American Samoa Coral Reef Monitoring Program

Progress Report FY13/14

Award Period: 10/01/2013 – 09/30/2015 (ext. 09/30/2016)

Department of Marine and Wildlife Resources

Coral Reef Advisory Group

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Contents

1. Program Overview

In 2005 the Department of Marine and Wildlife Resources (DMWR) initiated a comprehensive long-term monitoring program for the reefs in American Samoa, the American Samoa Coral Reef Monitoring Program (ASCRMP). Funding was provided through the Coral Reef Conservation Program (CRCP) of the National Oceanic and Atmospheric Administration (NOAA) and the National Ocean Services (NOS).

Although there have been previous monitoring surveys in American Samoa covering a variety of spatial and temporal scales, the ASCRMP represents the first attempt to annually monitor representative reefs in American Samoa, starting initially around Tutuila and eventually in the Manu'a islands and the two atolls, Rose and Swains. The program has been set up with long-term government funding, and is therefore capable of accumulating long-term data sets annually over a larger geographic scale.

The primary objectives of the American Samoa Coral Reef Monitoring Program are to: (1) Monitor the status and trends in the distribution and abundance of reef biota on reefs in American Samoa, and (2) Provide environmental managers, as well as other decision makers, with information that is pertinent to managing coral reefs in the territory. As a monitoring program, ASCRMP's goal is to document change - i.e. where, how much, and what kind of changes take place at the various monitoring sites. The ideal is to resolve change at scales which will allow judgments to be made as to which changes are within normal, natural variability, and which are outside it.

Eleven sites around Tutuila Island were initially chosen by the American Samoan Governors Coral Reef Advisory Group (CRAG) and a Monitoring Working Group that was established for this purpose. Monitoring sites chosen represented what was thought to be a reasonable sample size around the main island of Tutuila and the nearby small island of Aunu'u, providing a reasonable geographic distribution and some of the variety of reef types and exposures (i.e. windward/leeward). The site plan for the ASCRMP incorporated federal, territory, and community-based MPAs. Three of the 11 monitoring sites are community-based MPAs within DMWR's Community-based Fisheries Management Program (CFMP) (Fagamalo, Vatia, and Amaua) and 2 sites are federal MPAs (Fagatele and Tafeu).

The project is coordinated by two staff members that are funded by the program; the Coral Reef Monitoring Benthic Ecologist, and the Coral Reef Monitoring Fish Ecologist. The Benthic Ecologist position was filled by Dr. Doug Fenner from 2006 until August 2013 and in May 2014 Dr. Mareike Sudek was hired to fill the benthic ecologist position. The Fish Ecologist position was initially filled by Lesley Whaylen in 2006 and then by Benjamin Carroll between 2007 and August 2012. The DMWR's Chief Fisheries Biologist (Dr. Domingo Ochavillo) filled in the fish ecologist duties up until February 2013 when the position was filled part-time by DMWR fisheries supervisor Alice Lawrence and part-time by DMWR fisheries technician Saolotoga Tofaeono. The position was filled full-time by Alice Lawrence in February 2014 which continues until the present time.

Based on population density and subsequent impacts to the watershed, the ASCRMP incorporated villages in the complete range of the ASEPA watershed classification scale; pristine, minimal, intermediate, and extensive (DiDonato 2004). Three of the 11 monitoring sites (Leone, Nu'uuli and Faga'alu) are categorized as Extensive, three sites are categorized as Intermediate (Amaua, Aoa, and Fagasa), one site is categorized as Medium (Vatia), and three sites are categorized as Pristine (Fagatele, Tafeu and Fagamalo). In 2007 an additional site, Massacre Bay, was added on the northwest sector to improve north-south/east-west balance, and thereby provided a balance of the four geographical quadrats of Tutuila (NW, NE, SE & SW). In 2009 five sites surrounding Swains Atoll were surveyed for the first time and the program is able to participate in opportunistic research trips to Rose and Swains when possible. Dr. Douglas Fenner conducted monitoring surveys in the Ofu and Olosega reef flat and lagoons in November 2011, which was visited again in February 2015 by Alice Lawrence and Mareike Sudek to establish semi-permanent transects (using GPS coordinates).

The program utilizes the DMWR Boston Whaler vessel to access survey sites around Tutuila, however the boat was out of action between January 2014 and November 2014, and again between November 2015 and April 2017. There were attempts to utilize local fishing boats to conduct surveys with varying success, due to problems with late payments, safety issues and logistics related to the smaller and slower engines used by the local fishing boats.

In an attempt to pool resources and increase efficiency between the NOAA CRCP-funded Coral Reef Monitoring Program and the three USFWS-funded DMWR coral reef monitoring programs, in January 2013 the DMWR Fisheries division made a decision to integrate the programs which included the Key Reef Species Program (KRSP), the Community-based Fisheries Management Program (CFMP), and the No-take MPA Program (NTMPA). The key objectives of the integration were to reduce duplication of effort and to enable the effective monitoring of 30 MPA and non-MPA sites using the same monitoring methods with the same trained surveyors. It was hoped that a larger, more statistically robust monitoring data set would be available to answer different management questions by the different programs. The fish ecologist worked on developing accessible monitoring protocols, and implementing training for species ID, monitoring methods, data entry and analysis. Details of the Integrated Coral Reef Monitoring Program are shown in Appendix 1. Unfortunately in September 2014 the USFWS Sports Fish Restoration grantors decided to cancel the agreement to integrate the programs due to grant administration issues. This caused a halt in survey efforts as the integrated survey methods, which had already been carried out at six sites, require four divers in the water. This led to complications with use of the DMWR boat and boat drivers for conducting surveys. The ASCRMP program staff worked to adjust the monitoring survey protocols to allow the monitoring to be conducted by only two divers, and to increase data quality, add additional data, and make it more comparable to data collected by other monitoring programs (for example NOAA CREP, and the ASEPA watershed monitoring program). In 2015 a total of 8 out of the 12 monitoring sites were surveyed, with benthic cover and demography data as well as fish diversity and biomass data collected. The 10 surveys conducted in 2014 by DMWR Fisheries staff and the program fish ecologist as part of the integrated program, are considered as ‘training surveys’ and were not included for analysis. Additionally, in 2015, bleaching monitoring sites were established at 8 reef slope sites, 3 reef flat sites and 4 pools. Temperature loggers were installed and are regularly exchanged.

2. Methods

The coral reef monitoring program has 12 semi-permanent sites around Tutuila as shown in Figure 2.1 (see Appendix 2 for a list of sites with GPS coordinates) with the goal of surveying them annually. Stakes will be installed at the individual sites (1 stake every 30m marking the beginning of the transects; 6 stakes/site), to permanently mark transects and aid relocation through time (permit pending).

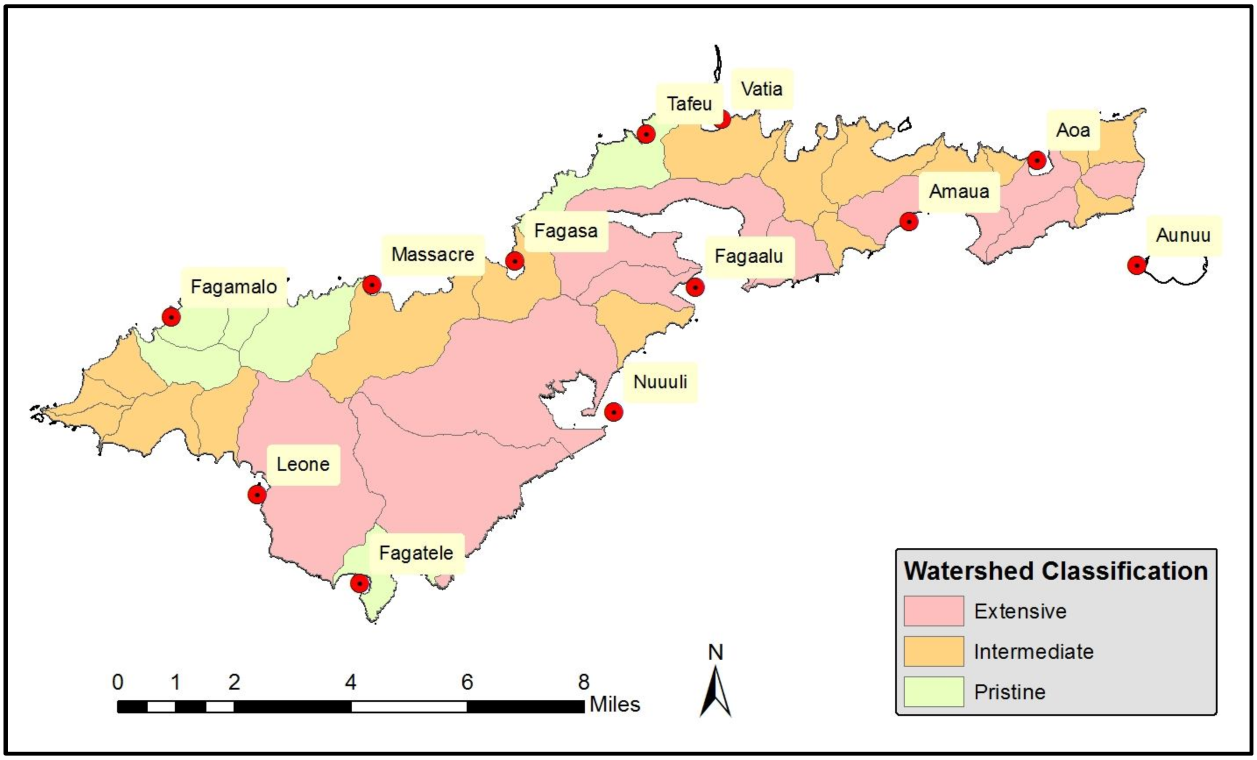


Fig. 2.1: Map of Tutuila showing the 12 monitoring sites

2.1 Benthic survey methods

Up until 2014, the line-point intercept method (LPI) was utilized to assess benthic cover. Four 50 m transects were laid out along a depth contour of 8-10 m and benthic categories recorded every 50 cm (100 data points/transect). In addition, a roving dive was conducted to record species diversity recorded on the DACOR scale. For more information on these methods see reports from 2005 to 2013 compiled by Doug Fenner.

In 2015, the methods were altered to increase data quality, add additional data, and make it more comparable to data collected by other monitoring programs. The LPI method was changed to photo quadrats to increase the amount of data points collected and decrease the time spend collecting the data. Additionally, coral demographic data is now collected along the transect to be able to make inferences of size distribution and recruitment.

Two 100 m tapes are laid out end to end on the 30 ft depth contour along the reef slope consisting of six individual transects (0-25 m, 30-55m, 60-85m, 90-115m, 120-145m, 150-175m). The beginning of each transect will be permanently marked with a rebar (six rebars total at 0, 30, 60, 90, 120, and 150m). For each transect, benthic photos are taken every meter using a 1m long monopod (26 photos per transect; a total of 156 photos per site). These photos are then analyzed using CPCe to obtain benthic cover estimates for the individual sites (20 points/photo = 520/transect). In addition, a 1 x 1 m quadrat is haphazardly laid out on the reef every 20m (10 per site) and every coral colony whose center falls within the quadrat is identified to genus, assigned a growth form and the largest diameter and width is measured (Adapted from Houk et al. 2013).

When possible (i.e. when an extra diver is available), large invertebrates (giant clams, sea cucumbers, sea urchins and crown-of-thorn starfish) are counted and measured on a 2 m wide belt along the six transects. If possible (i.e. when an extra diver is available), turf height is also measured at each site using 20 1x1 m quadrats (every 10 m) with 8 haphazard measurements per quadrat. This will indicate grazing pressure at the site (turf >5 mm = indicates reduced herbivory).

2.2 Fish survey methods

Up until 2013 the fish survey methods included recording all diurnally active, non-cryptic reef fish were to species level using belt transects. At each site, 6 replicate 30m transects were sampled with several passes and widths being used to sample different groups. The first pass was used to sample larger, more mobile species 7.5m either side of the transect as the transect is laid out. On the second pass parrotfish were recorded 5m either side of the tape. The third pass surgeonfish were recorded 2.5m either side of the tape. Every other species was then recorded 2.5m either side of the tape on the fourth pass, except damselfish, which were recorded on the fifth pass 1m either side of the tape. Each individual fish was counted and an estimation of length recorded. The fish ecologist and the benthic ecologist conducted their surveys separately and at times the distance between the divers underwater could be up to 150 meters.

The Integrated Coral Reef Monitoring Survey protocols were developed, tested and implemented between January 2013 and September 2014. Information about the program and the monitoring protocols is shown in Appendix 1.

In 2015, the fish survey methods were altered to improve diver safety protocols in line with the updated DMWR Dive Safety Manual and in particular to ensure that the benthic ecologist and the fish ecologist were able to conduct the surveys in close proximity to each other. Survey methods were designed to increase data quality and make it more comparable to data collected in the territory by other monitoring programs such as the ASEPA coral reef monitoring program (Houk *et al.* 2013) and the NOAA CREP protocols (Heenan *et al*. 2014). Starting at 0m and then every 20m, a Stationary Point Count (SPC) is conducted in a 7.5m radius from the diver for 3 minutes. A total of 12 replicate SPCs are completed along the transect tape. Each SPC is a visually estimated 15m diameter cylindrical plot extending from the substrate to the limits of vertical visibility. Each count consists of two components. The first of these is a 1 min species enumeration period in which the diver records the taxa of all species observed within their cylinder. At the end of the 1 min period, the diver begins the tallying portion of the count, systematically working through their species listing and recording the number and estimated size (total length, TL, to the nearest cm) of each individual fish. The tallying portion is conducted as a series of rapid visual sweeps of the plot, with one species-grouping counted per sweep. To the extent possible, the diver remains at the center of their cylinder throughout the count. However, small, generally site-attached and semi-cryptic species, which tend to be underrepresented in counts made by an observer remaining in the center of a 7.5-m radius cylinder, are left to the end of the tally period, at which time the observer swims through their plot area carefully searching for those species. In cases where a species is observed during the enumeration period but is not present in the cylinder during the tallying period, divers record their best estimates of size and number observed in the first encounter during the enumeration period and mark the data record as "non-instantaneous." Surveys are not conducted if horizontal visibility is < 7.5 m, i.e., when observers cannot distinguish the edges of their cylinder. Biomass per fish is then calculated using the standard length-weight equation.

2.3 Bleaching

In 2015, bleaching monitoring sites were established at 8 reef slope sites, 3 reef flat sites and 4 pools, including installation of temperature loggers (see Appendix 3 for a list of sites with GPS coordinates). On slopes, a 100 m tape was laid out on the 30 ft depth contour along the reef consisting of three individual transects (0-25 m, 30-55m, and 60-85m). In pools and on reef flats, three 25 m transects were laid out haphazardly. On the slope, the beginning of each transect was permanently marked with a rebar (3 rebars total at 0, 30 and 60m). In pools and on reef flats, the beginning and the end of the transect were permanently marked with a rebar (six rebars total, 2 rebars/transect).

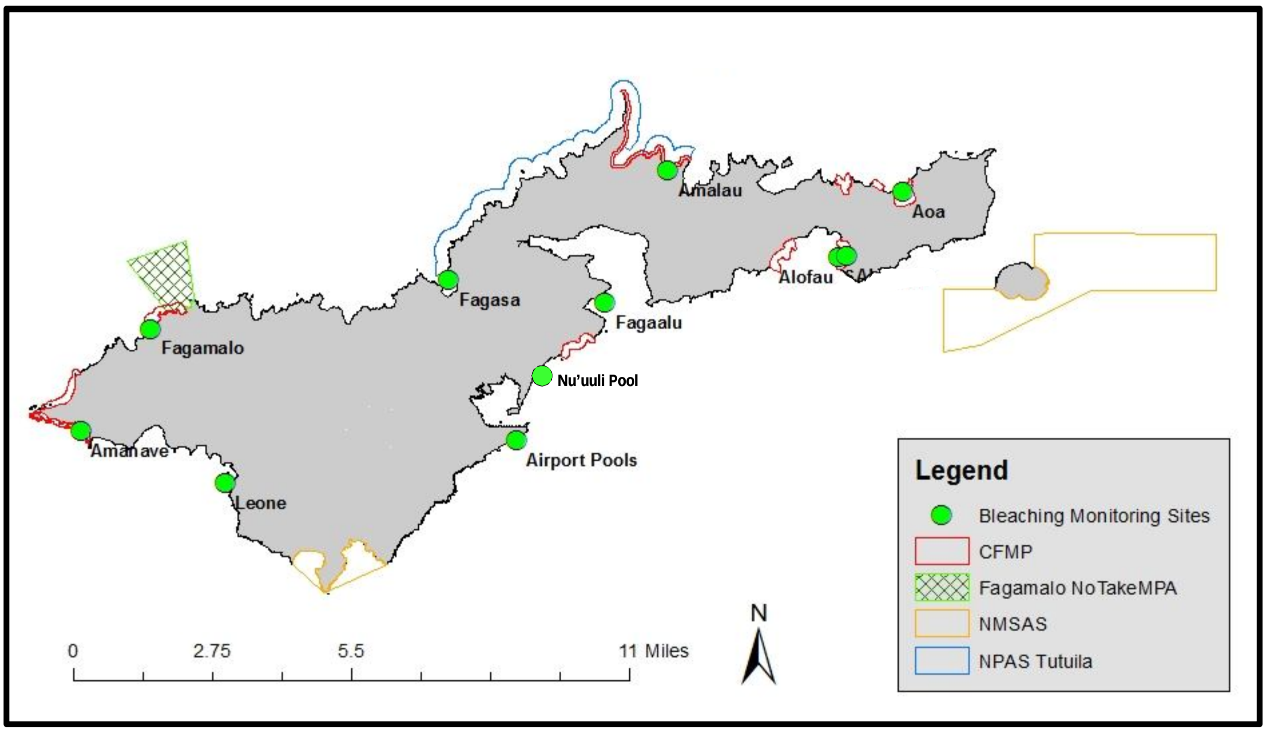


Fig. 2.3.1: Map of Tutuila showing the bleaching monitoring sites. Some sites have pool, reef flat and/or slope associated with it.

For each transect, benthic photos were taken every meter using a 1m long monopod on slopes and a 0.75m monopod on reef flats and in pools (26 photos per transect; a total of 78 photos per site). These photos will then be analyzed using CPCe to obtain coral cover estimates for the site. The coral cover estimates can then be compared to cover data after a bleaching event to assess the impact bleaching had on the reef assemblage.

Two HOBO® Pendant temperature loggers (www.onsetcomp.com) were installed at each site near two of the stakes using zip ties. The logger (length 5 cm) was attached to an area of reef (solid rock) where no coral was injured in the process. The loggers were exchanged every few months to maintain a continuous data set.

During a bleaching event, in addition to the photos, a belt survey will be carried out to obtain data on the percent coral that is bleached and how different genera are affected. Every coral colony within a 1 m wide belt along the transects will be identified to genus and assigned a bleaching severity ranging from 0-4 (0=no bleaching; 1=partially bleached; 2=white; 3=bleached and partly dead; 4=recently dead; see Marshall & Schuttenberg 2006). Additionally, a number of bleached colonies (a max of 5 per transect) will be tagged using numbered cable ties to monitor bleaching mortality/recovery over time at the induvial colony level. Tagged colonies will be photographed during and after the bleaching event has ended. The software 'Image_J' will be used to calculate tissue mortality and/or recovery for each colony ($area^2$). In addition, both divers will make an estimate of the general proportion of coral affected by bleaching for the reef as a whole using a scale from 0-4 (0=<1% - no bleaching; 1=1-10% - mild bleaching; 2=10-50% - moderate bleaching; 3=50-90% - high bleaching; 4=>90% - extreme bleaching; see Marshall & Schuttenberg 2006). Up to this date, no major bleaching occurred around Tutuila and so these methods have yet to gain results.

3. Monitoring Activities

The main obstacle to implementing coral reef monitoring using SCUBA diving has been related to maintenance issues related to the DMWR vessel which was out of service between January 2014 and May 2015 and again between November 2015 and April 2017. Where possible dive surveys were conducted using a rental fishing boat, however most of the local fishing boat drivers do not have training on working with divers in the water and don't have adequate safety equipment on board. In June 2015 the monitoring surveys were conducted by doing time-intensive shore dives.

Table 3.1 shows the monitoring surveys that were conducted at the original 12 sites and the additional integrated monitoring sites during the different financial years.

