Reef Coral Communities at Pila'a Reef: Results of the 2004 resurvey.

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Summary

- Large storm surf during the winter of 2002-2003 and 2003-2004 resulted in rapid flushing of mud from the Pila'a coral reef.

- There was a significant increase in the number of coral colonies in the impact area during the period 2002 to 2004. The number of colonies doubled through recruitment and regeneration of remnant portions of dying colonies. However, these are small colonies. Total coral coverage showed an apparent decrease from 2.7% cover to 1.9% (non-significant), which probably reflects the subsequent death of many of the stressed large colonies observed in 2002.

- The increase in numbers of colonies and the lack of stressed or dying colonies indicates that reef recovery in the impact site has begun. However, the recovery process will take a number of years (probably 10 years) to reach the estimated former levels of coral cover. The loss of the 100-year-old corals cannot be replaced in less than a century.

- Large storm waves from a highly unusual storm event on November 20-21, 2003 caused extensive damage to the reference (control) site on the west side of Pila'a, but did not fragment corals in the impact site on the east end of the reef. The impact site is protected from storm damage by a much wider and shallower reef crest and reef flat. Kepuhi Point on the east of Pila'a further protects the impact area from NE swell.

- The presence of very large colonies of the branched coral <u>Porites</u> (estimated to be over 100 years old by Jokiel et al. 2002) in the impact site can thus be attributed to the observation that the impact area is protected from extreme storm waves. Unfortunately, most of these large colonies have been killed recently by sedimentation.

- The November 2003 storm surf event significantly reduced coral cover at the more wave-exposed reference (control) site at the west end of Pila'a reef. Coverage dropped from approximately 14% to 6%, while total number of colonies decreased by approximately 30% (non-significant).

- The investigation at Pila'a is providing an excellent scientific opportunity to document the impact of a severe anthropogenic stress (mud flows) and a natural event (storm waves) on a coral reef and to document the subsequent rates and patterns of reef recovery.

- The increase in number of coral recruits at the impact site and reduction of sediment within the reef system suggests that the remedial action on land has been effective in reducing further sediment flow onto the reef.

Introduction and Methodology

This report summarizes further observations at sites previously surveyed at Pila'a during 2002 (Jokiel 2002, Jokiel et al. 2002). The impact site was visited briefly by Paul Jokiel and Eric Brown on September 5, 2003. The impact and the reference (control) site were resurveyed quantitatively during April 5-6, 2004 following the same methodology employed in the 2002 survey.

To simplify this presentation, statistical analyses of the changes observed between 2002 and 2004 are summarized in Appendix A of this report. Our use of the term "significant" refers to statistically significant differences as calculated in the Appendix A. Grigg et al. (2003) did not conduct a statistical analysis of their data. Therefore, we analyzed their data to determine how much confidence can be placed in their conclusions. Our analysis of the Grigg et al. (2003) coral data is contained in Appendix B of this report.

Results

Sediment removal by wave action.

Extremely heavy surf occurred off the north shore of Kauai during the winters of 2002-2003 and 2003-2004 (Fig. 1). Wave action flushed the accumulated mud from the impact area of the Pila'a reef into the deep channel and out to sea (see p. 47 in Jokiel et al. 2002). Extensive remedial action on land was highly effective in reducing further sediment flow onto the reef.

Coral communities

Significant changes in the coral communities occurred at the Pila'a impact and the reference (control) site between 2002 and 2004. These changes were as follows:

<u>Impact site</u>:

The massive soil stabilization effort conducted during 2001-2002 along with high flushing caused by large winter surf resulted in rapidly improved conditions on the reef. By September 5, 2003 much of the sediment noted previously (Jokiel et al. 2002) had been cleared from the reef, although mud continued to winnow out of the beach sands (Fig. 2). Clear signs of coral recovery were noted. Corals that had survived the sediment events showed rapid growth at the margins (Fig. 3). Bleached, dying and recently killed corals were not encountered in 2003 whereas approximately half of the corals encountered in the 2002 survey had been classified as stressed or dying. New coral recruits were observed. We also noted a dramatic influx on juvenile reef fish. A diverse mix of green and red alga species was replacing the blue-green algal mat noted during the 2002 survey.

