Sea Surface Temperature as a Habitat Defining Parameter

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This article is structured as a presentation. As such, there are repeated figures in some places and personal pronouns are used. Read it as if I were speaking it.

The presentation was originally given at the 72nd Annual Meeting of the Florida Academy of Sciences, March 14, 2008.

Introduction:

The frequency of using Sea Surface Temperatures (SST) by Environmental Managers and Researchers to account for ecological events and observations as well as to predict the ecological future has increased steadily.

The Situation:

The frequency of using Sea Surface Temperatures (SST) by Environmental Managers and Researchers to account for ecological events and observations as well as to predict the ecological future has increased steadily.

The key concepts in the sentence are *account* for events and observations and *predict* the future.

Sea Surface Temperature and its interpretation came to my attention during a dive to 90 feet in the Caicos. I had just read an article about coral bleaching and SST. At 90 feet I noted that there was a noticeable number of blanched or bleached corals. Looking up at the surface through 90 feet of water I wondered, how does sea surface temperature affect, or initiate, coral bleaching?

But more importantly, How thick is the Sea Surface? During the next few weeks I inquired about this, questioning NOAA staff, DEP staff, Oceanographers and Marine Scientists from private practice, government, and research facilities. I received answers that ranged from "I don't know," through "Probably 20 feet," to "The first 100 meters." The disparity was cause for concern because the SST citation was appearing quite frequently in journals and government reports. Ultimately, I met Dr. Chris Moses who explained it. The question is important because.we frequently see this reference, "Temperature has been linked to bleaching; and it has. The quality of that link is questionable, but that is a different topic.

We see it stated as recently as the week before this conference on the Coral List Server in a more dramatic manner: and no less frequently stated that "Coral bleaching is caused by elevated SST."

Our questions are:

"How thick is the Sea Surface?"
And
"How does SST affect Coral Bleaching?"

The fact is that SST is actually two dimensional. Dr. Moses explained to me that the satellites doesn't measure temperature at all. They capture the black body heat radiation of the sea and then calculate what the temperature must have been in order account for the observed radiation. The satellites make 8 passes a day and record as many as 40 readings per pas per pixel. The warmest value is the one presented on the SST website.

So how strong is the link between bleaching and SST? Leading to our final question, "Can SST define the habitat parameters for all species at all depths?"

The fact that not all coral grows at the surface creates a direct disconnect between the SST and the temperature to which coral, or any marine organism is exposed during the course of the day. The temperature to which organisms are actually exposed, is a habitat defining parameter. So the question arises, Can SST define this habitat parameter? Compounding the situation, there is a common and recent tendency towards making broad generalizations. The generalization in this instance of SST being linked to physiological responses is that it is linked to all species of coral or even other marine organisms and at all depths. The occurrence of disease is also commonly implicated.

Our Study Sites:

1: Ft. Desoto: Pinellas County, West Central Florida

2: Lower Florida Keys

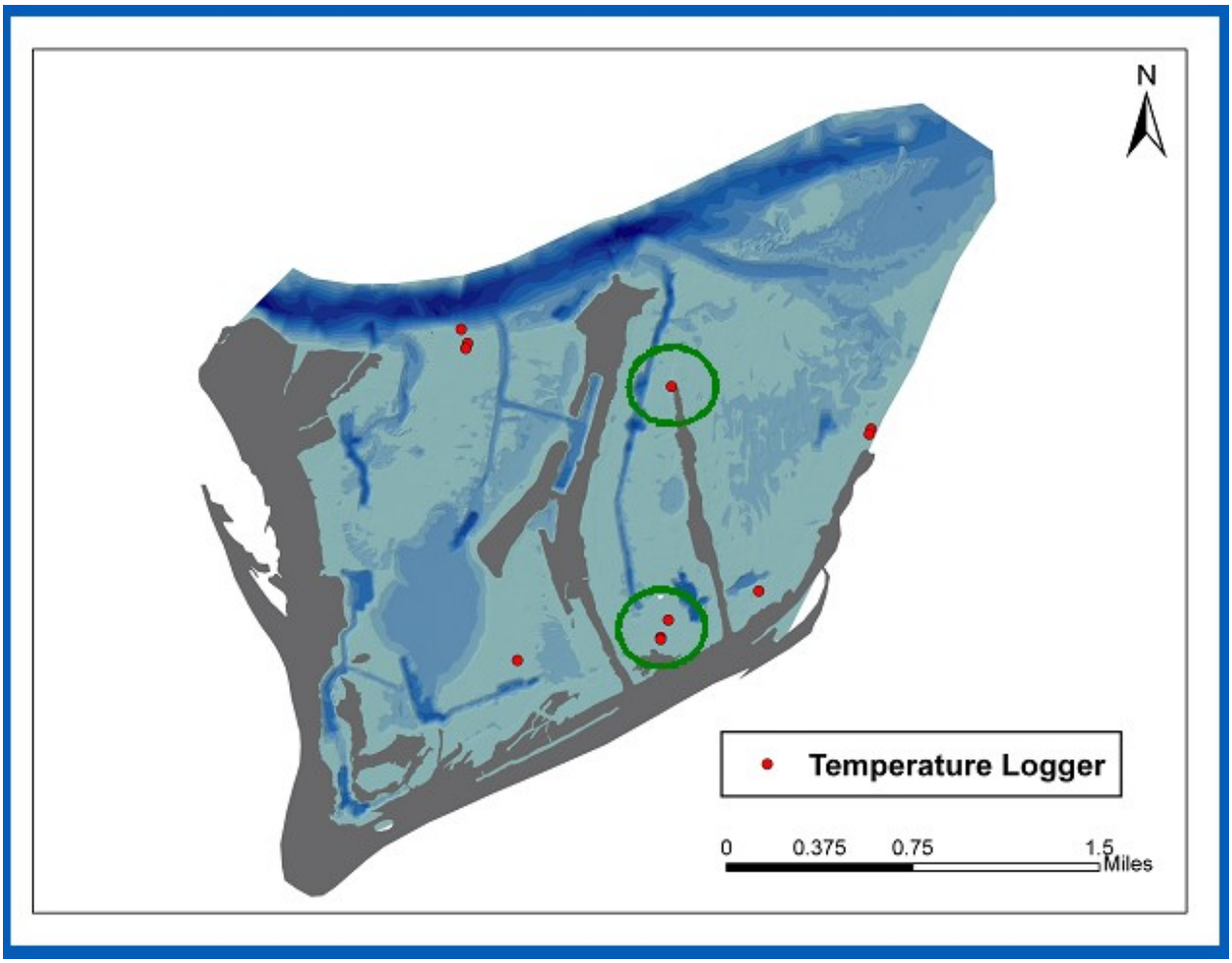
We were fortunate that we already had a study underway at Ft. Desoto Park located at the mouth of Tampa Bay where the red star is. The study had been underway since 2003 and we had been collecting hourly water temperature data at several locations.

We constructed a new study in the lower Florida Keys, where the yellow star is. In that study we placed 30 data loggers at various depths throughout the lower keys. We will

compare these data sets to the SST data on public websites.

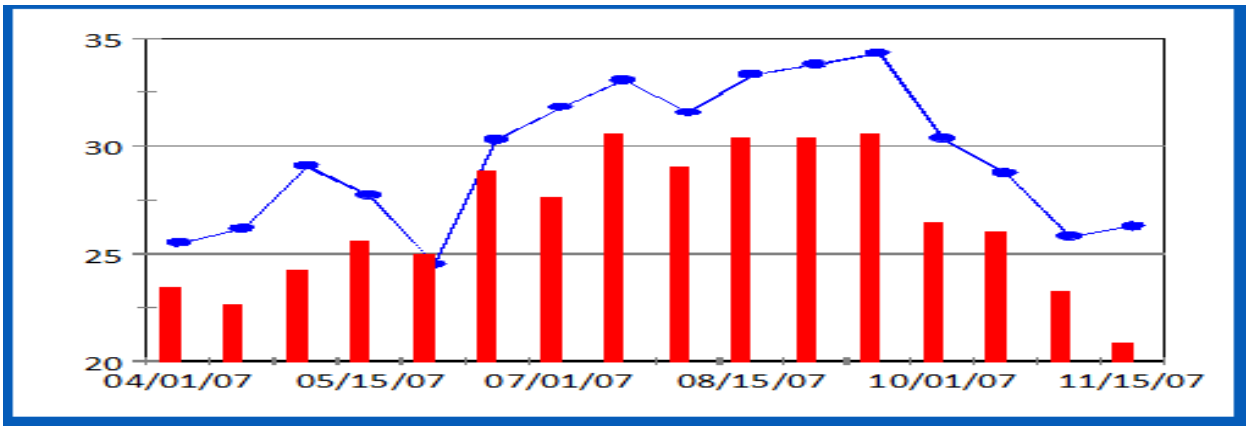
Ft. Desoto Aquatic Management Area

The Ft DeSoto study was located in shallow grass flats. Data loggers were installed in areas where tidal exchange was restricted by the island physiography and in areas which were exposed to normal tidal exchange rates. We will be examining data from the site PO6 in the south of the lagoon (green circle) and from site 2N (second green circle) located in the more open waters to the north. The nearest SST node is located north and east but is also in an area of shallow grass flats. The node is the central position of a 28 sq km box which makes up the pixel of the SST data.

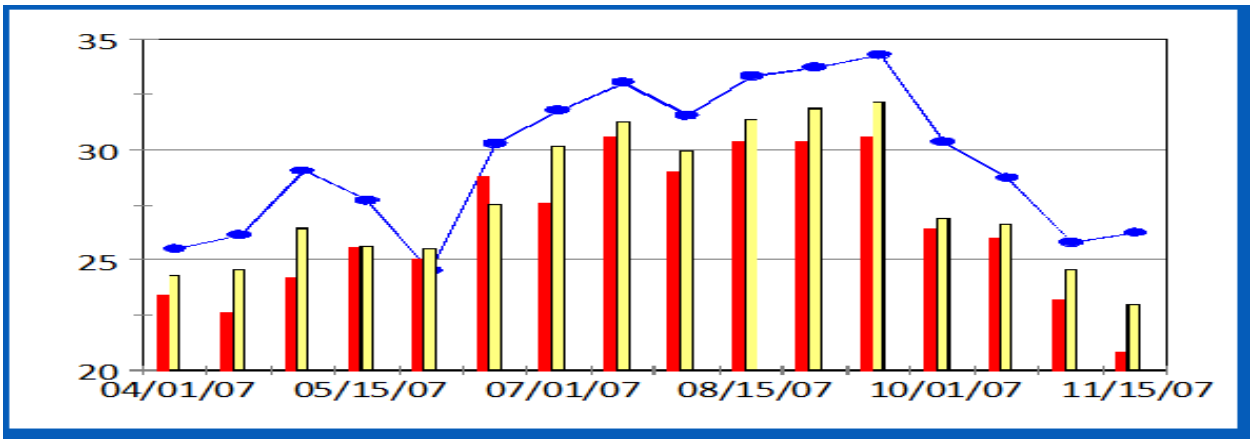


Top - Ft DeSoto Site 2N daily maxima (line) and SST (bars).

The graph below displays a comparison between the daily maxima of the water temperature and the data retrieved from the SST website. The daily water temperature maxima was used as an analogue to the SST method of using the maximum temperature. The period shown here and in most of the other slides is from April through November of 2007. The Y axis here and elsewhere, unless specifically noted, is from 20 to 35 degrees C. The data shown are points from the 1st and 15th of each month. Note that the general profiles are similar while there is substantial disagreement in the values.

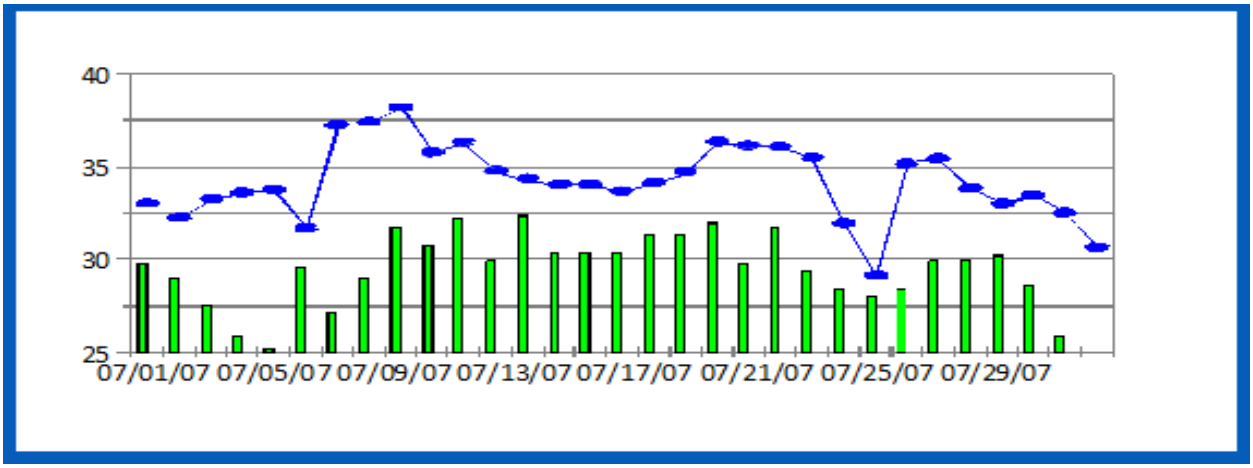


Ft DeSoto Site 2N daily maxima (line) and SST (red bars) with Ft DeSoto daily mean (yellowbars).



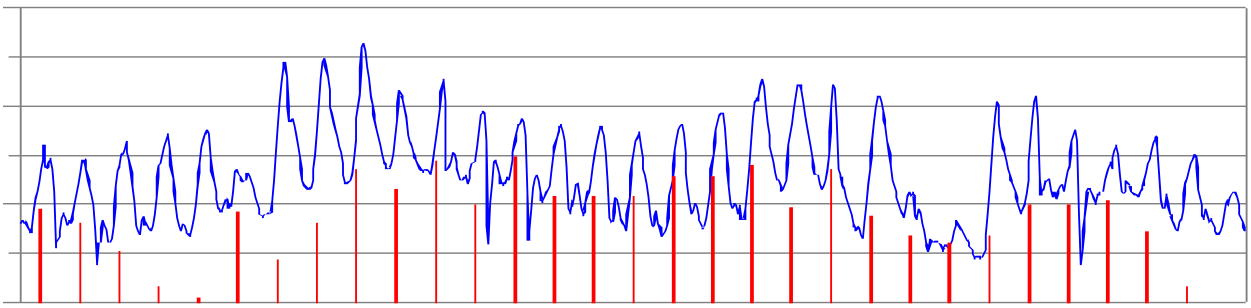
Looking at the daily average water temperature (above), the yellow bars, the agreement between water temperature and SST data is closer, but still substantial when considering the upper tolerance limits (broadly considered to be a stressor at temperatures above 30 deg C).

