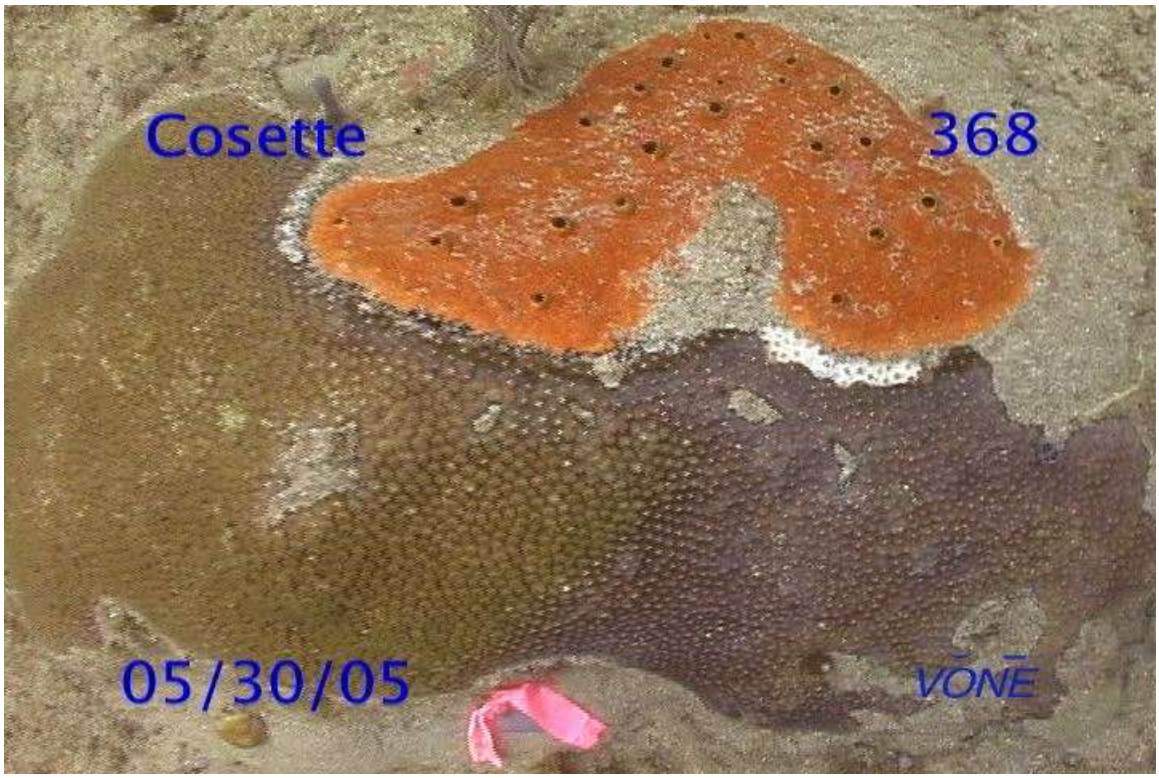
Vŏnē Research Inc.

Diving to Make a Difference!

Site Cosette Coral Reattachment
Broward County, FL

Three-Year Monitoring Report



Report to Florida Fish & Wildlife Conservation Commission
Re: SAL# 05SRP-829 (Site Cosette)

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EXECUTIVE SUMMARY

Vŏnē Research Inc. was informed about vessel grounding damage in April 2005. The grounding caused 52 scleractinian corals to become dislodged from the hardbottom reef. Environmental impacts of the grounding damage included damage to corals, sponges and the underlying substrate on one reef, named the Cosette, after the name of the vessel that caused the damage. On Sunday October 10, 2004, the "Cosette," a 300 to 400 foot long vessel, grounded off of Port Everglades. It was observed when the Federal Pescardores was being towed off its location on the reef by Dick Shaul, a restoration contractor, and by a U.S. Coast Guard official. The vessel was able to free itself within one hour. Dick Shaul dove the site, found numerous impacted corals and uprighted some of the corals.

Vŏnē sought permits to repair the damage and be assisted by Dick Shaul. Coral reef restoration projects such as surveys, mapping and re-attaching corals began in the latter part of April 2005 and were completed by May 2005 . Re-attachment operations were performed by Dick Shaul. After the reattachment was complete, Vŏnē Research Inc. mapped and photo documented Site Cosette, herein referred to as the reattachment site (Figure 1 and 2) and established a reference site to compare the reattachment site to. Repairs included reattaching 52 corals back to the hardbottom substrate. Furthermore, Vŏnē Research monitored the reattachment site in order to document changes of the reattached corals over time and compare those changes to an ecologically similar reference site (Figure 3). By surveying the reconstructed area periodically and comparing the data to the similar reference site, the restoration of this area was monitored and the relative health quantified. Success was determined by the survival and growth of the reattached corals. Monitoring dives were performed on July13, 2008.

