Fall 2011

A Study of Sponge Aquaculture in Jambiani: Is Shallow Farming Feasible?

Sarah Friday
SIT Study Abroad, sarah.friday@richmond.edu

A study of sponge aquaculture in Jambiani: Is shallow farming feasible?

By Sarah Friday

Project Advisors: Dr. Matt Richmond and Dr. Narriman S. Jiddawi

School for International Training Fall 2011
Tanzania-Zanzibar: Coastal Ecology and Natural Resource Management

Academic Director: Helen Peeks

Acknowledgements

I would like to thank Christian Vaterlaus and Mohamed Mrisho Haji (Okala) of Marinecultures for welcoming me into their sponge aquaculture project and for sharing with me their wealth of knowledge and resources. Also, I extend a special thanks to Okala for helping with field work, organizing local contacts, translating interviews with fishermen, and inviting me into his family. Without either of them, this project would not have been possible.

I would like to thank Dr. Matt Richmond and Dr. Narriman S. Jiddawi for their support and guidance through defining and executing a study project. Thank you to IMS for lending me their refractometer. I would also be remiss without thanking Dr. Malcolm Hill for inspiring me with his passion of sponges, sharing with me his understanding of these elusive organisms, and helping me through the data analysis of my project.

Thank you to all of my fellow SIT students for their words of encouragement and comic relief during ISP, especially to Erika, Steven, Hanna, and Sarah for their much appreciated company in Jambiani. Thank you to Said Hamad Omar for all of his wisdom and unforgettable metaphors. And of course, thank you to Helen Peeks, my SIT academic director, for her advice and support throughout the ISP period and entire program.

Table of Contents

List of Figures

Abstract

In the village of Jambiani, Unguja, a Swiss NGO called *Marine Cultures* has established an experimental sponge farming initiative to improve local employment and support economic development. Currently, the main farming site is only accessible through SCUBA diving. This is consistent with experimental farm sites in other oceanic regions, as most are located in depths of at least five meters with sponges suspended vertically to maximize water flow exposure. Farms located in shallower water may not be conducive to sponge growth due to highly variable environmental conditions; however, no conclusive research has been conducted on this matter (Duckworth 2009). Nonetheless, shallow farms could be beneficial, for they may be accessed through wading or snorkeling, eliminating the need for costly SCUBA certifications and swimming skills, both of which are impractical for local people. The feasibility of shallow sponge farming in Jambiani was investigated through the construction of a shallow test farm. By testing of three different farming treatments, conducting surveys for commercially viable sponges, and assessing aquaculture awareness and perceptions of local fishermen, it was determined that shallow sponge farming has definite potential for successful implementation within the region.

1. Introduction

1.1 Sponge biology, diversity, and distribution

Sponges (Phylum Porifera) are ancient, sessile invertebrates with a simple organization of cells. The body of a sponge is organized into three main layers: the pinacoderm, an outer layer comprised of pinacocytes; the choanosome, or internal canal system; and the mesohyl, an extracellular matrix of non-differentiated (totipotent) cells that contains components of the sponge skeleton (Osinga et al 1999) made of either calcium carbonate or silica material (Hooper et al 2002). The aquiferous system of channels and chambers is responsible for the sponge's highly efficient water pumping abilities. Water enters this system through inhalant pores, called ostia, and is pumped in a unidirectional current by a single layer of flagellated choanocyte cells (Hooper et al 2002), supplying food and oxygen to the sponge while simultaneously removing metabolic waste as water is released back into the water column through exhalant pores called oscula (Fig. 1). Sponges filter feed unselectively on particles between 0.1 to 50 micrometers, including phytoplankton, heterotrophic bacteria, heterotrophic eukaryotes, and detritus (Osinga 1999). While most species are able to reproduce asexually, propagation may also occur

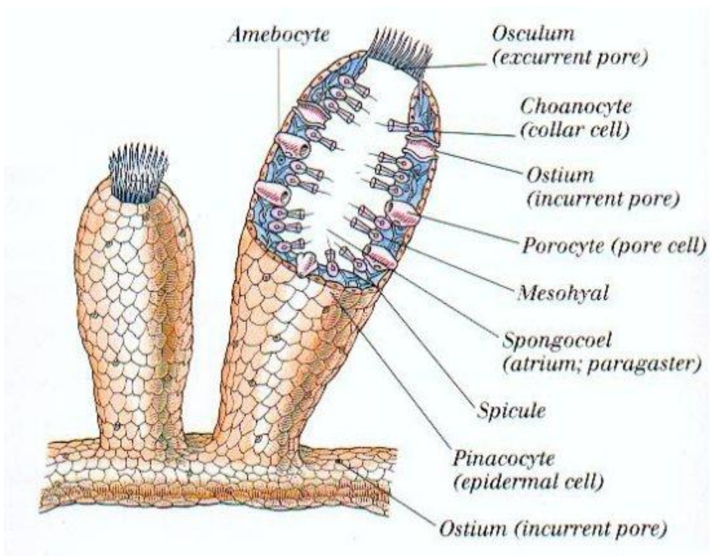

Fig. 1. Diagram of marine sponge showing basic morphology and cell types.

through oviparity or viviparity; larvae are free-swimming or creeping. Regardless of reproduction method, all sponges have extensive regenerative capabilities that are crucial to the subsistence of local populations (Hooper et al 2002).

In the 580 million years that sponges have inhabited our oceans, they have evolved into a highly adaptable group of organisms that are represented in all aquatic habitats, including polar, temperate, tropical, subtropical, and even some freshwater localities (Hooper and Van Soest 2002). Sponges are divided into three distinct classes: Hexactinellida, Demospongiae, and Calcarea (Hooper et al 2002). Currently over 7,000 species have been described, although this is likely only a fraction of existing species, with several hundred inhabiting the waters of East Africa (Richmond 2011). They represent one of the most diverse invertebrate phyla in both number of species and in morphological plasticity (Barnes and Bell 2002). Individuals can exhibit a wide array of forms, such as encrusting (sheet-like), excavating, digitate (finger-like), globular, and branching growth patterns (Boury-Esnault and Rützler 1997). It is this inter- and often intraspecific plasticity that has resulted in a long history of taxonomic identification difficulties. Proper identification requires observation of subtle diagnostic clues (i.e. color, morphology) and tedious microscope work to identify skeletal types which are often taxonomically specific, making field identification of sponges extremely difficult (Hooper et al 2002, Diaz and Rützler 2001).

1.2 Importance of sponges

Sponges have an important and multifaceted role in maintaining the framework of marine ecosystems. This role ranges from competing for space with other sessile organisms and serving as a food source for fish populations to filtering particulate matter from the water column (Duckworth 2009). Through complex symbioses, sponges also have the capacity to mediate processes such as nitrification and primary production, facilitating nutrient cycling of various oceanic zones (Diaz and Rützler 2001, Duckworth et al 2009). Bioeroding sponges play a fundamental role in the habitat composition of coral ecosystems; by breaking down the calcium carbonate of coral, they produce small niches for reef dwelling organisms, generate a significant amount of the sediment present on a reef, and can result in a decrease in net coral growth. In contrast, non-burrowing sponges have been shown to bind coral colonies and increase carbonate accumulation by dampening wave action, fish predation, and other destructive forces within both deep and shallow reefs. High diversity, abundance, and biomass of sponges only intensify their influence within marine communities, coral reefs in particular (Diaz and Rützler 2001).

