

DOCUMENTING THERMAL REGIMES ON CORAL COAST REEFS:

An ongoing study of coral community susceptibility and resilience to coral bleaching



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Current objective:

To better understand the thermal regime of Coral Coast reefs across range of reef habitats and document incidences of coral bleaching.

This is being achieved by:

- 1) Documenting the thermal regime corals are exposed to across a range of reef habitats at two sites on the Coral Coast.
- 2) Documenting the condition (bleached or not) of corals (scleractinia and alcyonacea) at each location where thermal regime is recorded.

Methodology:

Ten Vemco mini-T temperature loggers have been deployed across a range of reef habitats and locations around Votua Reef (Figure 1) and Tagaqe Reef (Figure 2). Reef habitats where loggers are deployed were selected to represent a range of common reef habitats across the Coral Coast and include reef flat moats, the edges of reef channels, and the forereef. Votua Reef was selected because it is a coral-rich area and is similar in topography to most of the Coral Coast fringing reef. Tagaqe Reef was selected because it has a slightly deeper reef flat habitat than Votua and most areas and therefore it was anticipated that it would have slightly different temperature dynamics. Loggers deployed on the reef flat in Votua are ~2m deep (max high tide) and in moats with live hard and soft coral communities. Tagaqe reef flat is slightly deeper than Votua (by about 2m), but loggers were placed at similar depths on the reef flat and channel edges as in Votua. Loggers deployed along the channel edges are ~2m deep (max high tide) and also placed in areas with live coral communities. Loggers deployed on the forereef are at 10m and 30m depth and also in areas with live coral communities. To facilitate an accurate documentation of the range of temperatures corals in each habitat experience on a daily basis, loggers were programmed to sample the water temperature every 10-120 minutes, depending on the habitat where the logger is deployed. Shallower, reef flat and channel sites have shorter sampling periods and deeper, fore reef sites have longer sampling periods. Temperature loggers were initially calibrated to one another, though no recalibration has been done.

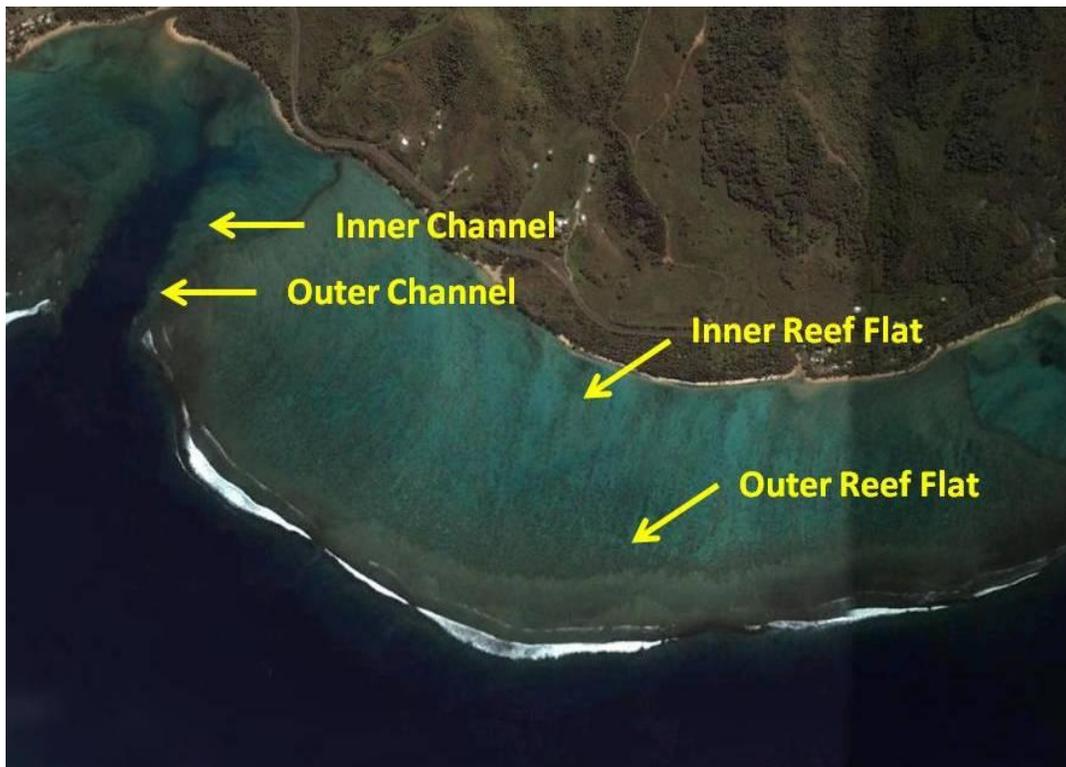
The daily mean, maximum, and range in temperatures have been calculated for downloaded data in order to gain an understanding of the temperature regime at each sampling site. It is anticipated that degree heating index will also ultimately be calculated for each site for comparison once several years of data are obtained.