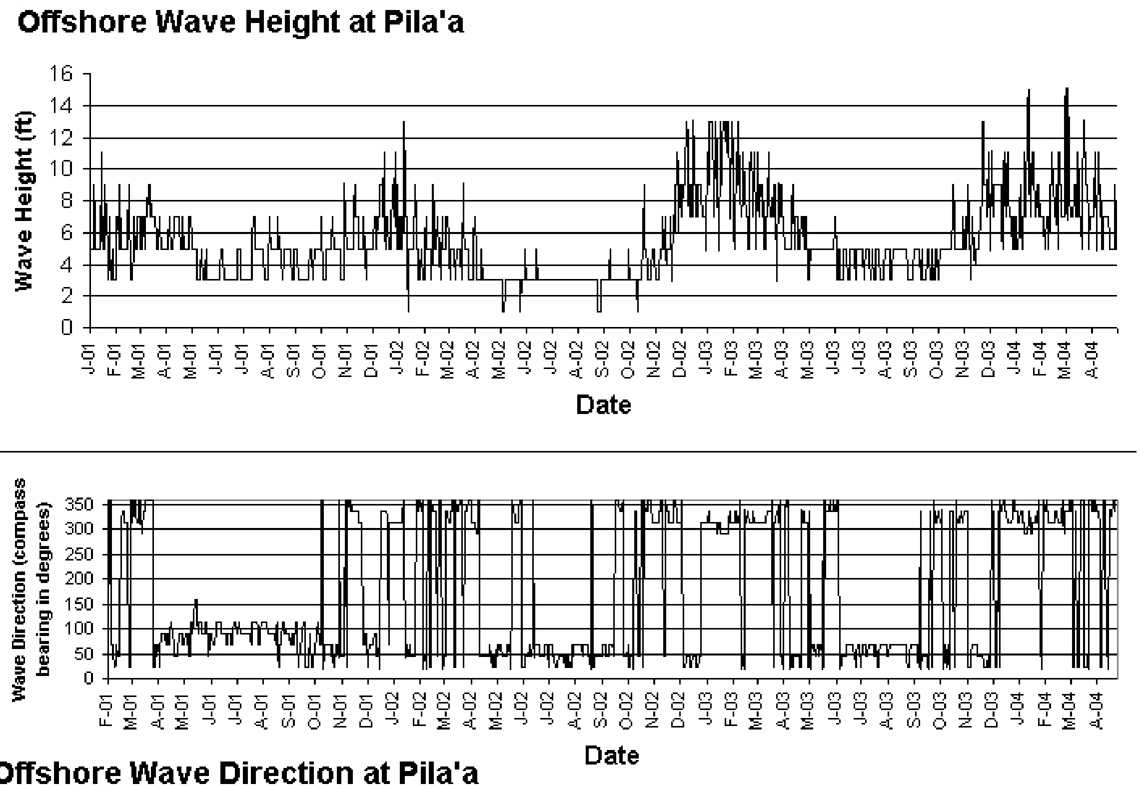

Fig. 1 Heavy wave action during the winters of 02-03 and 03-04 resulted in flushing of sediments from the Pila'a reef.

Fig. 2. September 5, 2003. A large amount of the subtidal mud had been flushed out of the system, but enough remained on the beach to cause turbidity along the shoreline.

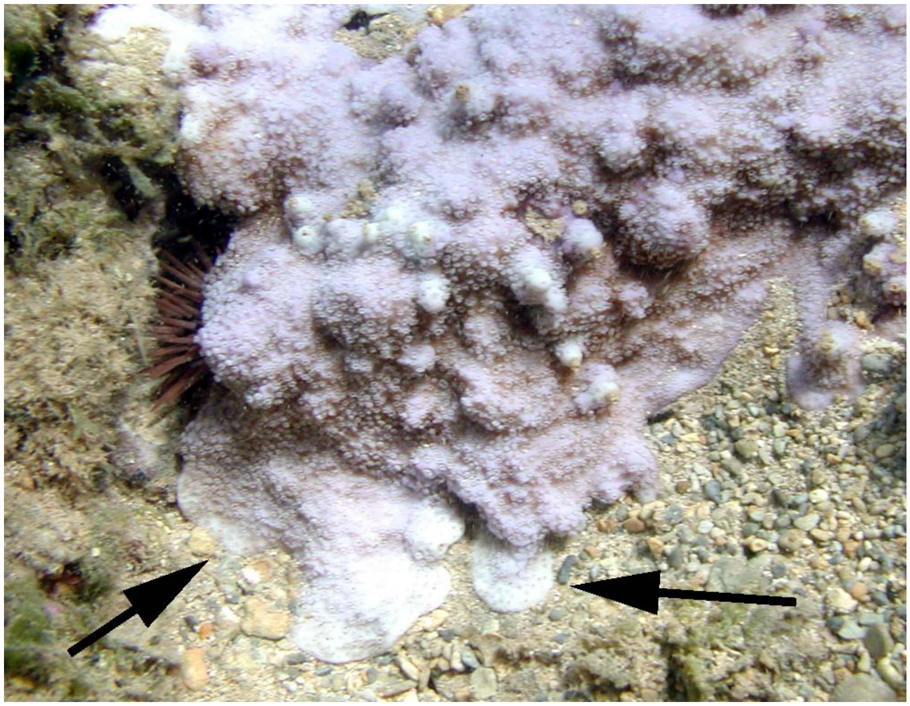

Fig. 3. Rapid growth of surviving corals (arrows) was evident on surviving corals in 2003 following reduction of sediment input and flushing of sediments from the reef.

The 2004 quantitative survey revealed a significant increase in the number of coral colonies at the impact site. However, total coral cover at this site showed a 30% relative decrease (non-significant) between 2002 and 2004. At the time of the previous 2002 survey, approximately 50% of the colonies were in the category of "bleached" or "dying". Many of these probably succumbed to sedimentation in the following months before conditions on the reef improved.

Regeneration of surviving remnants of older colonies and an influx of new coral recruits resulted in a significant increase in the number of colonies in the impact area. These corals are small in size, so coverage is less than in 2002, even though there are a greater number of colonies. Obviously the coral community in the impact area is showing the first signs of recovery. Environmental conditions in the impact area have improved greatly and are now highly favorable to coral growth. However, it will be many years before the coral community reaches its probable former condition. Old colonies (50-100 years of age) killed by the sediment flows (Jokiel et al. 2002) cannot be replaced in less than 50-100 years. The presence of very old colonies in 2002 was evidence that the Pila'a impact site had been an environment highly favorable to coral growth for at least a century. However, most of these colonies have died recently due to sedimentation.