Vŏnē Research Inc. has found that reattachment efforts such as the ones that we demonstrated at Site Cosette are viable restoration methods when performed by trained divers in a timely manner. 81% of the corals were relocated and surveyed at the reattachment site and they have shown 100% survivability after reattachment. However, many of them did show mortality of polyps from unknown causes. Seven percent of the corals showed growth, many of which were growing over the cement. Twentyfour percent of the surveyed reattached corals showed a decrease in size due to unknown variables. Sixtyeight percent showed no significant change in colony area. Two percent more corals showed growth at the reference site than at the reattachment site, and three percent more corals showed polyp loss at the reference site than those at the reattachment site.

Based on our three-year evaluation of the reference site and the reattachment site, Vŏnē Research recommends the following actions: monitoring continue on Site Cosette and other sites similar to the Cosette in order to gain a better understanding of the long-term viability of the reattachment effort and to determine potential causes of individual colony polyp loss; reduce the response time to reef damage events to promote higher survivability and reef recovery.

INTRODUCTION

Coral reefs and associated habitats are characterized by their high species diversity supporting up to one-quarter of all marine fish species (Chabanet et al. 2005; Jameson et al. in press; McAllister 1988),which is correlated to their high gross productivity (Chabanet et al. 2005; Jameson et al. in press). Over half of the the fisheries species which are managed in the United States spend a stage of their life on or around coral reefs (Jameson et al. in press). The role of coral reefs in cultivating biodiversity, fisheries, coastal protection through diffusing the intensity of waves, aesthetics, and its increasing importance for tourism revenue make this ecosystem an extremely valuable natural resource providing numerous benefits to humans. Coral reefs contribute to economic benefits estimated at $375 billion per year worldwide (Jameson et al. in press). In Florida, recreational use of coral reefs generated approximately $1.6 billion US dollars in 1990 (Jameson et al. in press). However, the conditions and health of coral reefs in southeast Florida have been, and continue to be, negatively impacted by both natural and anthropogenic variables (SFCRI 2006, Collier 2006) which will eventually reverse the positive affects that coral reefs have on the economy of Florida, comercial fisheries, and the quality of life of Florida residents and visitors. The current rate of degradation of natural habitats worldwide due to human impact is unprecedented in history (Vitousek 1997). These systems are deteriorating far beyond the level where simple conservation methods, such as setting aside an area for preservation, can correct the situation.

Anthropogenic impacts include but are not limited to coastal development, beach renourishment, increased nutrient load and sedimentation due to runoff, dredging activities, cable drags, anchor damage, Carbon Dioxide build-up in the atmosphere and groundings. Coral growth rates are very slow thus coral ecosystems may take decades to recover from such activities if they can recover at all. Corals are colonial organisms that house themselves in a calcareous structure and host an endosymbiotic alga (zooxanthellae), which assists with primary production on the reef. Coral reefs increase at the gradual rate of 1 to 5 meters per 1000 years (Jaap 2000). Due to this growth rate, damaged reefs may not naturally recover in our lifetime. A more aggressive approach involving actively restoring damaged sites is needed if this ecosystem is to be saved. As our reefs continue to disappear at an alarming rate, the act of reef restoration may become the dominant conservation act (Rinkevich 2005). Reef restoration efforts such as coral transplants and coral reattachment can help to reverse some anthropogenic impacts such as cable drags, anchor damage and groundings. Vŏnē Research Inc. has been permitted by the State of Florida to respond to such events that impact reefs in Broward County in order to document damage, stabalize and repair reefs.

On Sunday October 10, 2004, the "Cosette," a 300 to 400 foot long vessel, grounded off of Port Everglades. It was observed when the Federal Pescardores was being towed off its location on the reef by Dick Shaul, a restoration contractor, and by a U.S. Coast Guard official. The vessel was able to free itself within one hour. Damage included impacts to corals and the hardbottom. Dick Shaul, a restoration contractor, dove the site and uprighted some of the impacted corals. Coral reef restoration projects such as surveys, mapping and re-attaching corals began in the latter part of April 2005 and were completed by May 2005 . Re-attachment operations were performed by Dick Shaul. After

the re-attachment was complete, Vŏnē Research Inc. mapped and photo documented site Cosette, herein referred to as the reattachment site (Figure 1 and 2) and established a reference site to compare the reattachment site to. Repairs included reattaching 52 corals back to the hardbottom substrate. Furthermore, Vŏnē Research monitored the reattachment site in order to document changes of the reattached corals over time and compare those changes to an ecologically similar reference site (Figure 3). By surveying the reconstructed area periodically and comparing the data to the similar reference site, the restoration of this area was monitored and the relative health quantified. Success was determined by the survival and growth of the reattached corals.

STUDY SITES

Site Cosette and the reference site are characterized by the presence of hexacorals, octocorals and sponges that are significant constituents of the macrofauna growing on a hardbottom reef which parallels the coast (Figure 1).

