American Samoa Community Based Monitoring Program

Data Assessment and Program Development Workshop

Summary and Recommendations

Dr. Peter Houk

People. Science. Environment.

Pacific Marine Resources Institute

www.pacmares.com

12-16 April 2010

Table of Contents

Introduction – Scope of Report

The American Samoa Department of Marine and Wildlife Resources (DMWR) initiated the Community Based Fisheries Management Program (CBFMP) in 2001, with the goal of assisting Tutuila's villages in identifying traditional management practices to conserve their coral reef resources, and monitoring the effectiveness of resource management activities. The management activities that have been selected by the villages range from complete closure of the coral reef fishery in the nearby coastal waters, to several forms of limited harvest involving seasonal and customary access. Compliance with these locally driven management regimes is based upon traditional leadership, and enforced at the village level. In August 2004 the need for ecological monitoring data to assess trends over time became apparent, and a monitoring program was designed to match the existing expertise that was locally available to conduct scientific monitoring (Musburger 2004). Methodologies included establishing 1 – 3 permanent transect locations within the boundaries of each local management zone. At each station, a re-bar was used to guide the transect placement. Surveys were conducted by lying a 25m transect line along the reef flat at each station, and enumerating the fish, macroinvertebrates, and benthic life forms using standardized methods (Musburger 2004), described below.

Much data has been collected since the inception of monitoring activities, as the program has expanded to include 11 villages where quarterly (i.e., four times a year) monitoring was desired. However, given seasonal changes in oceanographic conditions and varying degrees of oceanic exposure at each site, monitoring was conducted on a less frequent basis for some villages. Currently, much data exists, however a formal assessment of the data for statistical considerations and their ability to answer village-based management questions was never conducted. This situation has led to this collaboration between the Pacific Marine Resources Institute, and the CBFMP program presented here.

Clearly the ability of ecological monitoring data to answer questions with sufficient statistical power to detect change varies with the methods selected for monitoring activities (Weinberg 1981; Houk and van Woesik 2006; Leujak and Ormond 2007). The greatest concern is that data must match a conceptual framework that is defined by question driven monitoring. Such a framework includes:

- *Matching monitoring with questions, here driving questions are:*
    - *What are the trends in harvestable food resources over time?*
    - *What are the relationships between populations of fish and macroinvertebrates and coral reef 'health'?*
    - *Are the community management programs accomplishing their resource conservation goals?*

- *Second, ecological data collection needs to be quantifiable and repeatable for long-term investigation.*

- *Third, there is a need to develop criteria for acceptable levels of statistical power (the probability of accurately detecting change should it occur) based upon human and financial resources available to conduct monitoring.*

While these preliminary concerns seem fundamental in nature, many monitoring programs throughout the Pacific do not match the above noted framework to date (Houk 2009).

This report first presents initial analyses of all of the existing data collected by American Samoa's CBFMP. Specifically, data were examined for their ability to address management questions as well as for their statistical considerations. Subsequently, a summary of the presentations and discussions during the jurisdictional visits is reported. Discussions were held regarding how to improve the monitoring program design and ecological data collection to better address program needs. Third, a collaborative, adaptive monitoring approach was tested at two sites in Vatia bay. This approach aims to provide sound, ecological monitoring that matches the financial, personnel, and scientific expertise available within the program. This effort, and the resultant data, are discussed and compared with existing datasets. Finally, recommendations are made to maintain and improve the long-term CBFMP monitoring program.

Methods and Outline of Data Presentation

Existing data collected since 2004 were assessed for all sites where yearly sampling was conducted and sufficient temporal data existed: Alofau, Amaua & Auto, Aoa, and Vatia. First, summary graphs were generated to examine the estimates of fish density and benthos coverage, and the confidence intervals surrounding the field data. Subsequently, newly collected data from Vatia using a slightly modified technique are similarly presented. Finally, all data are considered for their multivariate properties, given the multivariate nature of ecological data and their change over time.

Because great attention will be given to statistical power it is essential to define. Statistical power is defined as the probability (0 to 100%) that collected datasets will be able to detect a desired level of change in the abundance or density of coral, fish, or invertebrates in question. Power is calculated for individual categories of dependent variables that are user defined, such as "food fish", "Acanthuridae fish", "coral", "*Porites*", or other categories that need to be examined for change over time. Obviously 0% power is not desirable, but 100% is equally unattainable unless sampling effort, defined by the number of transects surveyed at each site, is increased beyond realistic levels. Studies agree that power should be 70% or higher (Brown et al. 2004; Houk and van Woesik 2006; Leujak and Ormond 2007) for detecting a relative 20 – 30 % change in the resource abundance in question. Here power was calculated using the free software R (http://www.r-project.org/), and these estimates led to the identification of the % change that would be detected given the sampling regimes.