Reference (control) site:

The reference site showed a significant relative decline in coral cover of approximately 60% from 2002 to 2004. There was extensive breakage of coral colonies into rubble (Fig. 4) at the reference site. Damage at the reference (control) site can be attributed to a major storm surf event that occurred on 20-23 November 2003 (Fig. 5). Such breakage did not occur at the impact site, which is sheltered by Kepuhi Point and has a much wider and shallower reef crest (Fig. 6).

Fig. 4. Corals at the reference (control) site were impacted by severe winter storm surf during November 2003. Colonies observed during the 2002 survey (left) were broken and abraded into rubble (right).

The following report was issued in late November 2003 by the National Weather Forecast Office, Honolulu (http://www.prh.noaa.gov/hnl/pages/watchwarn.php):

> "During the latter part of November, several unique weather systems in the north and northeast Pacific combined to produce a long lasting destructive surf event along northeast facing shores of the Hawaiian Islands. Surf heights of 15 to 25 feet, with some sets up to 40 feet were reported beginning on the 20th and peaking on the 21st before slowly diminishing. Although surf events of this magnitude occur several times a year in Hawaii, they generally come from major storms far to the northwest of Hawaii and thus impact northwest facing shores. Over the eons, coastlines on these sides of the islands have been "shaped" to be able to handle such high surf with minimal impact. High surf of this magnitude from other directions is exceedingly rare, and thus when it occurs, can cause significant damage."

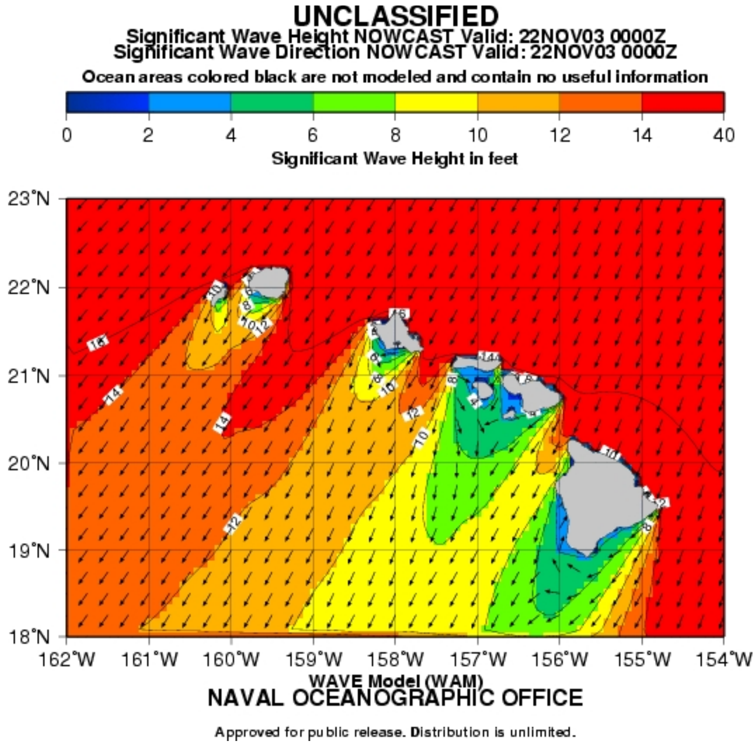

Fig. 5. Major storm surf from the NE struck caused extensive damage throughout the Main Hawaiian Islands on November 20-23, 2003.

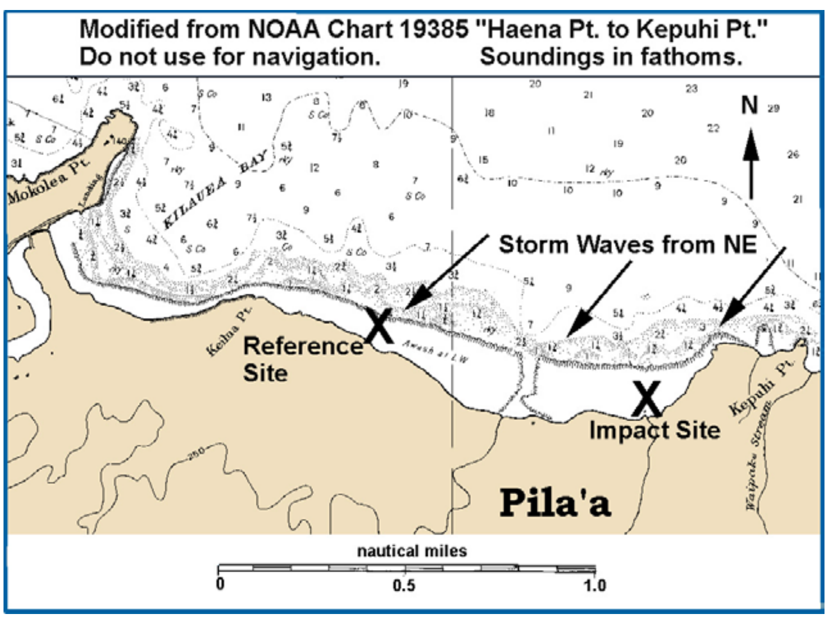

Fig 6. The impact site was protected from the NE storm surf by Kepuhi Point and by a very wide reef crest and shallow reef flat. In contrast, the reference site was not protected and received the full impact of the storm waves during November 2003.