Ft. DeSoto SST (bars) P06 Daily Maxima (line); July 2007

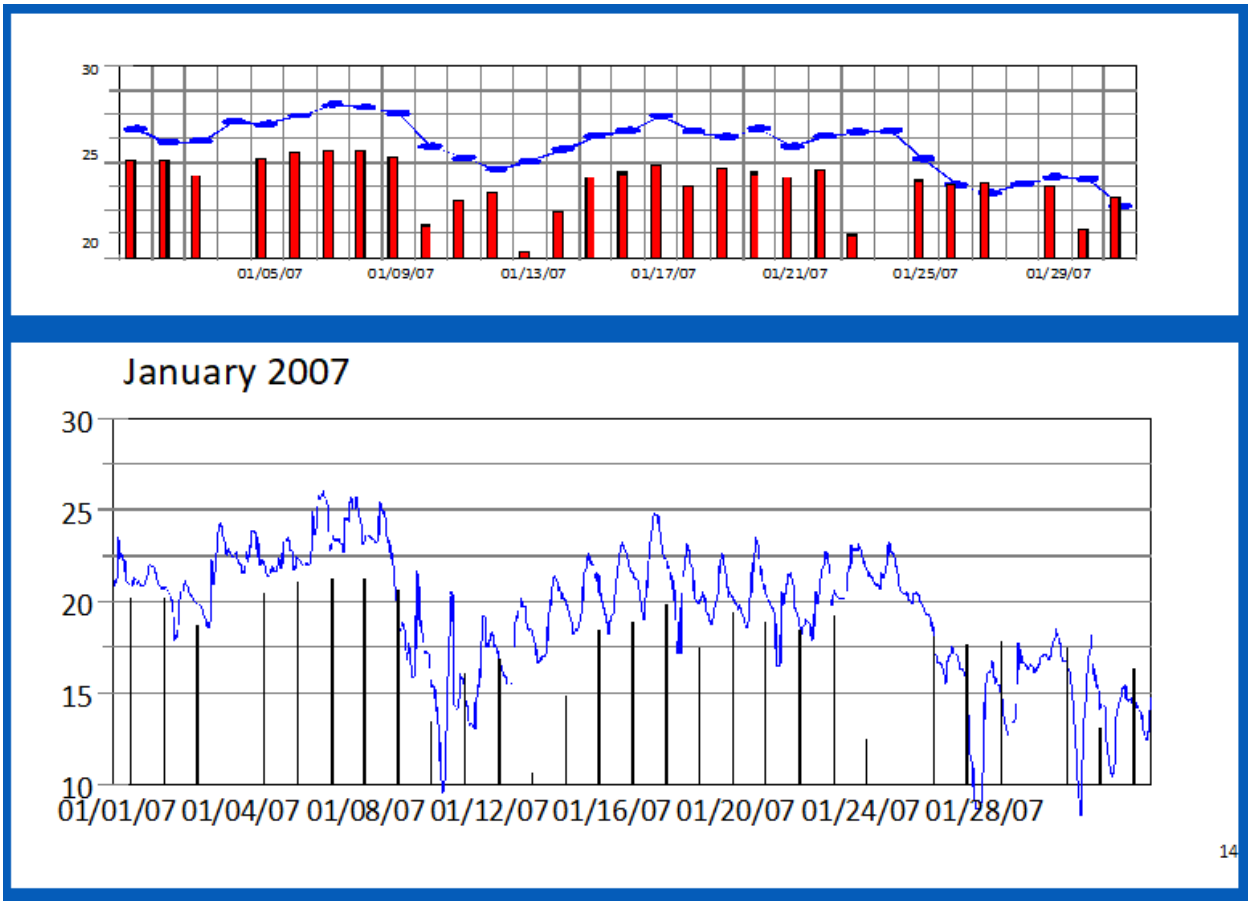


A closer examination of a single month of data, July of 2007, is presented. The water temperature is from the southern site and is the daily maxima while the green bars are the SST data.

We can now look more closely at the actual habitat by examining the hourly data from the data logger (blue line) and comparing it to the reported SST values. The blue line represents the temperature (habitat) to which the organisms are actually exposed. Peaks in these data can be related to insolation, tides, rainfall or any combination of those parameters.

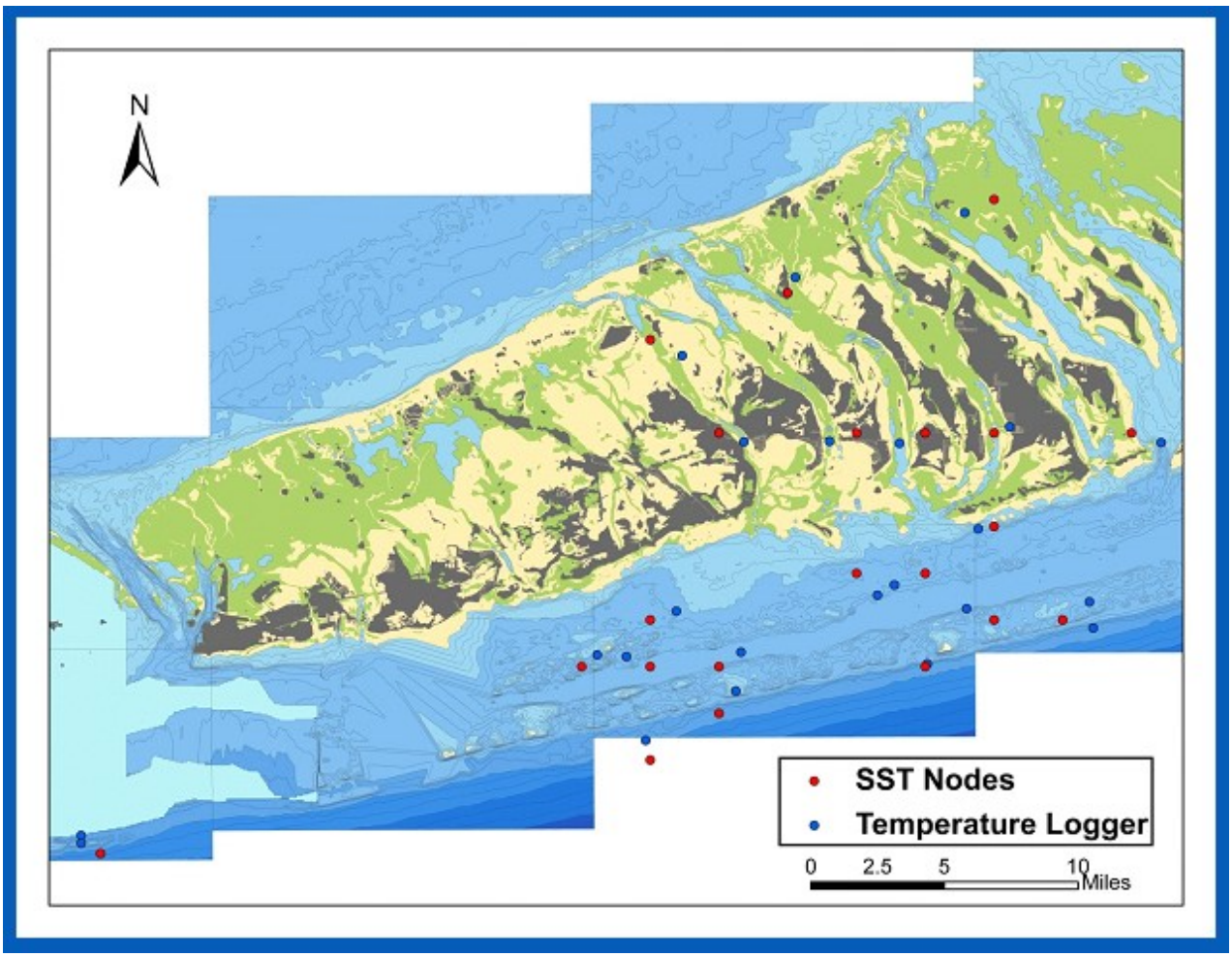


The January (7-1 to 7-29) data were examined to provide insight to seasonal consistency of the disparity between SST values and water temperatures. The daily graph at the top (bars = SST, Line = water temperature daily maxima) and the hourly trace in the graph at the bottom reveal that the winter SST values are not representative of actual water temperature. Note the change in the scale of the Y axis.



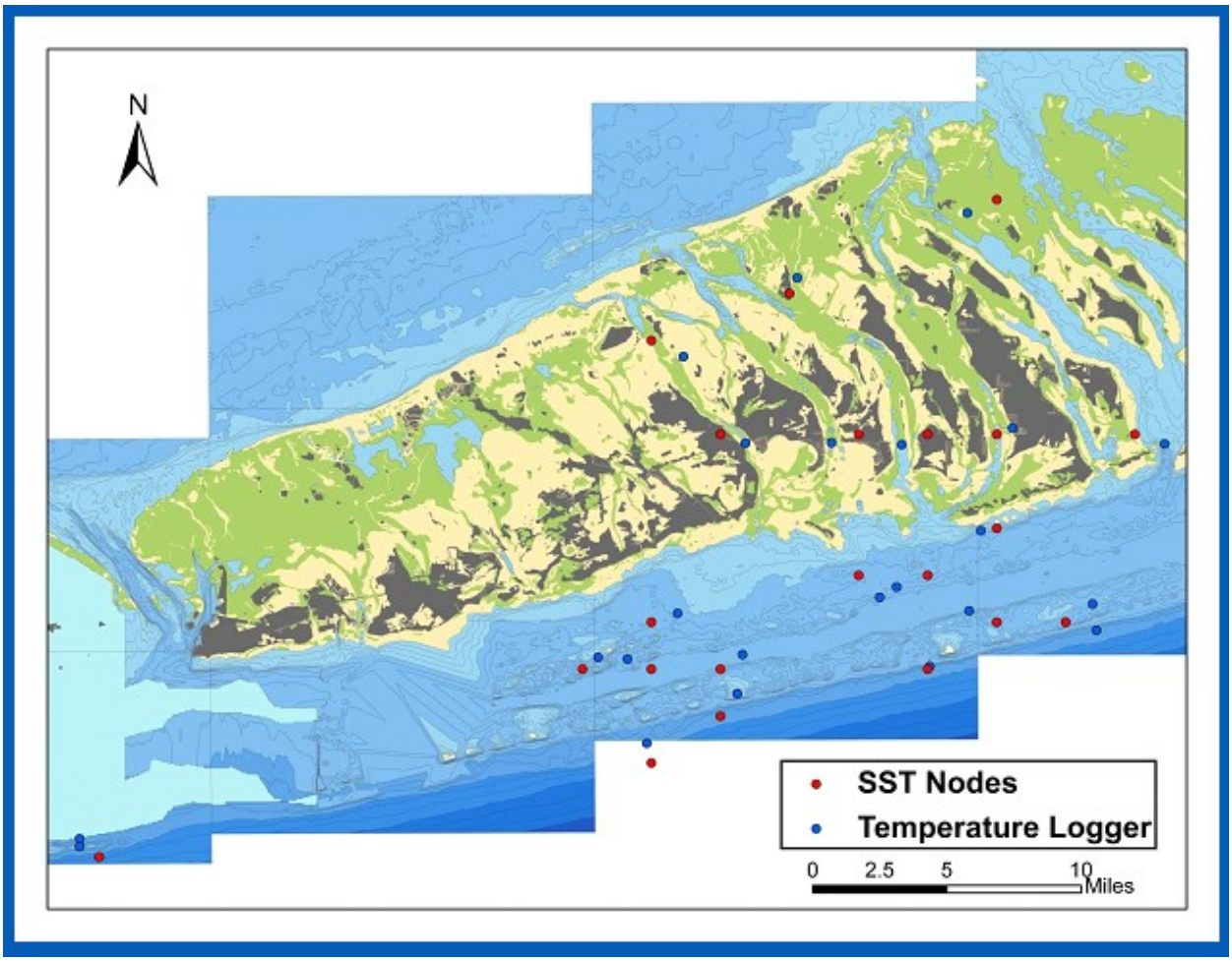
Lower Florida Keys

In the lower Florida Keys, we deployed 30 data loggers at depths ranging from 3 feet to 100 feet. In this slide and the subsequent slides, the red dots are the SST node and the blue dots are the locations the data loggers. The dark grey shapes are the actual islands. Green is seagrass. Tan represents sandy areas, and the blues are deeper than one meter. The map is from the Florida Keys Sanctuary GIS benthic habitat database.

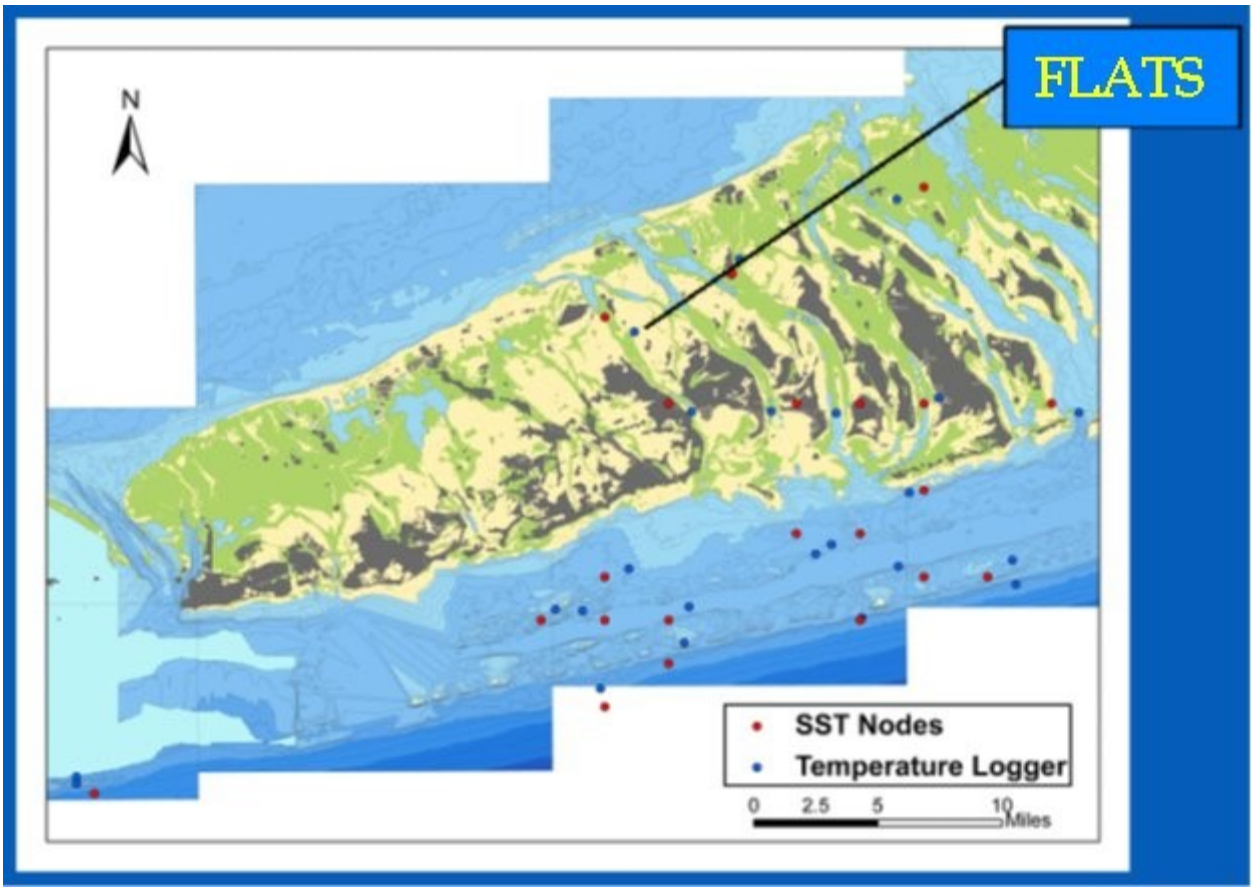


A Priori Geomorphological Stratification*

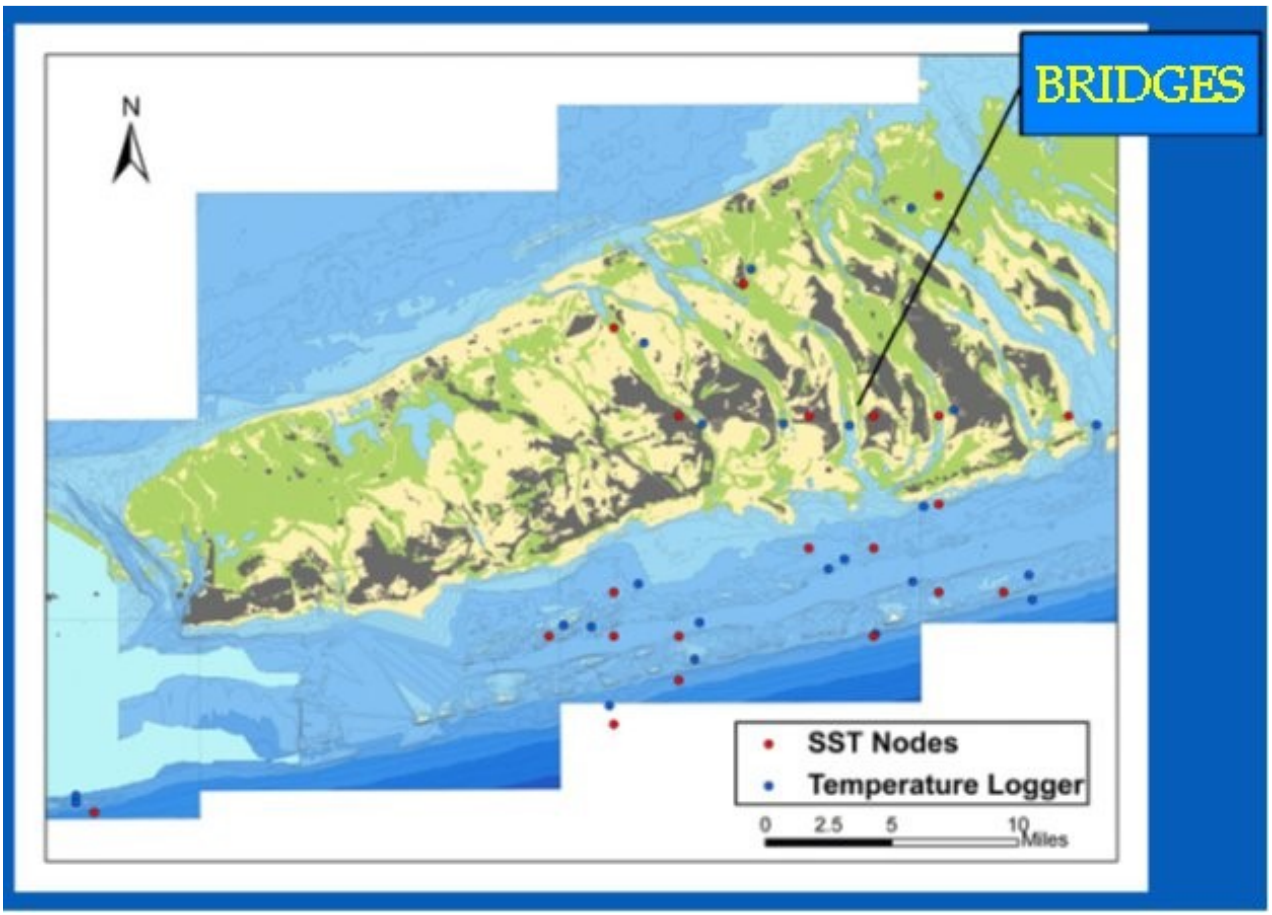
The initial locations were selected based on an *a priori* stratification based on geomorphology. The asterisk on stratification is to make certain that the viewer recognize that the strata were selected using physical features and not the currently popular method based on spatial distribution.