While power analyses are useful to examine univariate measures (such as coral or other individual categories describe above), multivariate analyses take the abundances of numerous categories into consideration when determining change over time. For example, multivariate analyses can compare two sites based upon the abundances of *Porites*, *Acropora*, *Favia*, and all other corals encountered in the benthic surveys together. To understand this ecological variation similarity matrices were first generated (PRIMER Software, Clarke and Warwick 2001). These represent cumulative, summed differences in species abundances between each pair of sites. A mathematical summary is below,

$$D_{(y1,\ y2)} = \sum |y_{1j} - y_{2j}| \,/\, \sum (y_{1j} + y_{2j}) \qquad (1)$$

where D is the dissimilarity between sites, Y_1 is the abundance of one coral or fish genus at the first site, and Y_2 is the abundance at the second site. Thus, these matrices transpose multidimensional data into linear distances that can easily be interpreted by managers and biologist alike. Linear distances are viewed using a technique termed multi-dimensional scaling, which shows greater ecological dissimilarities as larger distances between data symbols for each transect surveyed. R-statistics can be calculated to determine the statistical significance between numerous transects from differing stations/sites/islands (Clarke and Warwick 2001).

Summary of Monitoring Datasets

UNIVARIATE CONSIDERATIONS OF FISH ASSEMBLAGES

Fish density data from monitoring sites showed high variability at the individual family level in most instances (Figures 1a-d). Typically, when standard deviations are equal to or greater than 50% of the mean, and sample sizes are lower then n=10 transects, statistical power is lower than desired by the question driven monitoring effort. If error bars are sufficiently low then the calculation of power becomes more relevant (presented later in this section). Here, the high error bars can indicate high variation due to sampling effort (i.e., number of transects), transect location (i.e., how far apart transects are), or inherent variation in the fish assemblages (i.e., the basic ecology of fish assemblages). The general trend of high error bars at the fish family level exists throughout the dataset, but many exceptions exist where low deviations were evident. Through discussions, it is apparent that the goals of the monitoring effort are to reduce these deviation bars to facilitate the detection of change over time and between sites.

Together, the monitoring team first considered the transect placement. These surveys were conducted using transects placed at relative large intervals from each other, often beyond 200m apart. These distances can increase the inherent variation by crossing major habitat boundaries, such as inner and outer portions of the village embayments, that are known to harbor differing fish assemblages, naturally. Beyond transect

Figure 1a-d. Fish density data from 2004 – 2010 community based monitoring program. Data are summarized at the family level, with only the most abundant families shown. One additional category ("food fish") is also presented. Error bars represent standard deviation.

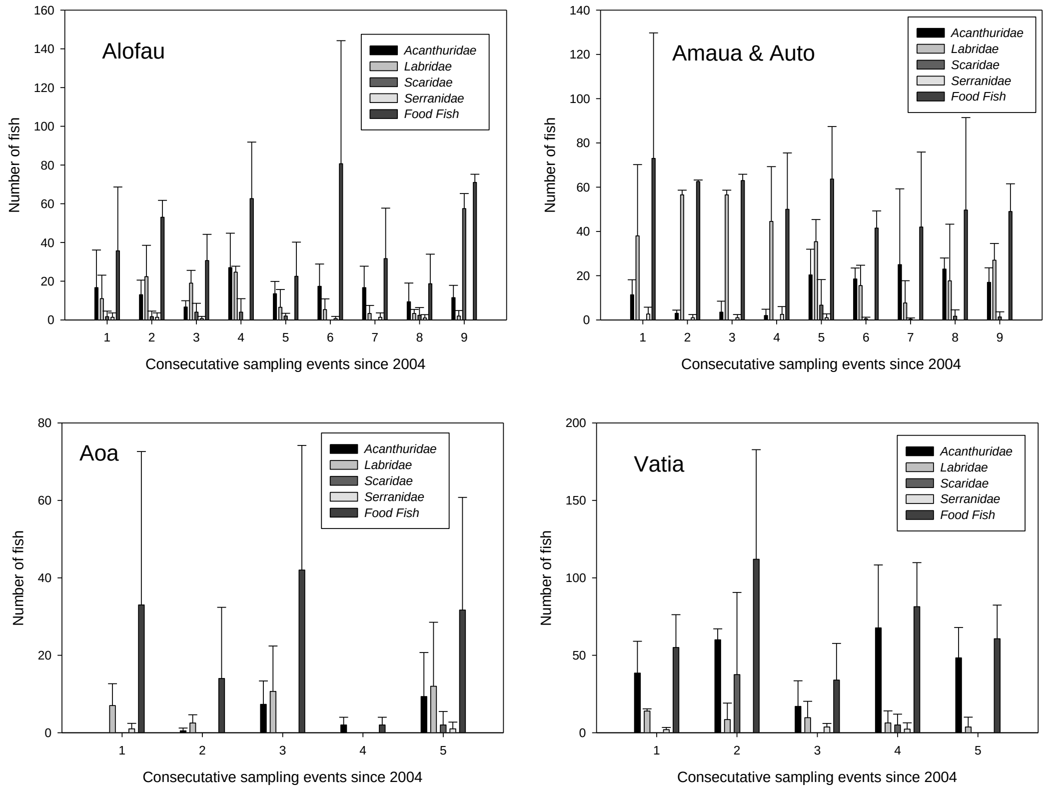
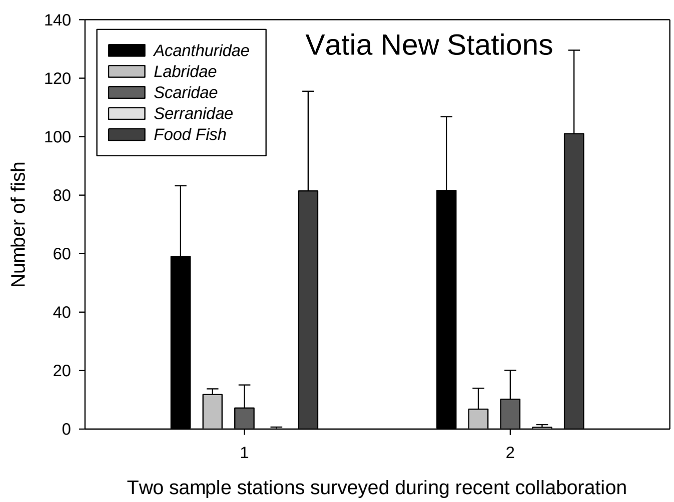