Statistical analysis of coral data in Grigg et al. (2003) report:

Grigg et al. (2003) did not analyze their data statistically, so their conclusions fall into the realm of opinion, albeit expert opinion. Details of our statistical analysis of their data are presented in Appendix B of this report. Analysis of coral data of Grigg et al. (2003) demonstrated that their sampling design lacks the statistical power needed to detect differences between their control sites and the impact site. The low power was due to small sample size and the high variation present in the benthic assemblage. This was the same problem initially encountered by Jokiel et al. (2002). The original sample size of n=3 yielded a very low statistical power, which necessitated returning to Pila'a for a second survey using a much larger number of transects (n=10) in a stratified random design within designated habitats. The larger sample size had sufficient power to detect differences.

In addition, Grigg et al. (2003) did not randomize transect placement. Transects were placed in a symmetrical pattern parallel to the shoreline at each site. Lack of random design in placement of the transects restricts interpretation to only that portion of the habitat under the transect and not the entire population or site (Zar 1999).

An ANOSIM analysis demonstrated the pitfalls of drawing conclusions from observations without using statistics to test data. The data of Grigg et al. (2003) do not support their conclusion (p. 23 of their report) that Pila'a is more similar to Ainahola than to Limahuli. In fact the opposite is true (see Appendix B, p. 20 of this report), giving credence to the observations of Jokiel (2002).

In sum, nothing conclusive can be said using their data set other than their sample size was too small to detect any differences between locations. We know from the data of Jokiel et al. (2002) and from data taken in the present study that significant differences exist between reef flat sites along this coastline. Differences can be detected only if sample size is large enough to insure adequate statistical power.

Discussion

From a scientific perspective, the studies at Pila'a are extremely valuable. The studies furnish vital information on the impact of two major environmental events on the reef corals. The first major event was the extreme sedimentation episode culminating in the large mudflow of 2001. This sediment input was finally curtailed by massive efforts to correct the problem in the watershed. The second major event was the severe winter storm of late November 2003, which damaged reef corals in the reference (control) site, but did not damage the corals in the wave-protected impact site. Having the base-line data needed to evaluate the effects of storm waves was indeed fortuitous. This type of NE storm wave event probably occurs rarely, perhaps on the order of a "50 year event" according to the National Weather Service and as reported by many of the older residents living along NE exposed coasts of Oahu. Such natural events occur very seldom, but are important in determining the natural structure of coral reefs in Hawaii. Future studies will document the rate of recovery of these reefs from damage due to both anthropogenic (sediment) and natural (wave damage) stressors.

Natural versus anthropogenic factors is a contemporary theme in coral reef conservation and management (Wilkinson 2000). It has been said that waves in Hawaii damage more corals than humans. The implication is that reef damage done by humans is trivial and can be ignored. The situation at Pila'a provides an excellent opportunity to explore this point of view. Anthropogenic impacts, such as the grading of the watershed at Pila'a create a chronic disturbance that gradually leads to long-term decline unless arrested. If the massive restoration activity had not taken place on the watershed, the Pila'a reef would continue to undergo further decline. With the sediment problem under control, the process of renewal has begun. In many other reef flat situations throughout Hawaii this is not the case and chronic anthropogenic factors such as increased sedimentation and nutrification continue to degrade the reefs. In contrast, natural events such as storm waves are infrequent and acute damaging events that play an important role in structuring and renewing coral reefs (Grigg 1983).

Wave action, however, is only one factor among many natural and anthropogenic factors controlling the spatial and temporal distribution of reef corals in Hawaii (Jokiel et al. 2004). Jokiel et al. (2004) reported that natural factors influencing reef coral community structure in Hawaiʻi include depth, wave height, wave direction, island age, rugosity, and sediment grain size. Possible anthropogenic impacts were inferred for reefs experiencing a decline in coral cover. Reefs showing decline were concentrated on islands with high human population or in areas suffering from extensive sedimentation. Anthropogenic impacts dominate in environments where wave forces are not the major controlling factor, as shown by Grigg and Dollar (2004) for Honolua Bay, Maui. In some ways the Pila'a impact area is similar to Honolua in that it is vulnerable to poor watershed management even though it receives fairly good wave flushing.

In summary, both natural and anthropogenic factors are playing a role in shaping the reef community at Pilaʻa, although at different temporal cycles. Connell et al. (1997) found that reefs subjected to acute stresses (e.g. storm waves at the reference site) recovered more quickly than reefs impacted by chronic stresses (e.g. sedimentation at the impacted site). The results of the ongoing present study will provide an excellent case study on reef recovery rates because the impact on the reef community from known natural and anthropogenic disturbances has been documented.

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Appendix A. Statistical analysis of CRAMP data (2002 vs. 2004).

Question 1: Did the impact site experience a decline in colony abundance in comparison to the reference site following the acute sediment disturbance in 2001?

H_0: Colony abundance per unit area at the impacted and reference sites remained stable from 2002 to 2004.

H_A: Colony abundance per unit area at the impacted and reference sites changed from 2002 to 2004.

Question 2: Did total coral coverage change at the impact site in comparison to the reference site following the acute sediment disturbance in 2001?

H_0: Percent coral cover at the impacted and reference sites remained stable from 2002 to 2004.

H_A: Percent coral cover at the impacted and reference sites changed from 2002 to 2004.

