PHOTOGRAMMETRIC CLASSIFICATION OF SPONGE MORPHOMETRIC DIVERSITY

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Abstract

Sponge communities form an important component of marine ecosystems. However, very little is known on the distribution of sponge species, and variations in sponge communities within south eastern Australia. This problem is compounded by inherent difficulties in sponge taxonomy. Previous studies have shown that sponge morphological diversity is a good proxy for sponge species diversity.

This study investigated the capacity of close range photogrammetry to provide measurements of sponge morphology for classification of sponge functional groupings. A stereo camera system was designed and constructed. Calibration and accuracy assessment on the system showed it to provide measures within the predicted accuracy range.

The system was subsequently deployed at two sites, one a soft sediment sponge community, and the other a rocky reef sponge community. 100 sponges were measured at each site, with 21 morphometric measurements made for each sponge. Of nine pre existing functional groupings (Bell and Barnes 2001), seven were observed across the two study sites. Discriminant analysis showed varying degrees of separation between these functional groupings based on the morphometric measurements. Between the two sites there was a difference in the makeup of the sponge community based on these functional groups. No differences were observed in the gross morphometric measurements for the common functional groups between the two sites.

1. Introduction

Sponges play an important role in marine ecosystems, forming complex structures on the sea floor, which provide habitat for many fish and invertebrate species. There is a need to document the distribution of sponge biodiversity to assist in management of sponge habitat. Sponge biodiversity is affected by environmental conditions including depth, slope, current, and water conditions (Roberts and Davis 1996, Bell and Barnes 2000a, Bell and Barnes 2000b, Bell et al. 2002, Hooper and Kennedy 2002). In order to assess biodiversity, a measure of species composition and species distribution is required. However the taxonomy of sponges is inherently difficult, with colour, shape and size often variable within single species (Bell and Barnes 2001, Bell et al. 2002), confounding visual identification. Sponge functional morphology has been shown to be a useful surrogate for sponge biodiversity (Bell and Barnes 2001, 2002).

To obtain repeatable classification of sponge functional morphology quantitative measurement of sponge morphometric characteristics is required. Due to the vulnerability and slow growth of many sponge species, it is preferable to make *in situ* measurements than remove the sponges for measurements. *In situ* measurements using conventional methods, such as diver surveys, are not always possible due to the excessive sampling time required and depth limitations. The use of remotely controlled cameras to provide a photographic solution presents a potentially viable option to overcome these constraints.

3D measurements are often the desired result of a photogrammetric solution. For 3D measurement and modelling, two or more exposures are required. A pair of images, such as from a stereo camera, can be used to derive 3 dimensional measurements of a target, however they cannot normally be used to create a 3 dimensional model of a solid object because not all aspects of the object will be visible in a single stereo pair. This will require multiple exposures from a variety of locations surrounding the object. These may be multiple stereo pairs, which allows for stereo-viewing of the surfaces, or multiple single-exposures. As a general rule, increasing the number of images to cover the target from all angles increases the accuracy and fidelity of the derived data (Eos Systems Inc 2000).

A stereo camera (two cameras in a fixed geometry) is a simple photogrammetric system that can be used to obtain accurate 3 dimensional measurements. Stereo cameras rely on fixed interior and exterior orientation to relate points in image space to real world locations in object space. Calibration using fixed arrays prior to deployment give these systems the capacity to convey scale to the 3D measurements. Stereo camera systems have been successfully employed in the measurement of highly mobile organisms (Klimley and Brown 1983, Bräger et al. 1999, Harvey et al. 2001), and also fine scale 3D modelling of targets (Hale and Cook 1962, Moore 1976, Doucette et al. 2001).

A stereo camera system can be constructed using either stills or video cameras. Still cameras will have a higher resolution than video cameras, typically 5 – 10 mega pixels for still cameras compared to less than 1 mega pixel for consumer grade digital video. Typically higher resolution images will increase the measurement accuracy of the system. Still cameras in a stereo camera configuration need precise synchronisation, so that the fidelity of the stereo camera geometry can be assumed, they are also limited in the rate at which exposures can be collected. Video on the other hand can be easily synchronised using a common signal such as an audio beep or flashing light. Video also collects at a significantly higher frame rate (25 frames per second for PAL video). Higher frame rates are an advantage where rare or mobile organisms, or when a remote system is used, as this increases the chance of obtaining a useful stereo pair. Due to the often patchy distribution and inaccessible nature of many sponge beds a stereo video system was chosen for this study to increase the likelihood of obtaining an adequate quantity of useable stereo pairs.

