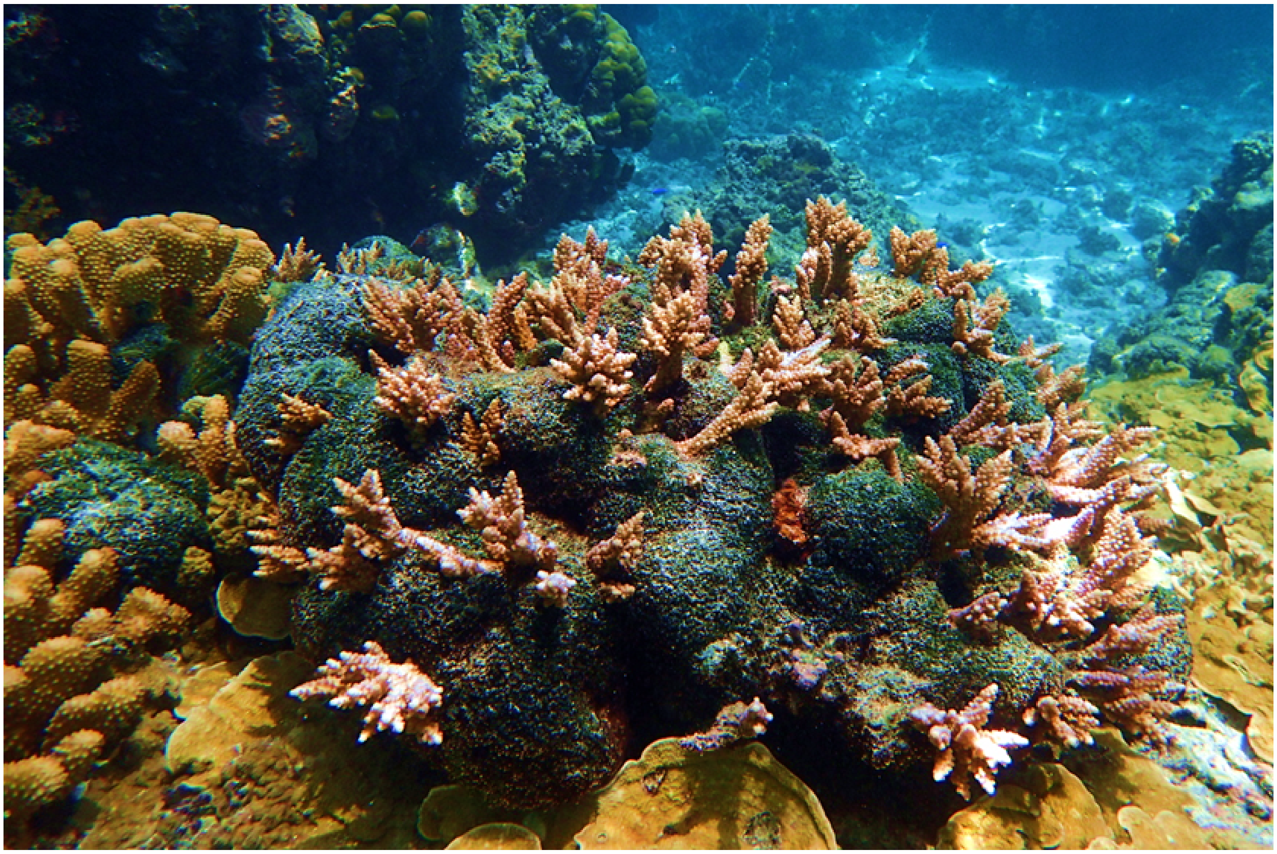
Ofu-Olosega Invasive Algae Monitoring Report



Field Report

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Glossary

CRAG	American Samoa Coral Reef Advisory Group
DOI	U.S. Department of Marine and Wildlife Resources
NPSA	National Park of American Samoa
GIS	Geographic information system
GPS unit	Global positioning system tracking unit

Background

Ofu Island contains a coral reef system unparalleled for its biological, cultural, and academic importance. The lagoon is highly diverse and contains nearly 300 species of fish and 80 species of coral including an endemic species, *Porites randalli* (Forsman and Birkeland 2009), and an Endangered Species Act (ESA) listed coral, *Isopora crateriformis* (Craig et al. 2001, NOAA 2018). It is culturally important to the Samoan communities and is a valuable source of protein for many local families. Further, the pools have been a site of scientific research for nearly two decades as the corals have exhibited resilience against high temperatures. Extensive physiological manipulation and reciprocal transplantation studies have been conducted by researchers at Stanford University, Old Dominion University, and the University of Hawaii (Smith and Birkeland 2007, Barshis et al. 2014, Seneca and Palumbi 2015).