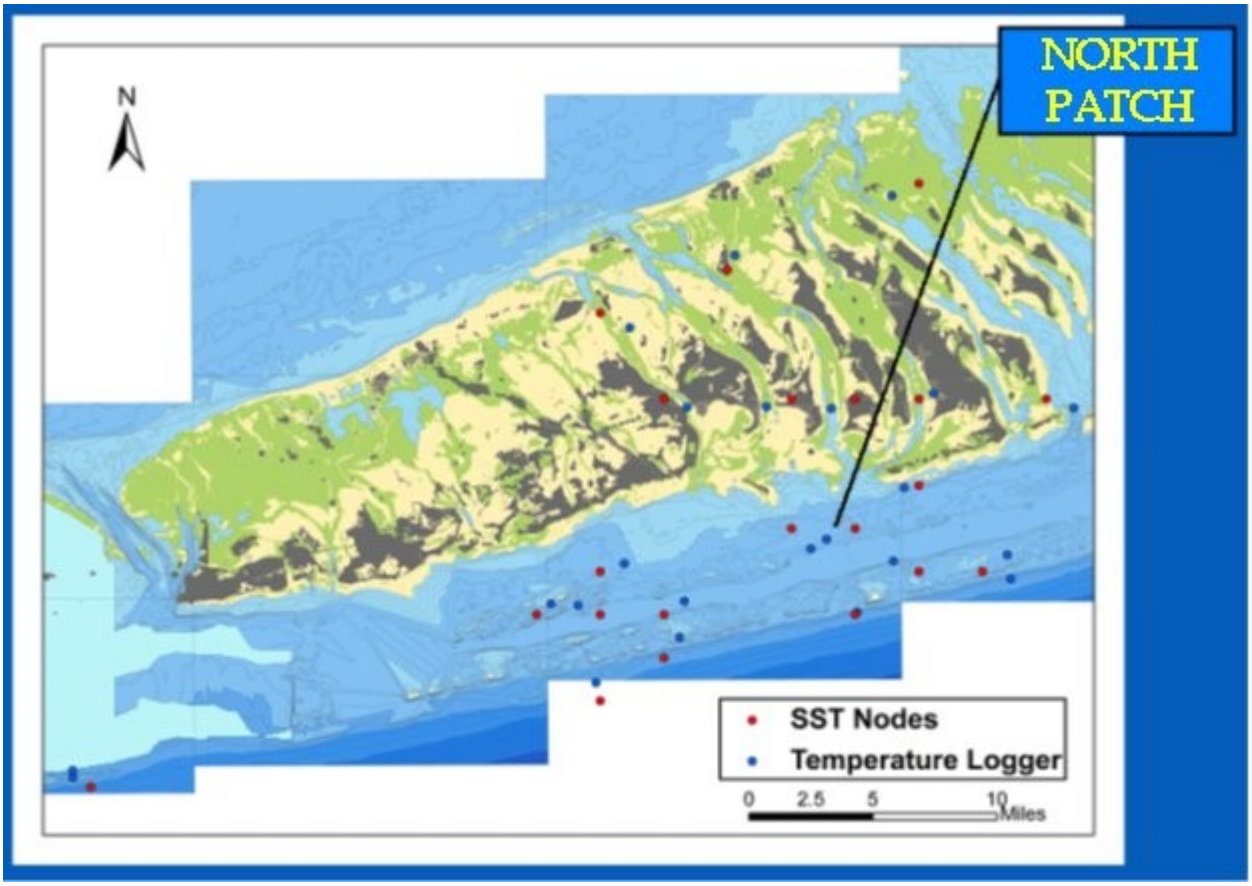
The strata chosen are the flats, which refers to the broad flat areas north of the islands. These areas have scattered small patches of corals too small to be classified as a reef. Larger patch reefs do occur at the northern edge of the flats. The general water flow from these shallows is south through the passes between the islands and then west in Hawk Channel.



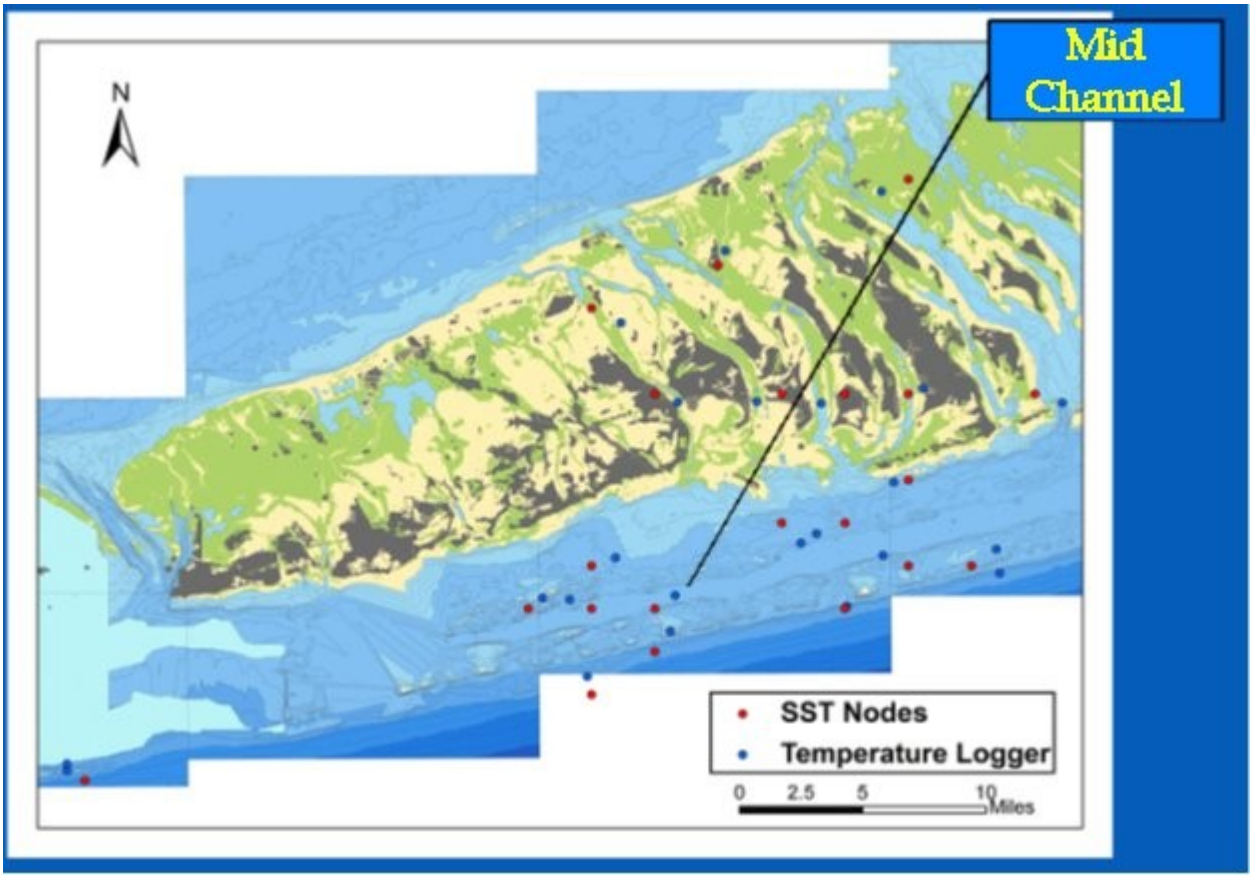
Five data loggers were installed in the passes under the bridges. The intent was to capture data from potentially very warm water generated in the flats as it passed to the south.



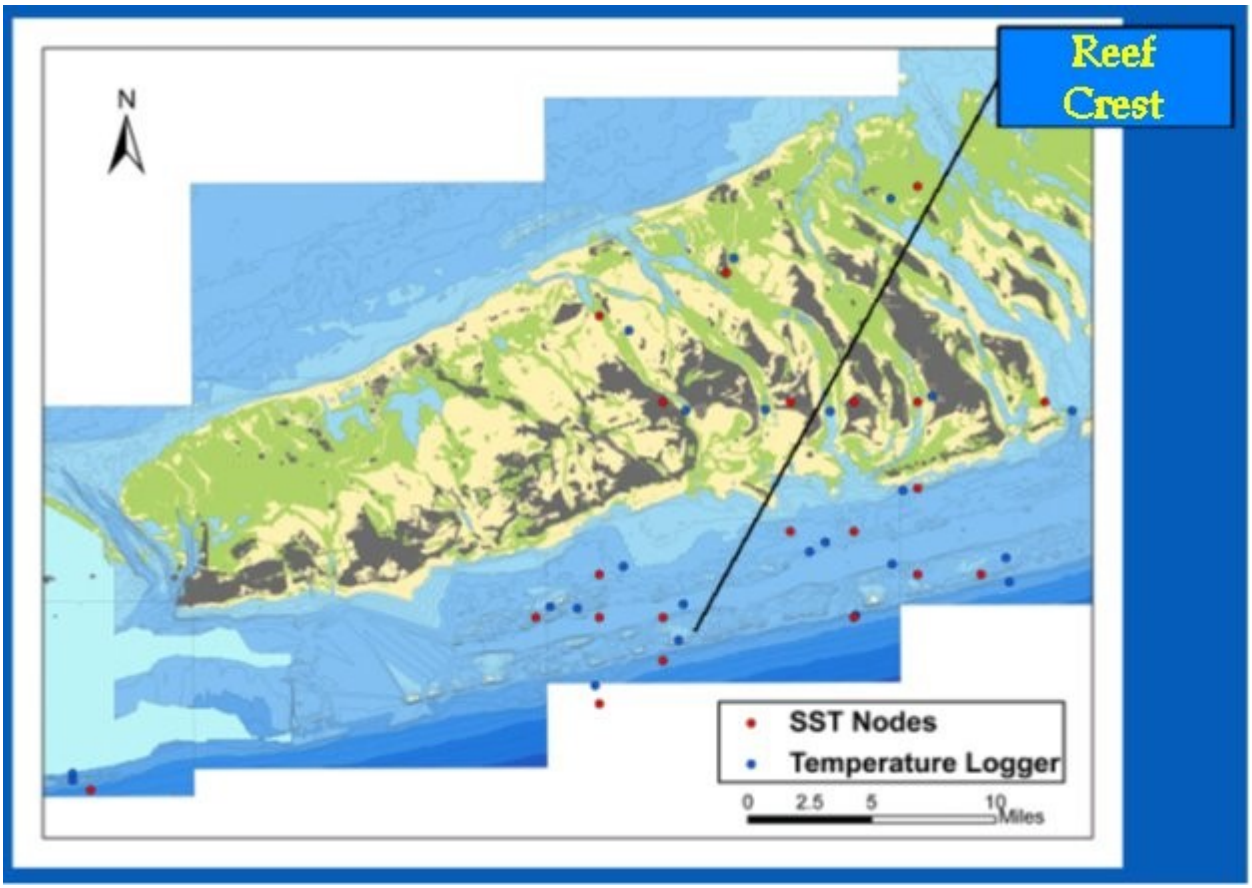
The area referred to as the North Patch is a broad flat bank south of the islands and up to 30 feet in depth. The bank does have grasses (not shown) and large sandy areas (not shown). The bank supports numerous outcrops of substantial patch reefs which are well developed. These are typically more diverse and less susceptible to disease and bleaching than those on the south side of Hawk Channel (personal observation).



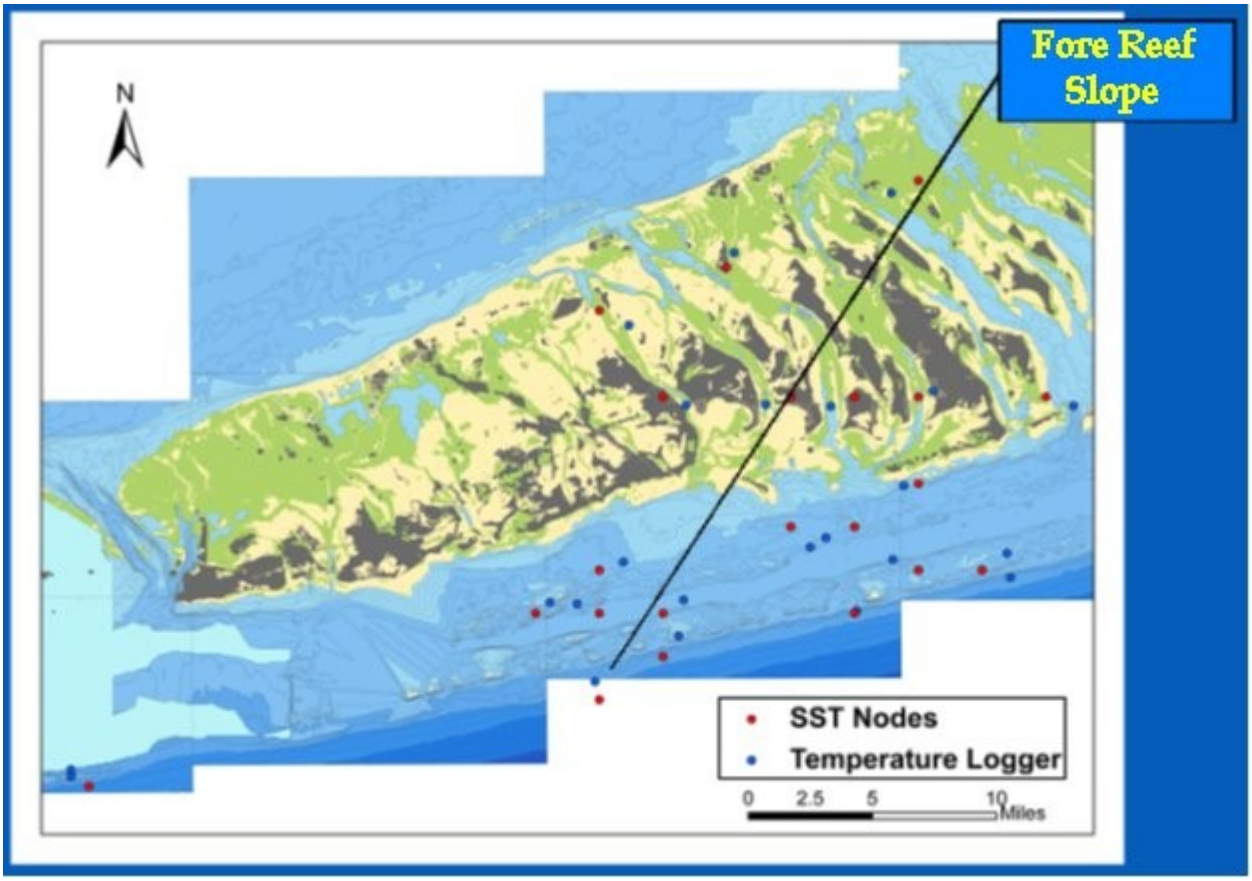
The mid channel data logger was installed at the bottom of Hawk Channel.