This paper investigates the capacity of a stereo camera system to accurately measure morphometric features of sponges. These morphometric features will then be related to predefined functional groups (Bell and Barnes 2001) and also used to investigate the morphological differences in sponges between two sites.

2. Methods

2.1 Stereo camera system design and construction

A stereo camera system was constructed for the photogrammetric measurement of sponge morphology comprising a pair of Sony TRV22e video cameras in Amphibico underwater housings. The cameras were mounted with parallel orientation in a rigid frame as a stereo pair, with this frame mounted in a towfish with a downward facing orientation.

Video footage was synchronised between the two cameras using a pair of flashing LEDs. Single red LEDs were mounted in each of the housing and linked to a common control circuit which triggered them to flash synchronously for 1/25th of a second every 10 seconds. The Sony TRV22e video cameras record an interlaced signal containing an upper and a lower field. Stereo pair images were captured from the recorded video using a DVRaptor capture card and exported as bitmap files lower field first. Adobe Photoshop was used to remove interlacing artefacts, by interpolating the even field.

The precision of a stereo camera system is related to the focal length of the cameras, the separation and orientation of the cameras, and the pointing precision. Errors in pointing precision will result in increased X, Y, and Z standard errors, with these errors larger in the Z plane than the X and Y planes. The formulas of Abdel-Aziz (1974) were used to estimate accuracy in X, Y, and Z planes for a series of camera base distances, which in turn were used to select an appropriate camera base for the stereo system.

2.2 Camera Calibration

The stereo camera system was calibrated using a two-step process comprising interior and exterior orientation, with calibrations carried out in a saltwater tank. Interior orientation of both the left and right cameras was calculated in the software Camera Calibrator 4.0 (Eos Systems) using the calibration slide and methodology recommended in the user manual (Eos Systems Inc 2000). The interior orientation parameters for each camera were saved for later use. The cameras were then mounted in the stereo geometry and a second in water calibration for exterior orientation was conducted using a fixed calibration array consisting of a 5 x 5 grid of 5 mm black targets separated by 50 mm in the X, Y plane, with four of the targets extending 125 mm and a central target 250 mm into the Z plane.

Stereo pairs of the fixed calibration array were collected and imported into photogrammetry software Photomodeler 4.0 (Eos Systems). The left and right stereo images were assigned corresponding interior orientation parameters from the data calculated in CameraCalibrator 4.0. The 25 control points on the calibration array were marked using the sub pixel marking mode and the project set as fixed control points. The project was processed and the resulting camera stations were then used to hardwire the exterior orientation.

2.3 System Validation

To assess the accuracy and precision of the stereo camera system nine stereo pairs of the calibration array, collected from a variety of angles and orientations, were processed as described above. To test system accuracy the computed camera station information from six of the calibration projects was used to estimate the control point positions from one of the nine other stereo pairs. To achieve this, the control points in each image were marked using the sub-pixel marker mode; however in this instance these points were not assigned the control frame X, Y, and Z co-ordinates. Instead the co-ordinates for these points were calculated in PhotoModeler based on the calibrated interior and exterior orientation data. These calculated point co-ordinates were exported to a text file for comparison. As these point co-ordinates were relative to the camera station they needed to be transformed into a consistent co-ordinate system for comparison. A least squares rigid motion transformation was run in MatLab 6.5 (The MathWorks Inc.) to fit the measured control points to the control frame X, Y, and Z co-ordinates. This routine solved for 3 rotations and 3 translations around the X, Y and Z axis using a least squares rigid motion.

The precision of the camera system was assessed by repeated measurement of the position of the 25 points of the calibration array using the calibrated system in PhotoModeler4.0. For one of the stereo pairs each point was marked and measured 6 times with the resulting point co-ordinates exported for comparison.

2.4 Field Surveys

Field surveys were conducted at two locations. The first site was off Babel Island on the northeast coast of Flinders Island (Figure 1). This site was on soft sediment in approximately 38 m water depth. The second site was off Rocky Cape (Figure 1). This site was on reef in approximately 24 m water depth.

