SIT Graduate Institute/SIT Study Abroad
SIT Digital Collections

Independent Study Project (ISP) Collection | SIT Study Abroad

Spring 2017

Small-Scale Farming of Sandfish (Holothuria scabra) at Unguja Ukuu, Zanzibar

Claire Hacker
SIT Study Abroad

Small-Scale Farming of Sandfish (*Holothuria scabra*) at Unguja Ukuu, Zanzibar

Claire Hacker

Advisor: Dr. Narriman Jiddawi

Academic Director: Dr. Richard Walz

SIT Tanzania-Zanzibar, Spring 2017

Table of Contents

Acknowledgements

My sincere thanks to the sea cucumber farmer at Unguja Ukuu for welcoming me to his farm, for allowing this study to take place, and for sharing his knowledge and experiences with me. Thank you to Dr. Narriman Jiddawi, my project advisor, for always making time to talk with me and for her energy, ideas, support, and vast knowledge of everything related to fisheries in Zanzibar. I owe many thanks to my interpreter, Abdullah, not only for making my interviews possible but also for putting so much extra time and effort into helping me succeed, and also for his friendship. Many thanks to Mwinyi and family for welcoming me into Unguja Ukuu, and for all the hospitality and coconuts they shared. Thanks also to the village of Unguja Ukuu, for welcoming me, being willing to answer my questions about sea cucumbers, and even keeping me company while I worked. I also thank Bi Mwati and Arabia for allowing me to stay in their home and for taking such good care of me. Many thanks to Richard for all of his support and help, both academically and with life and ISP in general. Finally, sincerest thanks to Said and all of the SIT office staff for the incredible work they all do to make everything possible. I could not have succeeded without everyone's support.

Abstract

The biological and social components of sandfish farming were studied at Unguja Ukuu, Zanzibar. Measurement of temperature and depth, along with quadrat sampling of substrate and sea cucumbers, led to recommendations for future management of depth, biomass per area, disease and crabs, and substrate. Interviews revealed the role and potential benefits of sea cucumber farming for communities. Several barriers to, and complications with, the expansion of sea cucumber farming were also identified. This study provided information for improvement of this farm and hoped to spread knowledge of sandfish farming to Zanzibaris, who may benefit economically from the practice.

Introduction

The sandfish, *Holothuria scabra*, is an ecologically and economically important species, yet it is heavily threatened by overharvesting to feed the demand for bêche-de-mer in Asia. Aquaculture has arisen around the world as a potential solution to this problem, but this practice has not yet become popular in Zanzibar. This study examined small-scale sandfish farming in Unguja Ukuu, Zanzibar, with the goal of characterizing the biological and social context of these farms and making recommendations accordingly. Data were collected from two farms, as well as from local fishers and other community members. The results of the study allow for an evaluation and comparison of physical conditions and sea cucumber population, biomass, size distribution, and health at the two farms. Further, the social context of farming and its implications for communities and economies were considered. These outcomes are important for the improvement of these particular farms, and for a more general understanding and improvement of sea cucumber farming. More broadly, this study has documented and evaluated a biological and social phenomenon that is new to Zanzibar, and in doing so will hopefully contribute to the spread of sea cucumber farming as a livelihood option for numerous coastal people.

Background

Sea cucumbers, including *Holothuria scabra*, or sandfish, are members of the phylum Echinodermata and the class Holothuroidea. Sea cucumbers have elongate bodies with a mouth and feeding tentacles at one end and an anus at the other (Rowe & Richmond, 2011). Like other echinoderms, they have tube feet driven by a water vascular system for use in locomotion (Rowe & Richmond, 2011). Some species are suspension feeders while others are deposit feeders (Rowe & Richmond, 2011).

H. scabra is one of approximately 140 sea cucumber species found in the shallow Western Indian Ocean and occurs throughout the Indo-Pacific region (Rowe & Richmond, 2011). Individuals may grow to 40 centimeters in length and are described as having a “firm, loaf-shaped body” that is grayish in color (Rowe & Richmond, 2011). *H. scabra* reproduces sexually, with males and females releasing gametes into the water for fertilization (Rowe & Richmond, 2011). The larvae are planktonic and feed in the water column, and move through several developmental stages before settling on the substrate (often seagrass) after around two weeks of life (Hamel et al., 2001). *H. scabra* is a deposit feeder and is therefore found in sandy habitats (Rowe & Richmond, 2011). As a result of deposit feeding, sea cucumbers in general are known to contribute to the recycling of nutrients, such as ammonium, a process that has been shown to increase the growth of microscopic algae (Uthicke, 2001; Uthicke & Klumpp, 1998). One study found that the exclusion of sea cucumbers from seagrass beds resulted in reduced seagrass biomass, suggesting sea cucumbers may also play an important role in maintaining seagrass bed health (Wolkenhauer et al., 2009).

Despite sea cucumbers’ important role in coastal ecosystems, they are threatened worldwide by overharvesting. Multiple species, including *H. scabra*, are harvested for the production of bêche-de-mer, which is the dried body wall of the animal. The bêche-de-mer is then exported from various producing countries for consumption in Asia, particularly China (Ferdouse, 2004). *H. scabra* has been listed as Endangered on the IUCN Red List since 2013, as its “populations are estimated to have declined by more than 90% in at least 50% of its range, and are considered overexploited in at least 30% of its range” (Hamel et al., 2013). As one example, studies leading up to the formation of the Mafia Island Marine Park identified an existing and rapidly expanding sea cucumber fishery, and predicted the collapse of the fishery due to overharvesting (Horrill et al., 1996).

In Zanzibar, sea cucumbers are collected both intertidally and by diving (Eriksson et al., 2010). In 2010, 94% of the Zanzibari fishers surveyed stated that sea cucumbers were becoming more difficult to find, reflecting widespread population declines (Eriksson et al., 2010). Specifically, this same study found that *H. scabra* was considered to be a high-value sea cucumber species, but was found in very low abundance in transects (Eriksson et al., 2010). This overexploitation represents a threat to coastal ecosystems as well as coastal communities, who largely depend on marine resources for food and income.

Aquaculture is one way to reduce pressure on wild sea cucumbers while providing people with an alternative source of income. For Mafia Island, one management recommendation provided in response to the overharvesting of sea cucumbers was "investigation of mariculture potential" (Horrill et al., 1996). Sea cucumber aquaculture is currently practiced in many countries, including Australia, Canada, China, Cuba, Egypt, France, Malaysia, New Caledonia, Papua New Guinea, Seychelles, Tanzania, and Vietnam - all countries that sent representatives to present at a workshop called "Advances in Sea Cucumber Aquaculture and Management," organized by the FAO in 2003 ("Introduction," 2004). In Madagascar, sandfish farming has occurred since 2008 through partnerships between communities and a private company, in a process that involves a hatchery as well as ocean farms (Robinson & Pascal, 2009). The Zanzibar Fisheries Policy treats aquaculture positively in general, describing it as "a viable means of fostering economic development and… one possible source of alternative income for resource poor coastal communities of Zanzibar Island" (The Revolutionary Government of Zanzibar, 2013). However, sandfish farming is still a very new practice in Zanzibar, with only a few farming locations currently on Unguja Island (Dr. Narriman Jiddawi, personal communication, March 29, 2017).

The primary location for this study was an *H. scabra* farm near the village of Unguja Ukuu, on Unguja Island in the Zanzibar Archipelago, Tanzania (Figure 1).

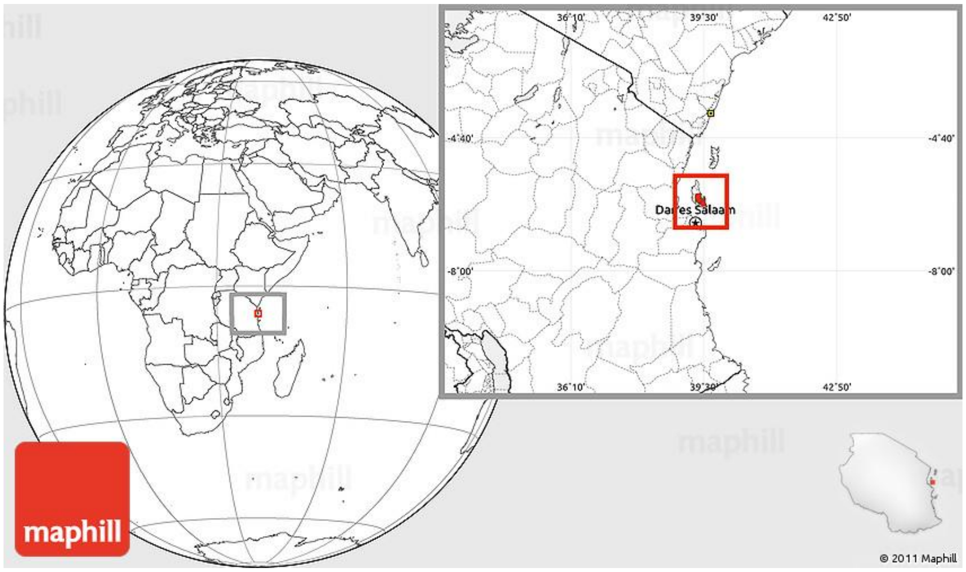


Figure 1. Location of Unguja Island. Image source: maps.maphill.com/tanzania/kusini-unguja/location-maps/blank-map/blank-location-map-of-kusini-unguja.jpg.

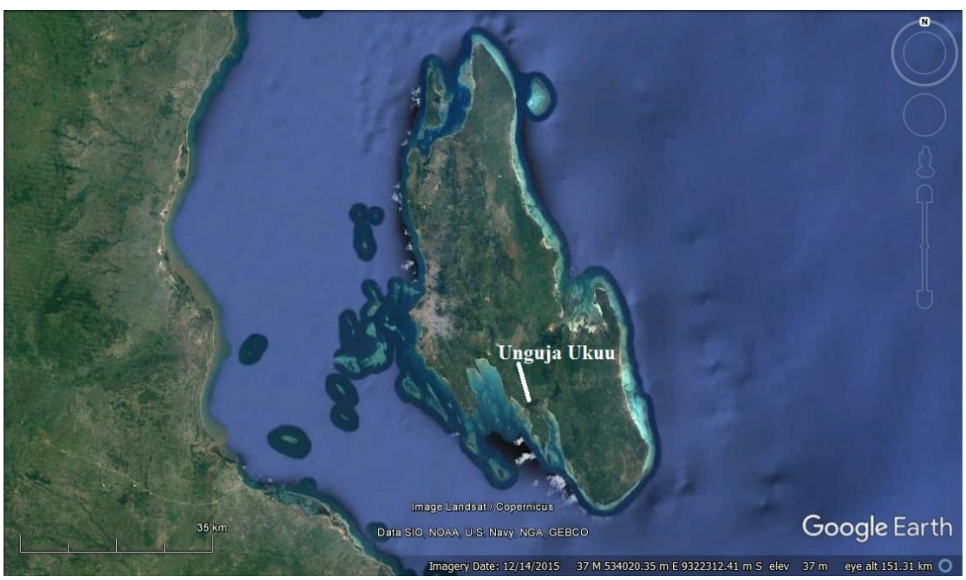


Figure 2. Location of Unguja Ukuu on Unguja Island.

