

Ecological Role and Potential Value of Sponges to Torres Strait

Annual Report 2008

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Australian Institute of Marine Science



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Summary

Sponges are a dominant organism on coral reefs throughout Torres Strait and elsewhere have been shown to play an important ecological role by acting as a nursery or recruitment habitat for other species of economic importance. Sponges can also compete for food and space to the detriment of other sessile coral reef organisms. In addition to their ecological importance, sponges that have good quality spongin fibres have commercial value and may be sold as bath sponges.

A recently completed three-year CRC Torres Strait study between the Australian Institute of Marine Science (AIMS) and the Yorke Island Council developed farming procedures to commercially grow the common bath sponge *Coscinoderma mathewsi* around Masig (Yorke). To examine the sustainability of a bath sponge industry in Torres Strait, it is important to understand the dynamics and structure of bath sponge population(s) and explore the risks and threats to these populations. In early summer and winter of each year, surveys are done around Masig to examine the temporal variation in abundance and size of *C. mathewsi*. Abundance in November 2007 was low compared to previous surveys and approximately one-third the abundance recorded during Year 1 of this MTSRF project¹. Considering that spongivores rarely prey upon *C. mathewsi* and disease is rare, it is unlikely that either biotic factor reduced sponge numbers between surveys. Differences between years may result from variation in sponge recruitment and survival rates, mediated by abiotic factors like substrate type. Because the abundance of *C. mathewsi* can vary greatly over short spatial scales, it is also likely that differences between monitoring times result from different sites around Masig being surveyed. Size frequency patterns of *C. mathewsi* at Masig have also changed over time with a general decrease in the proportion of large sponges (>20 cm in length), constituting almost thirty percent of the population in July 2004 but only nine percent in November 2007. Considering that several hundred large sponges are needed to supply explants for the commercial sponge farm at Masig, decreasing numbers of large sponges is a potential concern.

This project is also exploring the recruitment of bath sponges (and other sessile organisms) to central Torres Strait. *C. mathewsi* recruits to coral reefs in Torres Strait throughout the year, however, recruitment peaks from September to March and correlated with high water temperature. Compared to most sponge species, *C. mathewsi* recruits in low numbers to Torres Strait coral reefs, generally less than ten recruits per square metre. Survival of these recruits is poor in late summer, possibly resulting from dislodgement or 'bulldozing' from *Diadema* urchins. At least thirteen other sponge species, plus numerous species of ascidians, bryozoans, coral, bivalves and polychaetes, were found to recruit to plates situated in central Torres Strait. Among the various taxonomic groups, polychaete worms dominated recruitment abundance in both summer and winter, while algae had the highest percent cover.

This recruitment study will continue for another two years, providing important information about the temporal and spatial recruitment patterns of *C. mathewsi*. For all field work in Torres Strait, the Masig Islanders John Morris and Samson Lowatta are employed to help with the various experiments. This has achieved effective capacity building and contributes income directly into the local community.

¹ Marine and Tropical Sciences Research Facility Project 1.3.2 Ecological role and potential value of sponges to Torres Strait: http://www.rrrc.org.au/mtsrf/theme_1/project_1_3_2.html

1. Introduction

1.1. Background

Sponges are an important component in many reef habitats in terms of biomass and diversity (Reiswig 1973; Dayton *et al.* 1974; Schmahl 1990) and they may interact with the wider community in several important ways. Sponges can provide food (Ayling 1981; Wulff 1994) or shelter (Costello and Myers 1987; Duffy 1992) for other organisms. They can also filter and extract much of the available phytoplankton (Reiswig 1971; Pile *et al.* 1996; Duckworth *et al.* 2006) to the possible detriment to other suspension feeding organisms. Sponges can compete for and dominate the substrate (Dayton *et al.* 1974) and thereby exclude other organisms from settling and recruiting into the community.

In addition to their ecological value in community dynamics, some sponges also have commercial value. Commercial bath sponges, species from the order Dictyoceratida that have a high quality spongin skeleton, have industrial and house-hold value. To supply global markets, commercial bath sponges have traditionally been harvested from natural populations in the Mediterranean Sea and around Florida in the United States. Over-harvesting and periodic disease outbreaks have decimated these natural populations and severely limited the yield of bath sponges (Pronzato 1999). In 2003, for example, global trade in natural sea sponges was 2,127 metric tons but reported global production from harvesting was a mere 55 metric tons (FAO 2004). Because harvesting natural populations cannot meet demand, an opportunity exists to develop alternative supply methods. In-sea aquaculture has the potential to supply sufficient and sustainable quantities of bath sponges to meet market demand.

A Torres Strait wide survey in 2004 discovered a commercial bath sponge species, *Coscinoderma mathewsi* (Figure 1.1) around several islands in the eastern and central regions (Duckworth *et al.* 2007b). In 2006, a survey across central and eastern Torres Strait (Duckworth *et al.* 2007a) determined that *C. mathewsi* is most abundant in the Masig island-group (Figure 1.2). Market analysis on a conspecific population from the central Great Barrier Reef determined that *C. mathewsi* has commercial grade spongin.

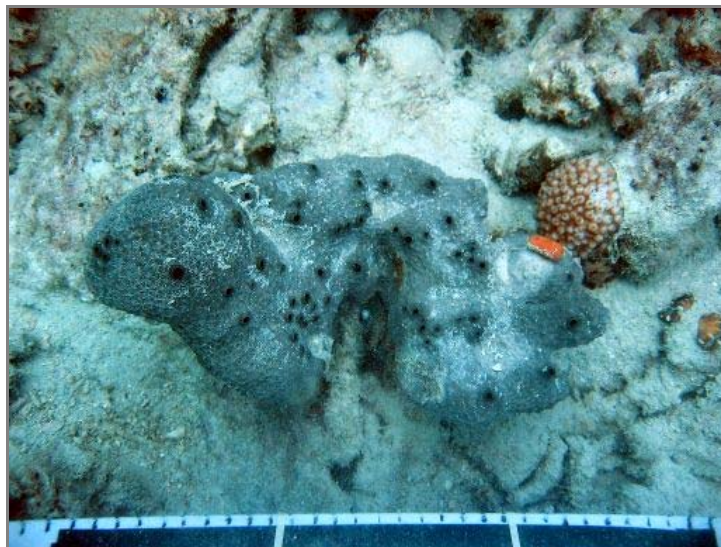


Figure 1.1. Photo of the bath sponge *Coscinoderma mathewsi*. This individual is approximately 30 cm in length.

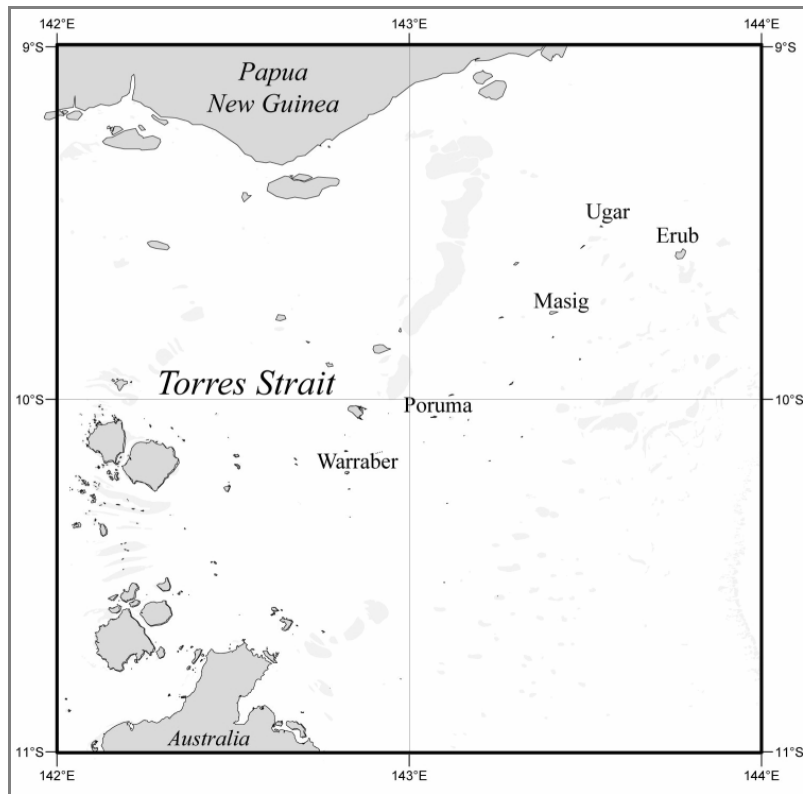


Figure 1.2. Map of Torres Strait showing the five island groups where *C. mathewsi* is found. It is most abundant at Masig.

A recently completed farming study in Torres Strait (CRC Torres Strait Task 1.6) has identified good farming procedures, and coupled with the high growth rates of *C. mathewsi*, suggests that bath sponge aquaculture in Torres Strait will be a viable industry (Duckworth and Wolff 2007a).

This current MTSRF project builds on the outputs of sponge aquaculture research in Torres Strait to help determine the sustainability of a sponge farming industry in Torres Strait. This will be achieved by gaining a greater understanding of the dynamics and structure of bath sponge population(s) and exploring the risks and threats to these populations. Given sponges play an important ecological role in tropical ecosystems, through acting as nursery or recruitment habitat for other species of economic or ecological importance (Butler *et al.* 1995), factors that influence dominant sponge species can have wider community effects. Sponges are useful indicator or sentinel species for environmental stress, and can provide relevant information of general habitat risk from pollution, disease, invasions or sedimentation (Carballo *et al.* 1996).

This MTSRF project will:

- Determine the size of the *C. mathewsi* population in Torres Strait, and explore and identify the environmental factors that structure the abundance and size patterns of the bath sponge species;
- Determine the possible risks of translocating individuals of *C. mathewsi* within Torres Strait, to possibly set-up bath sponge farms where it is not naturally abundant; and
- Determine when, where and how often sponges such as *C. mathewsi* (and other sessile organisms) recruit onto coral reefs in Torres Strait.

1.2. Objectives

The specific objectives of this project are as follows:

1. Undertake an assessment of the distribution and abundance of wild commercial sponge species in Torres Strait, identifying elements of environmental risk (evidence of disease, sedimentation, invasives), and establish a sustainable strategy for seed stock harvest;
2. Determine connections between sponge populations and risks in translocation; and
3. Determine patterns of sponge recruitment/mortality and the environmental risk of seed stock harvest leading to development of a sustainable seed collection strategy.

Objectives 1 and 2 are ongoing, and will run for the full length of the project. Objective 2 was completed in Year 1 of the MTSRF project (Duckworth *et al.* 2007b)

1.3. Involvement of Torres Strait Islanders

This MTSRF project involves much field and diving work in Torres Strait, particularly around Masig Island. For all field work, two Torres Strait Islanders from Masig, John Morris and Samson Lowatta, are employed (Figure 1.3). For the diving work, a boat is hired daily from a Masig Islander, further contributing to the local economy. This is based on the good working model established from the previous CRC Torres Strait project (Duckworth *et al.* 2007a).



Figure 1.3. Photos of Torres Strait Islanders involved in the MTSRF project, (*left*) Samson Lowatta surveying the waters of Masig for *C. mathewsi* (Objective 1); and (*right*) John Morris attaching settlement plates to the coral reef in central Torres Strait, to help determine when and where bath sponges recruit (Objective 3).

2. Abundance and size of *C. mathewsi* in the Masig Island-group

OBJECTIVE 1. Undertake an assessment of the distribution and abundance of wild commercial sponge species in Torres Strait, identifying elements of environmental risk (evidence of disease, sedimentation, invasives), and establish a sustainable strategy for seed stock harvest.

2.1. Introduction

Abundance and size frequency patterns of sessile organisms such as sponges may vary among and within neighbouring islands and regions. Heterogeneity over both small and large spatial scales is the result of the interaction of physical, biological and stochastic factors influencing the distribution and abundance of individual species (Wilkinson and Cheshire 1989; Zea 2001). Sponges are an important component in many benthic communities and can dominate the benthos in some regions in terms of biomass and diversity (Schmahl 1990; Wilkinson and Cheshire 1990). Being efficient filter feeders of small particulate matter, sponges also represent an important energy coupling between the benthic and pelagic communities (Reiswig 1971; Pile *et al.* 1996; Duckworth *et al.* 2006).

The abundance and distribution patterns of sponges can be influenced by water flow and depth (Wilkinson and Evans 1989; Roberts and Davis 1996), larval dispersal and recruitment patterns (Maldonado and Young 1996), predation (Dunlap and Pawlik 1996), light intensity (Wilkinson and Trott 1985) as well as substrate and habitat type (Reiswig 1973; Adjeroud 1997). Environmental and biological factors such as disease can also generate randomness in sponge distribution (Zea 2001). The influence or impact of each factor varies between sponge species, often restricting species to a specific area or depth (Wilkinson and Evans 1989) and exacerbating heterogeneity in community structure between and within reefs or islands.