Visual surveys of the condition of corals (bleached or not) were conducted across reef habitats at least monthly during the summer months for most of the project period. Only the forereef sites, particular at 30m, were less consistently visited. A quantitative sampling methodology for colony condition has not been employed to date, though various options are being considered for use this summer season.

Figure 1. Location of the six sampling stations on Votua Reef.



Figure 2. Location of the four sampling stations on Tagaqe Reef.



Discussion of data collected to date:

During the duration of this study, daily maximum and range in temperatures varied highly between sites, however daily mean temperature varied usually by no more than 1 °C (Figures 3-8) across sites. Daily mean temperatures peaked between January and April. During these months, daily mean temperatures exceeded 30 °C on several occasions (peaking at ~30.5 °C) at reef flat and channel sites, but were mostly between 28.5 - 30 °C. Between August and October, daily mean temperatures were at their lowest; mostly between 25 – 26 °C, however at times less than 25 °C and reached a low of 24.2.

The greatest daily maximum and daily range of temperature was recorded at the shallower inner reef flat sites (Figures 5-8). Maximum temperatures and temperature range were greatest in Votua where the reef area was shallower. In Votua, temperatures reached a maximum of 36 °C and varied as much as 9 °C daily at the inner reef flat site. At Tagaqe where the reef flat is slightly deeper, temperatures reached a maximum of only 34 °C and varied as much as 6 °C daily at the inner reef flat and inner channel sites; the deeper reef flat area at Tagaqe did not experience as extreme temperatures as Votua, though the mean temperature were similar. Peak temperatures were obtained during spring low tide periods occurring during late summer months (February – April); particularly during times when seas were calm and skies clear. As tides dropped and water flow from the fore reef decreased, temperatures heated up (or cooled off at night) rapidly across the reef flat. The inner reef flat sites generally heated up more than the outer reef flat sites and water heated up even more as it spilled into the inner channel site from the inner portion of the reef flat. The greatest daily and annual temperature ranges occurred at the reef flat and inner channel sites, where temperatures spiked during spring low tides during the day, and dropped dramatically during spring low tides at night. As the tide dropped, temperatures rose as quickly as 1.7 °C in 30 minutes and as the tide rose cooled as quickly as 2.5 °C in 30 minutes at the inner reef flat site (Figure 9). Temperatures did not remain at extreme maximums for very long however, thus demonstrating the need for short sampling intervals to accurately capture daily fluctuations occurring in some habitats. The outer channel and fore reef sites have far more stable temperature regimes than the reef flat or inner channel area where shallow pools and water flowing from the shallow pools have an opportunity to heat up.

Coral mortality due to bleaching was minimal during the current study period at all stations. Mortality from bleaching was observed mostly at the inner channel, outer reef flat, and outer channel area and was limited predominantly to a few species of *Acropora*. Observed mortality from bleaching was greatest at the channel sites during the late summer months (April – May).

Bleaching was observed most frequently at the reef flat and inner channel sites where it occurred both during summer and winter months, though was most extreme during late summer months. Mean daily temperatures were far below those associated with bleaching (30 °C) during some of the times that corals bleached, although daily maximums far exceeded those temperatures. Genera most affected by bleaching include *Acropora*, *Pocillopora*, *Millepora*, *Stylophora*, *Montipora*, *Goniastrea*, *Pavona*, and *Sinularia*; *Acropora* being the most specious genera at all sampling sites except those on the fore reef. Many species of coral showed no signs of bleaching during the study period though bleached corals surrounded them. Corals on the reef flat and inner channel area seem to be most susceptible to bleaching, as temperatures reach extreme degrees during spring tide periods year round and some shallow corals in the outer reef flat area are exposed during these times. Corals at the outer channel site are exposed during these times as well, however predominantly showed signs of bleaching only during later summer months when temperatures peaked and had been elevated for some time.