Unguja Ukuu is a small coastal village, and as such its citizens rely heavily on income and sustenance from marine resources, including sea cucumbers (Figure 2). This study site was recommended by Dr. Narriman Jiddawi as one of the few sandfish farming locations on Unguja Island. The farm is located near the Unguja Ukuu fish market and is in an upper intertidal area near the beach and a stand of mangrove trees (see additional maps in Appendix A). The farm is small, with three sides formed by walls that are made of coral rock and cement and are about one foot high (Figure 3). During a visit to the site prior to the study period, the farmer said he had started the farm about five months earlier, with the desire to be creative and try something new. He said he was "making it up" as he went and was very happy and willing for me to do a study there. When asked if there were any particular topics or issues he wanted to be addressed, he said he would like to know "anything."

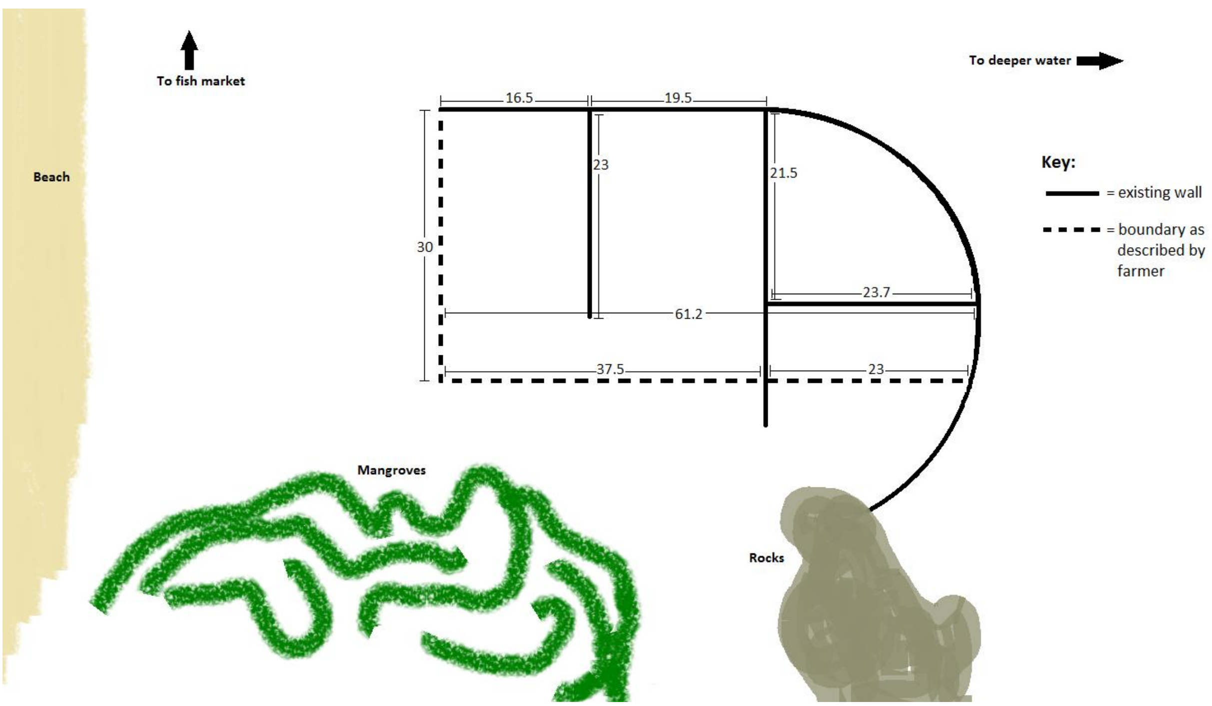


Figure 3. Diagram of the first farm and its location. Farm is to scale; surroundings are not. All measurements are in meters.

Additionally, early in the study period it was discovered that a second sea cucumber farm exists near Unguja Ukuu (see maps in Appendix A). The second farm is located in a subtidal seagrass bed surrounded by mangroves. It is approximately rectangular, and it is completely enclosed by a fence made of mangrove poles and netting. In the interest of comparing the two farms, the second farm was added as a secondary study location.

Methods

A combination of methods was employed over the course of the study in order to gain insight into both the biological and social aspects of sea cucumber farming at Unguja Ukuu. Broadly speaking, these methods were characterization of the physical conditions at the farm, quadrat sampling within the farm, and oral interviews with various actors. These three components of the study were conducted in an alternating fashion. Additionally, measurement of physical conditions and quadrat sampling were carried out at the second farm for the purpose of comparison. Data collection occurred between April 8, 2017, and May 2, 2017.

First Farm

The physical conditions that were measured were water temperature and depth. These were measured at varying times of day and tidal heights in order to capture a range of conditions experienced by the sea cucumbers. Sampling occasions included one spring tide, representing extreme conditions, as well as one neap tide and several other days that represented more typical conditions. During low tides, measurements were taken in a grid pattern, with approximately 15 meters between measurement points, to capture variation within the farm. At mid-tide, measurements were taken at only three points throughout the farm due to the logistical challenges of working in high water. Attempts to take measurements at high tides were unsuccessful. Water temperature was measured just above the sediment, since that most closely represents where the sea cucumbers are found. Temperature was measured using a simple glass thermometer, and depth was approximated using a notched stick. Salinity was also measured, using a hand-held refractometer, but the data were considered unreliable due to complications with equipment. All data were recorded in pencil on a slate. These measurements were taken with the goal of understanding of the environmental conditions at the farm, and further to allow for comparison with literature values on the ideal temperature range for the species and to make recommendations accordingly.

Quadrat sampling was conducted to quantify several parameters regarding the sea cucumbers and their habitat. This method was carried out during low tide on eight days, and on each occasion between eight and 12 one-square-meter quadrats were sampled. The number of quadrats sampled per day depended on factors such as the length of working time allowed by the tide and the amount of time required for each quadrat. Quadrats were placed randomly within the farm, using locations that were determined by generating random numbers, as the farm was too large for random tosses of the quadrat to be feasible. The random numbers were used to make coordinate pairs in the form (x, y), where x was the number of meters along the length of the farm and y was the number of meters along the width of the farm (Figure 4). A 50-meter tape measure was used to find each location for quadrat placement. For each quadrat, the percent cover of each substrate type was recorded, using a field guide for identifications as necessary (Richmond, 2011). Next, the entire quadrat was searched for sea cucumbers. It was necessary to search by touch as well as by sight because the sea cucumbers were often concealed by seagrass or sand. The total number of individuals in the quadrat was recorded, and the length of each individual was measured to the nearest half-centimeter using a small measuring tape. If the sea cucumber was curved sideways, the tape measure was also curved so as to measure its longest length along its center. Due to the necessity of searching by touch, all sea cucumbers were handled before being measured. However, the measurements were then taken as promptly as possible to minimize body expansion and contraction due to handling. Finally, each sea cucumber was examined for signs of poor health, including abnormal coloration and crab-induced cuts. All data were recorded in pencil on a slate. Quadrat sampling was carried out for multiple purposes, including understanding the farm's substrate composition, calculating the total sea cucumber population and biomass of the farm, finding the size distribution of the sea cucumbers, calculating the prevalence of disease, and making recommendations regarding all of these areas.

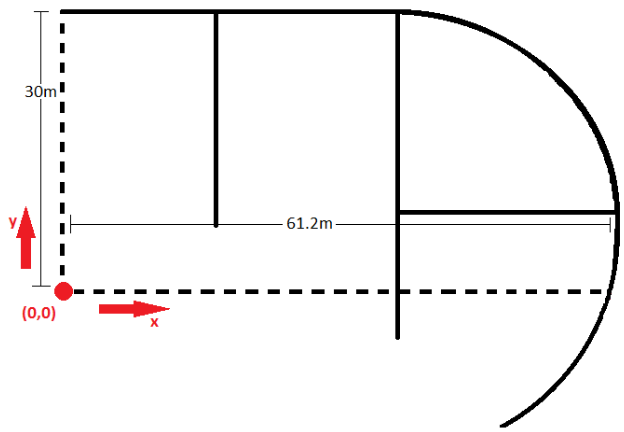


Figure 4. System for placing quadrats. X is a random number between 0 and 61, inclusive; y is a random number between 0 and 30, inclusive.

Second Farm

Due to time constraints, it was not possible to fully replicate the methods described above at the second sandfish farm. Many of the same techniques were employed, but with fewer sampling occasions.

Measurement of temperature occurred around low tide three times over two days, shortly after a spring tide. The measurements were taken at five locations throughout the farm: one near each corner, and one near the center. Measurements were taken using the same methods as for the first farm.

Quadrat sampling was carried out during low tide on two days, with 14 quadrats sampled one day and 18 the second day. Quadrats were placed using a system with randomly generated coordinate pairs, but to find each location, mangrove poles in the fence were counted rather than meters. Within each quadrat, the same methods were employed as for the first farm.

Interviews

Oral interviews with a variety of local people comprised the third component of the methods of this study. Multiple conversations took place with the farmer, himself, about many aspects of the farm, but farm assistants, a middleman for sea cucumbers and other intertidal organisms, and other fishers and community members were also interviewed. Additionally, a visit to a sea cucumber farm at Kilimani included an interview with one of its founders.

These conversations were facilitated by local interpreters, who were compensated for their time and assistance. General interviewees (e.g. fishers and community members) were found near the fish market and around the village. In some instances, random people who looked fairly unoccupied were selected, while in others, people were identified by the interpreter as someone he knew, someone he thought would like to talk, or someone who might know something about sea cucumbers. Potential interviewees were told the context and general idea of the study and were asked if they would be willing to answer a few questions. It was explained that there would be no problems if they chose not to respond. Interviewees' names were recorded when they were willing to provide them, but in the interest of the privacy of all participants, no names are used in this paper. During each conversation, notes were taken using pen and paper. Twenty-five people were interviewed in total (excluding the farmer), with interviews typically lasting about seven to 10 minutes each, and a few lasting up to 30 or 45 minutes.

For fishers and other community members, a fairly consistent set of questions was posed. However, due to each interviewee's unique experiences, the directions taken with follow-up questions, and the informality of the interviews, there was a fair amount of variation among the interviews. The basic questions asked were as follows:

Unafanya kazi gani?
(What work do you do?)
Unajua nini au unafikiri nini kuhusu majongoo?
(What do you know or think about sea cucumbers?)
Unajua nini au unafikiri nini kuhusu shamba ya majongoo?
(What do you know or think about the sea cucumber farm?)
Unafikiri shamba ni nzuri, au mbaya, au labda kuna matatizo?
(Do you think the farm is good, or bad, or maybe there are problems?)

The goal of these interviews was to understand the human network and context surrounding the sea cucumber farm, which is an important component of an analysis of sea cucumber farming as a new practice on Unguja.

Results

First Farm

Like many people in Unguja Ukuu, the farmer used to collect sea cucumbers, and he would also dry and sell them. However, sea cucumbers are now very scarce, so he decided to farm instead. He selected *H. scabra* (known locally as majongoo mweupe) because it would bring him the most money. He also said that sandfish can survive anywhere and are therefore fairly easy to raise, whereas other species can have more particular requirements. The location of the farm was chosen partly out of convenience, as it is located near the beach and the local center of fishing activity. The farmer was also concerned that selecting a deeper location would cause more sea cucumbers to escape from the farm and increase the risk of theft of the sea cucumbers. He said that he used coral rock to build the farm walls because it would make the farm more similar to the sea cucumbers' natural habitat, but a more typical pole-and-net construction would not have been possible due to the base of rock under the farm. Walls within the farm further divide it into several "rooms," as shown in Figure 3. These divisions have little significance, but the farmer does try to alternate where he harvests and adds sea cucumbers. He adds sea cucumbers of all sizes to the farm by buying them from fishers, both in Unguja Ukuu and in other villages. Additionally, one of the interviewees, a beach middleman, gives sea cucumbers to the farmer when he receives some that are too small to dry and sell. The farmer also thinks that reproduction occurs within the farm, representing another source of juveniles, and he purposely keeps large sea cucumbers there for this reason.