The Reef Crest, or the main reef tract, runs from west of Key West to North of Miami. It is shallow on the north side in the back reef and drops to more than a hundred feet on the reef face where a small shelf of sand is found, then it breaks down into the Florida Straights.



The Fore Reef sites were located at the deeper extent of the coral formations in waters of 100 feet.

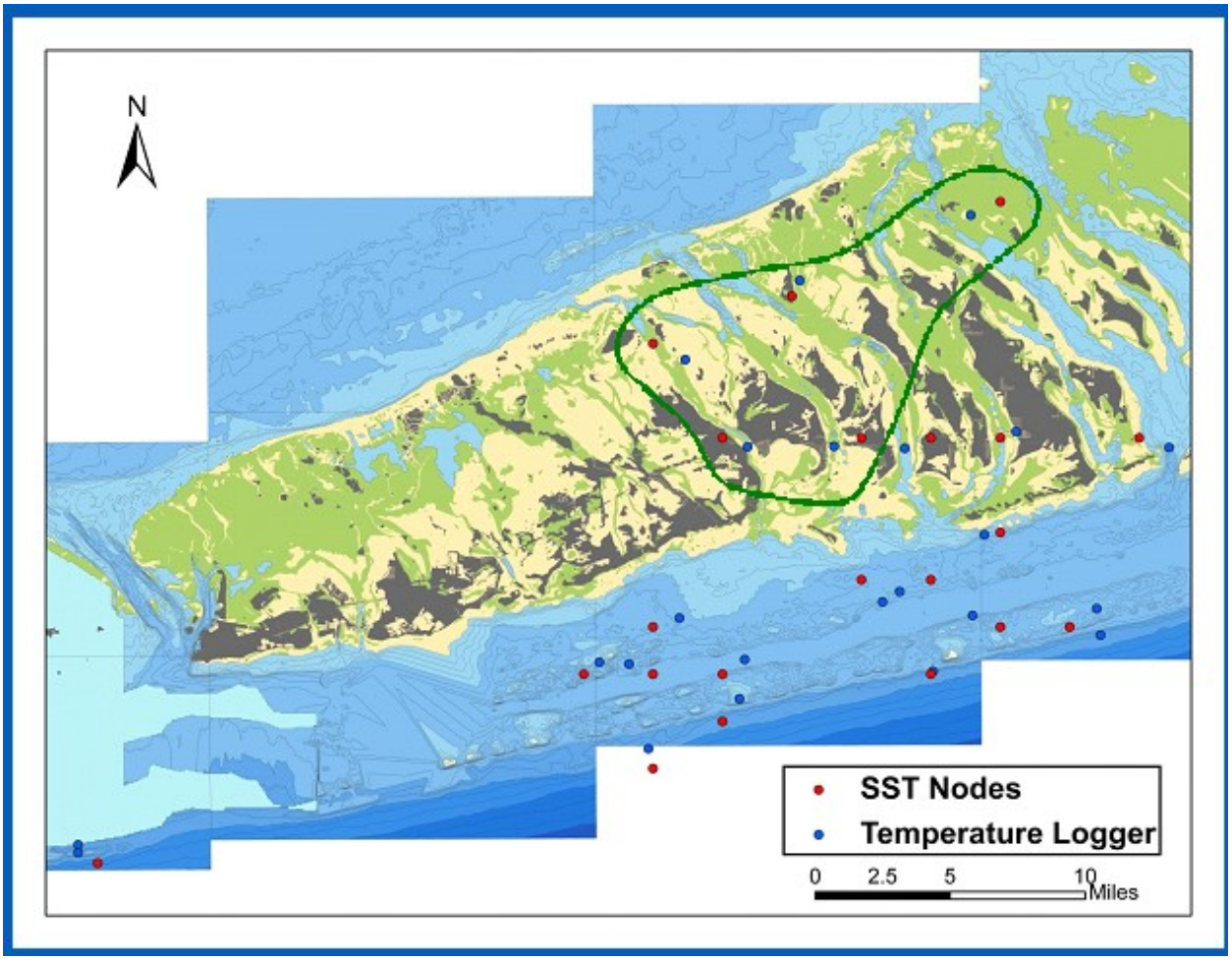


Data based geomorphological stratification Cluster Analysis Presented in terms of location.

The intent of the distribution of data loggers, both vertically and laterally was to gather data that would allow us to abandon the physiographic strata used to plan the study and develop a data based on geomorphological stratification using the results. This sounds complicated, but it is really just a cluster analysis presented in terms of location.

The next few slides will present the clusters that were formed. These were not formed based on statistical analysis, but on a more simple process of pattern recognition. Statistical treatment of these data is complex and underway, but incomplete. The pattern shows the spring warming, the summer heat, and the fall cooling. The data stream is from April through the end of November 2007.

Flats: Western Channels

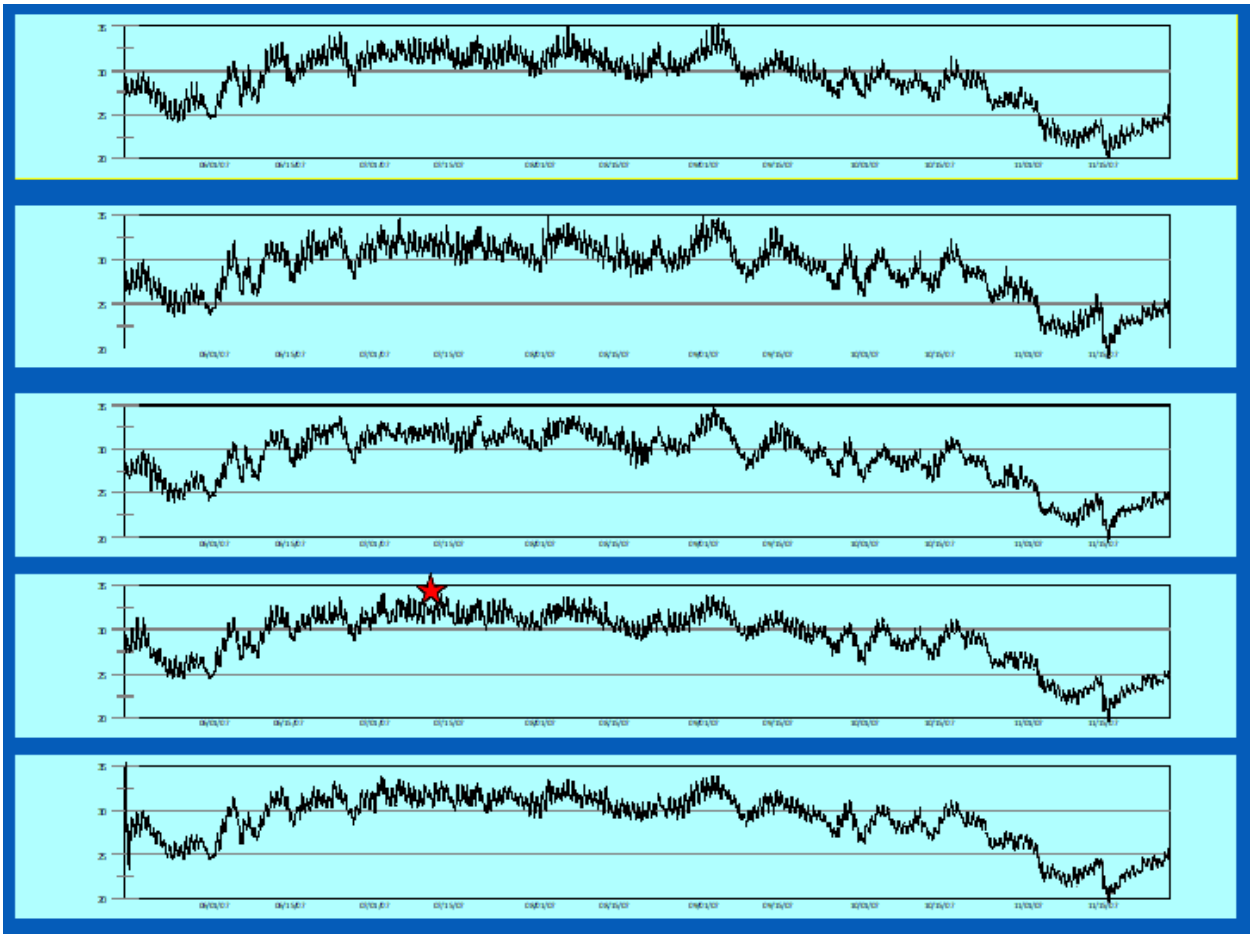


The green line encompasses the first group of similar data traces. The three northern flats sites and the two western bridge sites were assessed as being very similar. The implications of the similarity of the western bridges to the flats data and the less similar nature of the eastern bridges may give rise to future studies of water mass movement and mixing.

Group 1: Flats and West channels. Data trace is from May 16 to Nov. 28, 2007.

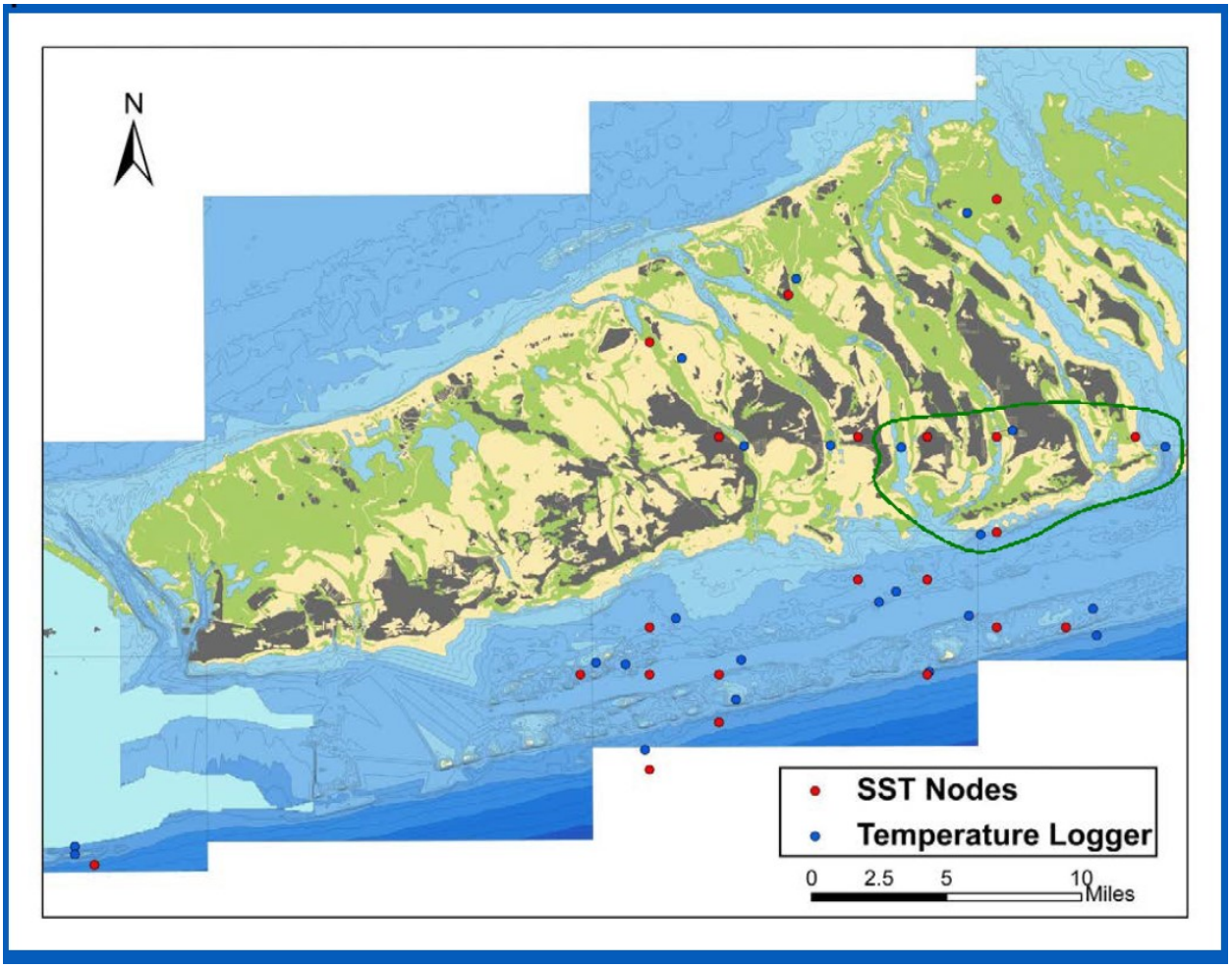
The traces for the five sites are shown here. The Y axis is from 20 to 35 degrees C and the X axis is from April to the end of November, 2007. Plotted at the same scale, the similarity of the traces do not need to be validated using statistics. The actual level of similarity will require such an analysis and is in preparation. Note that it is easy to pick out minor or daily deviations among the group of traces, but that the overall shape and attributes remain remarkably similar.

The red star is noteworthy as an aside, in that the piers and abutments of this channel and others are well populated with a variety of coral species, none of which were seen to exhibit signs of bleaching or disease, but all of which were subjected to actual water temperatures in excess of 30 degree C for more than 45 days. Delving into that topic is in preparation.



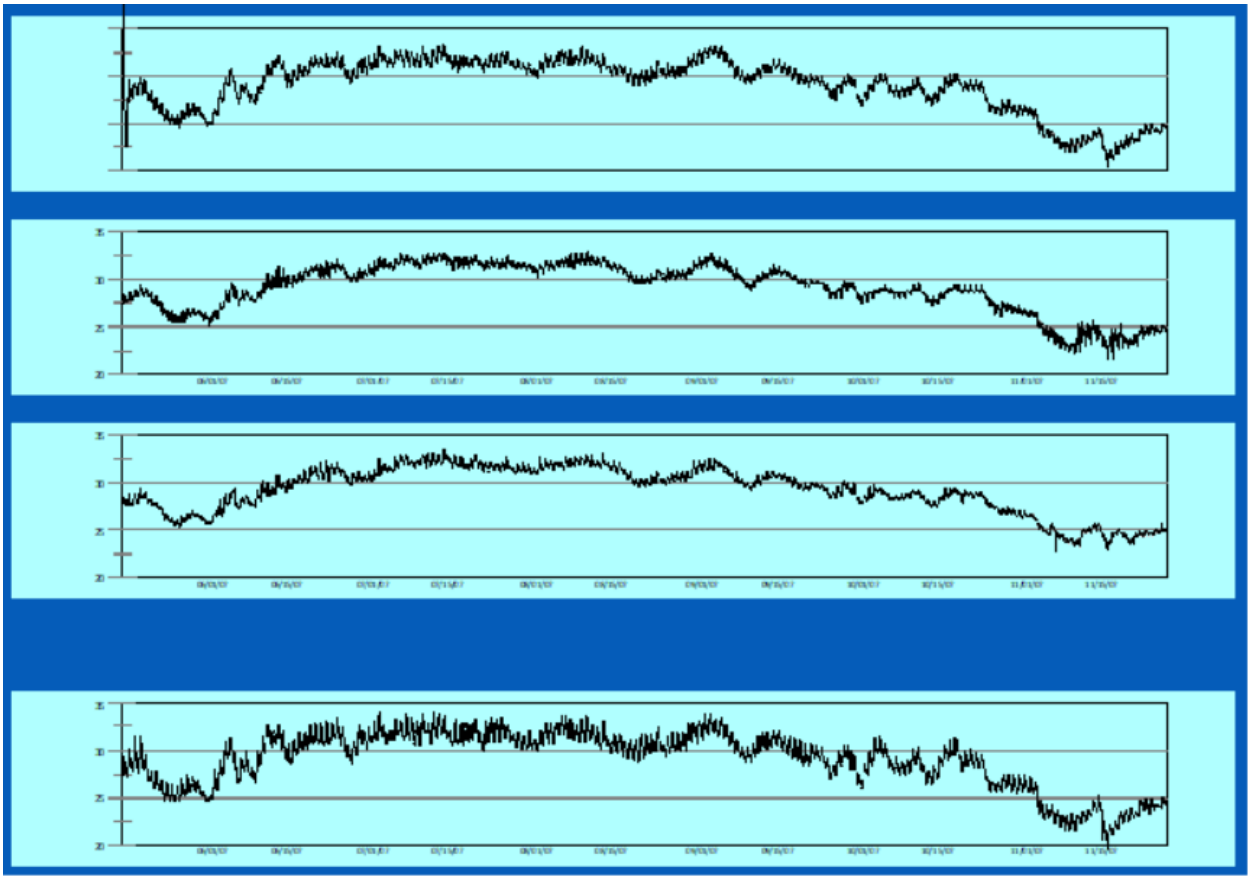
Traces, top to bottom: West Flat, Central Flat, East Flat, Channel 2, Channel 1.

