discontinued
MaintenanceSchedule	Text	50	Frequency of Maintenance
Comments	Memo	0	Ancillary data
ColdThreshold	Number	4	lower bleaching temperature threshold
HotThreshold	Number	4	upper bleaching temperature threshold

Table: tblData

Description: All water temperature data

Field Name	Type	Size	Description
DataID	Number	4	Unique number
Num	Number	8	Data record number from Hobo data logger
Station_number	Text	25	Site location ID number. Site details in tblStations
Datalogger_serial	Text	255	Hobo sensor ID number
Time_local	Time/Local	8	Date and Time of collection (local)
Sensor_number	Number	4	Unique number of the sensor when multiples sensors are deployed at a single site
Temp_C	Number	8	Temperature in degrees Celsius
Temp_C_status	Number	2	Status as valid or invalid: -1= invalid, 0=valid
Status_comments	Text	255	comments on the sensor status messages
QAQC_Complete	Yes/No	1	Has QA/QC been completed? (Yes/No)
Exported_DataForEVER	Yes/No	1	Has data been exported to DataForEVER? (Yes/No)

Table: tblOperationLog

Description: Log of all import and QA/QC operations performed on the database; includes the name of the individual, operation performed, and date.

Field Name	Type	Size	Description
QAQC_Complete	Yes/No	1	Has QA/QC SOP been completed for this data
QAQC_Person	Text	50	Initials of person conducting QA/QC
OperationID	Number	4	unique ID for the operation
OperationType	Text	50	type of operation performed on the database; likely data import. "Historical" is a log created by Andrea Atkinson by reviewing all data.
OperationDate	Time/Local	8	date the operation was performed on the database
UserName	Text	50	name of the individual interacting with the database
DataStartDate	Time/Local	8	start date of imported data
DataEndDate	Time/Local	8	end date of imported data
RowCount	Number	4	number of rows added to the database
ErrorCount	Number	4	number of automatically flagged errors on data import (starting 20110902 this includes blank records like those created by internal HOBO logger events)
SensorCount	Number	2	number of weather station sensors detected in the import file
StationID	Text	50	station ID for the imported data; user selected on import; details in tblStations
DataLoggerSerial	Text	50	data logger serial number for the imported data; automatically extracted on import
Comments	Memo	0	Comments/Metadata that applies to entire range of data

Table: tblFieldLog

Description: Log of all datalogger launches, deployments, and retrievals; includes the datalogger serial, date, and comments.

Field Name	Type	Size	Description
FieldLogID	Number	4	Automatically generated unique number
StationName	Text	50	Station Name - location where deployed
Datalogger_serial	Text	50	Hobo sensor ID number
Sensor_Number	Number	4	Unique number of the sensor when multiples sensors are deployed at a single site (1 or 2)
Action_Taken	Text	255	Action that was taken ("Underwater Download w/Shuttle"; "Sensor Deployment"; "Sensor Retrieval"; "Other (lost sensor, damage, etc.)")
Action_DateTime	Time/Local	8	Date & approximate time that the logger was downloaded underwater, physically deployed at site or physically retrieved from water
Launch_time	Time/Local	8	Date & time the logger was programmed to start (Select date, enter space, then give time, e.g.)
Comments	Memo	0	Comments
Depth	Number	4	Depth (in Ft)

Table: tblMissingDataRanges

Description: Table of missing data ranges and comments on likelihood of finding them with further searching.

Field Name	Type	Size	Description
ID	Number	4	Automatically generated unique number
StationName	Text	255	Combination of Park and Site name
StationID	Text	255	Station ID number. Links to details in tblStations
ParkUnit	Text	255	Park 4 letter code
Datalogger_serial	Text	255	Likely data logger serial number if known
DataStartDate	Time/Local	8	Beginning of missing data range
DataEndDate	Time/Local	8	End of missing data range
Comments	Memo	0	Comments on whether data is missing or may not actually exist