The ability of these corals to be resilient and acclimate following disturbance, most notably during bleaching events, however, is under threat. In 2017, a rapidly expanding *Valonia* spp. algae outbreak was reported in several lagoon pools of Ofu-Olosega, some of which fall within the U.S. National Park of American Samoa boundaries. The algae were observed in large clumps which grew around numerous branching coral species, smothering their tissue and subsequently inhibiting energy production via photosynthesis (Photo 1). When the algae were removed, the coral underneath was bleached white and algal smothering often resulted in mortality. Samples of this algae were identified as *Valonia fastigiata* by the University of Hawaii at Hilo (UH Hilo) Professor Dr. Karla McDermid-Smith and Samoan algae expert, Dr. Posa A. Skelton.

Photo 1. Side view (left) and close up (right) of branching *Acropora sp.* colony overgrown by Valonia sp. located in Ofu Pool 300 in 2019.

Climate-induced stressors, including temperature perturbations, are predicted to increase in intensity and frequency and it is likely that the corals in Ofu provide a critical source population for the surrounding territory, including a source of thermally tolerant genotypes. Hence, there is an urgent need to protect these corals from local (and manageable) stressors to prevent localized and regional extinctions.

There have been no studies examining the thermal tolerance of *V.fastigiata*. However, a similar species, *V. uticularis*, is capable of sustained growth at temperatures as low as 18-20 °C (Pakker and Breeman 1996). As ocean temperatures in Ofu rarely drop below 25-26°C in the winter months, it is unlikely that seasonal temperature changes will serve as effective environmental control. Further, no herbivores have been observed consuming *Valonia*, though saltwater aquarium enthusiasts suggest that surgeonfish (*Acanthurus spp*.) and rabbitfish (*Siganidae spp.)* may eat these algae (http://reefkeeping.com/issues/2002-02/hcj/feature/index.php). *V. fastigiata* reproduces both asexually through mitosis and sexually through the production of sporophytes (Beutlich et al. 1990). Despite being native to the Samoan Archipelago, and widely distributed throughout the

South Pacific and Indian Oceans (Littler and Littler 2003), this species usually occurs at low densities with minimal impact on the coral reef ecosystem. However, under favorable environmental conditions, with high nutrient input, this complex reproductive strategy enables rapid population explosions and overgrowth of entire coral reef ecosystems.

A reconnaissance survey conducted in February 2018 by the American Samoa Coral Reef Advisory Group (CRAG indicated an abnormally high density of *V. fastigiata* in Pools 300, 400, and an unnamed pool in front of the Vaoto Lodge (hereafter referred to as the Vaoto Lodge Pool). CRAG biologists theorize that the outbreak began in the Vaoto Lodge Pool and spread east with the prevailing current into the National Park.

Additional coral reef monitoring surveys identified cyanobacteria and other *Valonia* algae outbreaks on the shallow reef areas in front of the two main villages of Ofu and Olosega (see Figure 1). The shallow reef environment is connected from the village of Ofu along the coast to the Ofu Airport and the Vaoto Lodge and into the National Park area. This reef provides a buffer zone that reduces erosion on the island's beaches, which are critical nesting sites for endangered green (*Chelonia mydas)* and hawksbill sea turtles (*Eretmochelys imbricata;* M. MacDonald[1], direct communication).

The overall goal of this study is to control the spread of the *Valonia* algae in a three-pronged approach to enhance the coral reef resilience in Ofu and Olosega Islands, American Samoa. First, determine the source of nutrients (through extensive oceanographic and biological sampling) and the location they are entering the system, and using this information will attempt to reduce or prevent further contamination. Second, actively control

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[1] Mark MacDonald, American Samoa Department of Marine and Wildlife Resources, March 28, 2018

algae in the pools through manual removal efforts. The final phase includes restoration efforts which will allow for healthy corals to grow and replace those that were damaged or killed by the algae outbreak. The aim of this assignment will be focused on the first approach of this project which started in 2019 with final data collection in 2022.