The reattachment site is located at an approximate depth of 4-6 meters between GPS North datum coordinates N 26^{o} 07.408' and W 80 ^{o} 05.657' and South datum coordinates N 26^{o} 07.385' and W 80^{o} 05.650' (Figure 1 and 2). An adjacent undamaged portion of reef was chosen as a reference site (Figure 1 and 3) to be used as a control to monitor the progress of the reattachment. Depth at this site is approximately 5 meters, and contains similar coral types and ecological parameters as those of the reattachment site. The reference site is located south of the reattachment site at GPS coordinates N 26^{o} 07.380' and W 80^{o} 05.650'.

Figure1. Areal photographs showing Cosette site and GPS coordinates offshore from Ft. Lauderdale, FL.

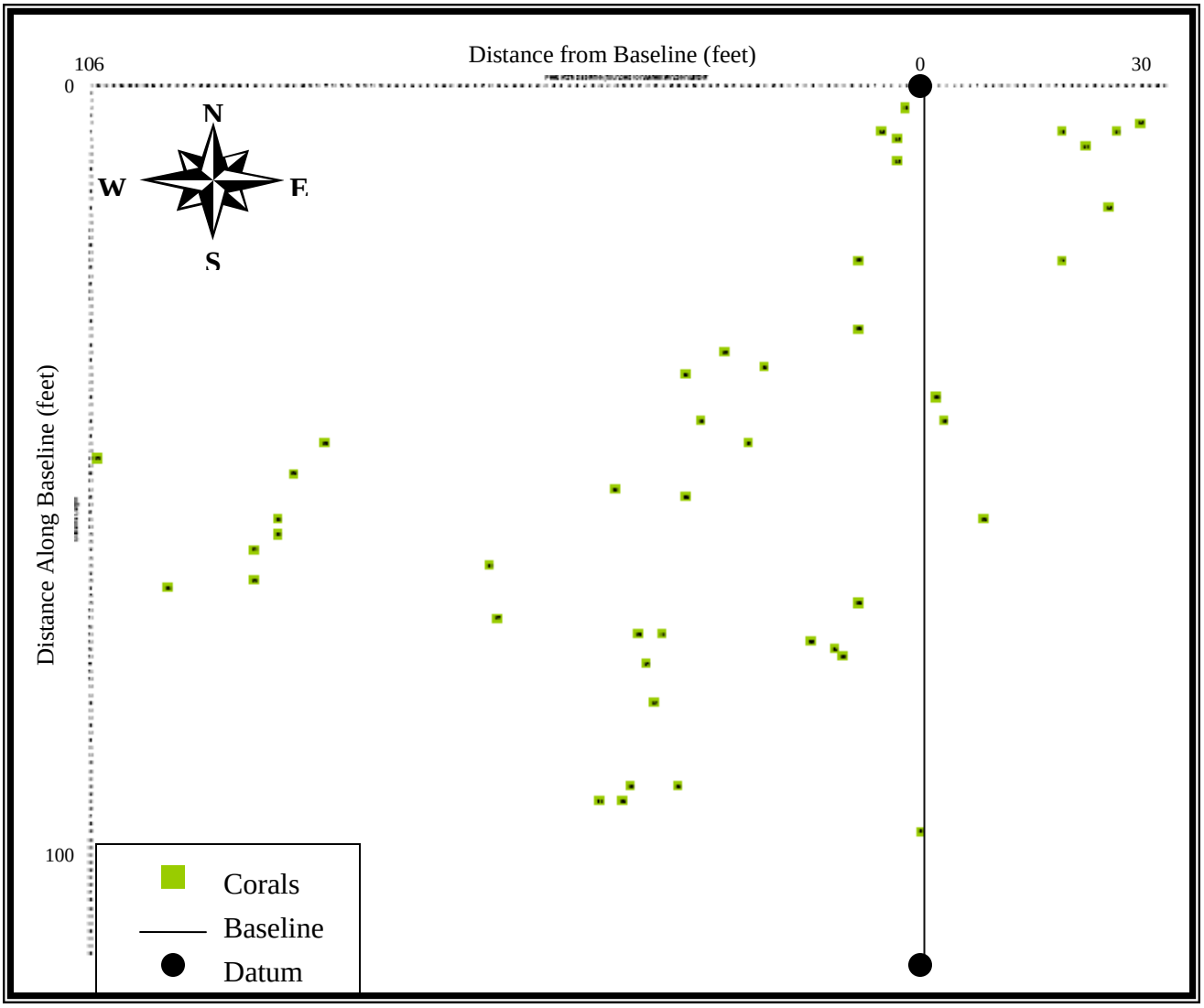

Figure 2. Map of Reattachment Site at Cosette. The baseline of the reattachment area is approximately 30 meters long. The total area of the reattachment site is 1263 square meters.

