EXECUTIVE SUMMARY

High Resolution Landscape (2-D) Mosaics for Improved Coral Reef Monitoring Capability

ESTCP Project RC-201021

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1.0 INTRODUCTION

The overall objective of ESTCP project RC-201021 was to demonstrate the utility of underwater image mosaics for coral reef monitoring. The problem of efficiently mapping and monitoring coral reef resources has relevance to the Department of Defense for several reasons. First, at least 46 US military facilities have adjacent coral reef sites. Second, federal policy mandates that DoD characterize, assess, and monitor underwater benthic communities at these sites to ensure that DoD operations do not lead to natural resource degradation. Third, coral reef ecosystems worldwide are presently threatened by increasing levels of both human and natural disturbance. Thus, monitoring efforts that can efficiently provide data that will help distinguish between reef degradation that can be directly attributed to DoD activities versus those that that are correlated with region-wide decline are of primary concern.

SERDP had previously supported a team from the University of Miami's Rosenstiel School of Marine and Atmospheric Research to research the creation and use of underwater image mosaics under Resource Conservation Project 13333. The result of the SERDP-supported research was a suite of image processing algorithms, software, and best-practices that together enabled new capability for mapping and monitoring coral reef resources. The SERDP project projected that use of meso-scale, 2-D, mosaicked images of reef plots could circumvent the limitations of current state-of-the-art methods in coral reef monitoring (i.e., diver transects, photo-quadrats, strip mosaics), while simultaneously maintaining the strengths of a diver-based approach. Testing this premise was the overall objective of this ESTCP project.

The overall goal of RC-201021 was to demonstrate that landscape mosaics extend traditional methods of coral reef monitoring by providing new capabilities, while simultaneously retaining the strengths of diver-based methods. Five demonstrations were conducted to test 18 performance objectives that had been identified in response to the needs assessment: Long-term Monitoring Demonstration, Endangered Species Demonstration, Grounding Demonstration, Traditional Metrics Demonstration, and Absolute Accuracy Demonstration.

The goal of the Long-term Monitoring Demonstration was to assess the potential benefits of using landscape mosaic technology in a long-term coral reef monitoring program. In particular we assessed the effectiveness of using mosaics to extract: 1) colony-based metrics of coral reef condition and 2) the metrics needed to map and monitor large-scale reef plots for change-detection purposes. In addition, we also evaluated the ease of use of the mosaic technology in terms of data collection.

The goal of the Endangered Species Demonstration was to evaluate the utility of mosaics for monitoring populations of threatened corals, particularly the species *Acropora palmata*. We evaluated the technology in its ability to replicate diver metrics of: 1) coral location and abundance; 2) coral colony size; and 3) colony condition.

The goal of the Grounding Demonstration was to evaluate the utility of mosaics for assessing damage to reefs caused by vessel groundings. We evaluated the utility of using mosaics to measure: 1) large areas of damage; 2) long linear-distances; 3) multiple methods of damage assessment; and 4) reef health. A fifth performance objective was devised to assess whether new users can extract data from image mosaics.

The goal of the Traditional Metrics Demonstration was to evaluate the utility of mosaics for coral reef monitoring efforts traditionally performed using diver-transect surveys. The performance objectives of this demonstration examined if: 1) mosaics could replicate ecological information extracted from diver surveys; 2) mosaics could estimate metrics obtained through multiple diver methods of reef health assessment; and 3) novice users can be trained to create image mosaics using a manual.

The goal of the absolute accuracy demonstration was to evaluate the accuracy and precision of size measurements made from mosaic image analysis and diver surveys. Unlike the other four demonstrations, the success criteria in this demonstration were based on the known sizes of objects and not the performance relative to diver surveys. For this demonstration we evaluated: 1) the absolute accuracy of mosaic and diver size measurements; 2) the precision of multiple mosaic and diver size measurements; 3) the precision of multiple mosaic analysts and diver size measurements; and 4) the bias of pool and field derived mosaic imagery. The average bias of measuring targets of known size between 5 and 120cm was approximately 1cm for both diver and mosaic methods. The same was true for estimating the projected length of inclined targets. No differences were observed when comparing results over multiple mosaics or when using multiple mosaic analysts. In addition, the measurement bias of objects placed in a pool was not significantly different than the bias measured in field mosaics. Thus mosaics were found to be highly accurate methods of estimating coral colonies on the cm scale and these results were found to be repeatable over different images and using different observers to carry out the analysis.

