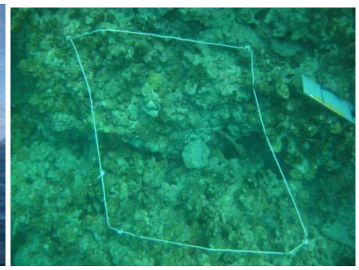
Assessment of Ecological Datasets and Recommendations for Monitoring Programs to Assess the Effectiveness of the Micronesian Challenge

Republic of the Marshall Island and the Federated States of Micronesia





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Executive Summary:

Statistically-sound science is required to assess the status of regional and local management efforts ranging from community-based marine protected areas to expansive networks defined by the Micronesian Challenge. This report summarizes the contemporary ecological datasets that are currently available throughout the Republic of the Marshall Islands (RMI), and each of the Federated States of Micronesia (FSM). Jurisdictional site visits were conducted between May and July 2009. In each instance: 1) all available ecological datasets were collected, 2) discussions were held regarding how scientific monitoring can address pressing management questions, 3) ecological monitoring designs were discussed and evaluated, 4) preliminary analyses were conducted and presented to relevant agencies and individuals, and 5) monitoring was conducted at one site using standardized methodologies encompassing criteria highlighted by Micronesia's *effective monitoring workshop*.

Existing datasets varied is scope and nature by jurisdiction however generalities existed. The majority of benthic datasets, that serve to estimate the abundances of corals, algae, and other sessile invertebrates, were collected at lower taxonomic resolution than required by the pressing management questions being asked, with varying degrees of statistical power. Using the foundation provided by previous regional workshops on coral taxonomy, a simplified photo-quadrat technique was introduced with accompanying software that provides for genus-level identification of dominant benthos. Further, this software generates excel-based datasets that are easy to enter into long-term databases. Fish and macroinvertebrate data consistently showed high variation when examined for each target species separately, however when combined for multivariate consideration significant patterns often emerged, providing enhanced 'statistical resolution' of these datasets. Despite these generalities, jurisdictions have unique strengths and weaknesses with their current monitoring efforts, discussed within. This report was created for monitoring programs and managers, and thus, each dataset is presented as a case study highlighting analysis decisions in a step-by-step manner.

The jurisdictional visits, as well as data collection and analyses efforts, represent a positive step for monitoring programs to judge their current progress and future needs. It is imperative that regional efforts continue to build upon the existing knowledge-base presented here. Logical next steps include addition database, management, and analysis training for the monitoring programs. In some cases continued collaboration with field data collection may be desirable as well; specifically with regards to coral population assessments, benthic data, and indicator fish estimates. Pertinent for all monitoring programs throughout Micronesia, including Palau, Guam and the CNMI, is to foster a more collaborative relationship within the region. This will enable programs to examine rates of change in pertinent ecological metrics (fish, corals, invertebrates) in accordance with management and policy, and more efficiently understand their resource status.

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Introduction – Scope of Report

Since the launching of the Micronesia Challenge (MC),a shared commitment by the Chief Executives of the U.S. Commonwealth of the Northern Mariana Islands (CNMI), the Federated States of Micronesia (FSM), the Republic of the Marshall Islands (RMI), the Republic of Palau (ROP), and the U.S. Territory of Guam, to effectively conserve at least 30% of the near-shore marine resources and 20% of the terrestrial resources across Micronesia by 2020, coral reef monitoring and management programs throughout Micronesia have attracted much needed funding and global attention. Despite having common goals of protecting their resources for future generations, jurisdictions throughout Micronesia strongly differ in their approach used to monitor coral reefs, and thus, in the information that is available for managers to act upon. This is, in part, due to unequal funding distributed throughout the region matching political status rather than resource abundances or ecological value. Additionally, differing scientific viewpoints and personnel capacity throughout the region account for large inconsistencies in the science that is available as well. Clearly, management and policy need sound science to serve as a foundation for actions and decisions. Recently, the 5 political jurisdictions of Micronesia have begun to try and address these issues, under the framework of the Micronesia Challenge. In June 2008, the newly formed MC Measures Working Group identified the need to develop an appropriate framework to assist monitoring programs in each of the jurisdictions to track their progress both locally and regionally in effectively managing their resources for sustainable use. The measures group recommended several key ecological attributes that monitoring should consider. For coral reefs these mainly include: benthic substrate coverage, size-class and species composition of corals, density and size classes of fish, abundances of macroinvertebrates, and locations of fish spawning aggregations. However, this report first takes a more rudimentary approach by considering survey designs and the specific questions that are being addressed prior to moving into in-situ monitoring methods.

Currently, monitoring throughout Micronesia ranges from reef-check surveys conducted by governmental and recreational divers in Kosrae, to seven-year programs supporting multiple trained biologists in the Commonwealth of the Northern Mariana Islands and Palau. Accordingly the questions being answered, statistical power to detect change, and the precision of the data differ considerably (Houk and van Woesik, 2006; Waddell and Clarke, 2008), presented herein. The greatest concern for the region and the MC movement is that data collection efforts have a similar conceptual framework:

- First and foremost, there is a strong need to ensure that scientific monitoring is addressing pertinent management questions; specifically that the survey designs match questions.
- Second, monitoring needs to be quantifiable and repeatable for future investigation to compare change over time with.
- 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 this report describes several jurisdiction and international monitoring efforts alike that do not match the desirable framework outlined above.

Herein, contemporary ecological datasets are presented, evaluated, and discussed from the Republic of the Marshall Islands (RMI), and each of the Federated States of Micronesia (FSM). Between May and July 2009, site visits to each jurisdiction were conducted by the author. During each visit all available ecological datasets were collected, discussions were held regarding how to specifically address relevant management questions, ecological monitoring designs were discussed, monitoring was conducted at least one site, and preliminary analyses were conducted together with relevant agencies and individuals. This report first evaluates the contemporary datasets; assessing them for statistical power and their ability to answer priority questions. Next, the report aims to highlight where inconsistencies were found between management needs and the science available to address them. Finally, the report aims to present a unified framework for understanding jurisdictional questions through sound, ecological monitoring that matches the financial, personnel, and expertise available on the islands. The scope of this work was limited to the RMI and FSM in Micronesia. Relatively, the CNMI, Guam, and Palau currently have more scientific and financial resources available to assist with their monitoring programs, and are thus in a position to assess the effectiveness of their MC internally. This work aimed to bring additional resources to where they are needed most.

Summary and Assessment of Datasets:

Throughout the RMI and FSM there have been numerous local, regional, and international monitoring programs collecting ecological and biological data. These encompass state and community-based programs as well as regional National Oceanic and Atmospheric Administration (NOAA) monitoring and international Secretariat of the Pacific Communities (SPC) finfish monitoring. While most programs are specific to each jurisdiction, and will be presented and discussed accordingly, some programs span across the entire study region (i.e., the SPC finfish monitoring). For this large-scale monitoring effort the data are presented together below for the entire region.

In each instance, datasets are analyzed for three main points of consideration: 1) what questions does the data aim to answer, 2) were the data collected in a repeatable manner so that trends can be established in the future, and 3) what was the statistical confidence achieved during the surveys. Because great attention will be given to statistical confidence, similarly known as 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. Obviously 0% power is not desirable, but 100% is equally unattainable unless sampling effort 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 Ormond2007) 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/).

SPC Finfish Monitoring in FSM and RMI

During the site visits data were collected from SPC's finfish resource assessments in the RMI and FSM. The locations of the surveys were Yyin and Riiken (Yap), Piis-Panewu and Romanum (Chuuk), Likiep, Ailuk, Arno, and Majuro (Marshall Islands). No citations are yet available for this work as only preliminary reports were available. However, datasets were graciously made available for the purposes of this assessment.

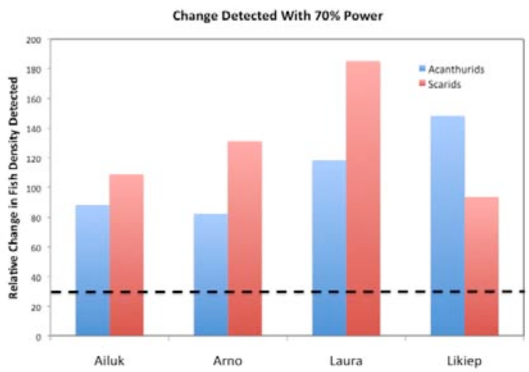
Briefly, finfish datasets were collected by SPC, often in coordination with island-based resource management staff, to detect changes among different islands, sites, and reeftypes. In the Marshall Islands four atolls were selected for surveying, and three reeftypes within each atoll were examined. In Yap and Chuuk, two sites were selected on the main islands of each state. At each atoll/site, sampling was conducted at numerous stations from each habitat type. At each station there were two replicate transects. Along each transect, fish population assessments were collected using belt-transects and/or modified stationary point counts.

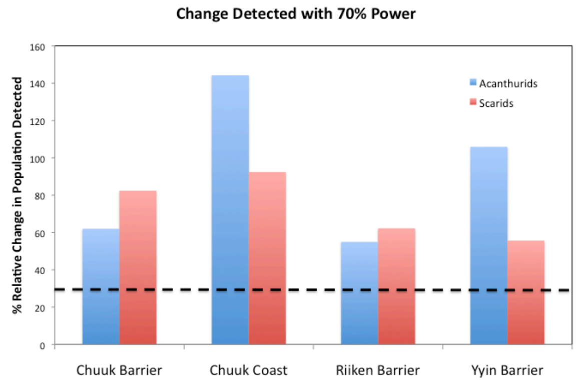
Table depicting the survey design used in the SPC finfish surveys.

Island	Site/atoll	Reeftype	Number of Stations	Number of Transects
Marshall Islands	Likiep	Outer	6	2
Marshall Islands	Likiep	Back	8	2
Marshall Islands	Likiep	Intermediate - Patch	6	2
Marshall Islands	Ailuk	Outer	6	2
Marshall Islands	Ailuk	Back	7	2
Marshall Islands	Ailuk	Intermediate - Patch	6	2
Marshall Islands	Majuro - Laura	Outer	6	2
Marshall Islands	Majuro - Laura	Back	6	2
Marshall Islands	Majuro - Laura	Intermediate - Patch	6	2
Marshall Islands	Arno	Outer	6	2
Marshall Islands	Arno	Back	6	2
Marshall Islands	Arno	Intermediate - Patch	6	2
Yap	Riiken	Inshore	6	2
Yap	Riiken	Intermediate - Patch	4	2
Yap	Riiken	Back	9	2
Yap	Riiken	Outer	6	2
Yap	Yyin	Back	12	2
Yap	Yyin	Outer	12	2

While the preliminary report does not yet contain a completed introduction and methods section stating what the driving questions behind the research were, one can make educated guesses based upon the data collection design. It appears there is a desire to detect change between each site/atoll in each reeftype surveyed. For example, statistical power should be sufficient to see a 20-30% relative change in parrotfish abundances along the outer reefs at Ailuk atoll. However, the two graphs below depict that only relative changes of >50% were discernable from the surveys at each atoll/site for two common fish families, the surgeon and parrotfish. Thus, while being repeatable, it appears the design of the data collection suffers from too much ecological variation between the stations surveyed, despite being in the same 'reeftype' classification.

Figures show what percentage of change in the fish density and biomass were detected. In all instances the level of change detected did not meet limits that are typically targeted in many monitoring programs (dashed black line). Data used in producing these graphs were from one atoll/site and one reeftype (outer reefs), respectively.





To better understand the variation between each monitoring station multivariate analyses were used (PRIMER Software, Clarke and Warwick 2001). Briefly, these analyses compare two sites based upon similarities in the abundances and densities of **all** species of fish recorded, simultaneously. The cumulative, summed differences in species abundances between each pair of sites results in the generation of 'similarity matrices'. These matrices transpose multidimensional data into linear distances that can easily be interpreted. 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.

Figure shows multivariate differences in fish abundances at the four atoll outer reefs surveyed in the Marshall Islands. The figure shows considerable overlap between different atolls (R-Statistic = 0.12, a non-significant value). This suggests that: 1) either the fish abundances are not significantly different from differing atolls, or 2) there is too much variation in the data between each station to detect differences at the island level.

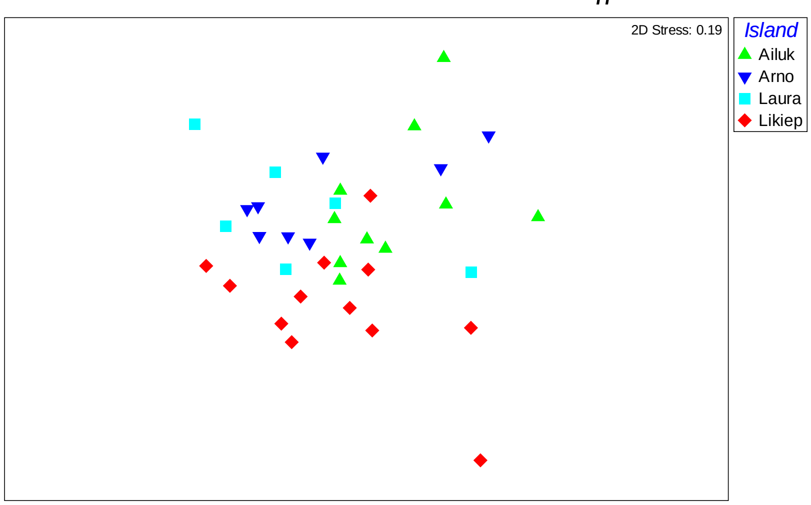
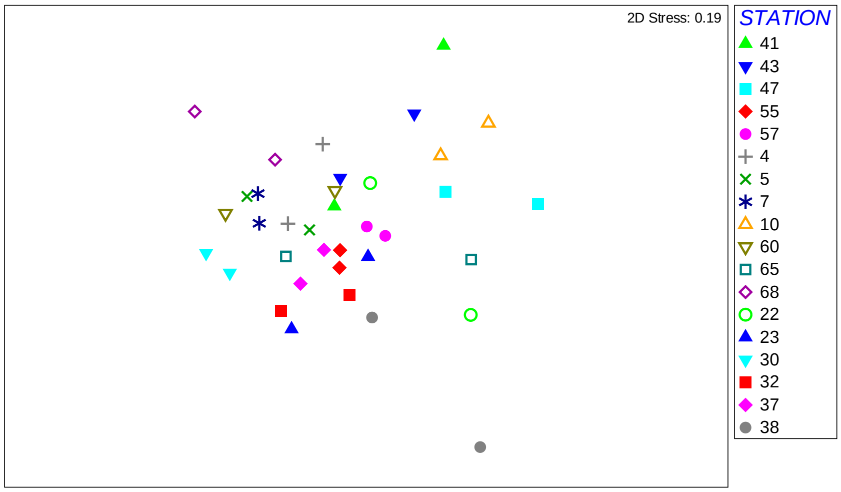


Figure below depicts the exact same dataset for all four atoll outer reefs, except, in this instance the data are grouped by station (n=2 transects at each station). In this case the global R-statistic is significant (0.49) confirming that much more of the variation in the fish assemblages can be explained by stations, and combining data from multiple stations introduces undesirable variation for detecting change over time.