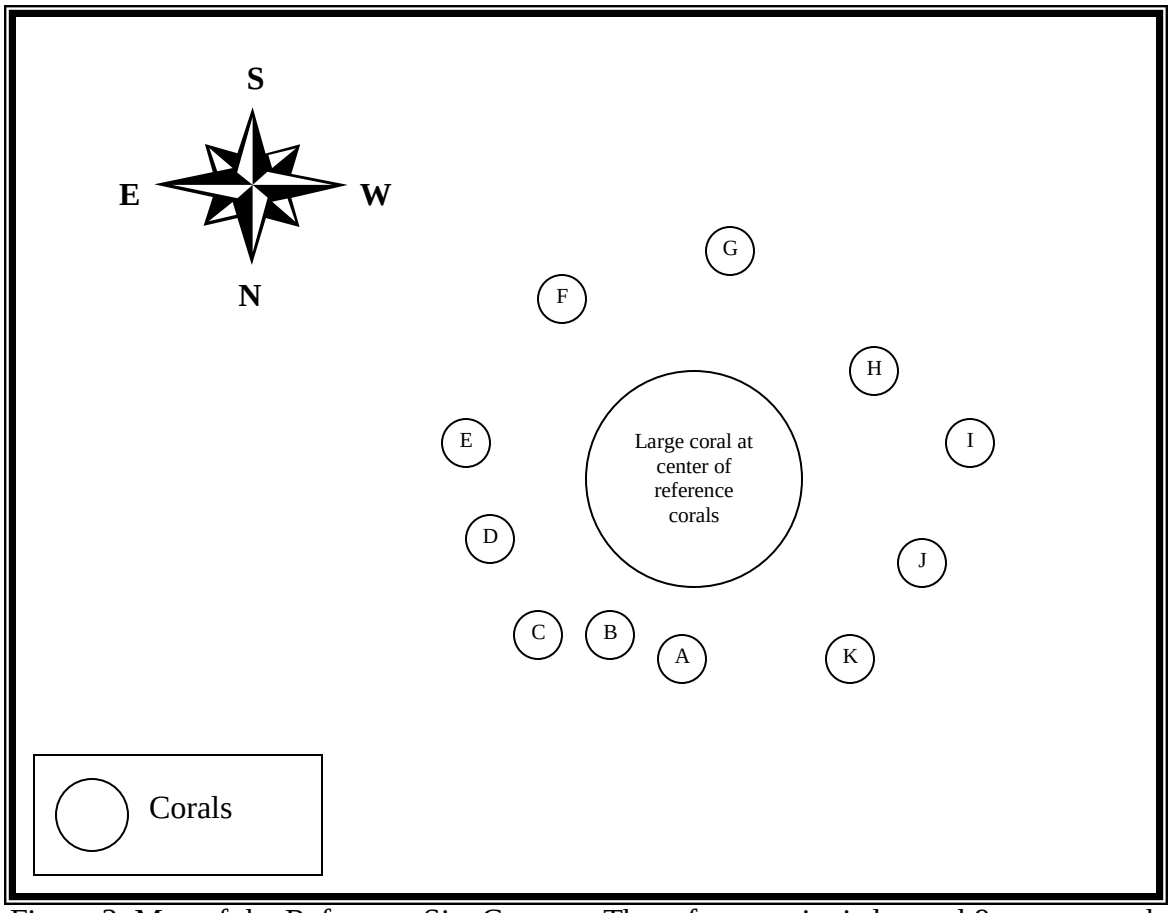

Figure 3. Map of the Reference Site Cosette. The reference site is located 9 meters south of the reattachment site.

METHODS & MATERIALS

Multiple dive teams performed initial survey and reef restoration dives in April and May 2005. Monitoring dives were performed at each site on May 22 and 30, 2005 and July 13, 2008.

Initial survey dives performed by Vŏnē Research and Dick Shaul included one to three teams of divers, which marked corals using a fluorescent plastic flagging tape that was loosely tied around the coral. Corals were then righted and reef damage was photographed. Reef restoration efforts were performed by Dick Shaul and his dive team. SCUBA teams were deployed onto the damaged reef to perform coral reattachment. His team used a thick mixture of cement. The SCUBA divers scrubbed the reattachment site on hardbottom clean of algae and loose sediment. Then a cement ball was firmly pressed onto the cleaned area and an upright coral was firmly pressed onto the cement. Each coral was identified using a stainless steel tag with sequential unique numbers on each. The tag was embedded into the reattachment cement and secured with a stainless steel lag bolt. Reef restoration monitoring included comparing reattached coral survivability and

growth to that of corals that were not impacted by the grounding. The reference and reattachment sites were revisited three years after the initial reattachment. The two sites were photographed and corals were measured.

Each site was located from the research vessel using a Garmin GPS. Three teams of scuba divers were deployed; one team focused on finding and measuring individual corals and one team focused on digitally recording coral health and site condition. Upon deployment, the scuba divers used maps (Figures 2 and 3) of the area that were drawn on underwater slates to determine the exact location of the datum and reattached corals.