Methods

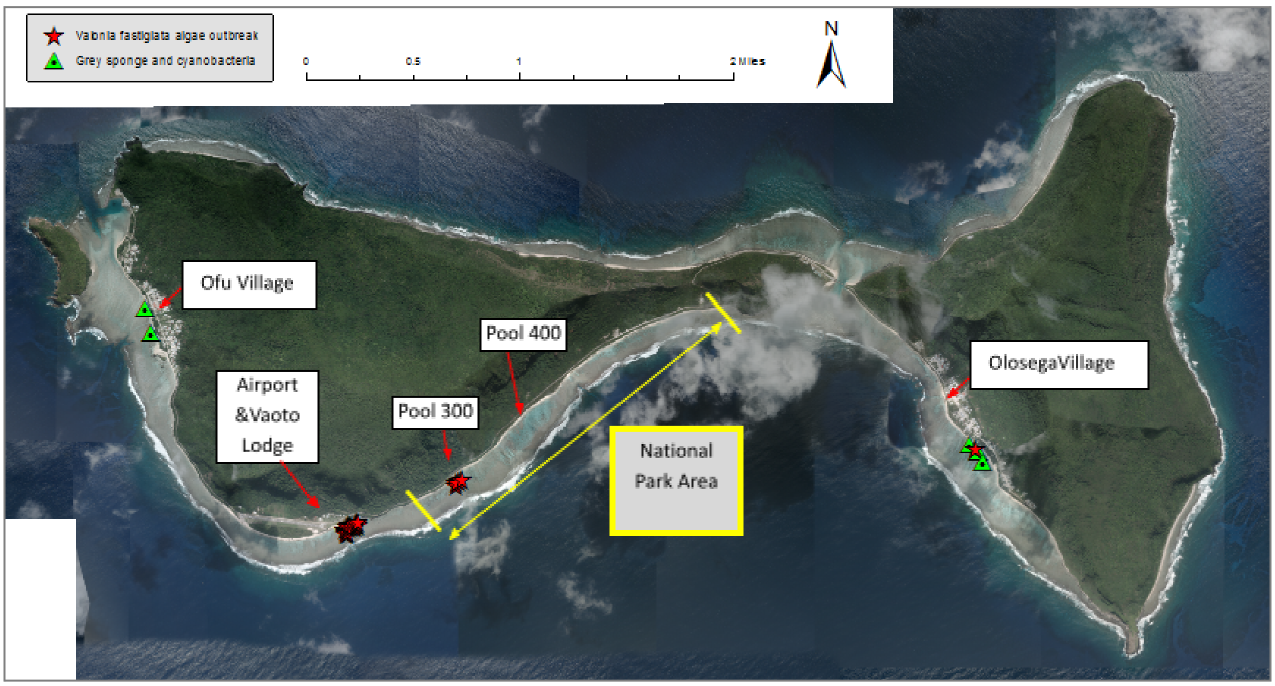


Figure 1: Location map showing proposed project area with areas of interest

Many algae outbreaks are the result of nutrient eutrophication from terrestrial sources. Prior to any control efforts, it is critical to have a thorough understanding of where these nutrient inputs are entering the system and how they are transported to different areas of the reef. Long-term data sets collected between 2009 and 2014 indicate that both total dissolved nitrogen and total dissolved phosphorous remain relatively constant within Park waters with only occasional spikes in concentrations (Raikow et al. 2017). However, the Vaoto Lodge and Ofu Airport are located upstream of the pools and are a potential source of terrestrial runoff. It is possible that runoff or improperly managed sewage was the stimulus for the algal outbreak, however, there may be additional land-based activities that are contributing to higher nutrient concentrations in the shallow reef area.

To determine where these contaminants are entering the ocean, a comprehensive oceanographic survey was undertaken covering the two main seasonal periods in the first year, 2019, of the project with opportunistic surveys in the following years. The project focused on 5 key areas: Ofu village; Vaoto Lodge Pool; Pool 300; Pool 400; and Olosega village. A previous study (in prep.) conducted by United States Geological Survey (USGS) staff indicated that subterranean groundwater discharge (SGD) is the main source of freshwater input into the coral reef environment in Ofu and Olosega (A. Brasher[2], direct communication). The location of freshwater input sources from SGD can be determined using a number of techniques at different tidal and lunar states.