Group 2: East channels and nearshore waters.



The second group includes the eastern bridges and the site from the flats closest to the shore (Newfound Harbor).

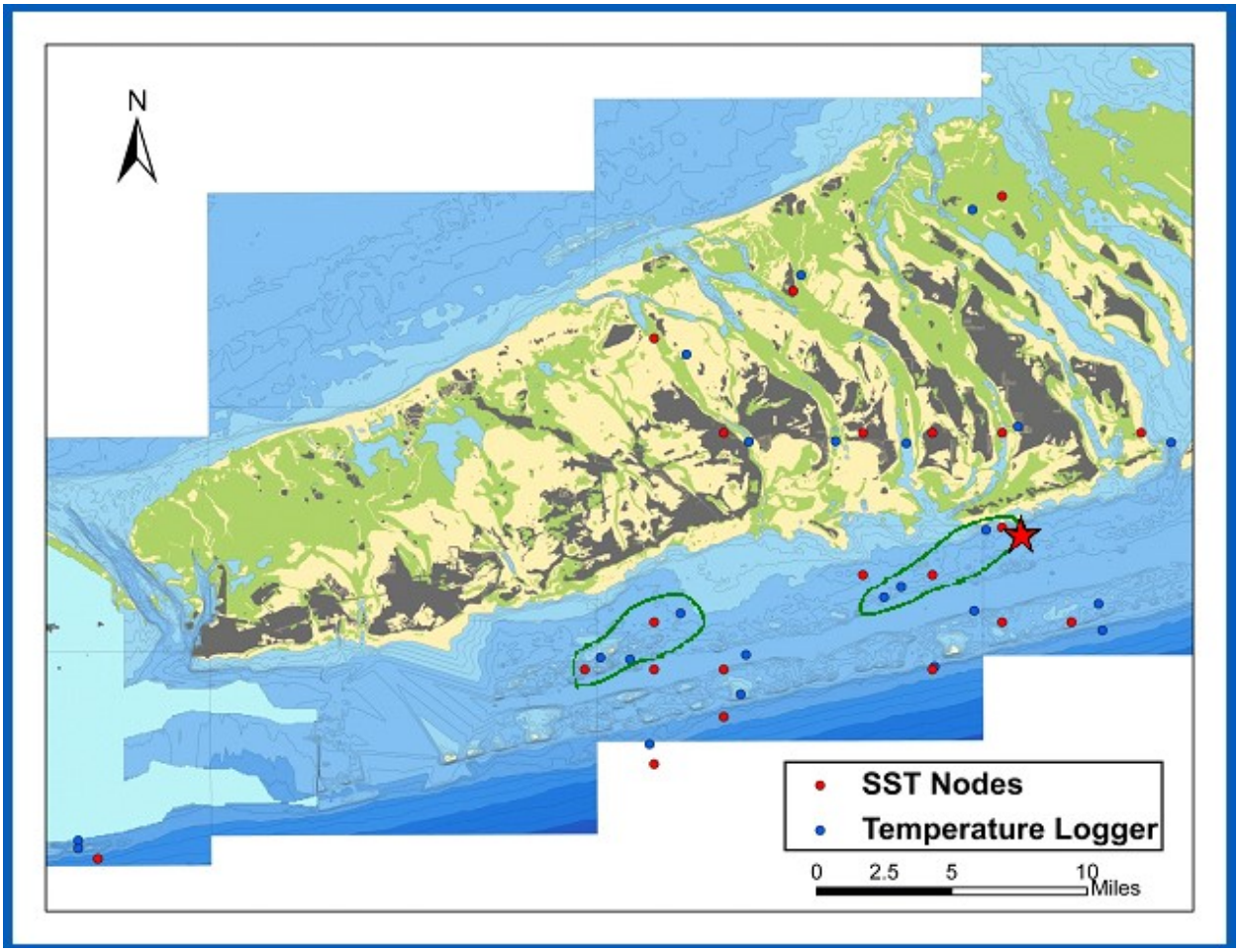
Thermal Traces from Group 2 sites. The Y axis ranges from 20 to 35 deg. The x axis is the first of June to November 15th, 2007. Sites are: Top to bottom, Channel 3, Channel 5, and New Found Harbor 1. The trace at the bottom of the slide is from group 1.



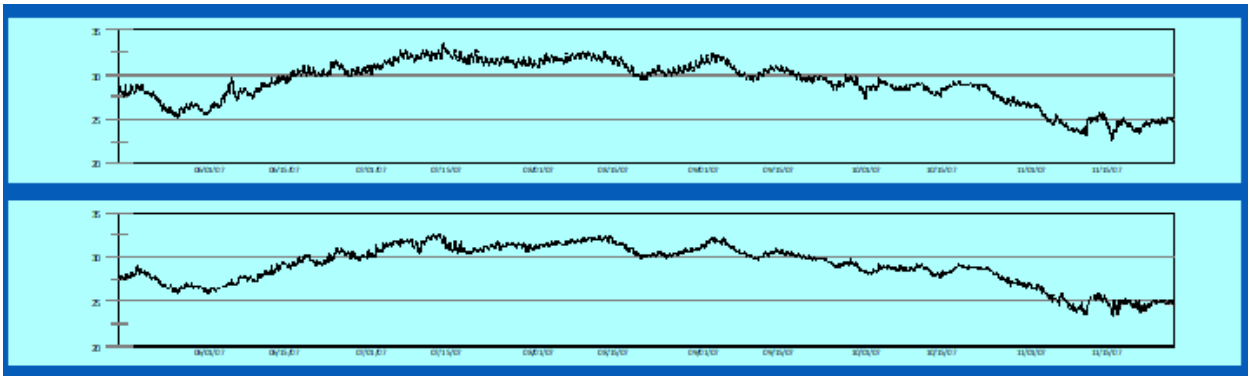
The major difference in the overall pattern is in the daily amplitude (fluctuation) of the thermal trace. It is suspected that the shallow waters of the northern flats warm and cool quickly under high insolation and that these discharge through the western passes. The eastern passes and the site at Newfound Harbor are more stable on a daily basis. The reason is not clearly understood.

Group 4: Eastern waters of the patch reefs
Group 5: Western waters of the patch reefs

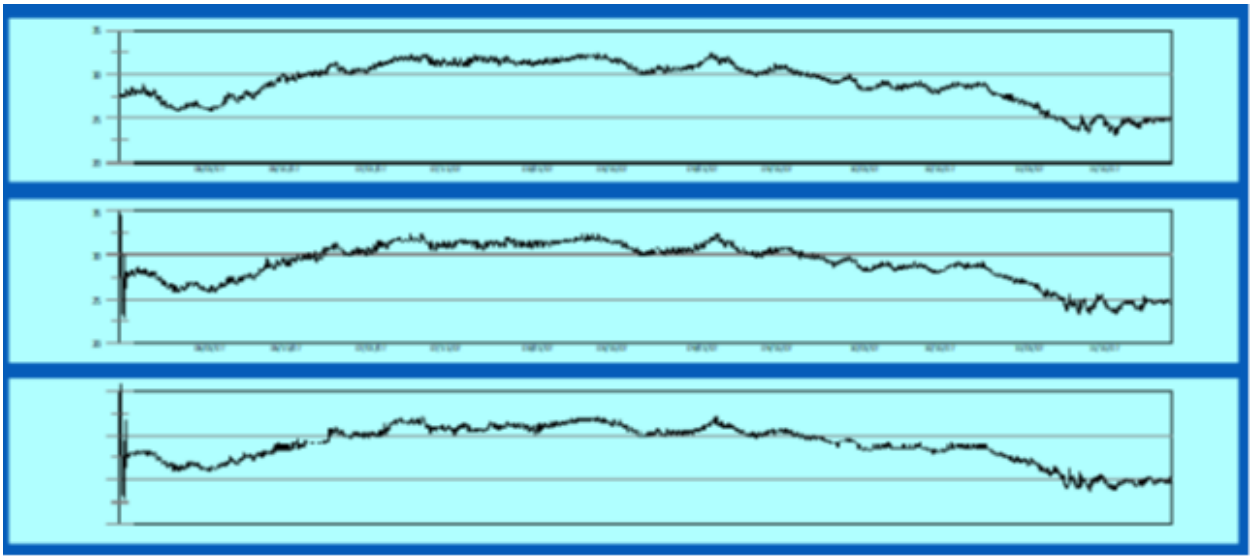
The next two groups share many similarities and yet were separated on present, but less dramatic differences in the traces. The two groups are the eastern and western patch reefs. Note (star) that the Newfound Harbor site was already included in group two and is again present here in group four. The explanation is that the former is the data from the surface logger (1 ft) while the trace in group 4 is the data from the data logger attached to the bottom (15 ft) at the same site.



The East patch bottom water is generally stable. The NFH15 site is closer to shore (Newfound Harbor) while the Hanoi site (named after the similarity in the reef shape to that of the Country of Vietnam), is at the southern extremity of the bank. Top Trace, NFH15, Bottom trace, Hanoi.

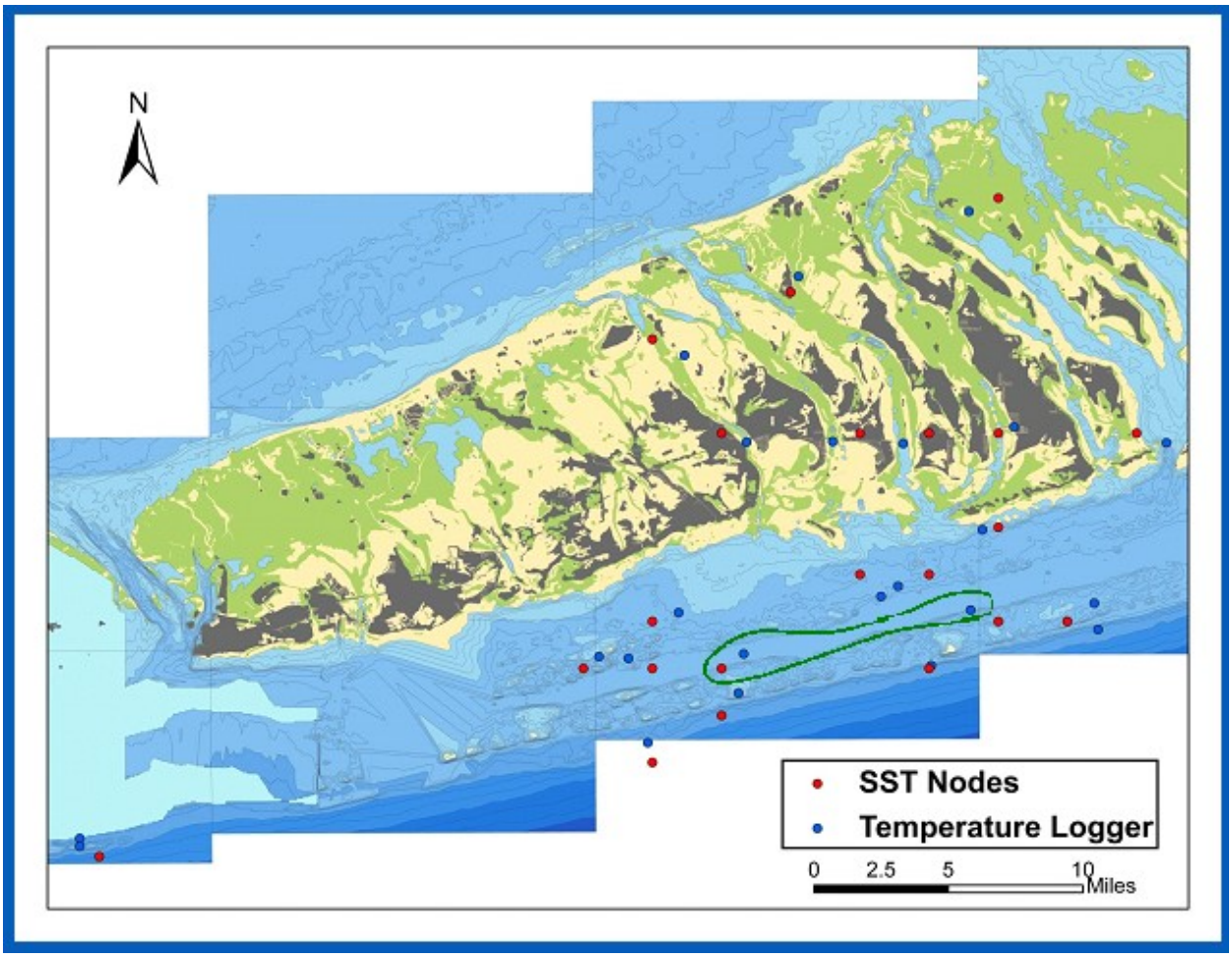


Comparing Groups 4 (above) and 5 (below), we see that the western patch reef bottom water is very similar. The groups, or sub groups, were separated primarily on differences in the late fall.

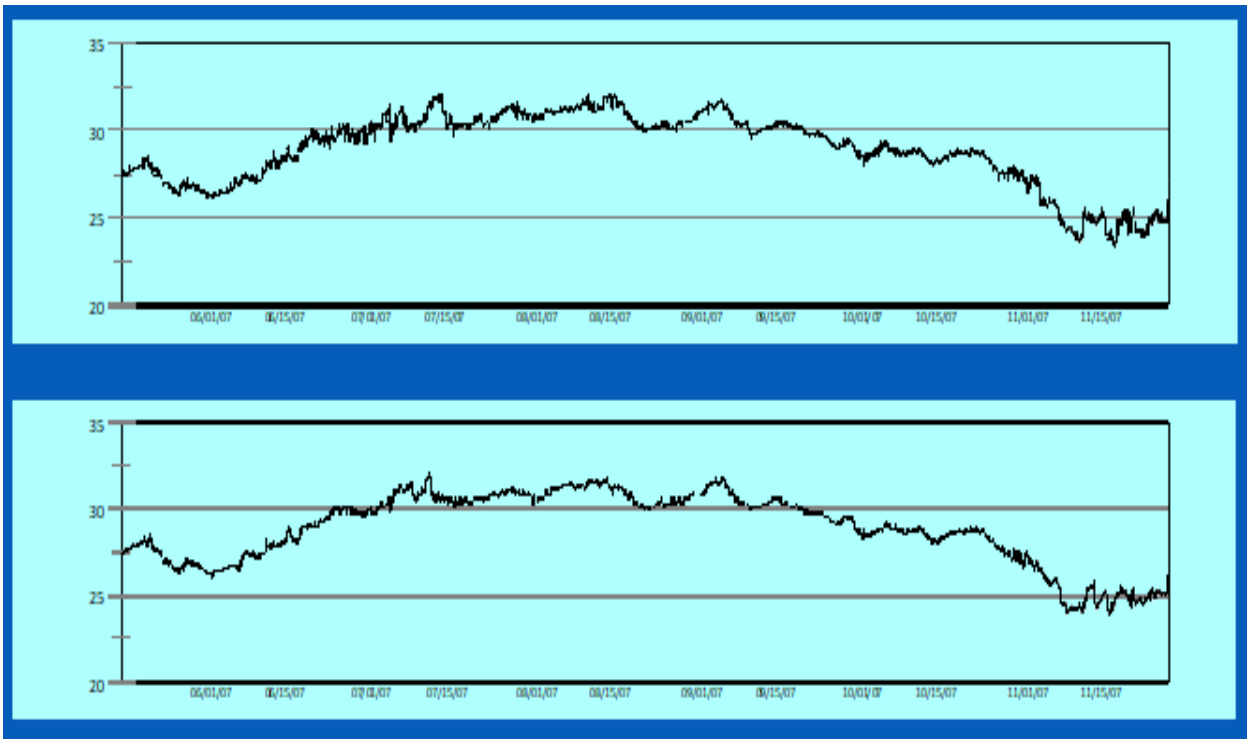


The traces are, from top to bottom, Nine Foot Reef, West Washer Woman (No. 35, Topwater), and West Washer Woman, bottom water, 30 feet.