Methods

Changes in colony abundance over time at the impact and reference sites was examined using a General Linear Model (GLM) two-way ANOVA. . Sites (impact and reference) and time (2002 and 2004) were factors with colony abundance (# $200m^{-2}$) as the dependent variable. Abundance of coral colonies was $Log_{10}(x+1)$ transformed to meet the assumptions of normality and homogeneity of variances. A two-way GLM ANOVA was also conducted using site and time as the factors with percent coral cover as the dependent variable. Coral cover data were ArcSin-Square Root transformed to produce a data set with an underlying distribution that was approximately normal. Post-hoc analysis used a Tukey Honest Significant Differences (HSD) test at $\alpha \leq 0.05$ to compare individual means across sites and times. Data were analyzed using Statistica 6.0 software for the PC.

Results

<u>Colony Abundance</u>

The impact site averaged 14.8 ± 1.3SE colonies in 2002 and 30.9 ± 3.0SE colonies in 2004 (Table A-1). In comparison, the reference site had 39.6 ± 1.7SE colonies in 2002 and 27.3 ± 1.7SE colonies in 2004.

A significantly higher number of colonies were documented at the reference site compared to the impact site ($F_{1,36} = 32.9$, $p<0.001$, Table A-2). Colony abundance showed an increase from 2002 to 2004 ($F_{1,36} = 4.8$, $p=0.035$) but statistical power was only 0.57. The site*year interaction term was significant, however, indicating that patterns in colony abundance at the two sites were not consistent across years ($F_{1,36}$ = 47.9, p<0.001, Fig. A-1). The Tukey HSD test showed that the impact site had significantly fewer colonies in 2002 than the reference site (Fig. A-1). There was a significant increase in number of colonies at the impact site in 2004 but no significant change at the reference site.

Table A-1: Mean number of colonies per $50m^2$ within each site during 2002 and 2004.

Factor	Year	N	Mean Number	SE	-95% CI	+95% CI
Impact	2002	10	14.8	1.3	11.8	17.8
Impact	2004	10	30.9	3.0	24.2	37.6
Reference	2002	10	39.6	1.7	35.9	43.3
Reference	2004	10	27.3	1.7	23.5	31.1

Table A-2: Univariate tests of significance comparing number of colonies between sites and years. Model: Colony abundance (# $50m^{-2}$) = constant + site + year + site*year.

	SS	df	MS	F	p	Power
Intercept	422.54	1	422.54	6529.39	0.000	
Site	2.13	1	2.13	32.88	0.000	1.00
Year	0.31	1	0.31	4.80	0.035	**0.57**
Site*Year	3.10	1	3.10	47.94	0.000	**1.00**
Error	2.33	36	0.06			

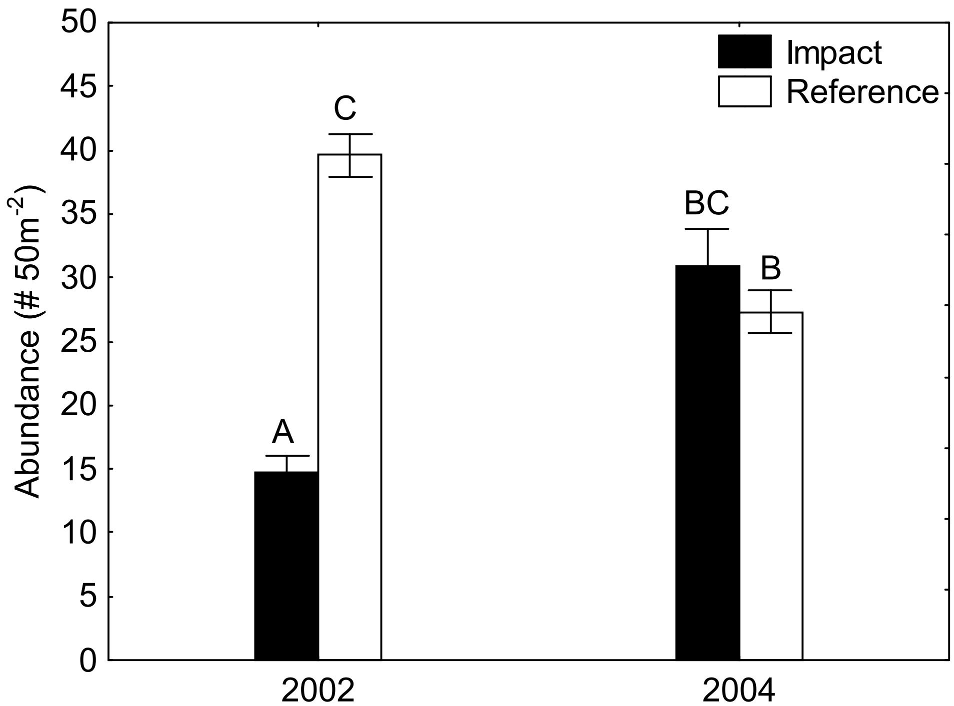

Fig. A-1: Mean number of colonies per $50m^2$ at each site in 2002 and 2004. (N=10, Mean ± SE). The same letter denotes homogenous means using a Tukey HSD post-hoc test on transformed data (p<0.05).

Coral cover

Coral cover at the impact site averaged 2.7% ± 0.5SE in 2002 and 1.9% ± 1.2SE in 2004 (Table A-3). In comparison, the reference site had 14.4% ± 2.6SE in 2002 which declined to 5.7% ± 1.6SE in 2004.