Table 3.1: Reef Slope Monitoring Sites Surveyed in FY2013, FY2014 and FY2015

Site	Survey date FY 2013 (Oct 2013 – Oct 2014)	Survey date FY 2014 (Oct 2014 – Oct 2015)	Survey date FY 2015 (Oct 2015 – Oct 2016)
Aoa	08/8/2014		11/17/2015
Amaua	08/15/2014		11/20/2015
Aunu'u			11/18/2015
Faga'alu			11/13/2015
Fagamalo		06/04/2015	
Fagatele Bay			
Fagasa	08/06/2014	06/02/2015	
Leone	05/21/2014		
Massacre Bay			
Nu'uuli			11/20/2015
Tafeu	07/15/2014		
Vatia	07/08/2014	06/03/2015	
Integrated Monitoring Survey Sites			
Alega (vMPA)	10/1/2013 *(fish only)*		
Auto (vMPA)	08/15/14		
Matu'u (vMPA)	10/2/2013 *(fish only)*		
Poloa (vMPA)	10/10/2013 *(fish only)*		
Sailele (vMPA)	10/8/2013, *(fish only)* and 8/13/2014		
Amalau (vMPA)	07/18/2014		
Amanave (vMPA)	01/23/2014 *(fish only)*		
Outer Island Monitoring Surveys			
Ofu-Olosega Pool & reef flat surveys		02/14/15 – 02/18/15	
Rose Atoll			08/31-09/03/2016
NOAA American Samoa Archipelago Cruise 2015 (benthic) & 2016 (fish & benthic)			
Tutuila		02/26 – 03/07/2015	04/15 – 04/25/2016
Rose Atoll		03/12 – 03/30/2015	04/26 – 05/6/2016
Ta'u		03/12 – 03/30/2015	04/26 – 05/6/2016
Ofu - Olosega		03/12 – 03/30/2015	04/15 – 04/25/2016

4. Analysis

4.1 Benthic surveys

Mean percent coral cover ±SE was visualized using a bar graph and analyzed in SigmaPlot 13.0 using a one-way RM ANOVA to test for significant changes in coral cover over time. The mean was used because not all sites were surveyed every year and therefore the dataset had a lot of missing data, weakening an analysis.

2014 and 2015 excluded due to 'training' and wrong site; change of methods

Benthic assemblage analyses were carried out using PRIMER7 and PERMANOVA+. Data was transformed into a zero-adjusted Bray-Curtis similarity matric (Clarke *et al.* 2006) and examined using Principal Coordinates Analysis (PCO) plots.

4.2 Fish surveys

Using the count and size estimate data collected during the surveys, the body weight of individual fish was calculated using length-to-weight conversion parameters taken from FishBase. The fish biomass was calculated per unit area (g/m^2) to enable comparison between methods.

Species data was summarized into the following consumer groups: ''primary consumers'' (herbivores and detritivores); ''secondary consumers'' (omnivores and benthic invertivores); ''planktivores''; and ''piscivores,'' with classifications based on diet information taken from FishBase.

The 2014 and 2015 data were excluded due to these surveys conducted during training for the Integrated Monitoring program.

Fish assemblage analyses were carried out using PRIMER7 and PERMANOVA+. Data was transformed into a zero-adjusted Bray-Curtis similarity matric (Clarke *et al.* 2006) and examined using Principal Coordinates Analysis (PCO) plots.

5. Results

5.1 Benthic cover

In previous reports, coral cover was reported on an island scale (i.e. mean coral cover/year). And although the graph implies a trend of increasing coral cover (Fig. 5.1.1), no significant difference in mean coral cover was found over time (One-way RM ANOVA: df = 11, F=1.978, p=0.066) between 2005-2013 (2014 and 2015 were excluded from the analysis, see section 3 for details). There was a number of missing data (see the n values in Fig. 5.1.1), especially in the later years which is when coral cover appears to be increasing. The average value for 2014 was particularly affected because the 3 sites that were surveyed that year had high coral cover. This exemplifies how the number of sites surveyed (depending if high or low coral cover sites happen to be surveyed that year) can skew the average and show a misleading increase or decrease in coral cover. It is therefore recommended that changes in benthic cover are only assessed at the site level if the dataset hasn't sufficient replication to report on an island-scale.

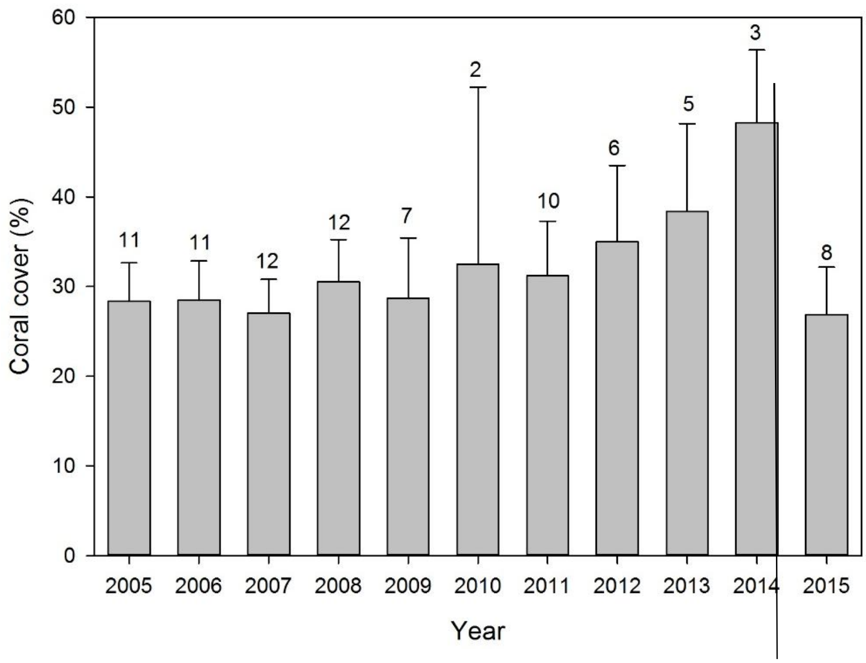


Fig. 5.1.1: Mean percent coral cover ±SE from 2005 to 2015 showing the number of surveys conducted each year (n) above the SE bar. The line indicates when survey methods were changed (2015).

A distinct difference in benthic assemblage can be observed between the north and south side of Tutuila. Generally, north sites have higher turf and macro algae cover whereas south sites have higher CCA cover.

Anthropogenic impact also seems to have some influence on benthic assemblages (Fig. 5.1.3) although some high and medium impact sites are grouping with pristine sites (i. e. Leone and Aasu, respectively).

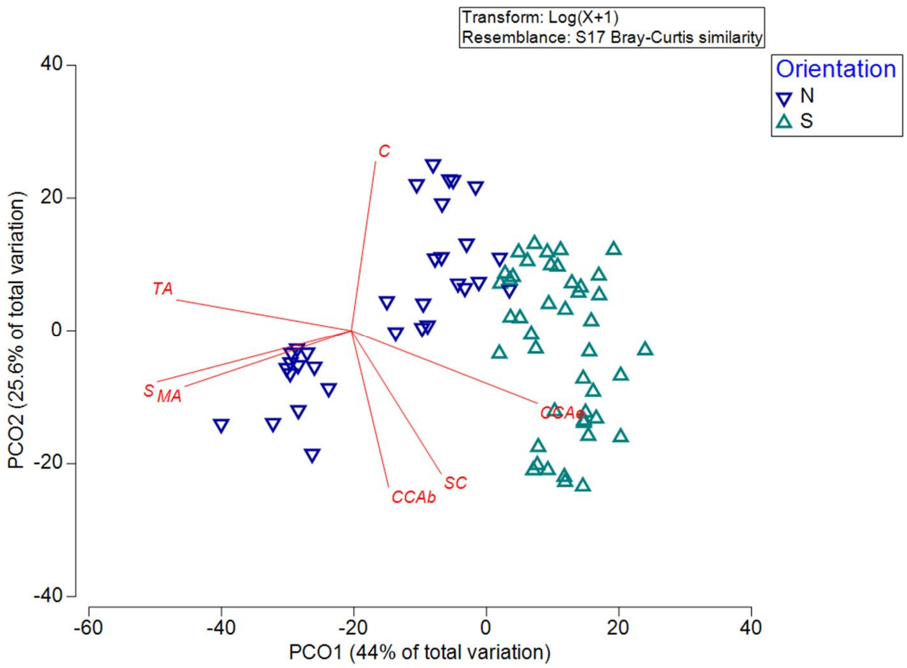


Fig 5.1.2: PCO plot of average benthic cover of the 12 CRMP monitoring sites for all years. Sites are colored by orientation (blue = North side of Tutuila, green = South side of Tutuila). Overlaid in red are the strongest drivers of this relationship (C = Coral, CCA-e = Crustose coralline algae encrusting, SC = Soft coral, CCA-b = Crustose coralline algae branching, MA = Macro algae, S = Sand, TA = Turf algae).

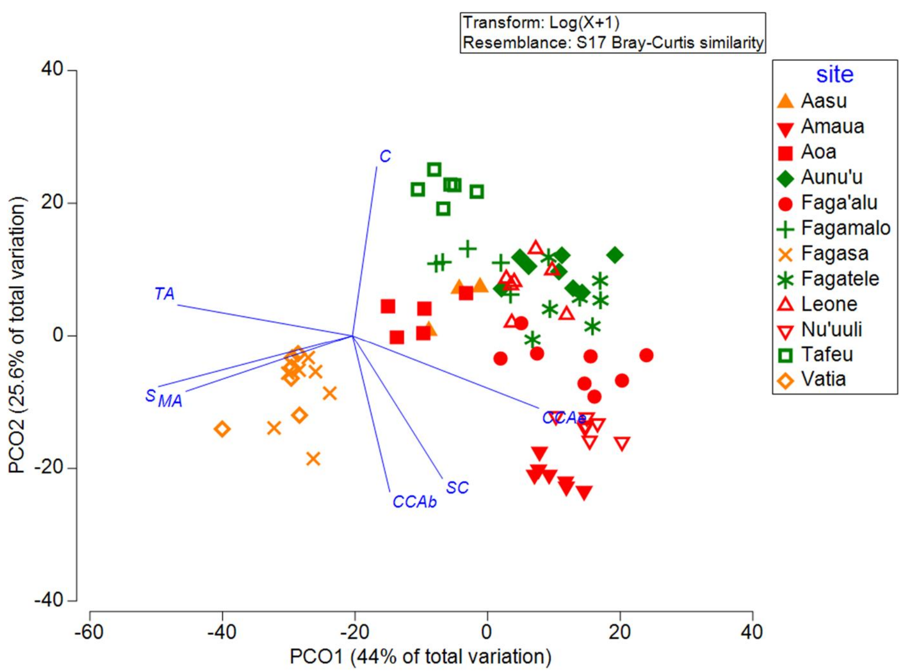


Fig 5.1.3: PCO plot of average benthic cover of the 12 CRMP monitoring sites for all years. Sites are colored by anthropogenic impact (red = high, orange = medium, green = low). Overlaid in blue are the strongest drivers of this relationship (C = Coral, CCA-e = Crustose coralline algae encrusting, SC = Soft coral, CCA-b = Crustose coralline algae branching, MA = Macro algae, S = Sand, TA = Turf algae).

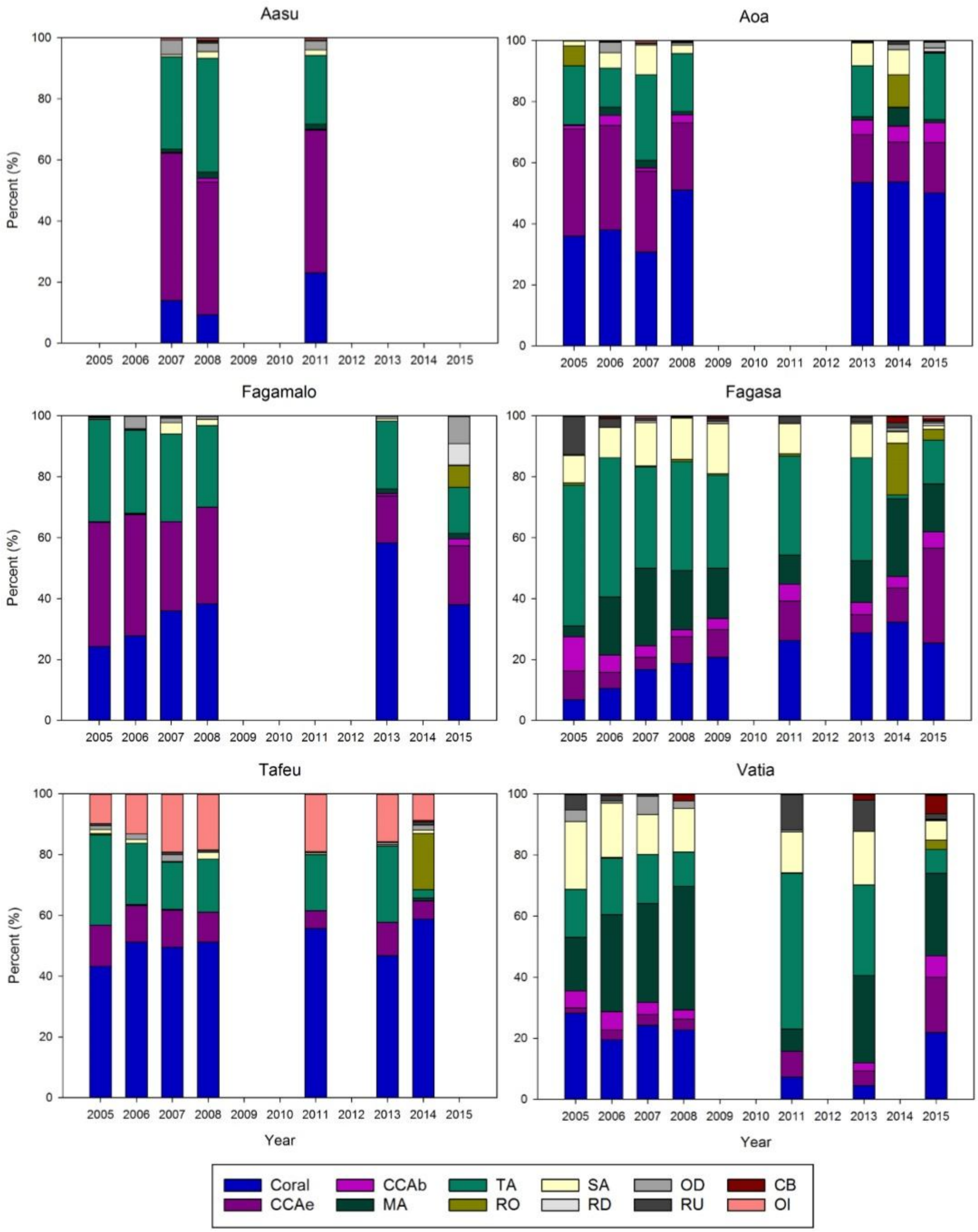


Fig. 5.1.4: Benthic cover (%) from 2005 to 2015 at the 6 north side monitoring sites. Missing data indicated that no surveys were carried out that year. (CCAe = Crustose coralline algae encrusting, CCAb = Crustose coralline algae branching, MA = Macro algae, TA = Turf, RO = Rock, SA = Sand, RD = Recently dead coral, OD = Old dead coral, RU = Rubble, CB = Cyanobacteria, OI = Other invertebrates).

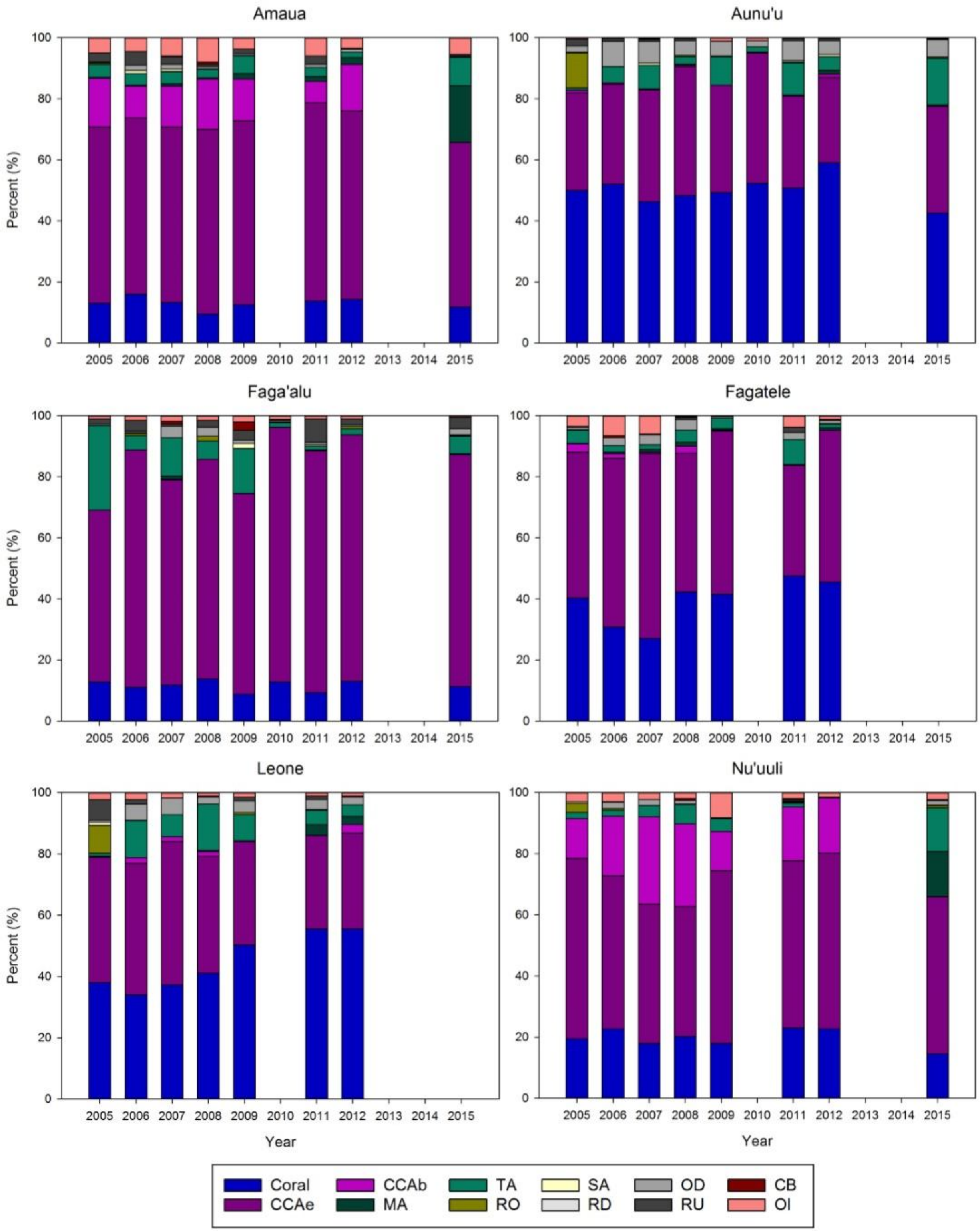


Fig. 5.1.5: Benthic cover (%) from 2005 to 2015 at the 6 south side monitoring sites. Missing data indicated that no surveys were carried out that year. (CCAe = Crustose coralline algae encrusting, CCAb = Crustose coralline algae branching, MA = Macro algae, TA = Turf, RO = Rock, SA = Sand, RD = Recently dead coral, OD = Old dead coral, RU = Rubble, CB = Cyanobacteria, OI = Other invertebrates).

Preliminary demographic results (Fig. 5.1.6) show that south sites seem to be skewed towards smaller colonies with Aunu'u showing a more normal size distribution. Two of the north sites (Vatia and Fagasa) are also skewed towards smaller colony sizes whereas the other two north sites show a normal distribution of size classes.

Aunu'u has a high number of coral recruits.

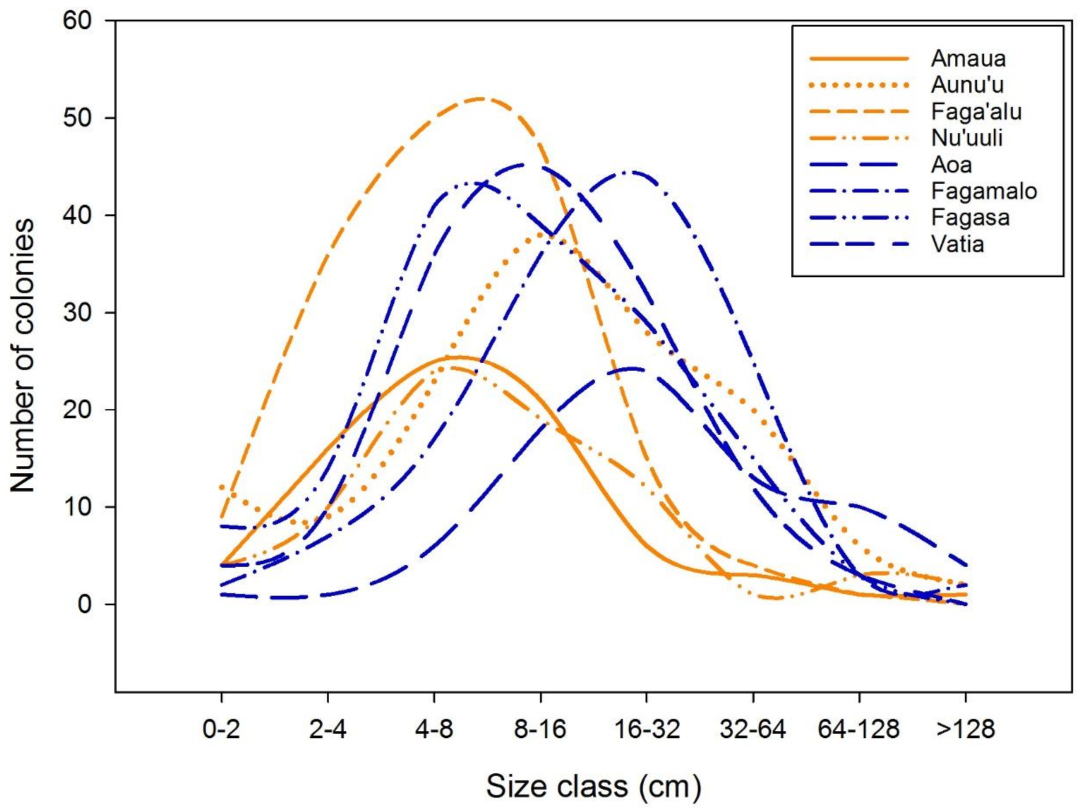


Fig. 5.1.6: Size class frequency distribution of the 8 sites monitored in 2015. Orange = south sites, blue = north sites.