2.0 OBJECTIVES

The overall objective of ESTCP project RC-201021 was to demonstrate the utility of underwater image mosaics for coral reef monitoring. The problem of efficiently mapping and monitoring coral reef resources has relevance to the Department of Defense (DoD) for several reasons. First, at least 46 US military facilities have adjacent coral reef sites. Second, federal policy mandates that DoD characterize, assess, and monitor underwater benthic communities at these sites to ensure that DoD operations do not lead to natural resource degradation. Third, coral reef ecosystems worldwide are presently threatened by increasing levels of both human and natural disturbance. Thus, monitoring efforts that can efficiently provide data that will help distinguish between reef degradation that can be directly attributed to DoD activities versus those that that are correlated with region-wide decline are of primary concern.

SERDP had previously supported a team from the University of Miami's Roesenstiel School of Marine and Atmospheric Research (UM/RSMAS) to research the creation and use of underwater image mosaics. The result of the SERDP-supported research was a suite of image processing algorithms, software, and best-practices that together enabled new capability for mapping and monitoring coral reef resources. The SERDP project projected that use of meso-scale, 2-D, mosaicked images of reef plots could circumvent the limitations of current state-of-the-art methods in coral reef monitoring (i.e., diver transects, photo-quadrats, strip mosaics), while simultaneously maintaining the strengths of a diver-based approach. Testing this premise was the overall objective of this ESTCP project.

In order to demonstrate the capabilities of the underwater landscape mosaic technology, the approach was to determine potential end users' specific applications and needs that could benefit from these new capabilities. Four field demonstrations and one pool demonstration were conducted to test 18 performance objectives that had been identified in response to the needs assessment (see Table 2 in Section 6.0 for a full listing). Most of the performance objectives had more than one metric to test, so there were a total of 57 metrics that were assessed during the project. Of the 18 performance objectives, 9 were considered completely successful, 9 were a partial success, and 0 were failures. Of the 57 metrics, 45 were considered completely successful, 12 were a partial success, and 0 were failures. Eight of the 12 metrics that were partial successes were technically not complete successes due to the way the performance tests were designed, but for practical purposes were still quite acceptable.

3.0 TECHNOLOGY DESCRIPTION

A mosaic is a single large image composed of many smaller overlapping images, each covering a small portion of the total area. Individual underwater images are taken close (~1-2 m) to the seabed; they have high spatial resolution and minimal water column attenuation. A mosaic of such underwater images enables a high-resolution "landscape view" of the seabed. The RSMAS team has developed techniques to construct spatially accurate mosaics covering areas up to 20×20 m with millimeter-scale resolution. First-generation mosaics, ca. 2004, were created with video images only and provided millimeter-scale resolution. In 2007, a second-generation system with sub-millimeter scale resolution was developed by integrating a high-resolution still camera with the original video acquisition system. This demonstration used the second-generation system.

The innovative aspect of the current mosaic technology is that the images provide both landscape-level maps and high resolution (sub-millimeter) images of individual coral colonies. Users can, moreover, collect imagery at both landscape and colony-levels for areas of several hundred square meters in under an hour of in-water dive time, creating mosaic products that provide increased information on coral colony health and small-scale competitive interactions. Landscape mosaics address several limitations of traditional, diver-based, coral reef monitoring techniques:

- Mosaics provide a landscape view of coral reefs that has previously been unobtainable;
- Mosaics are efficient tools for tracking patterns of change over time; and
- Mosaics have high spatial accuracy and precision.

The overall goal of RC-201021 was to demonstrate that landscape mosaics extend traditional methods of coral reef monitoring by providing new capabilities, while simultaneously retaining the strengths of diver-based methods (Table 1). Four field demonstrations were designed to test the mosaic capabilities relative to other techniques currently used for coral reef assessment. In addition, a fifth demonstration was conducted under controlled conditions in a pool using manmade targets of known size in order to assess the absolute spatial accuracy of the mosaics (as opposed to the field demonstrations, which assessed mosaic accuracy relative to diver-based measurements).

Table 1 shows for each mosaic capability, the end user applications/needs and the demonstration in which each was tested.

Table 1. Mosaic Capabilities, End User Applications/Needs, and Demonstration.