Structuring factors that promote patchy distributions may also influence size frequency patterns of sponges over short spatial scales. The effect of a physical or biological factor on size frequency patterns is often complex (Turon *et al.* 1998; Bell *et al.* 2002) and may have a positive or negative impact depending on its level of intensity. For example, sponge growth rates will generally increase as water flow increases because of the greater availability of suspended food (Wilkinson and Vacelet 1979; Duckworth and Battershill 2003), however, high water flow can also damage sponges, remove tissue, and decrease their size (Trautman *et al.* 2000)

A survey across central and eastern Torres Strait completed during Year 1 of this MTSRF project determined that *C. mathewsi* is most abundant in the Masig Island group (Figure 1.2). A small-scale survey, also carried out in Year 1, investigated the effect of depth and environmental factors on the abundance and size frequency patterns of *C. mathewsi* around Masig (Duckworth *et al.* 2007b). For the duration of this MTSRF project, surveys will be done in summer and winter around Masig to examine temporal variation in sponge abundance and size.

2.2. Methods

2.2.1. Study area and sampling strategy

This study is done in the Masig Island group, particularly around neighbouring Keats, Kodall and Masig Islands (Figure 2.1). Keats, Kodall and Masig are sand cays, low-lying (<10 m in height), small in size (<5 km²), and surrounded by coral reef. The coral reef slope generally starts at a depth of six metres (MLW) and stops on sand at fifteen metres, descending at an angle ranging from 20 to 60°. Southeasterly trade winds (15-20 knots) are common from April to December, while monsoon weather patterns with more northerly winds dominate during summer.

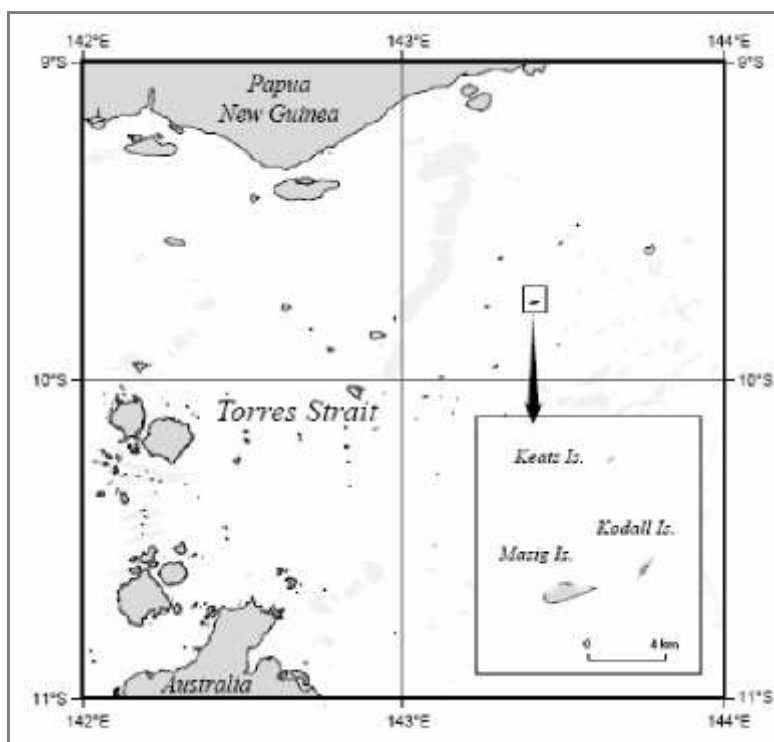


Figure 2.1. Map of the Masig Island group.

2.2.2. Abundance between depths and microhabitats

In November 2007 and May 2008, *C. mathewsi* was surveyed at six to ten sites on coral reef, with sites at least one kilometre apart. At each site, *C. mathewsi* was surveyed at both shallow (4-6 m) and deep (10-12 m) depths, with the former generally on the reef flat. Three 20 m x 1 m transects were examined at each depth, with transects separated by at least twenty metres to retain independence. For each transect, divers recorded every *C. mathewsi* sponge found within one metre of one side of the transect line. Basic environmental factors were also noted and for each transect we estimated the degree of reef slope and the percentage of dead coral rubble (rubble), sand and consolidated limestone rock (hereafter rock) free of living organisms.

For each sponge, we recorded the substrate type that it was attached to and growing on. Three types were identified: rock; rubble; and sand, with grain size ranging from 0.5-2 mm. These three substrate types vary in their level of stability for sponge attachment and growth,

with rock providing a secure immobile base for sponges, while sand being easily moved by water currents is a relatively insecure and fluid substrate for attachment. Rubble provides an intermediate level of stability; a separate study at Masig has found that rubble pieces (with a sponge attached) can move several meters between monitoring events (three months), at times causing the sponge to become partially buried by rubble or sand. For each sponge we also recorded whether it was living in an exposed microhabitat, such as on top of rock fully exposed to the ambient water flow, or in a sheltered microhabitat, such as under an overhang or protected between surrounding rocks.

To examine size frequency distributions patterns, the greatest length of every *C. mathewsi* was measured using a ruler attached to the dive slate and recorded. For graphical interpretation, sponges were grouped into two-centimetre size classes.

2.2.3. *Data analysis*

Note that only data from the November 2007 field trip is included in this report, as there was insufficient time to include and analyse the data from May 2008. The abundance of *C. mathewsi* between sites and depth was analysed using a two-way ANOVA, with site and depth as a random and fixed factor, respectively. Data was $\log(x+1)$ transformed to met the assumptions of ANOVA.

A MANOVA was done to examine the influence of site (random factor), depth (fixed factor) and their interaction on the four environmental factors (slope, %rock, %rubble and %sand), with factors arcsine transformed (Zar 1999). For all environmental factors, within-cell correlation analyses detected no multicollinearity problems (r -squared <0.99) while Bartlett-Box homogeneity tests determined that the covariance matrices are equal ($P>0.05$). Wilks' lambda statistic was used to compute F-ratios and data was then analyzed further by ANOVA.

To determine whether abundance of *C. mathewsi* around Masig varies over time, abundance data from November 2007 and previous surveys (July 2004, December 2005, November 2006, March 2007) was combined and analysed using GLM ANOVA, with survey date and site as a fixed and random factor, respectively. A repeated measures ANOVA was not done because the assumption of multivariate normality was violated. Abundance data from each survey was standardized to the number of sponges per hundred square metres. For the July 2004 data, three transects per site were randomly selected so that transect number was the same across all surveys. Survey depths were analysed separately. To examine size variation over time, sponges from each depth-survey were grouped into three size classes: small (≤ 10 cm), medium (11-20 cm) and large (>20 cm).

2.3 Results

2.3.1. Abundance in November 2007

In total, forty *C. mathewsi* were recorded and measured during the November 2007 survey. Statistical analysis determined that abundance varied significantly between depths ($F_{df=1,5}=12.4$; $P=0.017$), being seven times higher at deeper depths. The number of *C. mathewsi* per transect (20 m²) was, on average, two sponges at twelve metres and 0.3 sponges at six metres. Abundance did not differ significantly between the six sites ($F_{df=5,24}=0.64$; $P=0.67$), nor was there a significant site*depth interaction term ($F_{df=5,24}=0.63$; $P=0.68$). All recorded *C. mathewsi* were healthy, with no diseased sponge found on or off survey.

A similar number of *C. mathewsi* were found attached to and growing on rock and rubble substrate (Table 2.1); no sponges were found growing directly on sand. The majority of sponges were living in sheltered microhabitats, regardless of substrate type (Table 2.1).

Table 2.1. The number of *C. mathewsi* found in each substrate*exposure microhabitat.

Substrate	Exposure		Total
	<i>Sheltered</i>	<i>Exposed</i>	
Rock	18	5	23
Rubble	13	4	17
Total	31	9	40

2.3.2. Size frequency patterns for November 2007

The forty measured *C. mathewsi* ranged in length from 3-41 cm, averaging 12.7 cm. Small and medium sized individuals dominated the Masig Island group with the majority ≤ 20 cm (Figure 2.2). There were insufficient sponge replicates found at six metres ($n = 5$) to statistically compare size between depths, but large sponges (>20 cm) were found at both depths.

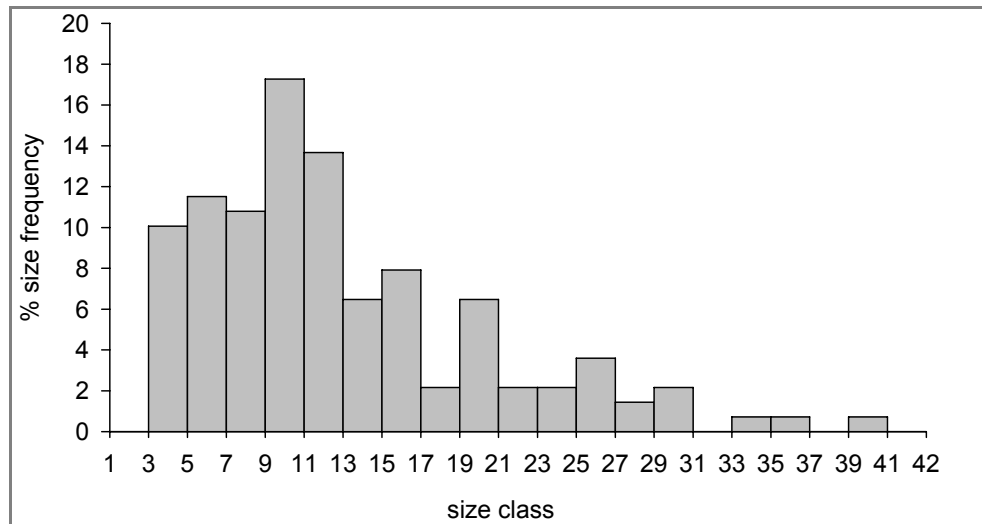


Figure 2.2. Percent size frequency of *C. mathewsi* in the Masig Island group ($n = 40$).

2.3.3. Environmental factors for November 2007

A MANOVA of the four environmental factors found a significant site*depth interaction (Wilks' lambda: $P < 0.05$). Of the ANOVA's examining the four environmental variables, the site*depth treatment was significant for percent rock, rubble and reef slope ($P < 0.05$), indicating that the intensity of each factor was greatest at either the shallow or deep depth depending on the survey site. Overall, reef slope and rubble substrate were greatest at twelve metres while rock substrate was more common at six metres.

2.3.4. Abundance across time at Masig

The abundance of *C. mathewsi* at twelve metres varied significantly across time ($F_{df=4,60}=4.04$; $P=0.006$). Mean abundance more than doubled from July 2004 to December 2005, then decreased slightly to November 2006 then increased sharply over the following four months to March 2007 (Figure 2.3). From March to November 2007, mean abundance at twelve metres decreased by two-thirds, with final abundance similar to what was recorded in July 2004. From 2004 to 2008, mean abundance at twelve metres was highest in March 2007, averaging 29.7 *C. mathewsi* per hundred square metres. Abundance at twelve metres also varied significantly between sites ($F_{df=15,76}=2.56$; $P=0.004$) and there was no significant interaction term ($P > 0.05$). In contrast, *C. mathewsi* abundance at 6 m was similar over time and between sites ($P > 0.05$), averaging 6.0 sponges per hundred square metres (Figure 2.3).

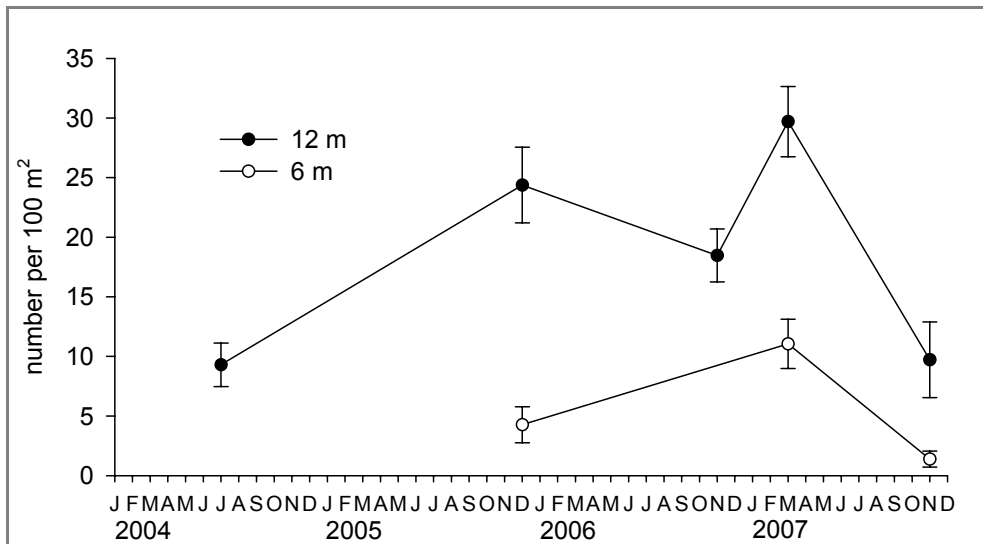


Figure 2.3. Mean abundance over time of *C. mathewsi* at six and twelve metres in the Masig Island group.