These organisms not only have ecological importance, but also economic significance. The ancient Greeks (Osinga et al 1999) and civilizations in the Caribbean and Mediterranean began harvesting sponges thousands of years ago for their valuable endoskeletons comprised of silica or calcite crystals, called spicules, and fibrous spongin protein. The composition of these structural proteins varies between species; only those with a high percentage of spongin have a soft, compressible texture that is marketable for bathing, cosmetic application, and artwork (Richmond 2011). Sponges have also historically been used as decoration and in the disciplines of medicine, astronomy, and chemistry. Within the past twenty years, the sponge market has broadened to include species containing biologically active metabolites with possible pharmaceutical benefits. Presently, sponges are reported to be used in over 5,300 pharmacological products (Celik 2011).

1.3 History of sponge aquaculture

As natural populations were strained from overharvesting and disease, sponge aquaculture became a viable and necessary solution to satisfy a growing global demand.

However, while sponges have been farmed for over 100 years the practice is still largely in its infancy; in 2003, global bath sponge trade was 2,127 metric tons, while global production from sponge harvesting contributed only 55 metric tons (Duckworth 2009, Duckworth et al 2007). The first scientific papers to discuss sponge farming methods were published in the late 19th and early 20th centuries. These generally involved cutting the sponge into small pieces, attaching them to concrete disks, and placing them back in the sea to grow (Osinga 1999). This method has since been improved with the introduction of synthetic nylon ropes for sponge suspension; however, the exact methods for farming optimization are still under development and often are dependent on local growing environments, as well as the sponge species of interest. Experimental farming sites in Australia and New Zealand have found that sponge cuttings, termed explants, generally need high water flow and minimal to moderate ultraviolet radiation (UV) exposure. Consequently, most existing farm sites are located in areas of at least five meters in depth, with explants suspended vertically in the water column (Duckworth 2009). That being said, there has been some preliminary success in more shallow farming sites using horizontal suspension systems. Studies conducted in Micronesia, Australia, New Zealand, and the Mediterranean Sea have demonstrated that sponges may be farmed using simple techniques and cheap equipment. These characteristics make sponge farming ideally suited for communities with limited opportunities for enterprise, bolstering local employment and economic development (Duckworth et al 2009). Presently, there is no established sponge aquaculture within the Western Indian Ocean. However, there is potential, particularly in Zanzibar where seaweed aquaculture is widely practiced and may serve as a useful guide for establishing a comparable marine trade.

A number of factors must be considered in establishing successful sponge aquaculture. As suggested by numerous studies, final sponge survival must be ≥90% and explants should at least double in size every year for sponge culture to be commercially viable (Verdenal and Vacelet 1990). The economic viability of sponge aquaculture depends on the cost of production, harvest, amount produced, and market price. Prices vary according to shape, quality, species, and size, with the wholesale price increasing rapidly as size increases (Hawes and Oengpepa, Shang 1991). Major sponge markets are located in developed countries, including France, the United States, Japan, and Italy (Shang 1991).

1.4 Introducing sponge aquaculture to Zanzibar

An NGO called *Marine Cultures* is currently exploring the possibility for sponge aquaculture in the village of Jambiani, located on the east coast of Unguja Island. Based in Zurich, Switzerland, *Marine Cultures* has been registered with the Zurich Cantonal Commercial Registry since 2008. A small branch of the organization was registered with the Zanzibar Revolutionary Government on March 30, 2009 by Christian Vaterlaus. Once registration was granted, Vaterlaus met with two area shehas (leaders) and local fisherman to obtain permission to use the marine resources of the Jambiani lagoon. After receiving approval, a series of educational presentations were given, the first for the Fishermen Committee of Jambiani, and the second two for the general fishermen community. The meeting covered fundamental aspects of *Marine Culture's* sponge farming research and general aquaculture benefits. A majority of the 30 to 40 fishermen in attendance had no previous knowledge of sponges. Many were also fearful of the environmental sustainability focus of the organization, perceiving "preservation" as prohibition from utilizing marine resources and supporting their families. However, once it was conveyed that this "preservation" was based on sustainable, not restrictive harvesting, the fishermen expressed excitement about the possibility of another source of income.

Currently, there is one main sponge farming test site in the Jambiani lagoon at a depth ranging from 4.5 to 9 meters (m) due to tidal variation. Accessible through SCUBA, it is a 20 m by 8 m rectangular plot with six buoys hanging about 3 m above the seabed. There are currently eleven lanterns, or mesh baskets, and five mesh frames that hang vertically in the water column approximately 1 m above the seabed to minimize disturbance from benthic organisms and boat traffic. While the project is still in early research stages, *Marine Cultures* has already succeeded in bolstering the village economy by supporting a number of local artisans; all of the bags, baskets, ropes, and nets used for farming research are made or sold locally. Additionally, all transportation is provided through local dive centers or fishing boats. *Marine Cultures* is also in collaboration with a number of local organizations including Jambiani Tourism Training Institute, IMS, and JAMABECO[1].

Through surveying local reefs for commercially viable sponge species and testing sponge farming methods, the goal of *Marine Cultures* is to introduce sponge aquaculture to Zanzibar, specifically within the village of Jambiani. Seaweed farming is the only existing aquaculture infrastructure in the area; however, due to buyer monopolies and a relatively low global market price, it cannot generate enough income to satisfy the needs of local families. Sponge aquaculture may be able to fulfill this financial need. If research is successful, *Marine Cultures* plans to train local people to farm sponges, microfinance individual startup costs, and develop a fair trade business model. Nonetheless, local accessibility to the main farm is relatively low due to the need for SCUBA certification and swimming skills, both of which are impractical for village residents. If sponge aquaculture is ever to be adopted as a widespread profession in

[1] Institute of Marine Science, University of Dar es Salaam; Jambiani Marine and Beach Conservation

Jambiani, determining successful shallow farming methods, accessible through walking or snorkeling, for the region is of the utmost importance.

1.5 Study aims

The aim of this study is to determine the feasibility of shallow sponge farming in the village of Jambiani through (1) constructing a shallow sponge test farm, (2) determining regionally-appropriate farming methods, (3) performing surveys to investigate the commercial potential of natural sponge populations within the lagoon, and (4) assessing local awareness and perceptions of aquaculture. Shallow sponge farming is a largely unexplored practice. Most sponge aquaculture trials have taken place in deeper water where sponges can be cultured throughout the water column, receiving greater water flow, and food availability (Duckworth 2009). Shallow, intertidal conditions will challenge the adaptability of the transplanted sponges, as the environmental factors are continuously fluctuating. It is expected that individuals that are not heavily manipulated or cut during transplantation into the farm will be able to direct sufficient energy towards filter feeding and ultimately survive.

2. Study Area

2.1 Study Site

This study was conducted in Jambiani, a village spanning between seven to ten kilometers along the southern east coast of Unguja, with a population of about 6,000 people. It is currently and historically supported largely by marine-based trades, including fishing, seaweed farming, octopus hunting, coconut rope making, and shell collecting. All of these activities occur within a coastal lagoon that stretches roughly three miles into the Western Indian Ocean. *Marine Cultures* has one main sponge farm test site located in the lagoon at S 06° 18.73 E 039° 33.531. The newly constructed shallow farm site is positioned at S 06° 19.199 E 039° 33.205 (Fig. 2).

2.2 Collection Sites

All sponges used in this study were partially harvested from naturally occurring specimen within the Zanzibar archipelago by either Christian Vaterlaus or Okala between July 2010 and March 2011, leaving at least one third of the sponge behind to regrow. Collection sites include Bawe Island, Bweju, Pungume Island, and outer reefs of the Jambiani lagoon at depths ranging from 4 to 20 m. After harvesting, all sponge cuttings were placed into the vertical lantern system of the main farm, from which explants were selected in November 2011 to be transferred to the shallow farm. Three sponge species were harvested using the same sustainable method within the lagoon at a depth of 1 to 5 m and directly transplanted into the shallow farm.