Coastal springs are easily located along the coastline during spring low tides in the project area. USGS scientists suggested that it is likely that other sources of freshwater are entering through the coral reef matrix and into the middle of the lagoon at unknown locations. Water samples were collected from 16 sites, coastal springs, wetlands, and nearshore sites close to where landfills were located every 4-5 months. Samples were sent to NOAA National Centers for Coastal Ocean Science to perform nutrient laboratory analysis. Analysis of the samples is still ongoing with a few collections remaining. Water samples will be analyzed for a standard suite of nutrient analytes: nitrate (NO3-), nitrite (NO2-), orthophosphate (HPO4=), ammonium (NH4+), urea ((NH2)2CO), total nitrogen, total phosphorus, and silica. Water samples will provide

[2] Anne Brasher, United States Geological Survey

nutrient data for the area to determine if there is a spatial correlation between algal outbreaks and elevated nutrients. Additionally, dietary tracer (sucralose/caffeine) data will be used to determine if human waste (a nutrient source) is reaching the coastal ocean.

Temperature sensors were deployed at strategic points inside and outside the affected areas to assist with characterizing the oceanographic dynamics that may be causing the invasive algae outbreak to proliferate in certain areas.

A multi-parameter sonde (YSI Exo 3) was deployed in each of the key target areas over a 3-month period and will be rotated around to cover the priority areas in 2019. The sonde recorded salinity (parts per thousand (ppt)), temperature (°C), dissolved oxygen (percent saturation), chlorophyll (ug/L), pH, turbidity (Formazin Nephelometric Units (FNU)), and blue-green algae concentration (ug/L) at 10-minute intervals. Deployment locations were chosen based on the high-density percent cover of Valonia spp. and the presence of living hard coral.

Sonde tows were conducted in all study sites by swimming transects with a multi-parameter sonde (YSI Exo 3) and GPS unit. Transects stretched from the shoreline to the reef crest and were approximately 10 meters apart (Figure 2). Surveyors followed a landmark and swam perpendicular from the shoreline to the reef crest. At the end of the transect, the surveyor swam parallel to shore for 10 meters then began a new perpendicular line back to the shore. The GPS unit and the sonde were set to collect data at five-second intervals. After each survey, the locations from the GPS unit were manually combined with the sonde data into a database. Sonde surveys were completed in June 2019, September 2020, and March 2021 within all study sites.

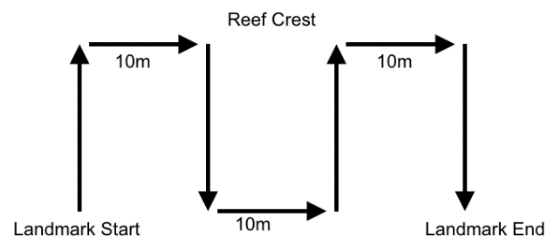


Figure 2. Sonde tow transect: Schematic to outline the sonde tow pattern. Surveyor began at the shoreline swimming perpendicular toward the reef crest. At the end of each transect, the surveyor swam 10 meters parallel to the shore before beginning a new transect from the reef crest to the shoreline. This pattern was repeated for the length of each pool.

The data from all these sensors and equipment will provide the ability to conduct a comprehensive characterization of the spatial and temporal oceanographic dynamics occurring in the proposed project area. The datasets provided by this study can be used to create useful visualization tools to understand the system dynamics and provide effective materials to communicate the issues and needs to local community members and relevant natural resources agencies.

Algae Surveys

Algae surveys were conducted across all priority study regions to determine the extent and density of six dominant algal genera/groups: *Valonia, Caulerpa, Chlorodesmis, Dictyosphaeria,* cyanobacteria, and *Halimeda.* The surveyor began at a predetermined landmark and swam in a straight line, perpendicular to the shore, from the shoreline to the reef crest. At the reef crest, the surveyor swam 5 meters parallel to shore and began a new perpendicular transect from reef crest to shore (Figure 3).

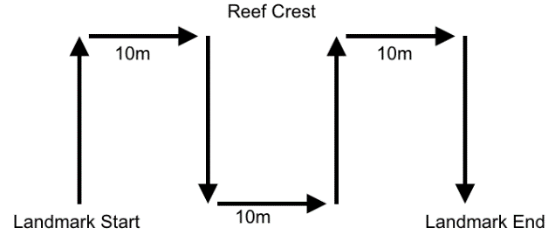


Figure 3. Algae survey transect: Schematic to outline the survey pattern. Surveyor began at the shoreline swimming perpendicular toward the reef crest. At the end of each transect the surveyor swam 10 meters parallel to shore before beginning a new transect from the reef crest to the shoreline. This pattern was repeated for the length of each pool.