The combined results of the power and multivariate analyses suggest that efforts might be best spent trying to characterize fish assemblages at the individual site-level, and not grouping entire islands into a single analysis. In order to increase the statistical power at each site one would have to one or more of the following: 1) increase the number of replicate transects at each station, 2) increase the transect length for all replicates, and/or 3) increase the amount of data collected on each transect (i.e., increase the width of transect).

MARSHALL ISLANDS MONITORING DATA SUMMARIES

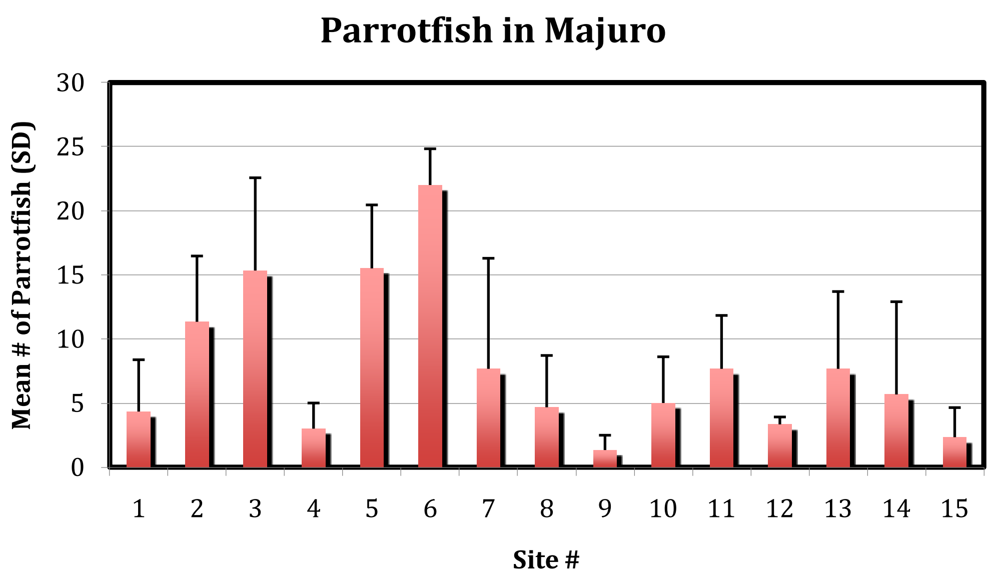
In comparison to other FSM islands, the RMI has had the most extensive coral and fish survey work conducted from a large variety of governmental/non-governmental organizations, often in partnerships. Because of the overwhelming number of atolls and associated coral reef environments, most work to date has been conducted through rapid ecological assessments (REA's). REA's work has been coordinated by the local college as well by off-island scientists in partnerships with the college and the resource management agencies. This has resulted in the beneficial documentation of species diversity for many groups of corals and reef associated fish, invertebrates, and algae (Pince 2004, Marshall Islands Natural Resource Assessment Team 2001). Probably due to personnel, funding, and time limitations, the outcome of the REA surveys have been less rigorous from a quantitative ecological standpoint, whereby the ability of the data to examine change over time is somewhat limiting. As one example, the fish dataset from a Majuro REA in November 2004 are discussed below (Pinca 2004).

The 2004 monitoring effort in Majuro aimed to use experts as well as trained governmental and community representatives to learn about the current status of Majuro's reef fish population (Pinca 2004). Three 50m transects were placed at each station and observers counted the fish along 2.5m of both sides of the transect. Three passes were conducted for each transect line, counting the largest, medium, and smallest fish size classes, respectively. Benthic coverage was estimated using the point-intercept technique (i.e., noting the benthos underneath the transect at each 50 cm interval). Invertebrates were counted along the transects using a similar 2.5 m width on each side of the line. Finally, corals were identified and binned according to size classes in belts along the transects as well.

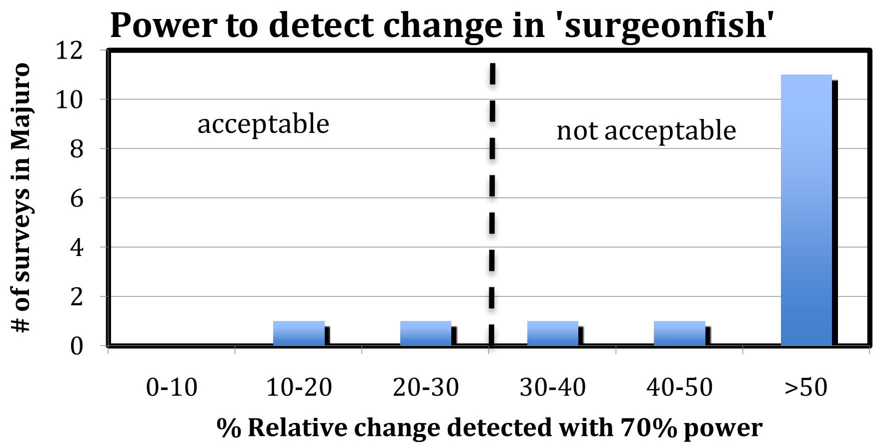
Here, this report focuses upon the results of the fish surveys, as benthic data collected in the exact same fashion are discussed in the 'Kosrae' section of the report, the coral size-class data were not available, and the invert data collected in a similar fashion are discussed in the 'Chuuk' section of this report.

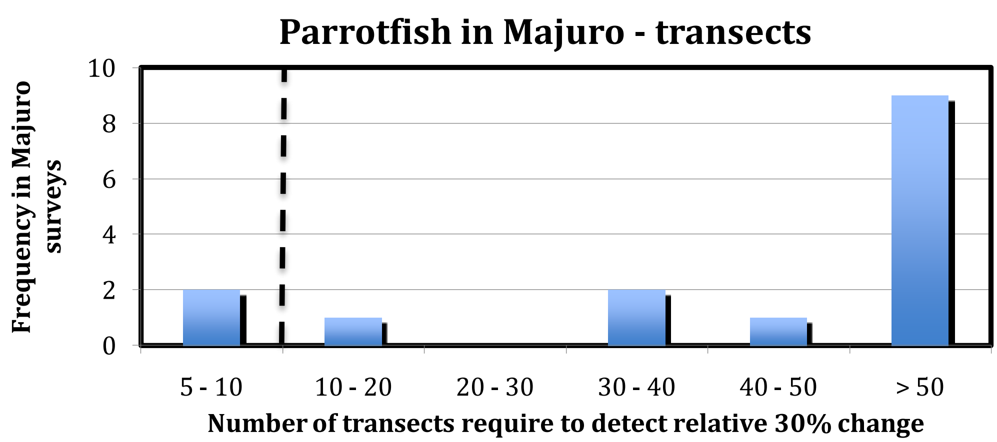
It appears the goals of the fish surveys were to gather sufficient data to record a baseline and gain the ability to detect change over time at varying reef sectors, however the data are first examined at the site level.

Figure shows the mean number of parrotfish at each site and the standard deviation (SD) bars. One initial indicator of statistical power that is easy to examine are SD bars, typically for sample sizes <10 transects (or other units of replication) these should be less than ½ of the mean. Here, one can see initial concerns with the relatively high SD bars.



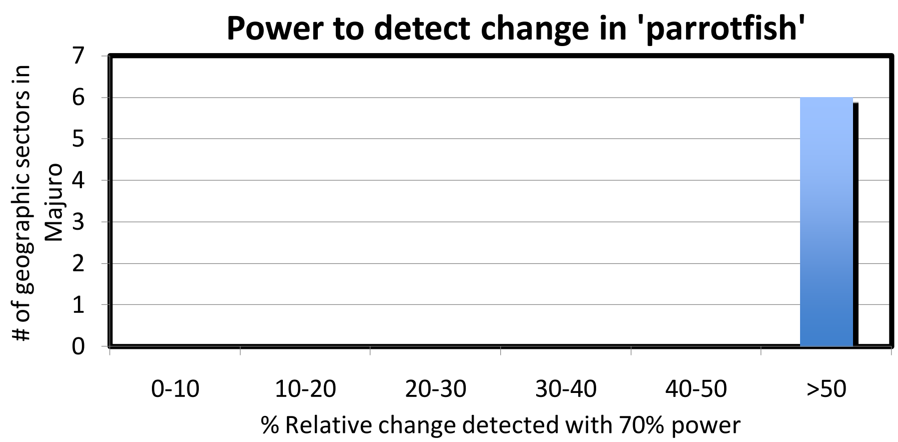
Figures below show how many sites (vertical axis) could successfully detected at least a 30% relative change (horizontal axis) in fish abundance (top graph) and how much work (i.e., how many transects) would be required to detect change with 70% power at the individual sites surveyed (bottom graph).

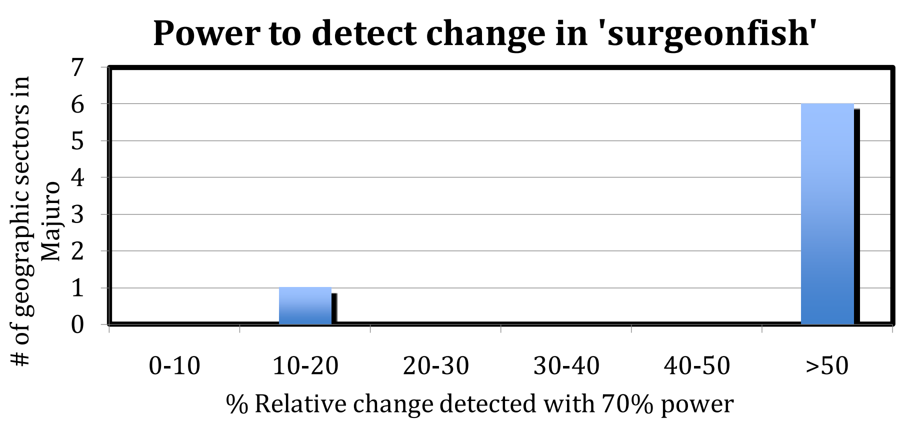




In accordance with the overall monitoring goals, statistical power is now analyzed by combining sites in accordance with geographic location (Lagoon NE patch reefs, etc.) to detect change over time for the two most abundant fish families (parrotfish and surgeonfish).

Figures below show the resultant statistical power for Majuro fish surveys once data are combined by geographical sector. In the case of parrotfish (top graph), none of the geographic sectors had sufficient statistical power to detect a relative 30% or greater change with sufficient power. For surgeonfish, one 1 sector had sufficient power.





The results of the Majuro REA fish surveys support the findings described earlier for the SPC surveys, namely that the majority of variance in fish assemblages and abundances occurs inbetween sites. Combining sites and transect to the level of geographic sectors actually resulted in a reduction of power and thus, a reduced ability to understand change over time here. It appears that site-based questions might be employed to best understand change over time. Else, sample sizes would need to be substantially increased within each sector. To improve power at individual sites one could: 1) increase the number of replicate transects at each station, 2) increase the transect length for all replicates, and/or

3) increase the amount of data collected on each transect (i.e., increase the width of transect).

Similar REA surveys have been conducted for Likiep, Mili, Namu, Rongelap, any perhaps others that this report is not aware of. It was not realistic to analyze all of these datasets for statistical power and their ability to address the various questions that can be answered, however, in each instance similar designs and methodologies have been taken. In summary, REA surveys fill a much-needed gap to bring initial information to resource managers and monitoring programs. It is essential for contemporary monitoring programs to build from these initial investigations, but caution must be used when selecting survey designs and in-water monitoring techniques. Long-term programs aimed at detecting change over time at specific sites are desirable but require a different framework as compared with the REA surveys.

Currently, local resource management agencies (Marshall Islands Marine Resources and Marshall Islands Conservation Society) are involved in community-integrated monitoring at several locations around Majuro, and potentially expanding to some of the outer atolls in the near future. Considering that these programs are site specific and are aimed at examining change over time, care should be taken to ensure that their designs and methods match the questions. The final section of this report describes a universal framework to long-term monitoring that was tested on each island, what the initial results were, and describes how it might be applied to each jurisdictional monitoring program that the author was introduced to.

KOSRAE MONITORING DATA SUMMARIES

Governmental and private sector monitoring efforts have had a long history on Kosrae compared with all other islands visited. The most extensive datasets come from reef check surveys (www.reefcheck.org) conducted by the Kosrae Marine Resources and a mixed private/volunteer group based out of the Village Hotel. These surveys have been ongoing since the late 1990’s. More recently, monitoring using line intercept transects has begun at two inner reef sites associated with popular recreational areas for the public by the Kosrae Conservation and Safety Office. In addition, catch data from two marina’s has been recorded during the past year or so.

Reef Check Dataset

The modified reef check surveys used by Kosrae consists of recording the benthic lifeforms under the transect line at 50cm intervals, along 5 x 20m transect lines. Surveys have been conducted at ~20 locations with sample frequencies ranging from bi-annually to every 2 years. Here, the benthic datasets are extensively examined. In addition, fish abundances have also been recorded along belt transects. Fish belt transects have been describe for the Marshall Islands, and are extensively described for Pohnpei and Yap. Because the techniques for conducting fish surveys are more intensive for the other islands (i.e., the transect lines are longer and replication is similar), it is assumed that results and discussions are comparable.

In a similar manner described above with the Marshall Islands fish data, the first graph examined here shows the average coral cover at nine monitoring sites on Kosrae, accompanied by standard deviation (SD) bars. Because the estimates of coral cover have low SD's associated with them, it becomes desirable to examine statistical power.

Figure below shows average coral cover on Kosrae at nine sites and SD bars. Initial inspection reveals that the SD's were often lower than ½ the means, and thus power for detecting change in coral cover should be further examined.