Appendix B. Sample Graphs and Tables from Graphing Templates

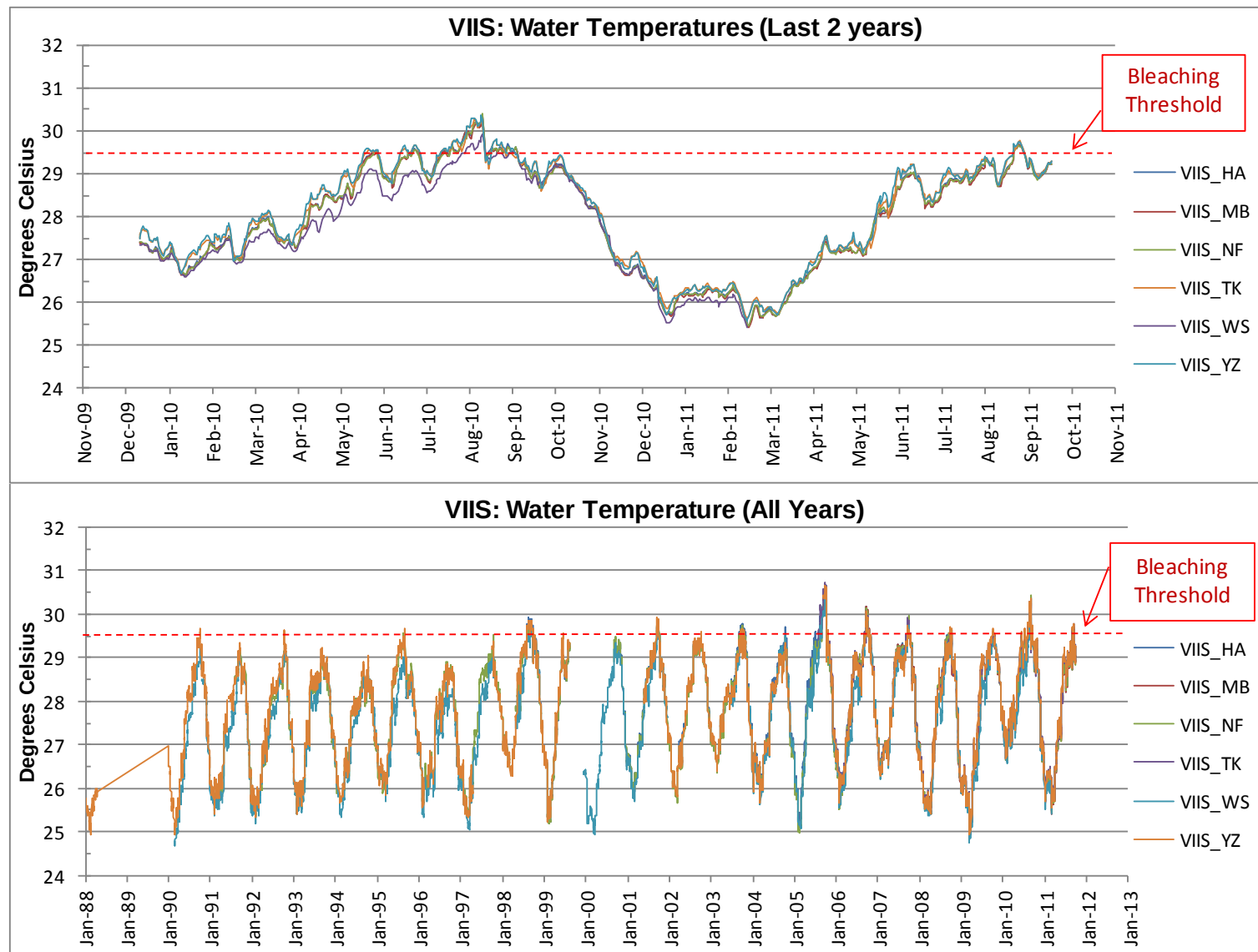


Figure VIIS Temperature-1. Virgin Islands National Park water temperature summary graphs. Top: Water temperatures for past 2 calendar years. Bottom: Graph of all water temperature data. Bleaching stress threshold of 29.5 °C is shown.