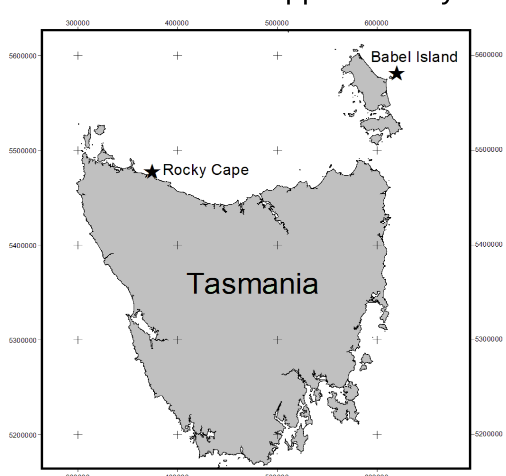

Figure 1. Map showing location of survey sites at Rocky Cape and Babel Island.

Prior to deployment at each site the camera system was setup and the calibration array recorded to monitor the system stability. The system was then left intact until deployment. At each site the camera system was lowered to the seafloor using an electric winch and held approximately 1 m above the seafloor. The system was left to record for approximately 1 hour, while the vessel was allowed to drift. A separate underwater video camera on an umbilical was attached to the stereo system to provide real-time images to the vessel. Artificial lighting was provided by a pair of 50 w halogen lights mounted off axis to reduce backscatter from particulate matter in the water column.

2.5 Measurement of sponges

From the stereo camera data acquired at each site, stereo pairs were exported corresponding to each 1 second of video. For each site 100 stereo pairs were processed. These stereo pairs were processed in PhotoModeler 4.0 using the parameters from the camera calibration to hardwire the system geometry. Each sponge was visually classified into one of the 9 morphological variants described by Bell and Barnes (2001): encrusting (EN), massive (MA), globular (G), pedunculate (PE), tubular (TU), flabellate (FL), repent (RE), arborescent (AR), and pappillate (PA). For each sponge a series of metrics were then measured including height, width, depth, branch lengths and angles (Table 1).

Table 1. Sponge metrics measured in PhotoModeler

Metric	Description
Growth Habit	EN,MA,G,PE,TU,FL,RE,AR,PA
Height	Maximum height from the sea floor
Width	Maximum width
Depth	Depth of sponge
Width of base	The width of the attachment to the sediment
Branching	Yes/No
Primary/secondary branching	Primary/Secondary
Number of Branches	Count of total branches
Length of trunk	Length of trunk for branching sponges
Length of primary Branch	Average length of primary branch
Width of primary branches	Average measure of the width of the primary branches at the widest point mid way up the branch
Width to depth ratio of primary branches	The ratio of the width of the branches to the depth at the mid point of the primary branches
Primary Branching Angle	Average branching angle of primary branches
Length of secondary Branch	Average length of secondary branches
Width of secondary branches	Average measure of the width of the secondary branches at the widest point mid way up the branch
Width to depth ratio of secondary branches	The ratio of the width of the branches to the depth at the mid point of the secondary branches
Secondary Branching Angle	Average branching angle of secondary branches
Number of pores	Count of the number of visible pores
Width of pores	Average width of pores
Colour	The RGB (Red, Green, Blue) colour value

2.6 Analysis of functional structure

Of the nine morphological variants described by Bell and Barnes (2001) only eight were observed in this study, with papillate sponges absent. As pedunculate sponges were only observed on one occasion, they have been removed from the analysis. All of the remaining seven variants were present at the Babel Island survey site, with only five present at the Rocky Cape site (arborescent, flabellate, globula, massive, and tubular). Discriminant analysis in JMP (SAS Institute) was used to examine the relationship between the measured metrics and the functional groups. For the functional groups that occurred at both of the sample sites, a comparison of the metrics was used to investigate differences in the gross morphology between the two sites. Analysis of variance (ANOVA) was used to examine for differences in growth and branching metrics.

3. Results

3.1 System design

The predicted measurement precision of the stereo camera is related to the camera base. The X and Y accuracy remains fixed regardless of the camera base for a fixed object distance, while the Z accuracy decreases with increasing camera base (Figure 2a). The optimal camera base will thus be where the Z precision falls within an acceptable range, whilst still maintaining adequate image overlap (Figure 2b). For this system, at an object distance of 1 m and a pointing precision of 1 pixel, camera bases between 0.2 and 0.4 m will result in a stereo model with greater than 60% overlap and a Z standard error (m_z) of less than 10 mm. Based on these considerations, the stereo camera system was set up with a 0.35 m camera base.