2.3.5. Size frequency patterns across time

For *C. mathewsi* at twelve metres, size patterns have changed over time. In July 2004, there was a similar frequency of small, medium and large sponges (Figure 2.4). From December 2005 onwards, however, there has been a general decrease in the percentage of large sponges around Masig from 29% to 9% by November 2007. During this time, the proportion of small sponges initially increased, peaking at 63% in November 2006, then decreasing to 46% of the population one year later. The percentage of medium-sized sponges increased from December 2005 to November 2007, from 24 to 46%. The size patterns of *C. mathewsi* at six metres also varied over time, with a general decrease in the proportion of small sponges and an increase of medium and large sponges from December 2005 to November 2007. However, these patterns at six metres have to be treated cautiously because of low replicate number in November 2007.

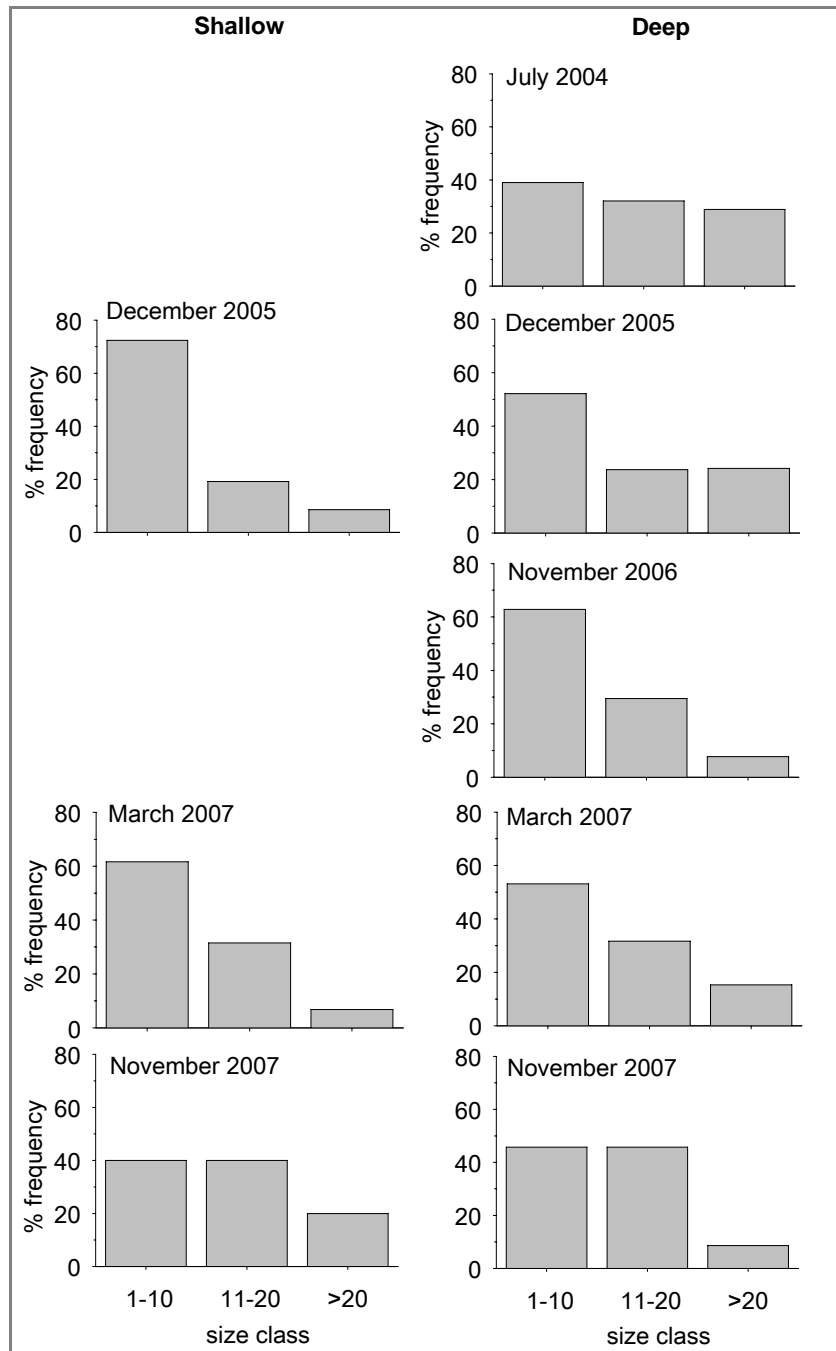


Figure 2.4. Size frequency patterns over time of *C. mathewsi* at six and twelve metres in the Masig Island group.

2.4 Discussion

In November 2007 the abundance of *C. mathewsi* was greater at twelve metres than at six metres, supporting the findings of previous surveys in Torres Strait (Duckworth *et al.* 2007a; Duckworth and Wolff 2007b). Many other sponge species are also more common in deeper water (Wilkinson and Evans 1989; Schmahl 1990; Roberts and Davis 1996), possibly due to lower levels of water turbulence and ultraviolet radiation (Reiswig 1973; Jokiel 1980, Wilkinson and Trott 1985). An Acoustic Doppler Current Profiler determined that water flow on Masig coral reefs is twice as great at six metres than at twelve metres (Duckworth *et al.* 2007a). Differences in water flow between depths would be even greater during storms, when most of the wave energy is concentrated in the shallows. The damaging effect of water flow may also explain why most individuals of *C. mathewsi* were found in sheltered microhabitats.

Another abiotic factor that can effect distribution patterns of sponges is reef slope (Bell and Barnes 2000), with some species excluded from flat habitats due to high sedimentation levels clogging their inhalant canals preventing them filtering efficiently. In a previous survey in Torres Strait, *C. mathewsi* was most commonly found on steep reefs (Duckworth *et al.* 2007a). The coral reef around Masig is generally steeper at twelve metres than at six metres, which is likely another contributing factor for the greater abundance of *C. mathewsi* on deeper reef.

The average abundance of *C. mathewsi* at twelve metres in November 2007 was relatively low and similar to the abundance recorded from the first survey in July 2004. Considering that spongivores rarely prey upon *C. mathewsi* and disease is rare (Duckworth *et al.* 2007a), it is unlikely that either biotic factor reduced sponge numbers between surveys. A 27 month-long study examining the population dynamics of *C. mathewsi* at Masig found that its numbers varies among years, with substrate stability greatly influencing survival rates (unpublished data). Therefore, annual variation in sponge recruitment and survival rates, mediated by abiotic factors like substrate type, promotes differences in abundance among years. The abundance of *C. mathewsi* can vary greatly over short spatial scales (Duckworth *et al.* 2007a, Duckworth and Wolff 2007b), thus differences among surveys may also result from different sites around Masig being surveyed. These differences highlight the importance of multi-year surveys in central Torres Strait to investigate temporal variation in *C. mathewsi* abundance across depth. Only after several years will we have sufficient data to understand population dynamics, required to successfully manage the bath sponge population for commercial enterprise.

Temporal variation in size patterns of *C. mathewsi* at twelve metres suggests a recruitment pulse between July 2004 and December 2005, increasing the proportion of small sponges in the wild population. With time, these recruits grew eventually swelling the numbers of medium sized sponges. The decrease of large sponges from 2004 to 2008 suggests that either medium size sponges are not growing further or that large sponges are dying at relatively high rates. Considering that several hundred large *C. mathewsi* will be partially harvested from the wild population to supply explants for the bath sponge farm, this is a potential concern and requires further investigation over the coming years.

3. Recruitment of bath sponges and sessile organisms to Torres Strait coral reefs

OBJECTIVE 3. Determine patterns of sponge recruitment/mortality and the environmental risk of seed stock harvest leading to development of a sustainable seed collection strategy.

3.1. Introduction

The recruitment of sessile organisms to the benthic habitat can vary greatly across time and space (Adjeroud 1997; Watson and Barnes 2004; Rule and Smith 2007). Variation in the recruitment of larva between species greatly influences the composition and diversity of the benthic community (Smith and Witman 1999), and can explain much of the difference in community structure between regions, and across seasons and years. Variable recruitment of sponge and coral species that are community determiners – whose abundance or biomass contribute greatly to the benthic community – could have significant and wide-ranging effects on the health of the marine environment in Torres Strait.

The recruitment of coral species to reefs in Torres Strait has been investigated. In a large study done over the full length of the Great Barrier Reef including Torres Strait, Hughes *et al.* (1999) found that the recruitment of coral brooders (which release fertilised larvae similar to Dictyoceratid sponges) varied more within reefs than between reefs. In contrast, the recruitment patterns of sponges to coral reefs in Torres Strait are unknown. For a commercial species such as *C. mathewsi* to be properly managed in Torres Strait it is important to know when, where and how often it recruits to the coral reef habitat. A three year long study, starting November 2006, in the Masig island-group is currently determining the recruitment patterns of bath sponges and other sessile organisms to Torres Strait coral reefs.

3.2. Methods

3.2.1 Study site and plate deployment

This study is being done at Marsden and Masig Islands, located in central Torres Strait (Figure 3.1). Both islands are sand cays with fringing coral reefs, low-lying (<10 m in height) and small in size (<5 km²). Marsden and Masig are separated by five kilometres of open water; maximum depth between the islands is roughly thirty metres, with the substrate consisting of muddy sand (Harris 1988). The coral reef slope generally starts at a depth of six metres (MLW) and stops on sand at fifteen metres, descending at an angle ranging from 20 to 60°.

Settlement plates are deployed at three locations on the northern side of each island, with locations two hundred metres apart. The northern side was chosen as it allows greater access and safer diving during most weather conditions. Each location is further divided into three sites, each twenty metres apart. At each site, five plates are deployed at six metres and at twelve metres using the direct-attachment method developed by Mundy (2000). In this method the settlement plate is securely attached to a stainless steel base plate, which is anchored to the reef. The settlement plate rests approximately one centimetre above the reef allowing the settlement and recruitment of organisms on both sides of each plate. At each site-depth, plates were roughly one metre apart. Terracotta plates 11 cm x 11 cm in size with pitted surfaces were used in the study, as they have found to be a good and reliable substrate for recruitment studies (e.g. Mundy 2000).

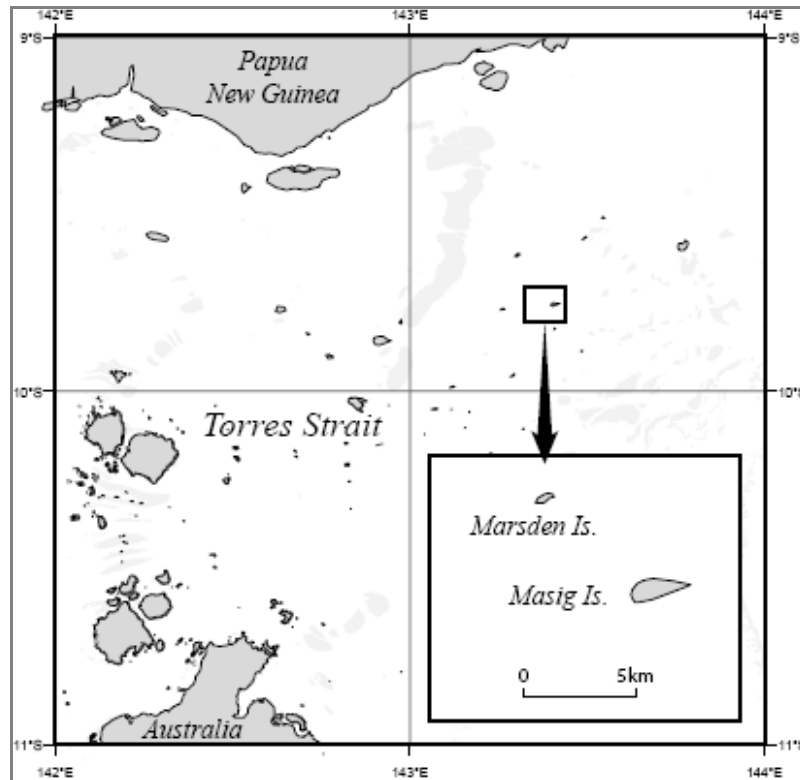


Figure 3.1. Map of Torres Strait showing the location of Marsden and Masig Islands.

This study is also investigating the recruitment of benthic organisms across seasons and years. Terracotta plates are deployed in November, at the start of summer, and in May, at the start of winter. Plates are left attached to reef at Marsden and Masig for six months, thus comparing the recruitment of organisms over summer and winter respectively. This study will run for three years, from November 2006 to November 2009. Each season, 180 plates will be deployed at Marsden and Masig, thirty plates per location. Each plate will be only used one, to prevent any confounding effects. At the end of each season, the top- and underside of each plate are photographed *in situ*. A new plate is then deployed onto the basal plate. Each plate has a small numbered-tag on both sides on one corner, clearly identifying the plate in the photographs.

During the first year only plates are photographed *in situ* after four months in each season: March 2007 in summer; and September 2007 in winter. This will provide information about the recruitment of benthic organisms within a season.

3.2.2. *Photographic analysis*

An underwater close-up frame was constructed to photograph settlement tiles at a fixed distance and to record site and tile information on its frame (Figure 3.2.). As the aspect ratio of the digital images allowed for the recording of extra information on each image, due to the tiles being square, a four-digit code wheel was built into one side of the frame. The framer was adapted to accommodate either an Olympus C-7070 or Canon IXUS 850IS camera in underwater housings. Both these cameras have identical lenses and sensor-resolution and images produced are comparable in quality and view.