The farm is still quite new, and the farmer has not yet sold any sea cucumbers for export. However, he has sold to other farms that are being established in Unguja Ukuu and elsewhere. Early in the study period, he estimated that he was harvesting 3,000 to 4,000 individuals each week to send to other farms. To the second farm in Unguja Ukuu, he indicated that he sends sea cucumbers of about the length of his hand. He said he wants to wait and amass a large number of sea cucumbers of harvestable size before exporting any, but he also suggested that he wants the first farm to be more of a nursery than a place for harvesting for export. To handle harvesting and other tasks, the farmer employs around five young men as helpers. These men also have other jobs but come to the farm as needed, typically a few times each week. Currently, the farmer watches over the farm himself rather than paying a guard, and he even comes most nights to check on the farm. He does not think any theft has occurred, but says it is a possibility, particularly once people start to see his success with farming.

The farmer estimates that it will take about six more months until the sea cucumbers at the farm are ready to be harvested for export. When that time comes, he will dry the sea cucumbers with assistance from his helpers, and sell them to an exporter in Stone Town. He says that sea cucumber prices fluctuate and depend on the quality of the product, but that 10,500 Tsh per kilogram would be a decent price for live sea cucumbers that are not too large. It seems that government control over sea cucumbers comes into play not at the level of people like this farmer, but rather at the level of exporters, who are required to have exporting licenses.

In the future, the farmer would like to extend the walls of the farm and make them wider and taller. This may help to retain water in the farm at low tide, as the current walls leak in many places. However, this activity depends on whether he is able to get enough money, especially since concrete is expensive. He also has plans to start a second farm. He says he will choose a subtidal location and use poles and netting to make the walls. The timing of this construction, too, depends on money. Thinking more broadly, he expects the farm will cause wild sea cucumber populations to increase due to the release of eggs from the farm as well as any individuals that may escape the walls.

Water temperature at the farm was measured on six occasions: four at low tide and two at mid tide. For each occasion, the minimum, maximum, average, and range in temperatures were found (Table 1). Across all days, the minimum temperature recorded was 25ºC, and the maximum temperature was 36ºC. For a given sampling occasion, the average temperature ranged from 25.7ºC to 33.9ºC, and the temperature range was between 0ºC and 4ºC. At high tide, efforts to sample were unsuccessful, but the water near the sediment was noticeably cooler than the surface water.

Table 1. Water temperature of the first farm on six occasions. Low tides each have 12 to 13 data points; mid tides each have 3 data points.

Date	Tide	Minimum Temperature (ºC)	Maximum Temperature (ºC)	Temperature Range (ºC)	Average Temperature (ºC)
April 18	Low	31	35	4	32.8
April 19	Low	30.5	32	1.5	31.3
April 22	Low	27	28	1	27.3
April 23	Mid	30	30	0	30.0
April 26	Low	32	36	4	33.9
April 29	Mid	25	26	1	25.7

The salinity of the water was measured along with the temperature on each sampling occasion. The refractometer was calibrated with bottled water, with the plan of later testing the bottled water against deionized water and adjusting the data accordingly. However, deionized water was not able to be acquired, so the salinity values were considered unreliable and are not included in this paper.

Water depth was measured on seven occasions: six at low tide and one at mid tide. Low tide sampling included 13 data points, while mid tide sampling included three data points. Example depth profiles are shown in Figure 3. Across all low-tide occasions, the minimum depth recorded was zero centimeters, while the maximum was 27 centimeters. However, these depths did not occur at random locations; as demonstrated by Figure 5, there is a distinct pattern of depth throughout the farm due to the way in which the walls retain water at low tide. At the shallower end of the farm, large areas were exposed at low tides, whereas the deeper areas were never exposed. The intertidal area surrounding the farm is also exposed at low tide. At one mid tide, water depth ranged from 60 to 90 centimeters, and at a spring high tide the farm was covered by at least 150 centimeters of water.

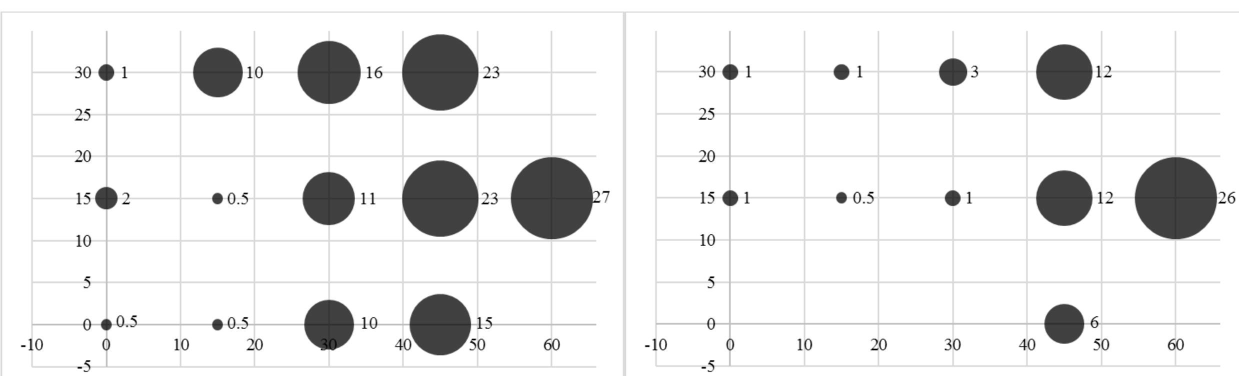


Figure 5. Example water depth profiles of the first farm at low tide. The area of each circle is proportional to the water depth; numbers represent depth in centimeters. *Left:* sampling occurred early in a neap low tide. *Right:* sampling occurred late in a spring low tide. Missing circles indicate a lack of water.

A total of 81 quadrats were sampled, with a total of 738 sea cucumbers counted and measured. This sampling yielded data on substrate composition of the farm as well as multiple characteristics of the sea cucumber population.

The substrate types observed were sand, seagrass (*Thalassia hemprichii*), a colonial zoanthid (likely *Zoanthus natalensis*), a red macroalga (likely *Gracilaria salicornia*), rock, rubble, and concrete. The sand was generally fairly shallow, as the entire farm has a base of rock, with a few patches of deeper, mucky sand. Overall, the farm substrate was dominated fairly equally by both seagrass (37.9%) and sand (36.1%), followed by the zoanthid, rock, the macroalga, rubble, and concrete (Figure 6). Seagrass and sand both occurred across wide areas of the farm but in somewhat different patterns, with seagrass generally being more concentrated in the deeper areas and sand in the shallower areas (Figure 7).

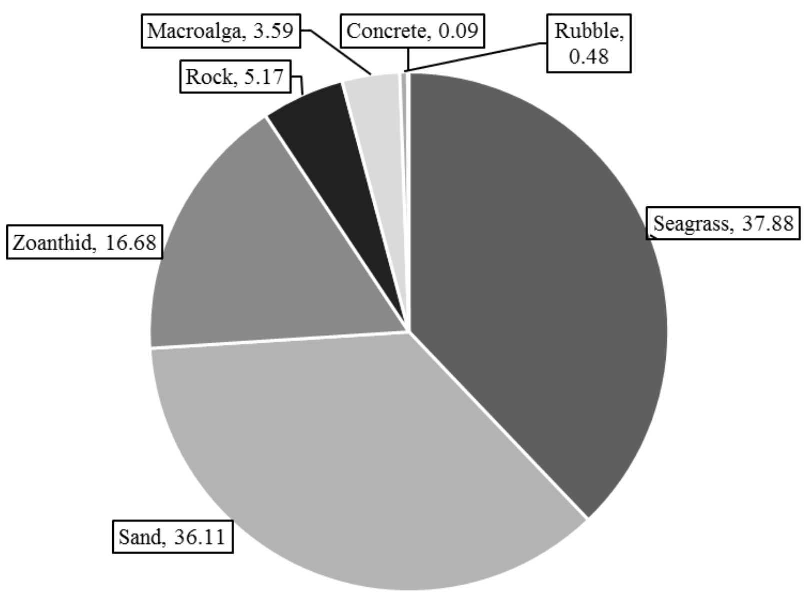


Figure 6. Substrate of the first farm. Numbers are percentages (%). Seagrass is *Thalassia hemprichii*, zoanthid is likely *Zoanthus natalensis*, and macroalga is likely *Gracilaria salicornia*.

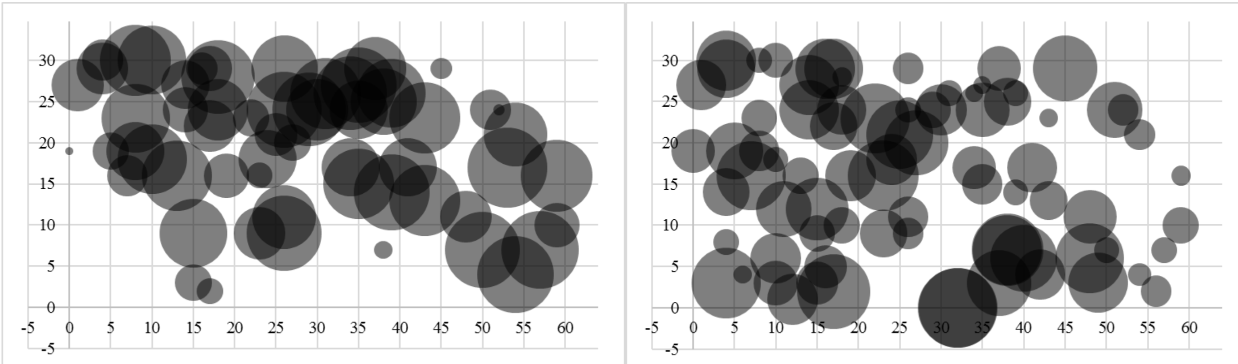


Figure 7. Distributions of seagrass and sand at the first farm. The area of each circle is proportional to the percentage of the quadrat composed of that substrate type. *Left:* seagrass. *Right:* sand.

The length of the sea cucumbers ranged from 4.5 to 16 centimeters (Figure 8). The average length was 7.86 centimeters, and the median length was 7.5 centimeters. While the largest sea cucumbers found in quadrats were 16 centimeters in length, several individuals of 20 centimeters or more were observed outside of quadrats.