Coral assemblages on Tutuila are dominated by encrusting coral colonies (Fig. 5.1.7). Laminar columnar colonies (which is almost always *Porites rus*), as well as plating colonies are more common on the north side. Branching colonies are relatively common on both the north and the south side.

Overall, coral reefs on Tutuila are dominated by Montipora corals. Three genera (Montipora, Porites and Pavona) are making up >70% of the coral community and seven genera are making up >90% of the coral community (Fig. 5.1.8).

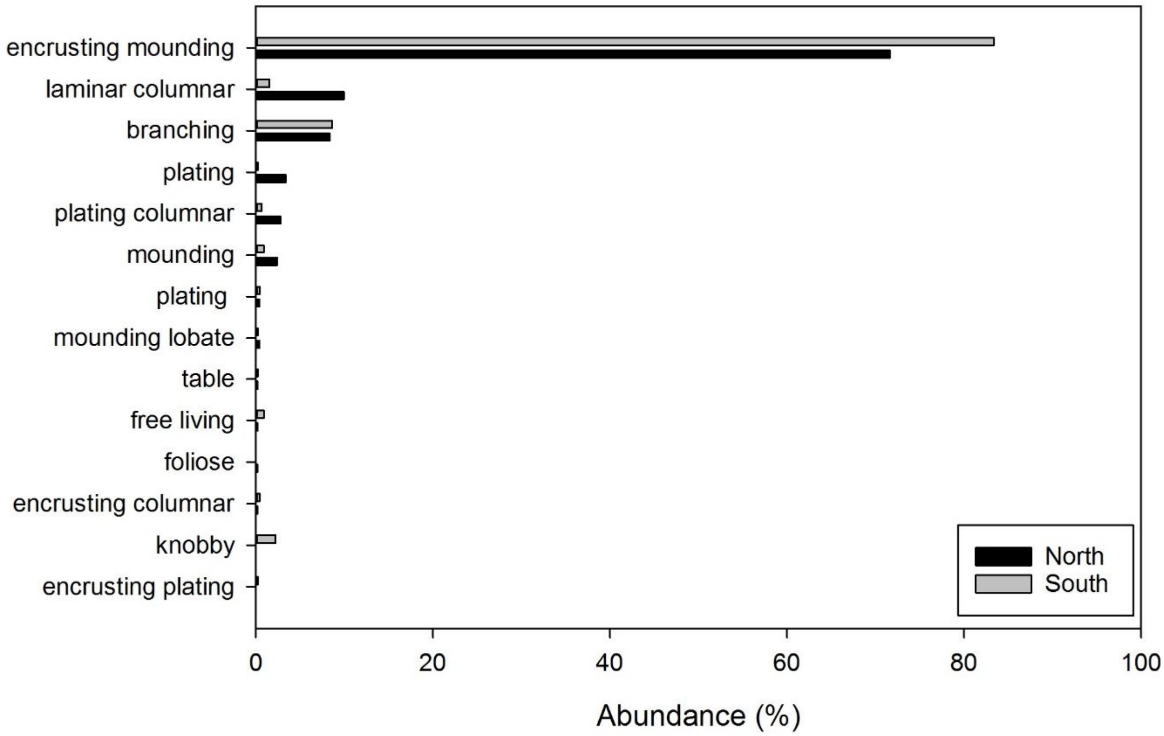


Fig. 5.1.7: Percentage of coral colonies within growth form categories on the north (4 sites) and south side (4 sites) of Tutuila in 2015.

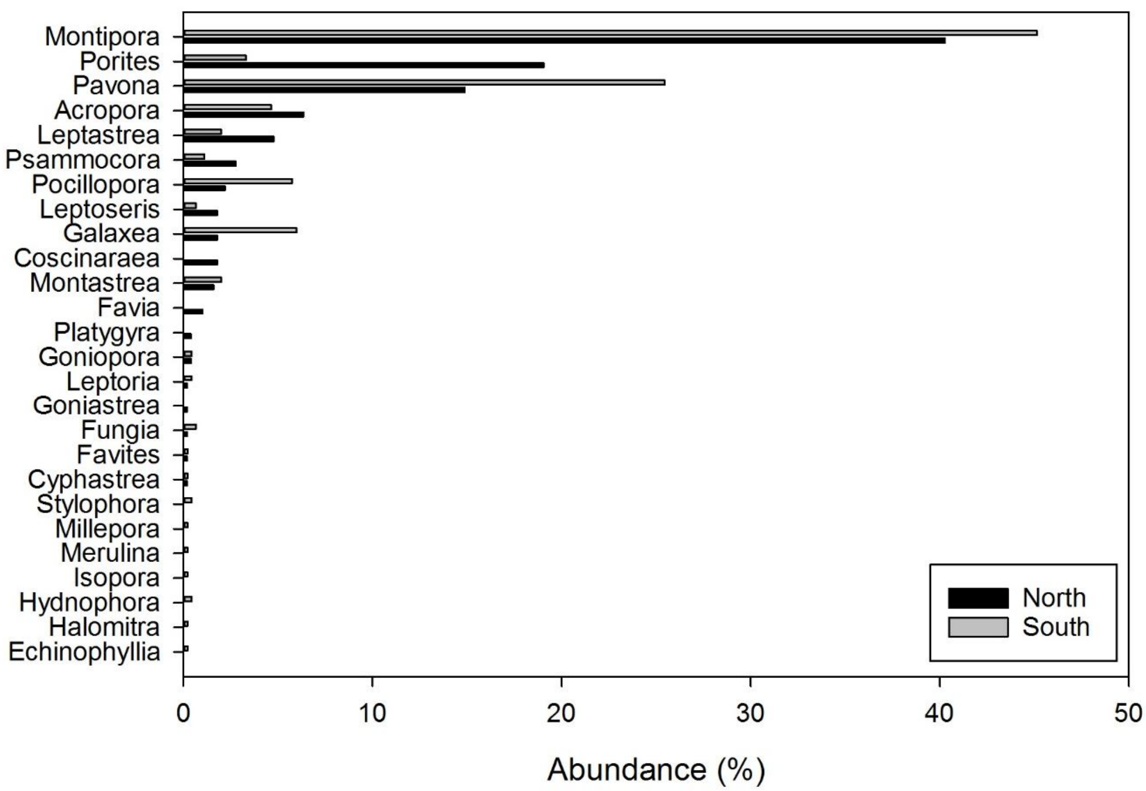


Fig. 5.1.8: Percentage of genus abundance on the north (4 sites) and south side (4 sites) of Tutuila in 2015.

5.2 Fish biomass

The data analysis for this report did not include the 2013 and 2014 data as explained previously due to those data being collected during training dives and by a number of different observers. The 2015 data was analyzed and compared to the previous fish survey data collected by Ben Carrol between 2006 and 2011. Figure 5.2.1 shows the mean total fish biomass across all sites surveyed, with a much lower mean total fish biomass in 2015 than in previous years. The difference may be explained by the change in monitoring protocols and also that only two-thirds of the total number of sites were surveyed. As discussed in the benthic cover section, when the full set of sites are not surveyed the mean total fish biomass is skewed depending on the sites surveyed. Figure 5.2.2 also demonstrates the high variability between survey years at each of the survey sites.

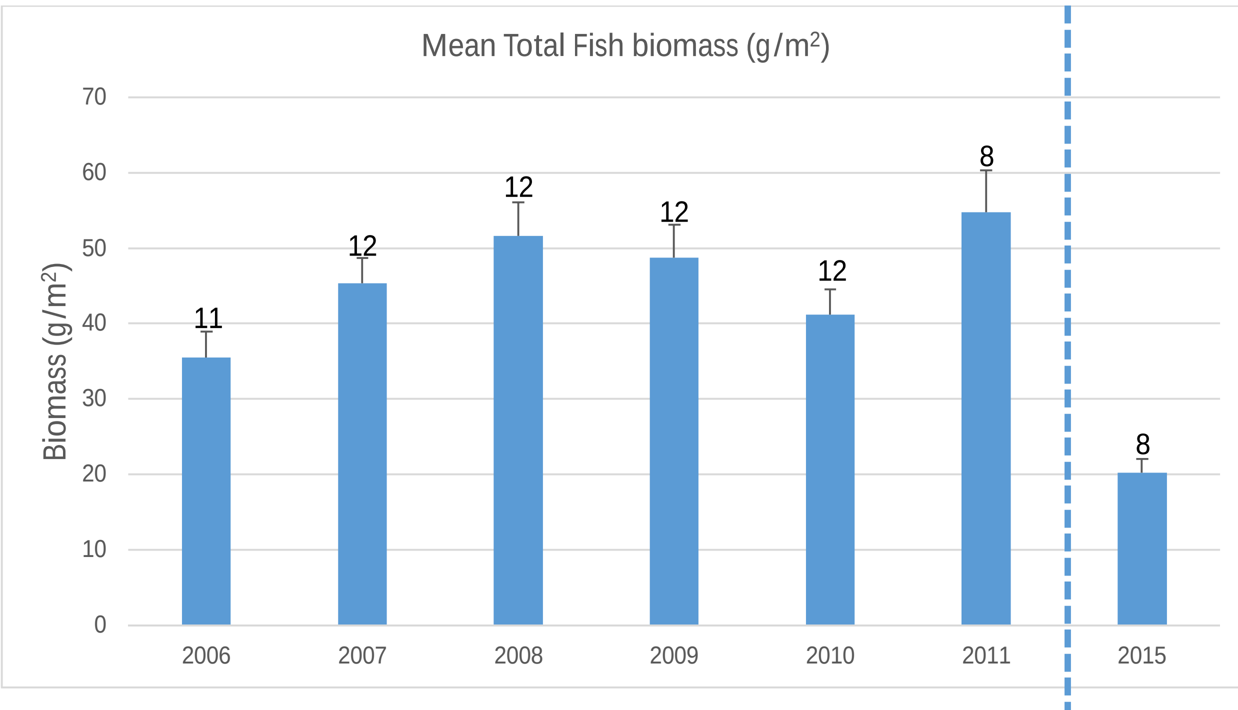


Fig. 5.2.1: Mean total fish biomass (g/m^2) ±SE from 2006 to 2011 and 2015 showing the number of surveys conducted each year (n) above the SE bar. The line indicates when survey methods were changed in 2015.

To account for the change in methods and observer between 2015 and the previous data, the fish trophic group composition was determined per site for each survey year. Each site is presented within their respective sectors; South East, South West, North East and North West, as shown in Figures 5.2.3 through 5.2.6. In comparing the trophic group composition between the newer 2015 data and the previous data there are no clear discrepancies, however less planktivores were recorded in the 2015 surveys which may be due to the different survey protocol.

When investigating potential differences in fish assemblages between the north and south sites (as shown in Figure 5.2.7) there are no clear differences, although the south sites of Aunu'u and Nu'uuli differ from the other sites due to higher composition of planktivores and piscivores. The potential effects of anthropogenic influences was investigated using population density as a proxy (see Figure 5.2.8), and although the lower impact sites (shown in green) clustered loosely there were no obvious distinctions between the sites.

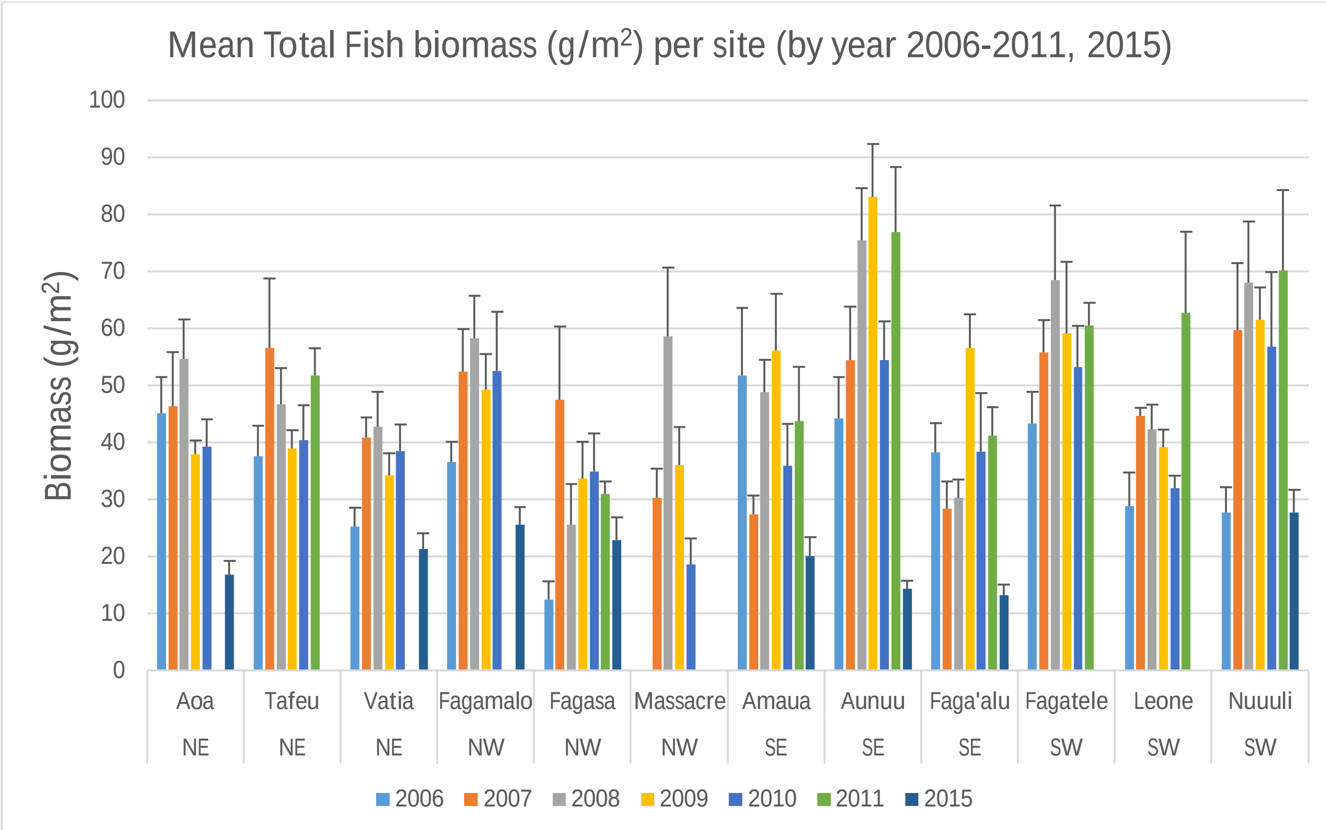


Fig. 5.2.2: Mean total fish biomass (g/m^2) ±SE at each site from 2006 to 2011 and 2015. Geographic sectors are denoted as North East (NE), North West (NW), South East (SE), and South West (SW).

Fish Trophic Group Composition - South East Sector

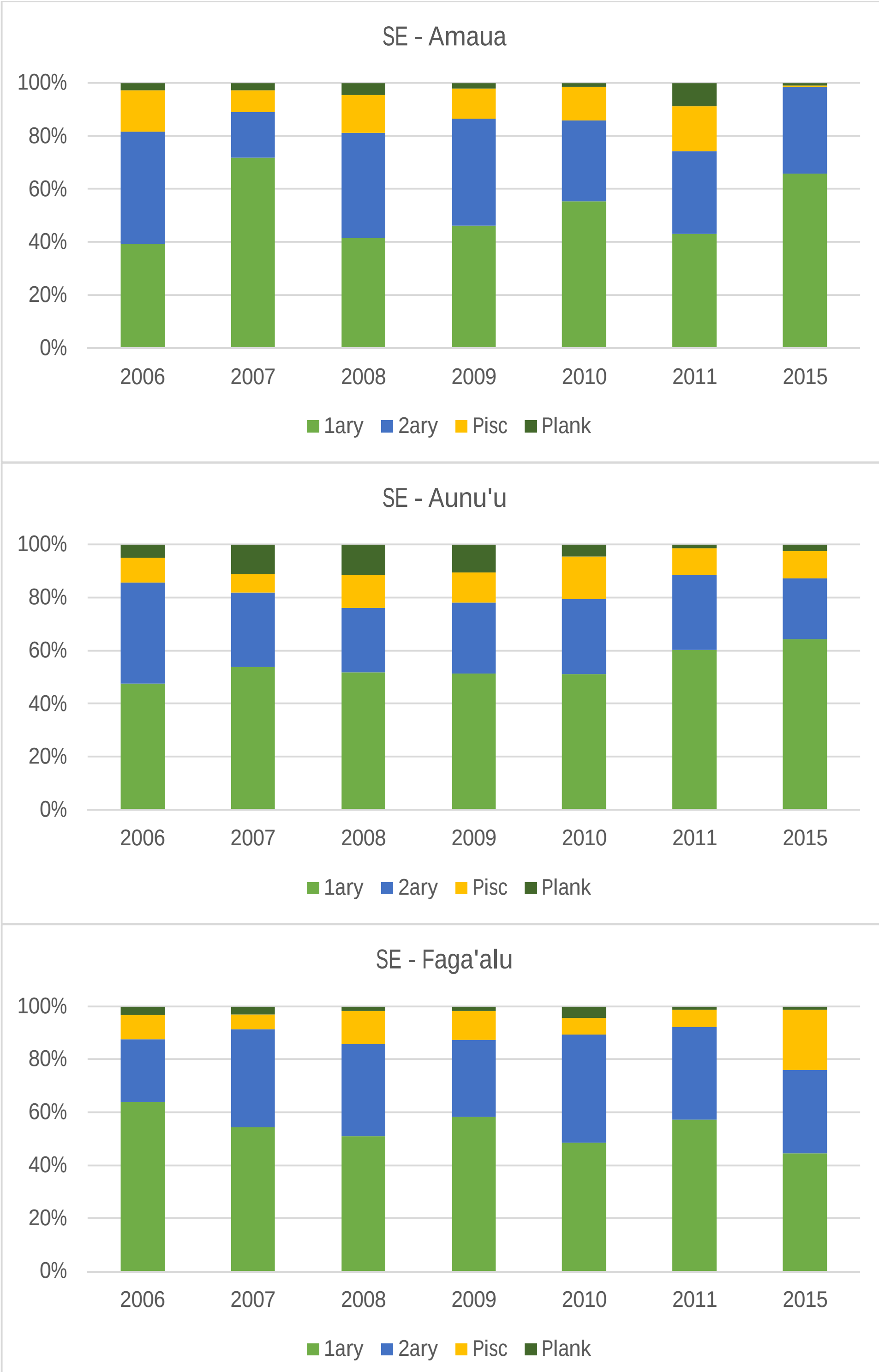


Fig. 5.2.3: Trophic group composition of Mean Total Fish Biomass (%) from 2006 to 2011 and 2015 at the 3 South East sector monitoring sites. Missing data indicated that no surveys were carried out that year. (1ary = Primary Consumers, 2ary = Secondary consumers, Pisc = Piscivores, Plank = Planktivores).