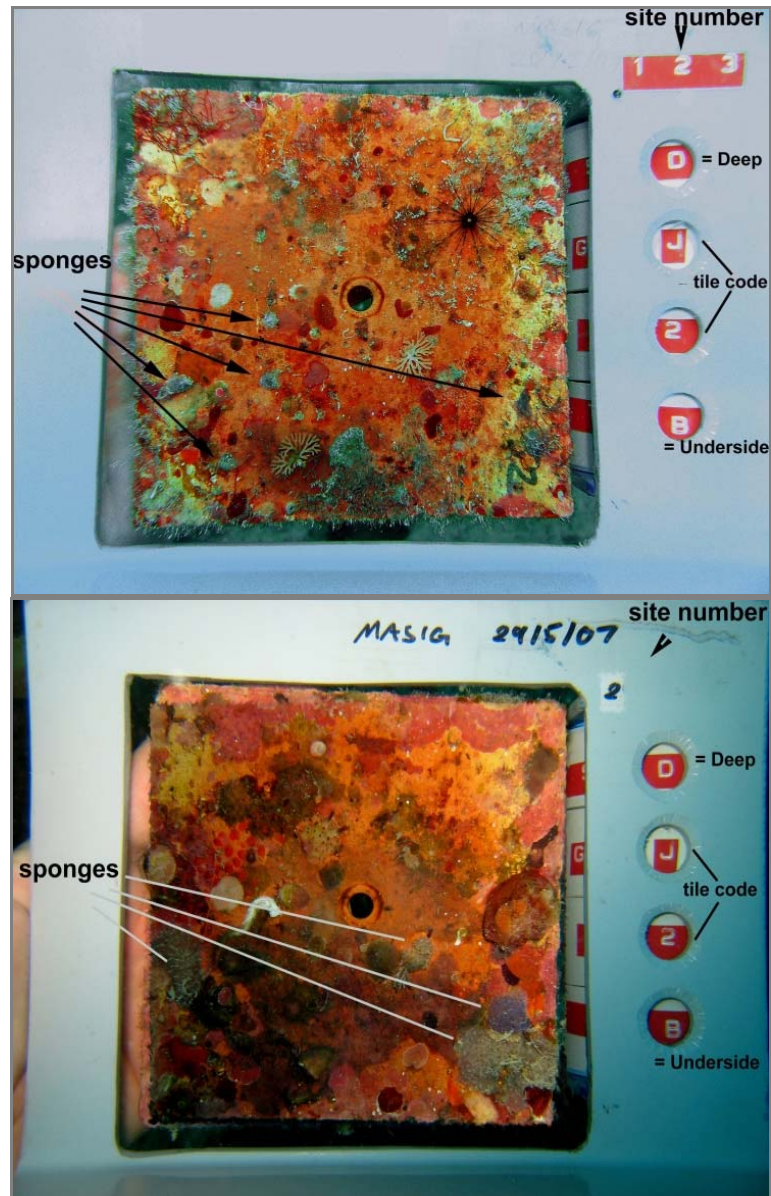


Figure 3.2. Photos showing sponges on the underside of settlement plate J2 taken in March 2007 (*top*) and May 2007 (*bottom*). Also shown is the frame used for each photograph, with site and plate information.

The recruitment of sessile organisms to central Torres Strait was determined for both abundance and percent cover. To determine the abundance of each taxa, an overhead transparency marked with a square was overlaid on a PC-screen. All images of tiles were displayed by Microsoft Windows XP Picture and Fax Viewer™ and enlarged by clicking the zoom-in button sufficient times to identify each organism. To measure surface area occupied by each taxa, a forty point grid was overlaid on the PC-screen image. For both abundance and percent cover, the square or grid was reduced by a one centimetre margin to eliminate any potential edge effects.

3.2.3. *Data analysis*

Abundance and percent cover results are available for the bottom side of settlement plates for Year 1: March and May 2007 (summer) and September and November 2007 (winter). Final abundance and percent cover for each season was analysed separately for each taxonomic group using GLM ANOVA. Season, island and depth were fixed factors, while location (island) and site location (island) were nested factors. Data for all species in each taxonomic group was pooled, and log or arcsine transformed to meet assumptions of ANOVA for abundance and percent cover, respectively. Phyla with high numbers of '0' values, indicating very low recruitment, were not statistically analysed. Full ANOVA tables for each taxonomic group are given in Appendix 1.

3.3. *Results*

3.3.1. *Taxonomic groups*

Seven taxonomic groups of sessile organisms recruited in both summer and winter to plates situated on coral reefs in central Torres Strait (Figure 3.3). Note that red, green and brown algal species, thus of different phyla, recruited to plates but for simplicity they have been combined into one group. Comparing abundances between seasons, total recruitment was almost a third higher in winter (16,615 organisms) than in summer (11,964 organisms). Seasonal differences resulted from the considerably higher recruitment of polychaetes worms in winter (Figure 3.3). For the remaining taxonomic groups, recruitment was similar between summer and winter (Figure 3.3). Polychaete worms dominated recruitment numbers in central Torres Strait, ranging from 47-58% of total recruitment. Because of the high recruitment of polychaetes in winter, the recruitment proportion of other groups was lower in winter. After polychaete worms the next most abundant groups were ascidians and algae, followed by bryozoans, sponges and bivalves. Cnidarians, consisting of Scleractinian, soft coral and hydroid species, recruited in comparatively low numbers to central Torres Strait.

For many taxonomic groups, final percent cover in summer and winter differed greatly from recruitment abundance. This was most notable for polychaete worms, which dominated abundance yet covered <5% of plates in both seasons (Figure 3.3). Overall, algal recruits had the highest percent cover (Figure 3.3). In winter, algal species covered 31% of the plate, while percent cover of algae in summer was similar to bryozoans (22-23%). The percent cover of sponge and ascidian recruits was also relatively high, ranging from 12-21% depending on the season. Cnidarians had the lowest percent cover, covering <0.25% in both seasons. Bare space, or the percentage of plate that was not covered by any organism, was similar in summer (12%) and winter (13%). Thus, invertebrate and algal recruits covered >85% of most plates after 6 months regardless of season. In addition, bare space did not vary significantly between sites, locations, islands and depths ($P>0.05$).

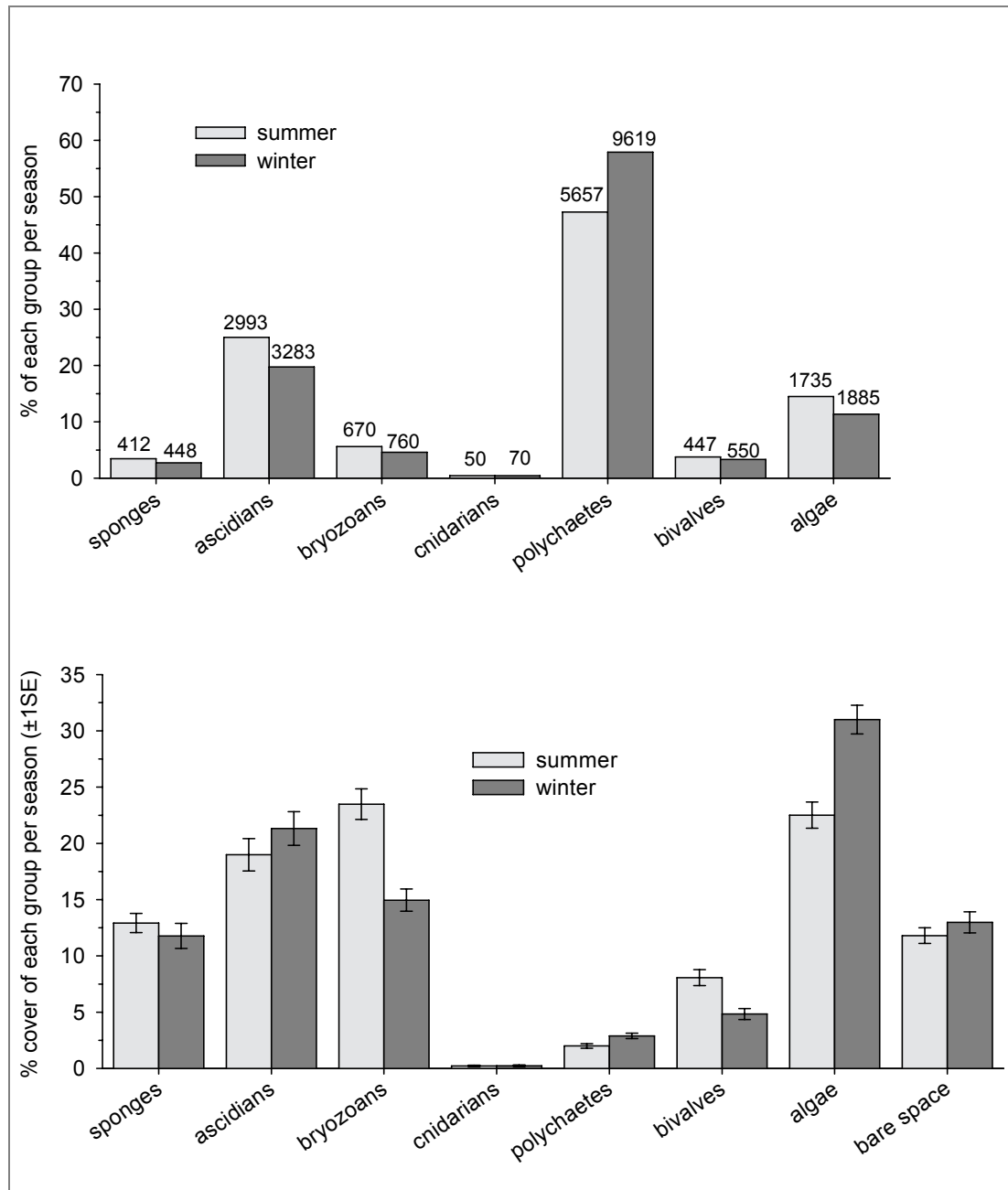


Figure 3.3. Final percent abundance (*top*) and percent cover (*bottom*) of each taxonomic group that recruited in summer and winter. For the abundance graph, the numbers above each bar refer to the actual number of recruits for each season. For the percent graph, bare space is also included

3.3.2. Sponges

Statistical analysis of sponge abundance found a significant season*island interaction ($P < 0.0006$), with more sponges recruiting to Masig than Marsden in summer, but the opposite in winter (Figure 3.4). Averaging over seasons, recruitment abundance was similar between the two islands, being 2.4 (SE = 0.2) sponges per 100 cm³. Recruitment did not vary significantly between locations or sites, indicating low variation over tens and hundreds of meters. Variation in sponge abundance between neighboring plates (within a site-depth) was also low, with most plates containing between one and five sponge recruits. Although depth was not significant, more sponges settled at twelve metres than at six metres in each season and at each island (Figure 3.4).

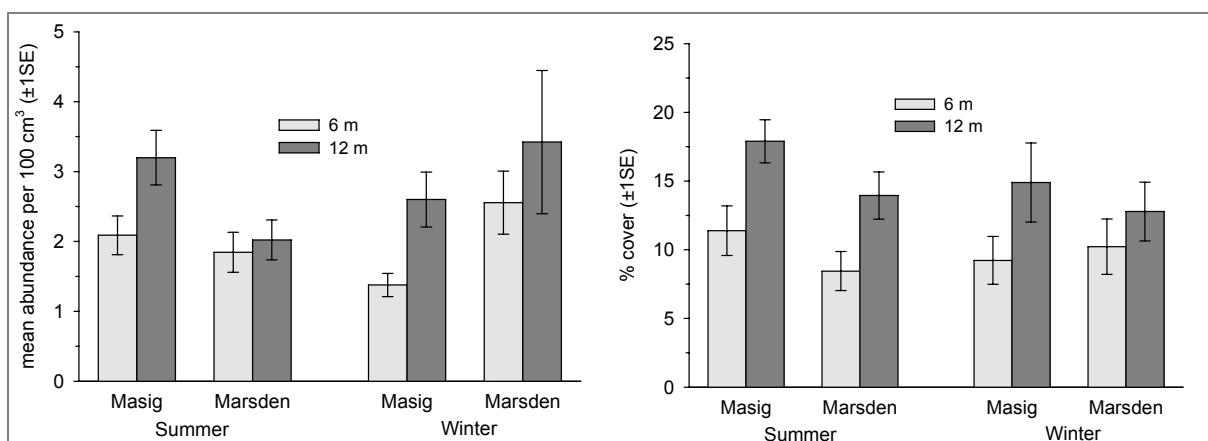


Figure 3.4. Final sponge abundance (*left*) and percent cover (*right*) in summer and winter at six and twelve metres' depth at Masig and Marsden.

Analysis of percent cover of sponge recruits found a significant season*location interaction ($P = 0.016$), indicating that final sponge cover on plates at a particular location could vary greatly between summer and winter. For example, percent cover of sponge recruits at one location was more than double in summer than in winter, while sponge cover at another location was >50% higher in winter. Overall, final percent cover was similar between summer and winter, averaging 13% and 12% respectively (Figure 3.4). Percent cover was also similar between Masig and Marsden (Figure 3.4), but varied significantly among sites ($P = 0.037$), indicating variation over tens of meters. Although not significant, final percent cover of sponges was greater at twelve metres than at six metres (Figure 3.4).