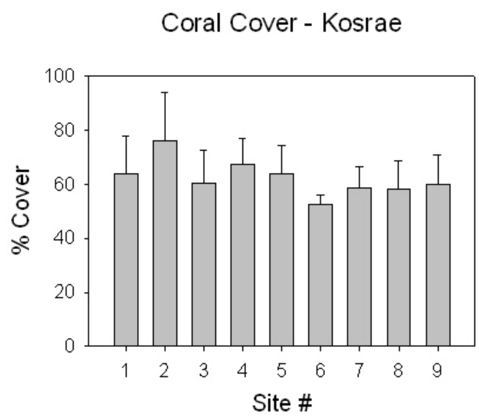
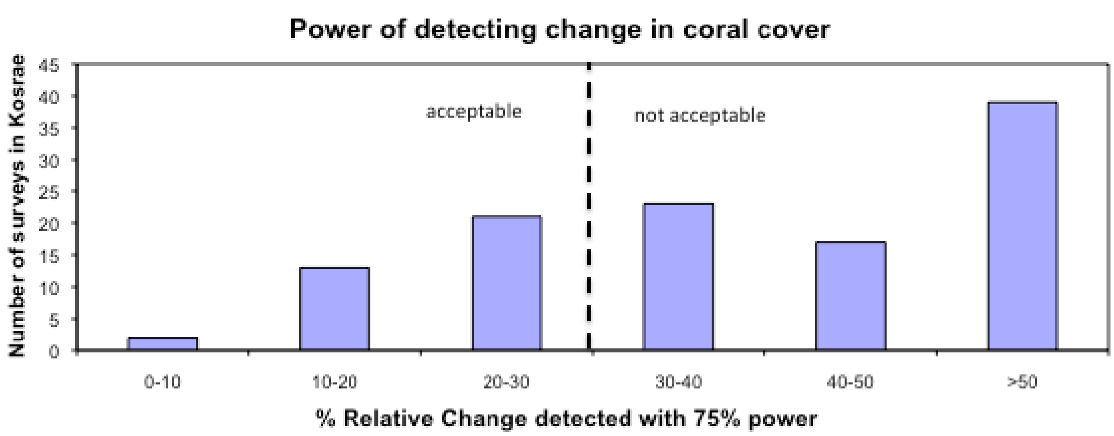


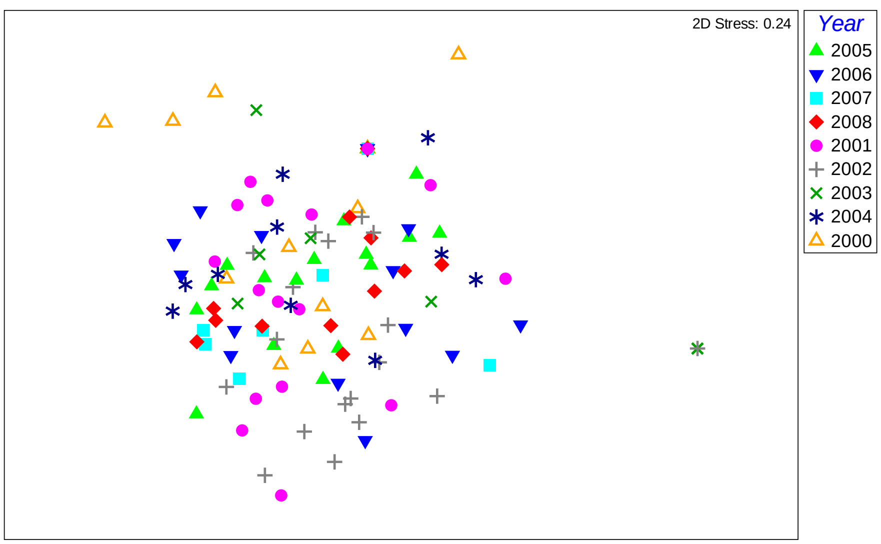
Figure below shows the resultant statistical power of detecting change in coral cover from surveys conducted in Kosrae from the late 1990's until the present. For the majority of surveys the resultant level of change detected was higher than typically acceptable levels descried in the introduction. However, in many instances less than 30% relative change was detected.



While these initial results are mixed for the monitoring program's success in meeting their desired goals of detecting change at the site level, it is imperative to move beyond just coral cover. Many studies show that coral cover is highly variable over time (Connell et al. 1997), being strongly dependant upon the timing, extent, and nature of recent disturbances. Houk and van Woesik (2009) support this and further show that estimates of community evenness or other measure of diversity are better suited for understanding changes in the 'integrity' of coral assemblages. The reef check data do not allow for these analyses because corals were only described in two categories (Acropora or non-Acropora), and not by individual genus or species. However, the benthic data are multivariate in nature, consisting of abundance of corals, turf algae, coralline algae, dead coral, etc., at each site. In accordance, it is appropriate to examine if any structure exists in the multivariate dataset despite the limited benthic categories used. Described above in the section discussing the SPC-Finfish dataset from FSM, multivariate analyses were again used here (PRIMER Software, Clarke and Warwick 2001). Summarizing again, these analyses compare two sites based upon similarities in abundances and densities of **all** benthic categories, simultaneously. The cumulative, summed differences in species abundances between sites result in similarity matrices that give linear distances between samples. These linear distances are viewed using a technique termed multi-dimensional scaling, which shows greater ecological dissimilarities as distances between the data points is larger on the plot below. R-statistics are calculated to determine the statistical significance between numerous sites from differing islands.

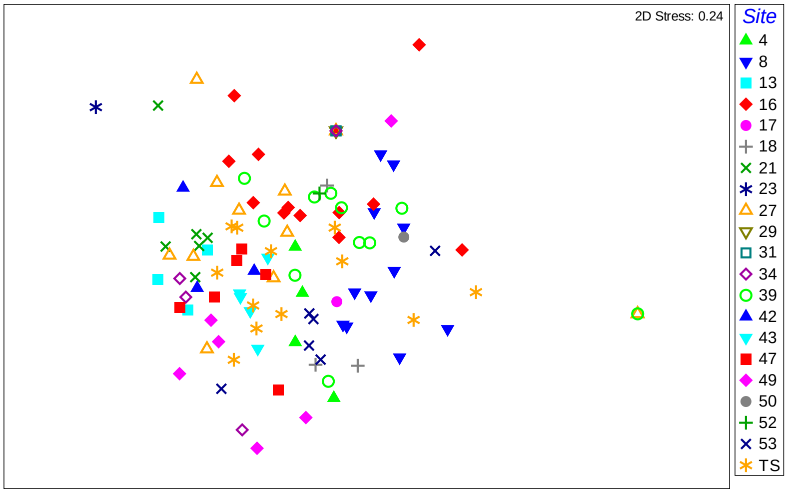
Initially the Kosrae benthic data were combined for the entire island, and examined on a yearly basis.

Figure below shows very little structure apparent in the MDS plot that examines differences in benthic assemblages of Kosrae (sites grouped) throughout the years. In accordance with the lack of visual structure, the R-Statistic is low and not significant (0.15).



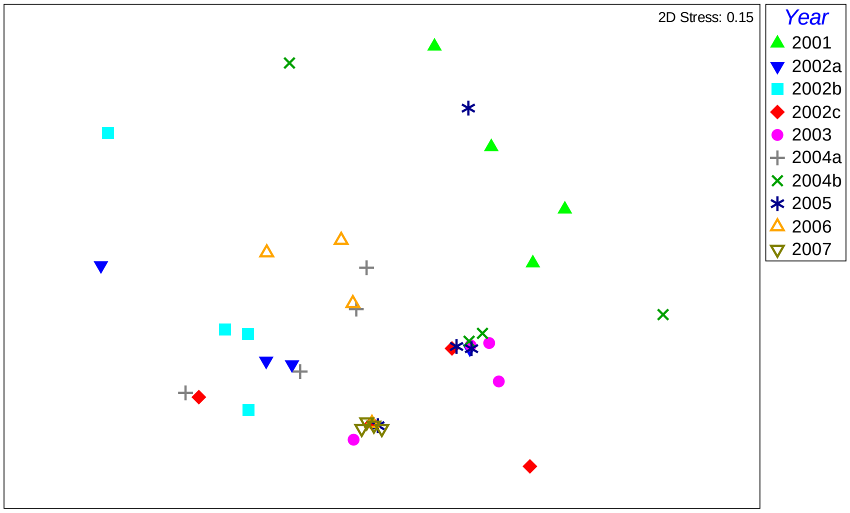
Although the data show no differences among the different survey years, this may be an artifact of grouping all of the sites together. To examine site-based differences the data are next grouped for all years, and the sites are compared with each other.

Figure below shows a bit more structure in the resultant MDS plot when the data were examined at the site level. Yet still, there is a lot of unexplained variation and a non-significant R-statistic (0.33) was found.



The initial conclusions are that these data are best examined at the site level, but there may be too much variation that is resultant from combining datasets from all of the survey years. The final examination presented isolated upon only one site (#8) and looks for significant differences between years.

Figure below shows an MDS plot depicting the changes in the benthic assemblage at site 8 between 2001 and 2007. Overall the findings are not significant (R-statistic = 0.35), however significant differences (R-statistic = 0.73) were found between the benthic assemblage in 2001 (green triangles) and the remaining years.



Examining the data further reveals those differences are mostly attributed to the high occurrence of 'DCO' in the reef check dataset in 2001, or dead coral. Either there was a disturbance prior to 2001 and recovery was just beginning, or observer bias occurred (the surveyors between the different years used different classifications for the coral framework). This is suggested because only in the year 2001 was 'DCO' recorded on any datasheet.

Regardless of the cause, the long-term dataset here is notable for its ability to detect changes in coral cover at individual sites with relatively high statistical power. However, the benthos classification scheme does not provide sufficient characterization of the coral and algae assemblages to examine yearly difference further and approach an understanding of the causes of change over time, a desired result for monitoring to eventually be able to accomplish.

Working together with resource management agencies and collaborators on Kosrae benthic data were collected using a modified point-quadrat technique, data were analyzed, and presented at the end of this report.

Marina Fish Catch Dataset

In order to improve upon the understanding of Kosrae's fisheries resources the Kosrae Conservation and Safety Organization (non-governmental organization) worked closely with governmental staff situated at each of the boat marinas. The marina employees were asked to record the numbers of fish caught by family on a daily basis. While these data did not include size-class estimations, and thus can't estimate total amount of fish landed, they are very useful for understanding the dynamics of the nearshore reef fishery, and planning future fishery monitoring and management efforts. The most complete datasets comes from the Okat marina from March to December 2008, or 10 months during 2008.

Initial inspection of the dataset shows a large increase, nearly a doubling, of the fish landings during the months associated with calm oceanographic conditions (July – November). Additionally, there is a smaller, secondary trend showing anomalously high landings during the spring and fall (May and September). To better understand these preliminary findings, fish landings are next examined by family. The second graph clearly shows that general trends noted above do not hold for all fish families examined. While some families show the dual trends noted above, that fish catches increase with calm months and show dual peaks in the spring and fall, others have very unique landing records. Fish landings have been previously associated with spawning seasons (Rhodes and Tupper 2006), during which catch rates increase. Here, the trends for emperors, parrots, grouper, and sweetlips suggest that two peak spawning events may be evident (spring and fall), however exact months differ for each family. In contrast, the unicorn fish (*Naso unicornis*) and rabbitfish show peak catch rates in October and March, accordingly. While the goal of this report is to evaluate the datasets, and not to analyze causation in the trends, it becomes clear how useful catch data can be for understanding fisheries and planning monitoring and management.

Figure below shows the landings of all fish grouped together for each month surveys were conducted in 2008. There is a large, notable increasing trend associated with calm oceanographic conditions (July – November), and a smaller trend showing two anomalously high peaks in the spring and fall.

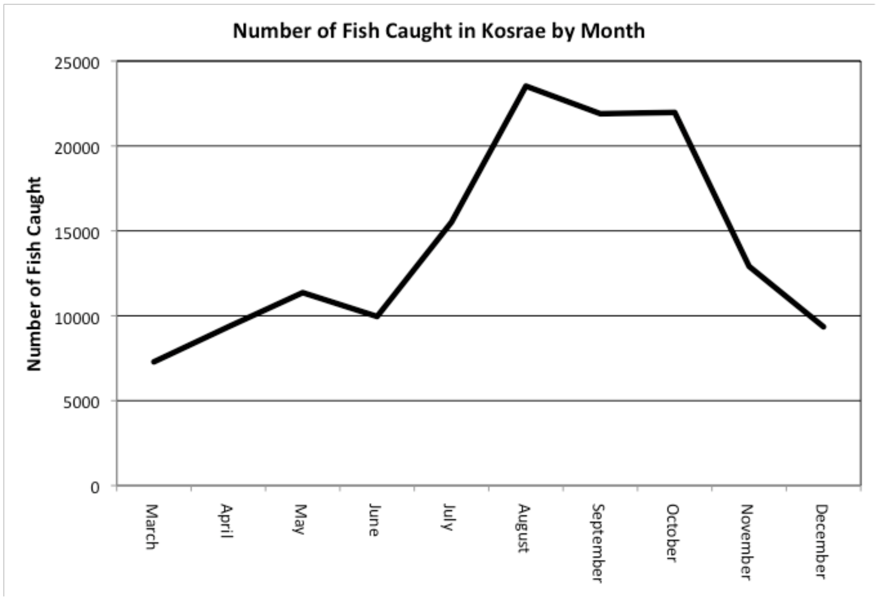
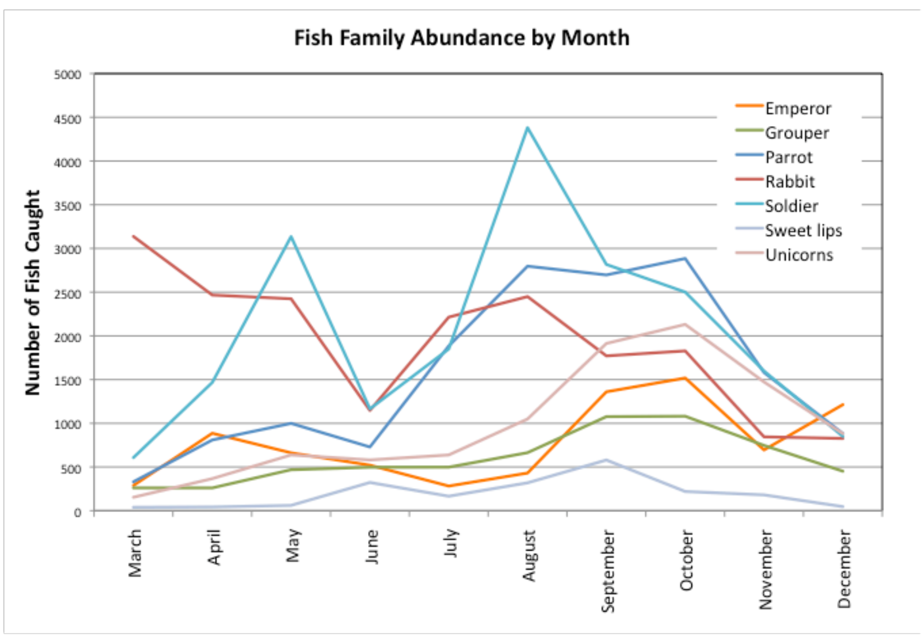


Figure below shows landings of fish by family for Okat marina in 2008. It appears that trends might be related to spawning cycles of the various fish families, representing very informative data for management to consider.