Coral cover was significantly higher at the reference site compared to the impact site ($F_{1,36}$ = 26.1, p<0.001, Table A-4, Fig. A-2). Overall coverage declined from 2002 to 2004 ($F_{1,36}$ =9.1, p=0.005, Table A-4, Fig. A-2). The site*year interaction term was not significant indicating that patterns in coral cover were similar across years ($F_{1,36}$ = 3.0, p=0.30, Table A-4, Fig. A-2). Therefore, the significant decline in coral cover from 2002 to 2004 was attributed to the decrease in cover at the reference site. There was not a significant change in cover at the impact site.

Table A-3: Percent coral cover within each site during 2002 and 2004.

Factor	Year	N	Mean Number	SE	-95% CI	+95% CI
Impact	2002	10	2.7	0.5	2.1	3.2
Impact	2004	10	1.9	1.2	0.7	3.1
Reference	2002	10	14.4	2.6	11.7	17.0
Reference	2004	10	5.7	1.6	4.1	7.3

Table A-4: Univariate tests of significance comparing percent coral cover between sites and years. Model: Percent coral cover = constant + site + year + site*year.

	SS	df	MS	F	p	Power
Intercept	1.83	1	1.83	176.70	0.000	
Site	0.27	1	0.27	26.10	0.000	1.00
Year	0.09	1	0.09	9.14	0.005	**0.84**
Site*Year	0.03	1	0.03	2.96	0.094	**0.39**
Error	0.37	36	0.01			

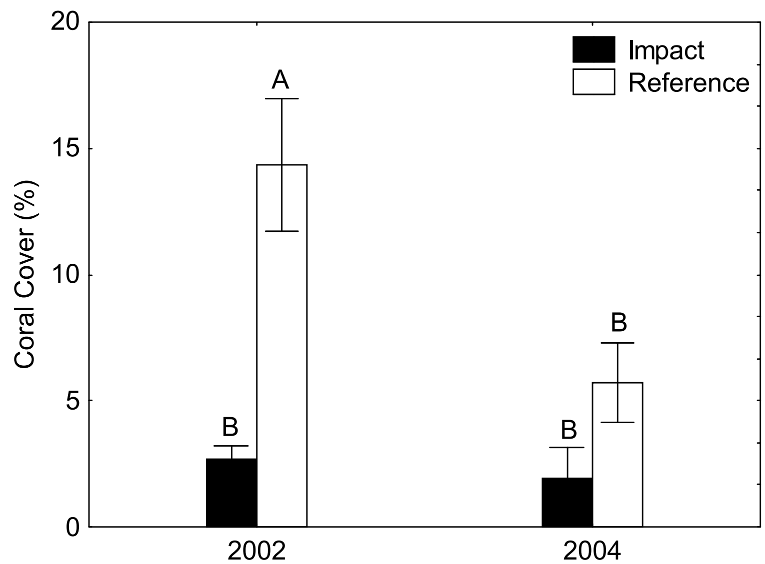

Fig. A-2: Mean number of colonies per 50m^2 at each site in 2002 and 2004. (N=10, Mean ± SE). The same letter denotes homogeneous means using a Tukey HSD post-hoc test on transformed data (p<0.05).

Discussion

There was a significant increase in the number of coral colonies in the impact area during the period 2002 to 2004. The number of colonies doubled through recruitment of new colonies and regeneration of remnant portions of dying colonies. However, these are small colonies. Total coral coverage showed an apparent decrease from 2.7% cover to 1.9% (non-significant), which probably reflects the subsequent death of many of the stressed large colonies observed in 2002.

The November 2003 storm event significantly reduced coral cover at the more wave-exposed reference (control) site at the west end of Pila'a reef. Coverage dropped from approximately 14% to 6%, while total number of colonies decreased by approximately 30% (non-significant).

Appendix B. Statistical analysis of data from Grigg et al. (2003).

Introduction

Grigg et al. (2003) did not perform a statistical analysis of their coral data. Nevertheless they draw a number of important conclusions from this information. The validity of their conclusions was statistically analyzed using data from Appendix A of the Grig et al. (2003) report. The following questions were addressed:

1. Was there a difference between Pīla‘a and the other control sites (‘Anini and Limahuli) in terms of total coral cover?

2. Using a multivariate approach, did certain species or assemblage characteristics help explain the perceived differences among sites?

Methods

Data used for this analysis were derived from Appendix A in Grigg et al. (2003). A Univariate General Linear Model (GLM) nested Analysis of Variance (ANOVA) was used to examine differences among sites with percent coral as the dependent variable and sites (Pīla‘a, ‘Anini, and Limahuli) with transects nested within sites as factors. In this case, the quadrat was treated as a subsample within each transect. The rationale for using the transect as the sampling unit rather than the multiple quadrats was that the quadrats were dependent on the placement of the transect line and therefore not independent of each other. Thus, individual quadrats did not have an equal probability of sampling any given sector of the site but instead were constrained by the transect. In addition, using transects as the sampling unit reduced the overall variation in an effort to increase the statistical power of the test. The nested factor accounted for some of the within-group variability. Thus it was useful to focus on the site differences, which are the primary factor of interest. Both site and transect were treated as fixed factors since Grigg et al. (2003) did not randomly selecting transects within the site. Their maps show a series of transects placed symmetrically parallel to shore. Percent cover data was arcsin-square root transformed to meet the assumptions of normality and homogeneity of variances (Zar 1999). Univariate statistics were performed using Statistica 6.1 and JMP 4.0.