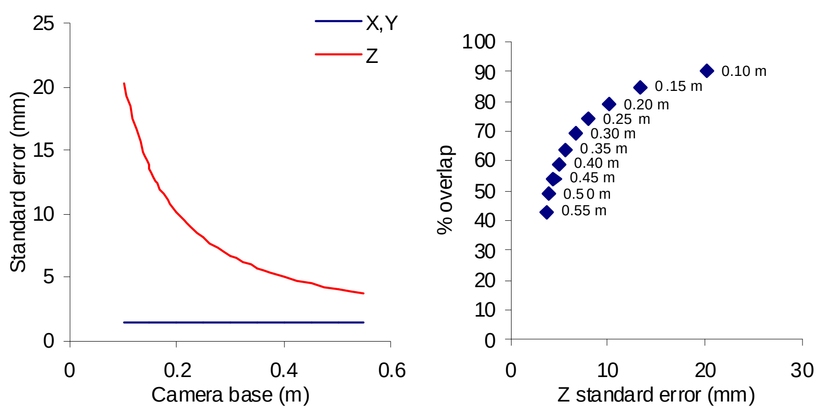

Figure 2. (a) Predicted accuracy m_x, m_y and m_z (standard error) of the stereo camera system for camera base distance between 0.1 and 0.55 m and object distance of 1 m and pointing precision of 1 pixel. (b) Predicted Z standard error (m_z) as a function of image overlap (%) for camera bases between 0.1 m and 0.55 m (labels) and an object distance of 1 m and a pointing precision of 1 pixel (Abdel-Aziz 1974).

3.2 Interior orientation

The magnitude of the radial lens distortions for each of the cameras was similar, with the left camera showing slightly higher distortions than the right camera, with these differences consistent across multiple calibrations. The radial distortion was typically less than 50 μm within 1.5 mm of the principal point, increasing to a maximum of up to 100 μm at the edge of the imaging array.

3.3 Exterior orientation

A series of nine exterior orientation calibrations were conducted, each produced different relative camera station information based on the orientation of the calibration array to the camera system, however the relative geometry between the cameras was consistent. A comparison of the camera separation distance for each of these calibration projects showed this to be highly consistent, 34.95 cm ± 0.5 mm (average ± S.E). Exterior orientation information from six of the trials was used to calculate the position of the control points from the randomly selected photos from one of the other trials. To allow comparison of the results a least squares rigid motion transformation was used to align the measured control point data. The average error on the control points following transformation was 1.41 mm ± 0.09 mm, with the maximum error for any single control point 3.07 mm ± 0.42 mm.

The repeatability of measurements was used to estimate the precision of the system. The precision was calculated as the maximum measurement error in X, Y, and Z based on six repeated measurements of the control frame, in all cases this was less than 1 mm.

3.4 Field measurements of functional groupings

Of the nine functional groupings described in Bell and Barnes (2001), seven of these were observed and measured across the two study sites (Table 2). The most common functional group was the arborescent sponges, which represented approximately 40% of all the sponges. The least common functional groupings were the repent and tubular, which each represented less than 5% of all the sponges. Large variations in the gross sponge morphometric measures were observed both within and between all functional groups (Table 2). Branching was observed in the majority of arborescent sponges (93%), and a small proportion of massive sponges (8%), while only one specimen of tubular sponge exhibited branching. Visible pores (osculum/ostium) were observed on all tubular sponges (100%), slightly over half globular sponges (57%), and approximately one third of massive sponges (32%).

Table 2. Summary of sponge metrics (mean and standard deviation) by functional grouping based on stereo camera measurement.