Fish Trophic Group Composition - South West Sector

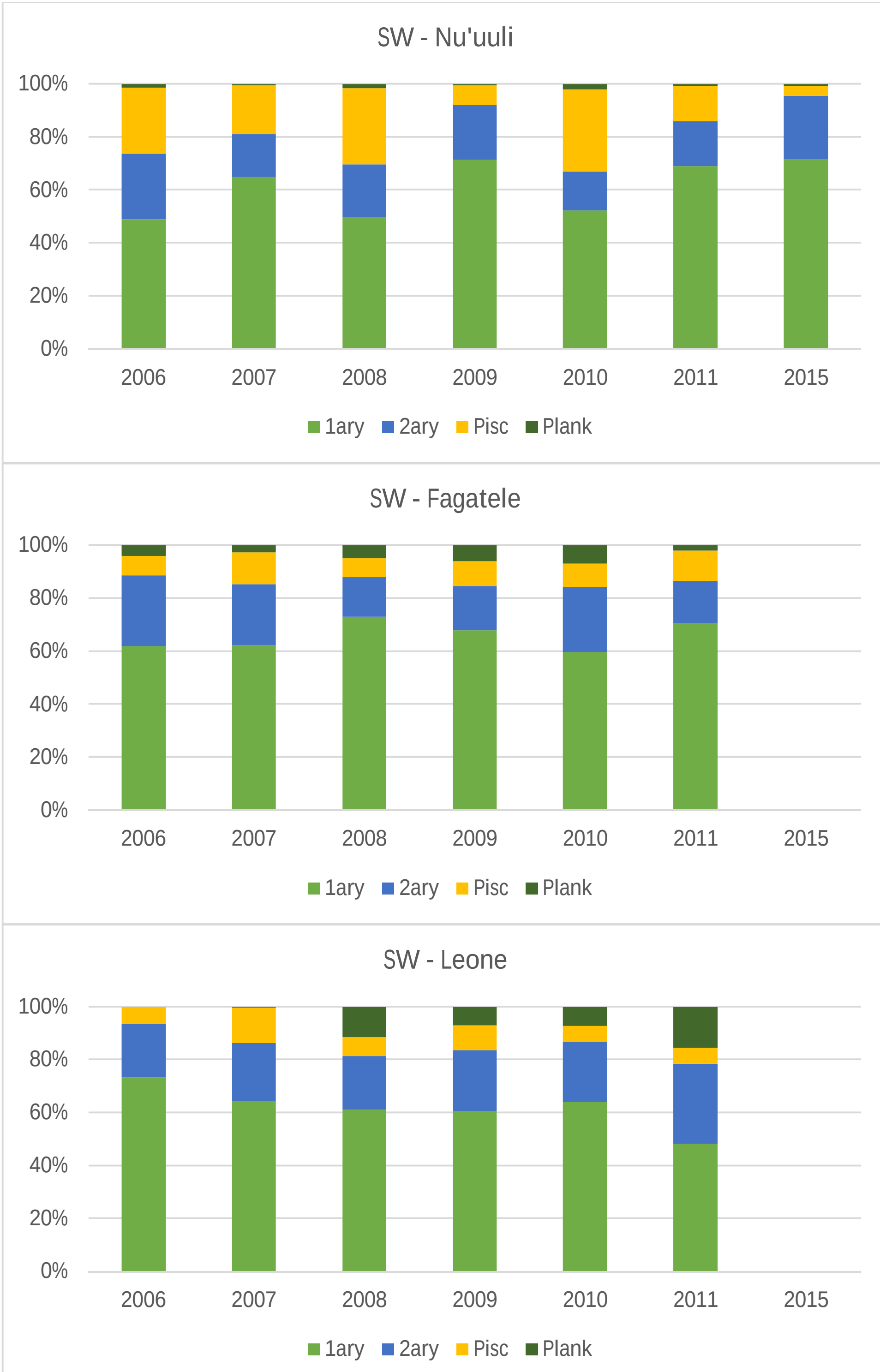


Fig. 5.2.4: Trophic group composition of Mean Total Fish Biomass (%) from 2006 to 2011 and 2015 at the 3 South West sector monitoring sites. Missing data indicated that no surveys were carried out that year. (1ary = Primary Consumers, 2ary = Secondary consumers, Pisc = Piscivores, Plank = Planktivores).

Fish Trophic Group Composition - North East Sector

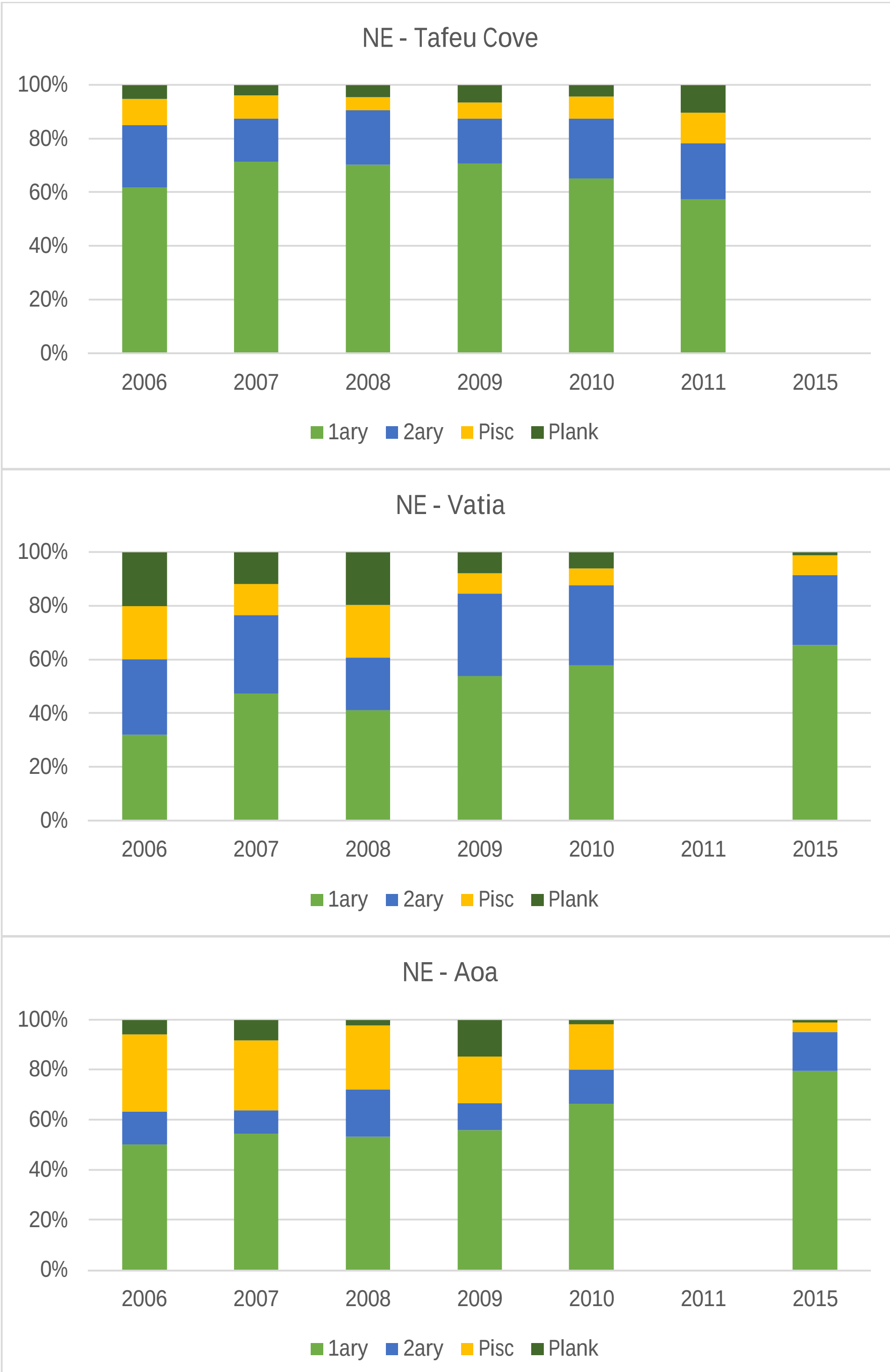


Fig. 5.2.5: Trophic group composition of Mean Total Fish Biomass (%) from 2006 to 2011 and 2015 at the 3 North East sector monitoring sites. Missing data indicated that no surveys were carried out that year. (1ary = Primary Consumers, 2ary = Secondary consumers, Pisc = Piscivores, Plank = Planktivores).

Fish Trophic Group Composition - North West Sector

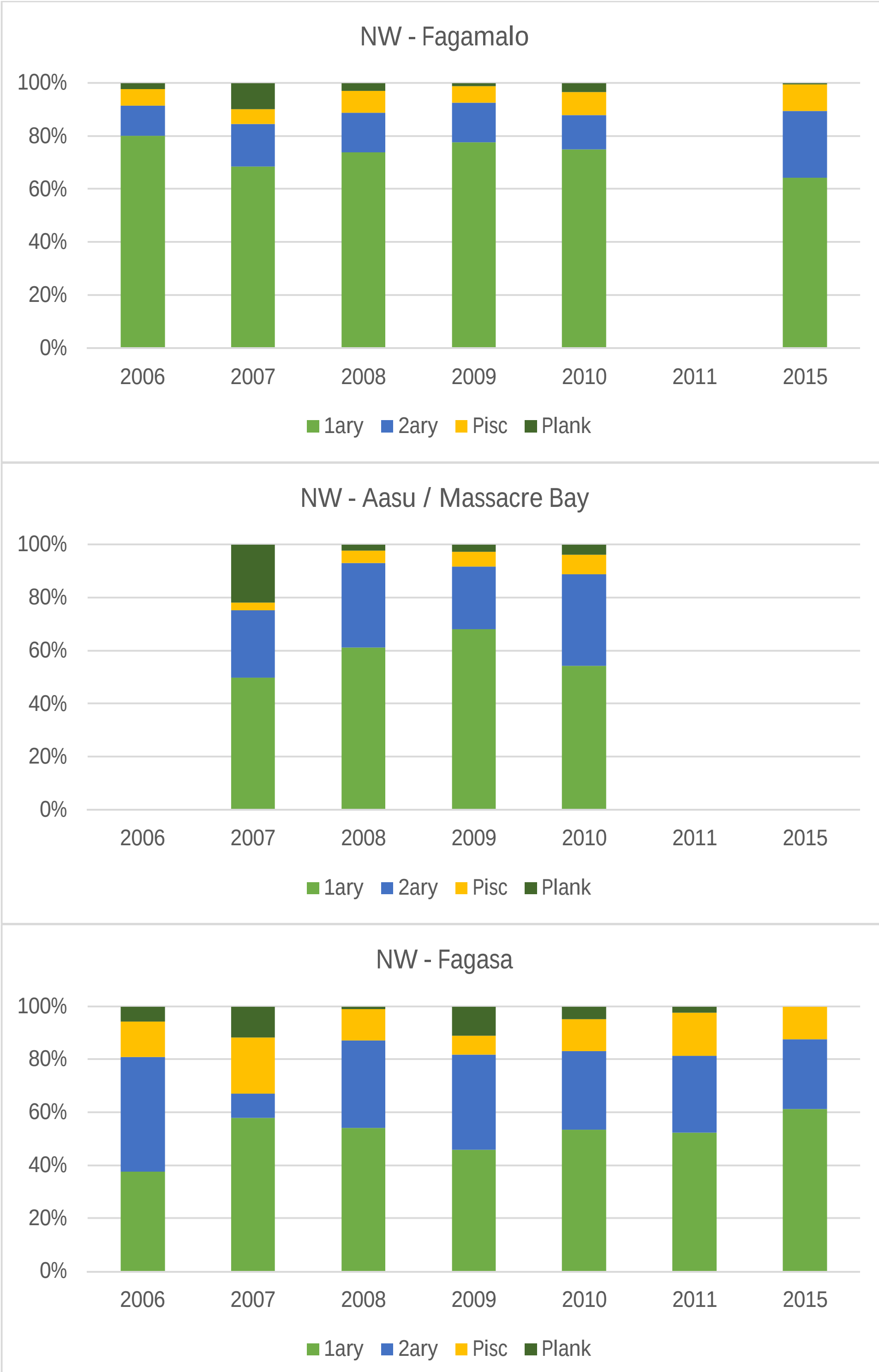


Fig. 5.2.6: Trophic group composition of Mean Total Fish Biomass (%) from 2006 to 2011 and 2015 at the 3 North West sector monitoring sites. Missing data indicated that no surveys were carried out that year. (1ary = Primary Consumers, 2ary = Secondary consumers, Pisc = Piscivores, Plank = Planktivores).

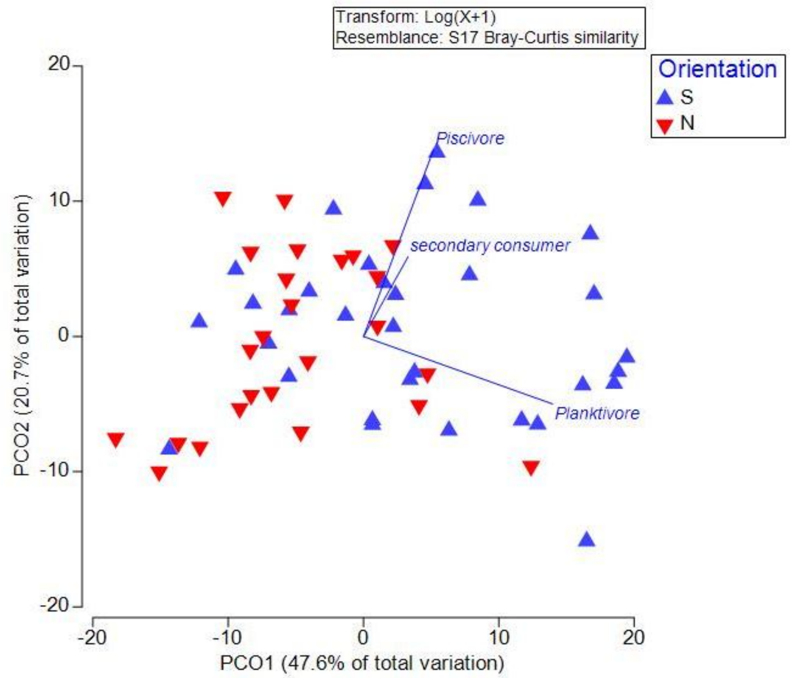


Fig 5.2.7: PCO plot of mean total fish biomass (g/m^2) of the 12 CRMP monitoring sites from 2006 to 2011. Sites are colored by orientation (blue = South side of Tutuila, red = North side of Tutuila). Overlaid in blue are the strongest drivers of this relationship (Piscivores, Secondary consumers and Planktivores).

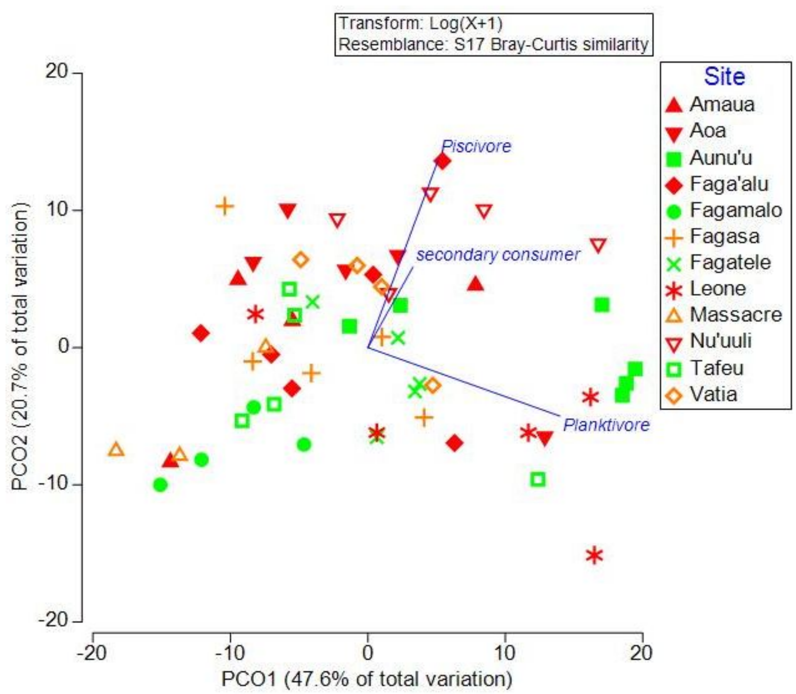


Fig 5.2.8: PCO plot of mean total fish biomass (g/m^2) of the 12 CRMP monitoring sites from 2006 to 2011. Sites are colored by anthropogenic impact (red = high, orange = medium, green = low). Overlaid in blue are the strongest drivers of this relationship (Piscivores, Secondary consumers and Planktivores).

5.3 Bleaching

In mid-January 2015, sea surface temperatures in American Samoa rapidly rose by 2 °ºC reaching temperatures around 30 ºC for several months (Fig. 5.3.1 and 5.3.2). Only in mid-May temperatures finally dropped below 29.5 ºC. These temperatures were recorded by the PACCIOS temperature buoy permanently deployed off Aunu'u. Temperatures on the reef slopes and especially inside the backreef pools reached even higher temperatures then what was recorded by the ocean buoy. This severe temperature stress caused coral bleaching starting in the backreef pools and reef flats and eventually reef slopes.

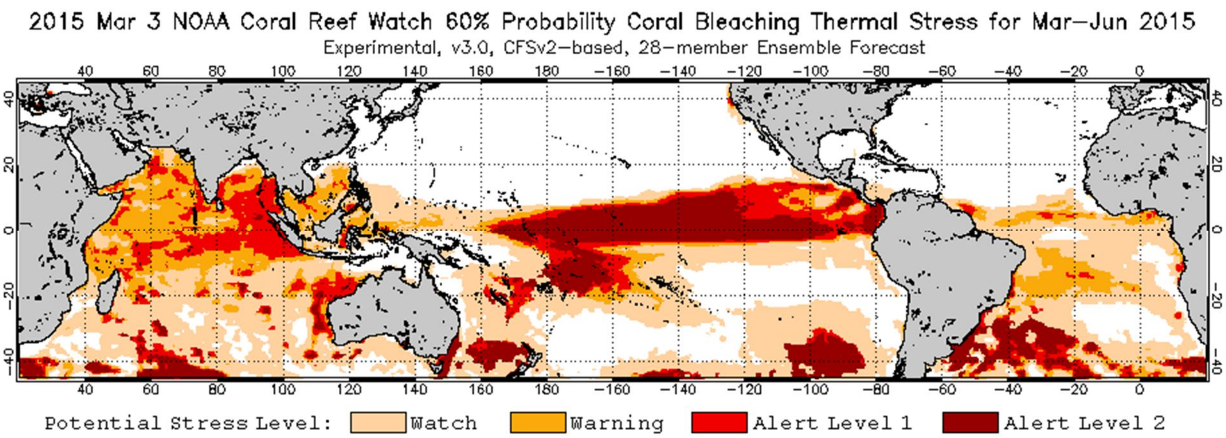


Fig. 5.3.1: Thermal Stress in March 2015, note red color in the area where American Samoa is located.

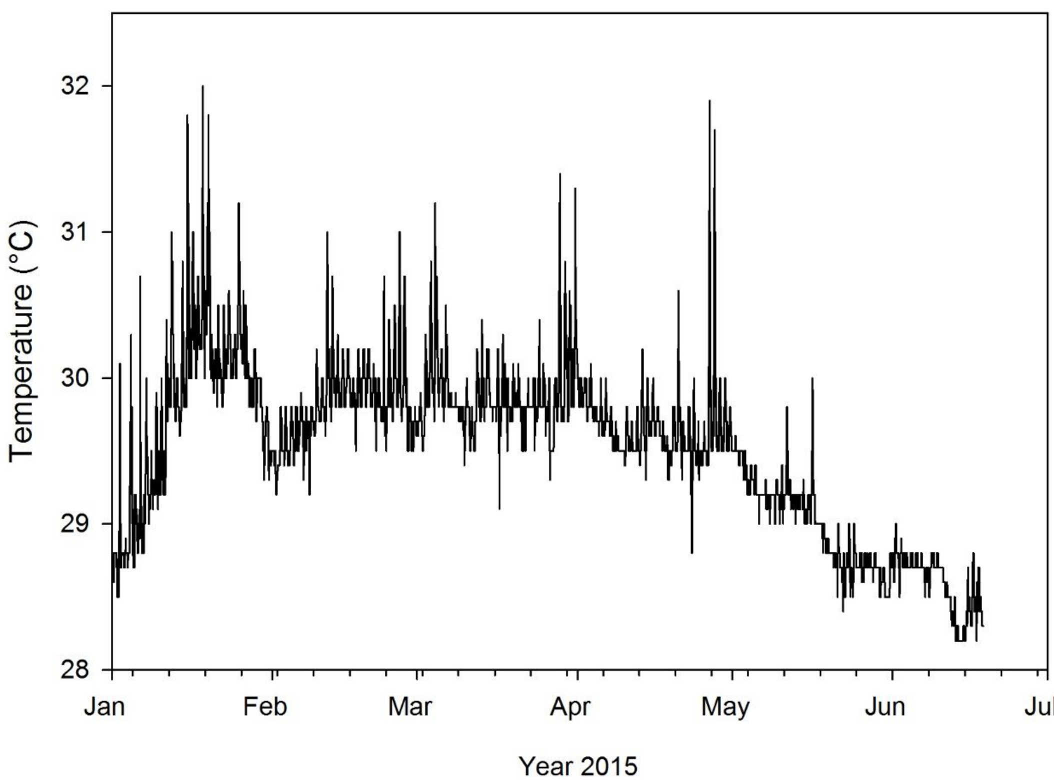


Fig. 5.3.2: PACIooS temperature data derived from the buoy located off Aunu'u. Note sea surface temperature increase from January to May.