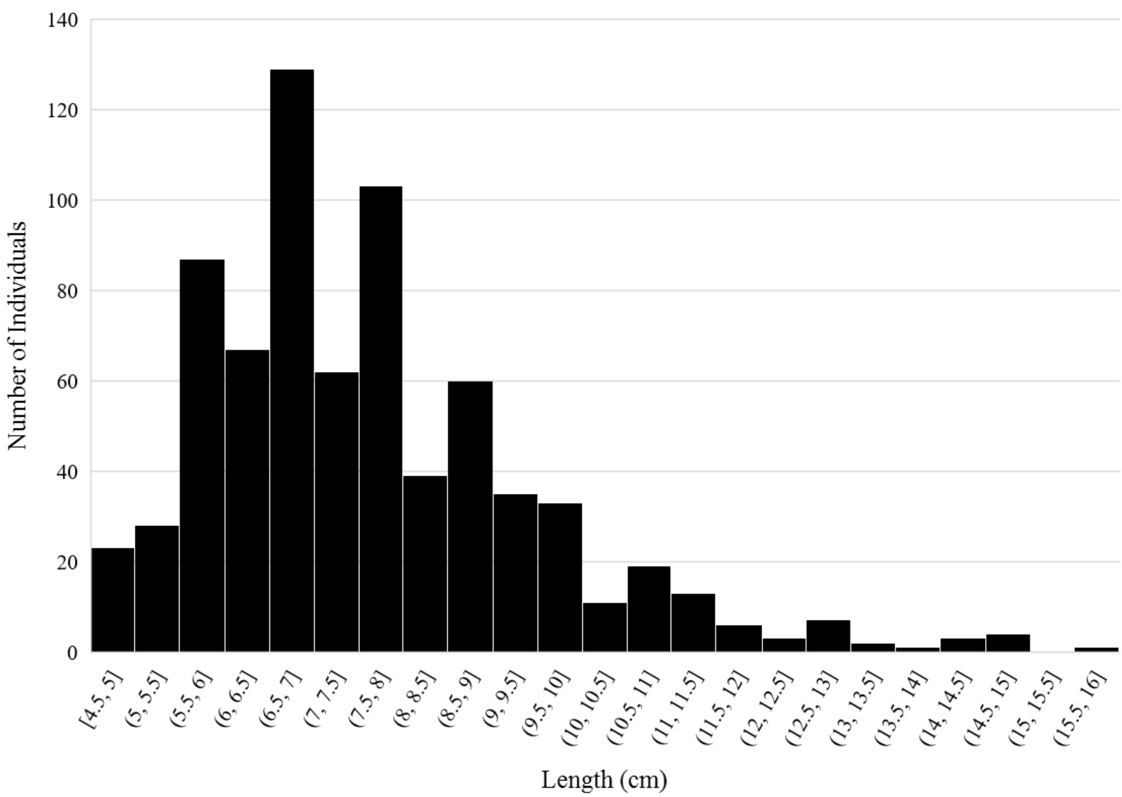


Figure 8. Size distribution of all sea cucumbers sampled at the first farm (n=738).

Using the numbers of sea cucumbers found in each quadrat, the population density and total population of the farm were calculated (Table 2). These were calculated separately for each day, and then those values were averaged to determine the overall population density and total population. The average population density was found to be 9.11 individuals per square meter, and the total farm population was estimated to be 15,698 individuals. Population densities were calculated using 1,724 square meters as the total area of the farm (explained in Appendix B).

Using the length data, it was also possible to estimate the mass of each sea cucumber, and therefore the biomass of sea cucumbers in the farm. For each sea cucumber, length was converted to weight using the following relationship, published by Pitt and Duy (2004):

$$y = 0.0735x^{2.8}$$

where y is weight in grams and x is length in centimeters. The biomass per area and total biomass were then calculated (Table 2). These were calculated separately for each sampling occasion, and then those values were averaged to calculate the overall biomass per area and total biomass. The average biomass per area was found to be 244 grams per square meter, and the total farm biomass was estimated to be 421,482 grams.

Table 2. Population density, total population, and biomass of first farm. Each day has between 8 and 12 data points.

Date	Population Density (individuals/m^2)	Total Farm Population (individuals)	Biomass per Area (g/ m^2)	Total Farm Biomass (g)
April 9	8.25	14,223	193	331,905
April 12	3.42	5,890	84	144,778
April 14	19.27	33,226	523	900,836
April 18	5.78	9,961	116	200,112
April 19	9.67	16,665	201	345,986
April 20	9.18	15,829	265	456,286
April 23	9.44	16,282	322	555,974
April 24	7.83	13,505	253	435,978
Average	**9.11**	**15,698**	**244**	**421,482**

Additionally, the distribution of sea cucumbers throughout the farm was found not to be uniform, with more sea cucumbers generally found near the farm's outer walls (Figure 9).

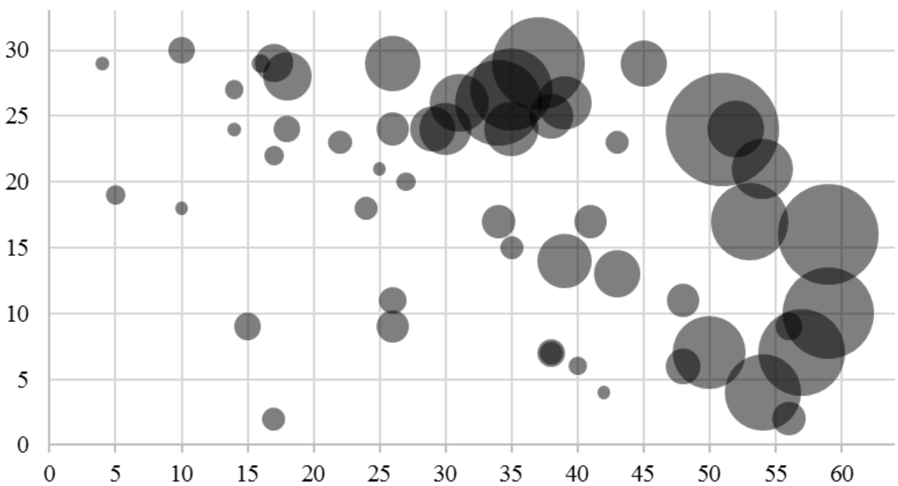


Figure 9. Distribution of sea cucumbers throughout the first farm. The area of each circle is proportional to the number of sea cucumbers found in that quadrat.

The prevalence of signs of poor health was also calculated. These symptoms were divided into two categories: discoloration and cuts. Discoloration was a blue tinge, or occasionally brown, that covered anywhere from a small patch to the majority of the animal, most often on the ventral surface (photographs in Appendix E). Across all quadrats, it was found that 15.92% of individuals had some sort of discoloration, and 2.23% of individuals had cuts. In sum, 18.15% of the individuals that were examined showed some sign of poor health. Further, the average size of sea cucumbers in poor health was found to be significantly different from the average size of healthy sea cucumbers. Calculation of 95% confidence intervals suggested that the true mean length of unaffected sea cucumbers likely fell between 7.86 and 8.18 centimeters, while the true mean length of affected sea cucumbers likely fell between 7.07 and 7.63 centimeters. In sum, unhealthy sea cucumbers were significantly smaller than healthy ones.

Second Farm

The second farm is owned by a man who lives in Stone Town, but he rarely visits the farm and pays the farmer at the first farm to take care of it. It is newer than the first farm. The sea cucumbers at this farm have been sourced from the first farm, as previously described, as well as from fishers in other locations. The sea cucumbers here are still growing, and none have been sold for export yet. The farmer thinks this farm is in a better environment than the first farm.

Temperature was measured on three occasions, all at low tide. Considering all measurements, the minimum temperature recorded was 28ºC, and the maximum temperature was 33ºC. For a given sampling occasion, the average temperature ranged from 28ºC to 32ºC, and the temperature range was between 0ºC and 2ºC (Table 3).

Table 3. Water temperature of the second farm on three low-tide occasions. Each sampling occasion has 5 data points.

Date	Minimum Temperature (ºC)	Maximum Temperature (ºC)	Temperature Range (ºC)	Average Temperature (ºC)
April 27 (AM)	28	28	0	28
April 27 (PM)	31	33	2	32
April 28	28	28	0	28

Unlike the first farm, there was no obvious pattern of depths at the second farm. The farm is in a shallow subtidal area, so it remains submerged at low tide, with the exception of very small sandy patches. On one low-tide occasion, the depth of water at the farm was between approximately 20 and 36 centimeters.

Over two days, a total of 32 quadrats were sampled, and 62 sea cucumbers were counted and measured.

The substrate types observed were sand, a red macroalga (likely *Sarconema filiforme*), and three species of seagrass: *Thalassia hemprichii*, *Halodule uninervis*, and *Enhalus acoroides*. The sand was deeper and coarser than that at the first farm, with no rocky base. Overall, the farm substrate was comprised of 46.3% sand and 53.3% total seagrass (Figure 10). Among the three seagrass species, *H. uninervis* dominated, followed by *T. hemprichii* and then *E. acoroides*.

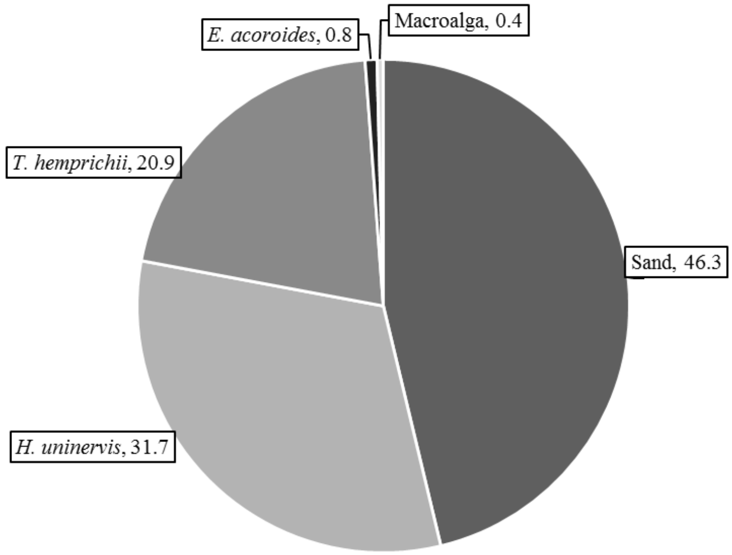


Figure 10. Substrate of the second farm. Numbers are percentages (%). *T. hemprichii*, *H. uninervis*, and *E. acoroides* are seagrasses. Macroalga is likely *Sarconema filiforme.*

The length of the sea cucumbers was found to range from 8.5 centimeters to 15.5 centimeters (Figure 11). The average length was 11.72 centimeters, while the median length was 12 centimeters.

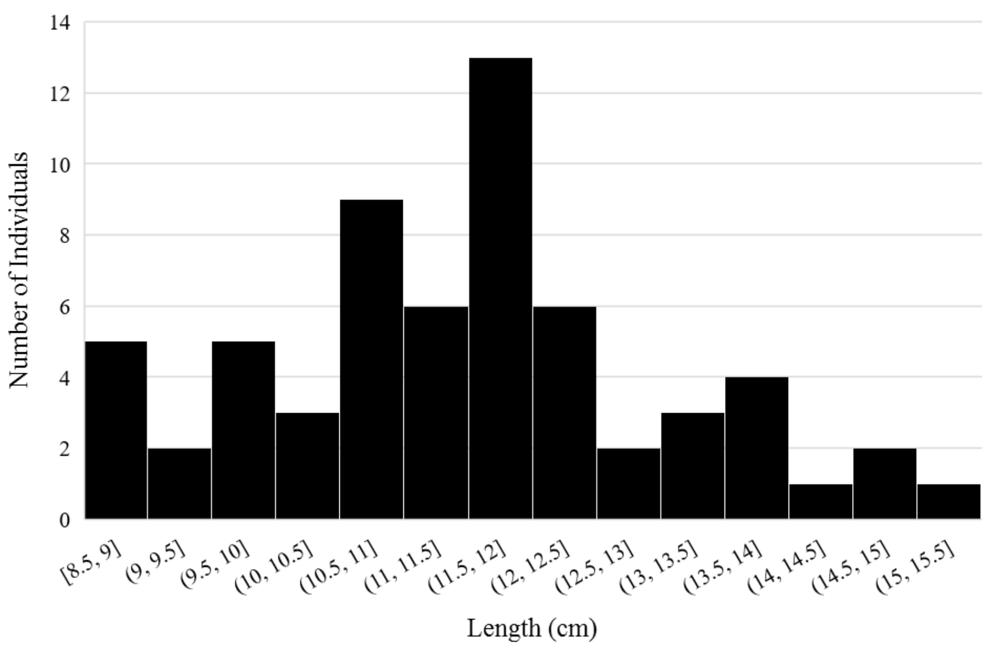


Figure 11. Size distribution of all sea cucumbers sampled at the second farm (n=62).