Multivariate analysis in PRIMER 5.0 (Clarke and Gorley 2001) used an ordination of samples by non-metric multi-dimensional scaling (MDS). A preliminary hierarchical clustering technique showed that community variation among all transects was more continuous rather than discontinuous (classification) (Gauch Jr. 1982). Percent cover by substrate type was arcsin-square root transformed and aggregated by transect which was then plotted to reveal similarities/dissimilarities of faunal assemblages among all transects. Stress level was derived to determine the adequacy of the MDS representation (Clarke and Warwick 2001; McCune et al. 2002).

In addition, the benthic assemblage of each site was compared to the other sites using a non-parametric multivariate Analysis of Similarities (ANOSIM in PRIMER 5.0) test that was roughly analogous to a univariate ANOVA test (Clarke and Gorley 2001;

Clarke and Warwick 2001). The pairwise R values were multiple comparisons that gave an absolute measure of how similar (R=0, indistinguishable) or dissimilar (R=1 all similarities within groups are less than any similarity between groups) the sites were (Clarke and Gorley 2001). A BVSTEP routine in PRIMER 5.0 was then conducted to find the best combination of species that accounted for the observed patterns of dissimilarity between each of the site groupings (Clarke and Gorley 2001).

Results

The whole model (Site + Transect(Site)) explained only 28% of the variation in coral cover but this was significant ($F_{13,126} = 5.15$, $p<0.001$). Coral cover among the 3 sites (factor of primary interest), however, was not significantly different ($F_{2,126} = 2.01$, $p = 0.14$, Table B-1) indicating that the significant portion of the variation was explained by variation within groups (Transect(Site): $F_{11,126} = 5.73$, $p < 0.001$). Using the original data, Pīlaʻa had the highest coral cover at 6.5 ± 1.0% followed by Limahuli (6.0 ± 1.8%) and then ʻAnini (3.9 ± 2.0%) (Table B-2). The statistical power of this test, however, was low (Adjusted Power = 0.22, Scale 0 = poor to 1 = good) indicating that the experimental design was not likely to detect a difference at □ = 0.05 between the impact site and the control sites. Adjusted power was calculated to correct for bias in estimating the raw effect size (delta, $\delta = 0.02848$) from the square root of (SS of Site)/n. In essence, this particular sampling design would require approximately 72 more quadrats in a similar configuration (i.e. 5 transects with 50 quadrats at Pīlaʻa and 1 transect with 10 quadrats at both ʻAnini and Limahuli) to achieve a significant difference among sites. Even with the increased effort, however, the statistical power would only be raised to approximately 0.5 (JMP statistical software 2001).

Table B-1. Univariate tests of significance for percent total coral cover among sites using a nested ANOVA. Percent coral cover was arcsin-square root transformed.

	SS	DF	MS	F	p
Intercept	2.11	1	2.11	74.51	0.000
Site	0.11	2	0.06	2.01	0.139
Transect(Site)	1.78	11	0.16	5.73	**0.000**
Error	3.57	126	0.03		

Table B-2. Mean percent coral cover among the 3 sites using the original data. Mean percent ± 1SE.

Site	N	Percent Coral Cover	
		Mean	SE
Pīla‘a	10	6.5	1.0
Limahuli	2	6.0	1.8
‘Anini	2	3.9	2.0