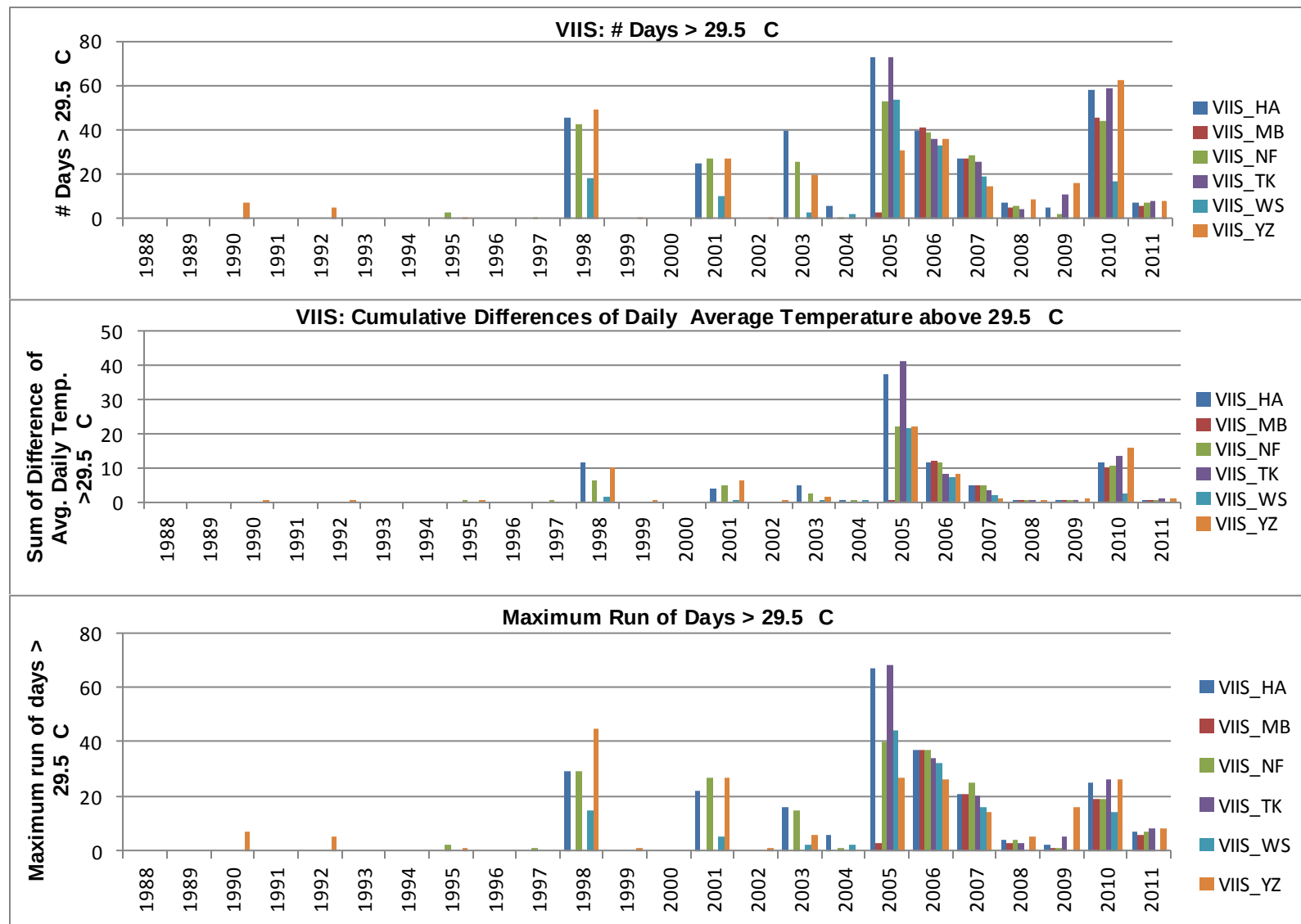


Figure VIIS Temperature-2. Virgin Islands National Park water temperature stress threshold graphs. Top: Number of days above 29.5°C stress threshold. Middle: Cumulative sum of differences of daily average temperature from 29.5°C for days above the threshold. Bottom: Maximum consecutive run of days above the 29.5°C threshold.