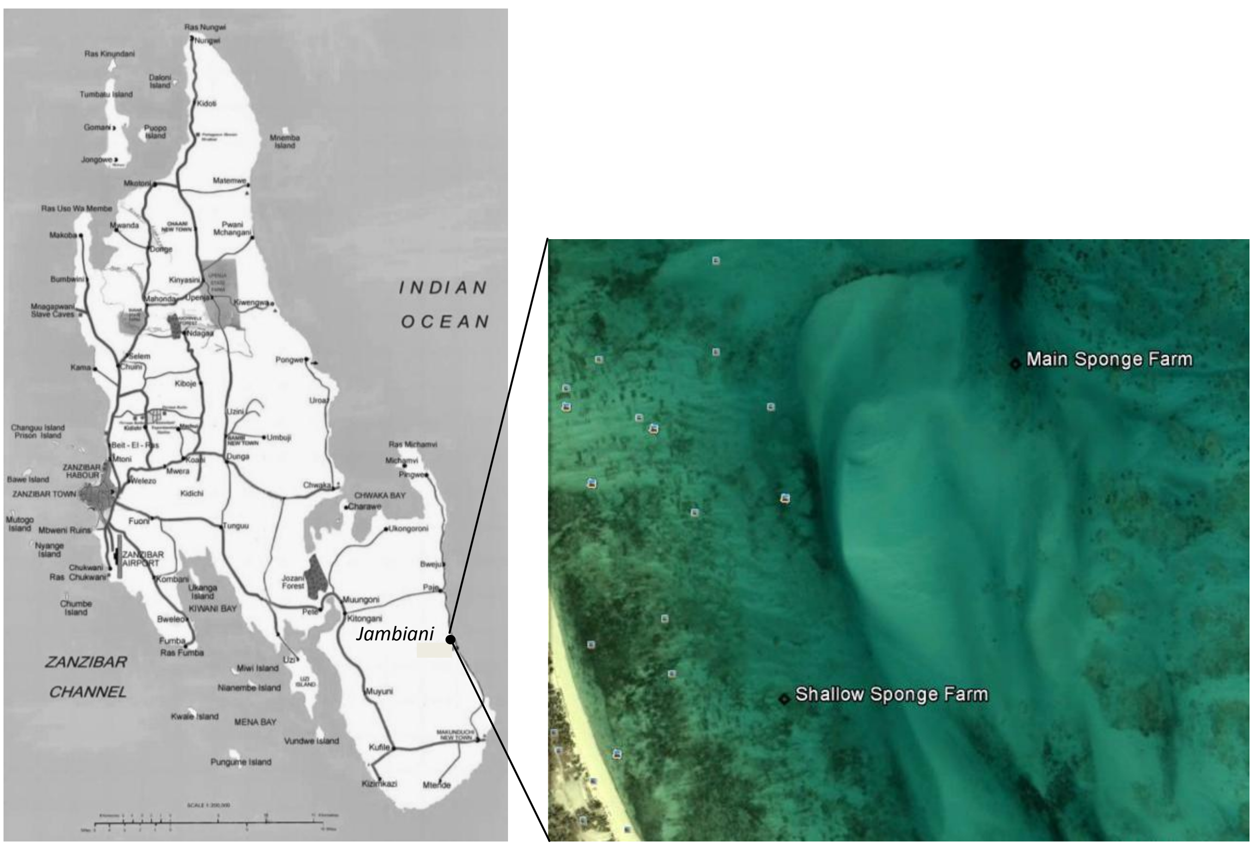

Fig. 2. Map of Unguja Island and the Jambiani lagoon, showing the main and shallow sponge farms.

3. Methodology

3.1 Constructing a shallow test farm

A shallow farming test site was re-constructed from a preliminary structure assembled by Okala in January 2011. This initial farm held 34 explants and was unmonitored throughout the course of the year. In October 2011, the site was revisited and all construction materials were replaced. A horizontal rope system was erected, forming a 6 m by 6 m suspended underwater grid. Cement cylinders were used to anchor the corners and circular buoys were fixed to the center of each side; the site was marked by three plastic buoys visible at low tide. Initial explants were transferred to the improved farming structure (Fig. 3). Lacking proper taxonomic identification, the species were differentiated by their external color and referred to as the *green-brown*, *brown*, and *orange* sponges.

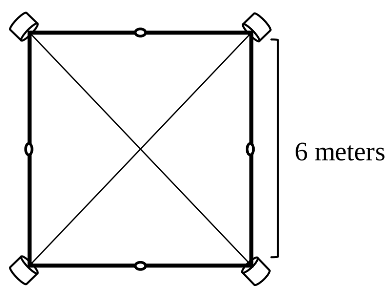

Fig. 3. Schematic drawing of the shallow farm structure erected October 2011. Top view.

In addition to these explants, 59 sponges from the main farm were transplanted to the shallow farm. All explants were transplanted using the threaded-line method (see section *3.2* for definition) and monitored through the duration of the study. Initial and final measurements were recorded for the preliminary explants, as these had been exposed to shallow environmental conditions for the longest period of time. Throughout the period of study, water depth, temperature, and salinity (using VEE GEE® STX-3 Refractometer) were measured daily at low tide and once during high tide to determine the range of environmental conditions experienced by explants within the shallow farm. One set of measurements was also obtained from the main sponge farm, from which most of the sponges were transplanted.

3.1.1 Pinacoderm re-growth trial

To assess the ability of explants to regenerate their pinacoderm within the shallow farm, three species were collected from the main farm and transplanted using the threaded-line method. Unidentified species used were the *purple*, *green*, and *red* sponges. Explants were cut in half using a very sharp knife and pinacoderm regeneration was monitored daily. Two replicates were used for each species. Photographs of initial cuts and the healing progress on subsequent days were taken to measure development.

3.2 Developing a suitable farming method

In this experiment, three general farming techniques were tested: cut-explant, threaded-line and anchor methods. For the cut-explant method, the sponge piece was cut halfway through using a sharp knife, allowing for rope to be pushed into the cut slot. A needle and thin cotton thread were then used to sew the newly cut ends of the explant together (Fig. 4A). Within several weeks, the thread would dissolve, leaving enough time for the cut sides to rejoin. For the threaded-line method, a long metal needle was used to thread a piece of string through the tissue of the explant. This string was then tied around the main horizontal rope, allowing the explant to hang (Fig. 4B). For the anchor method, the explant was threaded as those in the threaded-line method, then tied attached to a cement block using another rope (Fig. 4C). Sponges were kept underwater at all times.

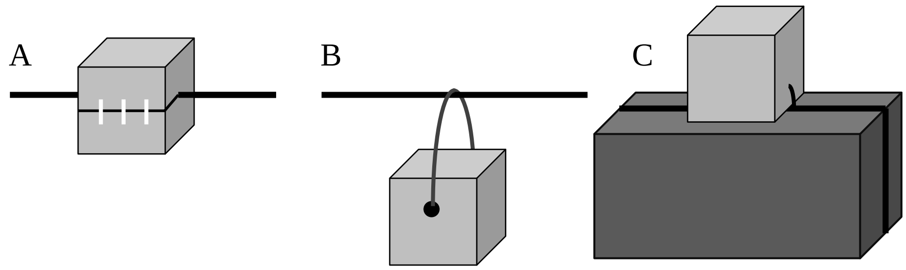

Fig. 4. Schematic diagram of the three farming methods: A. Cut-explant method (cotton stitching shown in white); B. Threaded-line method; C. Anchor method.

For both the cut-explant and threaded-line methods, explants were transplanted onto the main horizontal rope system. Individuals farmed within the cut-explant method were suspended 15 to 22 centimeters (cm) off the substrate, while those within the threaded-line method were suspended 38 to 53 cm. Anchored explants were raised 10 to 14 cm from the substrate (the height of the cement blocks). For all methods, explants were placed approximately 10 cm a part; spacing within the anchor method was slightly less.