It is strongly recommended to continue and enhance the marina catch data statistics by recording and weighing individual fish, rather than just tallying them. This will enable Kosrae to address pressing questions in a repeatable manner: 1) to determine trends in the sizes of fish that are being caught, 2) determine trends in catch-per-unit-effort, and 3) determine the effectiveness of management and policy aimed at keeping fisheries sustainable. Future data collection efforts would need to evaluate the statistical power associate with catch statistics to ensure that data collection efforts match requirements for determining rates of change over time.

Accompanied with in-water fish monitoring surveys, these complimentary datasets would best serve to evaluate the effectiveness of the Micronesian Challenge, as well as other management and policy, for fisheries resources. The most extensive in-water fish survey data was found for Pohnpei and is described in the next section.

Line Intercept-Transect Data

Recently, line-intercept transect data have been collected by the KCSO to evaluate trends at two inshore reef sites that are popular for recreational activities, and may represent future desirable MPA locations (UBR and TMPA). Although not presented in detail due to their limited temporal nature (only 1 year of data exists), these data were evaluated. In both instances the data were found to incorporate desirable levels of statistical power; >70% power for the majority of survey events when detecting a relative 30% change in the dominant coral *Porites*. Suggestions were made with KCSO to consider switching benthic data collection to the point-quadrat technique described in the Chuuk section of this report for simpler data analyses and database generation purposes only, as automated software was presented to the organization to aid the process. Additionally, statistical power shows improvement with the recommended point-quadrat process.

POHNPEI MONITORING DATA SUMMARIES

Among all of the jurisdictions visited Pohnpei has the greatest number of concurrent monitoring programs. Ongoing programs include MPA, long-term, community-based, and sedimentation monitoring, as well as infrequent trochus and sea cucumber assessments. These programs represent unified efforts between governmental agencies and the Conservation Society of Pohnpei (CSP) (non-governmental). Pertinent attributes of each program are discussed below, however, it is clear that long-term planning for these agencies must strive to focus efforts where they are most needed, and not spread limited resources too thinly.

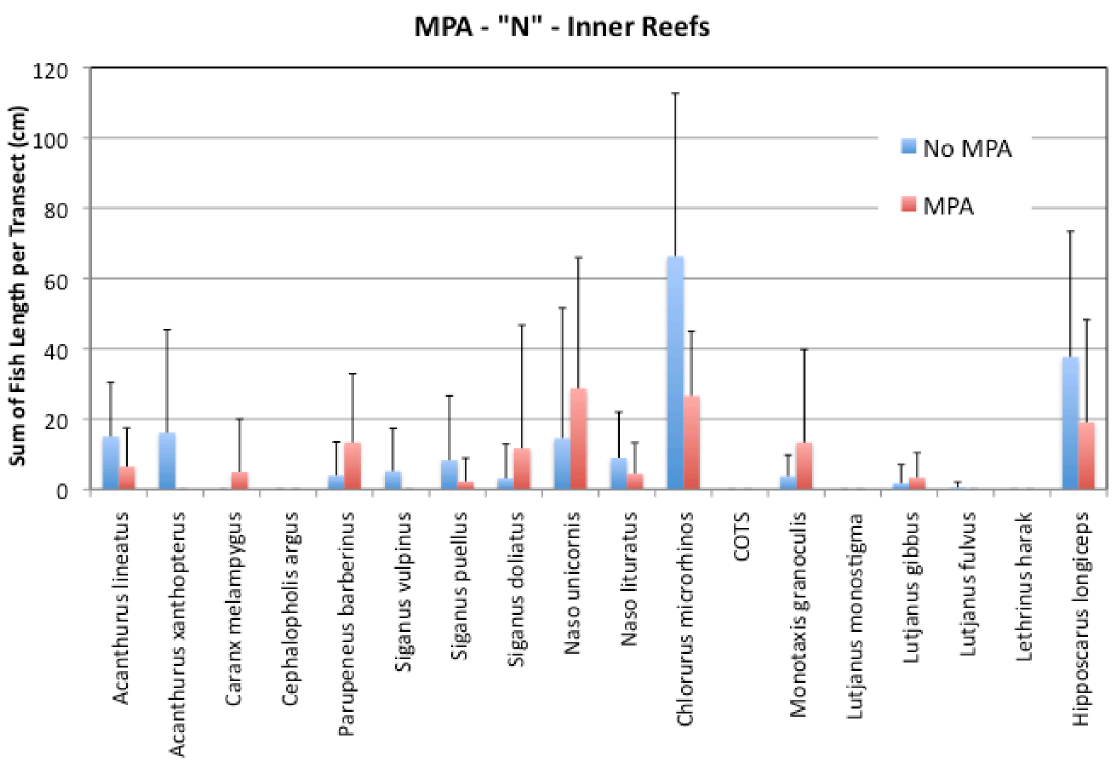
MPA and Long-Term Monitoring

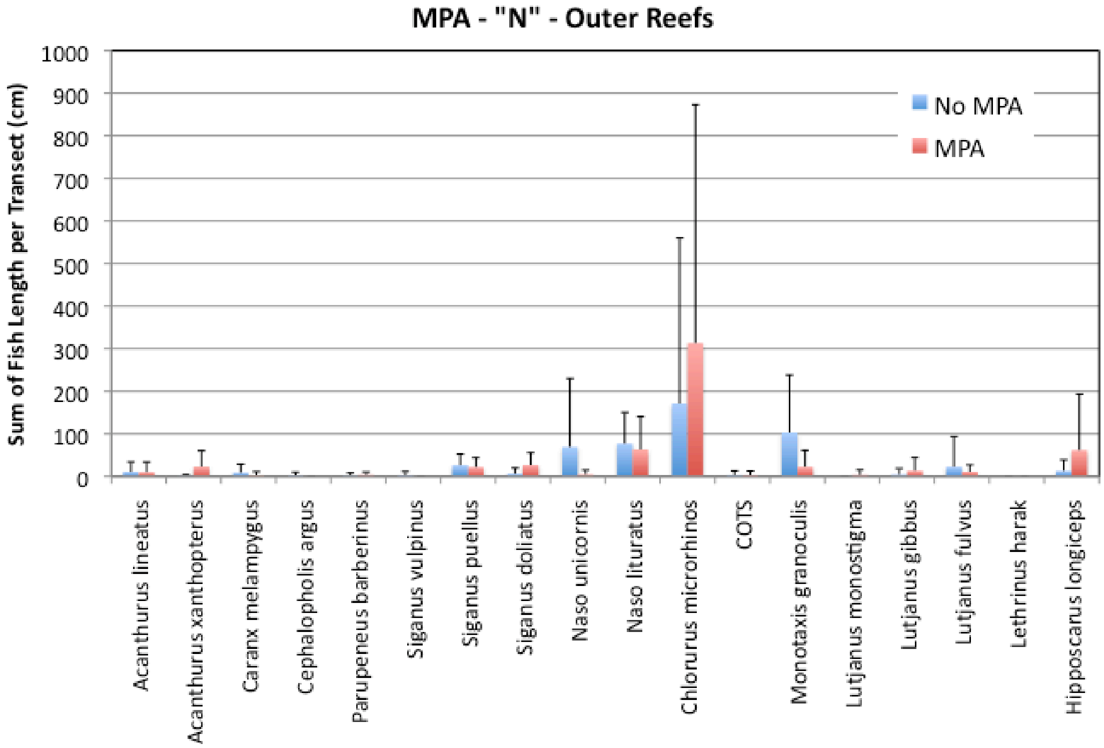
Over the past several years benthic and fish monitoring have been conducted for five MPA's selected by communities in conjunction with the CSP. For simplistic reasons the five MPA's will be designated by the first letters of the village/hamlet; M, D, K, L, and N. Benthic data were collected using similar protocols described in the Kosrae section of this report. Because they were fully assessed there, and because there is mounting support to shift to the point-quadrat techniques described at the end of this report, no further analyses were conducted. Because the fish dataset represents the most extensive effort in the region, this assessment focuses upon them, and how well (statistically) they can assess effectiveness of MPA's.

Abundances of 17 indicator fish were estimated along 5 x 50m transects at two inner and outer reefs within each MPA. For comparative purposes, reference sites were also established for each MPA, both inner and outer reefs. Initial analyses of the data showed similar statistical power surrounding the data within each MPA, thus presentations are limited to several aspects of one representative example in each case. In all instances the standard deviation bars surrounding species abundance estimates were large, suggesting that desirable levels of statistical power were not met at the individual species level.

These initial results for highly mobile fish species are not surprising. Similar findings were also presented for the SPC-finfish dataset above. However, monitoring programs must consider the distribution of the population(s) that are being surveyed, and these initial analyses represent an integral first step towards gaining much needed insight. The most obvious ways to improve upon estimates (i.e., lower the SD bars) are to: 1) increase the width surveyed from 2.5m on each side of the transect line to 5m, and 2) increase the number of times per year observations of fish abundance are recorded from once per site to twice.

Figure below shows averaged total fish lengths (a proxy for biomass) and standard deviations for the indicator fish species of "N" MPA, inner (top graph) and outer (bottom graph) reefs.





MPA - "N" - Outer Reefs
Sum of Fish Length per Transect (cm)
1000
900
800
700
600
500
400
300
200
100
0
No MPA
MPA
Acanthurus lineatus
Acanthurus xanthopterus
Caranx melampygus
Cephalopholis argus
Parupeneus barberinus
Siganus vulpinus
Siganus puellus
Siganus doliatus
Naso unicornis
Naso lituratus
Chlorurus microrhinos
COTS
Monotaxis granoculis
Lutjanus monostigma
Lutjanus gibbus
Lutjanus fulvus
Lethrinus harak
Hipposcarus longiceps

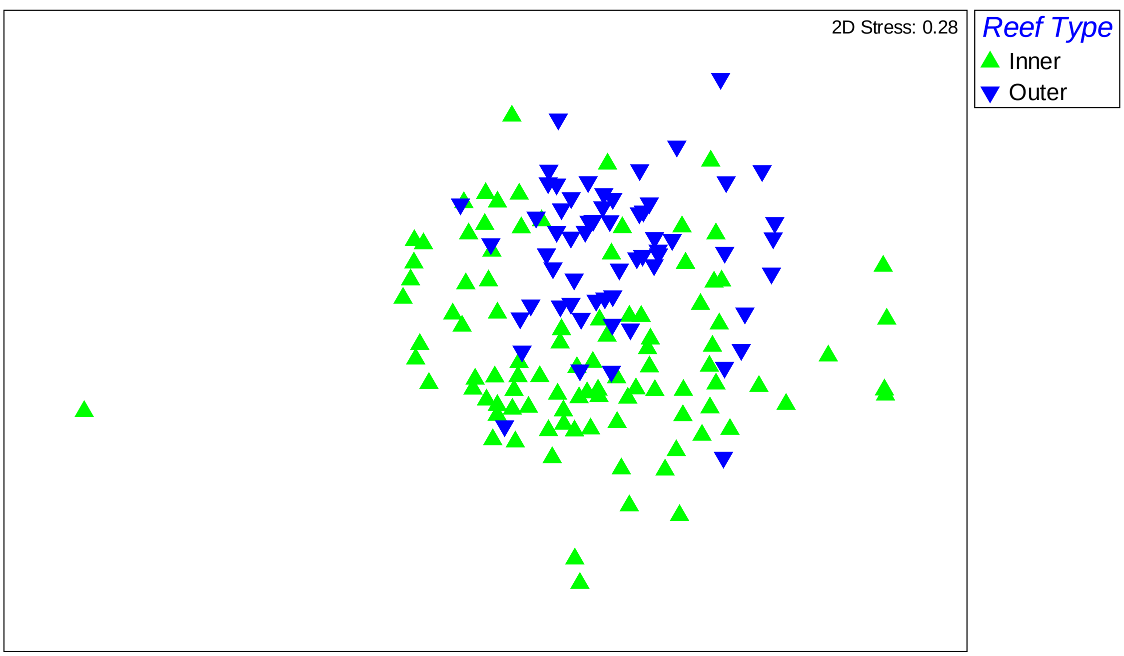
	No MPA								MPA							
	Inner Reefs					Outer Reefs			Inner Reefs					Outer Reefs		
	DO	KO	LO	MO	NO	KO	MO	NO	DI	KI	LI	MI	NI	KI	MI	NI
Acanthurus lineatus	0 (0)	9.2 (16.2)	0 (0)	0 (0)	15 (15.4)	8.4 (26.6)	14.2 (23.6)	10.6 (23.9)	0 (0)	8.1 (10.2)	0 (0)	0 (0)	6.4 (11)	0 (0)	0 (0)	10 (24.2)
Acanthurus xanthopterus	0 (0)	1.5 (4.7)	0 (0)	0 (0)	16.1 (29.3)	0 (0)	0 (0)	1 (3.2)	4.4 (6.5)	8.6 (13.7)	10.7 (24)	0 (0)	0 (0)	54.9 (126)	25.5 (36.9)	22.7 (37.6)
Caranx melampygus	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	5.6 (17.7)	0 (0)	9 (20.2)	0 (0)	0 (0)	0 (0)	0 (0)	5 (15)	11.9 (28.9)	0 (0)	2.7 (8.5)
Cephalopholis argus	0 (0)	7.5 (12.3)	0 (0)	7.4 (8.1)	0 (0)	6.3 (15.2)	1.5 (4.7)	2.4 (7.6)	1.5 (4.7)	1.4 (4.4)	0 (0)	11 (25)	0 (0)	4.6 (9.8)	6.1 (12.9)	0 (0)
Parupeneus barberinus	10.5 (14.3)	4.3 (10.6)	5.1 (11)	10.2 (13.6)	3.9 (9.6)	0 (0)	0 (0)	2 (6.3)	12.7 (28.6)	6.4 (10.1)	14.3 (16.6)	6.5 (20.6)	13.3 (19.5)	2.5 (7.9)	0 (0)	3.9 (6.5)
Siganus vulpinus	16.5 (24.9)	0 (0)	6.3 (8.6)	39.5 (50.4)	5.2 (12.1)	2.7 (8.5)	65.5 (29.1)	2.8 (8.9)	8.1 (14.4)	9.1 (15.6)	40.4 (52.1)	11.2 (18.9)	0 (0)	9.6 (21.4)	15.9 (13.7)	0 (0)
Siganus puellus	18.3 (33)	0 (0)	12.4 (19.4)	18 (14.1)	8.3 (18.3)	21.1 (16.2)	22.9 (29.4)	26.3 (26.3)	3.5 (7.4)	2.2 (5)	7.8 (16.5)	19.5 (38.8)	2.2 (6.7)	23.5 (29.1)	5.8 (9.4)	21.9 (22.2)
Siganus doliatus	18.8 (22.4)	6.2 (7.8)	3.6 (11.4)	27.5 (39.4)	3.1 (9.8)	4 (12.6)	45.8 (51.7)	6.3 (13.4)	0 (0)	5 (9.3)	2.8 (8.9)	23.4 (28.3)	11.7 (35)	0 (0)	14.7 (19.7)	26.7 (29.3)
Naso unicornis	3.5 (11.1)	0.6 (1.9)	0 (0)	0 (0)	14.5 (37.1)	1.6 (5.1)	0 (0)	69 (161.1)	0 (0)	0 (0)	6.3 (19.9)	18.3 (19.7)	28.8 (37.2)	0 (0)	0 (0)	4.8 (10.5)
Naso lituratus	43.3 (117)	12.5 (19)	15.8 (18.1)	24.4 (32.3)	8.9 (13.1)	154.2 (128.1)	174.9 (133.2)	77.4 (72.9)	1.1 (3.5)	0 (0)	27.3 (39.3)	0 (0)	4.4 (8.8)	48.2 (48.5)	67.1 (21.9)	63.2 (77.2)
Chlorurus microrhinos	37.5 (69)	59 (43.7)	25 (21.6)	28.7 (33.9)	66.3 (46.3)	51 (46.5)	102.6 (39.1)	170.7 (389.5)	31.9 (38.4)	52.8 (46.5)	100.5 (180.6)	40.7 (54.3)	26.6 (18.4)	78.6 (57.4)	47 (51)	313.3 (559.9)
COTS	1.3 (4.1)	10.2 (17.8)	8 (16.9)	11.5 (24.3)	0 (0)	0 (0)	49 (66.9)	3.2 (10.1)	1.8 (5.7)	9.5 (21.3)	0 (0)	9.5 (30)	0 (0)	10.1 (16.3)	6 (10.5)	3.1 (9.8)
Monotaxis granoculis	10.8 (14.9)	2.2 (7)	20.7 (29.8)	0 (0)	3.7 (6)	168.5 (247.5)	28.5 (38.5)	102.9 (135.2)	3.9 (8.5)	12.1 (33)	67.9 (75.2)	21.3 (30.3)	13.3 (26.5)	210.8 (313.8)	38.2 (106.2)	22.4 (39)
Lutjanus monostigma	2.5 (7.9)	0 (0)	0 (0)	0 (0)	0 (0)	42.5 (116.1)	0 (0)	0 (0)	0 (0)	0 (0)	11.5 (36.4)	17.3 (25.5)	0 (0)	10 (22.7)	0 (0)	3.8 (12)
Lutjanus gibbus	0 (0)	2.9 (6.1)	0 (0)	0 (0)	1.7 (5.4)	2.7 (8.5)	13.6 (28.7)	4.5 (14.2)	8.5 (15.6)	0 (0)	25 (79.1)	3.5 (11.1)	3.3 (7.1)	3 (9.5)	289.5 (899.8)	13.7 (30.6)
Lutjanus fulvus	0 (0)	0 (0)	0 (0)	0 (0)	0.5 (1.6)	136.2 (298.2)	0 (0)	22.5 (71.2)	11.6 (20.5)	6 (11)	19.6 (29)	3.5 (11.1)	0 (0)	112.5 (355.8)	0 (0)	10.9 (16.4)
Lethrinus harak	1.3 (4.1)	0 (0)	0 (0)	0 (0)	0 (0)	4.2 (13.3)	53.6 (137.7)	0 (0)	3.6 (11.4)	0 (0)	74.3 (149.5)	15.6 (49.3)	0 (0)	0 (0)	0 (0)	0 (0)
Hipposcarus longiceps	70.3 (78.3)	16.8 (18.4)	26.7 (30.3)	26.8 (42.8)	37.6 (35.8)	9.1 (16)	0 (0)	13.2 (25.7)	14.5 (22.6)	13.9 (14.4)	171.8 (212)	5.8 (18.3)	19.1 (29.1)	4.2 (9.1)	30.7 (24.5)	61.8 (131.5)