B-4

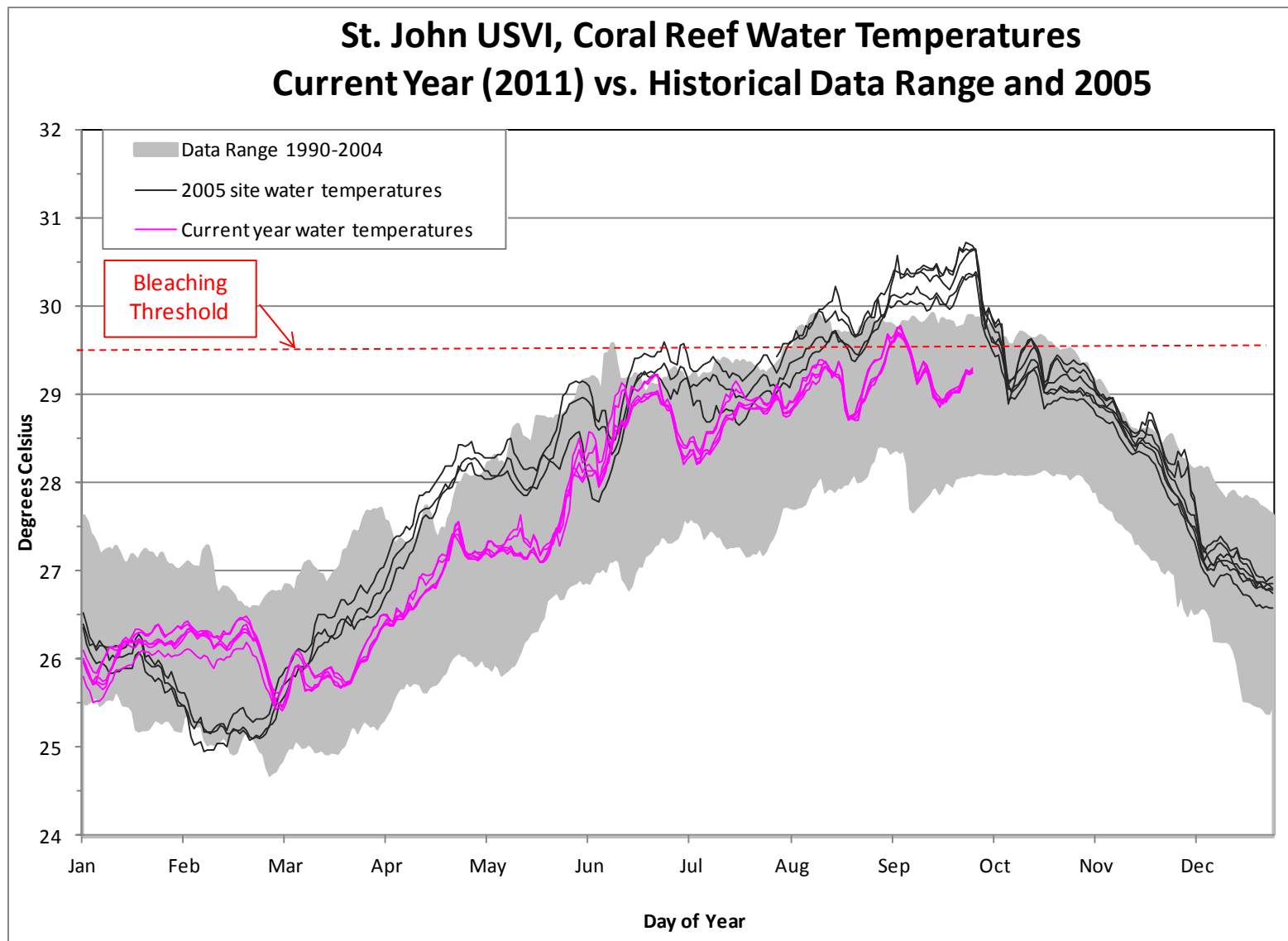


Figure VIIS Temperature-3. The current year's water temperature for Virgin Islands National Park compared with 2005 (an extensive bleaching year) and the 1990-2004 range of daily average temperatures for all sites.

Table VIIS Temperature-1. Virgin Islands National Park water temperature data summary at coral monitoring sites.

StationName	Year	# Days Monitored	Avg. Temp. (°C)	Max. Temp. (°C)	Min. Temp. (°C)	# Days >29.5 °C	Sum of differences >29.5 °C	Maximum Run of Days >29.5 °C	Average of Cold Months (Dec [prev yr] - Mar) (°C)	Average of Warm Months (July-Oct) (°C)
VIIS_HA	1998	148	28.9	29.9	26.8	46	11.5	29		29.5
	1999	224	27.4	29.3	25.2	0	0.0	0	26.4	28.9
	2000	100	28.3	29.4	26.5	0	0.0	0		29.2
	2001	306	27.9	29.9	25.9	25	4.2	22	26.5	29.1
	2002	280	28.3	29.4	26.5	0	0.0	0	26.8	29.0
	2003	364	28.1	29.8	26.4	40	5.2	16	27.1	29.1
	2004	352	27.7	29.7	25.8	6	0.7	6	26.8	28.9
	2005	365	28.2	30.6	25.2	73	37.4	67	26.2	29.7
	2006	365	28.1	30.2	25.8	40	11.7	37	26.6	29.2
	2007	364	28.1	30.0	26.4	27	5.1	21	27.0	29.3
	2008	366	27.6	29.6	25.5	7	0.3	4	26.3	29.0
	2009	365	27.6	29.5	24.9	5	0.1	2	25.9	29.1
	2010	365	28.3	30.4	26.0	58	11.9	25	27.4	29.4
	2011	273	27.5	29.7	25.5	7	0.8	7	26.2	29.0
VIIS_HA Multi-Year		4237	28.0	30.6	24.9	334	89.0	67	26.6	29.2
VIIS_MB	2005	87	28.3	29.6	26.7	3	0.3	3		29.2
	2006	365	28.1	30.2	25.7	41	12.1	37	26.5	29.2
	2007	364	28.1	29.9	26.3	27	4.8	21	27.0	29.3
	2008	366	27.6	29.6	25.5	5	0.2	3	26.3	29.0
	2009	365	27.6	29.5	24.9	1	0.0	1	25.9	29.1
	2010	365	28.2	30.4	26.0	46	10.2	19	27.4	29.4
	2011	273	27.5	29.7	25.4	6	0.7	6	26.1	28.9
VIIS_MB Multi-Year		2185	27.9	30.4	24.9	129	28.3	37	26.5	29.2