At least fourteen species of sponges recruited to the bottom side of plates at Masig and Marsden, including the commercial bath sponge *C. mathewsi* (Table 3.1). The majority of species were found to recruit in both seasons. Several sponge species have not been formally identified, but tissue samples have been collected from representatives of all unidentified species to allow identification at a later date. (Note that the species "massive grey" that was included in the sponge list in the February report has been identified as an ascidian)

Sponge recruitment patterns within a season varied between summer and winter. During winter, the majority of sponges (62%) recruited in the final two months (Table 3.1). In contrast, a 31% increase in total sponge abundance from March to May 2007 (Table 3.1), suggests a relatively steady recruitment pattern over the summer period. The large recruitment pulse at the end of winter resulted largely from the recruitment of five sponge species, namely *Adocia* sp., *Dysidea* sp. (purple), *lotrochota* sp., and two thin-encrusting

species (orange and yellow) (Table 3.1). Although several sponge species showed substantially greater recruitment in the final two months of summer, several species lost recruits from March to May (Table 3.1). Approximately one-third of *Iotrochota* sp. recruits, for example, died during the final two months of summer. Although recruitment patterns within a season varied between summer and winter, total recruitment after six months was similar (Table 3.1).

Table 3.1. Abundance of sponge recruits (and percent of total) after four and six months in summer and winter. Species ranked according to final winter data. The bath sponge *C. mathewsi* is shown in bold.

Species	Summer		Winter	
	4 months	6 months	4 months	6 months
Thin-encrusting, orange	75 (26.6)	62 (15.0)	35 (20.2)	165 (36.8)
Thin-encrusting, yellow	10 (3.5)	55 (13.3)	25 (14.5)	76 (17.0)
<i>Adocia</i> sp.	81 (28.7)	69 (16.7)	25 (14.5)	66 (14.7)
<i>Dysidea</i> sp., purple	8 (2.8)	16 (3.9)	11 (6.4)	44 (9.8)
<i>Iotrochota</i> sp.	27 (9.6)	17 (4.1)	7 (4.0)	36 (8.0)
<i>C. mathewsi</i>	7 (2.5)	4 (1.0)	1 (0.6)	12 (2.7)
<i>Clathria</i> sp.	6 (2.1)	21 (5.1)	8 (4.6)	11 (2.5)
Thin-encrusting, green	6 (2.1)	39 (9.5)	2 (1.2)	11 (2.5)
<i>Dysidea</i> sp., grey	17 (6.0)	41 (10.0)	16 (9.2)	5 (1.1)
<i>Calcarea</i> spp.	6 (2.1)	3 (0.7)	0	4 (0.9)
Tetillidae family, <i>Cinachyra</i> sp.?	0	0	0	4 (0.9)
Reticulated, yellow/green	0	0	0	4 (0.9)
<i>Nara nematifera</i>	2 (0.7)	5 (1.2)	7 (4.0)	3 (0.7)
<i>Hyrtios erecta</i>	3 (1.1)	2 (0.5)	0	0
Unidentified sponges	34 (12.1)	78 (18.9)	36 (20.8)	7 (1.6)
Total	282	412	173	448

The bath sponge *C. mathewsi* recruited to central Torres Strait in both seasons; however, its largest recruitment pulse occurred between September and November (Table 3.1). In contrast, the final two months of summer was notable for several deaths of *C. mathewsi* recruits. Overall, replicate number is low so these findings have to be treated cautiously. Over the first year of this recruitment study, *C. mathewsi* was the ninth most common sponge (out of fourteen species/genera) to recruit to Masig and Marsden; in winter, *C. mathewsi* was a more dominant recruiting species.

Table 3.2. Mean percent cover of sponge recruits after four and six months in summer and winter. Species ranked as in Table 3.1. The bath sponge *C. mathewsi* is shown in bold.

Species	Summer		Winter	
	4 months	6 months	4 months	6 months
Thin-encrusting, orange	1.72	2.64	0.79	2.78
Thin-encrusting, yellow	3.64	5.29	1.47	3.06
<i>Adocia</i> sp.	1.25	2.00	1.06	2.86
<i>Dysidea</i> sp., purple	0.07	0.19	0.15	0.33
<i>Iotrochota</i> sp.	0.14	0.43	0.03	0.04
<i>C. mathewsi</i>	<0.01	0.04	0.03	0.17
<i>Clathria</i> sp.	0.21	1.07	2.06	1.81
Thin-encrusting, green	0.01	0.28	0.03	0.19
<i>Dysidea</i> sp., grey	0.10	0.17	0.15	0.04
<i>Calcarea</i> spp.	0.04	0.01	0.00	0.06
Tetillidae family, <i>Cinachyra</i> sp.?	0.00	0.00	0.00	0.01
Reticulated, yellow/green	0.00	0.00	0.00	0.19
<i>Nara nematifera</i>	0.06	0.19	0.11	0.17
<i>Hyrtilos erecta</i>	<0.01	<0.01	0.00	0.00
Unidentified sponges	0.24	0.60	0.54	0.07
Total	7.47	12.92	6.42	11.78

The total percent cover of sponges was similar between summer and winter after four and six months (Table 3.2), showing a steady increase within each season. At each monitoring time, three species dominated cover namely *Adocia* sp. and two thin-encrusting species. For some sponges, final percent cover varied between seasons. For example, cover of *Iotrochota* sp. and *Dysidea* sp. grey, was greatest in summer, while *Adocia* sp. and *Clathria* sp. was highest in winter (Table 3.2). For *C. mathewsi*, percent cover was also greatest in winter; compared to other sponge species, it had medium to low percent cover in summer and winter.

3.3.3. Ascidiarians

The abundance of ascidian recruits varied significantly between depths ($P = 0.013$), with twice the number of ascidians, on averaging, recruiting to plates situated at twelve metres (23.8 ascidians) than at six metres (11.0) (Figure 3.5). Recruitment abundance did not differ significantly between seasons, islands, location or sites, indicating little variation in ascidian recruitment from tens of metres to kilometers in central Torres Strait in both summer and winter. In stark contrast, ascidian recruitment could vary greatly among neighbouring plates 1 m apart. In both summer and winter, about half of the 36 depth-site combinations recorded more than a 50 recruit difference among the five neighbouring plates. The greatest variation occurred at a Marsden deep site in winter with ascidian abundance being 4, 12, 21, 49 and 289 individuals per plate.

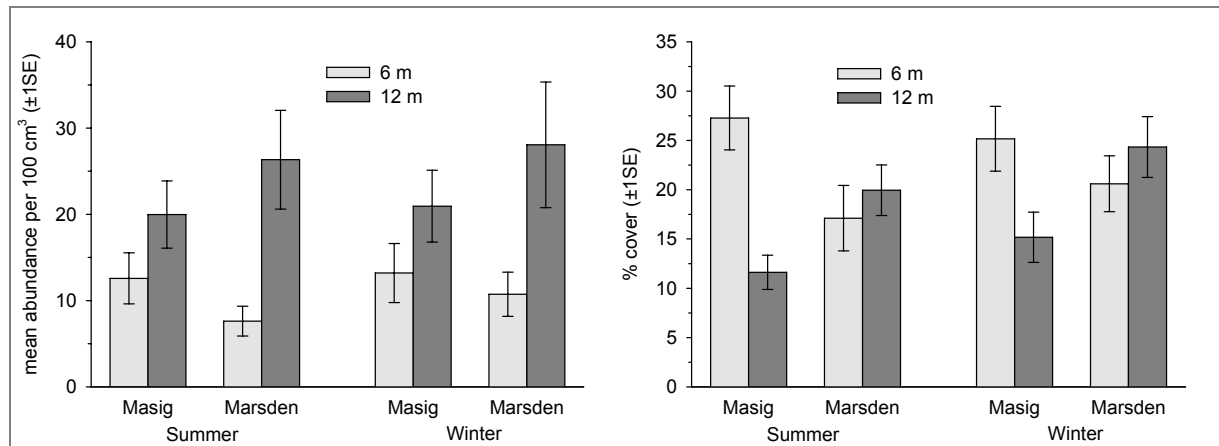


Figure 3.5. Final ascidian abundance (*left*) and percent cover (*right*) in summer and winter at six and twelve metres at Masig and Marsden.

Percent cover of ascidians showed a significant location*depth interaction ($P = 0.006$), with final cover greater at six metres than at twelve metres at some locations but the reverse pattern at neighboring locations. This pattern occurred in both summer and winter. Percent cover of ascidians also varied significantly between sites ($P = 0.007$), indicating variation over tens of meters within a location. Final percent cover did not vary significantly between summer and winter or between Masig and Marsden ($P > 0.05$).

Among the 7+ ascidian species that recruited to plates in central Torres Strait, a thin-encrusting species (currently unidentified) was the most abundant species in both summer and winter, constituting 73% of total ascidian recruits (Table 3.3). Seasonal variation in recruitment was observed for most ascidian species. Recruitment of *Styelidae* and *Botryllus* species was highest in summer, while *Clavelina* sp. recruited only in winter (Table 3.3). The main recruitment period for the thin-encrusting, grey species straddled both seasons, with most recruitment occurring from March to September. By November, 12% of these recruits had died. Poor survival within a season was also recorded for *Clavelina* sp. (Table 3.3).

Table 3.3. Abundance of ascidian recruits (and percent of total) after four and six months in summer and winter. Species ranked according to final winter data.

Species	Summer		Winter	
	4 months	6 months	4 months	6 months
Thin-encrusting, grey	177 (21.3)	1963 (65.6)	3030 (83.4)	2668 (81.3)
<i>Didemnum</i> sp. white-green	134 (16.1)	230 (7.7)	194 (5.3)	182 (5.5)
<i>Didemnum</i> spp.	127 (15.3)	316 (10.6)	189 (5.2)	169 (5.1)
<i>Styelidae</i> spp.	108 (13.0)	213 (7.1)	13 (0.4)	81 (2.5)
<i>Botryllus</i> spp.	57 (6.9)	153 (5.1)	17 (0.5)	24 (0.7)
<i>Clavelina</i> sp.	0	0	103 (2.8)	18 (0.5)
Unidentified species	228 (27.4)	118 (3.9)	85 (2.3)	141 (4.3)
Total	831	2993	3631	3283

Although total percent cover of ascidians was similar at the end of each season, cover varied after four months being higher for summer (Table 3.4). In summer, percent cover of ascidians decreased slightly during the final two months. *Didemnum* species dominated percent cover in both seasons, followed by *Styelidae* and *Botryllus* species (Table 3.4). Although the thin-encrusting, grey ascidian dominated recruitment numbers, it showed only moderate percent cover.

Table 3.4. Mean percent cover of ascidian recruits after four and six months in summer and winter. Species ranked according to Table 3.3.

Species	Summer		Winter	
	4 months	6 months	4 months	6 months
Thin-encrusting, grey	1.04	2.33	1.72	1.35
<i>Didemnum</i> sp. white-green	3.28	2.14	2.81	3.57
<i>Didemnum</i> spp.	6.56	6.96	4.79	5.97
<i>Styelidae</i> spp.	0.76	2.71	0.46	0.78
<i>Botryllus</i> spp.	1.14	1.14	0.31	1.01
<i>Clavelina</i> sp.	0.00	0.00	0.10	<0.01
Unidentified species	7.90	3.71	5.79	8.64
Total	20.68	18.99	15.97	21.32

3.3.4. Bryozoans

There was a significant season*site interaction ($P = 0.011$), indicating that total bryozoan recruitment among sites nested within a location could vary greatly between summer and winter. At twelve metres at a Masig location, for example, one site had four times as many bryozoans recruiting in summer than in winter, while a neighbouring site had twice as many recruit in winter; the third site had similar numbers recruit in both seasons. Thus, bryozoan recruitment in a season can vary greatly over short distances (roughly twenty metres). Statistical analysis also found a significant location*season*depth interaction ($P = 0.017$), with the numbers of bryozoans recruiting to six or twelve metres in summer or winter varying greatly between neighbouring locations. Recruitment was similar between seasons, islands and depths, averaging 3.97 (SE = 1.47) bryozoans per 100 cm³ (Figure 3.6). Recruitment was similar between neighbouring plates, with most plates having between one and six bryozoans by the end of summer or winter.

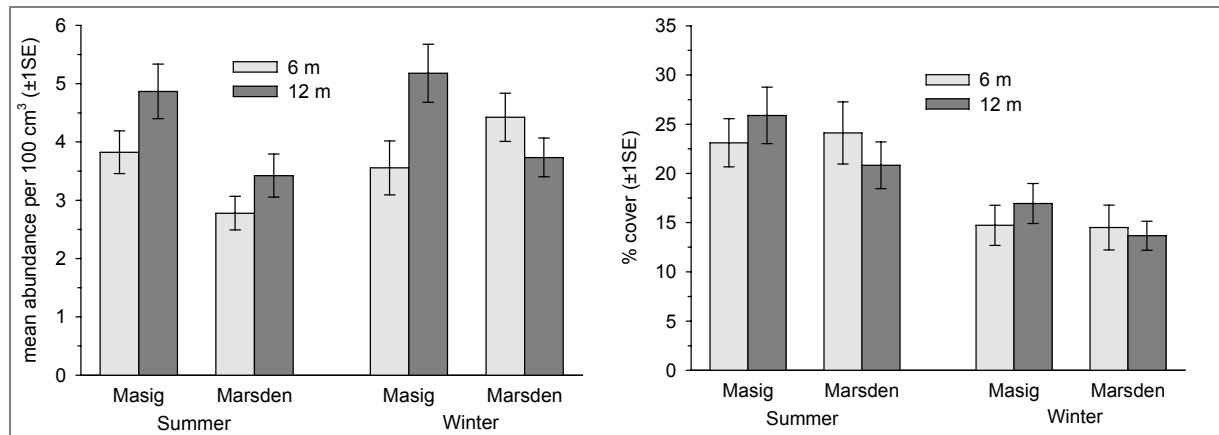


Figure 3.6. Final bryozoan abundance (*left*) and percent cover (*right*) in summer and winter at six and twelve metres at Masig and Marsden.