Group 3: Hawk Current waters

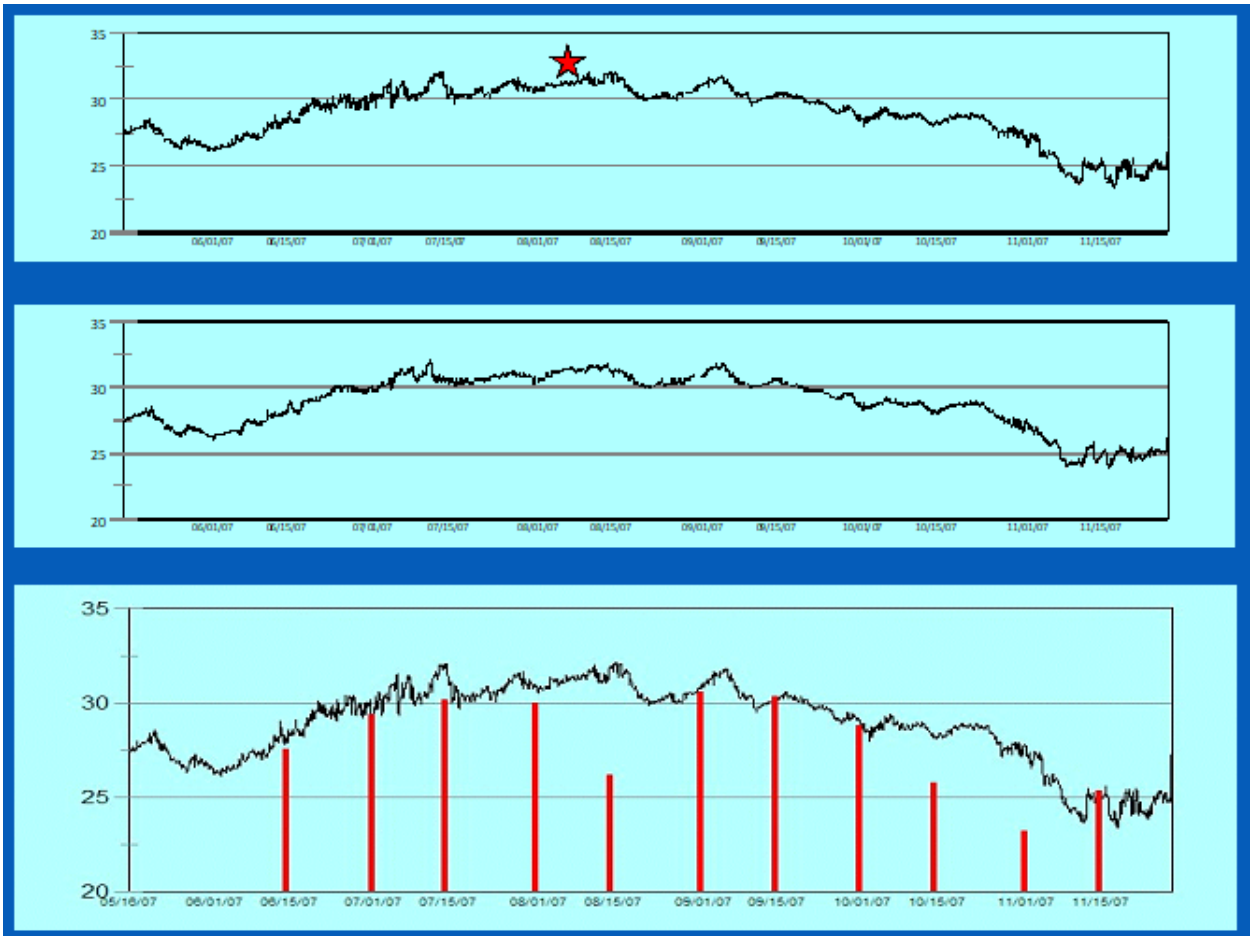


The expectation that the bottom waters of the Hawk Channel would be substantially different from the bank waters was upheld, but the inclusion of the eastern site in this cluster (IRAD) was unexpected.

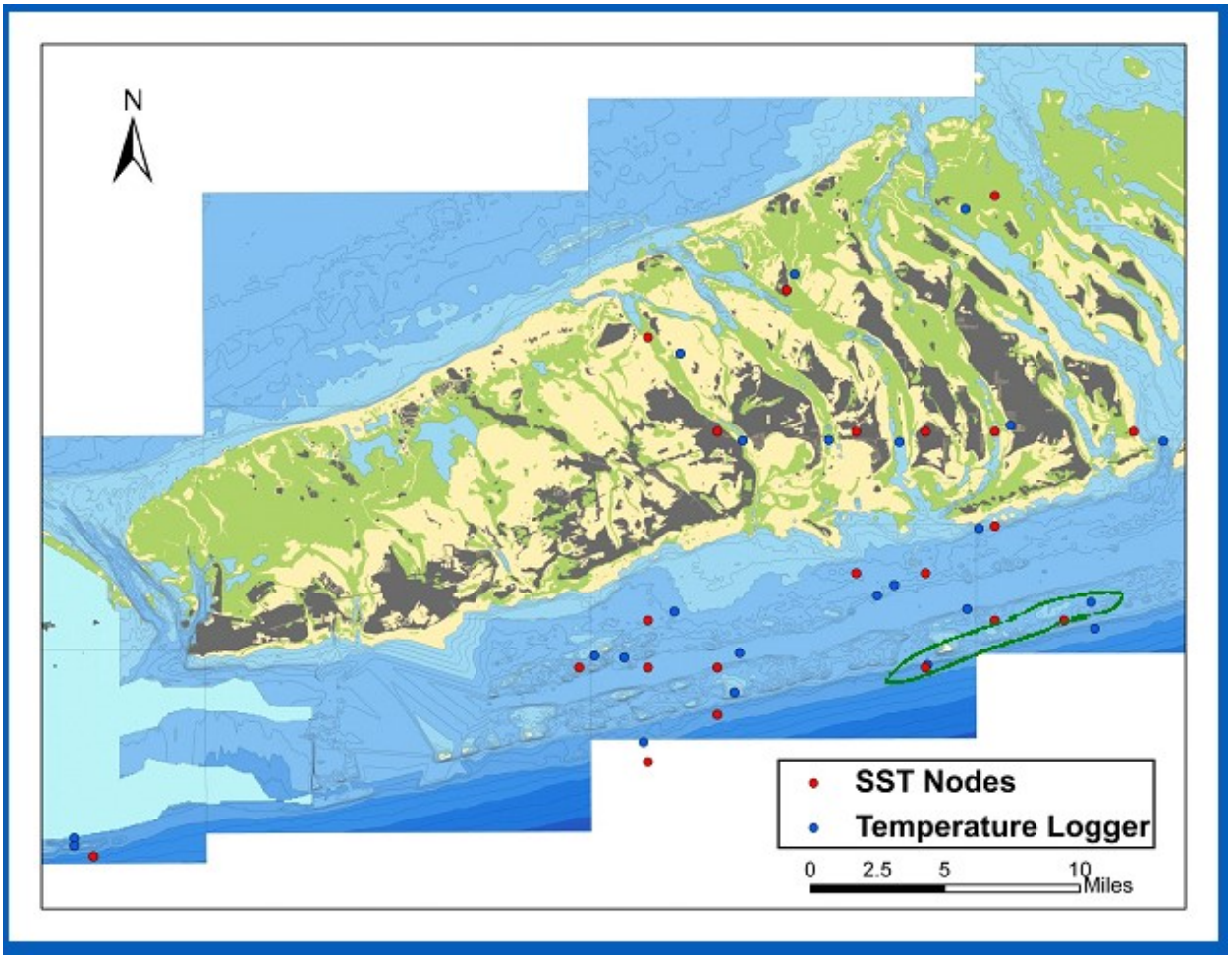


The bottom waters of the channel are very stable. The area supports no coral, but is a muddy sand flat. The waters of the IRAD station are shallower (15 ft) and so show more daily variability during parts of the trace but become very stable during other segments. The IRAD site supports a wide variety of corals, both hard and soft, and has been know to exhibit disease, especially Black Band disease. Trace: IRAD 15 (top) and 20A

The bottom graph has been added to allow for a comparison of the SST data to the trace from the IRAD site. For clarity of the slide, SST data are shown every 15 days (bars). There is a general agreement in the overall shape. Differences, especially those in the fall, are unexplained. The lower amplitude of the hourly trace serves to reduce the degree of disparity where the base values are similar, but the reliability on any given day remains uncertain. The star is added to highlight a portion of the IRAD trace where water temperatures, at depth, exceeded 30 degree C for nearly 60 days.

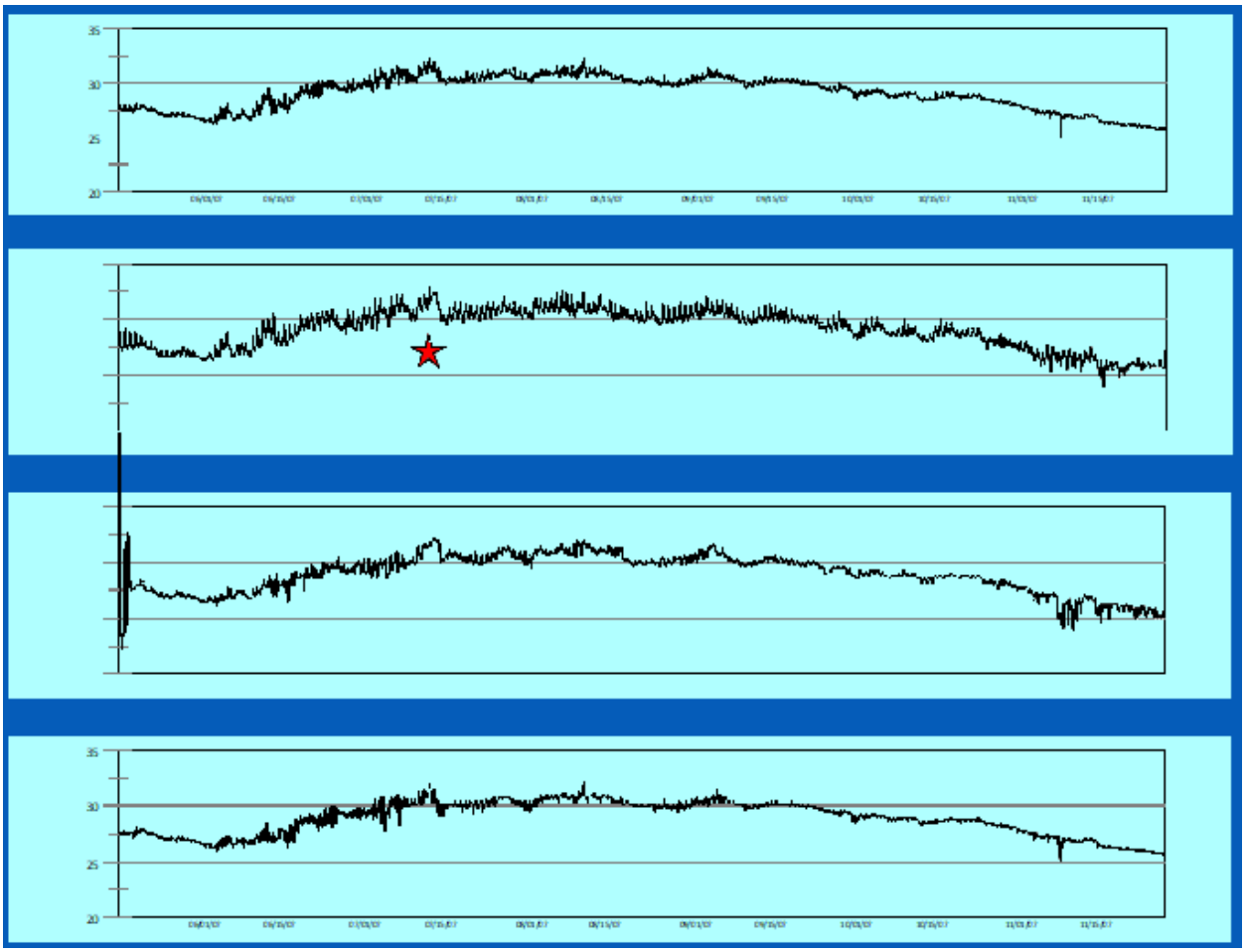


Group 6: Reef Crest



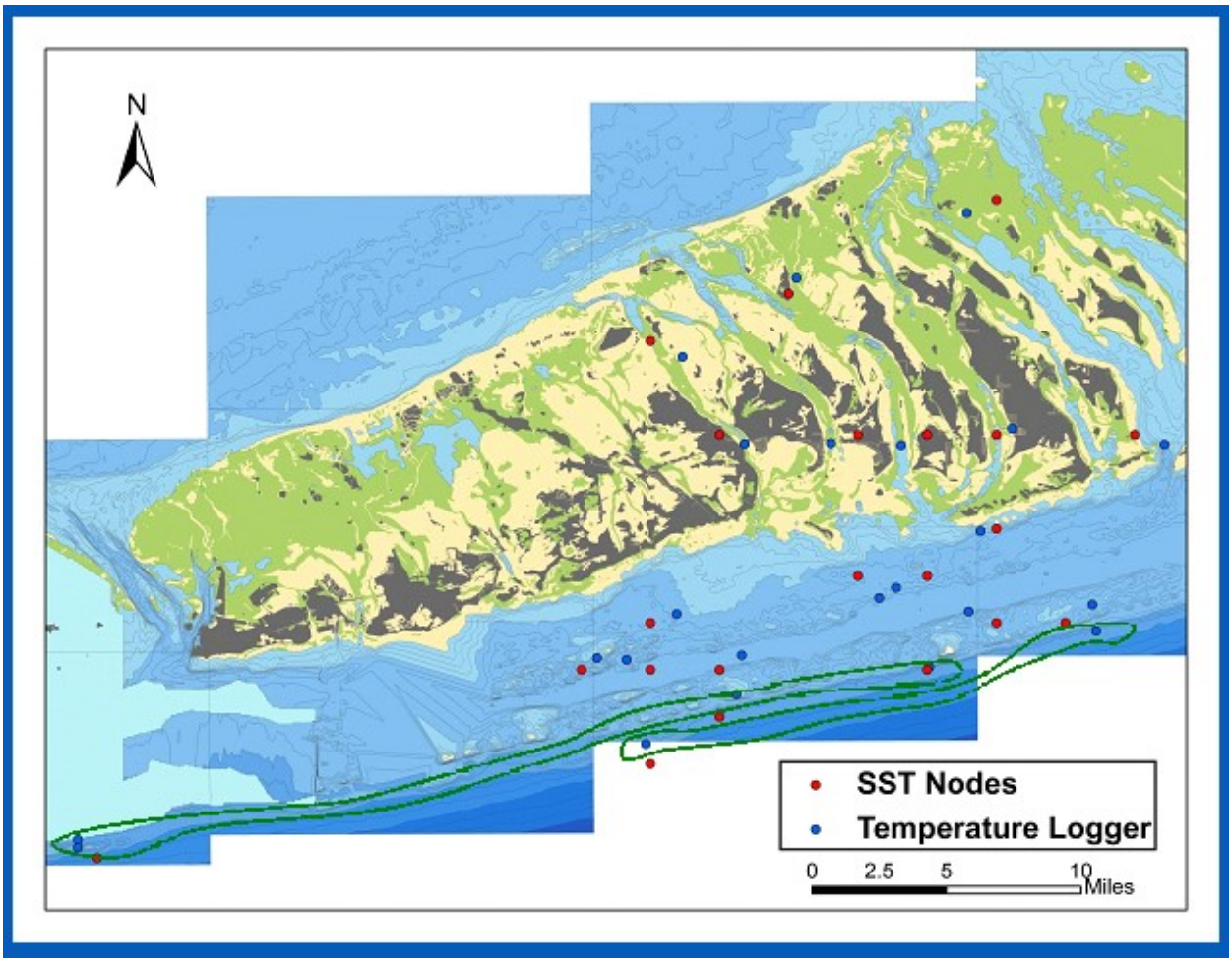
Group 6 is the reef crest. Big Pine Shoals (East site) and Looe Key form the group.