Table shows average, summed lengths, a proxy for biomass, for each indicator fish species and (standard deviations).

While univariate estimates of each target fish had high standard deviations, examination of their multivariate properties should be conducted to improve upon our understanding of inherent fish assemblage structure and potentially improve our understanding of the effectiveness of MPA's. Described above, multivariate analyses were conducted using PRIMER-E software, and the resultant multidimensional-scaling (MDS) plots are presented below for consideration. Again, MDS plots depict the multivariate distances between two fish assemblages that were surveyed, and R-statistics serve as a measure of significance for group separation (R-statistics >0.5 are typically considered significant) (Clarke and Warwick 2001).

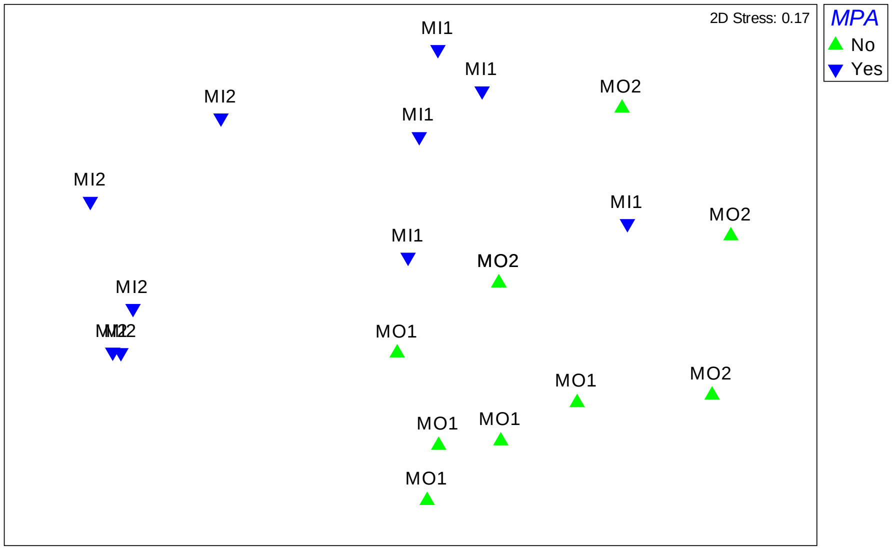
Initially, examination of the fish assemblages from different reef types (inner versus outer) was conducted. Trends (non-significant differences) were noted between fish assemblages on the outer compared with inner reefs (R=0.35). While fish abundance were larger on the outer reef, the relative abundances of a large variety of species was higher on the inner reefs (especially surgeon and rabbitfish). Notably, this inherent variation exists regardless of MPA status.

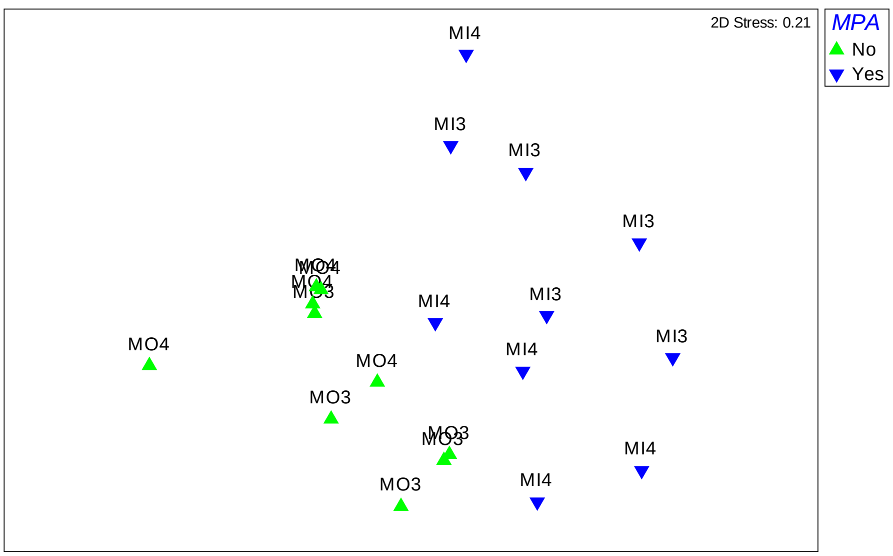
Figure below shows a MDS plot depicting the differences in fish assemblages between inner and outer reefs, regardless of MPA status (R=0.35).



Next, each MPA was examined individually, stratified by inner and outer reefs, to further understand MPA effectiveness. The MDS plot below, site "M", is indicative of the results found for each MPA. It shows that fish assemblages are indeed different depending upon MPA status, but more specifically, that fish abundances across all target species are **higher outside** of the MPA's as compared with **inside**. Clearly, multivariate analyses are better at explaining the variation in the dataset that is resultant from MPA status, but the results were only significant (R>0.5) for site "M".

Figures below show MDS plots comparing fish assemblages inside and outside of MPA's for inner (top graph) and outer (bottom graph) reefs (R>0.45 in both instances).





While the results showing higher fish abundance outside compared with inside MPA's are disappointing, they indicate that surveys are being conducted in a manner appropriate to answer effectiveness questions. These data are useful to continue to adapt management planning and community awareness campaigns. Without them, false conclusions and recommendations may arise.

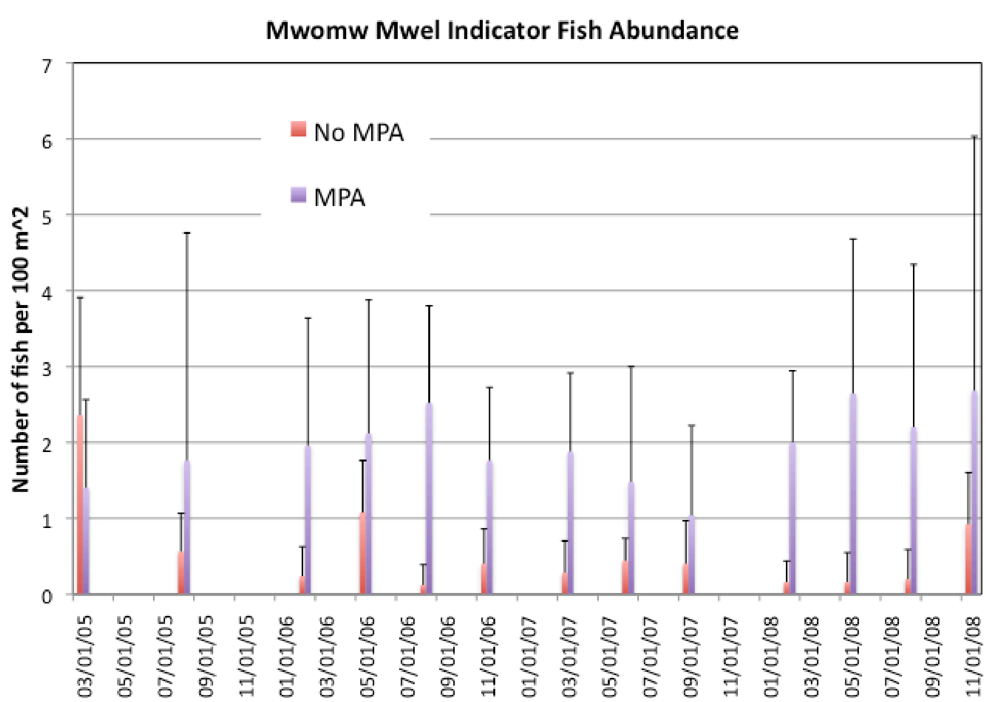
The long-term monitoring program is very similar with the MPA monitoring. Fish data are collected using the same indicator species and number of transects and lengths, only locations differ. Benthic data are collected using LIT (line-intercept transect techniques), described in the Kosrae section of this report. Because similar datasets have already been well discussed, these are not furthered here.

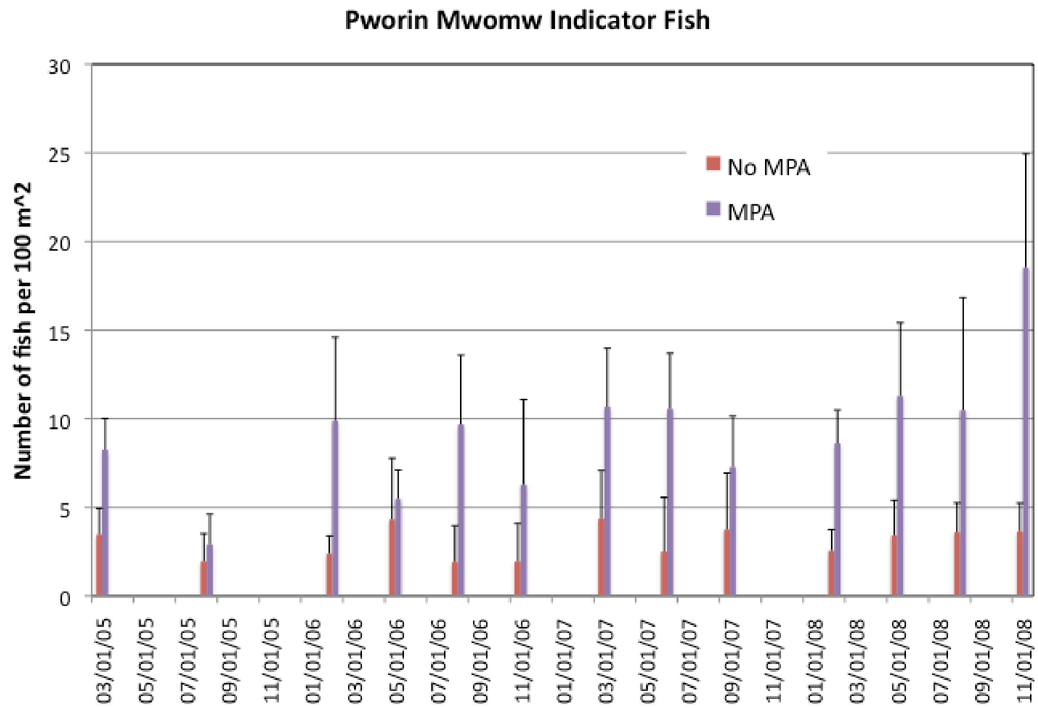
Community Monitoring

At several of the above noted MPA sites the communities have engaged in monitoring activities after being trained by CSP staff. Benthic and fish assemblages are both monitored by community representatives in each instance. Monitoring was conducted on the inshore reefs, closest to the villages. Benthic data were collected using a modified reef-check datasets, described in the Kosrae section in more detail. Here, analyses and discussions are focused upon the 5 x 50m transects where two indicator fish species abundances are monitored.

Similar to the MPA fish data analyses above, individual target species abundance estimates suffer from high standard deviations, and thus limit the statistical ability to detect change over time. The most obvious ways to improve upon estimates (i.e., lower the SD bars) are to: 1) increase the width surveyed on each side of the transect line, and/or 2) increase the number of times per year observations of fish abundance are recorded from once per site to twice. Additionally, incorporating more species of target fish for monitoring would enable a multivariate comparison of MPA status that was shown above to better address the mobility of target fish.