StationName	Year	# Days Monitored	Avg. Temp. (°C)	Max. Temp. (°C)	Min. Temp. (°C)	# Days >29.5 °C	Sum of differences >29.5 °C	Maximum Run of Days >29.5 °C	Average of Cold Months (Dec [prev yr] - Mar) (°C)	Average of Warm Months (July-Oct) (°C)
VIIS_NF	1991	304	27.2	29.2	25.5	0	0.0	0	25.9	28.7
	1992	366	27.3	29.2	25.3	0	0.0	0	25.9	28.5
	1993	365	27.4	28.9	25.4	0	0.0	0	26.1	28.5
	1994	365	27.3	28.6	25.7	0	0.0	0	26.3	28.2
	1995	365	27.8	29.6	25.7	3	0.1	2	26.5	28.9
	1996	366	27.3	28.9	25.7	0	0.0	0	26.6	28.4
	1997	365	27.6	29.5	25.4	1	0.0	1	26.1	28.8
	1998	361	28.1	29.8	26.3	43	6.6	29	27.1	29.4
	1999	224	27.4	29.3	25.2	0	0.0	0	26.3	28.9
	2000	125	28.5	29.5	26.6	0	0.0	0		29.2
	2001	365	27.9	29.8	25.9	27	5.2	27	26.5	29.1
	2002	365	27.8	29.4	25.7	0	0.0	0	26.6	29.0
	2003	365	28.1	29.7	26.4	26	2.6	15	27.1	29.1
	2004	352	27.6	29.5	25.8	1	0.0	1	26.7	28.8
	2005	365	28.0	30.4	25.0	53	22.2	40	26.0	29.5
	2006	365	28.0	30.1	25.5	39	11.9	37	26.3	29.3
	2007	363	28.1	30.0	26.4	29	5.2	25	27.0	29.3
	2008	365	27.6	29.6	25.5	6	0.4	4	26.3	29.0
	2009	219	28.6	29.5	26.0	2	0.0	1	26.4	29.1
	2010	365	28.2	30.4	26.0	44	10.5	19	27.4	29.4
	2011	273	27.5	29.7	25.4	7	0.7	7	26.2	29.0
VIIS_NF Multi-Year		6968	27.8	30.4	25.0	281	65.3	40	26.5	28.9

StationName	Year	# Days Monitored	Avg. Temp. (°C)	Max. Temp. (°C)	Min. Temp. (°C)	# Days >29.5 °C	Sum of differences >29.5 °C	Maximum Run of Days >29.5 °C	Average of Cold Months (Dec [prev yr] - Mar) (°C)	Average of Warm Months (July-Oct) (°C)
VIIS_TK	2005	153	29.2	30.7	26.9	73	41.2	68		29.9
	2006	365	28.1	30.1	25.7	36	8.4	34	26.7	29.2
	2007	364	28.1	29.9	26.3	26	3.6	20	27.0	29.2
	2008	365	27.5	29.6	25.4	4	0.2	3	26.3	28.9
	2009	365	27.7	29.6	25.0	11	0.4	5	26.0	29.1
	2010	365	28.4	30.3	26.2	59	13.7	26	27.6	29.4
	2011	273	27.6	29.8	25.6	8	1.2	8	26.3	29.1
VIIS_TK Multi-Year		2250	28.0	30.7	25.0	217	68.6	68	26.6	29.2