Figure 2. Fish density data from Vatia Bay collected in April 2010 by the community based monitoring program using slightly modified methods (described in report). Data are summarized at the family level, with only the most abundant families shown. One additional category ("food fish") is also presented. Error bars represent standard deviation.

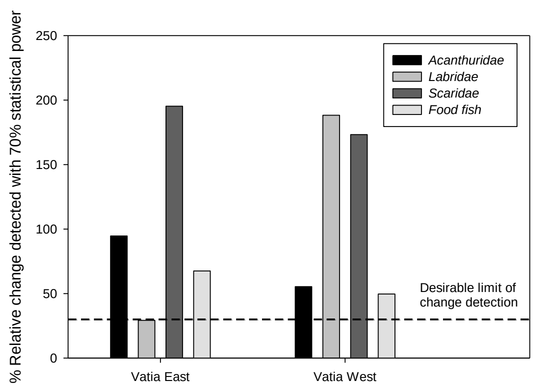


placement, statistical considerations can be improved by: 1) increasing the number of replicate transects at each station, 2) increasing the transect length for all replicates, and/or 3) increasing the amount of data collected on each transect (i.e., increase the width of transect).

In reconciliation, discussions were centered upon improving abundance estimates by employing a site-based design with increased replication. The modified approach increased the number of replicate 25m survey transects from n=3 to n=5 at each site, and placed the transects together within a single 'habitat' (defined by observations of satellite imagery and local knowledge). In comparison to the existing datasets, the modified approach reduced the standard deviations surrounding fish density estimates to a level where the calculation of statistical power became desirable (Figure 2). Power varied by fish family and site (Figure 3). Generally, the typically acceptable criteria of gathering data with an ability to detect a relative 30% change in fish density at the family level was not attained, despite much improvement in comparison with existing datasets.

Discussed in the recommendation section, it appears that the next logical step would be to conduct surveys at each location two times a year, and pool these annual data to yield a total of n=10 transects, and re-assess the situation, and adapt accordingly if necessary. However, multivariate considerations of the dataset must also be considered.

Figure 3. Statistical power calculations for three main fish families and a grouped, food fish category, based upon surveys conducted at Vatia Bay during the workshop. The dashed line represents typically acceptable criteria for detecting a relative 30% change in resource abundance.



MULTIVARIATE CONSIDERATIONS OF FISH ASSEMBLAGES

Multivariate analyses of the existing, long-term database indicate substantial variation at the individual site level (Figure 4a). The strong intermixing of different symbols on the graph indicated that no clear trends are apparent, and further statistical tests are not needed. The resource manager is left with two basic options when viewing these data. Either: 1) there are no differences in fish densities at all of the sites throughout all of the years, or 2) the data have a lot of inherent variation in them so that any site-level difference, or changes over the years, are masked to some degree. While it is entirely possible for both to be relevant, the univariate analyses presented above strongly indicate that these data have high inherent variation as a result of the disconnected placement of transects at each site.

Figure 4a. Multi-dimensional scaling plot showing the differences between fish assemblage similarities among the transects surveyed at each location (see methods for description).