Figures below show abundances of two target fish that are monitored by communities in their MPA's on reefs closest to shore. These results are for MPA site "D", however similar findings are evident for others as well.





Despite high standard deviations, the data show clear trends that are markedly different with the further offshore reefs monitored by government and CSP programs. At these reefs closest to the villages there are trends of higher fish abundances inside the MPA's compared with outside, however statistical significance is limited.

Sediment Monitoring

At Dausokele, one of the community-established MPA's, sediment traps have been deployed since September 2008. These consist of PVC tubes (2" diameter) fastened to re-bars driven into the reef. Traps are collected every 30 days and sediments are dried and weighed.

Examination of sedimentation rates show that no clear temporal trends have yet emerged, and high standard deviations are apparent. Clearly sediment data are one useful indicator of land-based pollution, however the time required to process sediment traps and the resultant accuracy of the data must be compared with other indicators and the time and resources required to gather data.

One potential alternative might be to utilize the YSI-Sonde water quality instruments that exist in most jurisdictions. These continuously recording instruments can be outfitted to collect high quality temperature, conductivity, dissolved oxygen, turbidity, and chlorophyll data. Setting up tows, or sampling profiles, using a small boat takes only hours, and can be conducted on multiple occasions during the wet and dry season to characterize watershed runoff. Further, the extremely large dataset provides for rigorous testing of significant change over time.

Figure below shows sedimentation rates and standard deviations.

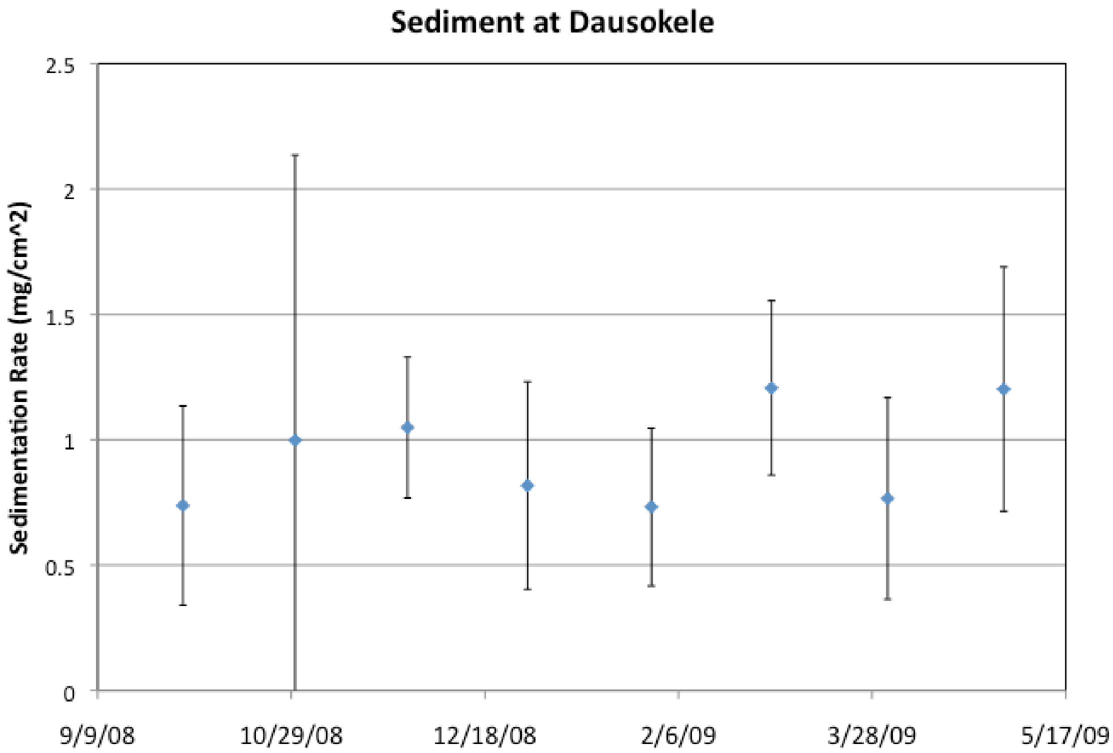
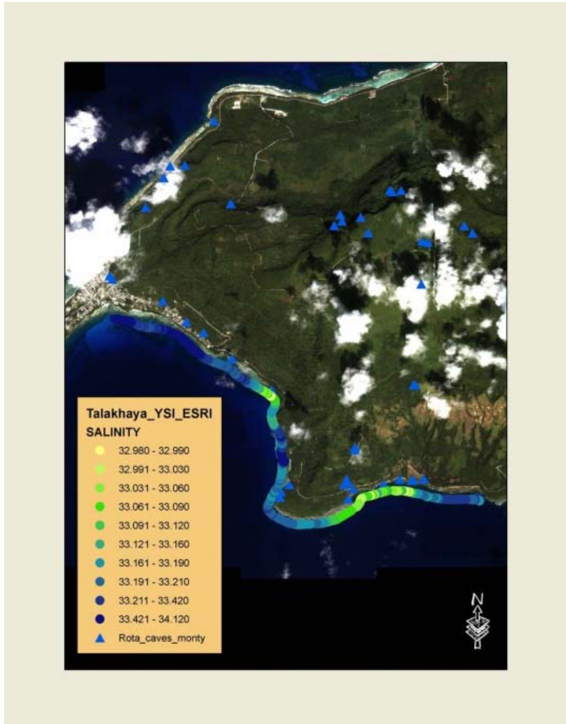


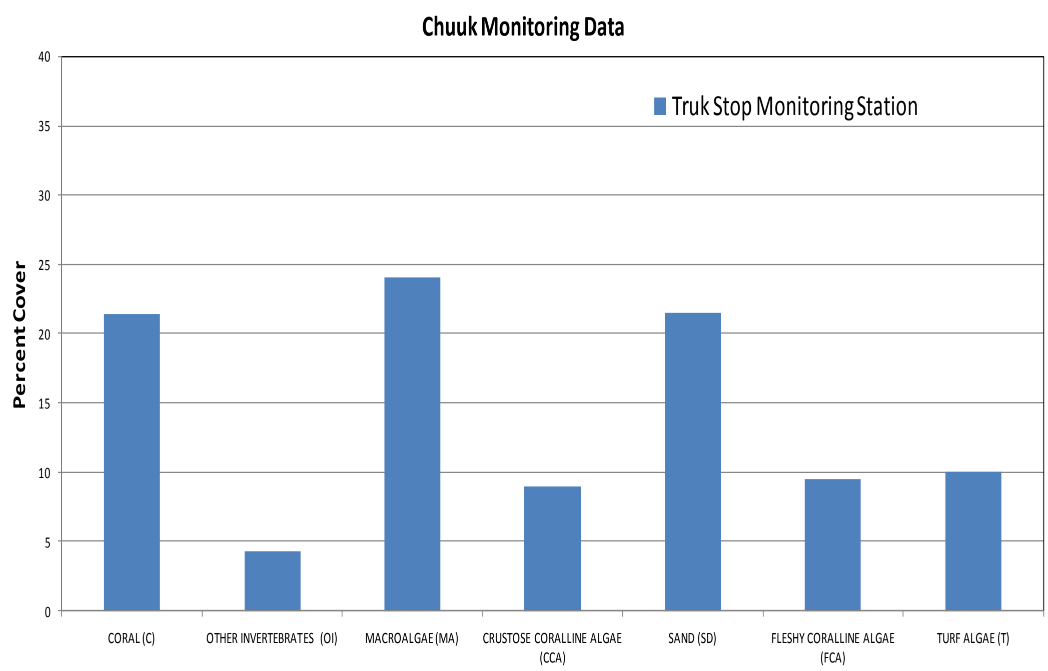
Figure below shows the results of a YSI-tow, highlighting where freshwater discharge is greatest around Rota Island, CNMI.



Chuuk Monitoring Data Summaries

Very little quantitative data describing the marine environment currently exists for Chuuk State. Through discussions the author learned of numerous studies and programs that existed in the past, however much of the data was reported lost while government agencies (such as Marine Resources) were required to switch offices in recent years, as well as through computer failures. Positively, this allows for the current monitoring effort to learn from the mistakes made by the numerous other monitoring efforts throughout Micronesia, and build upon them to form a desirable foundation. Work in Chuuk was focused upon the generation of methodologies and the collection of statistically powerful datasets at two locations: 1) near Uman village and 2) adjacent to the main island (Weno), next to the Truk Stop Hotel. The results from benthic data collection using 5 x 50m transects show that dominant benthos abundance estimates were collected with low standard deviations, and confidently detected relative 20 – 40% changes with high (70%) statistical power. The only exception to these findings was for the 'macroalgae', grouped together, that were unevenly distributed along the transects and had lower statistical power then typically desired.

Figure below shows dominent benthos abundance estimates for one of Chuuk's newly selected, long-term monitoring stations (SD bars). Most estimates fall within statistically desirable power ranges (i.e., detecting a 20 – 30% relative change with at least 70% power), except macroalgae that were grouped together to form this graph.

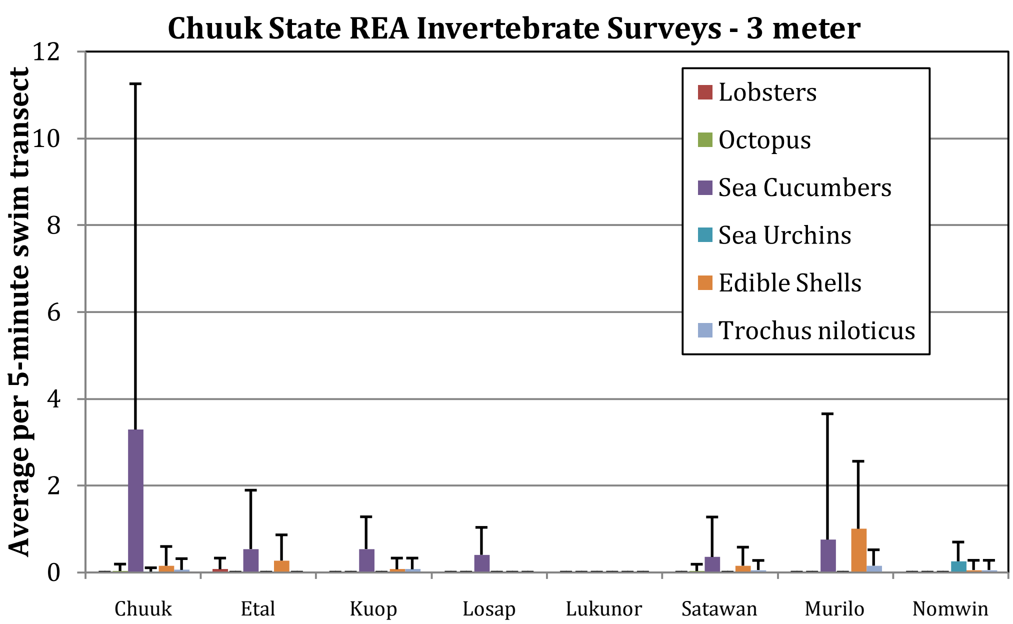


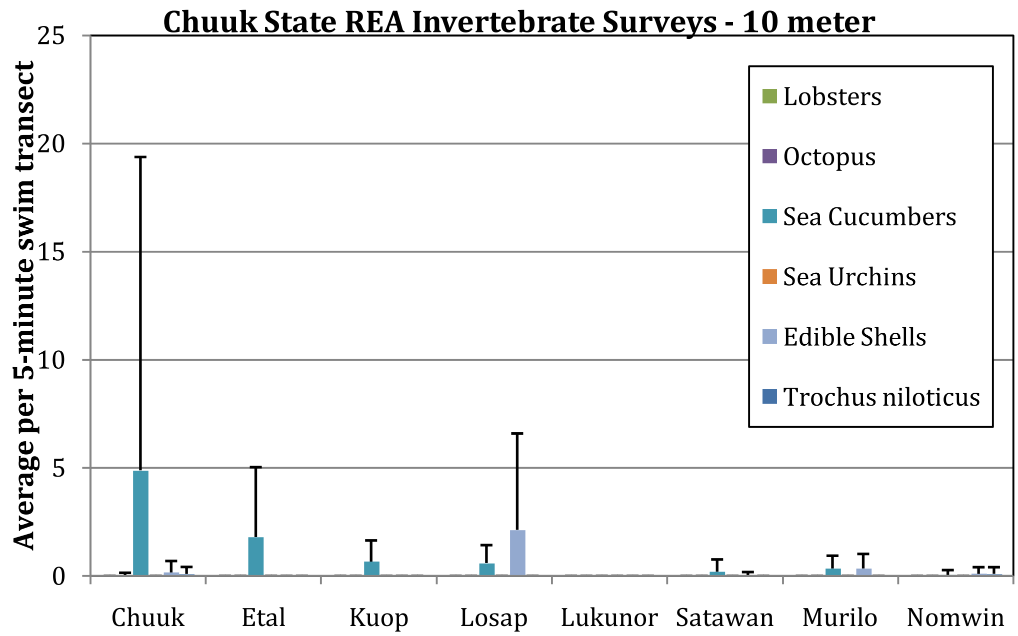
Fish abundance estimates were collected using similar methods described in the Pohnpei and Yap sections. Because only limited data are presently available for Chuuk, and because thorough analyses regarding the methods used already exist here, fish data will not be further discussed until more data are available to examine.