	AR	EN	FL	G	MA	RE	TU
No. Observations	88	24	24	28	50	10	8
Height (cm)	25.2 ± 14.2	2.8 ± 2.7	14.9 ± 7.5	6.6 ± 4.2	11.9 ± 10.1	2.9 ± 2	7.7 ± 4.7
Width (cm)	17.8 ± 12	11.4 ± 4.5	18.9 ± 9.7	10.1 ± 4.9	12.9 ± 6.3	17.7 ± 7.4	14.6 ± 14.9
Breadth (cm)	8.2 ± 9.7	9.4 ± 3.2	6.6 ± 8.6	8.2 ± 4.8	6.6 ± 4.9	6.1 ± 3.5	6 ± 5.5
Width of Base (cm)	6.4 ± 4.4	11.9 ± 4	7.5 ± 4.9	10.7 ± 8.6	10.7 ± 6.7	15.6 ± 6.5	13 ± 15.7
Sponges with Branching (%)	93.2	0	0	0	8	0	12.5
Sponges with Pores (%)	0	0	0	57.1	32	0	100
RED	168.4 ± 40.2	171.8 ± 29.7	129.2 ± 46	152.3 ± 53.5	184.8 ± 40.6	165.8 ± 25.6	170.3 ± 13.4
GREEN	137.1 ± 26.1	130.1 ± 28.3	116.1 ± 22.7	153.8 ± 39.5	142.6 ± 27.7	123.4 ± 23.9	138 ± 9.2
BLUE	115.4 ± 25.4	110.3 ± 23.9	100.6 ± 20.3	118.9 ± 29.4	102.4 ± 40.1	104 ± 15.6	106 ± 14.2

Of those sponges that exhibited branching, the majority exhibited only primary branching (Table 3). Secondary branching was only observed in the arborescent functional group (23.4%). Average primary branch length was longer in the arborescent functional group than in the globular or tubular functional groups, however this difference was not significant. There was little difference in the average width of the branches or the average branching angle between any of these functional groups. Average branching length, average branching width and average branching angle showed no significant difference between the primary and secondary branching.

Table 3. Summary of branching metrics by functional grouping for all sponges exhibiting primary and/or secondary branching

	AR	G	TU
% Primary Branching	75.6	100	100
% Secondary Branching	23.4	0	0
Number of Branches	8.1 ± 7.3	6.5 ± 1.8	7 ± 0
Primary Branch Length	14.6 ± 7.6	4.9 ± 1.8	2.7 ± 0
Primary Branch Width	2.3 ± 1.5	2.8 ± 0.7	1.3 ± 0
Primary Branching Angle	37.1 ± 29.6	35.1 ± 32.1	34.7 ± 0
Secondary Branching Length	11.6 ± 9	-	-
Secondary Branching Width	2.6 ± 2.5	-	-
Secondary Branching Angle	44.9 ± 41.9	-	-

The discriminant analysis using the 19 morphological metrics and a further four derived metrics showed varying degrees of separation of the seven morphometric sponge types (Figure 3). The arborescent variant showed the greatest separation from the other groups, with the flabellate variant also separating out, with the remaining variants displaying a high degree of overlap. Canonical 1 described 77% of the variation, while Canonical 2 described a further 12% of the variation, with 100% of the variation described by the first 6 canonicals. Canonical 1 had strong positive correlations with sponge branching, and whether a sponge displayed primary/secondary branching, and strong negative correlation with secondary branch width. Canonical 2 had strong positive correlations with the width of pores on the sponge and whether a sponge displayed primary/secondary branching and a strong negative correlation with sponge branching.

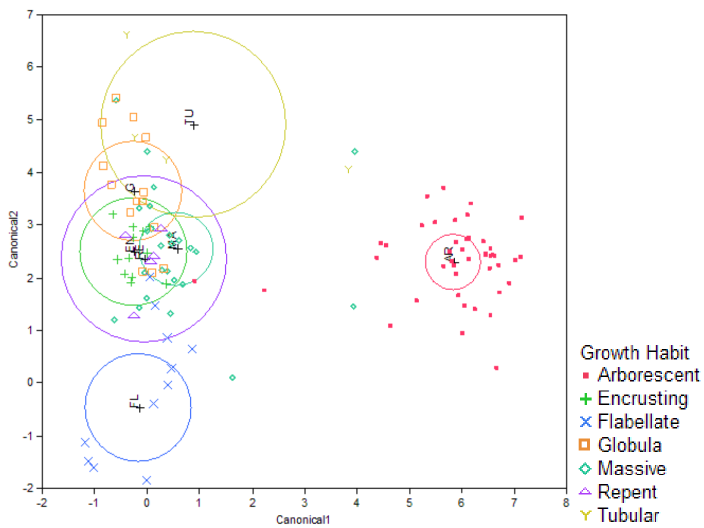

Figure 3. Results of discriminant analysis showing the separation of the seven morphological variants based on the 19 morphometric measurements. The coloured elipses represent mean confidence limit.