3.2.1 Determining optimal initial explant size

Within each farming method, three initial explant sizes (mean±SE) were experimentally farmed: small, 35.3±2.8cm^3; medium, 107.2±7.1cm^3; and large, 230.7±21.1cm^3. Two sponge species were used in the testing of explant size and farming method variation and were chosen based on their abundance within the main farm. The species were designated as the *red* and *white* sponges, based on the color of their choanosomal tissues. Each farming method contained each explant size for both the red and white sponge species. Three replicates were used in each treatment group; in total 54 explants were cultured. The experiment ran for 20 days. Length, width, and height of each explant were measured with measuring tape at the start and completion of the treatments; multiplying these measurements calculated explant volume. Photographs were also obtained at the start and completion of treatment to visually assess and help quantify changes in individual fitness over the course of the experiment. A digital camera (Canon Powershot G10, OLYMPUS Tough TG-810) was used for all photographs.

3.3 Data analysis

One-way Analysis of Variance (ANOVA) was used to test whether growth or survival varied significantly between farming method or initial explant size. Because initial explant sizes varied, percent growth was used to assess differences in growth rate using the formula:

% growth = (final/initial) x 100. Percent tissue loss was estimated to quantify survival, as the experiment could not run long enough for complete explant mortality to occur. In attempt to standardize these estimations, explants with dead tissue covering the entire surface area were said to have 5% tissue loss, those not covered completely in dead tissue were diagnosed as having 0-4% tissue loss, and those with their entire surface area and other internal sections of dead tissue received a value greater than 5%. To meet the assumptions of ANOVA, the growth and survival data were log and arcsine transformed, respectively (Zar 1999).

3.4 Sponge population surveys

Surveys were conducted using opportunistic observation within the intertidal (littoral) zone of the lagoon through walking and snorkeling at low tide. Transects were determined to be inappropriate due to the presumably wide, sparse distribution of sponges throughout the littoral and sublittoral zones. Sponge morphology, approximate size, external color, texture, and habitat were noted for each individual found; internal color was noted for harvested individuals. Water depth of the habitat was also measured. Species which could be commercially viable (those with a compressible, resilient texture) were partially harvested, leaving at least one third of the biomass remaining on the substrate to allow for regeneration. Sponge cuttings were transplanted into the shallow farm using the threaded-line method to test culturing potential.

3.5 Aquaculture awareness assessment

A series of formal interviews were conducted with fifteen local fishermen, as well as with the Chairman of the Fishermen Committee of Jambiani, to gauge the awareness of aquaculture, specifically sponge farming, and of *Marine Cultures* within the fishing community. All fishermen informants were male and lived in the Jambiani village. General questions inquired into each fisherman's attendance of *Marine Cultures'* educational meeting, knowledge of aquaculture and its perceived benefits for the village of Jambiani (Appendix A-B). These questions were developed from the PowerPoint presentation used to educate the fishermen in attendance of the meeting. A translator was used sparingly to aid in interpretation of ambiguous or regionally-specific phrases.

4. Results

4.1 Physical conditions

Water conditions in the shallow farm were recorded daily at low tide throughout the period of study, excluding two days. Temperature was only able to be measured for twelve of the twenty days due to equipment unavailability. All ranges in environmental conditions include the set of measurements taken during high tide; averages include only low tide measurements. Water temperature ranged from 28-31°C, with an average temperature of 29.625°C. Depth ranged from 0.823-3.31 m and averaged approximately 1.22 m. Salinity ranged from 20-36‰, with an average of 30.825‰ at low tide. At the main sponge farm, water temperature was 27°C, depth at high tide was 5-6 m, and salinity was 36‰.

4.2 Constructing a shallow test farm

Of the explants transplanted from the preliminary shallow farm, five of the 34 explants were lost between October and December. Over the period of study, the average explant growth was 134.14% ± 65.037 of initial explant size. Explant health was also assessed visually. All cut surfaces had fully healed from the transplantation in October and biofouling, undesirable accumulation of algae and microorganisms, initially observed had generally decreased by December. There was, however, some species variation; the *green-brown* explants had little to no biofouling and the *brown* explants had an increased amount of biofouling. Biofouling levels on the *orange* explant did not appear to have changed. Three of the explants had isolated, superficial tissue death. The 59 other sponge cuttings transplanted approximately half way through the study did not appear to have any major changes in health, yet five explants went missing.

4.2.1 Pinacoderm re-growth trial

The *purple* sponge had fully regenerated its pinacoderm in five days, while it took eleven days for the *green* sponge to heal completely. The *red* sponge, however, did not heal within the time of the study; instead, the cut tissue began to die. Moderate biofouling also occurred.

4.3 Developing a suitable farming method

A substantial amount of biofouling occurred within each treatment, beginning on the rope structures and progressing to the sponge cutting. Individuals of the *white* species generally had a higher occurrence of biofouling than those of the *red* species. Hermit crabs were also very prevalent on sponges within the anchor method, with each explant having at least two crabs burrowed into or resting beneath the sponge body. Explant spacing was retained for the threaded-line and anchor methods, but some individuals within the cut-explant method tended to cluster together on the rope. Cut and threaded surfaces of individuals receiving the cut-explant treatment did not heal; the thread also did not dissolve by the completion of the study (Fig. 6). Only one explant was lost during the duration of treatment; it was a small sized cutting of the *red* species within the threaded-line treatment. This individual was not included in the data analyses.

Final survival, in terms of percent tissue loss, varied significantly among the farming methods for both the *red* and *white* species (p=0.0006) and (p=0.044), respectively. Percent tissue loss was the highest within the cut-explant method, with the *red* explants having an average tissue loss of approximately 8.44% and *white* explants having that of 7.33% (Fig. 5). Final growth did not differ significantly among the farming treatments for the *red* species (p=0.072). For the *white* species, final growth did differ significantly (p=0.017). Growth was greatest for individuals farmed within the cut-explant and threaded-line treatments, with explants growing to approximately 140-150% of their initial size (Fig. 5).

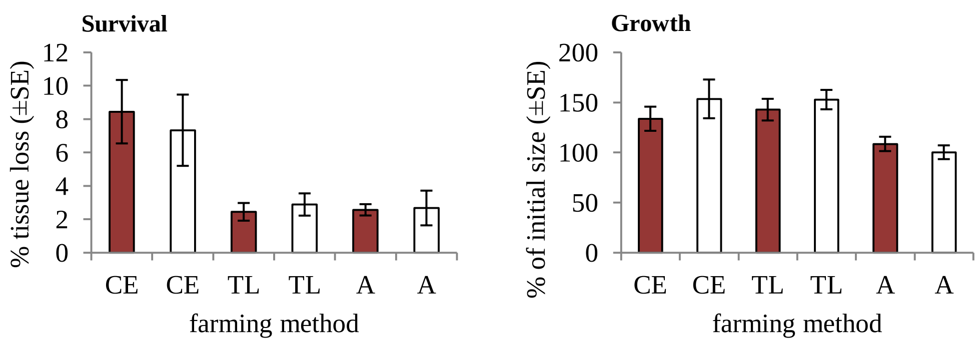

Fig. 5. Survival and growth of the *red* and *white* species farmed for 20 days in three farming treatments: CE = cut-explant, TL = threaded-line, A = anchor method. Error bars represent standard error of the mean. Dark bars denote the *red* species and light bars denote the *white* species.

4.3.2 Importance of initial explant size

Final survival was significantly different among explant sizes within the cut-explant treatment for the *red* species (p=0.019), with the average percent tissue loss being approximately 10% higher for the small explants than for the medium and large. There was no significant difference in survival between explant sizes for any other treatment (p>0.05). As for final growth, only *red* explants in the anchor treatment showed a significant difference in growth among explant sizes (p=0.031). Within this group, the large explants had the highest average growth of 116.76% of initial size, while the medium explants had the smallest average growth of 95.86% of initial size. All other treatment groups exhibited no significant difference in growth (p>0.05).