During the three-year monitoring survey, Vŏnē discovered that the stainless steel identification tags were difficult to find and read. Nineteen percent of the tags could not be found, either because the coral had grown over the tag and cement completely, or because growth of other organisms such as sponges, oysters, calcareous algae and macroalgae had covered them. Once the identification tags of each coral were found, they were scraped clean using a dive knife and coral identification was verified. A team of two divers measured the corals, each diver served as a quality control check of the other to ensure accuracy of measurements. Corals were measured using a measuring tape. The length and widest width of the coral skeleton covered by living tissue was measured to determine the approximate area covered by individual coral colonies.

Photographs and video were then taken using a Reefmaster digital camera and a Sony HDV camera secured in a Sea View underwater housing. Corals were photographed in alphabetical or numerical order and both divers in the photography team verified the coral tag identities.

RESULTS

A total of 52 corals were reattached in 2005. During the three-year monitoring, 81% of the corals were re-located. One-hundred percent of the surveyed reattached corals survived to 2008. Seven percent of the remaining reattached corals showed and increase of area covered by living tissue, while 24% showed a decrease in size at the reattachment site (Table 1, Figure 4 and Appendix A). Similarly, nine percent of corals at the reference site showed an increase in area covered by living tissue, while 27% showed a decrease in area covered by living tissue from 2005 to 2008 (Table 2, Figure 5 and Appendix A).

Table 1. Measurements of area covered by living tissue of corals observed at Reattachment Site Cosette in 2008. In 2008, 81% of the original 52 corals were relocated. Seven percent of remaining corals showed an increase in area covered from 2005 to 2008 according to the photographic analysis. Twentyfour percent of the surveyed reattached corals showed a decrease in area covered. Sixtyeight percent showed no significant change in area covered.

Coral #	Area Covered (cm^2)	
	June 2008	Change in area covered since 2005
342	1355	Not significant
346	2845	Increase
347	226	Decrease
348	465	Decrease
349	155	Decrease
350	645	Decrease
351	1161	Not significant
352	310	Not significant
353	497	Decrease
354	387	Increase
355	723	Increase
356	3871	Not significant
357	1645	Not significant
358	155	Not significant
359	290	Increase
360	1839	Not significant
361	923	Not significant
362	2065	Not significant
363	3265	Not significant
364	4800	Decrease
365	5200	Decrease
367	852	Not significant
368	2200	Decrease
369	271	Not significant
370	2968	Not significant
371	5961	Increase
372	1761	Decrease
374	1419	Unknown
375	2271	Decrease
377	5961	Not significant
378	645	Not significant
379	77	Decrease
380	839	Not significant
381	2787	Not significant
382	1161	Not significant
383	1310	Not significant
384	382	Not significant
385	271	Not significant
386	2323	Not significant
387	710	Not significant
389	1161	Decrease
390	2168	Decrease

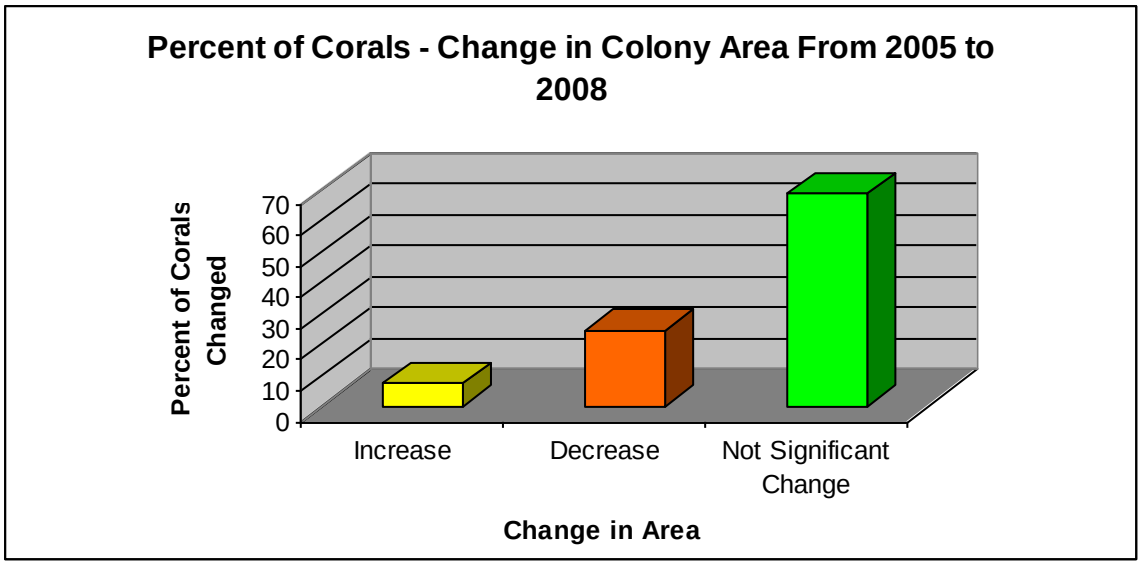

Figure 4. Observable change in coral area covered by living tissue from 2005 through 2008 at Reattachment Site Cosette. Seven percent of corals showed an increase in area covered by living tissue. Twenty four percent showed a decrease in area covered by living tissue. Sixty eight percent showed no significant change in area covered by living tissue.