Overall classification accuracy based on the discriminant analysis was 77%. Comparison of the classification accuracy of the seven morphological variants by comparing the actual class with the predicted class from the discriminant analysis showed classification success greater than 80% for the arborescent, encrusting, flabellate and repent variants (Table 4). The remaining 3 variants had between 56 and 75% classification success. Of these three, the globular and massive variants were commonly classified as encrusting (28.6% and 12% respectively), the tubular variant was also commonly classified as globular (25%). The repent variant, whilst classifying correctly 80% of the time, also classified as encrusting 20% of the time.

Table 4. Actual versus predicted morphological variant matrix for the seven morphological variants based on discriminant analysis.

		Predicted						
		AR	**EN**	**FL**	**G**	**MA**	**RE**	**TU**
Actual	**AR**	95.5	0.0	0.0	0.0	4.5	0.0	0.0
	EN	0.0	83.3	0.0	0.0	8.3	8.3	0.0
	FL	0.0	8.3	83.3	0.0	8.3	0.0	0.0
	G	0.0	28.6	0.0	57.1	7.1	0.0	7.1
	MA	8.0	12.0	0.0	8.0	56.0	8.0	8.0
	RE	0.0	20.0	0.0	0.0	0.0	80.0	0.0
	TU	0.0	0.0	0.0	25.0	0.0	0.0	75.0

3.5 Comparison of sponges at two sites

The sponge communities at the two sites surveyed differed markedly in their functional group composition (Figure 4). The soft sediment site at Babel Island was dominated by arborescent sponges, with a lesser amount of massive and encrusting sponges, while the consolidated sediment site at Rocky Cape was dominated by a mix of globular, massive and to a lesser extent arborescent and flabellate sponges. Encrusting and repent sponges were found at Babel Island but were not observed at Rocky Cape.

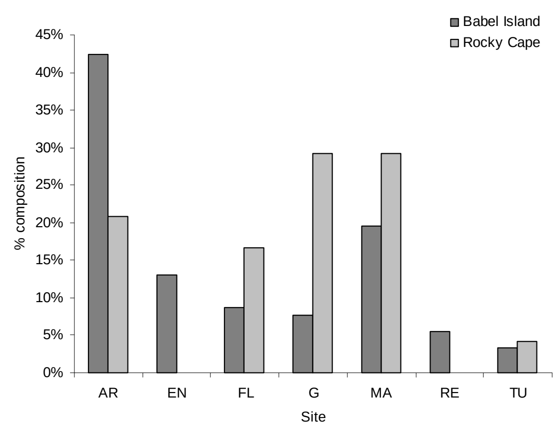

Figure 4. Percentage composition of sponge functional groups at the two surveyed sites based on visual classification.

Comparison of the morphometric measurements of the four most common functional groups between the two sites showed general differences (Table 5). The average height of the arborescent, flabellate, and massive functional groups were all greater at the Babel Island site, with the average height of the globular functional group greater at the Rocky Cape site. Similarly, differences were observed in the average width, breadth, and width of base between groups at the two sites. Significant differences in the means were observed between the two sites for the breadth of flabellate sponges, and for the height, width, and width of the base for massive sponges.

Table 5. Mean and standard deviation of the metrics height, width, breadth and width of base for two sites (Babel Island and Rocky Cape) as measured by photogrammetric analysis. (* indicates significant difference at p = 0.05)

	Data Set	AR	FL	G	MA
Height	Babel Island	26.3 ± 14.5	17.6 ± 7.6	5.1 ± 2.7	14.4 ± 10.7*
	Rocky Cape	16.6 ± 7.9	9.4 ± 3.4	8.2 ± 5	5.6 ± 4.1
Width	Babel Island	18.2 ± 12.5	15.3 ± 6.5	8.2 ± 3.4	14.9 ± 6*
	Rocky Cape	14.6 ± 6.8	26.3 ± 11.9	12 ± 5.8	7.6 ± 3.5
Breadth	Babel Island	8.2 ± 10.2	2.2 ± 1.3*	6.6 ± 3.7	7.4 ± 5.4
	Rocky Cape	8.1 ± 5	15.6 ± 10.3	9.7 ± 5.6	4.4 ± 2.5
Width of Base	Babel Island	6.7 ± 4.5	6.5 ± 2.8	8.4 ± 3.3	12.6 ± 6.6*
	Rocky Cape	4.3 ± 3.2	9.6 ± 7.9	13 ± 11.7	5.9 ± 4.1