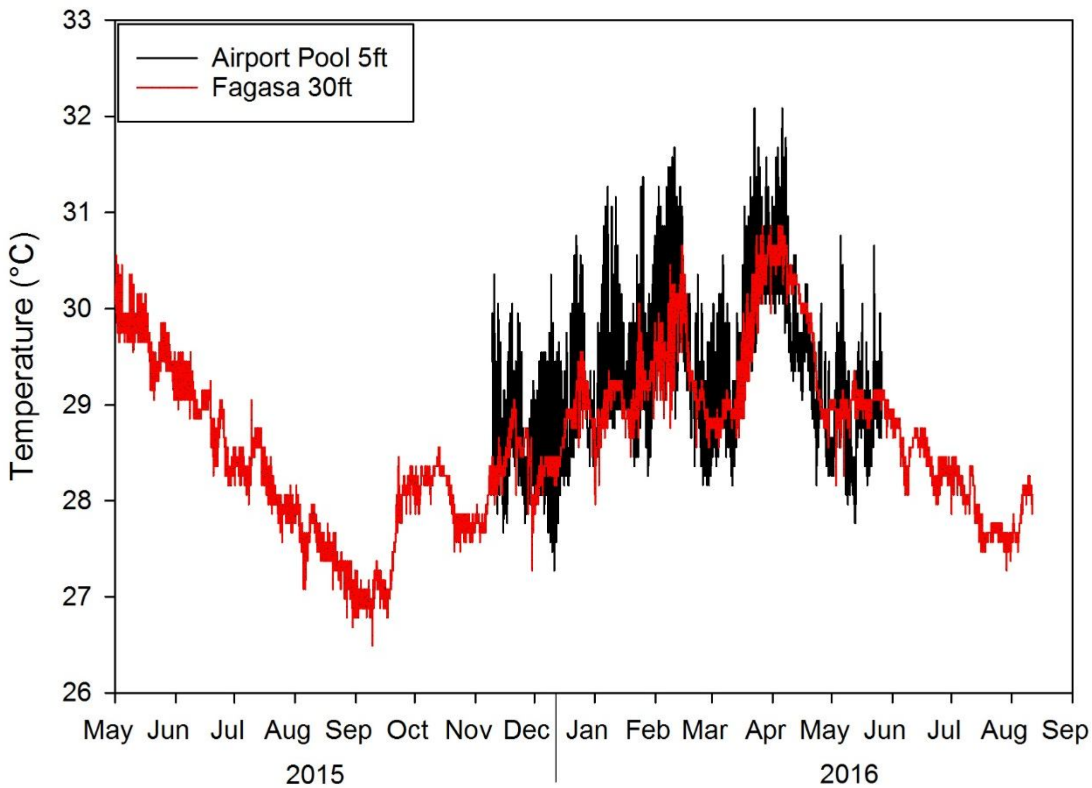


Fig. 5.3.3: Temperature data from 2 Hobo Loggers showing thermal pattern from May 2015 to September 2016.

Slope: Temperature variation between 26.5 and 31 degrees C

Pool: Temperature variation between 27.5 and 32 degrees C; higher fluctuations of >2 degrees C; at times > 1 degree C higher than on slopes

Reef flats, reef crest and shallow reef area (around 5ft)

No surveys were carried out in these areas before and during the bleaching episode in 2015 but anecdotal information of opportunistic observations by CRAG staff and Doug Fenner (the formal benthic ecologist for DMWR) suggest that a relatively high percentage of table Acropora in certain shallow reef areas were lost during the bleaching event (Fig. 5.3.4).


Fig. 5.3.4: Shallow reef (5ft) at Fagamalo. Note most table Acropora have recently died.

Reef slope (30 ft)

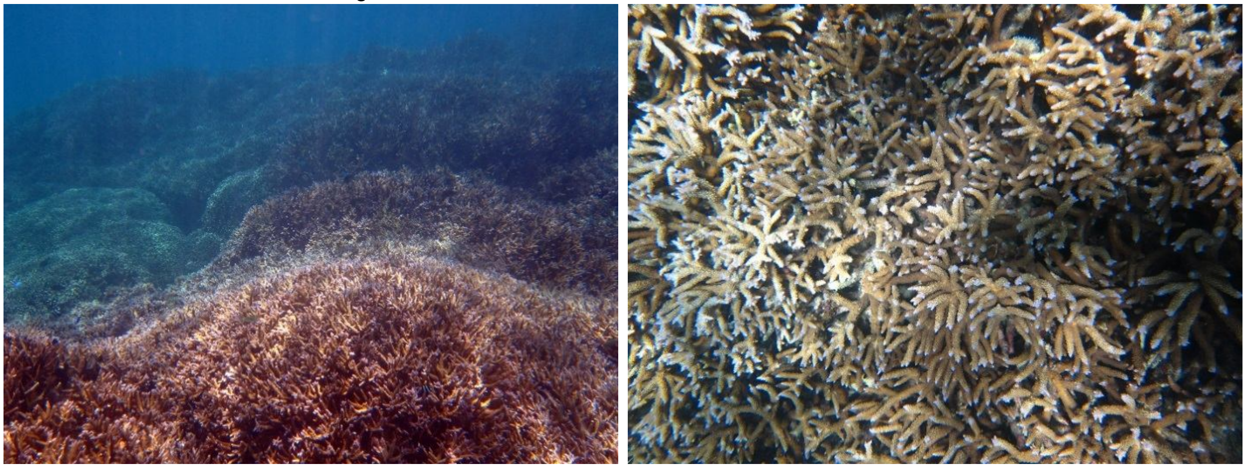
No quantitative surveys were carried out during the bleaching episode in 2015 but photos were taken of bleached coral and general, subjective observations of bleaching prevalence were made. It was estimated that around 1-10% of corals were bleached with differences in bleaching prevalence and severity depending on site. It appears that branching and table Acropora were affected the most. Other sensitive species are *Montastrea curta* and *Isopora crateriformis*.


Fig. 5.3.5: Bleached table and branching Acropora on the reef slope. Photo credit NOAA (RAMP cruise 2015)

Backreef pools

The airport pool (Fig. 5.3.6) is dominated by extensive staghorn (Acropora) beds and a branching Porites species (*Porites cylindrica*). The staghorns in the pools showed very high bleaching (up to 100%) whereas *P. cylindrical* did not bleach or only very lightly towards the end of the bleaching episode. Over the span of 3-4 months the staghorns in the pool showed very high mortality; an estimated 80% of the staghorns in the pools died.

December 2014: No bleaching



February 2015: mass bleaching of staghorns in the pool

April 2015: mass bleaching and mortality of staghorns in the pool

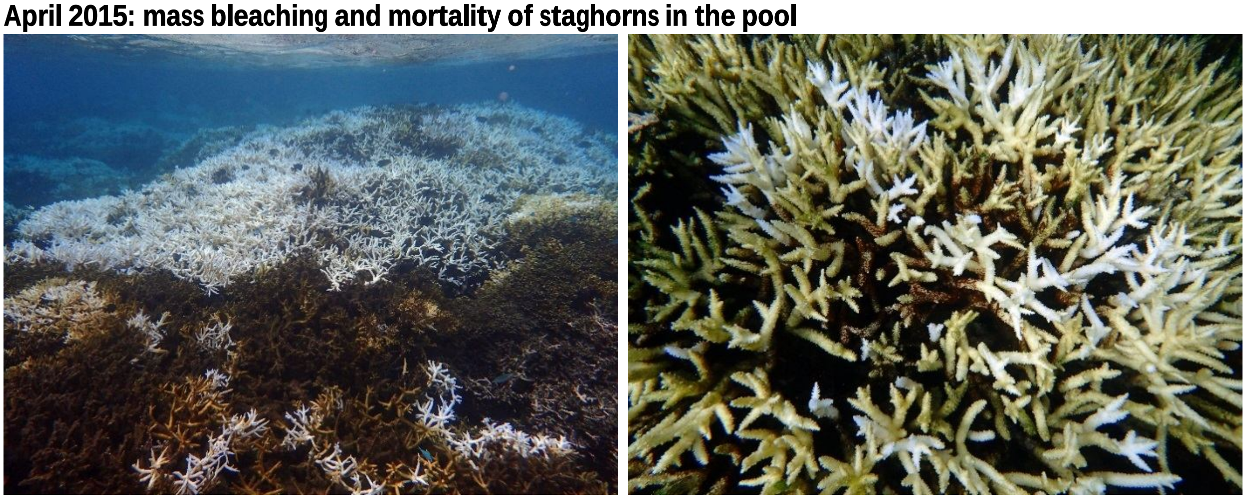


Fig. 5.3.6: Bleached corals in the Airport Pool

6. Discussion

In previous reports, coral cover was reported on an island scale (i.e. mean coral cover/year). However, between 2005 and 2015, not all sites were surveyed every year. It is therefore likely that the apparent trend of increasing coral cover in 2012 and 2013, and similarly the trend in decreased fish biomass between 2011 and 2015 is an artefact of less sites surveyed, 12 sites are not sufficient to draw conclusions at the island-scale. It is therefore recommended that changes in fish biomass and benthic cover are analyzed and interpreted at the site level rather than an island-scale.

Generally, reefs on Tutuila are dominated by encrusting Montipora spp. and overall, sizes of corals on the north side appear to be larger than the south side. A distinct difference can be observed between the benthic composition of the north and south side of Tutuila. It is therefore recommended to subset the data into north and south sites for statistical analysis. There also appears to be a pattern along an anthropogenic impact scale (EPA watershed classification based on population density). However, one high impact site (Leone) is grouping with the low impact sites. This site has, despite the high population density in its watershed, a very healthy coral reef with high coral cover and high diversity. As only 8 sites were monitored there is not enough statistical power to subset the data set as recommended above. However, in 2016 an extension of the monitoring program is planned in coordination with the Ridge to Reef program funded by the USEPA Wetland Program Development Grant. In light of the need for more robust monitoring datasets the monitoring program staff have been working towards increasing the number of survey sites across anthropogenic and biophysical gradients to understand contribution of individual local stressors to reef health. The program staff have been integral in the development of the USEPA-funded Ridge-to-Reef project which incorporates the existing 12 sites into a total of 30 sites. In conjunction with water quality sampling of associated watersheds it will be possible to conduct analyses to investigate the influence of anthropogenic activities, and using GIS-based data to incorporate the effects of biological and physical factors such as benthic habitat, oceanographic conditions and geology. The information will serve as a basis for watershed and coral reef based evaluations to inform local resource management decisions and implementation of effective community-based interventions.

7. Other Project Activities

Manu'a Monitoring Surveys - Baseline coral reef monitoring surveys of reef flat sites in Ofu and Olosega were conducted between 14 – 18 February 2015. Surveys were conducted at 12 sites around the islands of Ofu and Olosega as shown by the red lines in figures 7.1 and 7.2. GPS coordinates for each of the sites are listed in Appendix 4. The aim of these surveys was to conduct baseline surveys from which to detect temporal change if it should occur. Benthic surveys were conducted using line-point intercept survey methods to document benthic cover and coral growth forms (results shown in Figure 7.5, Figure 7.6, Figure 7.7, and Table 7.2 and Table 7.3). Line-point intercept was conducted on four 25 meter transects at a 50 centimeter interval (50 data points per transect). Opportunistic swims were carried out at the end of each survey (about 15 mins) to photograph bleaching and diseases. At each site fish surveys were conducted using the underwater visual census (UVC) method along four 20 meter transects. All non-cryptic fish species observed within a 5 meter wide belt along the transect were recorded to species level and fish sizes (total length) were estimated to the nearest cm. Fish survey results are shown in Figure 7.3 and Figure 7.4 and data results are listed in Table 7.1.

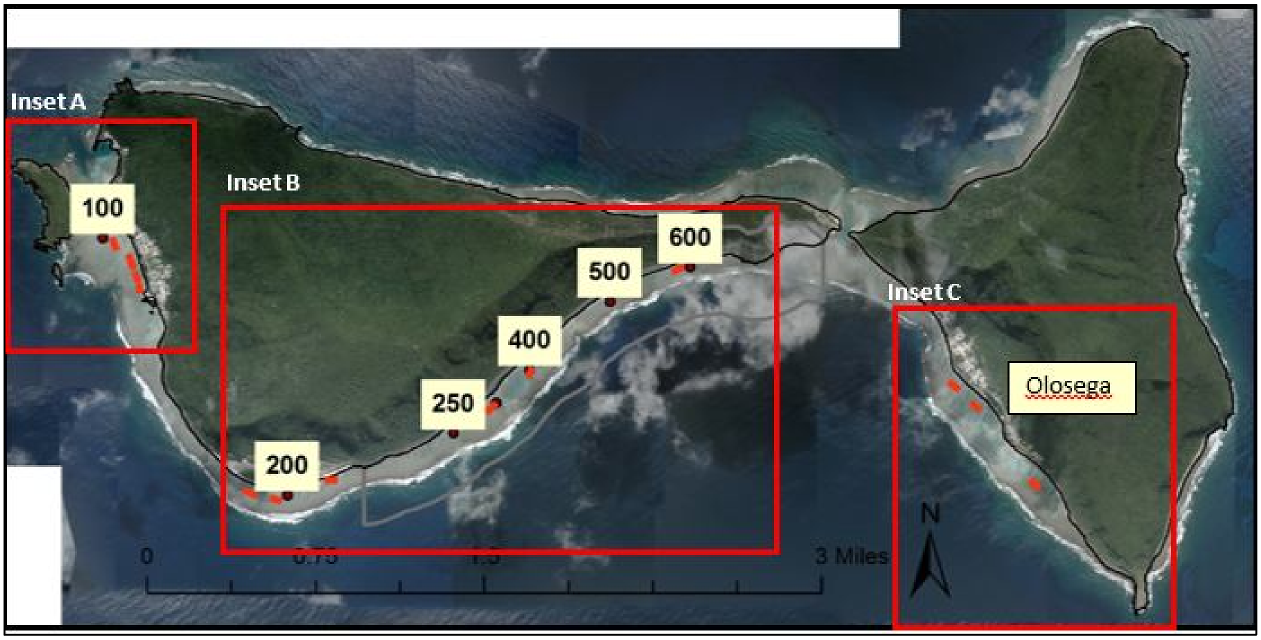


Figure 7.1: Map of survey sites around the islands of Ofu and Olosega, with Pool Numbers inside the yellow boxes.

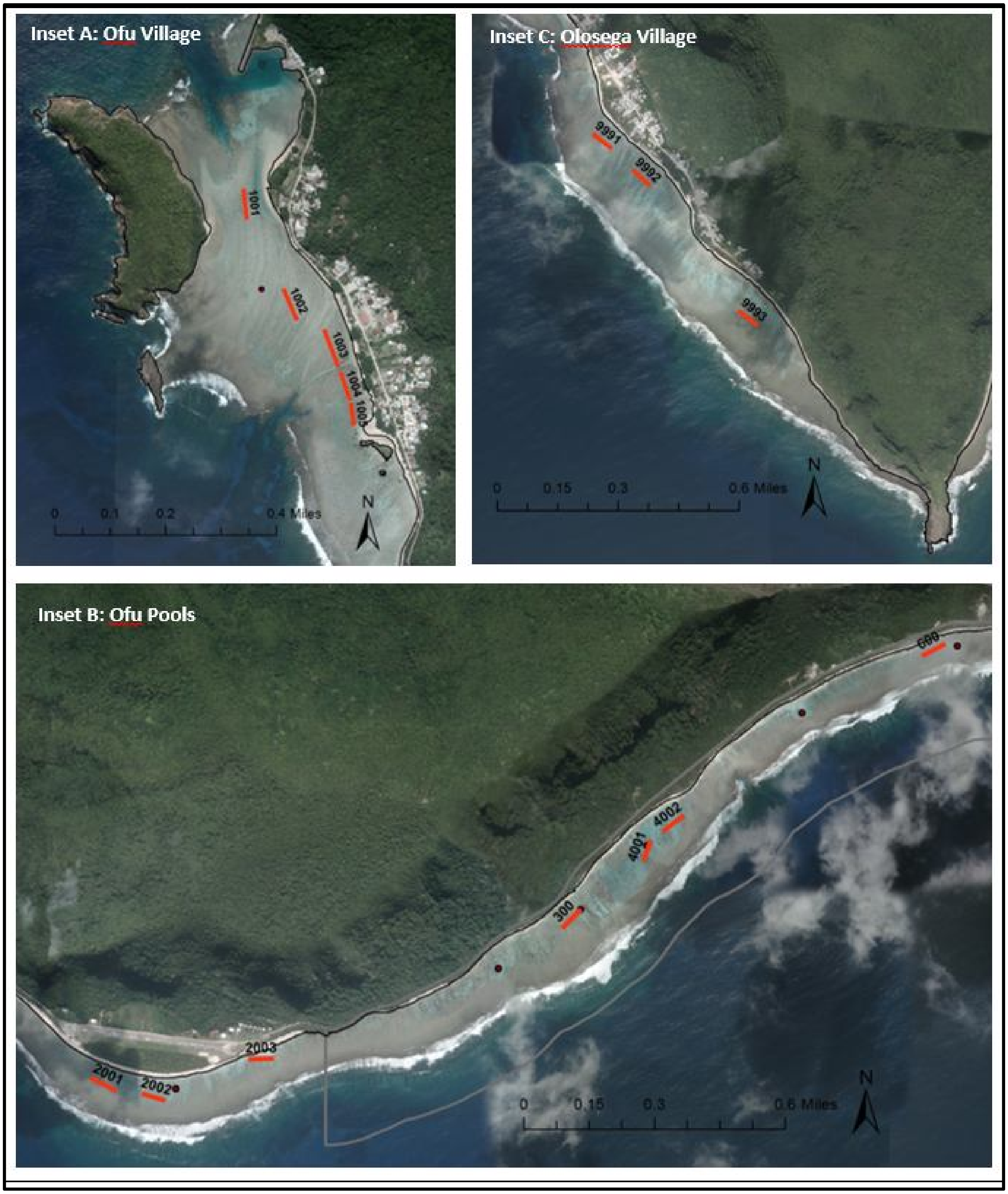


Figure 7.2: Inset maps from Figure 7.1 showing survey transect locations. Each transect is represented by a red line. The first three digits of the transect label represents the Pool number, and the last digit represents the transect number. Pool number 999 represents the Olosega Village site.

Reef Fish Survey Results

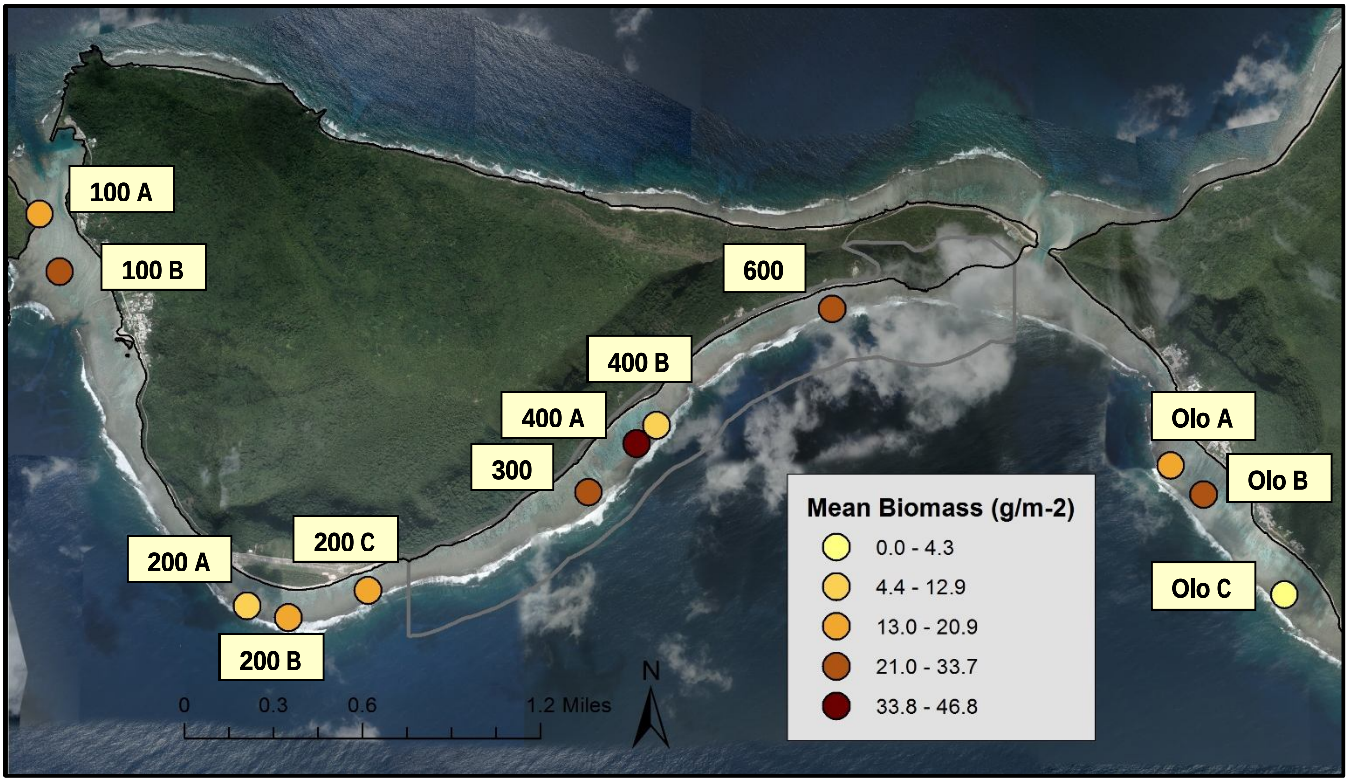


Figure 7.3: Mean fish biomass (g/m^2) recorded along each transect in Ofu and Olosega Islands.