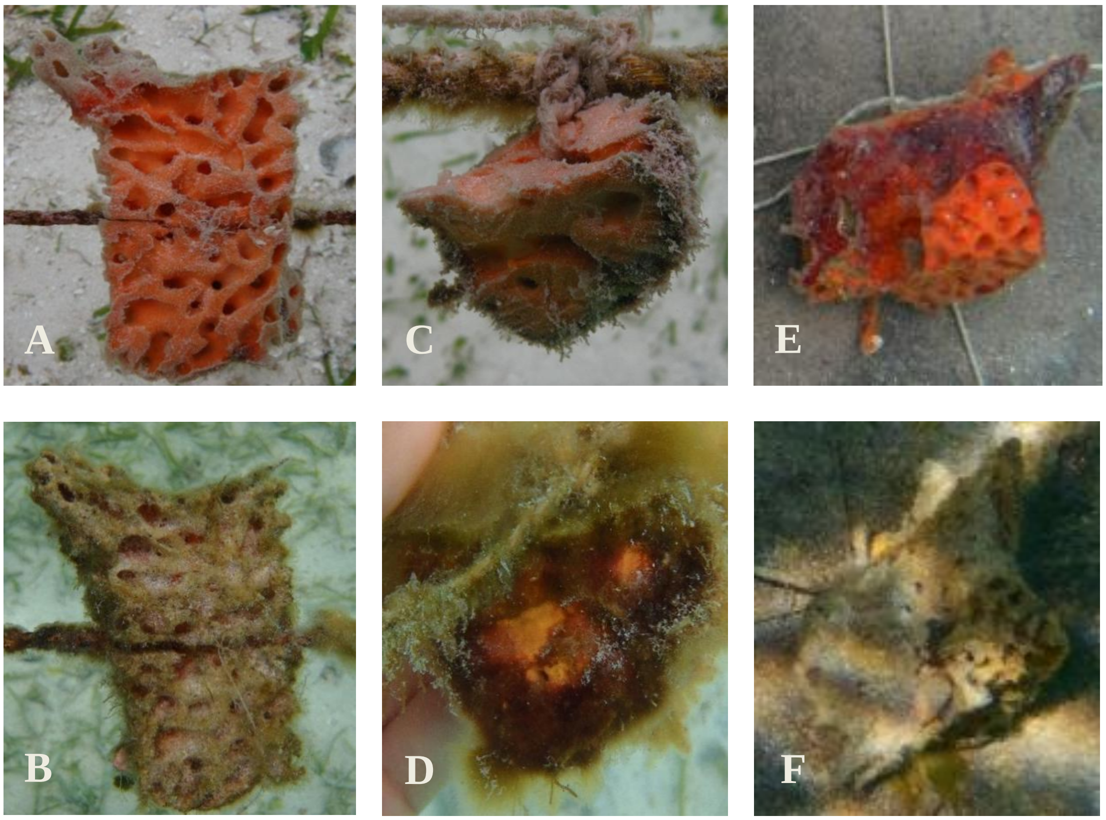

Fig. 6. *In situ* pictures of explants on the initial transplant day and on the final day (t=20) of farming treatment . A-B. *Red* species in cut-explant method of large initial size. C-D. *White* species in threaded-line method of small initial size. E-F. *Red* species in anchor method of large initial size.

4.4 Sponge populations within the lagoon

After performing a series of surveys in the lagoon through opportunistic observation, approximately 19 species were found inhabiting the intertidal zone (Table A1). Sponges were more dominant within the shallow regions accessible through walking and wading; no sponges were found through snorkeling in the deeper regions of the survey area, bordering the sublittoral zone. Three of the species encountered were partially harvested and transplanted into the shallow farm because they exhibited characteristics with commercial potential, namely a semi-spherical or mounding shape, and soft, compressible texture (Table 1). Only one cutting was harvested from each species, with the exception of the *pale green-gray* sponge, from which two cuttings from separated individuals were taken. Internal color was noted only for harvested individuals so as not to aimlessly cut the sponge.

Table 1. List of unidentified sponge species partially harvested because of commercial potential. Individuals were found conducting intertidal surveys using opportunistic observation. All data was collected from November 19-29, 2011 in the Jambiani lagoon between approximately S 06°18.879 E 039°32.814 and S 06°20.156 E 039°33.262.

External color	Internal color	Morphology	Locality
purple to gray-brown	purple, brown core	branching, massive, boring, ficiform, repent; apparent oscules; surface smooth, compressible light purple to brown exudate; one individual covered with green algal growth; 73.5-4,950 cm^3 volume	coral rock, sandy substrate; seagrass beds; 0.5-20 cm depth; some individuals partially exposed (to air)
pale green-gray	light brown to cream	branching, digitate; large oscules; surface papillate, compressible, velvety; green exudate; 65,360-66,000 cm^3 volume	coral rock; 13-42 cm depth; some individuals partially exposed
very dark brown light brown vein-like projections	light cream, veins run throughout tissue	ovate, mounding; surface rugose, verrucose[2], firm, slightly compressible; l320-3920 cm^3 volume	coral rock; 10-38 cm depth

4.5 Awareness of local fishermen

A series of meetings consisting of a PowerPoint presentation were conducted by *Marine Cultures* to address the basic principles of aquaculture, specifically that it is the cultivation of sea products, such as seaweed, sponges, shells, and fish, and involves restocking with “seeds” to allow for later harvest, much like land agriculture. It also conveyed the importance of providing an alternative source of income to the village, a supplement much needed due to the current unsustainable demand placed on the lagoon to provide fish and other marine resources.

[2] *ficiform*, meaning fig-shaped; *repent*, meaning growing along or above the substrate and attaching to the surface at intervals; *papillate*, meaning surface bearing papillae; *rugose*, meaning rough and ridged; and *verrucose*, meaning warty (Boury-Esnault and Rützler 1997)

Additionally, the general goals of *Marine Cultures* were communicated: to reduce poverty for fishermen and people of the community and to instate sustainable aquafarming.

Fifteen fishermen were interviewed to determine the level of information retained from the meeting as well as to gauge their perceptions of aquaculture. Fishing is a major livelihood for people of the village. On the northern side of Jambiani, fishermen use hand lines and “dema” (basket) traps, both of which comply with government fishing regulations. Conversely, the southern side is not in compliance, using drag nets and spear fishing to harvest their catch. This has resulted in pressure from the Department of Fisheries and caused stratification of the fishing community, with the south holding resentment towards the government for infringing upon their livelihoods and the north being mostly indifferent. While *Marine Cultures* is not affiliated with the Zanzibar government, interviews were limited to the northern side of the village to avoid any ill-aimed retaliation on the NGO.

Of the fishermen interviewed, only two had not attended a meeting. The number of years spent working as a fisherman ranged from 1 to 35 years. When asked to explain or give examples of aquaculture, approximately 47% of the interviewees likened aquaculture to seaweed farming, while 40% gave other examples of aquaculture, including pearl, sponge, coral, and fish farming. One fisherman even drew a picture in the sand of two circles connected by a line to represent sponges hanging from rope. The remaining 13% could not elaborate upon or give any examples of aquaculture; one within this group had not attended a meeting. While general sponge ecology was not covered in the presentation, basic knowledge of sponges was investigated. 40% of interviewees were able to recognize the word “spongi” (Kiswahili name for sponges), but could not elaborate or synthesize any information about them. Approximately 53% could recognize the name and were able to expand upon the subject, with four interviewees using hand gestures to make the general spherical shape of a sponge and three stating that sponges lived in the ocean. Only 7% could not recognize the word.