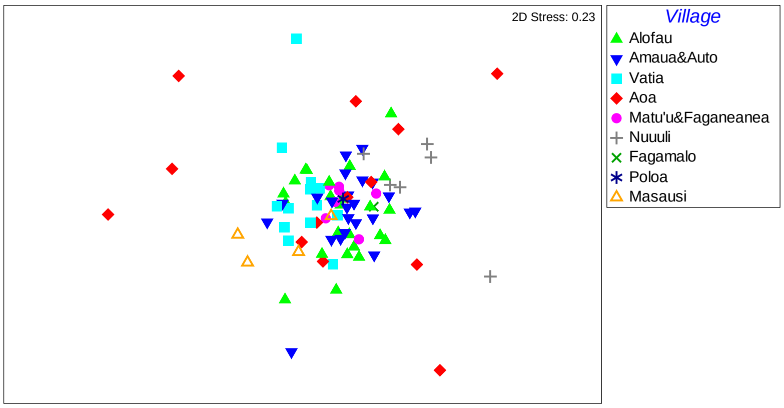
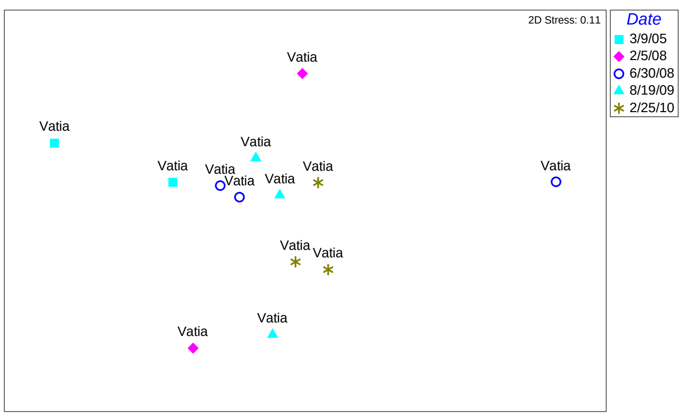


Figure 4b. Multi-dimensional scaling plot showing the differences between fish assemblage similarities at Vatia from 2005 to 2010 (see methods for description).



Similarly, when investigating change over time at any individual site no clear trends emerge (Figure 4b). Again, this may indicate high inherent variation in the data, as suggested above by the univariate analyses, but may also suggest that fish densities have not changed over time. Multivariate analyses of the data collected using the refined methodology, with higher transect replication, is not yet appropriate. Once sufficient data exists it will be pertinent to conduct these analyses, and provide more insight into whether or not the data collection techniques are addressing monitoring questions. One relevant example to this workshop is a similar dataset that was collected from Pohnpei (Houk 2009). The Pohnpei dataset had similar levels of statistical confidence as reported by the modified methods used here when univariate measures were considered. The univariate data showed no significant difference between sites inside of no-take protected areas, and reference locations. However, the multivariate properties of the dataset were extremely useful. The multivariate data from Pohnpei found clear, significant relationships that described more fish **outside**, compared with **inside** the no-take area. After further socioeconomic surveys, this awkward finding was the result of a strong social mis-understanding (Houk 2009). For American Samoa, it will be relevant to re-assess the multivariate properties of the fish datasets once sufficient sampling has been conducted.

UNIVARIATE CONSIDERATIONS OF BENTHIC ASSEMBLAGES

Existing benthic assemblage data were collected with limited taxonomic resolution, using grouped categories for all corals, macroalgae, and coralline algae. Similar to the fish data, high standard deviation bars existed, and are probable causes of irregular transect placement, limited replication, and also inherent variation in the benthic assemblages (Figure 5a-d). In reconciliation, discussions were centered upon improving the abundance estimates by testing a site-based design with increased replication. The modified approach, also described above, increased the number of replicate 25m survey transects from n=3 to n=5 at each site, and placed the transects together within a single 'habitat' (defined by observations of satellite imagery and local knowledge). In addition, a photo-quadrat technique for collecting and analyzing benthic data was introduced. Along each 25m transect line a photo-quadrat was taken at every 1m mark, and analyzed using the Coral Reef Point Count software (http://www.nova.edu/ocean/cpce/). This method decreased user bias and increased taxonomic resolution (i.e., genus level for all corals and macroalgae).

In comparison to the existing datasets, the modified approach reduced the standard deviations surrounding major benthic categories to a level where the calculation of statistical power was desired (Figure 6). Power varied by benthic category and site (Figure 7). Generally, the typically acceptable criteria of gathering data with an ability to detect a relative 30% change in benthos abundance at the functional level was not attained, despite much improvement in comparison with existing datasets.

Discussed in the recommendation section, it appears that the next logical step would be to conduct surveys at each location two times a year, and pool these annual data to yield a total of n=10 transects, and re-assess the situation, and adapt accordingly if necessary. However, multivariate considerations of the dataset must also be evaluated.