Coral	Area Covered (cm^2)	
	June 2008	Change in area covered since 2005
A	4645	Decrease
B	2329	Not Significant
C	5200	Increase
D	581	Not Significant
E	2574	Decrease
F	1471	Decrease
G	710	Not Significant
H	7948	Decrease
I	UNK	Not Significant
J	77	Not Significant
K	2206	Not Significant

Table 2. Measurements of area covered by living tissue of corals observed at the Reference Site in 2008. Nine percent of corals showed an increase of area covered by living tissue; twenty seven percent of corals showed a decrease in area covered by living tissue; sixty four percent showed no significant change in area covered by living tissue from 2005 to 2008 according to photographic analysis.

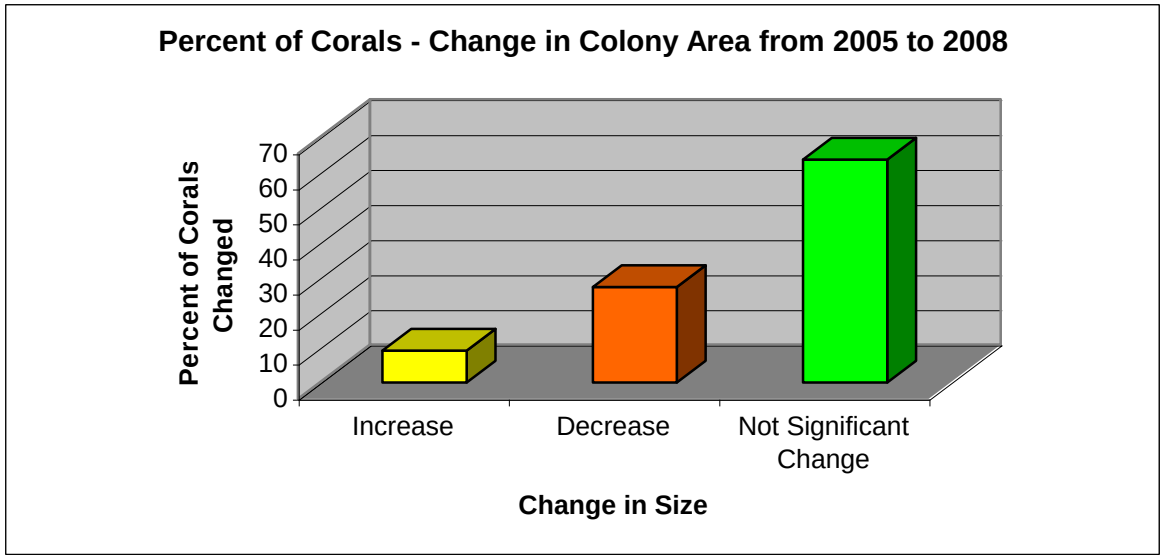

Figure 5. Change in Coral Area Covered by Living Tissue from 2005 through 2008 at Site Cosette Reference. Nine percent of corals showed an increase in area covered by living tissue. Twenty seven percent showed a decrease in area covered by living tissue. Sixty four percent showed no significant change in area covered by living tissue.

DISCUSSION

Vŏnē Research Inc. has found that reattachment efforts such as the ones demonstrated by Vŏnē Research Inc. at Reef Cosette can be a viable restoration method when performed by trained divers. The surveyed corals at the reattachment site have shown 100% survivability after reattachment. Seventy six percent of the surveyed corals showed growth or no significant change in size; many were growing over the cement implying that the cement has little or no negative impacts on the reattached corals. Twenty four percent of the surveyed reattached corals showed a slight decrease in size due to unknown variables. Twenty seven percent of corals in the reference site also showed a decrease in size due to unknown variables. A larger sample size is needed to accurately determine possible causes of polyp mortality and the significance of the colony growth versus polyp loss between the reattachment and reference sites. However at the rate of reef declination, any loss of area covered by coral is cause for further study.

RECOMMENDATIONS

Based on our three-year evaluation of the reference site and the reattachment site, Vŏnē Research recommends the following actions:

1) Continue monitoring on Reef Cosette in order to gain a better understanding of the long-term viability of the reattachment effort and to determine potential causes of individual colony polyp loss.
2) Reduce the response time to reef damage events to promote higher survivability and reef recovery. Historically, this resulted in a higher success of coral restoration projects (Jaap 2000).