As with the first farm, the population density and total population of the farm were calculated (Table 4). These were calculated separately for each day, and then the values from the two days were averaged to find the overall population density and total population. The average population density was found to be 1.97 individuals per square meter, and the total farm population was estimated to be 11,849 individuals. Population densities were calculated using 6,020 square meters as the total area of the farm (explained in Appendix B). The biomass per area and total biomass were also calculated (Table 4). The average biomass per area was found to be 149 grams per square meter, and the total farm biomass was estimated to be 894,468 grams.

Table 4. Population density, total population, and biomass of second farm. April 27 has 14 data points; April 28 has 18 data points.

Date	Population Density (individuals/m^2)	Total Farm Population (individuals)	Biomass per Area (g/ m^2)	Total Farm Biomass (g)
April 27	2.21	13,330	165	992,162
April 28	1.72	10,368	132	796,774
Average	**1.97**	**11,849**	**149**	**894,468**

Of the 62 sea cucumbers examined, only two showed signs of poor health: one had discoloration, and one had a cut. This meant that 6.45% of individuals were in some way affected, with 3.23% discolored and 3.23% cut.

Interviews

The following is a description of the information obtained from 19 general interviewees, including fishers and other community members, but excluding people who were interviewed to get specific details about the farms, such as farmers and farm helpers. The information gathered from the farmer at Unguja Ukuu, his assistants, and the farmer at Kilimani has been incorporated elsewhere in the paper.

The 19 interviewees included 10 females and nine males, of ages ranging from 19 to 58. They included eight fishers, one beach middleman, four seaweed farmers, two terrestrial farmers, three food-related businesspeople, one student, and two house mothers (some interviewees listed multiple jobs). The fishers included people fishing from boats with nets, divers, octopus fishers, and people collecting a mixture of intertidal organisms.

Interviewees gave a variety of responses regarding their knowledge of or thoughts about sea cucumbers. These responses fell into seven broad categories: collection by self or others (26%); sea cucumber population decrease (18%); biology, behavior, or ecology (18%); human uses (11%); collection methods (5%); other (5%); and none (13%) (Figure 12). In the first category, "collection by self or others," many interviewees simply stated that they collected sea cucumbers or used to do so, or that they know people who collect them. One person said that sea cucumbers are ignored rather than collected because they fetch low prices.

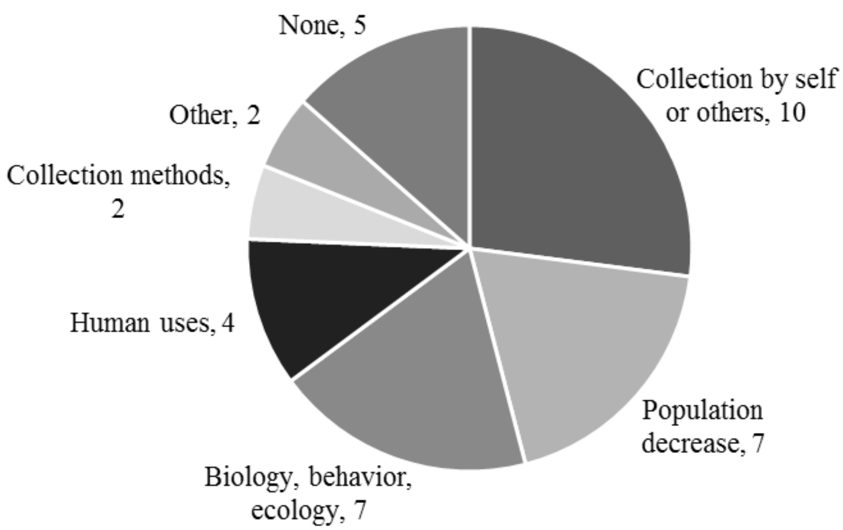


Figure 12. Categories of knowledge of sea cucumbers conveyed by interviewees. Numbers represent numbers of responses.

Seven interviewees in some way indicated that there has been a decrease in sea cucumber populations. Two people cited overharvesting as the cause of this decline, and another said it was due to seaweed farming because the motion of the seaweed wears away the sand. Another explained that people have started searching under rocks for them and leaving the rocks overturned, reducing sea cucumber habitat and potentially exposing and harming their eggs. A fifth did not know why sea cucumber populations were decreasing.

Responses concerning the biology, behavior, or ecology of sea cucumbers were also common. These responses included information about reproduction, burrowing behavior, which species are present locally, which species prefer different habitat types, and which species are active in the day versus at night. Knowledge regarding human uses of sea cucumbers included that they are eaten in China, that some species are eaten while others are not, and that some species are used to obtain a poison used for fishing. Responses in the "other" category were that sea cucumbers are an important marine resource that have to be used responsibly, and that sea cucumbers are a big business in Zanzibar, including both collection and farming. Finally, five individuals stated they had no knowledge of sea cucumbers. Two of these were businesswomen selling prepared foods, one was a fisherman who does not work with sea cucumbers, and one was an intertidal collector who said she collected sea cucumbers but claimed to know nothing about them.

The majority of interviewees had little knowledge of the sea cucumber farm. Five people did not know about the farm at all, six people had heard about it but not seen it, and one person had seen the farm but not visited it. One person had visited the farm once but did not offer other knowledge about the farm. Four people shared knowledge of the farm's purpose, for example that the farmer wants to raise sea cucumbers and help them grow well.

All interviewees had overall positive opinions of the sea cucumber farm. Fifteen interviewees said the farm was a good idea. While six people said that they saw no problems with the farm, several people identified concerns, including crabs and theft of the sea cucumbers. Two people expressed concern about the shallow depth of the sediment at the farm and said that the farmer should bring in more sediment from elsewhere. One further explained that without deeper sediment, the sea cucumbers will be less able to hide from the sun and will not grow as well. Interviewees were asked for their thoughts about the farm regardless of whether they had previous knowledge of the farm, so some responses represent ideas and speculation about sea cucumber farming in general.

Interviewees who thought the farm was a good idea were further asked why they felt that way. These ideas generally fell into four categories: increase in wild sea cucumber populations (27%); ease of harvest (20%); education (13%); and benefits to sea cucumber farming (13%) (Figure 13). Several single responses fell into the "other" category (27%).

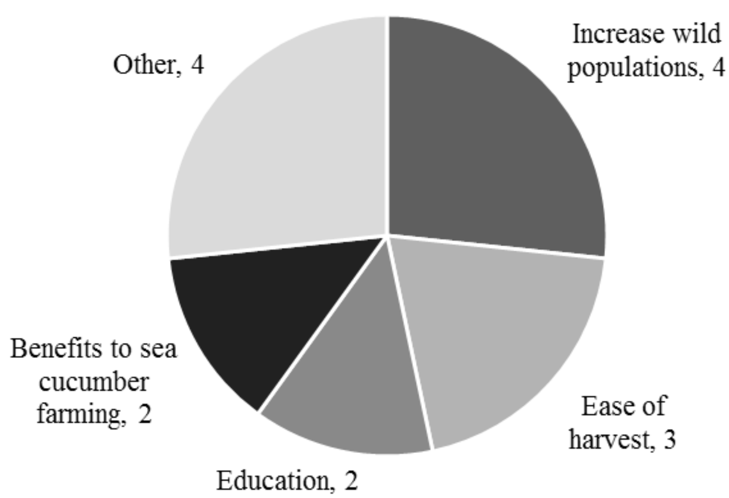


Figure 13. Categories of knowledge of sea cucumbers conveyed by interviewees. Numbers represent numbers of responses.

Four interviewees identified increases in wild sea cucumber populations as a good outcome of the farm, and one further explained that this would benefit intertidal collectors, who would then be able to find and sell some sea cucumbers. The "ease of harvest" category represents interviewees who said that a benefit of the farm was making sea cucumbers more accessible and easier to harvest, dry, and sell. Two interviewees listed education as a positive outcome of the farm, saying that it could be used to show and teach people about sea cucumbers.

Two people also identified benefits to sea cucumber farming more broadly, namely that this farm can supply sea cucumbers to other farms and that this farm will serve as an example and allow other people to try farming. This second interviewee added that it would be good for other people to start farming because it would bring income to more people. Finally, the “other” category included the following responses: the farmer creates jobs; the farm is a good opportunity for the farmer; the farm allows sea cucumbers to be protected, grow, and reproduce; and the farm has the potential to be used for tourism and bring in foreign money.

Interviews also yielded information that did not directly relate to the prepared questions. One interviewee said the second sea cucumber farm is much better than the first due to its soft sediment. Two people expressed beliefs that the practice of sea cucumber farming will not expand significantly. One of these people said that there will not be many farms because this farmer knows how to do it while other people do not. The other thought that no one else would do a farm like this because to do well one cannot have any other jobs or be busy with other things. He also stated that this farmer knows how to farm well because he has dealt with sea cucumbers since he was young.

Additionally, interviewees provided insight into sea cucumber collection at Unguja Ukuu, where many people collect sea cucumbers. One person said that only sandfish bring much money and that the prices of other species are very low, but the middleman identified several species as being quite expensive. Sea cucumbers are more difficult to find at certain times of the year. One person stated that the market for sea cucumbers is closed in Zanzibar and that this has led to illegal activity regarding their sale, but this was not supported by other sources. Some of the people who collect sea cucumbers are general intertidal fishers who are also gathering other animals such as octopus. Others collect sea cucumbers opportunistically, as demonstrated by one seaweed farmer. Still others (men) swim or dive to access sea cucumbers, and multiple people said that more sea cucumbers can be accessed by swimming or diving than by walking. Most of these collectors presumably sell their sea cucumbers to the beach middleman, but at least one occasionally sells them to the farmer, and a few dry and sell the sea cucumbers on their own. Sea cucumber collection practices here have changed somewhat since the farm started, since the middleman now buys smaller sea cucumbers than he did previously for the purpose of donating them to the farmer. This has given people a reason to collect small individuals, which they would not have done before.

Finally, these interviews, combined with all conversations held with the farmer and his assistants, allow for a summary of the social network underlying the sea cucumber farm. Within Unguja Ukuu, the farmer receives small sea cucumbers from the beach middleman, who provides them for free because of his personal relationship with the farmer. The farmer also buys sea cucumbers directly from local harvesters. Additionally, he pays a group of local men to help at the farm. Outside of Unguja Ukuu, he buys sea cucumbers from fishers in other villages. He also sells sea cucumbers to other farms that are being established, representing connections with Stone Town (through the owner of the second farm) and other villages where farms are located. In the future, the farmer also plans to have ties to sea cucumber exporters in Stone Town.