MULTIVARIATE CONSIDERATIONS OF BENTHIC ASSEMBLAGES

Multivariate analyses of the existing, long-term database indicate substantial variation at the individual site level (Figure 8a). The strong intermixing of different symbols on the graph indicated that no clear trends are apparent, and further statistical tests for significance are not relevant. Similar to the fish assemblage dataset, the resource manager is left with two basic options when viewing these data. Either: 1) there are no differences in benthic assemblages at all of the sites throughout all of the years, or 2) the data have a lot of inherent variation in them so that any site-level difference, or changes over the years, are masked to some degree. Similarly, no clear trends in benthic assemblages emerged at any individual site over the past 5-6 years based upon the long-term data that was collected (Figure 8b). It seems most probable that these data have

Figure 5a-d. Benthic assemblage percent cover data from 2004 – 2010 community based monitoring program. Data were summarized for major categories used (see text for more details). Error bars represent standard deviation.

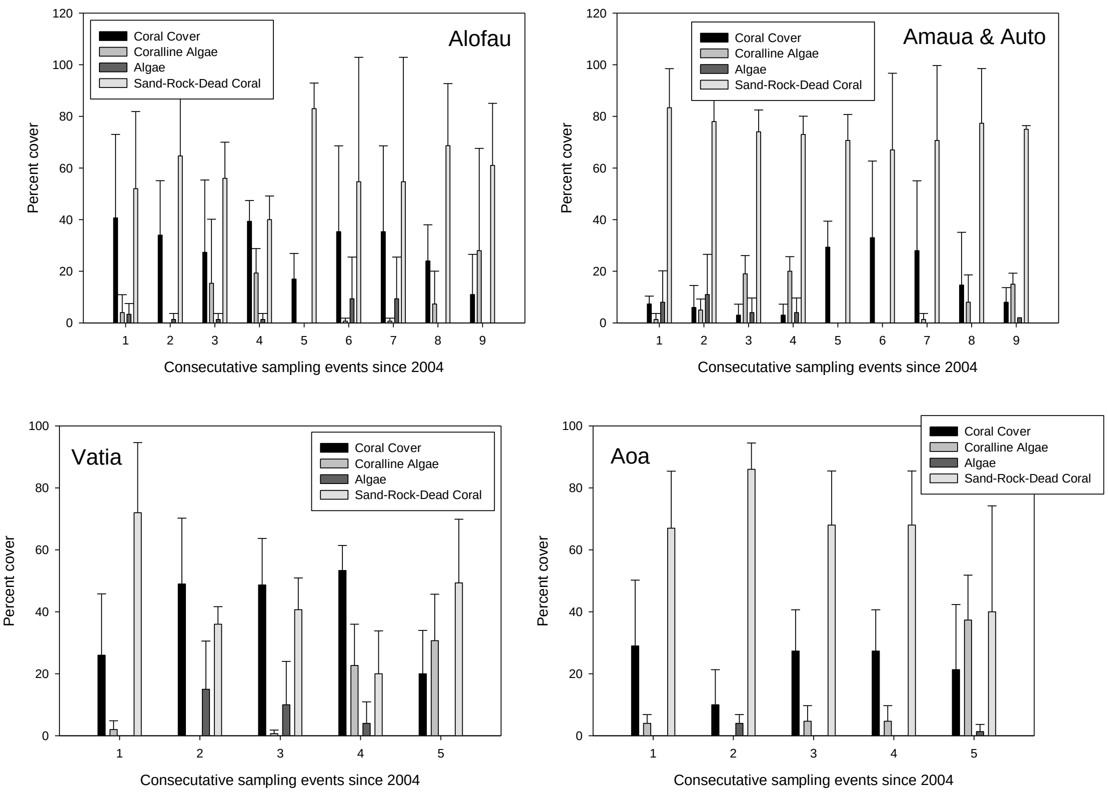


Figure 6. Benthic density data from Vatia Bay collected in April 2010 by the community based monitoring program using slightly modified methods (described in report). Data are summarized at a functional level, with only the most abundant categories shown, however increase taxonomic resolution was used (i.e., genus level for all corals and macroalgae). Error bars represent standard deviation.