Mosaic Capabilities	End User Applications / Needs	Demonstration
Addresses limitations of the diver transect	**NOT adequately addressed solely by divers**	
Landscape view	Assessment and monitoring ESA-listed species	ESA
Monitor without tagging	Monitoring coral community trends	Long-Term Monitoring
Relative Spatial accuracy	Assessment of acute physical damage	Grounding
Archive potential	Response to challenges of methodology	Traditional Metrics
Ease of use	Practical implementation of new technology	Multiple
Retains strengths of the diver transect	**Adequately addressed solely by divers**	
Traditional measurements (% cover, diversity, condition, size, juvenile denisty)	Assessment of coral community status New technology must not degrade what already works well	Traditional Metrics / Grounding
Absolute Accuracy		
Spatial accuracy (cm scale)	Need to know limits of technology	Pool
Spatial accuracy (m scale)	Need to know limits of technology	Grounding

4.0 PERFORMANCE ASSESSMENT

Long-term Monitoring Demonstration - The goal of this demonstration was to assess the potential benefits of using landscape mosaic technology in a long-term coral reef monitoring program. In particular, we assessed the effectiveness of using mosaics to extract: 1) colony-based metrics of coral reef condition and 2) the metrics needed to map and monitor large-scale reef plots for change-detection purposes. In addition, we also evaluated the ease of use of the mosaicking technology in terms of data collection. The results showed that measurements of colony size and percent cover made by divers in the water were not significantly different than those made from mosaic image analysis. Mosaic imagery was also capable of providing the same information as from hand-mapping reef areas. In addition, mosaic imagery and the process of mosaic analysis was found to be as consistent as using multiple diver observations. Finally, nonscientific divers were trained in mosaic image acquisition and acquired useable data. In terms of cost, there was little difference in mosaicking and diver methods of measuring coral colony sizes. However, given the same cost per unit effort (4 days of sampling, 2 divers) we estimated that divers would be able to map 62m^2 of reef resources using hand-mapping techniques as compared to ~3,800m^2 using landscape mosaics.

4.1 ENDANGERED SPECIES DEMONSTRATION

The goal of this demonstration was to evaluate the utility of mosaics for monitoring populations of threatened corals, particularly the species *Acropora palmata*. We evaluated the technology in its ability to replicate diver metrics of: 1) coral location and abundance; 2) coral colony size; and 3) colony condition. Mosaic imaging technology was able to replicate diver assessments of coral colony counts, location information, colony size estimates, and provide mosaic analysts with the information to accurately assess colony health information, such as percentage of live cover and colony type. When comparing the cost of assessing coral colonies for the above metrics image, mosaicking was less expensive than traditional diver methods.

4.2 GROUNDING DEMONSTRATION

The goal of this demonstration was to evaluate the utility of mosaics for assessing damage to reefs caused by vessel groundings. We evaluated the utility of using mosaics to measure: 1) large areas of damage; 2) long linear-distances; 3) multiple methods of damage assessment; and 4) reef health.

A fifth performance objective was devised to assess whether new users can extract data from image mosaics. We found no significant differences in measures of long-linear distances between divers and mosaics. GPS information was found to be less accurate than either divers or mosaics for the purpose of damage assessment. Measures of reef health agreed with mosaic-derived indices with the exception of categories such as sand and gorgonian cover that varied greatly between observers and methods. Novice analysts were able to derive estimates of coral colony sizes and percent cover of major categories that were indistinguishable from diver estimates. When comparing the cost of assessing reef damage, GPS methods were the least expensive followed by mosaic imaging. Diver–based assessment of reef damage was the most expensive method tested. The GPS method, although inexpensive was also the least accurate and most variable of the three methods tested. The mosaic is the most cost-effective method of measuring reef damage due to the accurate results and the increased ecological information provided over both diver-based and GPS methods.

4.3 TRADITIONAL METRICS DEMONSTRATION

The goal of this demonstration was to evaluate the utility of mosaics for coral reef monitoring efforts traditionally performed using diver-transect surveys. The performance objectives of this demonstration examined if: 1) mosaics could replicate ecological information extracted from diver surveys; 2) mosaics could estimate metrics obtained through multiple diver methods of reef health assessment; and 3) novice users can be trained to create image mosaics using a manual. In cases where we replicated the exact diver-based transect directly on a mosaic image, there was no significant difference found in estimating coral reef health parameters. However, some differences in methods were detected based on differences in the areas sampled by various diver transects and the variability of the reef itself. Novice users were trained to, with a manual, use mosaic software and create mosaic image data that was indistinguishable from those created by expert analysts. When comparing diver and mosaic methods of estimating ecological metrics we found that single-variable diver methods of estimating coral health are less costly than mosaic surveys. However, if end-users are interested in estimating more than one health parameter in a given survey, such as coral cover, coral size frequency, and species diversity, mosaic imaging is less expensive since all of these metrics can be obtained from a single mosaic survey. In addition, the ability to measure multiple variables at a later date, without advance planning, is a distinct advantage of mosaic imaging over diver surveys.