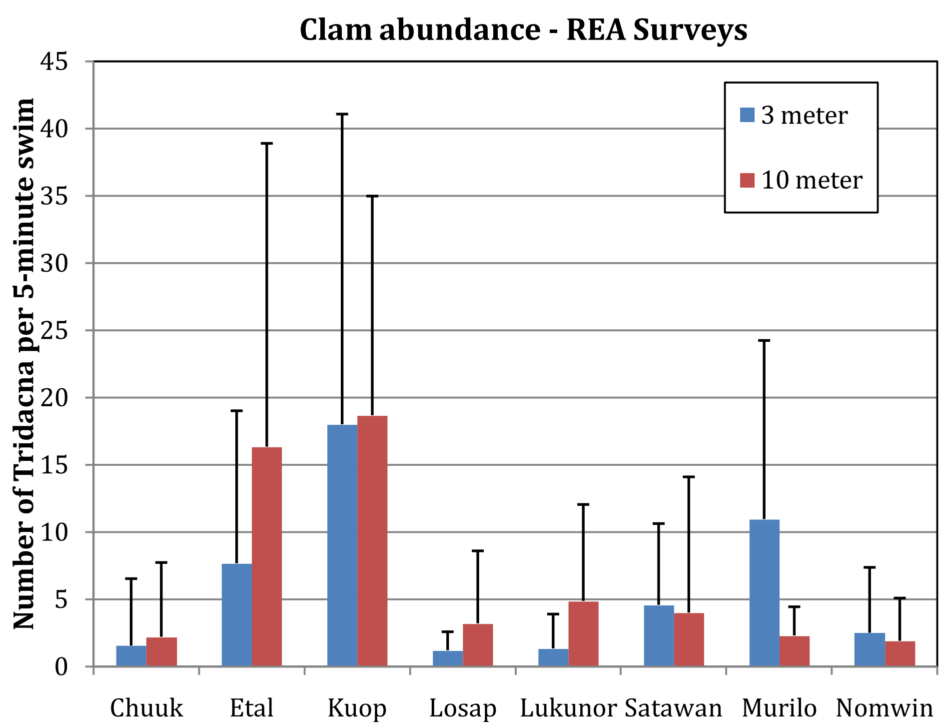
Macroinvertebrate data were collected along the 5 x 50m transects within 2m of each side of the lines. Initial inspection of these data from Chuuk, as well as most other jurisdictions, show that abundances of common, edible macroinvertebrates are very patchily distributed, and do not meet the statistical requirements for monitoring change over time with high confidence. To further examine, the report now looks at macroinvertebrate data collected during the Chuuk Rapid Ecological Assessment in 2007 using timed 5-minute swims instead of transects to estimate abundances. During the REA much larger replicated search areas were surveyed. An estimated 400 m^2 were covered in each replicate 5-minute swim as compared with 100 m^2 per replicate transect. Thus, these data serve as a good example of what might happen if programs were to greatly increase the transect sizes.

The initial results show extremely high variation at the individual site level, not graphed here because all results failed to detect accurate abundance estimates of sea cucumbers (grouped) and other edible shells and clams with sufficient statistical power. In an attempt to improve upon statistical considerations, data were grouped by islands and analyzed.

Figures below show common macroinvertebrate abundances grouped by island resultant from the Rapid Ecological Survey conducted for Chuuk State. Clearly, standard deviations are too high for detecting desirable levels of statistical power despite grouping by islands.





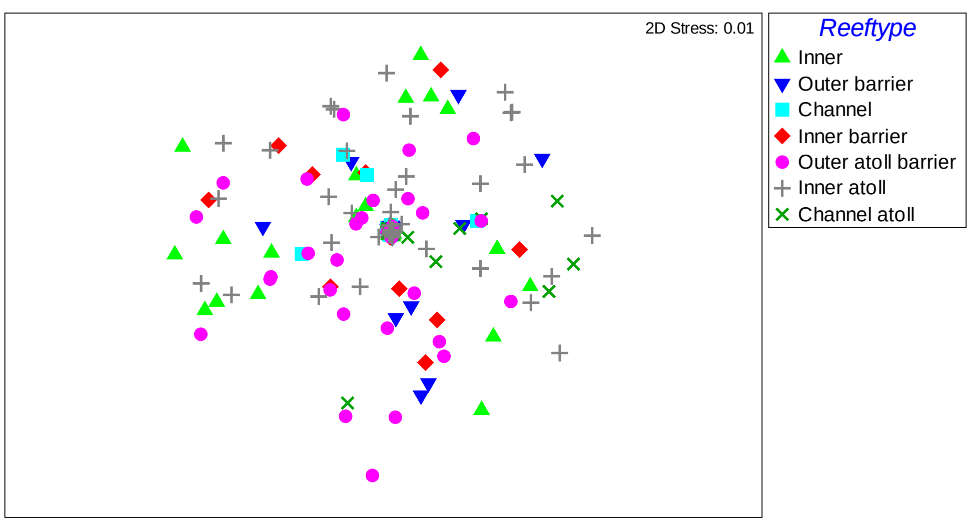


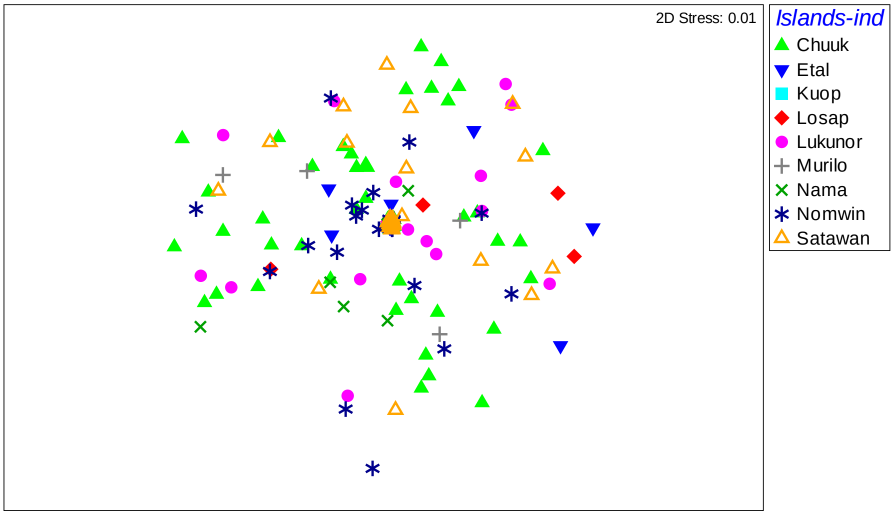
Given the high standard deviations associated with these data, multivariate analyses are next considered. These tests explore whether or not macroinvertebrate abundances can be explained by large-scale geographic and environmental variables. The resultant graphs show that wave exposure, geography (i.e., island), nor reeftype was able to explain any significant amount of the variance associated with macroinvertebrate abundances on Chuuk States reefs.

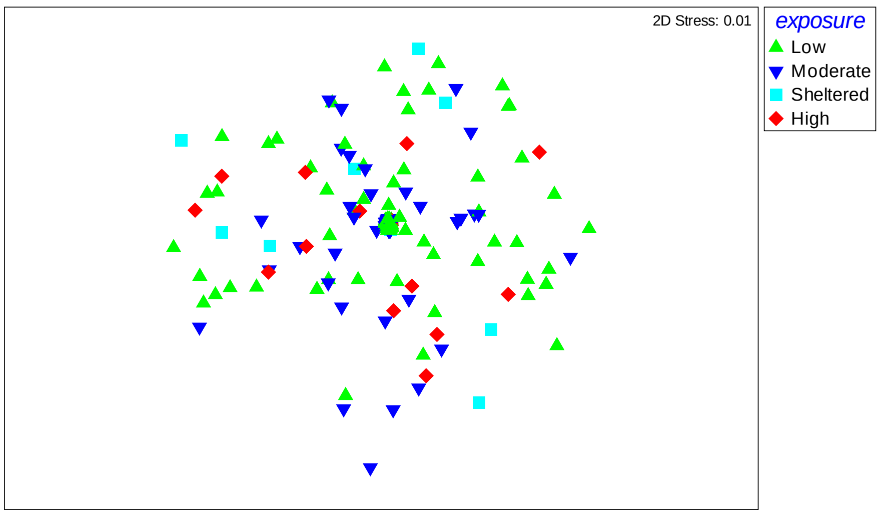
It culmination, is postulated that all of the above findings might reflect harvesting intensities, as the results show extremely low abundances of sea cucumbers on Chuuk State reefs. The greatest mean abundance was ~5 sea cucumbers per each 5-minute swim on Chuuk, and on all the outer islands of the Halls and Mortlocks there was only a maximum of 2. These numbers are substantially lower compared with similar surveys conducted on the nearby island of Pohnpei (data available from Pohnpei monitoring team).

Moving forward, the results teach us that macroinvertebrate abundances appear to be very patchily distributed at the site and island level, a trend that may be due to the nocturnal nature of many macroinvertebrates (Klumpp and Pulfrich, 1989) in conjunction with harvesting intensities. If confident estimates of macroinvertebrate abundances are the top goals of monitoring program alternative survey designs might be considered. The current efforts (5 x 50m transects, 2m on each side of the line) serve to document modern occurrences, but may be associated with low statistical confidence depending upon harvesting trends and/or other considerations.

The figures below show multidimensional scaling plots examining sea cucumber abundances found during each 5-minute swim in consideration with varying reeftypes, exposure, and islands. None of the predictor variables explained a significant amount of variance in sea cucumber distributions as shown by the intermixed and scattered nature of the symbols.







Yap Monitoring Data Summaries

The long-term monitoring efforts on Yap are relatively young compared with many of the other islands, however in their ~3 years of existence data collection efforts have been intense. Currently, this program is headed by a non-governmental organization, Yap Community Action Program (CAP), with varying levels of support from two governmental agencies, Yap Environmental Protection Agency and Marine Resources. In addition with the long-term monitoring program, several community-based monitoring programs exist as well as targeted resource surveys by Marine Resources.

MPA and Long-Term Monitoring

Over the past several years benthic and fish monitoring have been conducted for several MPA's selected by communities in conjunction with the YapCAP. Similar to Pohnpei, sites were selected on the inshore and outer reefs inside of each MPA and one associated reference site. Benthic data were collected using a video-transect method. Briefly, a video camera was used to record the benthic substrate along 5 x 50m transect lines, 40 frames were extracted from each, and five benthic data points were randomly placed on a monitoring for data collection. This represents the largest unit of replication for benthic data collected throughout Micronesia examined within this report. However, the resolution of benthic codes was limited to coral growth forms and geomorphology, and not to desirable taxonomic levels (i.e., genus). The data were analyzed for one representative site, Gachuug, looking at both the inshore and outer reefs at both depths. In comparison to many of the other benthic datasets analyzed here, dominant benthic organism abundances were estimated with relatively low standard deviations. Power analyses support this showing higher statistical power in comparison with others, however, power still did not meet desirable levels for the majority of benthos (figures below). The photo-quadrat protocols with higher taxonomic resolution, shown in the Chuuk section, are similarly recommended to improve upon benthic datasets. However, the existing data provide a useful baseline for future comparisons. Further multivariate analyses were not conducted because it was earlier shown, in the Kosrae section, that using coral growth forms and geomorphology many inherent differences in benthos assemblages may be masked without genus-level taxonomic resolution.

Figure below show dominant benthos abundance estimates found at Gachuug, Yap (SD bars).

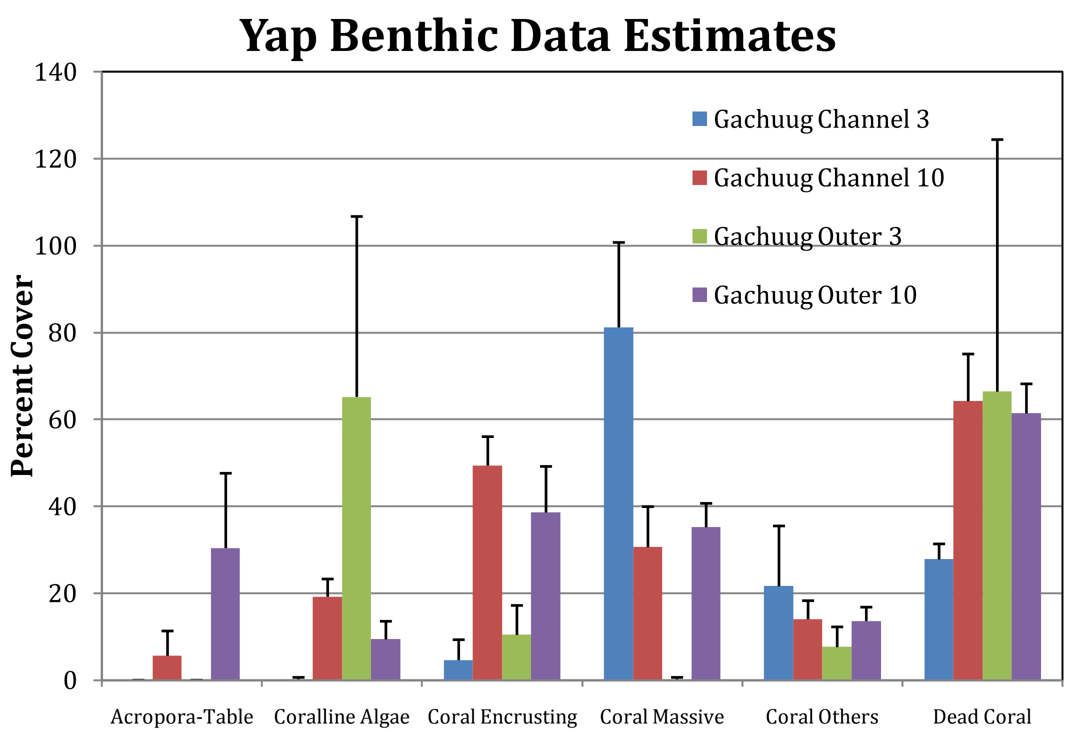
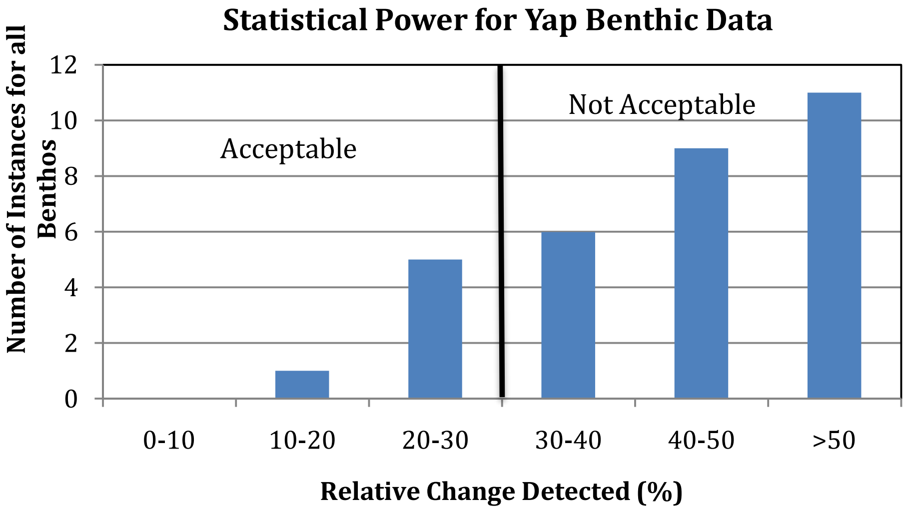


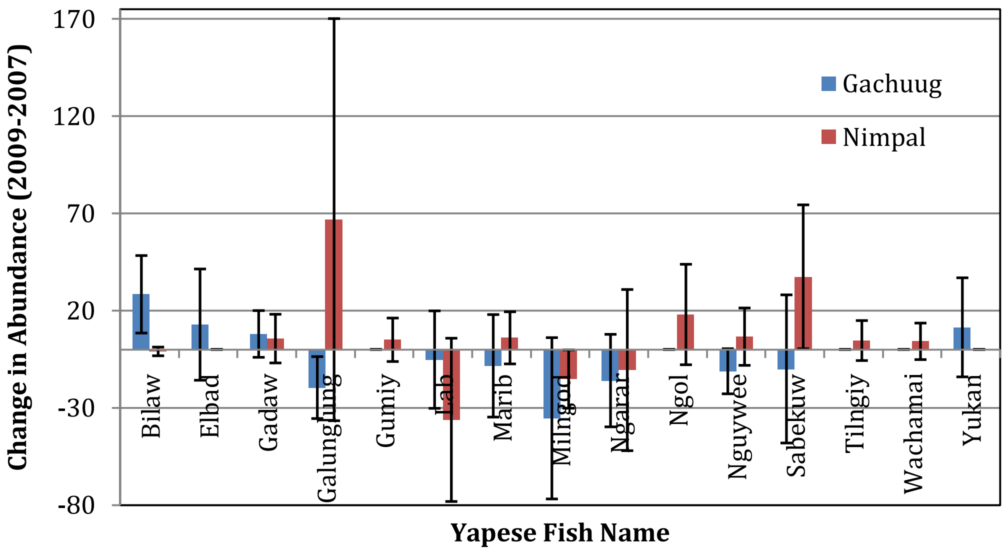
Figure below shows resultant statistical power surrounding the above shown benthos abundance estimates.