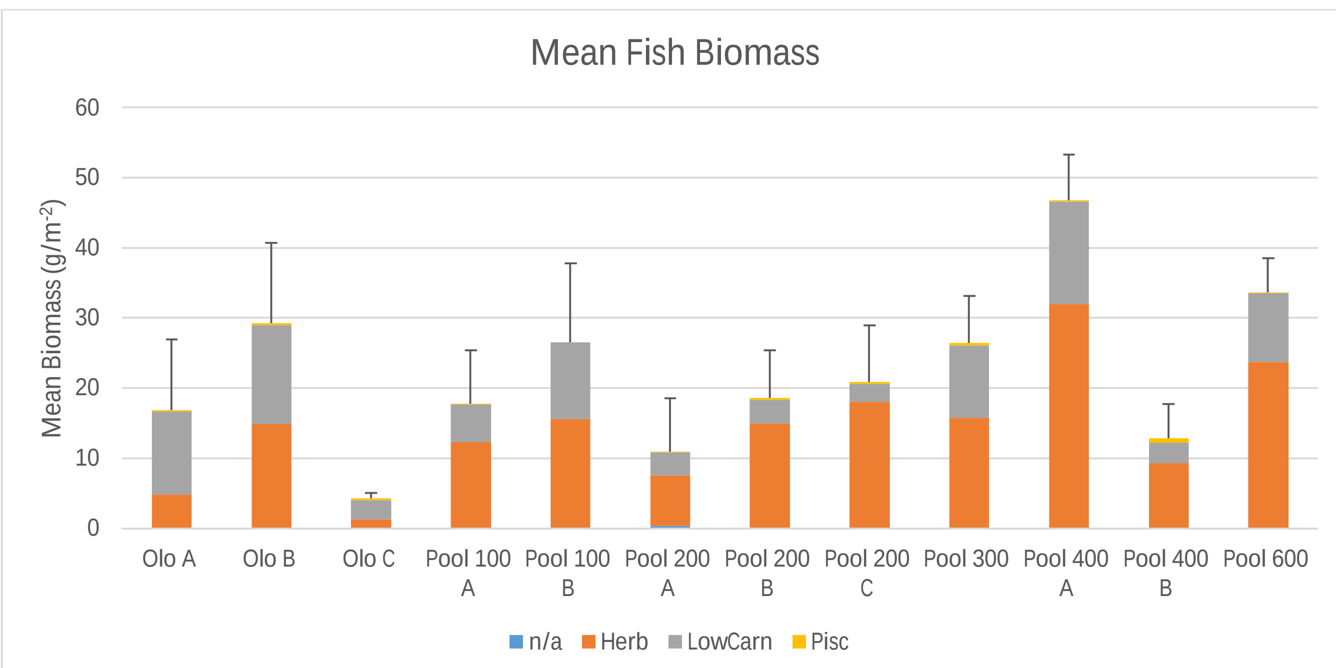


Figure 7.4: Mean fish biomass (g/m-2) at the 12 survey sites by fish functional group (Herbivores, Lower Carnivores, and Piscivores).

Table 7.1: Mean fish biomass (g/m-2) and SE at the 12 survey sites by fish functional group (Herbivores, Lower Carnivores, and Piscivores).

	Herbivores	Lower Carnivores	Piscivores	TOTAL Mean Biomass
Olo A	4.9 ± 2.2	11.8 ± 8.5	0.2 ± 0.1	16.9 ± 10
Olo B	14.9 ± 4.4	14.2 ± 8.2	0.3 ± 0.3	29.3 ± 11.4
Olo C	1.3 ± 0.3	2.8 ± 0.5	0.2 ± 0.1	4.3 ± 0.7
Pool 100 A	12.4 ± 5.7	5.3 ± 1.8	0.1 ± <0.1	17.8 ± 7.6
Pool 100 B	15.7 ± 6.7	10.9 ± 8.2	0	26.5 ± 11.2
Pool 200 A	7.2 ± 6.3	3.3 ± 1.4	0.1 ± 0.1	11.0 ± 7.5
Pool 200 B	14.9 ± 6.3	3.4 ± 1.2	0.2 ± 0.2	18.6 ± 6.8
Pool 200 C	18.1 ± 8.6	2.6 ± 1.1	0.2 ± 0.2	20.9 ± 8
Pool 300	15.8 ± 5.2	10.2 ± 3.4	0.4 ± 0.2	26.5 ± 6.7
Pool 400 A	32.1 ± 6.7	14.5 ± 10	0.2 ± 0.2	46.8 ± 6.4
Pool 400 B	9.3 ± 4.5	2.9 ± 0.4	0.7 ± 0.7	12.9 ± 4.9
Pool 600	23.8 ± 6.5	9.8 ± 6.6	0.1 ± 0.1	33.7 ± 4.9

Benthic Survey Results

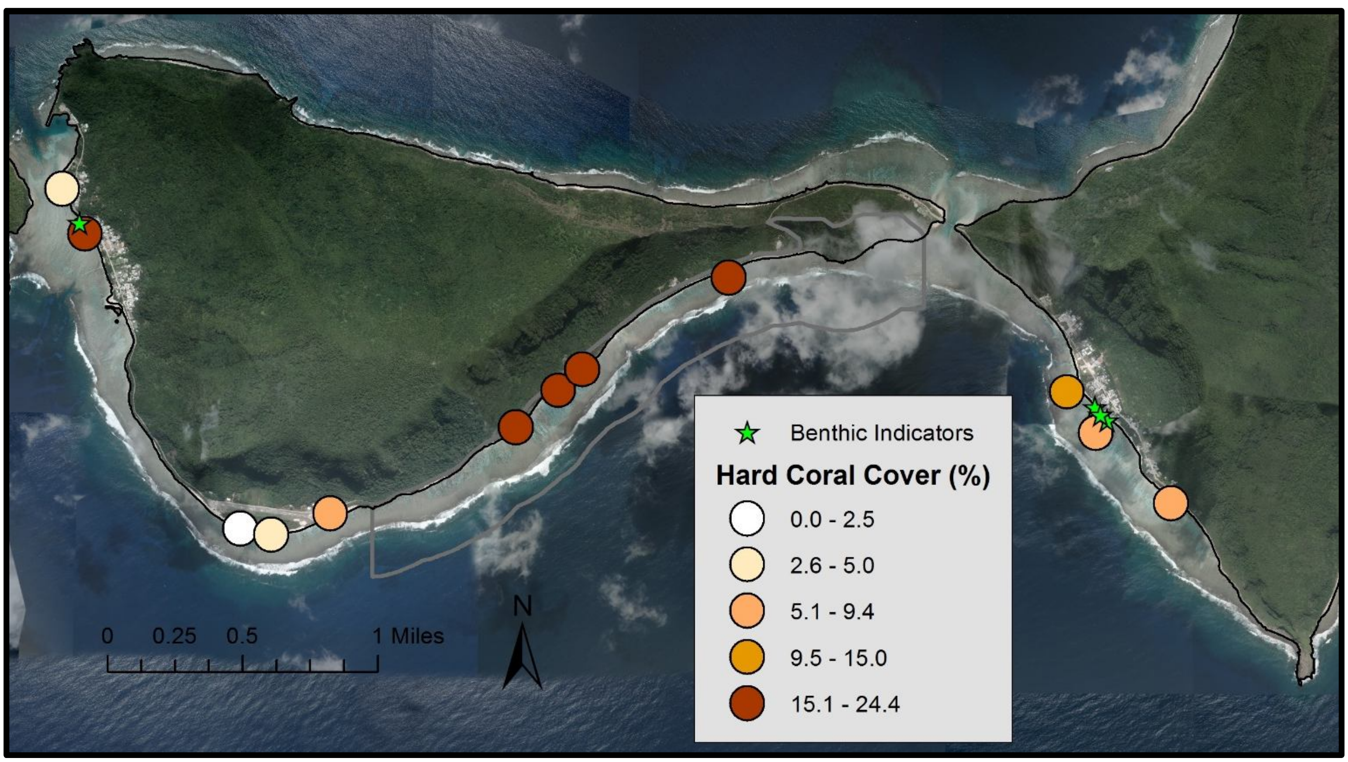


Figure 7.5: Coral cover (%) recorded along each transect in Ofu and Olosega Islands. Benthic indicators such as encrusting grey sponge and cyanobacteria algae are indicated by green stars.

Table 7.2: Benthic cover (%) and SE at the 12 survey sites by functional group. CCA = crustose coralline algae, CYA = cyano bacteria, DC = dead coral, HC = hard coral, MA + macro algae, RU = rubble, RO = rock with turf, SA = sand, SC = soft coral, TA = turf algae.

	CCA	CYA	DC	HC	MA	RU	RO	SA	SC	TA
Olo A	6.3 ± 2.6	0	0	6.9 ± 1.6	1.3 ± 1.3	38.1 ± 19	30.6 ± 10.7	16.9 ± 5.4	0	0
Olo B	6.9 ± 3.4	1.3 ± 0.7	0.6 ± 0.6	9.4 ± 2.8	2.5 ± 1	39.4 ± 8.1	31.9 ± 8.3	8.1 ± 2.8	0	0
Olo C	3.1 ± 2.4	0.6 ± 0.6	1.3 ± 0.7	2.5 ± 1	5.6 ± 2.4	37.5 ± 5.3	35.6 ± 6.6	11.9 ± 1.9	0	1.9 ± 1.2
Pool 100 A	0	0	0	4.4 ± 2.1	1.3 ± 0.7	10.6 ± 3.7	20 ± 2.7	40.6 ± 7	23.1 ± 7.3	0
Pool 100 B	0	0.6 ± 0.6	0	21. ± 3.3	1.3 ± 0.7	2.5 ± 1.8	45 ± 2.7	28.8 ± 1.6	0	0
Pool 200 A	6.9 ± 2.8	0	0	5 ± 2.7	10.6 ± 3.6	34.4 ± 9.3	30 ± 3.7	11.9 ± 2.1	0	1.3 ± 1.3
Pool 200 B	4.4 ± 1.6	0	0	6.9 ± 2.1	5 ± 2.7	43.8 ± 10.1	28.8 ± 6	11.3 ± 3.3	0	0
Pool 200 C	13.8 ± 1.6	0	0	19. ± 5.5	8.1 ± 3.6	2.5 ± 1	33.1 ± 2.8	23.1 ± 5.8	0	0
Pool 300	12.5 ± 5.3	0	1.3 ± 0.7	24. ± 1.9	3.8 ± 3	7.5 ± 1.4	18.8 ± 3.8	31.9 ± 5.2	0	0
Pool 400 A	3.8 ± 0.7	0	0.6 ± 0.6	21. ± 3.3	3.8 ± 0.7	5.6 ± 2.6	23.8 ± 3.8	40.6 ± 2.4	0	0
Pool 400 B	3.1 ± 2.4	0	5.6 ± 4	15 ± 2.3	6.3 ± 1.6	16.3 ± 7.3	13.1 ± 5.8	40.6 ± 10.4	0	0
Pool 600	25 ± 8.4	0	1.3 ± 0.7	20 ± 7.2	2.5 ± 1.8	0.6 ± 0.6	11.3 ± 3.3	38.8 ± 5.3	0	0

Table 7.3: Coral growth form (percent of coral cover) and SE at the 12 survey sites by functional group.

	bifocal plates	branching	encrusting	knobby	mounding	plating
Olo A	0	0	8.3 ± 4.2	0	91.7 ± 45.8	0
Olo B	8.3 ± 4.2	0	32.7 ± 16.4	0	58.9 ± 29.5	0
Olo C	0	16.7 ± 9.6	33.3 ± 19.2	0	50 ± 28.9	0
Pool 100 A	41.7 ± 24.1	0	16.7 ± 9.6	41.7 ± 24.1	0	0
Pool 100 B	74.2 ± 37.1	2.5 ± 1.3	0	10.6 ± 5.3	12.8 ± 6.4	0
Pool 200 A	0	33.3 ± 19.2	46.7 ± 26.9	0	20 ± 11.5	0
Pool 200 B	0	42.5 ± 21.3	30.8 ± 15.4	0	26.7 ± 13.3	0
Pool 200 C	9.4 ± 4.7	36.8 ± 18.4	33.4 ± 16.7	7.1 ± 3.5	13.3 ± 6.7	0
Pool 300	2.3 ± 1.1	2.3 ± 1.1	15 ± 7.5	20.4 ± 10.2	54.7 ± 27.3	5.4 ± 2.7
Pool 400 A	0	5 ± 2.5	14.6 ± 7.3	13.3 ± 6.7	67.1 ± 33.5	0
Pool 400 B	6.3 ± 3.1	21.1 ± 10.5	32 ± 16	0	34 ± 17	6.7 ± 3.3
Pool 600	0	3.9 ± 2	25.5 ± 12.8	0	70.5 ± 35.3	0

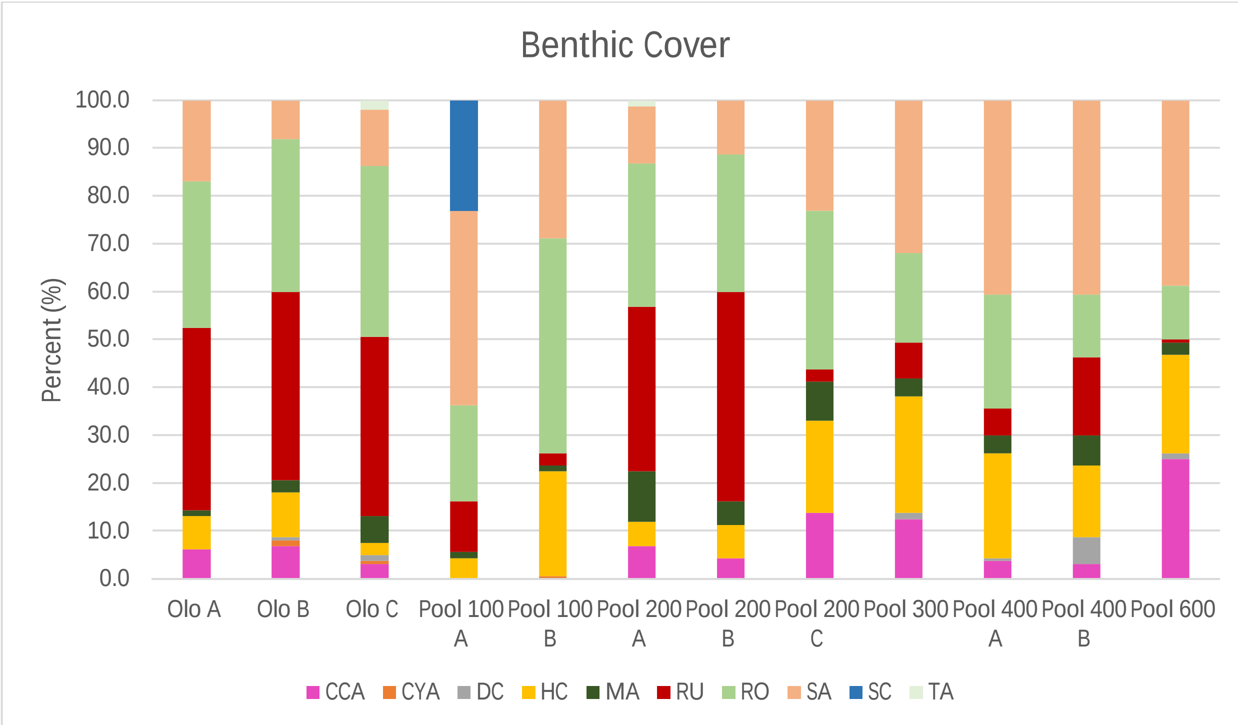


Figure 7.6: Benthic cover (%) and SE at the 12 survey sites by functional group. CCA = crustose coralline algae, CYA = cyano bacteria, DC = dead coral, HC = hard coral, MA + macro algae, RU = rubble, RO = rock with turf, SA = sand, SC = soft coral, TA = turf algae.

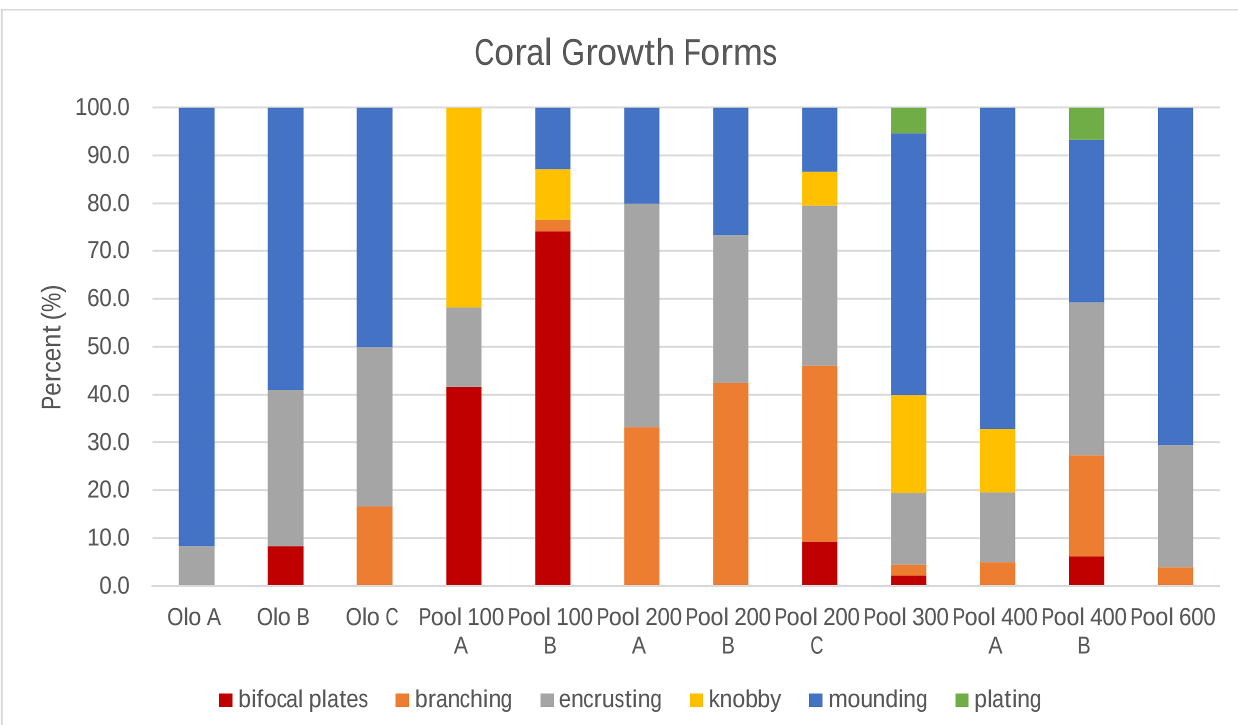


Figure 7.7: Coral growth form (% of coral cover) and SE at the 12 survey sites by functional group.

Fish Survey Data Summary

Overall, the highest mean fish biomass were recorded within the National Park boundary between Pool 300 and Pool 600. The highest mean fish biomass was recorded at Pool 400A with a mean biomass of 46.8 g/m^{-2}, of which 69% of the total biomass along this transect was attributed to herbivorous fish. Noticeably, a much lower mean biomass of 12.9 g/m^{-2} was observed at the nearby transect Pool 400B, suggesting a high variability of mean fish biomass within the same pool.

The lowest mean fish biomass of 4.3 g/m^{-2} was recorded at Olosega C, which was a site adjacent to the Olosega landfill site. The relatively moderate mean fish biomass observed along the three transects at Pool 200, adjacent to the Ofu airport, suggests that this area has overall lower biomass than the areas inside the National Park. Mean fish biomass at Pool 200 ranged from 11.0 g/m^{-2} at Pool 200A to 20.9 g/m^{-2} at Pool 200C. The highest proportion of the biomass along these transects was attributed to herbivorous fish, ranging from 65% at Pool 200A to 86% at Pool 200C.

The three transects surveyed along the reef flat in front of Olosega village showed high variability in fish biomass, ranging from 4.3 g/m^{-2} at Olosega C to 29.3 g/m^{-2} at Olosega B. The trophic composition of the fish observed along these transects was noticeably different than at all the other survey sites, with an equal or higher proportion of the total mean biomass being attributed to lower carnivorous fish compared to herbivorous fish. A similar fish population composition was observed at Pool 100B, in front of Ofu village, where 59% of the total mean biomass was attributed to herbivorous fish and 41% attributed to lower carnivorous fish.