Further research plans:

Climate change is expected to result in more frequent and severe coral bleaching events. This research has documented that corals across the reef are exposed to varying temperature regimes which are likely to be a dominant factor in structuring the coral community found in each habitat type. The zooxanthellae that a particular coral hosts largely affects the coral's susceptibility to bleaching and thus survivorship in a particular habitat. However, both temperature and irradiance exposure are key factors affecting large-scale coral bleaching, and corals may not bleach when exposed to elevated temperatures without high irradiance levels present.

In order to better identify habitat areas that may be more resilient or resistant to large-scale mortality from bleaching events it is also important to measure irradiance levels along with temperature. Additionally, it is important to have an understanding of the zooxanthellae that corals in a particular habitat host, as well as the survivorship of colonies with the varying zooxanthellae have. Thus, future research plans include seeking further funding and collaboration to expand the current project to include:

- 1) Monitoring of irradiance exposure in the same habitat areas as temperatures are being monitored.
- 2) Documenting the clade/s (or species) of zooxanthellae present in both common and rare coral species present at each sampling site.
- 3) Monitoring the condition / survivorship of coral colonies of which the zooxanthellae cladal composition is known.

By adding the above components to the current study, the aim would be to identify critical coral-rich habitats that would be priorities to protect in order to improve overall reef resistance and resilience to coral bleaching events.

Funding acknowledgements:

The purchase of current temperature loggers has been generously supported by funds from the NOAA International Coral Reef Conservation Program. Current monitoring work has been supported and facilitated by Reef Explorer Fiji Ltd.

Figure 3. Mean daily temperature (°C) at each sampling station on Votua Reef.

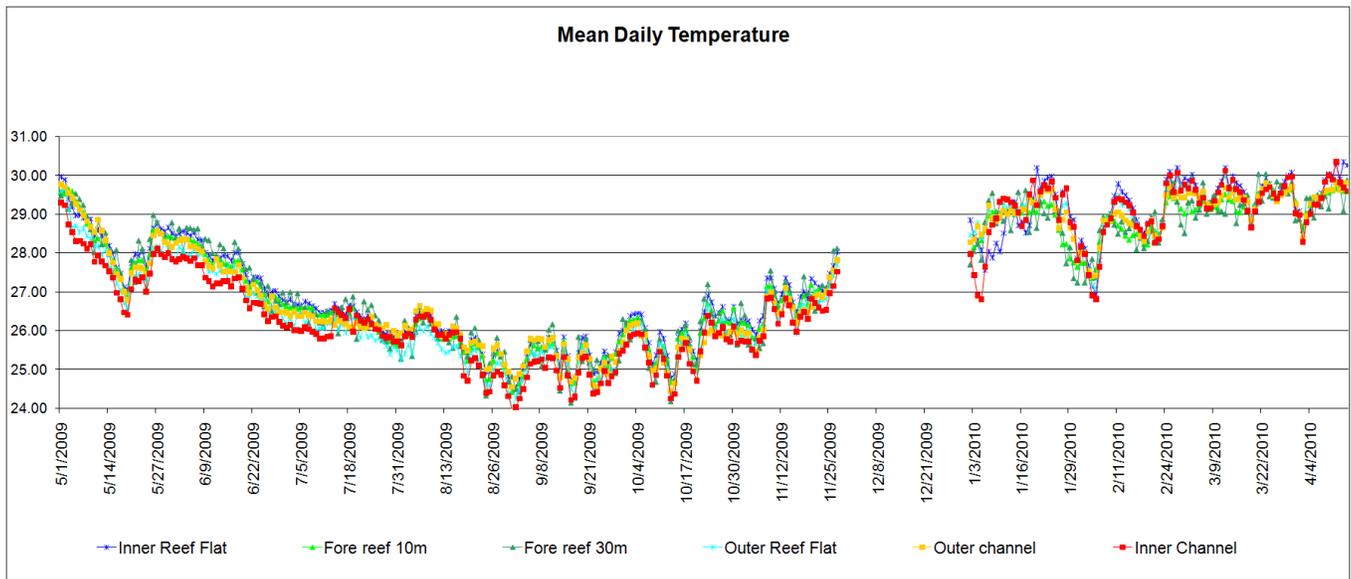


Figure 4. Mean daily temperature (°C) at each sampling station on Tagaqe Reef.