At least six species of bryozoans recruited to plates in central Torres Strait (Table 3.5); all have yet to be fully identified to genus/species level. A thin encrusting, white bryozoan dominated recruitment in both seasons. In both summer and winter, bryozoan abundance was greater after four months than at the end of the season. This resulted mostly from the high mortality of the thin-encrusting, white, and erect-branching species during the final two months of each season (Table 3.5).

Table 3.5. Abundance of bryozoan recruits (and percent of total) after four and six months in summer and winter. Species ranked according to final winter data.

Species	Summer		Winter	
	4 months	6 months	4 months	6 months
Thin-encrusting, white	869 (79.7)	544 (49.9)	787 (82.5)	655 (86.2)
Erect-branching, gray	142 (13.0)	20 (1.8)	96 (10.1)	53 (7.0)
Thin-encrusting, spotted	16 (1.5)	3 (0.3)	33 (3.5)	26 (3.4)
Thin-encrusting, orange	27 (2.5)	41 (3.8)	21 (2.2)	15 (2.0)
Thin-encrusting, pink	15 (1.4)	25 (2.3)	17 (1.8)	7 (0.9)
Thin-encrusting, purple	21 (1.9)	37 (3.4)	0	4 (0.5)
Total	1090	670	954	760

In contrast to abundance, total percent cover of bryozoans changed little during the last two months of either season: decreasing slightly in summer while increasing slightly in winter (Table 3.6). Similar to abundance data, the thin-encrusting, white bryozoan dominated percent cover at four and six months in both seasons.

Table 3.6. Mean percent cover of bryozoan recruits after four and six months in summer and winter. Species ranked according to Table 3.5.

Species	Summer		Winter	
	4 months	6 months	4 months	6 months
Thin-encrusting, white	26.79	22.04	10.63	14.26
Erect branching, gray	0.85	0.26	1.03	0.42
Thin-encrusting, spotted	0.21	0.57	0.24	0.03
Thin-encrusting, orange	0.33	0.47	0.08	0.15
Thin-encrusting, pink	0.07	0.14	0.08	0.07
Thin-encrusting, purple	0.06	<0.01	0	0.03
Total	28.31	23.49	12.06	14.96

3.3.5. Cnidarians

Too few cnidarians recruited to plates in central Torres Strait to allow for any statistical analyses (Table 3.7). Of the 360 plates transplanted over the year, only 68 (19%) contained Cnidarian recruits by the end of summer or winter. Although replicate number is too low for reliable comparisons, final abundance and percent cover appeared similar between Masig and Marsden and between six and twelve metres (Figure 3.7).

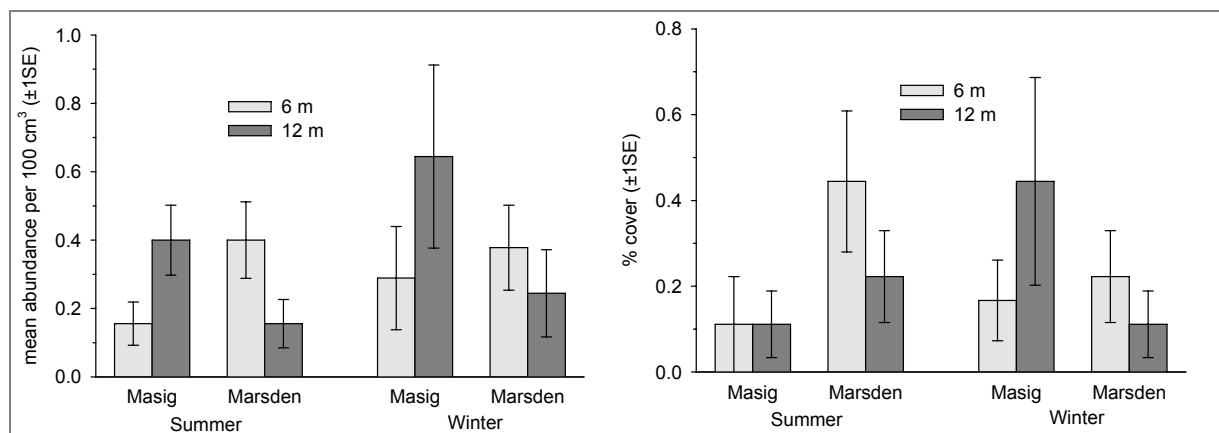


Figure 3.7. Final Cnidarian abundance (*left*) and percent cover (*right*) in summer and winter at six and twelve metres at Masig and Marsden.

Of the three groups of cnidarians that recruited to plates in central Torres Strait, Scleractinia spp., or stony corals, dominated in abundance in both seasons (Table 3.7). In both seasons, total abundance decreased from four to six months. Hydrozoa species in summer recorded the greatest decrease in numbers. Average percent cover was <0.2% for Scleractinia, Alcyonacea or Hydrozoa species in both summer and winter.

Table 3.7. Abundance of Cnidarian recruits (and percent of total) after four and six months in summer and winter. Species ranked according to final winter data.

Group / Class	Summer		Winter	
	4 months	6 months	4 months	6 months
Scleractinia spp.	32 (26.0)	27 (54.0)	66 (73.3)	50 (71.4)
Alcyonacea spp.	35 (28.5)	17 (34.0)	24 (26.7)	11 (15.7)
Hydrozoa spp.	56 (45.5)	6 (12.0)	0	9 (12.9)
Total	123	50	90	70

3.3.6. Polychaetes

Statistical analysis of polychaete recruitment found a significant island*season interaction ($P = 0.029$), with greater recruitment in winter than summer for both Masig and Marsden (Figure 3.8). Polychaete abundance in summer and winter was 31.4 and 53.4 individuals per 100 cm³, respectively. There was also a significant location*season*depth interaction ($P = 0.0169$), indicating that abundance, for example, was higher at six metres in summer at one location but greater at twelve metres in winter at a neighbouring location. Polychaete recruitment also varied significantly between sites nested in locations ($P = 0.0008$), indicating variation across tens of meters. For each season, recruitment abundance varied slightly among the five neighbouring plates at each depth-site, generally ranging from 10-50 and 30-80 polychaetes per 100 cm³ in summer and winter, respectively.

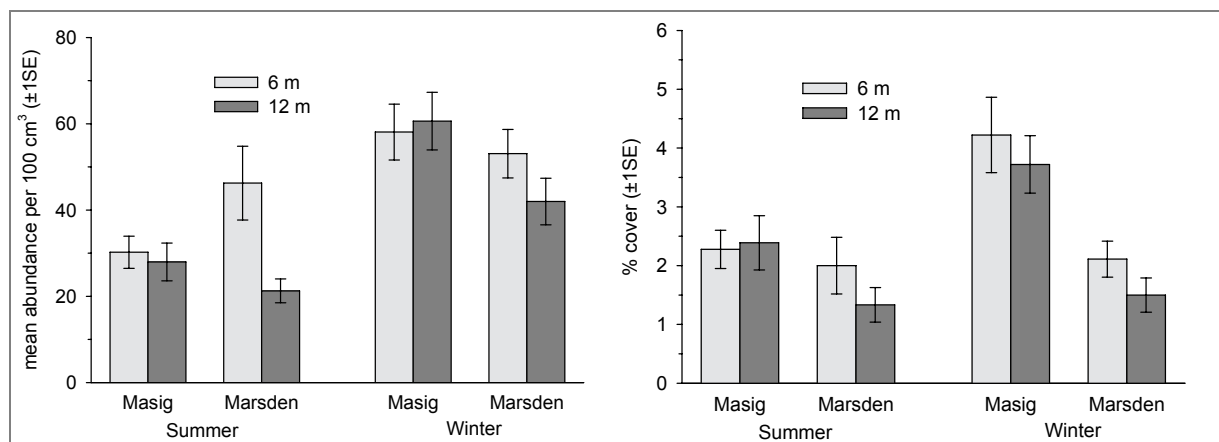


Figure 3.8. Final polychaete abundance (*left*) and percent cover (*right*) in summer and winter at six and twelve metres at Masig and Marsden.

Final percent cover differed significantly between seasons ($P = 0.039$), with polychaete cover nearly fifty percent greater in winter than in summer (Figure 3.8). Polychaete cover also varied significantly among locations nested in islands ($P = 0.035$), indicating variation over hundreds of meters. Percent cover was similar among islands, depths and sites (Figure 3.8)

Two polychaete genera were recorded from central Torres Strait, with *Metalaeospira* species dominating recruitment at all monitoring times (Table 3.8). Recruitment patterns varied between seasons, with a general increase in numbers from four to six months in summer, but a sharp decrease from four to six months in winter. Both genera showed high mortality, ranging from 38-56%, during the final two months of winter.

Table 3.8. Abundance of polychaete recruits (and percent of total) after four and six months in summer and winter. Species ranked according to final winter data.

Group	Summer		Winter	
	4 months	6 months	4 months	6 months
<i>Metalaeospira</i> spp.	3974 (77.7)	4674 (82.6)	12007 (71.1)	7476 (77.7)
<i>Galeotaria</i> spp.	1142 (22.3)	983 (17.4)	4877 (28.9)	2143 (22.3)
All	5116	5657	16884	9619

The percent cover of polychaetes decreased after four months in both seasons, most notably in winter when cover decreased by over fifty percent (Table 3.9). Recruitment cover of both genera decreased in summer and winter.

Table 3.9. Percent cover of polychaete recruits after four and six months in summer and winter. Species ranked according to Table 3.8.

Group	Summer		Winter	
	4 months	6 months	4 months	6 months
<i>Metalaeospira</i> spp.	1.46	0.94	3.16	1.21
<i>Galeotaria</i> spp.	1.90	1.06	3.08	1.68
All	3.36	2.00	6.24	2.89

3.3.7. Bivalves

Bivalve recruitment showed a significant location*season*depth interaction ($P = 0.047$), indicating that abundance could be higher at six metres in winter at one location but greater at twelve metres in summer at a neighbouring location. Overall, bivalve recruitment was similar between seasons, islands and depths, averaging 2.79 (SE = 0.19) bivalves per 100 cm³.

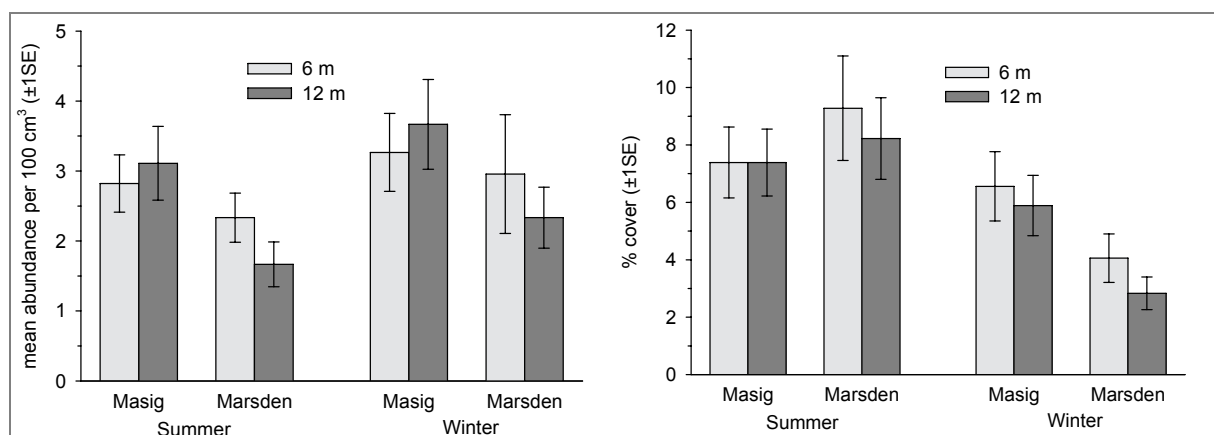


Figure 3.9. Final bivalve abundance (*left*) and percent cover (*right*) in summer and winter at six and twelve metres at Masig and Marsden.

Percent cover also had a significant location*season*depth interaction ($P = 0.0096$), thus cover varied across both time and space. Percent cover differed between seasons, being 40% greater in summer, and was similar between the two islands and two depths (Figure 3.9).

Bivalves that recruited to central Torres Strait likely included *Pinctada* and *Pteria* species, but could not be separated due to their small size. In both summer and winter, abundance and percent cover increased from four to six months (Table 3.10).