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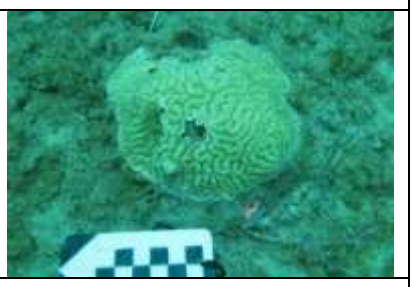
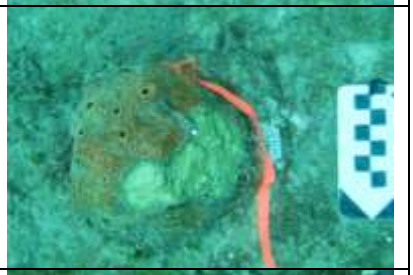
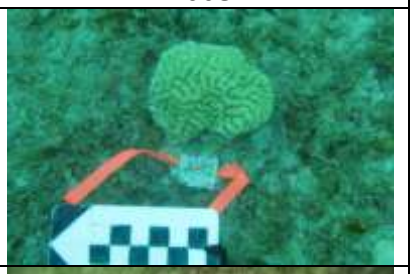
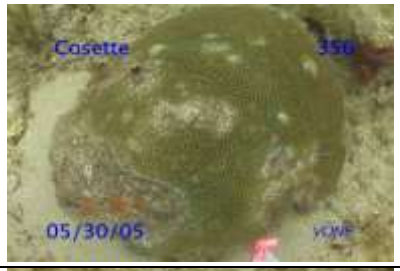
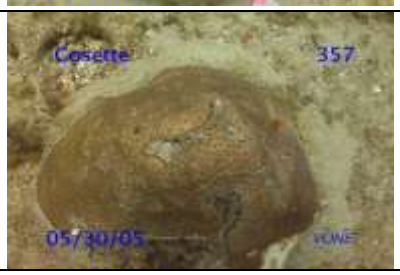
APPENDIX A

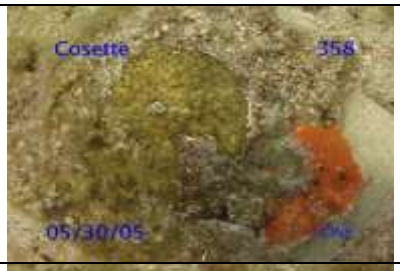
Photographs of coral changes at the Reference and Reattachment sites from years 2005 to 2008

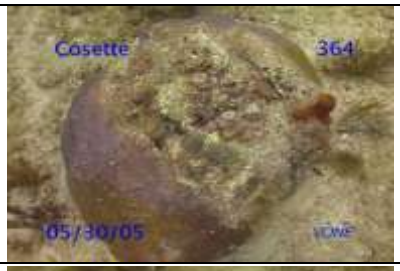
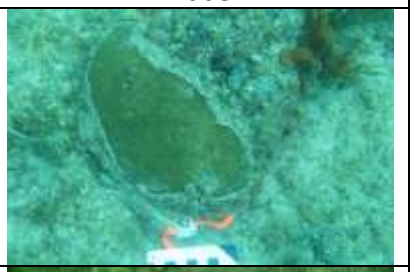
Appendix A. Photographs of coral changes at the reattachment site from the years 2005 to 2008.

Reattachment Site		
Coral	**2005**	**2008**
340: Knobby Star Coral *Solenastrea hyades*		N/A
341: Boulder Star Coral *Montastrea annularis*		N/A
342: Maze Coral *Meandrina meandrites*		
343: Knobby Star Coral *Solenastrea hyades*		N/A
344: Knobby Star Coral *Solenastrea hyades*		N/A
345: Boulder Star Coral *Montastrea annularis*		N/A

Reattachment Site		
Coral	**2005**	**2008**
346: Boulder Star Coral *Montastrea annularis*		
347: Knobby Star Coral *Solenastrea hyades*		
348: Knobby Star Coral *Solenastrea hyades*		
349: Scleractinian Coral *Porites sp.?*		
350: Great Star Coral *Montastrea cavernosa*		
351: Knobby Star Coral *Solenastrea hyades*		

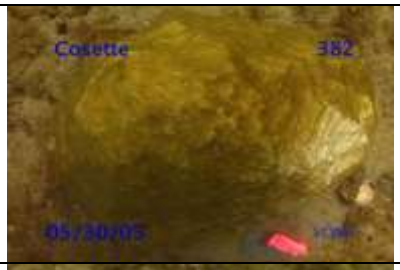
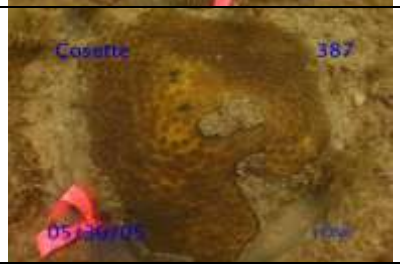
Reattachment Site		
Coral	**2005**	**2008**
352: Maze Coral *Meandrina meandrites*		
353: Knobby Star Coral *Solenastrea hyades*		
354: Mustard Hill Coral *Porites asteroides*		
355: Boulder Star Coral *Montastrea annularis*		
356: Boulder Star Coral *Montastrea annularis*		
357: Boulder Star Coral *Montastrea annularis*		