Group 6: Reef Crest data

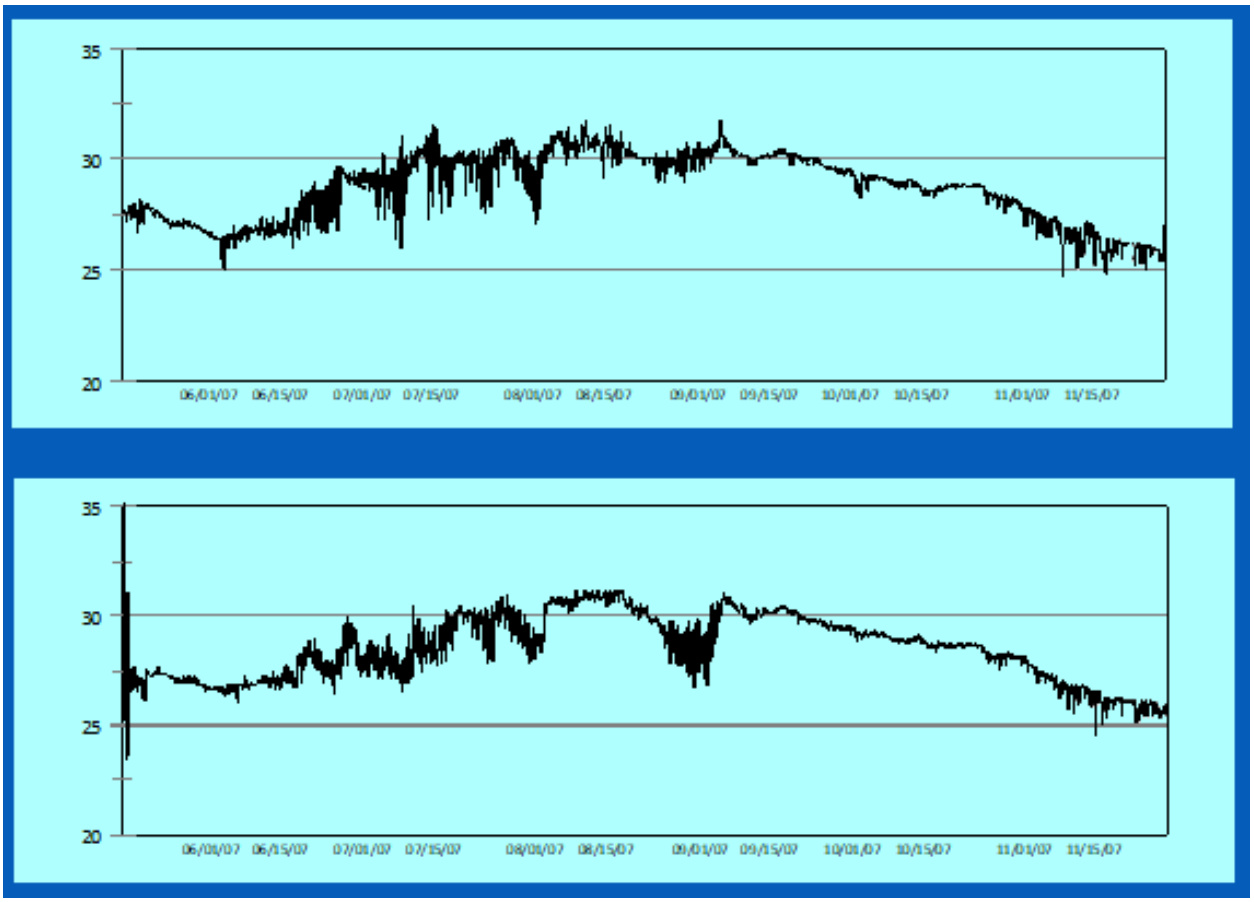


The traces shown include the subsurface logger (1 ft) and the 30 foot logger from Looe (top) as well as the Big Pine Shoals logger (15 feet, 3rd trace). The second trace is from Looe 42, which is located on the north or back reef side of the crest. The group is very loosely formed and perhaps not a very good group at all. It is included to contrast the differences among the loggers. The waters at Big Pine are sometimes rather stable, but seem to be more disturbed in the spring and fall. The Looe 42 (back reef) waters exhibit high amplitude fluctuations similar to the constrained waters of the flats, despite the close proximity to very open waters. The top trace (Looe subsurface) and the bottom trace (Looe 30) are separated vertically by 30 feet of water. The similarities are evident even though the top, shallow, trace exhibits a higher amplitude. The major differences occur in June and July. The red star is added to note that the site supports several *Acropora palmata* which were subjected to waters above 30 degrees C for several months and which exhibited only weak bleaching.

Group 7: Western Intermediate Reef Slope and Group 8: Fore Reef Slope.



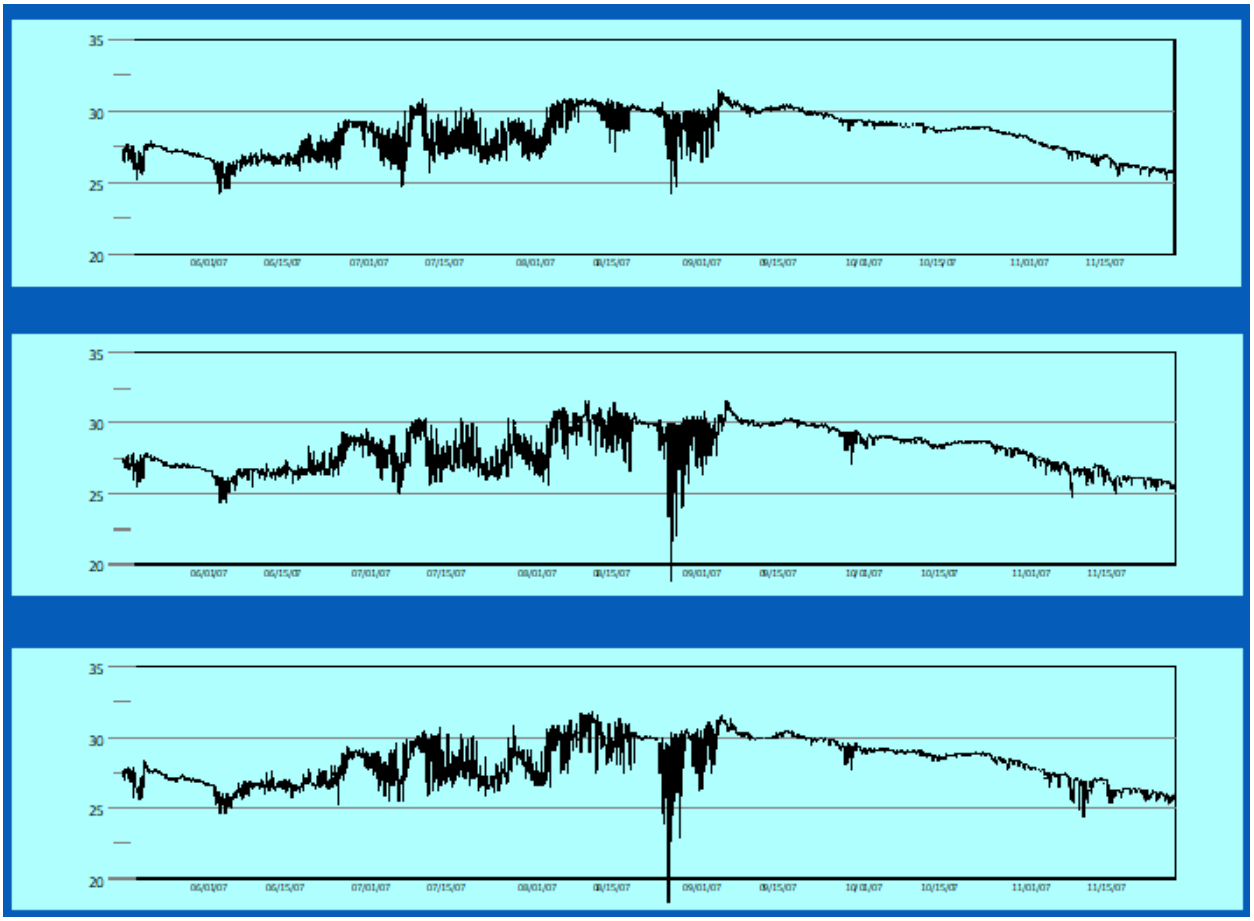
The last two groups are the Western Intermediate Reef Slope and the Fore Reef Slope. These thread thin groups reflect the change in habitat with depth along the fore reef.



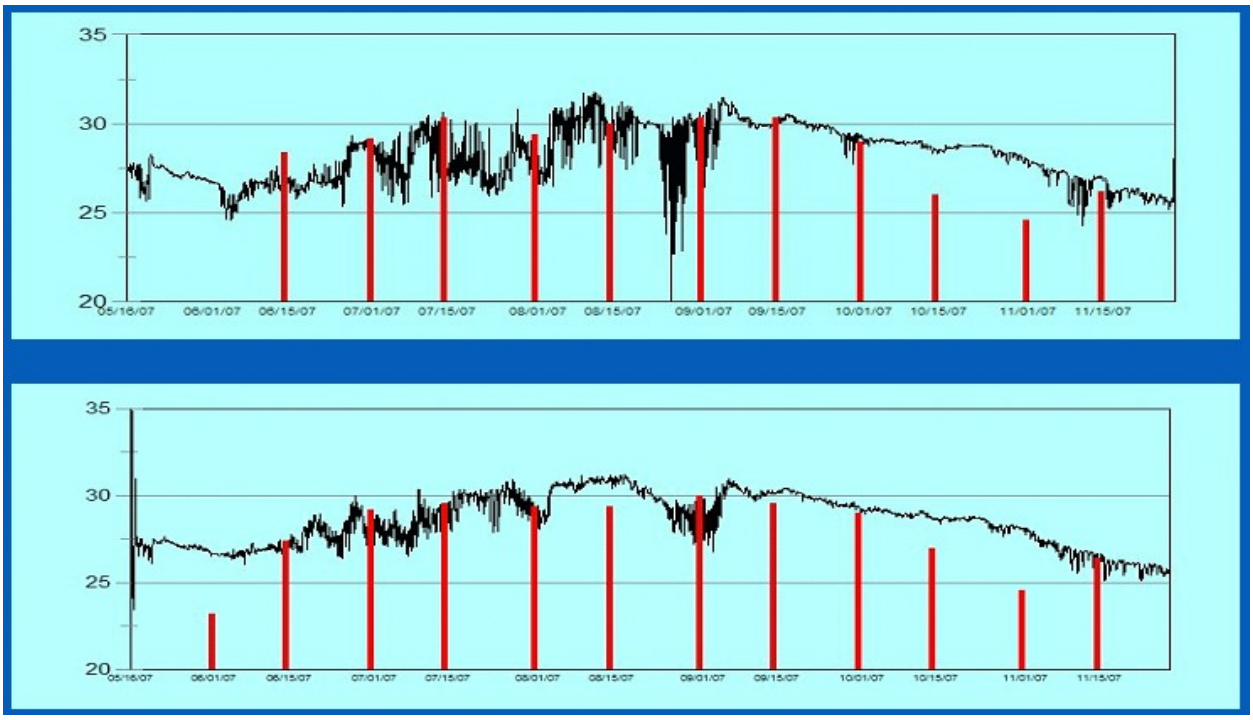
The Western Intermediate consists of the site south of Key West (43, top) and the trace from the 60 foot installation at Looe Key. The traces are dramatically different from those presented previously. The most striking change is in the movement from a very unstable thermal profile for the majority of the year and a stable profile during late summer and early fall.

Group 8: Fore Reef Slope.

The Fore Reef Slope group are all installations at 100 feet. These data not only exhibit the instability mentioned previously but include an extreme cold water event in late August. The implications are that some instances of summer bleaching of deepwater coral might be due to cold water events or even sudden changes in temperature rather than warm water events. The cause of the profile is unknown, but may be due to inshore migrations of the Florida Current. Top: Maryland Hump, Middle: Looe-90, Bottom: Site35.

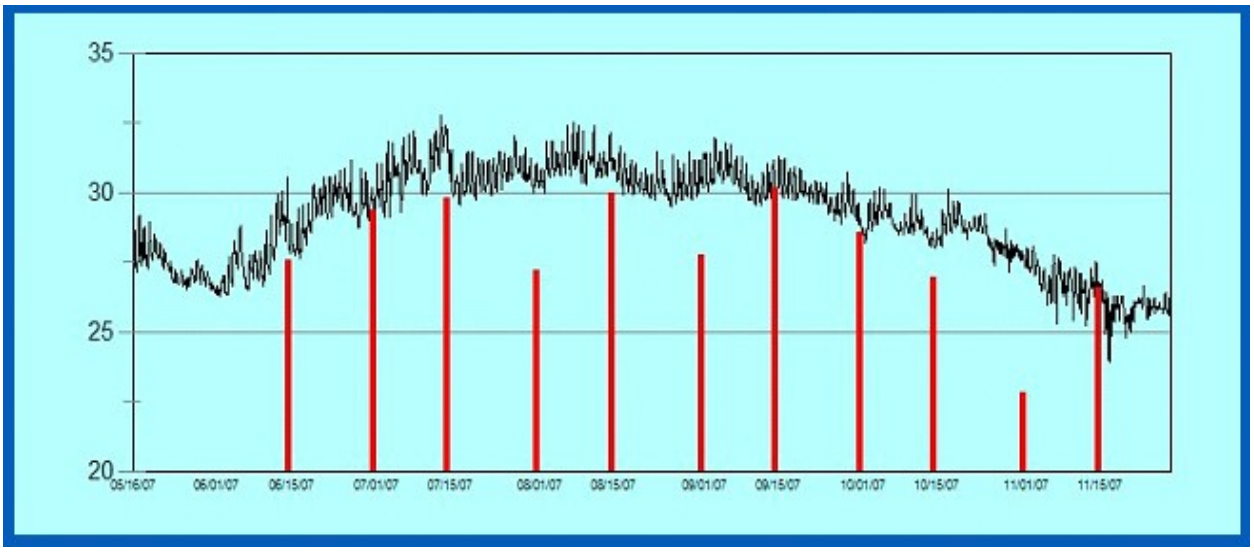


Sites 35 and 43 v. SST summer 2007



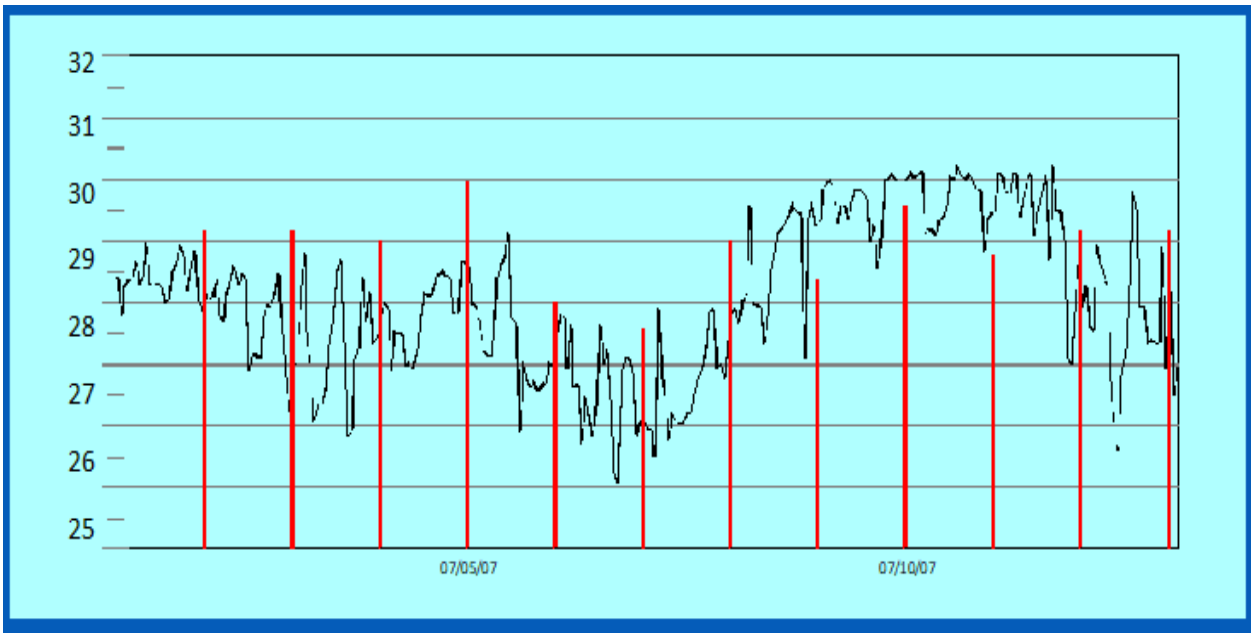
Examining the easternmost fore reef site (35) and the westernmost intermediate site (43) in comparison to the SST data reveals that the deep cold water events and the instability are not reflected in the SST data. The previously noted distance between the traces collected by loggers and the SST data in the fall recurs.