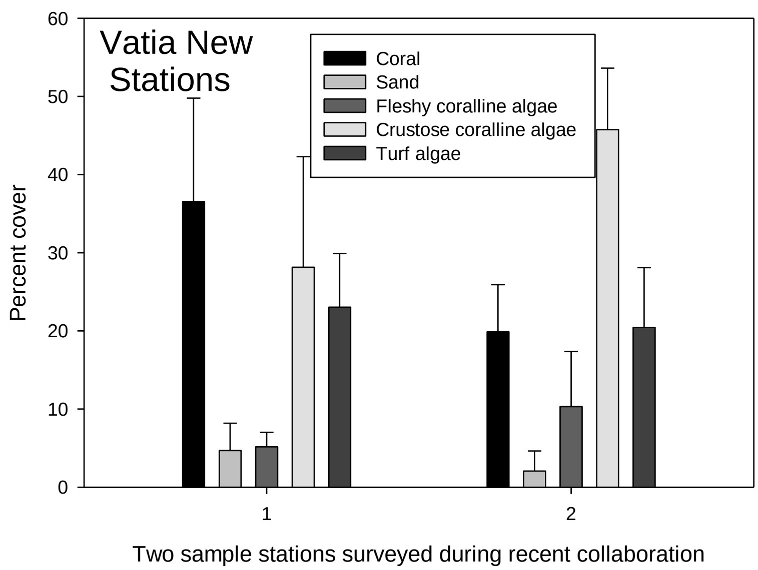


Figure 7. Statistical power calculations for three main fish benthic categories based upon surveys conducted at Vatia Bay during the workshop. The dashed line represents typically acceptable criteria for detecting a relative 30% change in resource abundance.

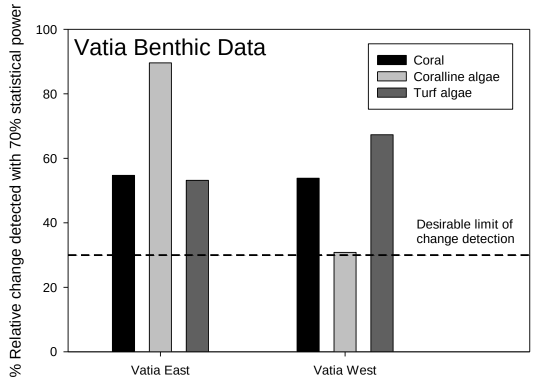


Figure 8a. Multi-dimensional scaling plot showing the differences between benthic assemblage similarities among the transects surveyed at each location (see methods for description).

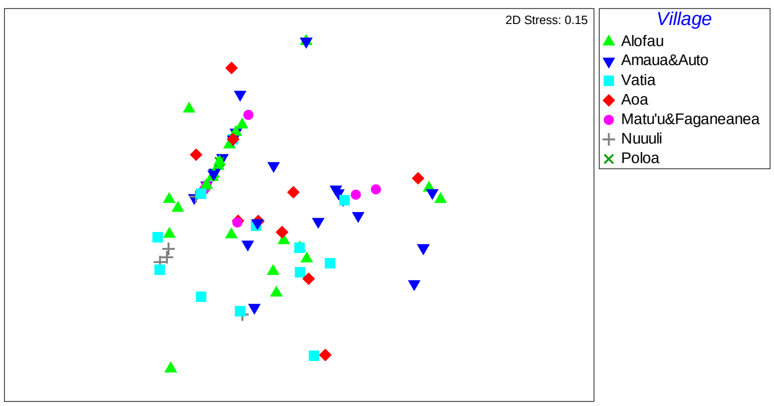


Figure 8b. Multi-dimensional scaling plot showing the differences between benthic assemblage similarities at Alofau from 2004 to 2010 (see methods for description).

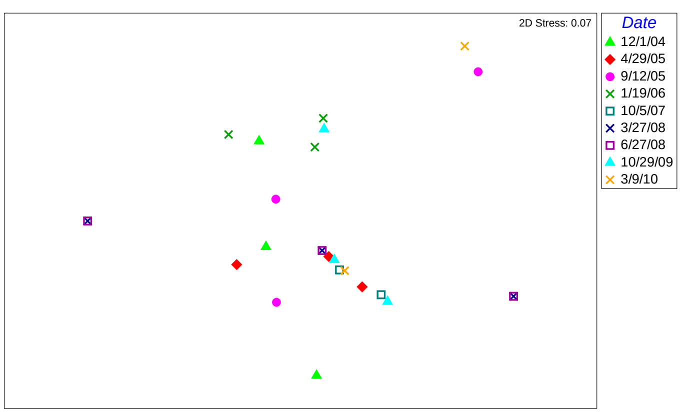
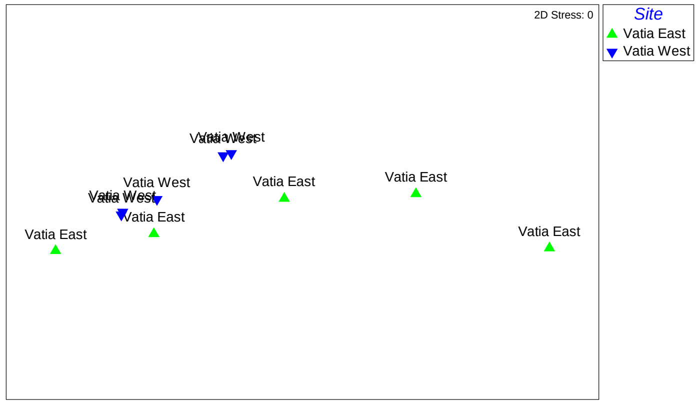