The branching morphology of the arborescent group was also compared between the two sites. Secondary branching was more common at the Rocky Cape site, 40% compared to 12.8% at Babel Island. The mean number of branches was higher at Rocky Cape; however there was large variation, especially at Babel Island. The average branching length, width and branching angles for both primary and secondary branches showed little difference between the sites, with a large amount of variation in all these metrics.

Table 6. Comparison of branching morphology statistics (average and standard deviation) for arborescent sponges at Babel Island and Rocky Cape.

	Babel Island	Rocky Cape
% Primary Branching	87.2%	60.0%
% Secondary Branching	12.8%	40.0%
Number of Branches	7.4 ± 7.4	13 ± 4.5
Primary Branch Length	13.9 ± 8.5	11.7 ± 6.1
Primary Branch Width	2.1 ± 1.6	1.5 ± 0.7
Primary Branching Angle	35 ± 31.7	24 ± 8.1
Secondary Branching Length	2.2 ± 6.2	4.1 ± 5.6
Secondary Branching Width	0.5 ± 1.6	0.7 ± 1.1
Secondary Branching Angle	8.2 ± 25.7	7.6 ± 10.4

4. Discussion

Sponge morphology has previously been shown to be a useful qualitative estimate of sponge species diversity (Bell and Barnes 2001). This paper investigated the use of a stereo camera system to obtain measurements of sponge metrics, and subsequent capacity of these metrics to assist in defining sponge functional morphology.

Based on the algorithms of (Abdel-Aziz 1974), the expected accuracy of the stereo camera system developed for this study was approximately 1 mm in the X and Y planes and 5 mm in the Z plane (object distance of 1 m and pointing precision of 1 pixel). Tank based calibration and accuracy assessment of the system showed error values within this range. The repeated calibration of this system showed very little variation in the geometry and calibration parameters. Stereo camera systems have previously been shown to be stable both within and between deployments (Harvey and Shortis 1998).

It is well known that multiple convergent photos gives the optimum accuracy in close range photogrammetry (Chong and Stratford 2002). The use of a single stereo pair limits the capacity to make accurate measures across all dimensions because not all of a sponge will be visible in a single stereo pair. The use of a single stereo pair prohibits the construction of complete 3 dimensional models of complex structures and instead allows measurement between points visible in both images. The sponge measurements collected in this study were selected because they represent broad morphological metrics, and were easily measured on most stereo pairs.

Of nine functional groups outlined by Bell and Barnes (2001), seven were encountered within this study. For some groups, including the arborescent, encrusting, flabellate and repent, greater than 80% were successfully predicted based on discriminant analysis while, for other groups, including the globular and massive this was between 50 and 60%. The low accuracies for some of the functional groups may b a reflection of the plasticity in sponge morphology (Ackers et al. 1992, Bell and Barnes 2000c, 2001). Sponges of a single species can display distinct morphology in relation to factors including bathymetry and flow regime (Bell and Barnes 2000c), create difficulties in attributing a sponge to a particular functional group. In reality sponges may often display traits of one or more of the functional groups, and often it can become a subjective decision when trying to visually classify a sponge into one of these groups. The use of the metrics from has the advantage that classification can become a more objective process.

The metrics developed within this paper were used to compare sponge communities between two sites with differences in bathymetry, substrate, exposure and potentially flow regime. Overall there was found to be a difference in the proportion of the different functional groups at the two sites. Environmental factors including depth, exposure, and flow regime have previously been shown to affect the distribution of sponge morphological diversity (Bell and Barnes 2000c). For the four most commonly occurring functional groups, a comparison of mean height, mean width, mean breadth, and mean width of base was made. Differences were observed across most of the functional groups between the two sites. However most of these differences were found to not be statistically significant. This may be a reflection of the large variations in morphology within each site and the relatively small sample sizes of many of the groups.