Benthic Survey Data Summary

Overall, Pool 100B, 200C, 300, 400A and 600 had the highest coral cover (19-24%). Highest coral cover was found in Pool 300 (24%) (Table 2 and Figure 6). Out of the coral cover documented for the specific sites, mounding, encrusting and branching coral was most often encountered (Table 7.3 and Figure 7.7).

All sites also showed high percentages of sand cover (8-40%) and hard bottom covered in turf (11-45%) which is characteristic for these pool environments (hard substrate bommies with sand channels). Highest macroalgae cover was found in pool 200A (10%) which was mostly Halimeda spp. Crustose-coralline algae (CCA cover) cover was low in most pools (majority 0-13%) with high CCA cover found at one site (Pool 600 with 25%). Soft coral was only found in Pool 100A (23%) which had very high flushing rates. High amounts of coral rubble were found at Olo A, Olo B, Olo C, Pool 200A and Pool 200B (34-43%) indicating disturbance (see Table 7.2 and Figure 7.6).

Low to intermediate levels of bleaching were seen (genera mostly affected were Millepora and Acropora, some massive Porites) and low levels of disease observed.

Observations of benthic indicators suggesting nutrient input were recorded on the nearshore reef flat areas in front of both villages as indicated by the green stars in Figure 5. On the reef flat in Ofu Village a grey encrusting sponge was observed covering the benthic substrate and on the reef flat in Olosega village mats of cyanobacteria were observed. Photographs from these areas are shown below:

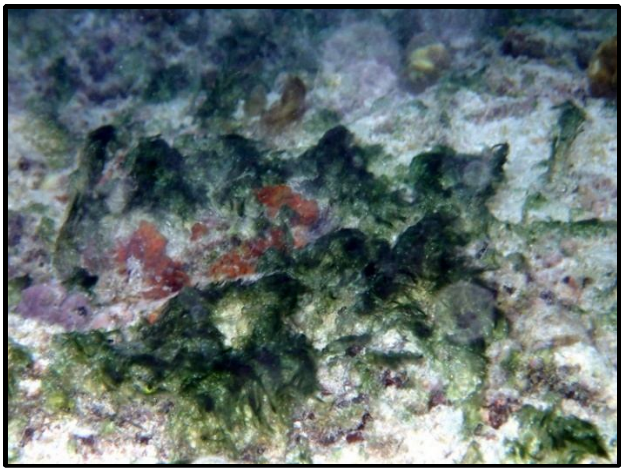


Figure 7.8: Cyanobacteria algae at Olosega village

Figure 7.9: Cyanobacteria algae at Olosega village

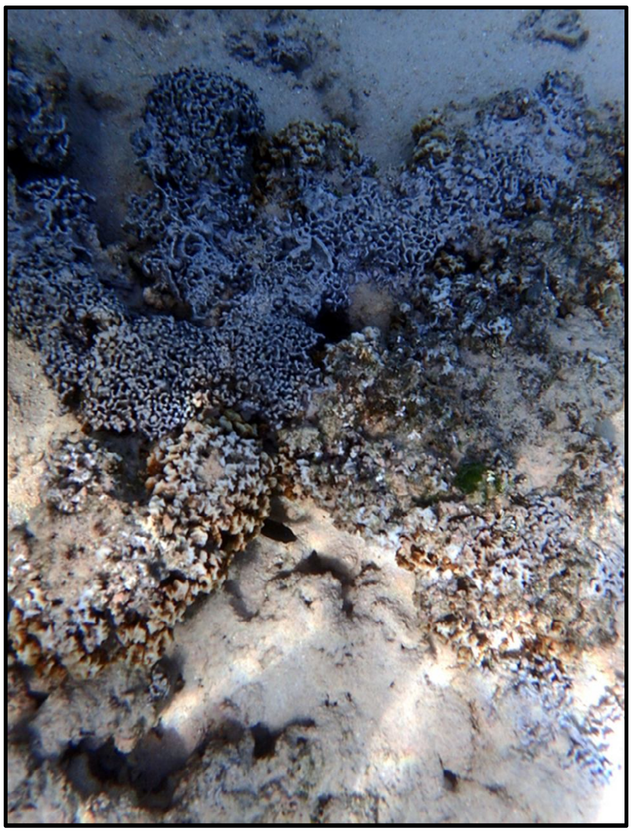


Figure 7.10: Encrusting grey sponge at Ofu village

Figure 7.11: Encrusting grey sponge at Ofu village

Crown of Thorns starfish outbreak - A Crown of Thorns starfish outbreak has been a territory-wide issue since late 2012 and was a high priority for the coral reef monitoring program. Program staff were instrumental in implementing an inter-agency COTS working group to develop a priority site list identifying sites to be checked on a regular basis for COTS outbreaks, with the aim of ensuring that the high biodiversity coral reef communities are protected in the event of a Territory-wide COTS outbreak. Control efforts included conducting COTS removal using SCUBA and snorkeling on the reef flat and reef slope. Focused efforts in October 2014 concentrated at north shore sites of Fagamalo and Fagasa and further efforts in November 2015, December 2015, and February 2016 concentrated in Fagamalo and nearby sites along the North Tutuila coast. Program staff completed the National Park Blue Card Certification training with the National Park Service of American Samoa National Parks in order to be able to dive off their vessel and more effectively help with the COTS eradication effort along the North Tutuila coastline. Program staff amended the USFWS State Wildlife Grant for a COTS control project which was funded in October 2016 and also coordinated with CRAG to establish fishermen contracts to remove COTS at night and also to order equipment and supplies to implement control efforts in the territory.

Sea Cucumber Surveys – Since early 2013 an additional problem in the Territory has been the initiation of a large-scale commercial sea cucumber fishery which resulted in local fishermen collecting large quantities of all species of sea cucumbers from the reef flat and reef slope areas around Tutuila and Manu'a. The cucumbers were being removed in large quantities and were being processed and exported to Asia as part of a lucrative commercial operation. The fish ecologist coordinated DMWR staff to conduct reef flat surveys to determine sea cucumber densities and a Sea Cucumber Health Assessment Report was completed in May 2014, in addition to working with DMWR staff and agency lawyers to develop and pass a Sea Cucumber moratorium which came into effect on 4th December 2013. The fish ecologist also assisted with developing educational materials and participated in a media campaign to raise awareness about the issue, which included participating in a local TV chat show, providing information and interviews for newspaper and radio coverage as well as information for an education workshop with the village mayors. Activities were conducted in collaboration with the DMWR enforcement division and staff from the Port Authority to ensure that export of the products were not successful.

Leone Village Coral and Mangrove Restoration project - The program staff have provided technical assistance to community staff that are based in the village with various project implementation activities including monitoring and maintaining the coral nursery, and coordinating the involvement of other ASG and federal agencies to assist with the mangrove restoration work. A monitoring survey was conducted at the coral nurseries on 21st May 2014, to assess growth rates of coral and presence of fish at the site. A Mangrove survey was conducted at the mangrove sites on July 1st 2014, to assess the condition of the restoration sites (amount of trash, etc.) and get exact GPS locations of the sites. The coral rope nursery was inspected on 9th July 2015 and photos of the coral nubbins were taken. Additionally, the new nursery structures that were placed by the Leone staff on the reef flat were inspected and photographed and GPS locations were taken to create a map of the nursery.

Vessel Grounding assessment surveys - Program staff organized and conducted salvage activities in relation to the longline fishing boat that grounded on the reef at Nu'uuli on Friday 22 May, 2015. Debris removal operation was conducted by 20 personnel using kayaks and small boats, with two Marine Patrol jet skis on scene to provide water safety support. Ropes and buoys were removed from the deck and transported to shore. Program staff produced a summary environmental assessment report the Governor of American Samoa, which included results from a visual assessment of the amount of debris coming off the vessel, the damage the grounding caused to the reef structure, and potential ongoing damage to the surrounding environment if the vessel remains on the reef.

Fishing Debris removal - Program staff coordinated the removal of a drifting Fish Aggregating Device, which was found on Faga'alu reef flat on May 21, 2015. The FAD was entangled on the coral reefs and estimated to have damaged more than 100 square feet of once live coral. A press release was issued, along with TV and radio interviews and program staff continue to work with the DMWR enforcement staff to help identify the source. Program staff coordinated the removal of a ghost gill net, which was found in the Nu'uuli pool on Sept 9, 2015. The net was entangled on the reef structure and posed as an entanglement threat to marine life in the area. Photos and information of the removal was published on social media to raise awareness of the threat of ghost nets.

Ridge-to-Reef Project – The fish ecologist collaborated with the ASEPA research scientist to develop a proposal for the USEPA-funded Wetland Development Program Grant, titled 'A framework to assess ridge to reef ecosystem health in American Samoa'. The project was successfully funded in October 2015 and project activities were initiated in May 2016 which included a Tutuila stream assessment, monthly stream sampling at 34 sites and the development of monitoring survey protocols and species identification training tools in preparation for biological monitoring surveys at 28 sites around Tutuila in November 2016.

8. Capacity Building Activities

Capacity building activities coordinated and implemented by program staff include:

- Revision and updating of the DMWR Dive Manual to ensure improved health and safety of snorkeling and SCUBA diving operations.
- Monitoring survey training tools were developed and implanted by program staff which included fish ID, coral ID and invertebrate ID training, fish size estimation training, dive safety drills and deployment of Surface Marker Buoys (SMBs) and signaling mirrors.
- Program staff developed and implemented training on data entry and basic data analysis skills, including the use of the Coral Point Count for excel (CPCe) software to analyze benthic quadrat photographs.
- A 4-day Coral Finder Toolkit workshop was held by Russell Kelley in September 2014 in which local staff learned to identify coral colonies to genus level. The training package was based on the Coral Finder toolkit developed in Australia. The workshop was a great success with 13 people from different agencies participating (DMWR, CRAG, NOAA PIRO, Leone village coral restoration project). The average ability of participants to identify coral to genus level increased by over 70% by the end of the workshop.
- In November 2014, a 4-day coral demographic training workshop was conducted by NOAA CRED staff Dr. Bernardo Varagas-Angel and Dr. Dione Swanson. During the workshop staff learned the benthic methods used Pacific-wide by CRED and discussed how these methods can be applied in the Samoan archipelago. The workshop was a great success with people from multiple agencies participating (DMWR, CRAG, NOAA PIRO, NMSAS, ASCC, Leone village coral restoration project and MNRE-Samoa).

- The benthic ecologist attended a training in December 2014 in Hawaii held by the Coral Reef Ecosystem Division (CRED). During this 1-week training she learnt the benthic monitoring methods used by CRED across the Pacific to` apply them in the field. The application of these benthic monitoring methods will widen the scope of data collected and make the data more applicable to management decision.
- Program staff worked with NOAA CRED to fund and implement a monitoring database project which will integrate all the monitoring data and provide a platform for data analysis and reporting as well as effective data entry and quality control procedures. This project will be implemented in FY2017.
- The fish ecologist attended and presented information at the Western Regional Fishery Management Council Plan Team Meetings in Honolulu in April 2014 and April 2015.
- The benthic ecologist participated in leg 2 and 3 of the 2015 NOAA ASRAMP cruise conducted between February and March 2015. During this time stratified random sites around Tutuila, Ta'u, Ofu-Olosega and Rose Atoll were surveyed. The benthic ecologist assisted the CRED benthic team in coral demographic surveys at 102 sites.
- In January 2016 program staff participated in a Habitat Mapping workshop led by Dr. Anthony Montgomery from the Pacific Islands US Fish and Wildlife office to assist with conducting rapid habitat assessment survey methods and mapping.
- In February 2015, a 5-day coral reef monitoring data training workshop was conducted by Dr. Peter Houk, funded by TNC. The workshop was conducted to improve the analytical expertise within resource monitoring and management programs in American Samoa. The workshop represented a logical progression of previous analytical themes that Dr. Peter Houk introduced to local programs during 2008. A third data analysis workshop was conducted in February 2016. The workshop involved a group assessment of coral-reef ecosystem condition across Tutuila, American Samoa, and modeling the individual contributions from human stressors. The skills developed during this workshop were utilized by program staff to assist with implementation of the EPA-funded Ridge to Reef Project.
- A 4-day Coral Disease Workshop was held between 30 June – 3 July 2015, by Dr. Thierry Work (Wildlife Disease Specialist for USGS National Wildlife Health Center in Honolulu, Hawaii). Monitoring partners from various agencies in American Samoa as well as Samoa participated in the workshop. The workshop aimed to raise awareness of wildlife diseases and covered the topics of wildlife disease investigation, examples of wildlife diseases including corals, how to identify and respond to unusual wildlife mortalities, and in particular how to identify coral diseases.
- The Fisheries Biologist attended the IUCN Red List workshop on Oceania Coral Reef Fishes in Fiji between 2 – 13 March, 2015. The assessments were global in nature, but based on species found in the Pacific Islands.
- A Coral Reef Monitoring Technician and Coral Reef Fellow were hired in May 2015 by CRAG to assist with the program activities. They have been scuba certified and were trained by the program monitoring staff in monitoring techniques and fish and benthic ID.
- The benthic ecologist participated in the NOAA grant developing workshop held in Pago Pago Aug 27, 2015. The workshop discussed techniques for successful grant development in the future.
- Program staff attended the Marine Mammal Stranding Response Meeting, held in American Samoa on August 12, 2015.
- Program staff participated in the DMWR-led American Samoa State Wildlife Action Plan development workshop on August 18, 2015, to contribute towards the update of the plan and the inclusion of marine species.

- Program staff coordinate with NOAA CRED project staff to implement the Nutrient dynamics and benthic algae cover in Vatia Bay. The benthic Ecologist has monitored the five permanent algae monitoring sites in Vatia established by NOAA CRED staff. Two 20m transects per site were laid out on the reef (shallow, <20ft) following the rebar markers. Every 2 months, benthic photos were taken on a 1m monopod every meter along the transects.
- Program staff attended the quarterly American Samoa Dive Safety meetings, and participated in discussions with NOAA Dive Safety Officer regarding NOAA dive reciprocity and implementing the Dive Safety Manual at DMWR.
- The fish ecologist and the coral reef monitoring technician participated in the NOAA fish training conducted by Paula Ayotte in April 2016, in preparation for the 2016 NOAA ASRAMP cruise.
- Program staff including the monitoring technician participated in the 2016 NOAA ASRAMP cruise conducted between April and May 2016. During this time stratified random sites around Tutuila, Ta'u, Ofu-Olosega and Rose Atoll were surveyed.
- The fish ecologist has been communicating and working with the NOAA CRED Fish team regarding potential data analysis and survey methods training opportunities. Discussions have also been conducted regarding potential collaborative projects to analyze CRED and Territorial monitoring data to answer priority management questions. Projects included the implementation of an integrated fish and benthic baseline monitoring survey report for the Fagamalo No-take MPA, and a stakeholder workshop 'Linking local and national monitoring data to test for marine protected area effectiveness in American Samoa' held in American Samoa in early May 2015.
- Program staff assisted Stanford University researchers with ongoing bleaching studies on Ofu Island in February 2016.
- Program staff prepared an oral and a poster presentation for the International Coral Reef Symposium in Honolulu, June 19 to 24, 2016. The fish ecologist presented an oral presentation: A framework to assess ridge to reef ecosystem health in American Samoa and the benthic ecologist presented a poster 'Long-term Coral Reef Monitoring Data in American Samoa'.
- Program staff attended a Coral ESA workshop held by NOAA in Honolulu June 25 to 26, 2016 to discuss the identification issues of the listed coral species, how the listing affected the different agencies and how potential problems could be solved.
- Program staff attended a workshop entitled "Building Resilient Coastal Communities in the National Marine Sanctuary and American Samoa" held in Pago Pago by NOAA NMS, July 19 to 20, 2016.
- The fish ecologist and the monitoring technician participated in a research trip to Rose Atoll with the Refuge and Marine National Monument manager between August 31 and September 3 to assist with establishing coral survey baselines in collaboration with Dr. Douglas Fenner.
- Program staff assisted a UH researcher in algae collections and took the opportunity to collect algae for a CRAG/DMWR algae library. The samples were preserved in formalin and identified to the lowest taxonomic level possible (with the help of the UH researcher). The algae library will be on display in the DMWR lab and can be used to future algae identification purposes.
- Program staff provided monitoring data for the UNEP-funded Global Coral Reef Monitoring Network (GCRMN) Pacific Workshop from 12-14 October 2016 in Hononlulu, to assist with and discuss the development of a Pacific Islands Status Report. The fish ecologist attended the meeting to provide information about the monitoring data and participate in discussions regarding report development.

Applications to Management - Examples of contributions of the monitoring program to coral reef management include:

- Data on fish abundance used along with data from other sources for determining annual catch limits by the Western Regional Fishery Management Council.
- Data on the presence of coral species that have been petitioned for Endangered Species status were provided to the NMFS Biological Review Board for their review of the petition.
- Project staff coordinated monitoring work with PhD researcher Alex Messina from San Diego State University who worked on sedimentation monitoring in the Faga'alu Watershed. Sediment traps were removed and photo quadrat surveys were undertaken along the NOAA CRED transects, which is a project undertaken in collaboration with Dr. Bernardo Vargas-Angel at NOAA CRED.
- Program staff coordinated with DMWR staff to conduct reef flat surveys to determine sea cucumber densities and a Sea Cucumber Health Assessment Report was completed, in addition to working with DMWR staff and agency lawyers to develop and pass a Sea Cucumber moratorium which came into effect on 4th December 2013.
- Participating in the inter-agency COTS control efforts to reduce the impact of the COTS outbreak in Tutuila and provided data and recommendations for reducing the impact of land-based sources of pollution to resource agency staff and public media outlets.
- Coordination of efforts to investigate the Red Tide event in Pago Pago Harbor in September 2013, including taking water quality samples and sampling dead fish, in addition to producing press releases and conducting TV and radio interviews. During June 2014, program staff collected water samples to be analyzed by Don Vargo at the ASCC Land Grant to identify dinoflagellate species, and communicated with the media and other agency staff at AS-EPA regarding the issue. Program staff assisted the DMWR director to draft an EO to establish a HAB Task Force in the Territory.
- The fish ecologist participated in the CRCP American Samoa Pilot Status and Trends Report Card workshop held in Hawaii on August 19 - 21, 2015. The workshop was the first step toward producing an ecosystem health report card for American Samoa. Discussions during the workshop involved conceptualizing key features and threats and reviewing potential indicators and available data to be synthesized into a draft document. Program staff continued to participate in conference calls and provided comments during the drafting and report card development process.

9. Acknowledgements

The Coral Reef Monitoring Program staff wish to thank the following for invaluable assistance in the field: Jeremy Raynal, Motusaga Vaeoso, Kim McGuire, Meagan Curtis, Trevor Kaitu'u, and Paolo Marra-Biggs.

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11. Appendices

Appendix 1: American Samoa Integrated Coral Reef Monitoring Program (AS I-CRMP) Survey Protocols

Appendix 2: List of the 12 monitoring sites with starting GPS coordinates and watershed classification.

Appendix 3: List of bleaching monitoring site coordinates with associated habitat.

Appendix 4: List of monitoring sites in Ofu-Olosega with start and end GPS coordinates.

American Samoa Integrated Coral Reef Monitoring Program Survey Protocols

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October 2013

Background Information

In 2013 the DMWR Fisheries division made a decision to integrate the four coral reef monitoring programs that had been implemented with varying effort and methods over the previous 6 years. The four programs are:

1. Key Reef Species Program (KRSP) – *funded by USFWS Sports Fish Restoration Program*
2. Community-based Fisheries Management Program (CFMP) – *funded by USFWS Sports Fish Restoration Program*
3. No-take MPA Program (NTMPA) – *funded by USFWS Sports Fish Restoration Program*
4. American Samoa Coral Reef Monitoring Program (ASCRMP) – *funded by* NOAA Coral Reef Conservation Program

The integration of monitoring methods from all four programs will involve combining components of the ASCRMP and KRSP methods, and focusing on the reef slope area at 10m/30ft depth. Reef flat areas at the same sites will also be monitored as well as 3 offshore bank areas.

The following text describes in detail the proposed objectives and methodology to be implemented by the ASICRMP.

The key benefits to an integrated monitoring program include:

- The CFMP program decided to switch from reef flat snorkel surveys to SCUBA surveys on the reef slope. Integrating the four programs will **reduce the strain on the boat and staff resources, and reduce duplication of effort where site lists overlap.**
- Historically, most programs failed to complete surveys at their designated sites within a 12 month period, mainly due to staff absences and boat availability issues. The integrated effort will ensure that **all the sites are completed on time.**
- Combining efforts into one program ensures that a total of 30 monitoring sites can be surveyed in one year and therefore **more data is available for each program to analyze.**
- A team of 8 DMWR staff available to undertake the monitoring surveys, split into 2 teams of 4 staff who will survey on alternative days. This ensures that if monitoring team members are sick or unable to dive on a scheduled day, a backup staff member will be available to step in and **enabling the survey schedule to stay on track**.
- Monitoring surveys are scheduled for a block of 4-6 months during the period of most favorable weather conditions. This ensures that **data is comparable between sites and ensures continuity and motivation within the survey team.**
- One main survey protocol, with the opportunity to add extra components depending on program needs, ensures that **all data collected is compatible and available for data analysis.**
- Monitoring team is trained at the same time and tests are conducted prior to start of monitoring season to **ensure quality control of data recorded.**
- A total of 30 monitoring sites will be surveyed, creating a larger and more robust data set which will be available for each program to analyze with respect to their program objectives.