At the beginning of each survey, the surveyor started a digital watch timer set to 30-second intervals. The surveyor swam for 30 seconds, stopped, and recorded the algae density within the 2-meter radius circle at that location. After 30 seconds, the surveyor repeated the process (swam 30 seconds, surveyed 30 seconds). A photograph of each survey location was also taken. GPS coordinates were recorded through a synchronized digital watch and GPS unit system. The surveyor towed a GPS unit and recorded the watch time of each stop. After each survey, the locations from the GPS unit were manually combined with the watch time data into an algae survey database.

At each stop, the surveyor recorded the time, to the nearest second, and within a 2-meter radius circle, estimated the percent of live coral cover and the extent of algal cover for the six dominant genera/groups using the severity scale outlined in Table 1. Upon completion of the survey, the live coral cover estimate was translated to the same severity scale. Prior to the start of each monitoring trip, all surveyors had to participate in calibration training for the identification of algal genera/groups and standardize surveyors on the algae survey severity index. The algae surveys were conducted at the same time as the when the sonde tows were conducted in 2019, 2020, and 2021.

Table 1. Algae survey severity index. The scale used to assess the severity of algae covers for six genera/groups.

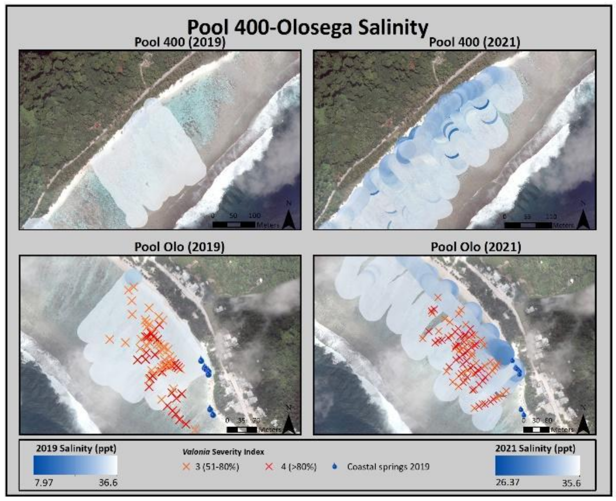
Severity Level	% Cover	Visual Assessment
0	No Coverage	None observed
1	Low (1-10% cover)	Patches spread-out over reef
2	Moderate (11-50% cover)	Concentrated growth beginning to cover coral
3	High (51-80% cover)	High cover of many corals
4	Severe (>80% cover)	Cover of most corals

Results and Discussion

The sampling for oceanographic conditions was completed earlier this year and processing and analysis are still ongoing with a few remaining water sampling trips planned around the end of the year.

Salinity and Algae

Exploring linkages between the oceanographic conditions and biological surveys was important to understanding what physical factors could be contributing to the spread of the algae. Preliminary maps combining algae survey and sonde data specifically looking at salinity data from 2019 and 2021 (Figure 4-5) show a clear pattern of the spread of the algae in all five sites with severity. The highest intensity of algae spread was found in Pool 300 and Olosega pools. The maps with overlay salinity, temperature, and algae data so far demonstrate no obvious links between freshwater input from the coastal springs, warmer pools, and algae hot spots. However, as other datasets are still being collected and processed with the aim of providing clarity on the trends for salinity and temperature and the other parameters measured by the EXO 3 multi-parameter sonde.



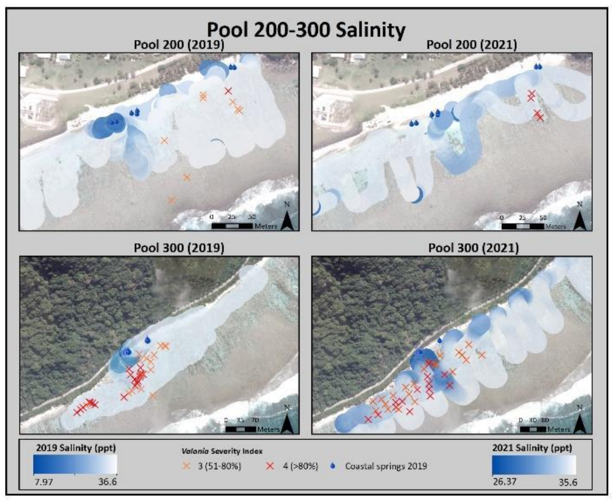


Figure 4. Salinity trends. Coastal springs are areas of freshwater input into the pools. Darker blue indicates areas of lower salinity (ppt) and lighter blue represents higher salinity (ppt). Orange and red marks depict locations where Valonia spp. Severity was recorded as a 3 (51-80%) or 4(>80%), respectively. Data displayed was collected in June 2019 and March 2021.