StationName	Year	# Days Monitored	Avg. Temp. (°C)	Max. Temp. (°C)	Min. Temp. (°C)	# Days >29.5 °C	Sum of differences >29.5 °C	Maximum Run of Days >29.5 °C	Average of Cold Months (Dec [prev yr] - Mar) (°C)	Average of Warm Months (July-Oct) (°C)
VIIS_WS	1990	306	27.3	29.3	24.7	0	0.0	0	25.0	28.4
	1991	361	27.0	29.0	25.4	0	0.0	0	26.0	28.3
	1992	366	27.2	29.1	25.2	0	0.0	0	25.8	28.4
	1993	365	27.4	28.9	25.4	0	0.0	0	26.1	28.5
	1994	365	27.2	28.8	25.3	0	0.0	0	26.2	28.2
	1995	365	27.5	29.3	25.7	0	0.0	0	26.6	28.5
	1996	366	27.0	28.5	25.3	0	0.0	0	26.4	27.9
	1997	302	27.1	29.0	25.0	0	0.0	0	25.8	28.5
	1998	211	28.8	29.7	27.4	18	1.6	15		29.2
	1999	16	26.4	26.4	26.3	0	0.0	0	25.6	28.7
	2000	366	27.3	29.3	24.9	0	0.0	0	26.4	28.9
	2001	347	27.7	29.7	25.7	10	0.8	5	27.8	
	2003	189	28.5	29.5	26.4	3	0.1	2		28.8
	2004	366	27.5	29.5	25.6	2	0.0	2	26.5	28.8
	2005	365	27.9	30.4	25.1	54	21.5	44	26.1	29.4
	2006	351	27.8	30.0	25.6	33	7.3	32	26.4	29.0
	2007	365	28.0	29.8	26.2	19	1.9	16	26.9	29.2
	2008	366	27.4	29.4	25.4	0	0.0	0	26.2	28.8
	2009	365	27.4	29.4	24.8	0	0.0	0	25.9	28.8
	2010	365	28.1	29.9	25.8	17	2.7	14	27.3	29.2
	2011	60	25.9	26.2	25.4	0	0.0	0	26.1	
VIIS_WS Multi-Year		6528	27.5	30.4	24.7	156	35.9	44	26.2	28.7

StationName	Year	# Days Monitored	Avg. Temp. (°C)	Max. Temp. (°C)	Min. Temp. (°C)	# Days >29.5 °C	Sum of differences >29.5 °C	Maximum Run of Days >29.5 °C	Average of Cold Months (Dec [prev yr] - Mar) (°C)	Average of Warm Months (July-Oct) (°C)
VIIS_YZ	1988	94	25.5	26.0	24.9	0	0.0	0	25.5	
	1990	365	27.4	29.7	24.9	7	0.8	7	25.7	28.8
	1991	357	27.3	29.3	25.4	0	0.0	0	26.2	28.6
	1992	366	27.5	29.6	25.4	5	0.4	5	26.0	28.7
	1993	365	27.6	29.2	25.4	0	0.0	0	26.3	28.7
	1994	365	27.4	29.0	25.7	0	0.0	0	26.4	28.3
	1995	355	27.8	29.7	25.9	1	0.2	1	26.6	29.0
	1996	339	27.4	28.9	25.5	0	0.0	0	26.7	28.4
	1997	190	27.0	29.4	25.3	0	0.0	0	26.0	28.9
	1998	365	28.2	29.9	26.3	49	10.5	45	27.0	29.4
	1999	224	27.5	29.6	25.2	1	0.1	1	26.4	29.0
	2001	222	28.7	29.9	27.0	27	6.4	27		29.2
	2002	365	27.9	29.6	25.8	1	0.1	1	26.7	29.1
	2003	365	28.0	29.7	26.4	20	1.6	6	27.2	29.0
	2004	323	27.6	29.3	25.6	0	0.0	0	26.6	28.7
	2005	110	28.8	30.7	26.8	31	22.1	27		29.9
	2006	365	28.0	30.1	25.6	36	8.2	26	26.6	29.1
	2007	363	28.0	29.8	26.3	15	1.4	14	26.9	29.1
	2008	364	27.5	29.7	25.4	9	0.8	5	26.2	28.9
	2009	365	27.7	29.7	24.9	16	1.0	16	26.0	29.2
	2010	365	28.4	30.4	26.1	63	16.1	26	27.6	29.5
	2011	273	27.6	29.8	25.5	8	1.3	8	26.3	29.1
VIIS_YZ Multi-Year		6865	27.7	30.7	24.9	289	70.7	45	26.5	28.9

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.

NPS 910/121579, July 2013

National Park Service
U.S. Department of the Interior



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