4.4 ABSOLUTE ACCURACY DEMONSTRATION

The absolute accuracy demonstration was designed to evaluate the accuracy and precision of size measurements made from mosaic image analysis and diver surveys. Unlike the previous performance objectives, the success criteria in this demonstration are based on the known sizes of objects and not the performance relative to diver surveys. For this demonstration we evaluated: 1) the absolute accuracy of mosaic and diver size measurements; 2) the precision of multiple mosaic and diver size measurements; 3) the precision of multiple mosaic analysts and diver size measurements; and 4) the bias of pool and field derived mosaic imagery. The average bias of measuring targets of known size between 5 and 120cm was approximately 1cm for both diver and mosaic methods. The same was true for estimating the projected length of inclined targets. No differences were observed when comparing results over multiple mosaics or when using multiple mosaic analysts. In addition, the measurement bias of objects placed in a pool was not significantly different than the bias measured in field mosaics. Thus, mosaics were found to be highly accurate methods of estimating coral colonies on the cm scale and these results were found to be repeatable over different images and using different observers to carry out the analysis.

5.0 COST ASSESSMENT

The performance objectives of the various demonstrations were chosen, in part, to extract cost information for different applications of the mosaic technology. Two cost models were derived for each performance objective under each demonstration separately: a diver model, and a mosaic model. The Absolute Accuracy Demonstration did not warrant a cost assessment because it was a one-time event set up under artificial, controlled conditions in a swimming pool.

Long-term Monitoring Demonstration: This demonstration compared the data extracted from the mosaics to diver-based data from the same tagged colonies. For the diver method, the cost per coral of data extraction ranged from \$9.33 to \$53.97. For the mosaic method, the cost per coral of data extraction ranged from \$9.20 to \$47.34. The second part of this demonstration compared the costs to create digitized maps of the seabed and extract coral sizes and percent live cover from them. For the diver method, the cost per coral ranged from \$178 to \$853 per m^2. For the mosaic method, the cost per m^2 ranged from \$36 to \$110 per m^2.

Endangered Species Demonstration: This demonstration compared data extracted from the mosaics to diver-based data using the using the Williams, et al. (2006) protocol. The total cost per coral colony to map, measure, type, and estimate live coral cover using the mosaic method (\$12.26 - \$51.56) was less-expensive per coral colony than the diver-based method (\$22.96 - \$131.52).

Grounding Demonstration: This demonstration compared the data extracted from two traditional methods used for assessing size of an area damaged by a ship grounding (snorkeler-based GPS technique and the diver-based fishbone technique) to the data extracted using the mosaic technique. The GPS method was least expensive (\$0.58 - \$3.42 m^2), the fishbone method most expensive (\$2.57 - \$15.91 m^2), and the mosaic method in-between (\$1.89 - \$7.40 m^2). Note that the costs for the mosaic method do not include the fact that the data could be used for other purposes besides area estimation.

Traditional Metrics Demonstration: This demonstration compared the data obtained by the mosaic method to the data obtained by the following traditionally used diver-based methods: the line-point intercept method, the belt transect method, the point-centered quarter method and the juvenile identification method. For most of the transect types, it was less expensive to use the traditional diver-based transect than to use mosaics if only one variable (i.e., one type of transect) were desired. On the other hand, if multiple types of information were required (i.e., if the survey demanded all four types of transects) then the mosaics became more cost-effective than using the diver transects.

The cost drivers for the technology were assessed based on the results of the suite of cost models. The cost analysis revealed three main cost drivers of the mosaic technology relative to existing alternatives. The most important cost driver was the type of measurement being made. The second most important cost driver was the number of variables that need to be measured. The third most important cost driver was the relative cost of lab vs. field time. Cost depends not just on technology but also on the specific application of the technology. The more one needs to do with the data, the more cost-effective mosaics become. Conversely, with a mosaic, one can do more with the same dataset, which is why they are so effective for archival purposes. Finally, the more expensive the field work, the more cost-effective mosaics become.