The branching dynamics of the arborescent sponges also showed variations. The arborescent sponges at Rocky Cape exhibited more secondary branching and more branches. However no statistically significant differences were detected in the length, width or branching angles for either the primary or secondary branches between the two sites. Again this is a reflection of the large amount of variation in all these parameters observed at both sites.

The use of photogrammetry in the assessment of benthic organisms, in this case sponges, has been shown to be a viable option for rapid collection of morphometric data. The accuracy of the system designed for this study was within the required range. The advent of consumer grade high definition digital video promises to increase the accuracy and precision of such systems.

References

Abdel-Aziz, Y. I., 1974, Expected accuracy of convergent photos. Photogrammetric

Engineering & Remote Sensing, 40, 1341-1346.
Ackers, R. G., Moss, D., and Picton, B. E., 1992, Sponges of the British Isles (Sponge V). Marine Conservation Society.
Bell, J. J., and Barnes, D. K. A., 2000a, The distribution and prevalence of sponges in relation to environmental gradients within a temperate sea lough: Inclined cliff surfaces. Diversity and Distributions, 6, 305-323.
Bell, J. J., and Barnes, D. K. A., 2000b, The distribution and prevalence of sponges in relation to environmental gradients within a temperate sea lough: Vertical cliff surfaces. Diversity and Distributions, 6, 283-303.
Bell, J. J., and Barnes, D. K. A., 2000c, The influences of bathymetry and flow regime upon the morphology of sublittoral sponge communities. Journal of the Marine Biological Association of the United Kingdom, 80, 707-718.
Bell, J. J., and Barnes, D. K. A., 2001, Sponge morphological diversity: A qualitative predictor of species diversity? Aquatic Conservation: Marine and Freshwater Ecosystems, 11, 109-121.
Bell, J. J., and Barnes, D. K. A., 2002, Modelling sponge species diversity using a morphological predictor: A tropical test of a temperate model. Journal for Nature Conservation, 10, 41-50.
Bell, J. J., Barnes, D. K. A., and Shaw, C., 2002, Branching dynamics of two species of arborescent demosponge: The effect of flow regime and bathymetry. Journal of the Marine Biological Association of the United Kingdom, 82, 279-294.
Bräger, S., Chong, A., Dawson, S., Slooten, E., and Würsig, B., 1999, A combined stereo-photogrammetry and underwater-video system to study group composition of dolphins. Helgoland Marine Research, 53, 122-128.
Chong, A. K., and Stratford, P., 2002, Underwater Digital Stereo-Obesrvation Technique for Red Hydrocoral Study. Photogrammetric Engineering and Remote Sensing, 68, 745-751.
Doucette, J. S., Harvey, E. S., and Shortis, M. R., 2001, Stereo-video observation of nearshore bedforms on a low energy beach, Department of Geography , University of Western Australia, Australia.
Eos Systems Inc, 2000, PhotoModeler Pro, Vancouver.
Hale, W. B., and Cook, C. E., 1962, Underwater microcontouring. Photogrammetric Engineering, 28, 96-98.
Harvey, E., Fletcher, D., and Shortis, M., 2001, Improving the statistical power of length estimates of reef fish: A comparison of estimates determined visually by divers with estimates produced by a stereo-video system. Fishery Bulletin, 99, 72-80.
Harvey, E. S., and Shortis, M. R., 1998, Calibration stability of an underwater stereo-video system: Implications for measurement accuracy and precision. Marine Technology Society Journal, 32, 3-17.
Hooper, J. N. A., and Kennedy, J. A., 2002, Small-scale patterns of sponge biodiversity (Porifera) on Sunshine Coast reefs, eastern Australia. Invertebrate Systematics, 16, 637-653.
Klimley, A. P., and Brown, S. T., 1983, Stereophotography for the field biologist: measurement of lengths and three-dimensional positions of free swimming sharks. Marine Biology, 74, 175-185.
Moore, E. J., 1976, Underwater Photogrammetry. Photogrammetric Record, 8, 748-763.
Roberts, D. E., and Davis, A. R., 1996, Patterns in sponge (Porifera) assemblages on temperate coastal reefs off Sydney, Australia. Marine and Freshwater Research, 47, 897-906.