Figure 8c. Multi-dimensional scaling plot showing the differences between benthic assemblage similarities at Vatia from surveys conducted along with this workshop in 2010 (see methods for description).



high inherent variation as a result of the disconnected placement of transects at each site, as clear improvements are noted from newly collected data (described below). Also, Houk and Musburger (2008) show strong differences in benthic assemblages for reef slope assemblages between sites and over time, using both a univariate and multivariate approach.

Using the newly collected data from two sites in Vatia (the east and west side of the embayment), with the modified benthic data collection techniques described, multivariate investigations were conducted. Despite the sites being located in the same embayment, and having strong similarities between their coral, algae, and other invertebrate species occurrances, as expected, there were notable differences in their finescale relative abundances (Figure 8c). The clustered nature of the "Vatia West" symbols in the figure indicate lower evenness, or that the percent cover of benthic organisms is dominated by one, or a few, categories as compared with "Vatia East". This is one common trend for benthic assemblages under increasing pollution loads (De'ath and Fabricius 2010), suggesting the western site may be exposed to poorer water quality, as compared to the east. While these are only initial, non-significant trends, it is clear that the multivariate properties of the dataset are will be beneficial to determine site-level differences and change over time. These considerations are furthered in the recommendations below.

MACROINVERTEBRATE ASSEMBLAGES

In all instances macroinvertebrate abundances were extremely low, furthering common findings from numerous studies and monitoring efforts around the territory. Based upon low densities, no formal assessment was relevant for the existing datasets. If community-based program goals change and wish to consider macroinvertebrate resources, an alternative sampling design would need to be discussed and created, that greatly expands the scale of investigation. However, considering the ease of data collection along the transect line based surveys introduced above, it is recommend to continue to collect these data as future population dynamics will always be unknown.

Conclusions and Recommendations

The development of American Samoa's CBFMP over the past 4-5 years has provided sufficient data upon which goals can be measures and future directions can be determined. During its existence, numerous staff have been trained in coral reef monitoring, data collection and entry, and basic applied management strategies. This is the foundation required to sustain a long-term program. However, one aspect of the program that has received less attention is the visualization and analyses of existing datasets to ensure that field data are matching management questions. This is not surprising and is commonly encountered in many, multi-year coral monitoring programs throughout the Pacific (Houk 2009). This workshop specifically examined the study design and data collection techniques, and together the American Samoa CBFMP staff and the technical support provided by the Pacific Marine Resources Institute have recommended an adaptive approach to improve monitoring. The adaptive framework discussed herein is focused at improving the resolution at the 'station' or 'individual site' level to account for the statistical variance that is of interest, detecting change over time in localized resources pertinent to the villages. The discussed framework is:

1) *Select sites in each partner village that is interested in participating. Use a scale of one site per kilometer of coastline. Based upon satellite imagery, this translates to only one site in each of the existing villages, except the larger Vatia Bay, where two sites have already been established. This represents a standard 10:1 ratio for ecological monitoring to account for variation in populations that occurs due to shifting spatial scales (Levin 1992).*

2) *Whenever possible, establish monitoring location(s) on the reef crest, shallow water coral assemblages, 1-3m below the water. Because this reef zone can often be accompanied with large waves, monitoring will have to be dependent upon ideal oceanographic conditions for several locations. The reef flat habitat is a suitable alternative if calm oceanographic conditions do not merge with available monitoring timeframes.*

3) *Based upon the initial test monitoring conducted for two stations in Vatia Bay it is recommended to visit each monitoring station twice a year. While benthic data might only need to be collected once based upon multivariate considerations, it is clear that fish density estimates will benefit from bi-annual data collection, increasing the sample sizes to account for inherent variation, and improving statistical considerations.*

4) *Conduct in-water monitoring using a slightly modified technique consisting of:*

    a. *5 x 25m transects laid at a 2-4m depth on the outer reef crest whenever available (or reef flat as an alternative).*
    b. *Benthic data collection using photo quadrats taken at each 1m interval, analyzed with "Pointcount" computer software with the adapted code-file*

for American Samoa. This program overlays 5 data points for each photo and allows the user to choose the benthos category. Coral, algae, and other commonly found invertebrates are identified to the genus level while less common invertebrates and substrate fall into grouped categories (i.e., crustose coralline algae, sponges, turf algae).

c. *Fish density of target fish families estimated along each transect line, 5m to each side. These data, along with macroinvertebrates are easier to collect and process, so repeating surveys at each station bi-annually is desirable.*
d. *Macroinvertebrate data collection for edible sea cucumbers, shells, and urchins, along each transect line, 2m to each side.*

With regards to in-water methodologies the noted parameters and techniques were tested during jurisdictional visits for only two stations. Based upon these results, the above noted criteria were recommended. Clearly, once more data is collected they should again be analyzed to ensure they are meeting the program goals, and any adaptations, if needed, should be made.