Table 3.10. Abundance and percent cover of bivalves after four and six months in summer and winter.

	Summer		Winter	
	4 months	6 months	4 months	6 months
Abundance	325	447	438	550
Percent cover	4.14	8.07	3.11	4.83

3.3.8. Algae

There was a significant site*season*depth interaction ($P = 0.0009$), indicating that algae abundance could be greater at six metres in summer at one site but higher at 12 m in winter at another site 20 m away. Overall, total abundance was similar between seasons, islands and depths, averaging 10.06 (SE=0.32) individuals per 100 cm³. Abundance was also similar between neighbouring plates at a site, generally ranging from 3 to 15 organisms per plate.

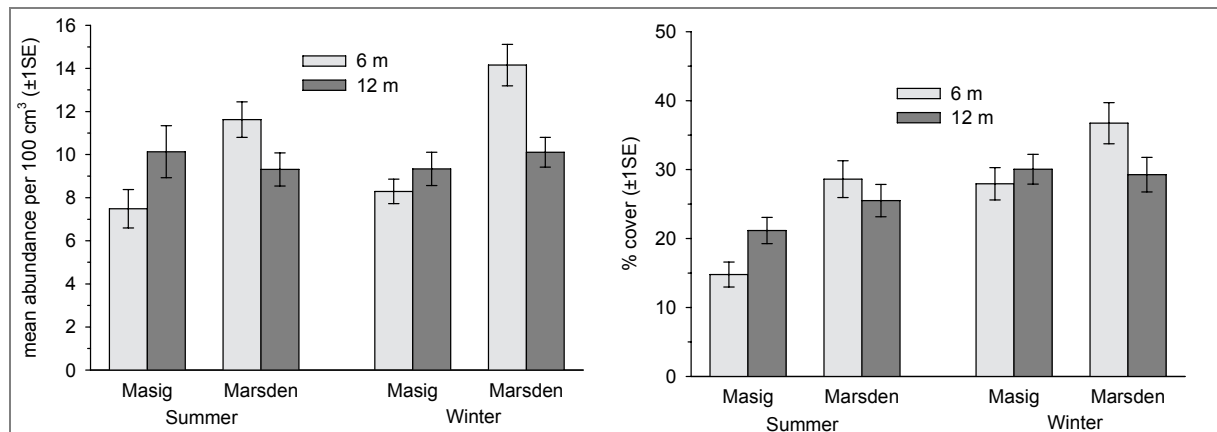


Figure 3.10. Final algae abundance (*left*) and percent cover (*right*) in summer and winter at six and twelve metres at Masig and Marsden.

Algae percent cover varied significantly between seasons ($P = 0.011$), being almost a third greater in winter (average = 31.00%) than in summer (22.51%) (Figure 3.10). There was also a significant location*depth interaction ($P = 0.0027$), with percent cover greater at six metres at some locations but higher at twelve metres at other locations. Overall, percent cover of algae was similar among sites and islands.

At least seven species of algae recruited to plates in central Torres Strait, dominated by thin-encrusting species (Table 3.11). Total recruitment was similar in summer and winter, but there were seasonal differences between species. For example, recruitment was highest in

winter for filamentous species, but greatest in summer for the brown and thin-encrusting, red species (Table 3.11). Most species showed a steady increase in recruitment within each season.

Table 3.11. Abundance of algae recruits (and percent of total) after four and six months in summer and winter. Species ranked according to Table 3.9.

Species	Summer		Winter	
	4 months	6 months	4 months	6 months
Thin-encrusting, green	192 (14.4)	472 (27.2)	614 (39.6)	575 (30.5)
Thin-encrusting, red	499 (37.4)	720 (41.5)	354 (22.8)	501 (26.6)
Filamentous, red	165 (12.4)	216 (12.4)	296 (19.1)	431 (22.9)
Filamentous, green	102 (7.6)	134 (7.7)	138 (8.9)	225 (11.9)
Brown	209 (15.7)	173 (10.0)	85 (5.5)	109 (5.8)
Blade, green	167 (12.5)	20 (1.2)	65 (4.2)	30 (1.6)
<i>Codium arabicum</i>	0	0	0	14 (0.7)
Total	1334	1735	1552	1885

Total percent cover of algae increased from four to six months in summer and winter (Table 3.12). In both seasons, however, most percent cover occurred during the first four months. Among the seven algal species, the thin-encrusting, green and red types had the greatest percent cover in winter and summer, respectively (Table 3.12).

Table 3.12. Percent cover of algae recruits after four and six months in summer and winter. Species ranked according to Table 3.11.

Species	Summer		Winter	
	4 months	6 months	4 months	6 months
Thin-encrusting, green	3.5	6.4	14.3	12.1
Thin-encrusting, red	7.0	8.2	2.3	4.9
Filamentous, red	3.8	3.3	5.5	8.9
Filamentous, green	1.8	1.9	2.7	4.1
Brown	1.8	2.4	0.8	0.8
Blade, green	0.2	0.2	0.8	0.3
<i>Codium arabicum</i>	0.0	0.0	0.0	0.3
Total	18.1	22.5	26.5	31.0

3.4. Discussion

This study indicates that levels of recruitment in central Torres Strait varies greatly between taxonomic groups such as polychaete worms and corals. Variation in total recruitment among the seven groups of sessile organisms reflects different levels of fecundity and survival. The majority of studies that have examined recruitment on corals reefs have focused, understandably, on corals (e.g. Hughes *et al.* 1999; Adjeroud *et al.* 2007). This study in Torres Strait will therefore provide important information on the recruitment of lesser known groups to coral reef ecosystems. At least three years of data are needed, however, to have a good understanding of the recruitment patterns of all sessile organisms across time and space in Torres Strait.

In both seasons, polychaete worms numerically dominated recruitment to central Torres Strait coral reefs, providing at least half of all recruits. Recruitment of both polychaete genera, and within-season mortality, were highest in winter. Temporal differences in polychaete recruitment probably resulted from seasonal variation in water temperature, as found for some coral reef invertebrates (Adjeroud *et al.* 2007). For the remaining taxonomic groups, total recruitment abundance was similar between summer and winter, although there were some significant temporal*spatial interactions.

Although total recruitment was similar for taxonomic groups like sponges, bryozoans and ascidians, many species had higher recruitment in a particular season, agreeing with other studies (e.g. Zea 1993; Newton *et al.* 2007; Whalan *et al.* 2007). Although successful recruitment of many species varied between winter and summer, most species recruited in both seasons suggesting continuous production of sexual and/or asexual recruits.

The bath sponge *C. mathewsi* also recruited in both seasons, although recruitment was highest in the last two months of winter and the first four months of summer, thus from September to March. Examining the reproductive patterns of the bath sponge *Rhopaloeides odorabile* from the Great Barrier Reef, Whalan *et al.* (2007) found that it is reproductively active from October to January, coinciding with high water temperatures. It is likely that reproduction and thus recruitment of *C. mathewsi* in Torres Strait is also driven by high water temperatures. Compared to most sponge species, *C. mathewsi* recruited in low numbers to Torres Strait coral reefs, generally less than ten recruits per square metre. In summer, survival of *C. mathewsi* recruits was poor. Urchin bulldozing, whereby recruits are dislodged from the substratum during grazing (Sammarco 1980; Maldonado and Uriz 1998), likely reduces *C. mathewsi* abundance in some parts of Torres Strait (Duckworth *et al.* 2007b). *Diadema* urchins were found under some plates and may have dislodged some *C. mathewsi* recruits.

Recruitment abundance did not correlate with percent cover for some taxonomic groups, most notably polychaete worms. Although numerically abundant, the small size of polychaete worms meant that they occupied a relatively small percentage of each plate. In contrast, total percent cover of algae, bryozoans and sponges was higher than their recruitment abundance, resulting from the high proportion of encrusting and spreading species that recruited to plates.

Variation in recruitment across space differed among the taxonomic groups (Table 3.13). For example, the recruitment abundance of polychaete worms varied across all spatial scales, from tens of meters to kilometers, while the recruitment of bivalves only varied significantly between locations, approximately two hundred metres apart. Such differences indicate that the impact and interaction of abiotic and biotic factors can vary greatly between groups. Overall, depth had the greatest impact on recruitment abundance, possibly relating to the damaging effects of high water flow in shallow water (Wilkinson and Evans 1989; Roberts

and Davis 1996; Duckworth and Wolff 2007b). Some coral reef organisms are also more common in deeper water due to lower levels of light intensity and thus ultraviolet radiation (Jokiel 1980; Wilkinson and Trott 1985). However, recruitment in this study was recorded from the underside and thus shaded side of plates, so it is difficult to determine the impact of light intensity in structuring recruitment patterns.

For many taxonomic groups, spatial variation in recruitment abundance did not match variation in percent cover (Table 3.13). For ascidians, for example, recruitment abundance varied only between depths, while final percent cover varied between locations, sites and depths. In contrast to recruitment abundance, final percent cover is affected by the growth and morphology of individual species, thus abiotic or biotic factors that effect abundance may not have the same effect on percent cover.

Table 3.13. Summary of summer recruitment patterns across space for each sessile group. X = total recruitment varied significantly; empty cell = non-significant.

Group	Island		Location		Site		Depth	
	A	%	A	%	A	%	A	%
Sponges	X			X		X		
Ascidians				X		X	X	X
Bryozoans			X		X	X	X	
Polychaetes	X		X	X	X		X	
Bivalves			X	X				X
Algae				X	X		X	X

4. Field work conducted

Scientists from the Australian Institute of Marine Science (AIMS) visited Torres Strait three times during the second year of this MTSRF project, diving the waters in and around Masig Island (Table 5.1.). During the field trips we worked alongside and dived with Torres Strait Islanders, namely John Morris and Samson Lowatta. This promoted the transfer of knowledge and experience between the project, Torres Strait Islanders and the local communities. Both John Morris and Samson Lowatta were formally employed for each day that they worked on the project, with a wage that was agreed and accepted to be fair by John Morris, Samson Lowatta, AIMS and Torres Strait Regional Authority.

Table 5.1. Field trips dates and objective researched during the second year of MTSRF funding.

Dates	Objective
Trip 4569: 3-10 September 2007	3
Trip 4609: 6-13 November 2007	1 and 3
Trip 4673: 26 May – 6 June 2008	1 and 3

5. Communication activities

Effective community extension has been a high priority of this project and the CRC funded project that preceded it. Besides actually involving community members in the research, steps were taken to fully inform Island councils and communities of the planned field work, before the work took place. For all field works to Masig, the project built on the excellent working arrangement between the Yorke Island Community Council and AIMS which was established during the previous CRC Torres Strait project based at Masig. After each field trip, Torres Strait Regional Authority was informed of activities and interactions with island communities.

A scientific manuscript describing the effect of abiotic and biotic factors on the abundance and size frequency patterns of *C. mathewsi* in Torres Strait has been submitted to a science journal. The recruitment study is still on-going and will be submitted to a science journal once finished.

6. Planned activities for 2008/2009

Two field trips are planned to Masig, one in November 2008 and the second in May 2009. During both field trips, benthic surveys will investigate the occurrence of disease, abundance and size frequency patterns of the bath sponge *C. mathewsi* (Objective 1), including the spread of invasive species and the possible changing levels of sedimentation. In addition, the field trips will examine the recruitment of bath sponges and other sessile organisms to coral reefs around Masig (Objective 3).