Site 42: Logger data (line) and SST (bars). The site contains *Acropora palmata* population.



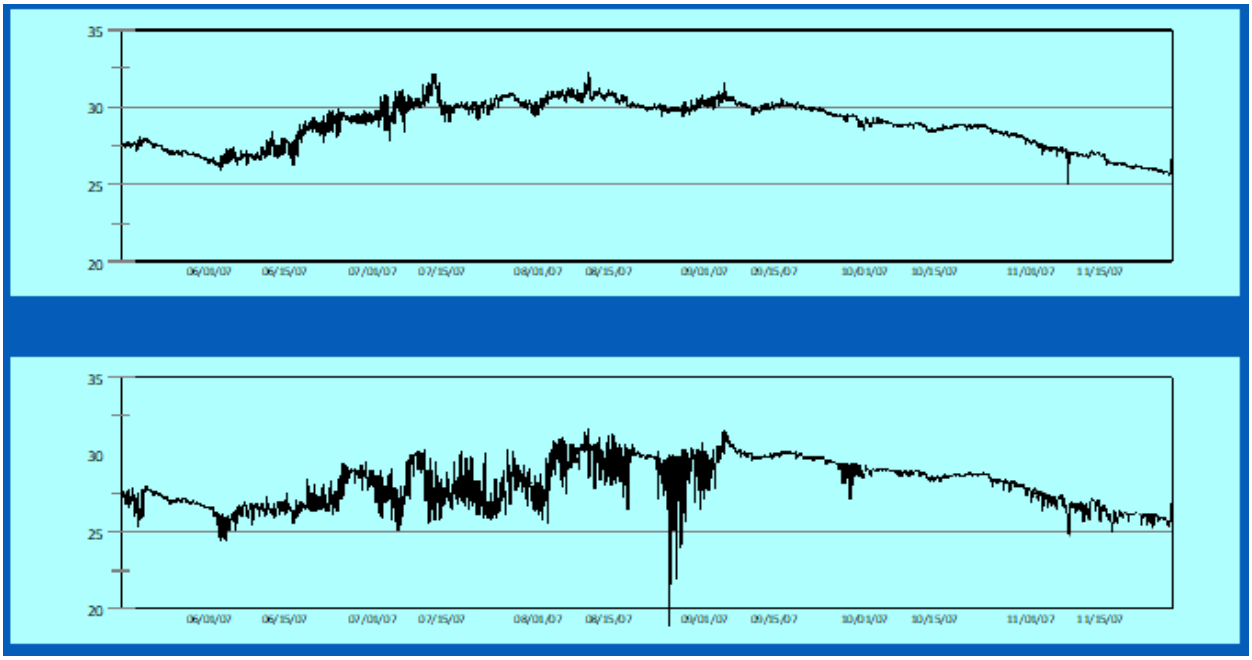
A closer examination of the Looe 42 site where the *A. palmata* population was noted shows that the SST data are consistently lower than the water temperatures and cannot reflect hourly fluctuations.

Looe Deep and SST: July 2007



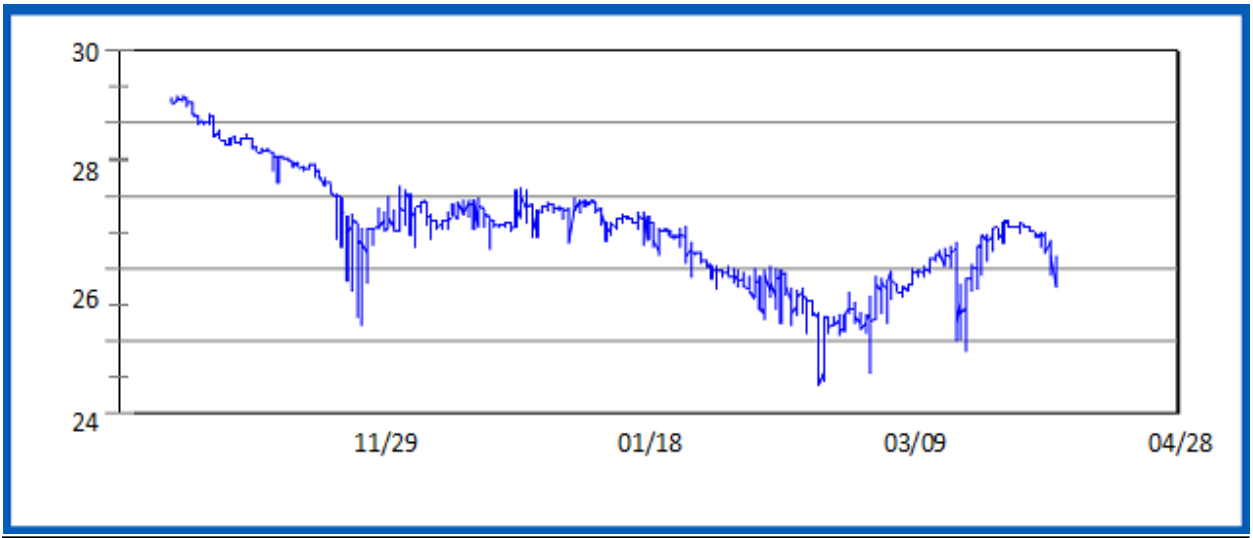
Hourly data from Looe Deep and SST daily data are compared. The time frame has been shortened to bring out the variation in hourly data and runs from July 1st to July 13th.

Looe 30 and Looe 90



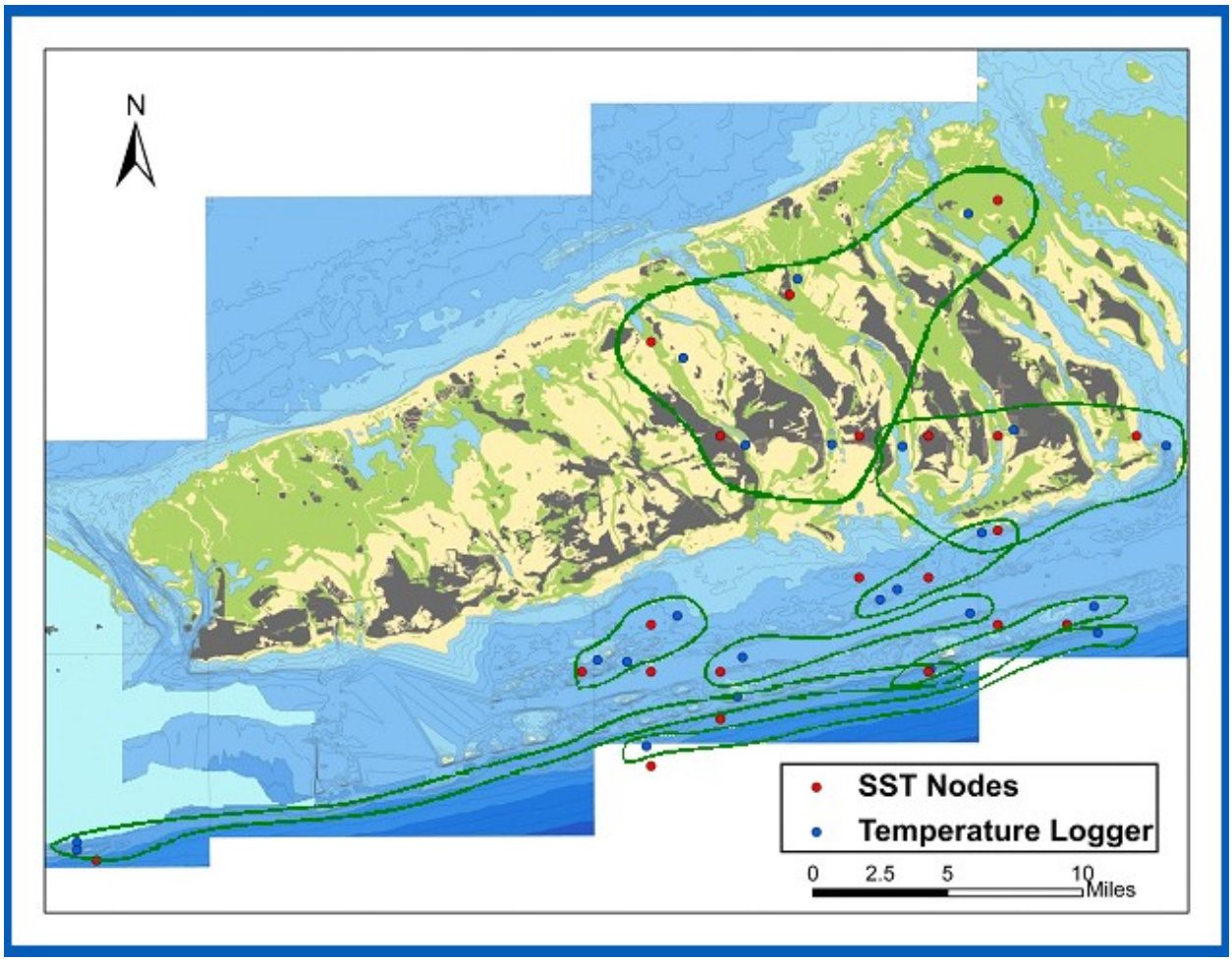
The two traces show the difference in hourly logger data from sites 60 feet apart (vertically). The two traces occur within the same SST pixel.

Maryland Hump: Winter 2006



The winter data from Maryland Hump (one of the deep fore reef sites) fails to fall below 20 degrees. It is unknown if this is typical or due to mild winter conditions or a lack of Florida Current migration. The corals at the site are infrequent, but moderately robust when they do occur (general observation).

Lower Florida Keys: Thermally defined habitat strata



The data loggers have provided us with thermally defined habitat strata which are notably dissimilar to either spatial stratification or *a priori* geomorphological stratification. It is likely that other habitat defining parameters would form different groupings requiring multi-variate data based stratification. Conducting such analyses is pivotal in comprehending the complex reef ecology at work in the Keys.

Summary and Conclusion:

We started with:

"The frequency of using Sea Surface Temperatures (SST) by Environmental Managers and Researchers to account for ecological events and observations as well as to predict the ecological future has increased steadily."

Findings:

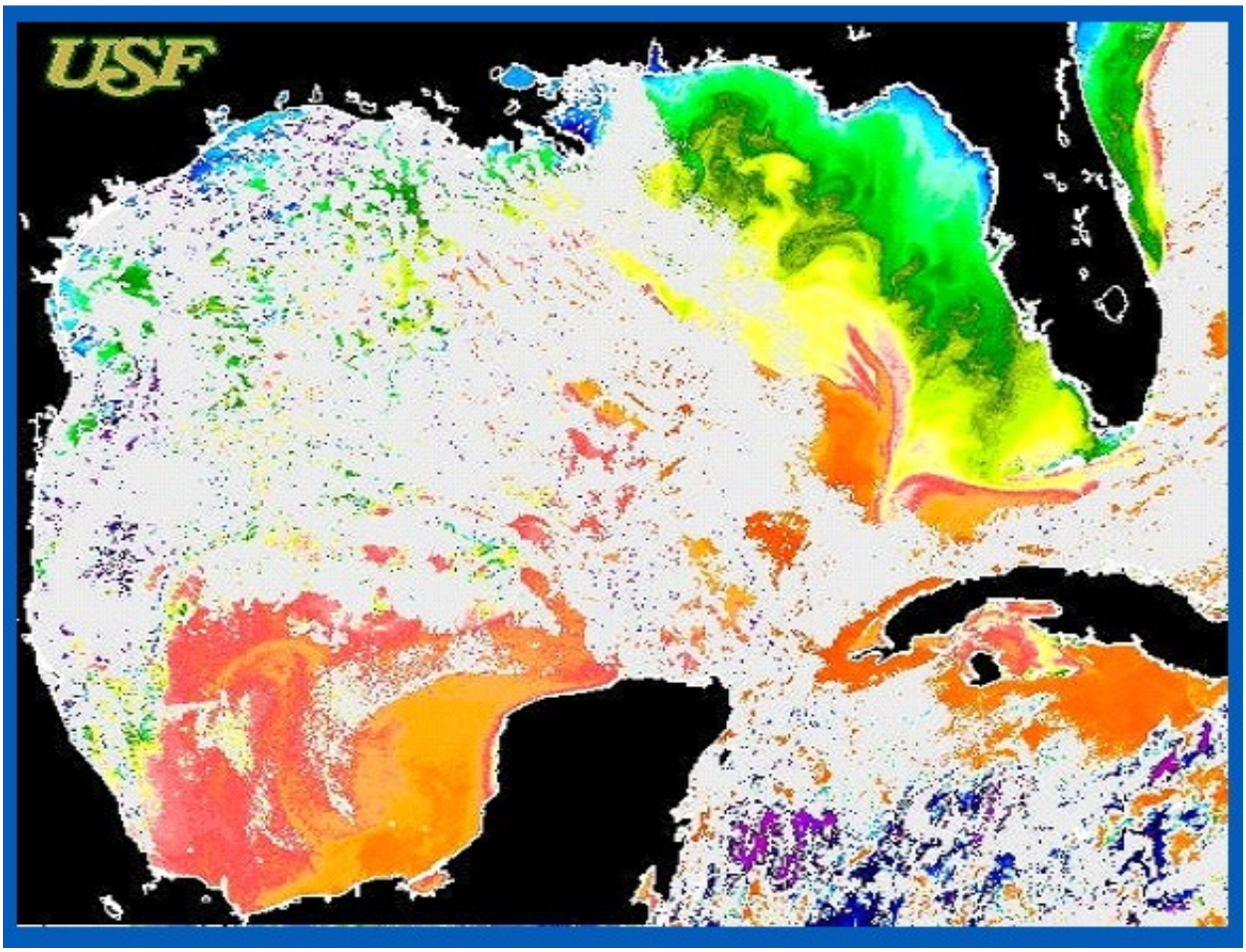
Sea Surface Temperature data are two dimensional and cannot be relied upon to predict subsurface habitat parameters.

SST maps do not have either the vertical nor temporal resolution to actually define habitat parameters.

Pixel shape is an unaccounted for source of ambiguity

CONCLUSION: SST maps do not appear useful in accounting for observations (post hoc ergo propter hoc) nor in predicting events except in only the most general terms.

This is not to imply in any manner that the collection of satellite data is un-fulfilling. But it is what it is, and it is not capable of defining reef habitat.



It is apparent that the maps such as the one shown in this slide are extremely valuable tools when properly employed. It is also apparent that defining localized habitat parameters is beyond the usefulness of the map.

The closing figure is a trace of the daily water temperature at the Looe Key Surface buoy (top) and the Looe Key deep installation (bottom) with the point data supplied by the University data base. It is clear that habitats are better defined by actual data. In SST reports, these two thermal regimes are equivalents.