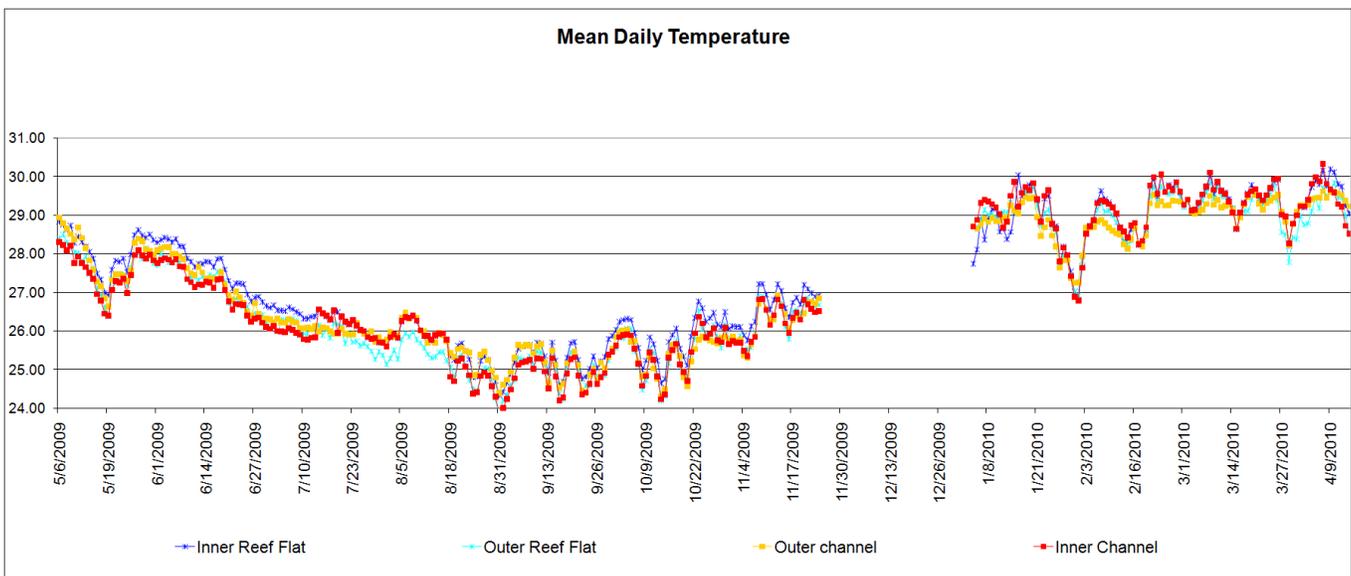


Figure 5. Maximum daily temperature (°C) at each sampling station on Votua Reef.