FUTURE DIRECTIONS FOR MONITORING PROGRAM

The recent collaboration and technical assistance with the American Samoa CBFMP represent a positive step for the program to judge their current progress and future needs. In the opinion of the author, the existence of a strong, dedicated program indicates success in the initial years of the community-based program development. Similar with many programs throughout the Pacific, an improved scientific foundation is desirable. It is logical that monitoring efforts continue to build upon the existing knowledge-base presented here. Some specific, next steps include:

1) Improved taxonomic identification skills development through coral, algae, and/or fish identification workshops. These should be conducted once every 2 years to ensure the transfer and stability of knowledge. These will aid with benthic data collection and improve the data accuracy.
2) Consider estimating fish sizes, as well as densities, along the survey transects. This would require a training and calibration of the users (i.e., the fish counters) with known values. Standard techniques are readily available for consideration and integration with local expertise.
3) Continue jurisdictional monitoring program collaboration with scientific expertise. Specifically, the next steps are to provide jurisdictional staff with data management and analyses training. There are some relevant regional efforts in the planning stages, however typically limited slots are available for each jurisdiction.
4) Building into the future, once statistically sound datasets are available for in-depth analyses, collaborations with regional graduate level educational centers should be initiated. This might consist of supporting key jurisdictional staff while they complete graduate degrees with relevant data, or foster relationships with existing research programs focused upon the driving questions each jurisdiction have.

In American Samoa, several MPA efforts are currently underway, with implementation ranging from the local to the federal level (NOAA 2010). One unique attribute of the community-based program is the positive relationship with the local villages. Clearly, local support is needed for optimal success in MPA efforts (Walmsley and White 2003), as the high coastal population density on Tutuila suggests high human interactions with the coral reef and fish assemblages that are traditionally owned. It will be pertinent for all MPA efforts to continue to collaborate in their design, implementation, and evaluation phases. Opportunities such as the Two Samoa's Initiative (NOAA 2010) have the ability to provide improved technical resources for all existing efforts, but in turn, rely upon local partners to foster relationships with community-based management activities. Together, the numerous programs are all plausible vectors for improved monitoring, data collection, and data analyses.

References Cited

Brown, E., Cox, E., Jokiel, P., Rodgers, K., Smith, W., Tissot, B., Coles, S.L., Hultquist, J. (2004). Development of benthic sampling methods for the coral reef assessment and monitoring program in Hawai‘i. Pac. Sci. 58:145-158.

Houk, P., van Woesik, R. (2006) Coral reef benthic video surveys facilitate long-term monitoring in the Commonwealth of the Northern Mariana Islands: toward an optimal sampling strategy. Pac. Sci. 60:177-189.

Houk, P., Musburger, C. (2008). Assessing the effects of non-point source pollution on American Samoa's coral reef communities. *Technical Report submitted to the American Samoa Environmental Protection Agency, Tutuila, American Samoa*. 45pp.

Houk, P. (2009). Assessment of ecological datasets and recommendations for monitoring programs to assess the effectiveness of the Micronesian Challenge. *Technical Report submitted to the Micronesian Conservation Trust.* Kolonia, Pohnpei. 40pp. (http://www.pacmares.com/resources/PMRI_MCT2009.pdf)

Leujak, W., Ormond, R.F.G. (2007). Comparative accuracy and efficiency of six coral community survey methods. J. Exp. Mar. Biol. Ecol. 351:168–187.

Levin, S. (1992). The problem of pattern and scale in ecology: the Robert H. MacArthur award lecture. Ecology 73:1943-1967.

Musburger, C. (2004). Monitoring recommendations for the community-based fisheries management program of Tutuila, American Samoa. *Technical Report submitted to the Department of Marine and Wildlife Resources, Tutuila, American Samoa*. 45pp.

National Oceanic and Atmospheric Administration Center for Coastal Monitoring and Assessment, Biogeography Branch. (2010). Biogeographic assessment of Samoa: In support of the Two Samoas Initiative. *Technical Report for jurisdictional partner.* 13pp. (http://ccma.nos.noaa.gov/ecosystems/coralreef/samoa_wp_jan2010.pdf)

Walmsley, S.F., White, A.T. (2003). Influence of social, management and enforcement factors on the long-term ecological effects of marine sanctuaries. Env. Conserv. 30:388-407.

Weinberg, S. (1981). A comparison of coral reef survey methods. Bijdr. Dierk. 51:199–218.