Farm at Kilimani

The sea cucumber farm at Kilimani, near Stone Town, was founded in March 2016 by a brother and sister who also have other jobs. They pay secondary school and university students and other community members to help at the farm. They are practicing co-culture of multiple sea cucumber species at three farms, and they currently have around 10,000 individuals. The farms are in a shallow subtidal area with sand and seagrass, and are enclosed by fences made of mangrove poles and plastic netting. Much has been learned through trial and error, including which species work better for farming than others. They buy their sea cucumbers from fishers in the area, with a preference for larger sea cucumbers that will be able to reproduce within the farm. They believe reproduction already occurs within the farm and have observed many young sea cucumbers.

At the time of the interview, the farmers were about to sell their sea cucumbers for export for the first time. They had a mixture of five species prepared, summing to one ton (dry weight). They currently export through a Chinese man in Zanzibar but hope to start doing the exporting themselves to save money. They have multiple permits allowing for export, and one farmer said there is a new law prohibiting the export of non-farmed sea cucumbers. The prices of the sea cucumbers vary based on the species and whether they have been dried, ranging from 20,000 Tsh per kilogram (live sea cucumbers) to 100,000 Tsh per kilogram (fully dried sandfish). Exporters earn much more money for the sea cucumbers, up to USD 300-400 per kilogram. One farmer estimated that for sandfish, it would take juveniles six to eight months to reach a sellable size. He showed an example of a dried sandfish that was nine centimeters long and indicated that it would have been near 35 centimeters long when alive.

Challenges faced by the farmers include theft and complex relations with local fishers. Due to the theft of sea cucumbers, the farm has two paid guards constantly on duty, and the farmers plan to get security cameras. The farmers have also experienced problems with boats destroying the farm's fences, so they have now added buoys marking the farm's location and also are educating fishers about the farm to motivate them to help protect it. However, they do not face any problems from crabs at this location, and say it is a good site for farming for that reason.

The farm location was selected with help from the government, but otherwise the government provided little information or advice. As a result, the farmers have tried to learn and improve through multiple methods, including using the internet, visiting other sea cucumber farms, and attending relevant seminars. The farmers themselves are now informally serving as sources of knowledge for other people who want to start farming sea cucumbers.

Discussion

In part, this study has generated information about the environment and biology of the first farm that will be useful to this farmer as well as a valuable addition to the growing body of knowledge about sea cucumber farming, particularly since this is the first data on this topic from Zanzibar. Regarding the helpfulness of this study to the farmer, a short document summarizing the major findings and recommendations has been prepared that will be translated into Kiswahili and passed along to the farmer for his use (see Appendix F).

While it may be expected that high temperatures would negatively affect sandfish health, several studies suggest otherwise. Kuhnhold et al. (2017) found juvenile sandfish to be capable of acclimating to potentially stressful temperatures, and as a result suggested that 33ºC may be a feasible temperature for farming juveniles. They also observed that juveniles increased their feeding activity at higher temperatures (Kuhnhold et al., 2017). This suggests that higher temperatures would lead to faster growth, assuming that food resources do not become limiting. Similarly, a study by Lavitra et al. (2010) suggested that higher water temperatures led to faster growth of juvenile sandfish, but that juveniles were negatively affected by temperatures above 39ºC and died at 41ºC. Taken together, these studies suggest that temperature is not a major concern at the first farm. The average temperature at the farm was found to be around 30ºC to 34ºC on four of six sampling occasions – in other words, near or below 33ºC. The maximum temperature observed was 36ºC, well below the potentially dangerous conditions at 39ºC. The moderately warm conditions at the farm may therefore be beneficial by promoting faster growth of the sea cucumbers. However, the present study was conducted during a season of relatively cool weather in Zanzibar, so it is still possible that water temperatures could approach 39ºC at other times of the year. Additionally, it should be noted that the cited studies were conducted on juveniles, not adults. These studies are relevant currently because the majority of the individuals at the farm are juveniles, but the same data may not hold true as the sandfish continue to grow.

Although the farm is covered by over a meter of water at high tide, the very low water levels observed at low tides may be cause for concern. Purcell (2012) suggested that farming areas should have water between 0.2 meters and 2-3 meters in depth (as cited in Altamirano et al., 2016), and another study recommended a minimum depth of 10 to 50 centimeters (Pascal & Robinson, 2011). This farm does not meet these criteria. The minimum water depth experienced at the farm is zero centimeters, and on one sampling occasion, just three out of 13 measurement locations had more than 10 centimeters of water. This suggests that only a portion of the farm may be good habitat for the sandfish to survive, an idea that is supported by their non-random distribution and their concentration near the farm's outer walls. The distribution of the sandfish throughout the farm aligns more closely with depth than with the distribution of seagrass or sand, suggesting the sandfish may need to move to stay in deeper areas. However, it is also possible that they are pushed toward the walls by wave action. This was suggested by the farmer and supported by an observation at high tide of several sea cucumbers outside the farm being rolled by the water's motion. Given the location of the farm, and the fact that its walls cannot be relocated, improving the walls may be an appropriate action to improve water depth. Even using cement to patch the holes in the walls would make a difference by keeping more water within the farm, and making the walls taller would further improve water retention. Future farms may experience greater success if placed in deeper areas.

The substrate of the farm is composed primarily of sand and seagrass (*Thalassia hemprichii*), although these are not evenly distributed throughout the farm. Several studies suggest that the presence of sand as a substrate is highly important for sandfish, with recommended substrates ranging from coarse sand to sandy mud to mud. One experiment on raising juveniles in tanks found that growth rates were significantly higher when sand was present than when tanks were bare (Robinson et al., 2013), and a second experiment measured sandfish growth on several substrate types and saw the best performance on sand (Kim, 2012). A guide to sandfish farming recommended selecting sites with “soft, sandy-muddy sediment,” and Mercier et al. also showed that muddy sand and mud were the most important substrate types for sandfish that are between four and 25 centimeters long (Pascal & Robinson, 2011; Mercier et al., 2000a). Silty mud, such as from mangrove areas, was found to be less preferred by juveniles than other substrates and also led to a negative juvenile growth rate (Altamirano et al., 2016). In contrast to sand, seagrass seems to be less important than sand for juvenile and adult sandfish. Juveniles in one study did not differentially prefer sand with or without *T. hemprichii* for burying or feeding, and as mentioned above, seagrass was not among the important substrate types identified by Mercier et al. (Altamirano et al., 2016; Mercier et al., 2000a). However, seagrass may be very important for the settlement of larval sandfish. One experiment measured the settlement rates of larval sandfish on various substrates and found the highest rates of settlement to occur on *T. hemprichii*, with settled juveniles then staying on the seagrass for four to five weeks (Mercier et al., 2000b). Taken together, these previous studies suggest that the first farm has been placed fairly well with regard to substrate. It has sand, which is important for the growth of juveniles and adults, as well as *T. hemprichii,* which will be important for any reproduction that may occur within the farm. However, much of the sand is fairly shallow, which may limit sea cucumbers' ability to burrow. For this reason, the farmer and several interviewees shared the idea of bringing additional sediment into the farm. The farmer said he plans to source this sediment from the nearby mangrove area, but the results of the cited studies suggest that selecting sand or sandy mud rather than silty mangrove sediment may result in better sandfish growth.

As expected, the size distribution of the sea cucumbers at this farm reveals that very few are currently of harvestable size. Values for harvestable sizes in the literature are about 350 grams or larger (approximately 20.5 centimeters, according to the length-weight relationship published by Pitt and Duy) (Lavitra et al., 2010; Pascal & Robinson, 2011; Pitt & Duy, 2004). Pascal and Robinson (2011) suggest that it takes five to 12 months for juveniles of 15 grams (about six and a half centimeters) to reach marketable size, while the farmer at Kilimani suggested six to eight months, so this farmer can expect to be able to begin harvesting in under a year and potentially in as little as four or five months. Additionally, the lengths of the sea cucumbers at the farm further reveal that very few are reproductively mature, as the size of sandfish at first maturity was found to be 16.8 centimeters in one study and 16 centimeters in another (Kithakeni & Ndaro, 2002; Conand, 1993). However, it should be noted that individual sandfish can vary greatly in length as they expand and contract. A small experiment conducted to supplement the present study found that an individual sea cucumber's length ranged from 7% to 24.4% of its mean length, with the average individual having a range in length that was 14.2% of its mean length (Appendix D). The length data from this study should be evaluated with this variation in mind.

The estimate of the farm population resulting from this study (15,698 individuals) will be important for the farmer's knowledge and management of the farm. However, regarding analysis of carrying capacity, most previous studies have focused on biomass per area rather than numbers of individuals. Reported values for sandfish farms' carrying capacity, or the maximum amount of biomass per area that the farm can support, vary greatly. Examples include 250 grams per square meter in sea pens (i.e. pole-and-net enclosures) (Purcell & Simutoga, 2008); 380 grams per square meter in sea pens (Juinio-Meñez et al., 2014); 692 grams per square meter in sea pens (Lavitra et al., 2010); and 611 to 777 grams per square meter in tanks (Altamirano et al., 2016). In one study, a carrying capacity was not observed before the experiment ended at 940 grams per square meter (Watanabe et al., 2014). Since carrying capacity differs for each location and was not assessed in the present study, it is not possible to confidently evaluate the biomass per area at this farm. However, since the farm is currently at 244 grams per square meter and studies have seen carrying capacities of 250 or 380 grams per square meter, there is a possibility that this farm is approaching its carrying capacity. In any case, the current biomass would need to increase more than tenfold for the average individual to reach a harvestable size, which would almost certainly put the farm beyond its carrying capacity. Thus, the farmer should be aware that he will likely be unable to obtain many harvestable sandfish from the farm with its current population size. To address this issue, the farmer could stop purchasing new sandfish and try to sell more sandfish to other farms in order to reduce the population. It would also be beneficial to determine the carrying capacity of the site, which can be done in a simple experiment using small test plots, as described by Pascal and Robinson (2011).

Disease is a matter of concern for the farm first because it can lead to the death of sandfish, and second because discolored individuals are not sellable, both of which impact the farmer’s income. The finding that 18.15% of the sandfish at the farm show signs of poor health is therefore problematic for the farmer. The cuts on some sandfish were almost certainly caused by crabs, and it is possible that discoloration may also be related to crab predation. Many crab species are present at the first farm, but no evidence was collected regarding which species harm sea cucumbers. The farmer believes that a small, hairy species (likely *Pilumnus verspertilio*) is the problem, and explained that these crabs stay in burrows and that sea cucumbers may try enter those burrows, provoking the crabs to attack. However, other sources have identified the crab *Thalamita crenata,* also observed at the first farm, as a predator of sandfish (Lavitra et al., 2009; Pascal & Robinson, 2011), and Richmond (2011) described the species as “aggressive.” The farmer believes that crab-induced wounds make the sea cucumbers more vulnerable to disease, leading to the discoloration that was observed. However, similar symptoms have also been found to be caused in sandfish by low salinity (Lavitra et al., 2009), and by fungal diseases in the temperate species *Apostichopus japonicus,* in which bacterial diseases also occur (Wang et al., 2004). In order to control predation by crabs, Pascal and Robinson (2011) suggest employing crab traps as well as searching for crabs and removing them from the farm. Specifically, since a significant difference in size was found between healthy and unhealthy sandfish at this farm, it may be beneficial to segregate the sandfish by size and focus on controlling crab populations where the smaller sandfish concentrate. It may even be advisable to construct a “juvenile nursery,” or a small pen that is enclosed with mesh on all sides and across the top, to better protect small juveniles (Pascal & Robinson, 2011). Pascal and Robinson (2011) found that juveniles were less susceptible to harm from crabs and better able to recover from cuts after reaching 50 grams (about 10.5 centimeters). Additionally, reducing the population density, as already recommended, may help reduce the spread of disease within the farm.