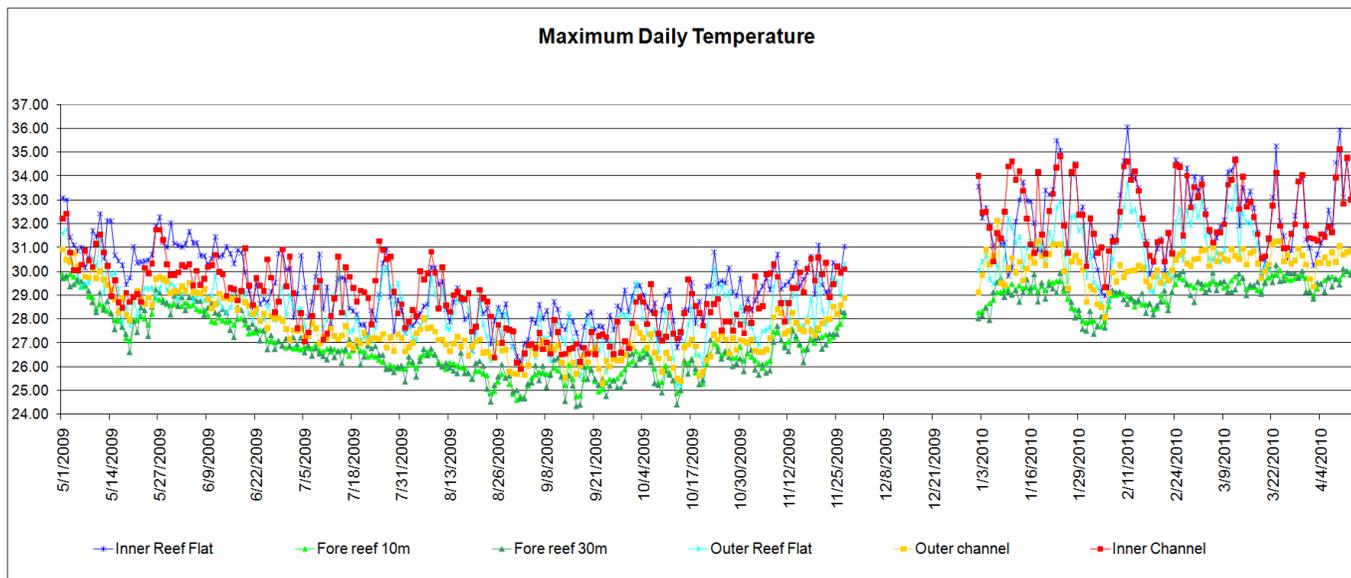


Figure 6. Maximum daily temperature (°C) at each sampling station on Tagaqa Reef.

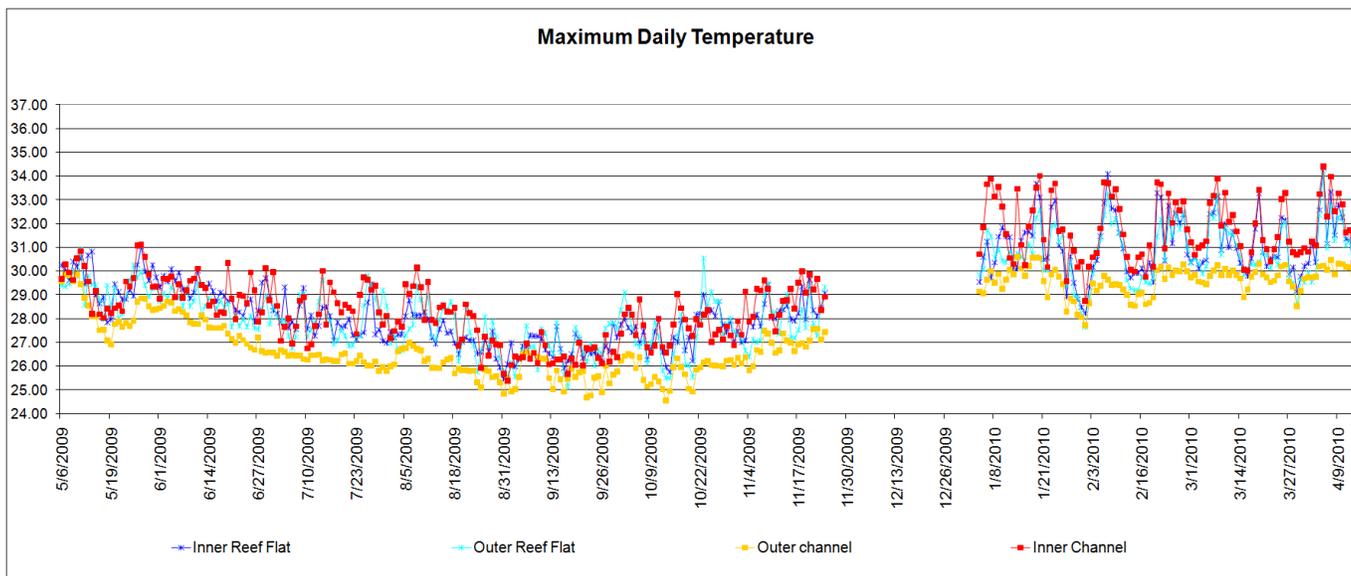


Figure 7. Daily temperature range (°C) at each sampling station on Votua Reef.