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Appendix 1

*Full ANOVA tables of abundance and percent cover recruitment for each taxonomic group. Prob. * < 0.05*

Sponge abundance

Source	DF	SS	MS	F-ratio	Prob.
A: island	1	6.836864E-03	6.836864E-03	0.03	0.878745
B(A): location	4	1.034853	0.2587133	2.16	0.135938
C(AB): site	12	1.43888	0.1199067	1.52	0.116235
D: season	1	9.816447E-04	9.816447E-04	0.13	0.735588
AD	1	0.7195842	0.7195842	96.12	0.000607*
BD(A)	4	2.994508E-02	7.486271E-03	0.10	0.980553
CD(AB)	12	0.902541	7.521175E-02	0.95	0.494312
E: depth	1	0.5000889	0.5000889	3.08	0.154104
AE	1	0.1670791	0.1670791	1.03	0.367744
BE(A)	4	0.649419	0.1623547	2.78	0.075705
CE(AB)	12	0.6998335	5.831946E-02	0.74	0.712777
DE	1	1.103092E-02	1.103092E-02	0.16	0.708793
ADE	1	2.972519E-03	2.972519E-03	0.04	0.845203
BDE(A)	4	0.2741496	6.853741E-02	0.92	0.483081
CDE(AB)	12	0.8925175	7.437646E-02	0.94	0.504771
S	288	22.72937	7.892144E-02		
Total (adjusted)	359	30.06009			

Sponge percent cover

Source	DF	SS	MS	F-ratio	Prob.
A: island	1	0.0893025	0.0893025	1.10	0.352596
B(A): location	4	0.3234389	8.085972E-02	1.30	0.326058
C(AB): site	12	0.7490034	6.241694E-02	1.87	0.037258*
D: season	1	0.0931225	0.0931225	1.47	0.292108
AD	1	0.0680625	0.0680625	1.07	0.358552
BD(A)	4	0.2534567	6.336416E-02	4.73	0.015952*
CD(AB)	12	0.1607233	1.339361E-02	0.40	0.962250
E: depth	1	0.5221225	0.5221225	3.76	0.124637
AE	1	1.236694E-02	1.236694E-02	0.09	0.780334
BE(A)	4	0.5559589	0.1389897	2.37	0.110447
CE(AB)	12	0.7024567	5.853806E-02	1.76	0.054916
DE	1	0.0416025	0.0416025	0.99	0.376468
ADE	1	4.913611E-03	4.913611E-03	0.12	0.749829
BDE(A)	4	0.1684122	4.210306E-02	1.88	0.178135
CDE(AB)	12	0.2682567	2.235472E-02	0.67	0.778856
S	288	9.5932	3.330972E-02		
Total (Adjusted)	359	13.6064			

Ascidian abundance

Source	DF	SS	MS	F-ratio	Prob.
A: island	1	8.086041E-03	8.086041E-03	0.01	0.925788
B(A): location	4	3.290002	0.8225004	1.51	0.260831
C(AB): site	12	6.539191	0.5449326	1.68	0.070724
D: season	1	0.5630916	0.5630916	0.73	0.442007
AD	1	1.858475E-03	1.858475E-03	0.00	0.963289
BD(A)	4	3.09971	0.7749274	2.58	0.091522
CD(AB)	12	3.610534	0.3008778	0.93	0.519963
E: depth	1	5.059982	5.059982	18.55	0.012574*
AE	1	0.8867928	0.8867928	3.25	0.145705
BE(A)	4	1.090995	0.2727489	2.00	0.158527
CE(AB)	12	1.635953	0.1363294	0.42	0.955115
DE	1	3.206743E-03	3.206743E-03	0.01	0.912118
ADE	1	6.189063E-02	6.189063E-02	0.27	0.632903
BDE(A)	4	0.928871	0.2322178	0.92	0.486280
CDE(AB)	12	3.04491	0.2537425	0.78	0.669070
S	288	93.45877	0.3245096		
Total (Adjusted)	359	123.2839			

Ascidian percent cover

Source	DF	SS	MS	F-ratio	Prob.
A: island	1	0.00361	0.00361	0.01	0.945024
B(A): location	4	2.681473	0.6703683	5.73	0.008110*
C(AB): site	12	1.402847	0.1169039	2.33	0.007377*
D: season	1	0.08281	0.08281	1.98	0.231953
AD	1	0.06084	0.06084	1.46	0.294036
BD(A)	4	0.1671333	4.178333E-02	1.53	0.254173
CD(AB)	12	0.3267867	2.723222E-02	0.54	0.885802
E: depth	1	0.28224	0.28224	0.86	0.406537
AE	1	1.167361	1.167361	3.55	0.132568
BE(A)	4	1.314636	0.3286589	6.27	0.005826*
CE(AB)	12	0.6294534	5.245445E-02	1.05	0.407150
DE	1	3.173444E-02	3.173444E-02	0.91	0.393729
ADE	1	0.02704	0.02704	0.78	0.427884
BDE(A)	4	0.1392289	3.480722E-02	0.97	0.458394
CDE(AB)	12	0.4298867	3.582389E-02	0.71	0.737678
S	288	14.45148	5.017875E-02		
Total (Adjusted)	359	23.19856			

Bryozoan abundance

Source	DF	SS	MS	F-ratio	Prob.
A: island	1	6.134445E-02	6.134445E-02	0.33	0.595201
B(A): location	4	0.7384573	0.1846143	0.83	0.530268
C(AB): site	12	2.663282	0.2219402	3.11	0.000362*
D: season	1	0.6671693	0.6671693	3.36	0.140583
AD	1	0.6577756	0.6577756	3.32	0.142713
BD(A)	4	0.7934575	0.1983644	1.25	0.340256
CD(AB)	12	1.896861	0.1580718	2.22	0.011213*
E: depth	1	9.503354E-03	9.503354E-03	0.05	0.840423
AE	1	1.571877E-02	1.571877E-02	0.08	0.796031
BE(A)	4	0.8238124	0.2059531	3.65	0.036108*
CE(AB)	12	0.6765875	5.638229E-02	0.79	0.660519
DE	1	0.3650776	0.3650776	1.15	0.344345
ADE	1	1.599409E-02	1.599409E-02	0.05	0.833555
BDE(A)	4	1.272245	0.3180614	4.62	0.017278*
CDE(AB)	12	0.8262408	0.0688534	0.97	0.482521
S	288	20.54834	7.134839E-02		
Total (Adjusted)	359	32.03186			

Bryozoan percent cover

Source	DF	SS	MS	F-ratio	Prob.
A: island	1	4.715111E-02	4.715111E-02	0.30	0.613742
B(A): location	4	0.6313689	0.1578422	1.79	0.194946
C(AB): site	12	1.05596	8.799667E-02	2.22	0.010883*
D: season	1	1.024	1.024	52.87	0.001900*
AD	1	8.604445E-03	8.604445E-03	0.44	0.541541
BD(A)	4	7.746889E-02	1.936722E-02	0.63	0.648770
CD(AB)	12	0.3673867	3.061556E-02	0.77	0.677542
E: depth	1	0.00676	0.00676	0.55	0.500763
AE	1	0.049	0.049	3.96	0.117396
BE(A)	4	4.947333E-02	1.236833E-02	0.23	0.917497
CE(AB)	12	0.6512867	5.427389E-02	1.37	0.178718
DE	1	1.111111E-02	1.111111E-02	0.23	0.659703
ADE	1	3.737778E-03	3.737778E-03	0.08	0.796669
BDE(A)	4	0.1971644	4.929111E-02	1.37	0.302227
CDE(AB)	12	0.4324067	3.603389E-02	0.91	0.536669
S	288	11.39676	3.957208E-02		
Total (Adjusted)	359	16.00964			

Polychaete abundance

Source	DF	SS	MS	F-ratio	Prob.
A: island	1	0.6863782	0.6863782	1.88	0.242450
B(A): location	4	1.462037	0.3655092	1.01	0.440692
C(AB): site	12	4.346354	0.3621961	2.92	0.000778*
D: season	1	31.52525	31.52525	257.22	0.000088*
AD	1	1.35163	1.35163	11.03	0.029354*
BD(A)	4	0.4902416	0.1225604	0.76	0.568033
CD(AB)	12	1.922824	0.1602354	1.29	0.223019
E: depth	1	0.4865575	0.4865575	1.17	0.340762
AE	1	0.1238485	0.1238485	0.30	0.614670
BE(A)	4	1.6674	0.41685	1.92	0.171099
CE(AB)	12	2.600223	0.2166853	1.75	0.057095
DE	1	0.2905852	0.2905852	1.59	0.275731
ADE	1	6.931151E-03	6.931151E-03	0.04	0.855040
BDE(A)	4	0.7305738	0.1826435	4.65	0.016851*
CDE(AB)	12	0.4709105	3.924254E-02	0.32	0.986253
S	288	35.7523	0.1241399		
Total (Adjusted)	359	83.91404			

Polychaete percent cover

Source	DF	SS	MS	F-ratio	Prob.
A: island	1	0.12321	0.12321	6.40	0.064610
B(A): location	4	7.694667E-02	1.923667E-02	3.68	0.035417*
C(AB): site	12	6.278333E-02	5.231944E-03	1.01	0.438264
D: season	1	4.807111E-02	4.807111E-02	9.22	0.038543*
AD	1	1.995111E-02	1.995111E-02	3.83	0.122107
BD(A)	4	2.085778E-02	5.214444E-03	1.43	0.282411
CD(AB)	12	0.04367	3.639167E-03	0.70	0.747902
E: depth	1	0.009	0.009	0.63	0.472230
AE	1	0.004	0.004	0.28	0.625067
BE(A)	4	5.726667E-02	1.431667E-02	2.87	0.070103
CE(AB)	12	5.986333E-02	4.988611E-03	0.96	0.483190
DE	1	0.00009	0.00009	0.05	0.836039
ADE	1	5.444444E-05	5.444444E-05	0.03	0.871968
BDE(A)	4	7.382222E-03	1.845556E-03	0.49	0.744810
CDE(AB)	12	4.540333E-02	3.783611E-03	0.73	0.720339
S	288	1.48984	5.173055E-03		
Total (Adjusted)	359	2.06839			

Bivalve abundance

Source	DF	SS	MS	F-ratio	Prob.
A: island	1	0.5117122	0.5117122	2.43	0.194299
B(A): location	4	0.8435547	0.2108887	1.10	0.399782
C(AB): site	12	2.296946	0.1914122	1.71	0.063856
D: season	1	8.872109E-02	8.872109E-02	0.19	0.688104
AD	1	0.0927124	0.0927124	0.19	0.681691
BD(A)	4	1.902849	0.4757122	3.54	0.039590*
CD(AB)	12	1.612796	0.1343997	1.20	0.281364
E: depth	1	0.1320394	0.1320394	0.61	0.477644
AE	1	2.087609E-02	2.087609E-02	0.10	0.771230
BE(A)	4	0.8625376	0.2156344	2.68	0.083260
CE(AB)	12	0.965973	8.049775E-02	0.72	0.732109
DE	1	0.8006143	0.8006143	4.41	0.103522
ADE	1	9.653693E-02	9.653693E-02	0.53	0.506062
BDE(A)	4	0.7254061	0.1813515	3.33	0.047267*
CDE(AB)	12	0.6543444	5.452871E-02	0.49	0.921499
S	288	32.21839	0.1118694		
Total (Adjusted)	359	43.82601			

Bivalve percent cover

Source	DF	SS	MS	F-ratio	Prob.
A: island	1	0.02601	0.02601	0.30	0.613627
B(A): location	4	0.3480489	8.701222E-02	3.56	0.038927*
C(AB): site	12	0.2932833	2.444028E-02	1.32	0.206760
D: season	1	0.2935511	0.2935511	10.46	0.031869*
AD	1	0.11025	0.11025	3.93	0.118579
BD(A)	4	0.1123022	2.807556E-02	7.61	0.002711*
CD(AB)	12	4.427667E-02	3.689722E-03	0.20	0.998435
E: depth	1	1.344444E-02	1.344444E-02	0.12	0.742704
AE	1	0.00361	0.00361	0.03	0.864197
BE(A)	4	0.4343956	0.1085989	5.06	0.012699*
CE(AB)	12	0.25769	2.147417E-02	1.16	0.312768
DE	1	1.604444E-03	1.604444E-03	0.03	0.870075
ADE	1	2.777778E-05	2.777778E-05	0.00	0.982798
BDE(A)	4	0.2111778	5.279445E-02	5.48	0.009592*
CDE(AB)	12	0.11571	0.0096425	0.52	0.901115
S	288	5.33728	1.853222E-02		
Total (Adjusted)	359	7.602662			

Algal abundance

Source	DF	SS	MS	F-ratio	Prob.
A: island	1	0.7006664	0.7006664	3.97	0.117248
B(A): location	4	0.7066511	0.1766628	1.09	0.406780
C(AB): site	12	1.953386	0.1627821	3.21	0.000243*
D: season	1	3.323168E-02	3.323168E-02	0.17	0.698179
AD	1	0.1757497	0.1757497	0.92	0.392019
BD(A)	4	0.7649403	0.1912351	1.12	0.392148
CD(AB)	12	2.048844	0.170737	3.37	0.000129*
E: depth	1	0.3683667	0.3683667	0.96	0.382471
AE	1	1.243642	1.243642	3.24	0.146052
BE(A)	4	1.533488	0.383372	3.88	0.030222*
CE(AB)	12	1.186832	9.890266E-02	1.95	0.028661*
DE	1	0.5514231	0.5514231	1.39	0.303927
ADE	1	1.449169E-04	1.449169E-04	0.00	0.985673
BDE(A)	4	1.588209	0.3970523	2.71	0.081247
CDE(AB)	12	1.760972	0.1467477	2.89	0.000852*
S	288	14.60247	5.070303E-02		
Total (Adjusted)	359	29.21902			

Algae percent cover

Source	DF	SS	MS	F-ratio	Prob.
A: island	1	0.5483403	0.5483403	1.48	0.290888
B(A): location	4	1.483711	0.3709278	10.53	0.000673*
C(AB): site	12	0.42257	3.521417E-02	1.15	0.321749
D: season	1	0.9620336	0.9620336	20.46	0.010635*
AD	1	0.1099003	0.1099003	2.34	0.201067
BD(A)	4	0.1881111	4.702778E-02	2.46	0.102374
CD(AB)	12	0.22987	1.915583E-02	0.62	0.821440
E: depth	1	0.0011025	0.0011025	0.01	0.943359
AE	1	0.3033403	0.3033403	1.57	0.278062
BE(A)	4	0.7713622	0.1928406	7.61	0.002710*
CE(AB)	12	0.30407	2.533917E-02	0.83	0.624171
DE	1	0.0837225	0.0837225	4.68	0.096579
ADE	1	2.006945E-03	2.006945E-03	0.11	0.754548
BDE(A)	4	7.158889E-02	1.789722E-02	0.77	0.566847
CDE(AB)	12	0.2800367	2.333639E-02	0.76	0.691313
S	288	8.8412	3.069861E-02		
Total (Adjusted)	359	14.60297			