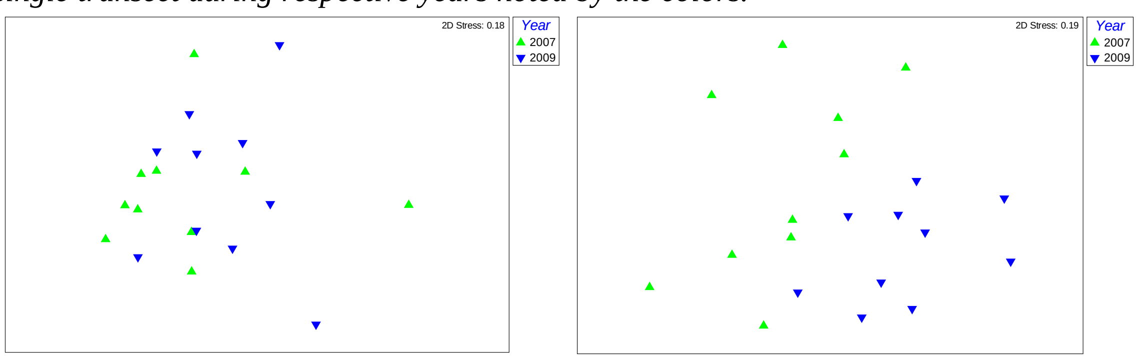
Indicator fish abundances were estimated along the 5 x 50m transects used for benthic data colletion, inside and outside of MPA's at two depths since 2007. Here, the Nimpal MPA site and the Gachuug reference site were analyzed for statistical considerations as they encompassed the largest temporal datasets available. The results show clear indications of increasing fish abundances inside the Nimpal MPA after ~2 years of its establishement in 2007. However, when examined for each indicator species separately variation was too high to detect significant differences for several of the indicator species (see graph below with high SD bars). These results were not surprising given similar findings for Pohnpei's fish dataset described earlier, and the SPC datasets. In culmination datasets stress the need to: 1) consider the inherent variation in the target indicators chosen for monitoring, 2) utilize multivariate as well as univariate statistics when examining results, 3) consider increasing the width of surveys from 2.5 m on each side of the transect line to 5m, and 4) increase the number of times per year observations of fish abundance are recorded from long-term monitoring sites.

Here, it is not possible to improve upon historical field sampling, however the data are next considered for their multivariate properties. Two graphs are presented below showing MDS plots of fish abundances for Nimpal and the Gachuug reference site. While there were no significant differences at Gachuug between 2007 and 2009 (R-statistic<0.1), positive, significant change was noted at Nimpal (R=0.48). This is a positive indicator for the community based MPA and the datasets both. However, the recommendations for enhancing sampling above are still warranted as the data presented here are only for a single MPA and reference site, while the resultant success of others are yet unknown.

Figure below shows the changes in fish abundances for Yap's indicator fish species (noted in Yapese) at Gachuug, the reference site, and Nimpal MPA. Note very high SD bars are associated with most indicator fish abundance estimates.



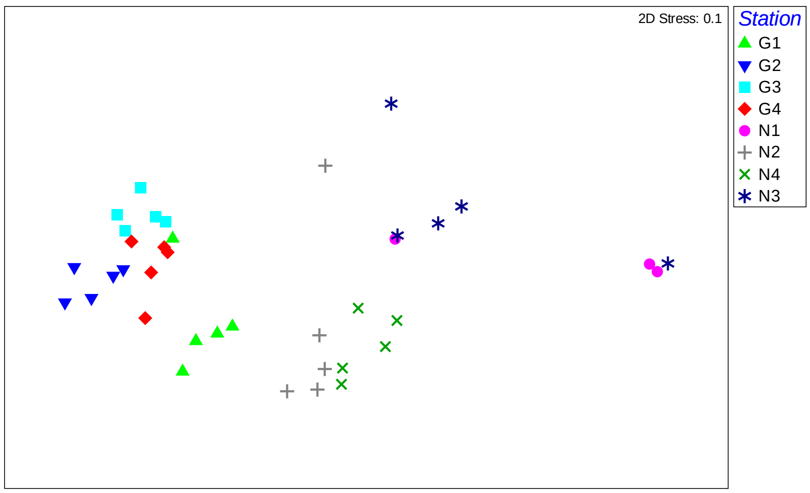
Figures below depict the multivariate differences in fish abundance datasets between Gachuug channel (reference site, left, no significant difference) and the Nimpal channel (MPA site, right, R=0.59). Each symbol represents indicator fish abundances along a single transect during respective years noted by the colors.



Community Monitoring

In addition to the YapCAP long-term monitoring program that encompasses several MPA's, community-driven monitoring on the reef-flat habitats inside of individual MPA's and reference sites is also conducted. Community monitoring comprises sampling of the fish and macroinvertebrate abundances only, along 5 x 50m transects described above. In Yap, the target indicator fish are the same for both the long-term and community program. Initial inspection of the data revealed that large differences exist between each reef-flat monitoring station (Global R-statistic=0.73), similar to the large differences found among the stations in the SPC surveys. This supports that the different stations within both the Nimpal MPA and the reference site should not be grouped as replicates, and thus the data have to be considered independently. As such, it is recommended to reduce the number of stations and increase the data collected at each to improve the resolution of data collection efforts. Discussions held with these communities regarding initial outcomes and improving future data collection efforts were successful in highlighting the nature of their initial data and suggesting minor changes to survey designs and methodologies.

Figure below shows a MDS-plot highlighting inter-site differences in fish assemblages from the community monitoring at Nimpal and Gachuug.



Government Agency Monitoring

In addition to the efforts described above two governmental agencies also conduct (or soon will be conducting) monitoring programs. Yap's marine resources agency has been conducting *Trochus* surveys, similar to Pohnpei, to ensure that current and future harvesting levels are indeed sustainable. While these data were not available for the present analyses, reports can be obtained from the marine resources agency. Similarly, they are charged with conducting stock assessments for commercially-desirable sea cucumbers. This effort is set to begin in the near future. Analyzed data included benthic datasets from inshore reefs adjacent to dredge sites using Line-Intercept-Transect methods. Because this is the exact same technique used in Kosrae, and discussed earlier, the results are not furthered here. However, discussions with key staff were centered upon improving data collection efforts through the use of photo-quadrats and accompanying software for simple analyses and databasing needs. This recommended technique was further discussed and analyzed in the Chuuk section of the report.

Yap Environmental Protection Agency will soon begin marine water quality monitoring for bacteria at several nearshore locations once the certification program is completed in September. In addition, there is a desire to improve upon site-specific water quality monitoring in the nearshore waters associated with concerned villages. Discussions were centered upon building a foundation and framework for site-based monitoring efforts.

CONCLUSIONS AND FUTURE DIRECTIONS

The numerous datasets presented here represent the contemporary science that is available to support management and policy throughout the Federated States of Micronesia and Republic of the Marshall Islands. In culmination, this report highlights that regional science must grow if assessments of large-scale management strategies, such as the Micronesian Challenge, are to be made. Clearly a strong and diverse scientific foundation exists among the jurisdictions. In comparisons with regional management strategies, numerous localized examples were found to provide accurate scientific datasets to assess individual management actions (i.e., community MPA's and *Trochus* harvesting). However, discussions with the majority of the jurisdictions resulted in an overwhelming support for the standardization of a long-term monitoring framework. This would: 1) ensure science and monitoring is matching the driving management questions, 2) simplify database and data processing needs, 3) eventually provide easy access for the database user community, and 4) greatly assist existing grant reporting and future grant writing.

A Framework for Long-Term Monitoring

While pressing management questions differed by jurisdiction, the majority of the concerns noted by resource managers indicate site-level database generation needs. Two common themes include fish abundance changes within select MPA's and impacts of watershed pollution on nearshore reefs. Thus, regional programs that assess fish populations or ecological metrics of coral assemblages at entire island scales were not well suited for jurisdictional needs. These programs typically establish numerous stations throughout each island, or sections of an island, and collect limited data at each 'station'. Thus, effort is maximized to increase the number of 'stations'. However, in numerous examples described above the analyses showed that variation is too high at the 'station'-level, and the resultant data had limited use to answer many questions that resource managers had. In reconciliation, the framework discussed herein is focused at improving the resolution at the 'station' or 'individual site' level to best focus on the statistical variance that is of interest. A suggested framework is:

1) Create survey designs, describing where monitoring stations are located based upon island size, jurisdiction size, and an overall priority ranking of management questions.
2) Discuss design with relevant local and regional agencies, as well as available scientists.
3) Finalize a priority map for desired monitoring stations.
4) Estimate the total budget, time, and staff available for field work on an annual basis.
5) Select/conduct monitor locations in prioritized order.

With regards to in-water methodologies the following parameters and techniques were discussed during jurisdictional visits, tested, and once enough data is collected they will be analyzed in culmination. In many instances they represent ongoing monitoring efforts proven to have good statistical confidence.

1) 5 x 50m transects laid at a 3-5m depth for inshore and channel reefs; a 8-10m depth might be incorporated or selected for the outer, wave exposed reefs.
2) Benthic data collection using photo quadrats taken at each 1m interval, analyzed with “Pointcount” computer software with the adapted code-file for Micronesia. 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).
3) Fish abundances of target food-fish estimated along each transect line, 5m to each side. Fish abundances as well as lengths are recorded. These data, along with macroinvertebrates are easier to collect and process, so repeating surveys at each station bi-annually is desirable.
4) Macroinvertebrate data collection for edible sea cucumbers and shells, as well as grazing urchins, along each transect line, 2m, or 2.5m, to each side. Only macroinvertebrate abundances are recorded as sample sizes are not expected to be large enough to gain meaningful results from size estimate data.

In addition, coral population surveys are highly recommended for all jurisdictions where expertise and available divers exist. For most jurisdictions 8 replicate 1x1m quadrats were tossed by the author at equal intervals along the transects. Surveys were conducted by identifying every coral colony whose centerpoint resided within the quadrat, and measuring the maximum and perpendicular-to-maximum diameter. Preliminary analyses of species saturation curves showed a constant asymptote was typically achieved (i.e., the species saturation curves flattened out) for all jurisdictions except Kosrae. Coral assemblages on Kosrae are clearly unique among Micronesia, holding much larger colonies and less diversity-per-unit-area, and thus, alternative considerations must be made. Discussions regarding coral population surveys remain ongoing with all jurisdictions.

Future Directions for Monitoring Programs

The recently completed jurisdictional visits and data collection and analyses efforts represent a positive step for all existing monitoring programs to judge their progress and future needs. In the opinion of the author this work has increase the moral surrounding monitoring programs and has resulted in added focus and improved science. It is imperative that regional efforts continue to build upon the existing knowledge-base presented here. Logical next steps include:

1) Continue jurisdictional monitoring program collaboration with scientific expertise. Specifically, the next steps are to provide jurisdictional staff with data management and analyses training. This could be conducted within each jurisdiction or in a bigger workshop setting.

2) For several jurisdictions it is best to continue collaboration with field surveys; most notably with coral population assessments, benthic data, and indicator fish data collection.
3) 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.

Pertinent for all monitoring programs throughout Micronesia, including Palau, Guam and the CNMI, is to foster a more collaborative relationship between the regional monitoring programs. This will enable programs to examine rates of change in pertinent ecological metrics (fish, corals, invertebrates) in accordance with management and policy, and more efficiently understand their resource status. Further, this will provide a vector for improving the way monitoring datasets are analyzed. Opportunities such as the Micronesian Challenge represent ideal strategies that can enhance connection among the jurisdictions, and potentially provide financial support for (some of) these efforts.

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Literature Cited:

Brown E, Cox E, Jokiel P, Rodgers K, Smith W, Tissot B, Coles SL, Hultquisdt J. 2004. Development of benthic sampling methods for the coral reef assessment and monitoring program (CRAMP) in Hawai'i. Pacific Science 58(2):145-158.

Clarke KR, Warwick RM. 2001. Change in marine communities: an approach to statistical analysis and interpretation. Plymouth Marine Laboratory, Plymouth UK.

Connell JH, Hughes TP, Wallace CC. 1997. A 30-year study of coral abundance, recruitment, and disturbance at several scales in space and time. Ecological Monographs 67(4):461-488.

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. Pacific Science 60(2):177-189.

Houk and van Woesik, 2009. Coral assemblages and reef growth in the Commonwealth of the Northern Mariana Islands. Marine Ecology. *In Press*

Klumpp and Pulfrich, 1989. Trophic significance of herbivorous macroinvertebrates on the central Great Barrier Reef. Coral Reefs 8:135-144.

Leujak W, Ormond WFG. 2007. Comparative accuracy and efficiency of six coral community survey methods. Journal of Experimental Marine Biology and Ecology. 351:168-187.

National Biodiversity Strategy and Action Plan Team of the Republic of the Marshall Islands. 2001. The Republic of the Marshall Islands Biodiversity and Action Plan. A report submitted to the Marshall Islands Marine Resources Authority.

Pinca S. 2004. Majuro Atoll Underwater Resources Assessment, NRAS. A report submitted to the Marshall Islands Marine Resources Authority.

Rhodes KL, Tupper MH. 2007. A preliminary market-based analysis of the Pohnpei, Micronesia, grouper (Serranidae: Epinephelinae) fishery reveals unsustainable fishing practices. Coral Reefs 26: 335-344.

Waddell, J.E. and A.M. Clarke (eds.), 2008. The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2008. NOAA Technical Memorandum NOS NCCOS 73. NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team. Silver Spring, MD. 569 pp.