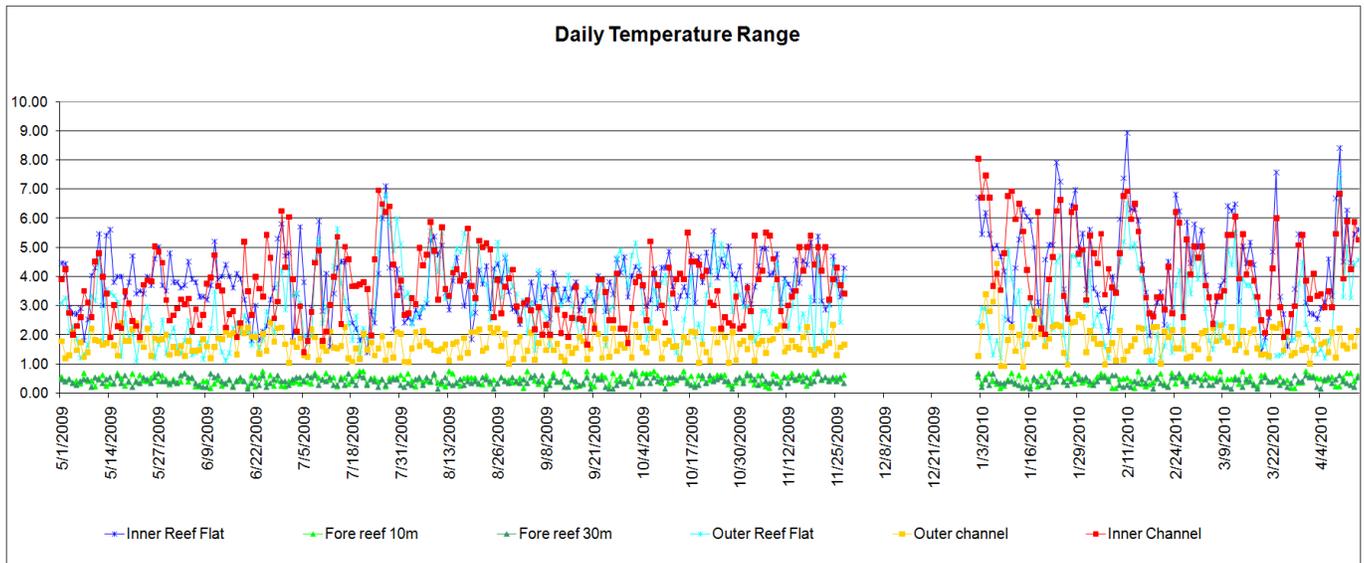


Figure 8. Daily temperature range (°C) at each sampling station on Tagaqa Reef.