6.0 IMPLEMENTATION ISSUES

Perhaps the most important question addressed during this project was "when are mosaics superior to traditional methods (as opposed to equaling performance of diver-based methods)?" Considering both performance and cost, we conclude mosaics are a superior approach:

- When dive or field time is relatively expensive
- For measuring sizes, distances, or areas
- For measuring multiple variables, or when you are not sure what to measure
- For low impact monitoring studies (no tagging)
- To leverage availability of non-biologist divers for data collection
- For long-term studies of a specific plot
- For archiving the state of the reef at a given time
- To communicate results visually, particularly to non-specialists

One intended end-user community includes the marine/coral reef ecologists with the Navy's Scientific Diving Services. Transfer of this technology to that group has completed and they have executed several field surveys already. The University of Miami continues to partner with other federal, state, local, and private organizations to expand the pool of users of this technology. Current UM/RSMAS partners include: NOAA (Restoration and Southeast and Pacific Fisheries Science Centers), Biscayne National Park, The Nature Conservancy, New England Aquarium, American Museum of Natural History, Scripps Institute of Oceanography, U. North Carolina Wilmington, Coral Restoration Foundation, and Dial Cordy, Inc.

Table 2, below, is a summary of results for each metric tested during the project. The high-level structure of the table matches rows from Table 1, but additional rows have been added for each metric. The "status" column shows the success (green), partial success (yellow), or failure (red) of the test for each metric. Of the 57 metrics 45 were successful, 12 were partial successes, and none completely failed. Eight of the partial successes (see Notes column and text for description) were really successes from a practical standpoint.

Table 2. Summary of results for each metric tested during the project

Mosaic Capabilities			End User Applications / Needs	Demonstration	Status	Notes
Addresses limitations of the diver transect			**NOT adequately addressed solely by divers**			
Landscape view			Assessment and monitoring ESA-listed species	ESA		
	Performance Objective 1: Coral Colony Location and Abundance					
		Colony abundance			Partial	1
		Colony location			Success	
	Performance Objective 2: Coral Colony Size					
		Colony size: Diver = Mosaic			Success	
		Colony size: (DiverA - Mosaic) <= (DiverA - DiverB)			Success	
	Performance Objective 3: Coral Colony Descriptors					
		% Coral cover: DiverA = Mosaic			Success	
		% Coral cover: (DiverA - Mosaic) <= (DiverA - DiverB)			Success	
		Colony type: Diver = Mosaic			Partial	2

Table 2. Summary of Results for Each Metric Tested During the Project (Continued)