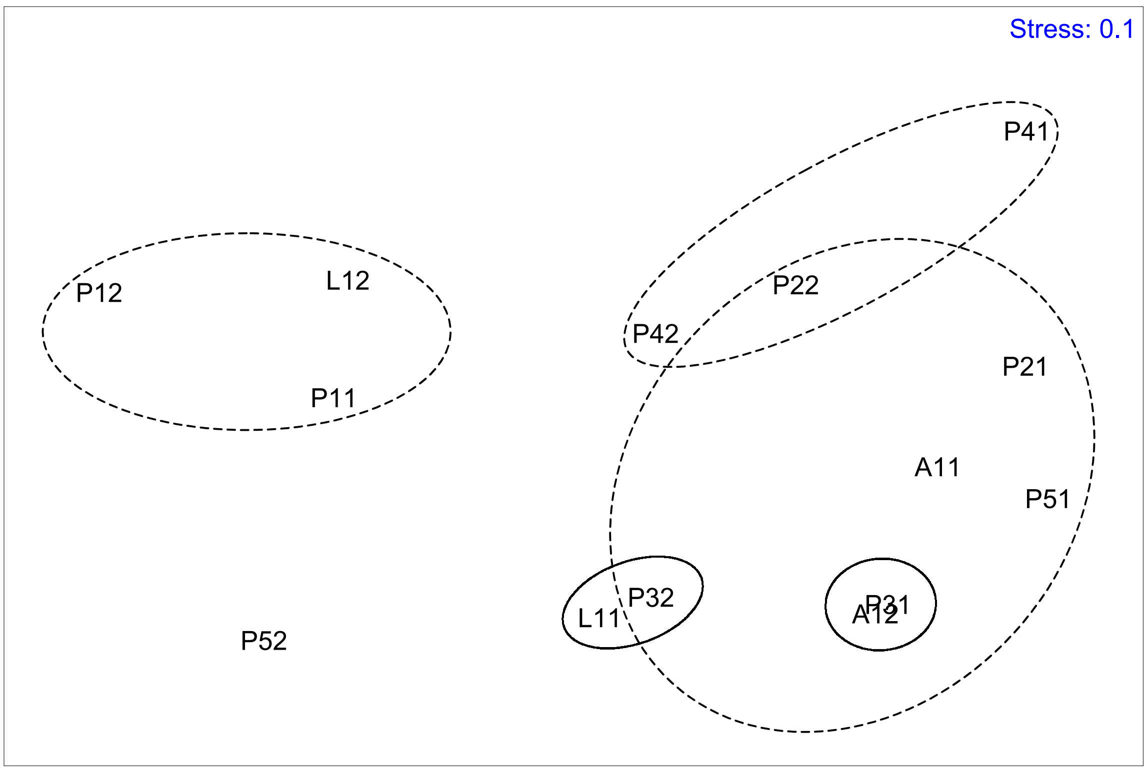

Fig. B-1. Two dimensional MDS plot with superimposed clusters that show similar transects with 90% similarity (solid line) and 80% similarity (dashed line). Transect codes with the prefix of A are from ‘Anini, L from Limahuli, and P from Pīla‘a.

An MDS plot of the data revealed that there was considerable overlap in coral community structure among the sites (Fig. B-1). Stress level was low at 0.1 implying that the MDS plot corresponded to a good ordination of the data set with no strong potential for misleading interpretations (Clarke and Warwick 2001). All of the transects had greater than 50% similarity to other transects regardless of site (Table B-3). It is interesting to note, however, that transect P12 in the impact zone was the most dissimilar from other transects primarily due to the relatively high percentage of *Montipora flabellata* and the lack of any sand in the quadrats.

Table B-3. Similarity matrix of community assemblage among all transects and sites. Transects codes with the prefix of A are from ‘Anini, L from Limahuli, and P from Pīla‘a.

Transects	A11	A12	L11	L12	P11	P12	P21	P22	P31	P32	P41	P42	P51	P52
A11														
A12	83.6													
L11	78.2	82.7												
L12	64.6	62.5	77.2											
P11	63.9	62.3	78.2	85.1										
P12	60.6	56.1	70.2	84.3	77.4									
P21	88.8	79.7	69.0	61.5	65.6	55.2								
P22	81.7	80.1	74.2	77.3	72.6	63.6	84.2							
P31	82.7	98.8	81.7	63.6	63.4	57.2	80.8	81.0						
P32	81.3	86.2	96.3	74.6	74.6	69.0	71.9	74.7	85.2					
P41	73.5	78.6	65.8	64.6	58.5	55.2	75.4	82.1	78.0	66.2				
P42	77.9	78.0	80.7	71.3	80.9	61.9	79.0	82.1	78.9	81.3	68.4			
P51	83.0	81.4	70.8	62.6	62.3	51.0	84.3	79.7	82.5	71.3	76.7	74.3		
P52	63.4	64.4	79.5	79.9	80.0	73.7	57.9	67.1	65.5	76.6	58.5	69.4	60.9	

The multivariate ANOSIM results supported the conclusions of the univariate nested ANOVA with no significant differences among sites (Overall p = 0.88). Limahuli and ‘Anini were the most dissimilar sites (R statistic = 0.5) in terms of the benthic assemblage whereas both sites were extremely similar to Pīlaʻa (Table B-4). Thus the data of Grigg et al. (2003) do not support their own conclusion that Pila'a reefs are more similar to Anini rather than Limahuli. Rather the data actually support the contention of Jokiel (2002) that the reef of the Pila'a impact site was similar to the Limahuli CRAMP site.

Table B-4. ANOSIM results testing for differences in benthic assemblages among sites. An R statistic of 0 indicates that the faunal composition among the site comparisons is nearly identical. An R statistic approaching 1 signifies that the sites are quite dissimilar.

Site Comparisons	R Statistic	p
Anini X Limahuli	0.5	0.33
Anini X Pilaa	-0.25	0.89
Limahuli X Pilaa	-0.128	0.73

The BVSTEP results showed that 7 of the benthic categories (*Montipora capitata, M. flabellata, Porites compressa, P. lobata,* Rubble, Sand, and Turf algae/bare substrate) accounted for the displayed pattern in the full data set with a correlation of 0.98. This means that neither single species nor small subsets of species were influential in explaining the full data set. Thus, the observed structure among sites is composed of similar contributions from many species (Clarke and Warwick 2001). This pattern can be attributed to the high variation in the benthic assemblage among transects. High variation within a site and a small sample size precluded any possibility of a significant outcome.

Discussion

The data of Grigg et al. (2003) do not show statistically significant differences between their control sites and the impact site. The low statistical power shown in the univariate tests and the high variation present in the benthic assemblage demonstrate that their sample size was too small to detect and differences. This problem was detected by Jokiel et al. (2002) early in their survey work at Pila'a. Statistical analysis of data taken during the initial survey showed the necessity for a second survey using a much larger number of transects in a stratified random design within designated habitats. The larger sampling design resulted in a much higher power that was able to detect differences in the communities.

Grigg et al. (2003) did not randomize transect placement. The transects were placed in a symmetrical pattern at each site that was parallel to shore. Lack of randomness in placement of the transects restricts interpretation to only that portion of the habitat under the transect and not the entire population or site (Zar 1999).

The ANOSIM analysis demonstrated the pitfalls of not using statistics to test data and drawing conclusions from such observations. The data of Grigg et al. (2003) do not support their own conclusions but actually give credence to the observations of Jokiel (2002).

Perhaps the data of Grigg et al. 2003 are useful in qualitative descriptions of the habitats, but are insufficient to draw conclusions about differences between the sites.

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