Aside from one of the fishermen who did not attend the meeting and had no prior knowledge of aquaculture, all others interviewed conveyed that aquaculture, specifically sponge farming, would be beneficial to Jambiani; however, their reasons as to why it would be beneficial differed slightly. The majority, roughly 79%, replied that aquaculture would be beneficial because it could provide money and employment to fishermen and support local families. The other 21% responded with more varied answers. One stated that the practice would be beneficial only if it could be executed easily by local people, expressing concern that the main sponge farm was too deep for many fishermen to use. The other two attested to the environmental benefits of aquaculture, offering that “seeds will be kept for next time” and the farm will “provide a house for the fish”.

All but two of the fishermen interviewed knew at least the general location of *Marine Cultures’* main sponge farm; some pointed to a spot on the horizon, while others replied that it was in “Bombweni”, a local word meaning the deep part of the lagoon. Both fishermen who had no knowledge of its location had attended one of the meetings. Despite some lack of familiarity with the aquaculture, every fisherman expressed an interest in trying sponge farming in the future. Aside from one fisherman who had not attended the meeting, 36% said that they had discussed the meeting with friends and family, 57% had conversed with other fishermen and/or seaweed farmers, and 7% had not disclosed any information. The general reasoning behind not discussing *Marine Cultures* was said to be that they were waiting for aquaculture to be ready for utilization by the people of Jambiani.

The Chairman of the Fishermen Committee of Jambiani was also interviewed to gain a different perspective of the fishing community's knowledge and perceptions. As chairman, his role is to organize fishing activities within the lagoon, specifically through generating teamwork among fishermen and spreading awareness of proper fishing techniques that follow government regulations and work best in the lagoon. He frequently communicates with the Department of Fisheries; however, conveying government policy is not solely his responsibility, but is shared by all members of the committee. Having attended two of the three meetings held by *Marine Cultures*, he remembers the general concept behind sponge aquaculture and the benefits that aquaculture can have on the economy of a village. In particular, he recounted that sponges fetch a high price in the global market. He believes that sponge aquaculture could be beneficial for Jambiani if the people are able to "involve themselves" and easily take part in farming practices. In the beginning only a few people will want to participate, but if the aquaculture research is seen to be successful more people will be willing to try it. The chairman encouraged other fishermen to attend the meeting and deemed that overall, the community attitude towards *Marine Cultures* is positive. Nonetheless, he admitted that it is difficult for fishermen to have any "long vision", or to see any projected benefit that sponge aquaculture may have in Jambiani. As of now, the fishermen have not kept much of the meeting in mind. When asked about the current divide between the north and south regions of the village, he did not allude to any stratification of attitude or perception within the fishing community. He also seemed assured that fishermen do not view *Marine Cultures* as part of the government (Chairman 2011).

5. Discussion

5.1 Shallow farm feasibility

As physical conditions of farming sites greatly influence sponge culturing success, an evaluation of measured water conditions is a logical first step in determining the feasibility of shallow sponge farming in the Jambiani lagoon. The physical conditions measured demonstrate the highly variable environment of the shallow farming site and present a demanding, continuously fluctuating habitat for sponges to inhabit. Water temperature ranged from 28-31°C within the month of November and temperatures will likely rise above 31°C during the hot, dry season from December to March. The measured temperatures were consistently 1-4°C higher than in the main farm. Temperature shocks are not usually well-tolerated by sponges, as most are accustomed to only subtle thermal change and are not adapted to more rapid changes, particularly with rises in temperature (Osinga 1999). Water depth varied by approximately 2.5 m between daily high and low tides and was roughly 4 m lower than the main farm at low tide. This shallow depth increases light intensity in the farm, resulting in an increase of biofouling, ultraviolet radiation, and wave shock, all of which can reduce sponge fitness (Duckworth 2009). Salinity ranged from 20-36‰, oscillating between brackish and saline water. While very little is known about how salinity levels affect sponges, it is predicted that sponges are sensitive to low salinities as it affects osmoregulation, the organism’s ability to maintain a balanced water content (Osinga et al 1999).

While the brevity of the study prevents assessment of the long-term impact of these abiotic factors on the transplanted sponges, a few short-term effects were able to be evaluated. The general decrease in biofouling among the preliminary transplanted sponges suggests gradual acclimatization to physical conditions. Biofouling commonly consists of microalgae and ascidian species that can reduce water flow and food availability for the sponge (Duckworth and Wolff 2007). Despite its negative impact, it is suspected that biofouling is a symptom, not a direct cause of physiological stress of explants (Kelly et al 2004). Therefore, it is likely that the explants were initially stressed upon transplantation, accumulating biological fouling agents, and then were able to adjust to the conditions, resulting in a disappearance of biofouling. Some herbivorous fish species were seen feeding on fouling agents; however, this did not greatly affect the amount of fouling present.

Cut surfaces of initial transplants had also fully healed, further indicating explant recovery. The disappearance of five of the 34 initial explants is most likely due to the explants being ripped from the line by strong current. Of the 59 other explants transplanted from the main farm, five were also torn from the line; these five most likely had fragile tissue or non-spherical morphology that was not conducive to the threaded-line method. The variability of pinacoderm regeneration time between the three species demonstrates the variability of fitness and adaptability among various sponge species. This healing ability is thought to be a survival mechanism against predation, grazing, disease, and storm damage (Duckworth and Battershill 2003).

The shallow sponge farming test site will remain in the lagoon and continue to be monitored by *Marine Cultures.* Once enough research has been conducted to implement sponge aquaculture as a widespread practice in Jambiani, the site will be used as an educational model for teaching local people sponge farming techniques. In addition, the farm may serve as an ecotourism site.

5.2 Farming method effectiveness

The farming response of the *red* and *white* species varied greatly between treatments, demonstrating the importance of developing a regionally-appropriate farming method. Survival was lowest overall within the cut-explant treatment for both species, with average percent tissue loss ranging from approximately 7.3-8.4%, over 4.5% higher than in the threaded-line and anchor treatments. One small explant of the *white* species within the threaded-line treatment group was lost over the course of the experiment. This loss was most likely caused by strong current tearing the explant, which may have had compromised tissue from the threading process.

While survival differed significantly for both species among treatments, growth differed significantly only among treatments for the *white* species, with growth being greatest within the threaded-line and cut-explant treatments and least within the anchor treatment. These results are partially supported by a sponge farming study conducted in tropical Australia (Duckworth et al 2007) in which it was found that farming methods requiring additional tissue damage, such as threading or cutting, resulted in low survival and growth. Inducing the most physical stress on explant individuals, it is unexpected that the cut-explant method would exhibit one of the higher growth rates of the three farming treatments. Lesser growth within the anchor method may be due to the fact that it received less water flow resting on the seabed. Explants within this method also collected a lot of loose sediment from their proximity to the sandy substrate; this may have inhibited water from being efficiently pumped. It is also possible that the anchored explants experienced greater predation from microorganisms and hermit crabs than the other two treatments.

Overall, however, the cut-explant method appeared to be the least effective farming treatment. In addition to requiring a cut deep into the choanosomal layer of the sponge, individuals had to be sewn back together, a tedious, time-consuming process in which harmful squeezing of the sponge was unavoidable.