At the second farm, water temperature was less variable than that at the first farm, likely due to the fact that it is subtidal and consistently covered with water, rather than intertidal. It was also generally cooler than the first farm, with a maximum temperature of 33ºC rather than 36ºC. This suggests that sea cucumber growth rates may be somewhat slower at the second farm than at the first farm, but temperature is likely not a concern with regard to sea cucumber survival.

The substrate composition of the second farm differed most noticeably from the first farm with regard to its diversity of seagrass species. The second farm has three species of seagrass, while the first farm has only one. While both farms will likely benefit from the presence of *T. hemprichii* due to its role in larval settlement, the greater diversity at the second farm may promote greater ecosystem diversity and health in general, which could benefit the sandfish and their food sources. The second farm also seems to have even more habitat for juveniles and adults, since it has a greater proportion of sand and has no rock.

The total population of the second farm is moderately lower than that of the first farm, but because the second farm is larger, its biomass per area is much lower. The 149 grams per square meter at the second farm is well below the lowest carrying capacity reported in the literature, 250 grams per square meter (Purcell & Simutoga, 2008). This lower biomass value is a positive sign for the continued growth of the sandfish. However, if the carrying capacity of the site is low, the biomass per area could still be too high for many individuals to reach harvestable size, since they need to grow quite a bit more. The current biomass of the farm would need to increase approximately fivefold for the average sandfish to reach a harvestable size, a biomass that would likely be supported by some sites but not others. To manage this uncertainty, the farmer should monitor the growth of the sandfish at this farm and take actions to reduce the population if sandfish growth seems to slow or stop, such as by selling sandfish to other farms.

As recommended for the first farm, a simple experiment to determine the site's carrying capacity could also be conducted.

The sea cucumbers at the second farm were larger than those at the first farm, and there was also a smaller range in length among the sea cucumbers. This is at least partly explained by the farmer's stocking practices, as he said that he does not add very small individuals to this farm. The data collected in this study is not sufficient to say whether the larger sizes at the second farm are due to faster growth rates. Similar to the first farm, the second farm has no, or very few, sea cucumbers that have reached harvestable size or reproductive maturity. However, at least a few individuals are approaching the 16- to 17-centimeter maturity length, so the farmer can expect that reproduction may begin occurring soon at the second farm. Due to the larger sizes of sea cucumbers at the second farm, the farmer can also anticipate being able to harvest from the second farm before the first farm is ready.

The data indicates a much lower prevalence of signs of poor health at the second farm compared to the first farm (6.45% and 18.15%, respectively). However, proposing a cause for this difference is not within the scope of this study. Multiple factors at the second farm could potentially contribute, such as a lower abundance of crabs, absence of certain crab species, or absence of certain pathogens. It is also possible that the lower population density at the second farm has played a role in reducing the spread of disease among the sea cucumbers.

The information gathered from interviewing community members contributes several insights into sea cucumbers and sea cucumber farming, both in Unguja Ukuu and more broadly. For instance, the interviews demonstrated that sea cucumbers play a significant role in the local economy and fishing practices. A large number of interviewees either collected sea cucumbers or knew people who collected them, and many demonstrated a deeper awareness of the sea cucumber fishery when they described declines in sea cucumber populations. Even the fact that a majority of respondents had some knowledge of sea cucumbers reflects the close relationship between this marine resource and the Unguja Ukuu community. These trends suggest that sea cucumber farming may represent an important way to revitalize the role of sea cucumbers in the local economy. In fact, interviewees did see the farm as something that would benefit the broader community. Reasons that interviewees saw the farm positively included the creation of jobs, since the farmer is employing other men to help him, and increases in wild populations as a result of the farm, which would increase fishers' income by allowing them to collect more sea cucumbers. Relatedly, the social network underlying the farm incorporates people both within Unguja Ukuu and across Unguja Island. Due to the nature of the product as something consumed mostly in Asia, the network even indirectly extends outside of Zanzibar. Thus, even a small sea cucumber farming operation can create a fairly widespread economic impact and represent a connection to the world economy.

A combination of ideas expressed by interviewees suggests that an important outcome of sea cucumber farming in general is that it makes access to sea cucumbers easier and more reliable. Sea cucumbers are currently rare to find on foot and must be collected largely by swimming and diving, a difficult and time-consuming activity. Additionally, sea cucumbers are mostly found only at certain times of the year, an element of uncertainty that would be eliminated in the context of harvesting from a farm rather than collecting intertidally. Farming would also help alleviate the concerns about low prices and price fluctuations that some people expressed, since people could choose to wait to harvest until prices are good, as opposed to relying on collecting sea cucumbers whenever they are found.

A general observation from the various interviews conducted is that there is a general lack of knowledge or certainty about what regulations, if any, exist regarding the collection, sale, and export of sea cucumbers. This is undesirable for multiple reasons. On one hand, if people are not aware of restrictions on the use of sea cucumbers, this may lead to overexploitation of the resource. On the other hand, if people falsely believe that there are rules against farming or exporting sea cucumbers, this may prevent people from engaging in a potentially beneficial livelihood activity. Clear communication from decision-makers in fisheries management will benefit both sea cucumbers and users of sea cucumbers.

Another broad theme to be considered is the transfer of knowledge about sea cucumber farming, which currently does not seem to be very easy or efficient. In Unguja Ukuu, two interviewees believed that sea cucumber farming would not expand significantly, both reasoning in part that no one else has the knowledge necessary to succeed at farming. At the farm at Kilimani, the farmer said that he had not received much help or information from the government when starting the farm. The farmers at Kilimani have turned to internet resources and seminars in order to learn about sea cucumber farming, but these resources are likely not available to many of the people who might be interested in farming. These difficulties are echoed by the Zanzibar Fisheries Policy, which states: “Promotion of fisheries through aquaculture has been concentrated on seaweed while little attention is given to other products. The production of other aquaculture products is inhibited by lack of expertise and financial resources” (The Revolutionary Government of Zanzibar, 2013, p. 17). Similarly, participants in a workshop on sea cucumbers in the Indian Ocean identified needs for training and knowledge regarding sea cucumber farming, hatcheries, and biology (“Report of the FAO Workshop on Sea Cucumber Fisheries…”, 2013). Taken together, these anecdotes imply that a person wishing to begin farming sea cucumbers in Zanzibar or elsewhere will struggle to receive or find knowledge about how to do so, which will likely limit the spread of this practice. Ideally the government will continue to work to make this knowledge available to people, but since these officials are occupied with numerous tasks, this may be a good opportunity for an NGO or other volunteer organization to step in. This organization could be responsible for compiling basic information regarding sea cucumber farming, as well as new or important findings, and distributing these to coastal villages around Unguja Island, where any individual would then be more able to begin farming. It is hoped that this study can contribute to the base of information about sea cucumber farming for others.

Briefly, additional barriers to the spread of sea cucumber farming are monetary ones. Starting a farm requires a substantial initial investment, as the farm must be constructed and stocked with sea cucumbers. The farmer also will not earn money at first, since the sea cucumbers will take time to reach a harvestable size. These factors will likely limit the ability of low-income people to participate in farming unless some sort of financial assistance is provided by the government or another organization, or perhaps by farmers whose farms are already well-established.

A topic of concern for this farm and others is the source of the sea cucumbers stocked at the farm. At Unguja Ukuu, this is a complex issue. The purchase of wild sea cucumbers supports local fishers, but it also has caused fishers to collect smaller sea cucumbers than they did previously because they can now get money for them. In this way, the farm may pose a threat to the wild sea cucumber populations in the area. These concerns may be alleviated by the government's creation of a hatchery, which is set to open later in 2017 (Dr. Narriman Jiddawi, personal communication, April 17, 2017). If knowledge about and access to this hatchery are widespread, then this would allow farmers to purchase sea cucumbers from a more sustainable source. However, buying from a hatchery means not buying elsewhere, so local fishers could experience more difficulty in trying to sell the sea cucumbers they have collected, posing a potential threat to their income.

Observing the construction of the sea cucumber farms at Unguja Ukuu and Kilimani invites consideration of the uses and management of coastal space. All of the farms necessarily occupy space in the intertidal and shallow subtidal; include fences or walls that may alter patterns of sedimentation and erosion, and may interfere with boat traffic and anchoring; and lead to a loss of space for other uses such as fishing. Thus, the construction of sea cucumber farms has implications for other community members who are using the coastal zone in other ways. Eriksson et al. (2012, p. 116) point out that the loss of area for other uses, like fishing, "may trigger competition for space and user conflicts," and Pascal and Robinson (2011) recommend that all such changes in the use of space should be discussed and agreed upon by all stakeholders. Presently, there are no formal regulations regarding construction in these spaces, and according to the Zanzibar Fisheries Policy, the National Land Use Plan does not address the use of land for aquaculture purposes (The Revolutionary Government of Zanzibar, 2013). In Unguja Ukuu and elsewhere, communities should be proactive in addressing how they use and share coastal spaces so the needs of sea cucumber farmers can be balanced with the needs of other resource users.

Finally, in addition to making access to sea cucumbers more reliable and easy, farming may also have the potential to make access to this resource more equitable. In the past, sea cucumbers were more abundant and could be found on foot by women or men. Currently, however, sea cucumbers can mostly be accessed only by swimming or diving, techniques that are only practiced by men. For several sites on mainland Tanzania, Mmbaga and Mgaya (2004) stated: "Adult males predominantly operate this fishery (male = 99%, female = 1%) because collection is physically difficult." Aquaculture, particularly seaweed farming, is already practiced by women in Zanzibar, so the possibility exists for women to become involved in sea cucumber farming, restoring more equal access to profits from sea cucumbers among genders.

When considering the outcomes and implications of this study, several limitations should be kept in mind, some of which have been discussed previously alongside the corresponding result. For the first farm, for instance, the farm boundaries used were somewhat arbitrary because the farm is not completely enclosed. However, the chosen boundaries were consistent, and only the selected area was sampled and used for population estimates. Additionally, the farm assistants said that they try to remove some of the more severely diseased sea cucumbers, which could mean that the data presented here underestimate the true prevalence of disease at the farm. For the second farm, a major limitation was the low sampling intensity. The sample sizes were much smaller at the second farm than at the first farm, so comparisons between the two farms should be interpreted accordingly. The population estimate for the second farm is also somewhat less reliable than that for the first farm due to the deeper water and denser seagrass at the second farm, which made it more likely to miss some sea cucumbers in quadrats. Regarding data collected from interviews, it should be noted that challenges were faced due to relying on an interpreter and being an outsider to the community. These factors may mean that responses were not understood exactly as interviewees intended to convey them, and that interviewees may have kept some information and opinions to themselves. While the topics of conversation were fairly mundane, it is always possible that interviewees held more emotional or personal ideas about the issues that they were unwilling to share with someone outside the community.