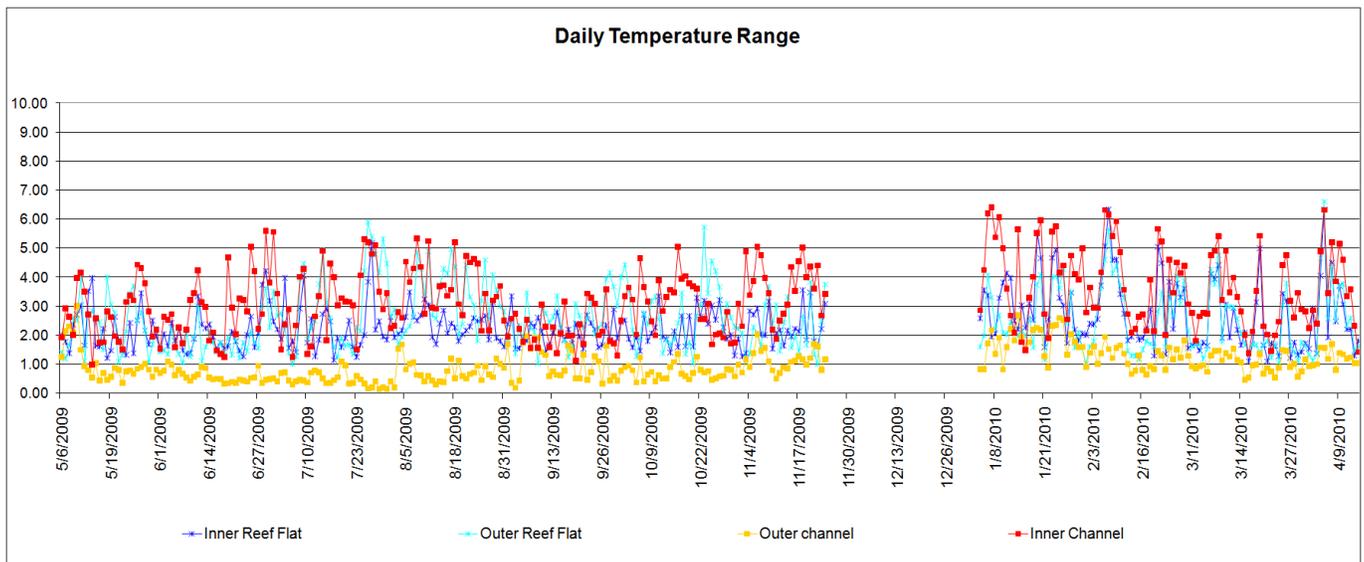
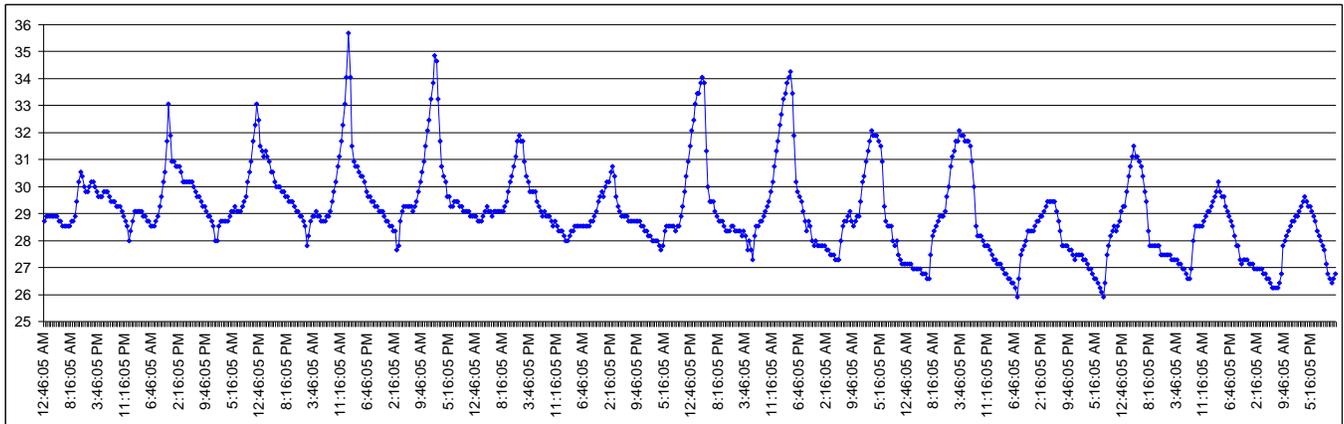


Figure 9. Votua inner reef flat site temperature readings (°C) taken every 30 minutes illustrating the rapid heating and cooling that occurs during low tide periods, particularly during spring tides that occur during the middle of the day during clear sky periods.



Appendix 1. Monthly visual observations of coral communities at the six Votua sampling stations.

April 2009

Minor bleaching of *Sinularia* colonies occurring on the reef flat ~30-50% colonies in shallower pools. Weather was rough during the full moon tides this month... water came over the village seawall. Lots of corals tumbled on the reef flat. By the end of the month, colonies of *Stylophora*, *Millepora*, *Acropora millepora*, *A. acuminata*, and several other *Acropora* species were heavily bleached on the reef flat - particularly in the outer pools. The occasional *Goniastrea edwardsi* and *Psammocora digitata* were also bleached on the reef flat. The staghorn *Acropora* in the inner reef flat were mostly all bleached, but all the other corals looked fine. In the inner channel area, corals looked fine except for the *Pocillopora damicornis*- which were bleached on the tops. Further out in the channel along the shallow ledge, almost all of the *Acropora digitifera* were bleached out and also scoured or broken badly from trampling. It is most likely that rubble from the reef flat was scoured across this area during the big swell around the middle of the month. In the outer channel area, corals were mostly fine, however, some species were consistently bleached. All *Goniastrea*, *Acropora nana*-type, *A. digitifera*, *Favia stelligera*, *Millepora*, some *Montipora* species, and some *Pocillopora* were heavily bleached, but still alive in the very outer channel areas- both sides. Corals on the forereef looked fine around Morgan's wall during the middle of the month, however some bleaching of areas of massive *Porites* was noted around the end of the month. Carpet anemones (*Stichtodactyla* spp) in the outer channel area are heavily bleached as were those seen in the outer reef flat. Some of the *Palythoa* was bleached in the outer reef flat and channel areas.