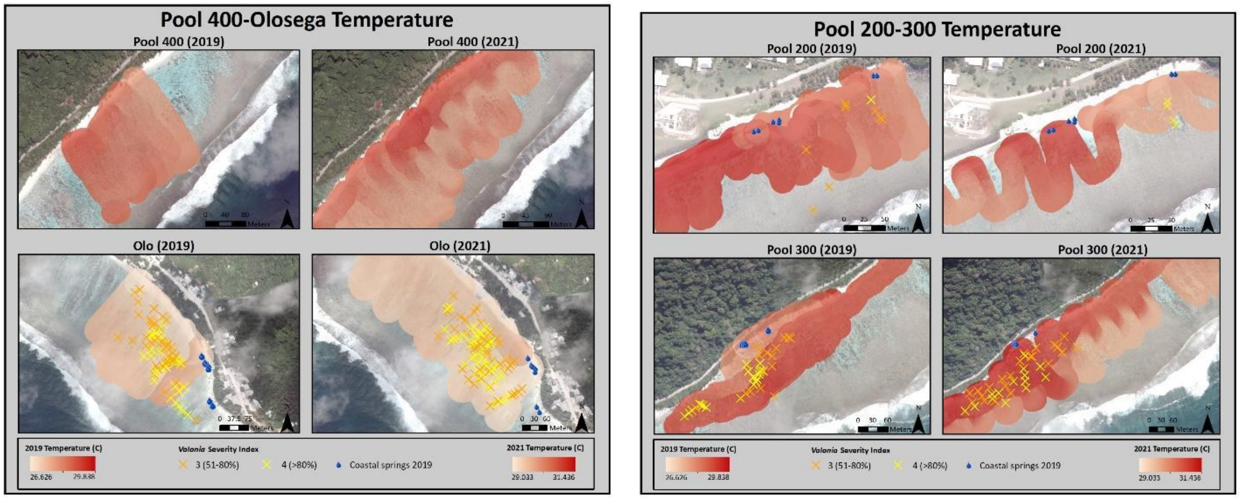


Figure 5. Temperature trends. Coastal springs are areas of freshwater input into the pools. Temperature (°C) is represented on the red scale; cooler temperatures are light red and warmer temperatures are dark red. Orange and red marks depict locations where Valonia spp. Severity was recorded as a 3 (51-80%) or 4(>80%), respectively. Data displayed was collected in June 2019 and March 2021.

The original design of this project was to conduct all sampling during the two seasons of American Samoa, the winter and summer months every year However, due to COVID-19 travel restrictions between the main island of Tutuila and the Manu'a Islands (Ofu and Olosega), sampling was constrained first to available capacity, travel permitted by the government, fair conditions. COVID-19 restrictions affected other sampling objectives of the project due to delays in shipment and low staff capacity.

A SeaBird EcoPAR sensor (http://www.seabird.com/ecopar) was to be deployed with the sonde to measure photosynthetically active radiation (PAR), an important parameter for water quality, phytoplankton productivity, and light availability of important benthic ecosystems like coral reefs and seagrass. This EcoPAR would measure the total PAR irradiance, and it is equipped with a bio wiper to maintain the optical sensor and ensure reliable measurements for long-term deployments. This measurement is important for satellite product validation of various NOAA satellite products like KdPAR and Light Stress Damage (LSD). The EcoPAR would be deployed on the surface, and the data will be paired with information derived from the temperature loggers located at various depths in the corresponding site.

An unmanned aerial vehicle (drone DJI Phantom) was also to be used to provide a synoptic view and photo mosaics of the areas of interest. These drone surveys would be essential to overcome cloud cover and the limited availability of high-resolution satellite imagery. In addition, a multispectral camera will be acquired to enhance the aerial surveys using the 4 spectral bands provided by a MicaSense camera and monitor the oceanographic conditions over a larger area. The addition of these spectral channels would allow the development of ocean color algorithms for chlorophyll-*a* and sediments to match with the field samples. This would be deployed by local staff every fortnight to monitor oceanographic conditions such as temperature hotspots, turbidity, plankton blooms, and will be used to validate algorithm development using the multispectral camera. In addition, the field data can be used to validate oceanographic satellite products from NOAA and other agencies.

Long-term monitoring of these sites will continue because of the importance of resilience and diversity of corals found in the Ofu Pools. In addition, continued monitoring will help track any spread of this algae in the future as the climate changes and how the community continues to use its coral reef ecosystem services.

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