5.2.1 Importance of initial explant size

Initial size of the explants seemed to have less of an effect on individual growth and survival than farming treatment. Only the *red* species showed a significant difference in survival within the cut-explant, with small explant survival being the lowest; and significant difference in growth within the anchor method, with large explants showing the highest percent growth. Despite the somewhat minimal effect of explant size, these isolated results follow trends observed in previous studies. It has been found that for certain species of sponges, growth and survival are lowest for small explants. Having a larger ratio of surface area to volume and smaller tissue reserves than larger cuttings, small explants must expend comparatively more energy to regenerate pinacodermal tissue and reorganize their internal canal system. This diverts energy away from somatic growth, increasing stress and, as a result, mortality (Duckworth 2009, Duckworth and Wolff 2007). Some species, however, have comparable growth and survival between small and large cuttings, helping to explain the lack of effect that explant size had within the *white* species treatment groups.

Methods for measuring survival and growth were adequate within the context of this study, but could be improved upon for future research. Lacking any instruments to quantify tissue loss, percentages had to be visually assessed. Furthermore, the growth percentages may be slightly flawed due to the relatively imprecise method of measuring. Ideally, initial and final wet weights would have been taken of each individual to assess growth; however, limited equipment required measurements to be taken using a measuring tape. As the explants were irregularly shaped, measuring at the same place on the sponge body for both initial and final measurements was problematic. Biofouling present on some individuals also made it difficult to take measurements solely of sponge tissue, not algal growth. This may have inflated some of the growth measurements. Nonetheless, these values do manage provide a numerical snapshot of how explants from the *red* and *white* species responded to abiotic conditions within the shallow sponge farm over a period of 20 days.

5.3 Commercial promise of sponge populations

Through opportunistic observation, 19 unidentified sponge species were found. Interestingly, all of the sponges were found within the shallows of the intertidal zone in 0.2-28 cm depth on either coral rock or sandy substrate among the seagrass beds (Appendix C). Furthermore, no sponges were found in the deeper regions of the survey area. This could be due to the difference in habitable substrate, as coral rock was prominent in the shallower region, while the deeper region was mainly sand. 13 of the 19 sponges found were rooted to coral rock through boring or encrusting; sponges may not be able to attach themselves to sandy substrate. The locality in which all species were found suggests that they are highly adapted to fluctuating environmental conditions. Intertidal zones can vary from being highly saline to nearly fresh with rain. Organisms may be dislodged from wave action and, due to very shallow water depth, experience high thermal stress. Sponges hardy enough to inhabit a region with such harsh conditions could be ideal for shallow sponge farming, if proper commercial qualities are possessed. Three types of sponges found in the intertidal zone were transplanted into the sponge farm. Individual growth and survival will have to be monitored over the next few months to assess culture potential for each species. While not harvested, the *light green-yellow* and *bright orange* sponge varieties, having compressible textures and semi-spherical shapes, may also have potential for use in the commercial sponge market.

The sponges found are in no way an inclusive list of all sponge species of the Jambiani lagoon. Characterization of encountered sponges into 19 possible species may be an over- or underestimate of the actual number of species found, for field identification of sponges is incredibly difficult, ridden with subtle differences in character and intraspecies plasticity (Hooper et al 2002). Sorting sponges into different species was very difficult and rather subjective, especially without a comprehensive taxonomic identification guide for the Western Indian Ocean. Furthermore, there is currently a divide in information about deep water and shallow water sponges; while shallow water sponges richer, they are much more poorly understood (Barnes and Bell 2002).

5.4 Awareness and perceptions of local fishermen

After interviewing the Chairman of the Fishermen Committee of Jambiani and local fishermen, the supposed divide between the north and south parts of the village seemed slightly blurred. Fishing techniques were regionally specific, but the stratification seemed to be limited to that, for no difference in fishermen attitudes was perceived from the interview with the chairman. He also seemed certain that no fishermen viewed *Marine Cultures* as part of the government. Nevertheless, interviews were conducted only with fishermen following government regulations to treat the current, if unseen, tension among the fishing community with sensitivity. Ultimately, the sponge aquaculture initiative is for the village; alienating any residents would negate any progress within regional sponge farming research.

Of the fishermen who were able to be interviewed, it was apparent that only simple information was retained from the educational meetings held by *Marine Cultures*. As a tangible representation of aquaculture, seaweed farming was the main way in which fishermen were able to conceptualize sponge farming, an abstract idea by comparison. Some other examples, such as pearl and fish farming were given, but the purpose of these practices did not seem to translate. A majority of the fishermen reasoned that the benefits of aquaculture were monetary, allowing for a profit to be earned. Only two fishermen described the environmental benefits of aquaculture, as a sustainable process that can provide micro-habitats for other organisms. Knowledge of sponges was minimal, although this is understandable, as it was not intensively covered within the meeting. Communication between fishermen about *Marine Cultures'* aquaculture initiative seemed to be a common occurrence and also very effective in propagating information. In certain cases, these informal conversations were more effective than the structured meetings; for instance, the two fishermen who did not attend the meeting knew where the main sponge farm was located, while two fishermen who had attended the meeting did not.

Considering the responses of the fishermen, the meetings seemed to be successful in at least generating a basic awareness of *Marine Cultures* and aquaculture in general. Much of the information presented in the meeting was not retained by the fishermen in attendance. However, this is to be expected given the infancy of sponge aquaculture research within the region, as well as the difficulty of explaining future projections, not tangible practices, to local people. Repetition of information and time will help to counteract these initial obstacles.

In general, the fishermen interviewed seemed enthusiastic about trying sponge farming in the future. Whether this enthusiasm may be attributed to financial or environmental benefit is uncertain; however, at this time the motives of interest are irrelevant. Any interest is a positive step for eventual integration of sponge farming into the community.

6. Conclusion

In the course of this multi-faceted study, the feasibility of shallow sponge farming in Jambiani was assessed. Despite the highly variable physical conditions measured within the shallow farm, some of the transplanted sponges appeared to adapt to the change in habitat. This is suggested by the loss of biofouling, an indicator of physiological stress, within the initial sponge transplants. Through testing three different farming methods, the cut-explant method was found to be the least successful farming treatment, as both the *red* and *white* species experienced the lowest survival in this method. Percent growth was less illustrative of farming effects on explants. Only the *white* species showed significant difference in growth between treatments, with growth being lowest in the anchor method. Initial explant size did not seem to have a large influence on individual fitness among treatments; however, the *red* species did have significantly lower survival among small explants in the cut-explant method and significantly higher growth among large explants farmed in the anchor method. These results agree with previous studies that small explants have lower fitness. Through conducting a series of surveys within the lagoon, sponge populations with un-tapped commercial potential were found, enhancing the sustainable aspect of local sponge aquaculture. Furthermore, interviews with local fishermen indicated that despite a basic and incomplete knowledge of aquaculture practice, the fishing community has a positive perception of *Marine Cultures* and a unanimous enthusiasm to try sponge farming in the future. The summation of these findings yields a fairly definite answer to the study question. Shallow sponge farming is feasible within the village of Jambiani.

7. Limitations & Recommendations

The deficiency of taxonomic knowledge of sponges within the Western Indian Ocean and the lack of time to gather more conclusive data were limitations of this study. Further research and time are required to assess the long-term effects of different farming treatments and initial explant size on explant survival and growth. While equipment availability is limited within this region, measuring methods could be improved upon in repeat studies, such as taking wet weights of explants to measure growth, in order to increase accuracy of measurement data. It may also be interesting to test shallow farming in another site on Unguja Island to investigate the possibility of widespread sponge aquaculture in Zanzibar. In order to gain a more comprehensive inventory of the local sponge community and to exhaust the search for commercially viable sponge species within the region, more surveys should be conducted within the Jambiani lagoon and neighboring reefs. Sponge taxonomy in general is vastly underdeveloped within the Western Indian Ocean. Any efforts of species classification or the development of a sponge taxonomic guide would be extremely advantageous for continuing sponge aquaculture research in Zanzibar.