May 2009

Soft corals on the reef flat have recovered from bleaching, however staghorns, some (10-20%) of the other *Acropora*, some (5%) *Montipora*, *Stylophora*, some (15-30%) *Pocillopora*, *Millepora*, 20% of the massive *Porites*, and *Psammocora digitata* remain bleached. An *Acropora echinata* type species seems to have suffered fairly high mortality on the reef flat... though some patches remain alive. *Entacma quadricolor* have all regained their color on the reef flat. Corals along the ledge in the inner channel remain bleached (mostly *A. digitata* and *P. verrucosa*), however most corals (all *Acropora*) along the outer channel have recovered except for the *Millepora*, which remain partly bleached on top. The carpet anemones are still light in the outer channel. On the forereef, there are some corals that bleached still, but these remain deep on the reef. 5-10% of the massive *Porites* below 35m have bleached areas. Additionally, the stand of *Pachyseris speciosa* on the eastern edge of the channel are ~ 40% bleached (40-55m deep). All other shallow-water corals remain healthy. There are occasional colonies of *A. nana* type on the shallow (<5m) reef front that appeared to have died during the bleaching, but mortality remains minimal.

June 2009

Corals in most areas appear normal coloration again. Only very shallow corals (those that are briefly exposed during low tides) in the outer reef flat remain mildly bleached.

July 2009

Corals appear normal in all areas.

Aug. 2009

Corals appear normal in all areas.

Sept. 2009

Corals appear normal in all areas.

Oct. 2009

Corals appear normal in all areas.

Nov. 2009

No signs of bleaching, though no observations were made at forereef sites.

Dec. 2009

Minor bleaching of *Sinularia*, *Millepora*, and staghorn *Acropora* in outer reef flat; staghorn *Acropora* in inner reef flat area. All other corals appear normal. No observations made at forereef sites.

Jan. 2010

Minor bleaching of *Sinularia*, *Millepora*, and staghorn *Acropora* in outer reef flat; staghorn *Acropora* in inner reef flat area. Corals that are exposed during low tides (*Acropora*, *Montipora*, *Pocillopora*, *Millepora*, some *Pavona*) in the outer reef flat are more heavily bleached. All other corals appear normal. Fore reef appeared normal.

Feb. 2010

No observations made

March 2010

No observations made

April 2010

Observations made late in the month at channel and reef flat stations. Minor bleaching of staghorn *Acropora* spp in the outer and inner reef flat areas. Minor bleaching of *Millepora* in the outer reef flat. Corals in all other areas appear normal.

May 2010

Minor bleaching of staghorn *Acropora* spp in the outer and inner reef flat areas. Minor bleaching of *Millepora* in the outer reef flat. No observations made at fore reef sites.

June 2010

Mild bleaching noted mid-month on *Acropora*, *Pocillopora*, *Montipora*, *Millepora*, and *Seriatopora* spp. in the outer reef flat; bleached colonies were those that are exposed or nearly exposed during the low tides. Low tides around spring tide periods coincided with clear sunny days. All other corals appear normal.

July 2010

All corals appeared normal at beginning of month – recovered from last month's mild bleaching. Heavy bleaching noted at end of the month on *Acropora*, *Pocillopora*, *Montipora*, *Millepora*, and *Seriatopora* spp. in the outer reef flat on colonies that are exposed or nearly exposed during the low tides. Low tides around spring tide periods coincided with clear sunny days. All other corals appear normal

Aug 2010

No signs of bleaching in any areas.