Mosaic Capabilities	End User Applications / Needs	Demonstration	Status	Notes
Addresses limitations of the diver transect	**NOT adequately addressed solely by divers**			
Monitor without tagging	Monitoring coral community trends	Long-Term Monitoring & Trad. Metrics		
Performance Objective 1: Provide colony-based metrics of coral reef condition.				
Colony size: Diver = Mosaic			Success	
Colony size: (DiverA - Mosaic) <= (DiverA - DiverB)			Success	
Colony size: (AnalystA - AnalystB) <= (DiverA - DiverB)			Success	
Colony size: (MosaicA - MosaicB) <= (DiverA - DiverB)			Success	
Colony size: AnalystA = AnalystA			Success	
Bleaching prevalence			Success	
Disease prevalence			Success	
% Bleached			Success	
% Recent Mortality			Success	
% Old Mortality			Success	
Performance Objective 2: Maintain continuity with long-term, map-based, coral reef monitoring data sets				
Colony size: Map = Mosaic			Success	
Colony size: (MapA - Mosaic) <= (MapA - MapB) and <= (DiverA - DiverB)			Success	
Colony size: (AnalystA - AnalystB) <= (MapA - MapB) and <= (DiverA - DiverB)			Success	
Colony size: (MosaicA - MosaicB) <= (MapA - MapB) and <= (DiverA - DiverB)			Success	
Colony size: AnalystA = AnalystA			Success	
% Coral cover: Map = Mosaic			Success	
% Coral cover: (MapA - Mosaic) <= (MapA - MapB) and <= (DiverA - DiverB)			Success	
% Coral cover: (AnalystA - AnalystB) <= (MapA - MapB) and <= (DiverA - DiverB)			Success	
% Coral cover: (MosaicA - MosaicB) <= (MapA - MapB) and <= (DiverA - DiverB)			Success	
% Coral cover: AnalystA = AnalystA			Success	
Relative Spatial accuracy	Assessment of acute physical damage	Grounding		
Performance Objective 1: Map the areal extent of damage				
Total damaged area diver = mosaic = gps			Partial	3
Performance objective 2: Comparison of Linear Damage Measurements				
Linear distances: Diver = Mosaic			Success	
Linear distances: (DiverA - Mosaic) <= (DiverA - DiverB)			Success	
Archive potential	Response to challenges of methodology	Traditional Metrics		
Performance Objective 2: Extract ecological measurements from mosaics using multiple methods				
% Cover: Mosaic virtual transects = Diver transects			Partial	
Coral Species richness: Mosaic virtual transects = Diver transects			Success	
Ease of use	Practical implementation of new technology	Multiple		
Performance Objective 1: Minimum training required for mosaic data acquisition		Long-Term Monitoring		
Incorporation %			Success	
Visual quality			Success	
Performance Objective 2: Minumum training required for creating mosaics from raw data		Traditional Metrics		
Incorporation %			Success	
Visual quality			Success	
Performance Objective 3: Minimum training required to extract ecological measurements from mosaics		Grounding		
Coral Size: Navy analyst = RSMAS analyst			Success	
% Coral Cover: Navy analyst = RSMAS analyst			Partial	
Retains strengths of the diver transect	**Adequately addressed solely by divers**			
Traditional measurements (% cover, diversity, condition, size, juvenile denisty)	Assessment of coral community status New technology must not degrade what already works well			
Performance Objective 1: Extract ecological measurements from mosaics comparable with diver-based metrics		Traditional Metrics		
Performance Objective 4: Assess reef condition within scar and in unimpacted reference areas		Grounding		
% Cover: Mosaic = Diver			Partial	
Coral Species Richness: Mosaic = Diver			Success	
Size frequency distribution: Mosaic = Diver			Success	
% Diseased: Mosaic = Diver			Success	
% Bleached: Mosaic = Diver			Success	
% Recent Mortality: Mosaic = Diver			Success	
% Old Mortality: Mosaic = Diver			Success	
Juvenile Density: Mosaic = Diver			Partial	
Absolute Accuracy				
Spatial accuracy (cm scale)	Need to know limits of technology	Pool		
Performance Objective 1: Absolute Accuracy of Mosaic and Diver Size Measurements				
Size - truth not different from zero for mosaics, divers			Partial	4
Mosaic bias <= diver bias			Partial	5
Size - truth not different from zero for mosaics, divers (inclined)			Partial	6
Mosaic bias <= diver bias (inclined)			Success	
Performance Objective 2: Precision of Multiple Mosaic and Diver Size Measurements				
Bias of multiple mosaics not significantly different from each other			Success	
Variance of multiple mosaics <= variance of multiple divers			Success	
Performance Objective 3. Precision of Multiple Mosaic Analyst and Diver Size Measurements				
Bias of multiple analysts not significantly different from each other			Success	
Variance of multiple analysts <= variance of multiple divers			Success	
Performance Objective 4. Comparison of mosaic bias in the pool vs. in the field				
Mosaic bias in field is not significantly greater than mosaic bias in pool (square tiles)			Success	
Spatial accuracy (m scale)	Need to know limits of technology	Grounding		
Performance objective 3: Accuracy of the Measurement of Large Linear Targets				
Size - truth not different from zero for mosaics, divers, gps			Partial	7
Mosaic bias = diver bias = GPS bias			Partial	8
% Coral cover: (AnalystA - AnalystB) <= (MapA - MapB) and <= (DiverA - DiverB)			Success	
% Coral cover: (MosaicA - MosaicB) <= (MapA - MapB) and <= (DiverA - DiverB)			Success	
% Coral cover: AnalystA = AnalystA			Success	

The eight partial successes (Table 2) that really would be acceptable for practical purposes were:

1. Diver and mosaic analyst disagreed on definition of a colony;
2. All colony types agreed between diver and mosaic except for one attached fragment labeled as a lose fragment;
3. GPS and mosaic agreed; the difference with the divers may be explained by different areas sampled;
4. Some errors were not exactly 0, but were very small;
5. Divers were better for only the small, flat targets, mosaics were better otherwise;
6. Some errors were not exactly 0, but were very small;
7. One of the divers differed from 0, but mosaics were successful; and
8. The GPS differed from 0 but mosaics were successful.