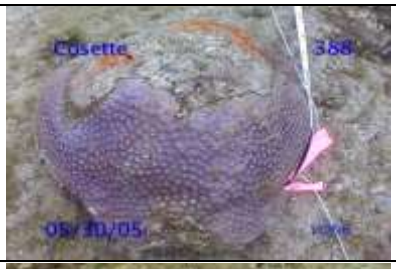
Reattachment Site		
Coral	**2005**	**2008**
358: Great Star Coral *Montastrea cavernosa*		
359: Knobby Star Coral *Solenastrea hyades*		
360: Boulder Star Coral *Montastrea annularis*		
361: Knobby Star Coral *Solenastrea hyades*		
362: Boulder Star Coral *Montastrea annularis*		
363: Great Star Coral *Montastrea cavernosa*		

Reattachment Site		
Coral	**2005**	**2008**
364: Boulder Star Coral *Montastrea annularis*		
365: Boulder Star Coral *Montastrea annularis*		
366: Mustard Hill Coral *Porites asteroides*		N/A
367: Great Star Coral *Montastrea cavernosa*		
368: 2 Species Star Coral (Left side) *Montastrea cavernosa* (Right side) *Montastrea annularis*		
369: Boulder Star Coral *Montastrea annularis*		

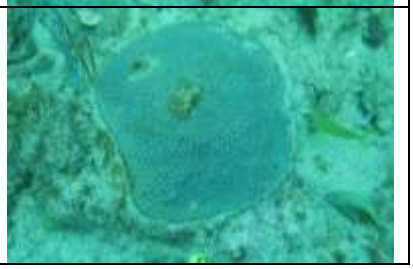
Reattachment Site		
Coral	**2005**	**2008**
370: Blushing Star Coral *Stephanocoenia intersepta*		
371: Boulder Star Coral *Montastrea annularis*		
372: Knobby Brain Coral *Diploria clivosa*		
373: Elliptical Star Coral *Dichocoenia stokesii*		N/A
374: Boulder Star Coral *Montastrea annularis*	No photo available	
375: Boulder Star Coral *Montastrea annularis*		

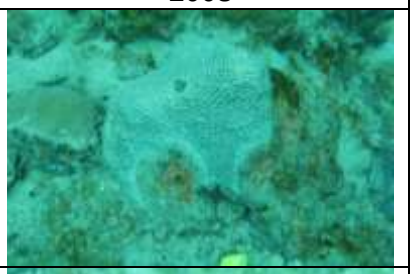
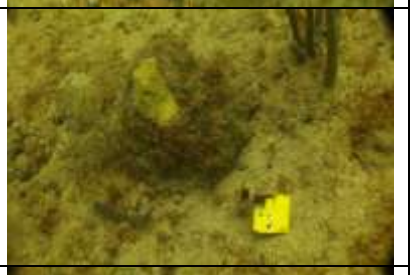
Reattachment Site		
Coral	**2005**	**2008**
376: Mustard Hill Coral *Porites asteroides*		N/A
377: Boulder Star Coral *Montastrea annularis*		
378: Elliptical Star Coral *Dichocoenia stokesii*		
379: Great Star Coral *Montastrea cavernosa*		
380: Boulder Brain Coral *Colpophyllia natans*		
381: Great Star Coral *Montastrea cavernosa*		

Reattachment Site		
Coral	**2005**	**2008**
382: Knobby Star Coral *Solenastrea hyades*		
383: Knobby Star Coral *Solenastrea hyades*		
384: Great Star Coral *Montastrea cavernosa*		
385: Great Star Coral *Montastrea cavernosa*		
386: Symmetrical Brain Coral *Diploria strigosa*		
387: Great Star Coral *Montastrea cavernosa*		

Reattachment Site		
Coral	**2005**	**2008**
388: Great Star Coral *Montastrea cavernosa*		N/A
389: Massive Starlet Coral *Siderastrea siderea*		
390: Boulder Star Coral *Montastrea annularis*		
391: Boulder Star Coral *Montastrea annularis*		N/A

Appendix A. Photographs of coral at the Reference site in 2008.

Reference Site		
Coral	**2005**	**2008**
A: Great Star Coral *Montastrea cavernosa*		
B: Boulder Brain Coral *Colpophyllia natans*		
C: Symmetrical Brain Coral *Diploria strigosa*		
D: Great Star Coral *Montastrea cavernosa*		
E: Great Star Coral *Montastrea cavernosa*		

Reference Site		
Coral	**2005**	**2008**
F: Great Star Coral *Montastrea cavernosa*		
G: Great Star Coral *Montastrea cavernosa*		
H: Boulder Brain Coral *Colpophyllia natans*		
I: Boulder Star Coral *Montastrea annularis*		
J: Knobby Star Coral *Solenastrea hyades*		
K: Great Star Coral *Montastrea cavernosa*