References

Barnes DKA, Bell JJ (2002) Coastal sponge communities of the West Indian Ocean: taxonomic affinities, richness and diversity. African Journal of Ecology 40: 337-349

Boury-Esnault N, Rützler K (1997) Thesaurus of Sponge Morphology. Smithsonian Contribution to Zoology, 596. Smithsonian Institution Press, Washington, D.C.

Celik I, Cirik S, Altinagac U, Ayaz A, Celik P, Tekesoglu H, Yilmaz H, and Oztekin A (2011) Growth performance of bath sponge (*Spongia officinalis* Linnaeus, 1759) farmed on suspended ropes in the Dardanelles (Turkey). Aquaculture Research 1-9

Chairman of Fishermen Committee of Jambiani. 2011. Interview on Knowledge and Perceptions of Aquaculture within the fishing community. Interviewed by Sarah Friday [in person]. Jambiani, Unguja

Diaz MC, Rützler K (2001) Sponges: An Essential Component of Caribbean Coral Reefs. Bulletin of Marine Science 69(2): 535-546

Duckworth AR (2009) Farming Sponges to Supply Bioactive Metabolites and Bath Sponges: A Review. Marine Biotechnology 11:669-679

Duckworth AR, Battershill C (2003) Sponge aquaculture for the production of biologically active metabolites: the influence of farming protocols and environment. Aquaculture 221:311-329

Duckworth AR, Wolff C (2007) Bath sponge aquaculture in Torres Strait, Australia: Effect of explant size, farming method and the environment on culture success. Aquaculture 271:188–195

Duckworth AR, Wolff C, Evans-Illidge E (2009) Farming Bath Sponges in Tropical Australia. World Aquaculture 20-22, 70

Duckworth AR, Wolff C, Evans-Illidge E (2007) Developing methods for commercially farming bath sponges in tropical Australia. Porifera Research: Biodiversity, Innovation and Sustainability 297-301

Hawes I, Oengpepa CP. Final Report for Mini-project MS0506: Village Scale Sponge Aquaculture in the Solomon Islands 1-28

Hooper JNA, Van Soest RWM (2002) Systema Porifera: a guide to the classification of sponges. Kluwer Academic/Plenum Publishers, New York, NY

Hooper JNA, Van Soest RWM, Debrenne F (2002) Phylum Porifera Grant, 1836. Systema Porifera: a guide to the classification of sponges. Kluwer Academic/Plenum Publishers, New York, NY

Kelly M, Handley S, Page M, Butterfield P, Hartill B, Kelly S (2004) Aquaculture trials of the New Zealand bath-sponge *Spongia (Heterofibria) manipulatus* using lanterns. New Zealand Journal of Marine and Freshwater Research 38: 231–241

Marshall E. Sponges on Chumbe Island. SIT Spring 2009

Osinga R, Tramper J, Wijffels RH (1999) Cultivation of Marine Sponges. Marine Biotechnology 1:509-532

Richmond MD (ed.) (2011) A Field Guide to the Seashores of Eastern Africa and the Western Indian Ocean Islands. Sida/WIOMSA

Shang YC (1991) Sponge farming in Micronesia: some economic aspects. INFOFISH International 2(91): 42-44

Verdenal B, Vacelet J (1990) Sponge culture on vertical ropes in the Northwestern Mediterranean Sea. New Perspectives in Sponge Biology. Smithsonian Institution Press, Washington DC 416–424

Zar JH (1999) Biostatistical analysis. Prentice-Hall, New Jersey

Appendices

A. Sample Questionnaire for Fishermen Interviews
November 13-14, 2011

1. How many years have you been a fisherman?
2. How did you hear about *Marine Cultures*?
3. Did you attend the *Marine Cultures* meeting about aquaculture?
4. What can you tell me about aquaculture/what do you remember from the meeting?
5. What do you know about sponges?
6. Do you think that aquaculture in Jambiani is a good idea? Why do you think so?
7. Would you like to try aquaculture in the future?
8. Do you know where the sponge farm is located?
9. Have you talked with anyone about *Marine Cultures*/aquaculture?

B. Formal Interview Questions for Chairman of Fishermen Committee of Jambiani
November 21, 2011; 5:45-6:30pm

1. How long have you been a fisherman in Jambiani? How long have you been chairman of the Fishermen Committee of Jambiani?
2. What is your role in the fishing community as chairman of the committee?
3. Did you attend the educational meeting held by *Marine Cultures*?
4. What do you remember from the meeting or about aquaculture in general?
5. Do you think that sponge aquaculture is a good thing for the village of Jambiani? Why or why not?
6. Did you encourage other fishermen to attend the general meeting held by *Marine Cultures*?
7. How do you think the fishermen community perceives *Marine Cultures*?
    a. Is there a divide between those that follow local fishing regulations and those that do not follow them?
8. Do any fishermen view *Marine Cultures* as part of the government?

C. Table A1. List of unidentified sponge species. Individuals were found conducting intertidal surveys using opportunistic observation. All data was collected from November 19-29, 2011 in the Jambiani Lagoon between approximately S 06°18.879 E 039°32.814 and S 06°20.156 E 039°33.262.

External color	Morphology	Locality
light green-yellow	branching, mounding; apparent oscules; surface firm, slightly compressible; 125-1000 cm^3 volume	coral rock, sandy substrate, beds; 10-15 cm depth
burnt red	branching; surface firm, verrucose some individuals grew around seagrass blades; 1650 cm^3 volume	sandy substrate, seagrass beds; 3-7 cm depth; some individuals partially exposed
green-brown	arborescent, thin branching tubes; surface smooth, slightly compressible; 4000 cm^3 volume	sandy substrate, seagrass beds 20-26 cm depth
bright orange	mounding, ficiform; large oscula; surface verrucose, velvety, compressible; 72-324 cm^3 volume	coral rock, sandy substrate; 3-9 cm depth
black	encrusting, repent; surface smooth, slimy some individuals grew around seagrass blades; 69-108 cm^3 volume	coral rock; 17-21 cm depth
brown, reddish brown specular projections	mounding, massive, repent; large, clustered oscula; surface villose, slightly compressible; 36-1152 cm^3 volume	sandy substrate, seagrass beds; 4-16 cm depth
brown	erect strategy, branching, digitate; surface firm, not easily compressed; 1-24 cm^3 volume	sandy substrate, seagrass beds; 0.2-1 cm depth; every individual partially to fully exposed
light brown	digitate; apparent oscules; surface very firm, not compressible; shells incorporated into tissue; not well-rooted to substrate; 420 cm^3 volume	sandy substrate, seagrass beds; 19 cm depth
dark brown, light green superficial growth	mounding; surface muricate, compressible; 1050 cm^3 volume	sandy substrate, seagrass beds; 23 cm depth
dark brown-green to gray-green	branching, mounding, repent; large, clustered oscula; surface very compressible, not resilient, nearly limp; brown exudate; 70-1456 cm^3 volume	coral rock, sandy substrate, seagrass beds; 3-21 cm depth
blackish green top layer purple bottom layer	repent; top layer: clustered oscula, surface firm, bottom layer: surface compressible, fragile 14,472 cm^3 volume	coral rock; 4 cm depth
dark brown	encrusting; surface velvety, compressible 25-125 cm^3 volume	coral rock; 3-12 cm depth
brown to medium brown	mounding; surface firm, slightly compressible, velvety; 560-3480 cm^3 volume	coral rock, sandy substrate, seagrass beds; 6.5-22 cm depth
blackish green	encrusting, thin; tiny oscula; surface firm, velvety; 3.2-4.2 cm^3 volume	coral rock 9-10.5 cm depth
medium brown to red	encrusting; clustered oscula; surface very firm, not compressible, verrucose; 10-1377 cm^3 volume	coral rock; 4-28 cm depth
green-brown	encrusting; apparent oscula; surface firm; 14 cm^3 volume	coral rock; 14 cm depth