Goal & Objectives

The key **goal** is to monitor the status and trends in the distribution and abundance of reef biota on reefs in American Samoa on a long-term basis, in order to provide information that is pertinent to managing coral reefs in the territory.

The **primary objectives** are to:

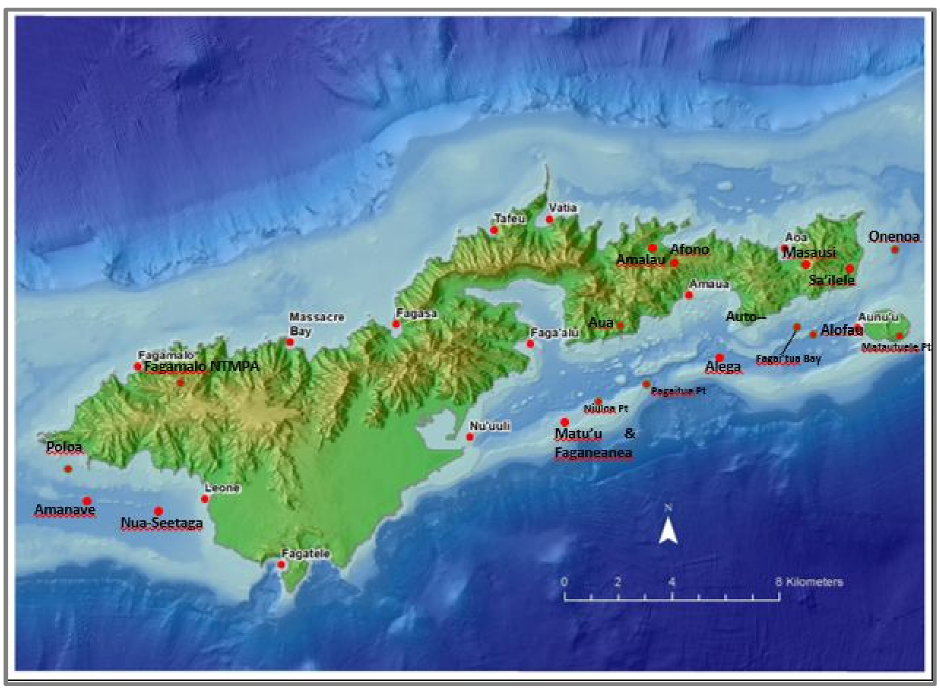
1. Combine multiple program resources to undertake annual surveys at 20 sites in Tutuila, and at least every 2 years in the Manu'a Islands, Rose Atoll, and Swains Island.
2. Track patterns in fish and invertebrate abundance and coral reef benthos data in selected sites. The now integrated monitoring program will also collect detailed size-frequency data for the most abundant hard coral species in collaboration with NOAA CRED.
3. Detect threatening changes rapidly and investigate rapidly developing problems, such as coral bleaching, algal outbreaks, disease outbreaks, crown-of-thorns starfish outbreaks, or cyclone and storm damage.
4. Collaborate with other locally-based agencies to understand the impact of land-based sources of pollution at the monitoring sites (to include sedimentation, water quality).

Site Selection

Site selection was based on the following priorities:

1. Include all sites where 3 or more years of data have been collected.
2. All Marine Protected Area (MPA) sites.
3. Ensure that each MPA sites has a relatively comparable non-MPA site nearby.

The following list shows the prioritized site list, which includes the original monitoring program that surveyed the site and the number of data sets (in years) per site:



Site #	Priority Group	Sector	Site Name	Original Monitoring program	# of data sets (years)
1	1	NE Sector	Vatia	ASCRMP, CFMP	7
2	1	NE Sector	Aoa Bay	ASCRMP, CFMP	6
3	1	SE Sector	Aunu'u	ASCRMP	7
4	1	SE Sector	Auto & Amaua	CFMP, ASCRMP	7
5	1	NE Sector	Masausi (CFMP on hold)	CFMP *(new site 2013)*	0
6	1	NE Sector	Sailele	CFMP *(new site 2013)*	1
7	1	NE Sector	Amalau	KRSP, CFMP *(new site 2013)*	1
8	1	SE Sector	Alofau	CFMP *(new site 2013)*	1
9	1	SE Sector	Matu'u & Faganeanea	CFMP *(new site 2013)*	1
10	1	SE Sector	Alega Marine Reserve	KRSP, CFMP (new)	3
11	1	NW Sector	Tafeu Cove	ASCRMP	7
12	1	NW Sector	Fagamalo Bay	ASCRMP, CFMP	6
13	1	NW Sector	Fagamalo NTMPA	NTMPA	0
14	1	NW Sector	Fagasa Bay	ASCRMP , NTMPA	7
15	1	SW Sector	Fagatele Bay	ASCRMP	7
16	1	SW Sector	Leone Bay	ASCRMP	7
17	1	SW Sector	Nu'uuli Pala	ASCRMP	7
18	1	NW Sector	Poloa Bay	CFMP, KRSP	3
19	1	SW Sector	Amanave	CFMP & KRSP	3
20	1	NW Sector	Massacre Bay/A'asu	ASCRMP & KRSP	6
21	1	SE Sector	Faga'alu Bay *(potential MPA)*	ASCRMP (& CFMP?)	7
22	2	NE Sector	Afono - (control for Amalau-Vatia CFMP)	*NEW SITE (CFMP control)*	***0***
23	2	NE Sector	Onenoa (control for Sailele & Aoa CFMP)	*NEW SITE (CFMP control)*	***0***
24	2	SE Sector	Faga'itua Bay (control for Amaua & Alofau)	KRSP *(CFMP control)*	3
25	2	SE Sector	Matautuele Pt (nr. Amouli, a potential MPA)	KRSP *(CFMP control)*	3
26	2	SE Sector	Aua Harbor (CFMP on hold)	KRSP (& CFMP)	3
27	2	NW Sector	Siliaga Pt (nr Massacre Bay)	KRSP	1
28	2	SE Sector	Pagaitua Pt (nr Laulii)	KRSP	2
29	2	SW Sector	Nua-Seetaga Bay (nr. Amanave)	KRSP *(CFMP control)*	2
30	2	SE Sector	Niuloa Pt (close to Faga'alu)	KRSP *(potential CFMP control)*	3
~~31~~	~~3~~	~~NW Sector~~	~~Leelee Pt (inside Fagamalo CFMP)~~	~~KRSP, CFMP, NTMPA~~	~~1~~
~~32~~	~~3~~	~~SW Sector~~	~~Faalagiunnuu Pt (check name?)~~	~~KRSP~~	~~0~~
~~33~~	~~3~~	~~SW Sector~~	~~Logo Logo Pt (nr Leone)~~	~~KRSP~~	~~1~~
~~*34*~~	~~*3*~~	~~*NE Sector*~~	~~*Folau Pt (nr Masausi)*~~	~~*KRSP*~~	~~*1*~~

Summary of Survey Methods

- **Site location –** GPS Co-ordinates, and metal rebar at MPA sites.
- **Underwater Visual Fish Census -** 4 x 50m-long transects surveyed at each site (total 200m transect length).
- **Transect widths**
    - o Large-bodied fish / predators: 20m total width (perhaps too wide? 5 m on each side, 10 m total?
    - o Small and Medium sized fish (not including damselfish): 5m total width (2.5m on each side of transect tape) (where do we put the damselfish? Is there a need for this?)
    - o Juvenile fish: 1m total width (0.5m on each side of transect tape)
    - o Invertebrate Indicators (giant clam, COTS, urchins): 1m total width (0.5m on each side of transect tape)
- **Reef Flat & Bank sites –** sites that are characterized by fast water currents, a timed swim (for 7 minutes) covering the same belt dimensions will be conducted.
- **Fish size measurements -** The Total Length (TL), in cms of the fish is estimated (NOTE: KRSP used to use Standard Length (SL), however TL is easier to estimate underwater, and also the NOAA CRED provide biomass coefficients using TL measurements).
- **Rugosity Index –** calculated using a 15m long rugosity chain.
- **Water clarity** –the horizontal visibility is recorded along the transect tape.
- **Benthic Line Point Intercept** - benthic substrate is recorded at 0.5metre intervals along the 50m transect tape.
- **Photo-quadrat transect** - implemented when the benthic surveyor doesn't have the taxonomic expertise to undertake the LPI. An underwater camera is mounted on a 1m high frame attached to a 0.5m x 0.5m quadrat, to take a high resolution photograph at 1m intervals along the transect tape.
- **Size-frequency of abundant hard coral species –** Largest width and height data will be collected for 5 abundant hard coral species from permanent belt transects that are going to be established in a few sites. Belt transects will be 25 m x 2m in dimensions.
- **Coral bleaching data collection –** Coral bleaching will be monitored on to be established- permanent sites on sites known to have experienced bleaching events. Belt transects will be 25 m x 2m in dimensions. Current monitoring is a qualitative visual assessment of bleaching on these sites by estimating % coral bleaching from wide-scale snorkeling surveys.
- **Sedimentation –** Sedimentation traps will be deployed in selected sites and regularly retrieved for sediment analyses.
- **Manta tow surveys –** Towed surveys will be regularly conducted to estimate crown-of-thorns abundance. Other modified large scale towed or timed-swim surveys will be conducted as needed, for example, to estimate sea cucumber abundance which is a developing fishery and derive estimates of stock size for fishery management policy purposes.

DETAILED Survey Methods (for Reef Slope sites at 30ft depth)

Personnel required**:**
(1) Fish Surveyor 1 (Large-bodied fish and all other fish)
(2) Fish Surveyor 2 (Transect layer, rugosity)
(3) Benthic Surveyor 1 (LPI /Photo-quadrat),
(4) Benthic Surveyor 2 – (Invertebrates, Coral disease, bleaching, disturbances, & transect retrieval)

1. **Site location –** A central point is located using GPS coordinates (and a metal rebar at MPA sites). Two dives are undertaken at each site, with two 50m-long transects surveyed per dive, therefore a total of 4 transects are surveyed at each site (total 200m transect length).

2. **Underwater Visual Census Fish Survey – '**Fish Surveyor 1' (FS1) works with **'**Fish Surveyor 2' (FS2) to determine a suitable location to tie the transect tape and start the transect (not necessary where a metal rebar exists). FS1 starts swimming ahead along the 10m/30ft contour line with FS2 following behind laying the transect tape. When the tape is nearing the 50m mark, FS2 makes a noise signal to inform FS1 that the transect is coming to an end. The second transect is started at a 5m/15ft distance from the end of the first transect. Appendix 1 and 2 show the survey sheet for the fish survey and the juvenile fish survey.
   - **Fish Surveyor 1** records the abundance and size (in cm) of the Large (>35cm TL) and Medium-sized fish (20 to <35cm TL) using a 20m total belt width for the Large fish and a 5m belt width for the Medium fish.
   - Once both transects have been swum, FS1 and FS2 wait for 7 minutes at the end of the second transect.
   - FS1 records the abundance and size (in cm) of the Small-sized fish (<20cm TL) and juvenile fish using a 5m belt width.

3. **Transect Laying & Rugosity Measurements – '**Fish Surveyor 2' swims away from the central point, and lays a 50-metre transect tape along the 10m/30ft contour. In attempt to minimize bias in laying the tape a route is chosen based on depth and anchoring points for the tape, and not the substrate.
   - The tape is passed along the sides of projections, including live corals such as Pocillopora and table corals, which usually have an overhanging side.
   - If it is passed around first one side of one projection and then the other side of another, it is anchored securely from wave action moving it either way at that point.
   - A cleft that is narrow and deep is crossed straight to an anchoring point on the other side. If it is large, then the tape may be laid along one side of it, going up toward shallower water but staying at 10m/30ft depth, and then when the bottom rises to that depth, crossing to the other side and continuing on that side out of the canyon.
   - If the tape is stretched between two points far apart and the surge is heavy, to minimize bias, the point on the bottom that is first seen from a vertical viewpoint, is recorded.
   - When the tape is nearing the 50m mark FS2 makes a noise signal to inform FS1 that the transect is coming to an end. The second transect is started at a 5m distance from the end of the first transect, and a second 50m transect tape is laid in the same way as the first.

- Once both transects have been swum, FS1 and FS2 wait for 7 minutes at the end of the second transect, before returning back along the transect. FS2 follows behind FS1 and at the beginning of the second transect FS1 carefully lays a 15m long Steel Rugosity Chain along the reef surface, noting the distance between the start and the end of the chain ends. FS2 repeats this at the beginning of the first transect.

Potential amendments to Fish Survey method (needs to be trialed)

- To quantify the abundance and biomass and size structure of populations of large vulnerable reef fish, a long swim following the belt transects is required (Choat and Pears 2003). The fish surveyors would ascend to 15ft depth and continue swimming 400m from the end of the second transect, estimating the abundance and TL (in cm) of Large-bodied fish (>35cm TL), in a 20m wide area (including below). This would require that two fish surveyors swim along the transect tapes, one surveying the large and medium-sized fish and the other surveying the small-sized and juvenile fish. An additional person would be required to lay the transect tape.

4. **Benthic survey -** Benthic Surveyor 1 (BS1) and Benthic Surveyor 2 (BS2) dive together to estimate the benthic cover and the abundance and sizes of key invertebrates. They also record incidences of coral disease, coral bleaching, other disturbances, and are responsible for transect tape retrieval).

- **Water clarity –** Benthic Surveyor 2 (BS2) records the horizontal visibility along the transect tape at the beginning of the survey, by quickly swimming along the transect tape until Benthic Surveyor 1 is no longer visible, and the distance along the transect tape is recorded.
- **Invertebrates** – Benthic Surveyor 2 (BS2) swims back to the start of the transect tape and records the abundance and sizes of key invertebrates along the transect using a 1m wide belt (0.5m on each side of transect tape). Appendix 3 shows the survey sheet for the invertebrate survey.
- **Line Point Intercept: -** Benthic Surveyor 1 (BS1) starts at the beginning of the tape and records the benthic categories under each 0.5 m point along the transect tape. The tape is read at each point by reading the substrate under the point at the time at which the diver is directly above the point. Benthic categories include live coral, dead coral, dead coral with algae, crustose calcareous algae, branching coralline algae, fleshy macroalgae, turf algae, rock, sand, rubble, soft coral, and sponge. Corals are identified to lifeform, genus, and species when possible, and if the macroalgae is Halimeda or Dictyota. Soft corals are recorded to genus when possible. Lifeform categories include encrusting, massive, foliose, branching, columnar, submassive, mushroom, Millepora, Acropora branching, Acropora table, Acropora digitate, and Acropora encrusting.

Alternative method when surveyor doesn't have the taxonomic expertise to undertake the LPI:

- **Photo-quadrat transect** Benthic Surveyor 1 (BS1) uses an underwater camera mounted on a 1m high frame attached to a 0.5m x 0.5m quadrat, to take a high resolution photograph at 1m intervals along the transect tape. Following the survey desk-based analysis using the Coral Point Count for Excel (CPCe)software is to analyze 10 points on each photograph, identifying coral to lifeform, genus, and species when possible.

Appendix 2: List of the 12 monitoring sites with starting GPS coordinates

Site	Latitude	Longitude
Amaua	-14.273677	-170.621908
Aoa	-14.25825	-170.589284
Aunu'u	-14.28465	-170.563628
Faga'alu	-14.290138	-170.67666
Fagamalo	-14.297957	-170.812132
Fagasa	-14.283607	-170.723062
Fagatele	-14.364332	-170.762564
Leone	-14.342235	-170.788984
Massacre	-14.289572	-170.759657
Nu'uuli	-14.321457	-170.697506
Tafeu	-14.252747	-170.6898
Vatia	-14.248162	-170.670099

Appendix 3: List of bleaching monitoring site coordinates with associated habitat

Site	Habitat
Airport	pool
Alofau	pool, reef flat, slope
Amalau	slope
Amanave	slope
Aoa	slope
Faga’alu	pool, slope
Fagamalo	reef flat, slope
Fagasa	reef flat, slope
Leone	slope
Nu’uuli	Pool

Reef slopes

Site	Latitude	Longitude
Aoa	-14.25825	-170.589284
Faga'alu	-14.290138	-170.67666
Fagamalo	-14.297957	-170.812132
Fagasa	-14.283607	-170.723062
Leone	-14.342235	-170.788984
Nu'uuli	-14.321457	-170.697506
Alofau	-14.277163	-170.60687
Amalau	-14.251703	-170.658084
Amanave	-14.327812	-170.831505

Reef flats

Site	Transect	Logger	Latitude	Longitude
Alofau	T1 start		-14.277194	-170.606735
Alofau	T1 end		-14.277092	-170.606538
Alofau	T2 start	2	-14.277146	-170.606847
Alofau	T2 end		-14.277028	-170.606647
Alofau	T3 start		-14.276947	-170.607124
Alofau	T3 end		-14.276755	-170.60697
Fagamalo	T1 start		-14.29772277	-170.8107538
Fagamalo	T1 end	1	-14.297609	-170.810957
Fagamalo	T2 start		-14.29763929	-170.8105782
Fagamalo	T2 end	1	-14.297556	-170.810792
Fagamalo	T3 start		-14.29755455	-170.8105456
Fagamalo	T3 end		-14.297461	-170.810756
Fagasa	T1 start	1	-14.28382474	-170.7224664
Fagasa	T1 end		-14.283762	-170.722244
Fagasa	T2 start		-14.28375215	-170.7225467
Fagasa	T2 end		-14.283701	-170.722326
Fagasa	T3 start	1	-14.2836053	-170.7225644
Fagasa	T3 end		-14.28354	-170.722344

Pools

Site	Transect	Logger	Latitude	Longitude
Airport pool	T1 start		-14.328252	-170.701105
Airport pool	T1 end	1	-14.328484	-170.701236
Airport pool	T2 start		-14.328678	-170.701104
Airport pool	T2 end		-14.32849	-170.701317
Airport pool	T3 start		-14.32918	-170.702213
Airport pool	T3 end	1	-14.329263	-170.701948
Alofau	T1 start	1	-14.27793394	-170.6052962
Alofau	T1 end		-14.27773613	-170.6053732
Alofau	T2 start		-14.27794869	-170.6055715
Alofau	T2 end		-14.27757662	-170.6055454
Alofau	T3 start	1	-14.27794207	-170.6058028
Alofau	T3 end		-14.27774015	-170.6056492
Faga'alu	T1 start	1	-14.2920898	-170.6803975
Faga'alu	T1 end		-14.29199173	-170.680637
Faga'alu	T2 start		-14.29198134	-170.6803477

Faga'alu	T2 end		-14.29174321	-170.6804825
Faga'alu	T3 start	1	-14.29200816	-170.6799738
Faga'alu	T3 end		-14.29178638	-170.6801405
Nu'uuli	T1 start	1	-14.31314254	-170.6968383
Nu'uuli	T1 end		-14.31321865	-170.6966678
Nu'uuli	T2 start	1	-14.31275681	-170.6960271
Nu'uuli	T2 end		-14.31285152	-170.6963127

Appendix 4: List of monitoring sites in Ofu-Olosega with start and end GPS coordinates

Pool Name	Site	Start / End	Latitude	Longitude
Olosega A	Olosega	Start	-14.17892371	-169.6246156
Olosega A	Olosega	End	-14.17838006	-169.625339
Olosega B	Olosega	Start	-14.17968035	-169.6238366
Olosega B	Olosega	End	-14.18025141	-169.6232116
Olosega C	Olosega	Start	-14.18528633	-169.6191932
Olosega C	Olosega	End	-14.18473229	-169.6199205
100 A	Ofu Village	Start	-14.16674607	-169.6820101
100 A	Ofu Village	End	-14.16755676	-169.6819197
100 B	Ofu Village	Start	-14.16936969	-169.6809167
100 B	Ofu Village	End	-14.17019748	-169.6805454
200 A	Airport	Start	-14.1856481	-169.6720762
200 A	Airport	End	-14.18608077	-169.6711851
200 B	Airport	Start	-14.18638989	-169.6695161
200 B	Airport	End	-14.1861702	-169.6703172
200 C	Vaoto	Start	-14.18497469	-169.6658096
200 C	Vaoto	End	-14.18500009	-169.6666678
300	Toaga	Start	-14.17993189	-169.6553384
300	Toaga	End	-14.18056439	-169.6559694
400 A	Toaga	Start	-14.17830949	-169.653213
400 A	Toaga	End	-14.17759567	-169.6529511
400 B	Toaga	Start	-14.17676797	-169.6518202
400 B	Toaga	End	-14.17731011	-169.652553
600	Toaga	Start	-14.1709936	-169.6429225
600	Toaga	End	-14.17140506	-169.6437222