In the future, work should be done to determine the carrying capacity of this particular farming site, as this would be extremely helpful for the management of the farm. An evaluation of the salinity at this site would also be an important addition to the temperature and depth data collected in this study. Studies should also be conducted to evaluate viable methods for controlling crab predation. This farm and others would further benefit from studies on the diseases of sandfish and their causes, prevention, and treatment. More broadly, it is highly important to seek information on the impacts of sea cucumber farming on the health and biodiversity of the ecosystems in which farms occur.

Conclusion

This study represents a biological and social description and evaluation of sea cucumber farming at Unguja Ukuu, Zanzibar, with implications for sea cucumber farming more broadly. Along with descriptive information on the farms and practices studied, specific environmental and biological data were also generated for the purposes of improving this and other sea cucumber farms. Information such as total populations and size distributions will be valuable to the farmer for managing the farms. Other data invite recommendations for improved management. At the first farm, water depth, biomass, disease, and substrate were found to be issues of concern. Specifically, the shallow water depth limits viable sea cucumber habitat; the current biomass per area may not allow sandfish to grow to harvestable size; the high prevalence of disease causes a loss of product; and the potential addition of mangrove sediment may be detrimental to sandfish growth. The farmer may therefore benefit from improving the farm's walls, reducing the biomass per area, controlling crab populations, and adding sand rather than mangrove silt. The second farm largely does not face these concerns.

The farms were found to bring together a network of people and money both within and outside of Unguja Ukuu. Community members revealed the importance of sea cucumbers in the local economy and saw potential community benefits arising from farming. It seems that sea cucumber farming has the potential to make access to sea cucumbers easier and more reliable for all fishers, as well as more equitable among genders. However, several large themes must be dealt with in order for sea cucumber farming to expand successfully, including the transfer of knowledge about farming, the sustainable sourcing of juvenile sea cucumbers, and the use of and rights to coastal space. Future studies should also work to clarify biological and ecological details, including those of disease and impacts on biodiversity. It is hoped that the information presented in this study will be important in disseminating knowledge about sea cucumber farming to Zanzibaris, ultimately benefitting both sea cucumbers and people.

References

Altamirano, J. P., Recente, C. P., & Rodriguez, J. C., Jr. (2017). Substrate preference for burying and feeding of sandfish *Holothuria scabra* juveniles. *Fisheries Research,186*, 514-523. doi:10.1016/j.fishres.2016.08.011

Conand, C. (1993). Reproductive biology of the holothurians from the major communities of the New Caledonian Lagoon. *Marine Biology,116*, 439-450.

Eriksson, B. H., De la Torre-Castro, M., Eklof, J., & Jiddawi, N. (2010). Resource degradation of the sea cucumber fishery in Zanzibar, Tanzania: A need for management reform. *Aquatic Living Resources,23*, 387-398. doi:10.1051/alr/2011002

Eriksson, H., Robinson, G., Slater, M. J., & Troell, M. (2012). Sea cucumber aquaculture in the Western Indian Ocean: Challenges for sustainable livelihood and stock improvement. *Ambio,41*(2), 109-121. Retrieved May 8, 2017, from http://www.jstor.org/stable/41417395

Ferdouse, F. (2004). World markets and trade flows of sea cucumber/beche-de-mer. In Lovatelli, A., Conand, C., Purcell, S., Uthicke, S., Hamel, J., & Mercier, A. (Eds.), *FAO fisheries technical paper 463: Advances in sea cucumber aquaculture and management*. FAO. Retrieved April 2, 2017, from http://www.fao.org/docrep/007/y5501e/y5501e0f.htm#bm15

Hamel, J., Conand, C., Pawson, D. L., & Mercier, A. (2001). The sea cucumber *Holothuria scabra* (Holothuroidea: Echinodermata): Its biology and exploitation as Beche-de-mer. *Advances in Marine Biology,41*, 129-223. doi:10.1016/S0065-2881(01)41003-0

Hamel, J.-F., Mercier, A., Conand, C., Purcell, S., Toral-Granda, T.-G. & Gamboa, R. (2013). *Holothuria scabra*. The IUCN Red List of Threatened Species 2013: e.T180257A1606648. http://dx.doi.org/10.2305/IUCN.UK.2013-1.RLTS.T180257A1606648.en. Downloaded on 01 April 2017.

Horrill, J. C., Darwall, W. R., & Ngoile, M. (1996). Development of a Marine Protected Area: Mafia Island, Tanzania. *Ambio,25*(1), 50-57.

Introduction. (2004). In Lovatelli, A., Conand, C., Purcell, S., Uthicke, S., Hamel, J., & Mercier, A. (Eds.), *FAO fisheries technical paper 463: Advances in sea cucumber aquaculture and management*. FAO. Retrieved April 2, 2017, from http://www.fao.org/docrep/007/y5501e/y5501e05.htm#bm05

Juinio-Menez, M. A., Evangelio, J. C., & Miralao, S. J. (2014). Trial grow-out culture of sea cucumber *Holothuria scabra* in sea cages and pens. *Aquaculture Research,45*, 1332-1340. doi:10.1111/are.12078

Kim, N. (2012). A study of sea cucumbers (Holothuriidae) *Holothuria scabra* with an assessment of its socioeconomic impact in Dar es Salaam, Tanzania. *SIT*.

Kithakeni, T., & Ndaro, S. G. (2002). Some aspects of sea cucumber, *Holothuria scabra* (Jaeger, 1935), along the coast of Dar es Salaam. *Western Indian Ocean J. Mar. Sci.,1*(2), 163-168.

Kuhnhold, H., Kamyab, E., Novais, S., Indriana, L., Kunzmann, A., Slater, M., & Lemos, M. (2017). Thermal stress effects on energy resource allocation and oxygen consumption rate in the juvenile sea cucumber, *Holothuria scabra* (Jaeger, 1833). *Aquaculture,467*, 109-117. http://dx.doi.org/10.1016/j.aquaculture.2016.03.018

Lavitra, T., Rasolofonirina, R., Jangoux, M., & Eeckhaut, I. (2009). Problems related to the farming of *Holothuria scabra* (Jaeger, 1833). *SPC Beche-de-mer Information Bulletin,29*, 20-30. Retrieved from http://www.spc.int/coastfish/en/publications/bulletins/beche-de-mer.html

Lavitra, T., Rasolofonirina, R., & Eeckhaut, I. (2010). The effect of sediment quality and stocking density on survival and growth of the sea cucumber *Holothuria scabra* reared in nursery ponds and sea pens. *Western Indian Ocean J. Mar. Sci.,9*(2), 153-164.

Mercier, A., Battaglene, S. C., & Hamel, J. (2000a). Periodic movement, recruitment and size-related distribution of the sea cucumber *Holothuria scabra* in Solomon Islands. *Hydrobiologia,440,* 81-100.

Mercier, A., Battaglene, S. C., & Hamel, J. (2000b). Settlement preferences and early migration of the tropical sea cucumber *Holothuria scabra*. *Journal of Experimental Marine Biology and Ecology,249,* 89-110.

Mmbaga, T. K., & Mgaya, Y. D. (2004). Sea cucumber fishery in Tanzania: identifying the gaps in resource inventory and management. In Lovatelli, A., Conand, C., Purcell, S., Uthicke, S., Hamel, J., & Mercier, A. (Eds.), *FAO fisheries technical paper 463: Advances in sea cucumber aquaculture and management*. FAO.

Pascal, B., & Robinson, G. (2011). *Handbook for sandfish farming* (M. De San, Ed.). ReCoMaP, Indian Ocean Commission. Retrieved from https://www.researchgate.net/publication/235900295_Handbook_for_sandfish_farming

Pitt, R., & Duy, N. (2004). Length–weight relationship for sandfish, *Holothuria scabra*. *SPC Beche-de-mer Information Bulletin,29,* 39-40. Retrieved from http://www.spc.int/coastfish/en/publications/bulletins/beche-de-mer.html

Purcell, S. W., & Simutoga, M. (2008). Spatio-temporal and size-dependent variation in the success of releasing cultured sea cucumbers in the wild. *Reviews in Fisheries Science,16*(1-3), 204-214. doi:10.1080/10641260701686895

Purcell, S. (2012). Principles and science of stocking marine areas with sea cucumbers. In: Hair, C.A., Pickering, T.D., Mills, D.J. (Eds.), *Asia-Pacific Tropical Sea Cucumber Aquaculture, ACIAR Proceedings* NO 136. Australian Centre for International Agricultural Research, Canberra, 92-103.

Report of the FAO Workshop on Sea Cucumber Fisheries: An Ecosystem Approach to Management in the Indian Ocean (SCEAM Indian Ocean) (Rep. No. 1038). (2013). Rome: Food and Agriculture Organization of the United Nations.

The Revolutionary Government of Zanzibar. (2013). *Zanzibar Fisheries Policy*.

Richmond, M. D. (Ed.). (2011). *A Field Guide to the Seashores of Eastern Africa and the Western Indian Ocean Islands* (3rd ed.). Sida/WIOMSA.

Robinson, G., & Pascal, B. (2009). From hatchery to community – Madagascar's first village-based holothurian mariculture programme. *SPC Beche-de-mer Information Bulletin,29*, 38-43. Retrieved from http://www.spc.int/coastfish/en/publications/bulletins/beche-de-mer.html

Robinson, G., Slater, M. J., Jones, C. L., & Stead, S. M. (2013). Role of sand as a substrate and dietary component for juvenile sea cucumber *Holothuria scabra*. *Aquaculture,392-395*, 23-25. http://dx.doi.org/10.1016/j.aquaculture.2013.01.036

Rowe, F. W., & Richmond, M. D. (2011). Phylum Echinodermata - Echinoderms. In M. D. Richmond (Ed.), *A Field Guide to the Seashores of Eastern Africa and the Western Indian Ocean Islands* (3rd ed., pp. 300-331). Sida/WIOMSA.

Uthicke, S. (2001). Nutrient regeneration by abundant coral reef holothurians. *Journal of Experimental Marine Biology and Ecology,265*, 153-170.

Uthicke, S., & Klumpp, D. W. (1998). Microphytobenthos community production at a near-shore coral reef: seasonal variation and response to ammonium recycled by holothurians. *Marine Ecology Progress Series,169*, 1-11.

Wang, Y. G., Zhang, C., Rong, X., Chen, J., Shi, C., 2004. Diseases of cultured sea cucumber, Apostichopus japonicus, in China. In: Lovatelli, A., Conand, C., Purcell, S., Uthicke, S., Hamel, J.-F., Mercier, A. (Eds.), *Advances in Sea Cucumber Aquaculture and Management*. FAO Fisheries Technical Paper, 463. FAO, Rome, 297–310.

Watanabe, S., Sumbing, J. G., & Lebata-Ramos, M. J. (2014). Growth pattern of the tropical sea cucumber, *Holothuria scabra*, under captivity. *JARQ,48*(4), 457-464.

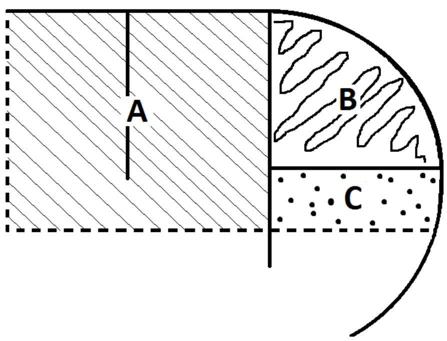
Wolkenhauer, S., Uthicke, S., Burridge, C., Skewes, T., & R. P. (2010). The ecological role of *Holothuria scabra* (Echinodermata: Holothuroidea) within subtropical seagrass beds. *Journal of the Marine Biological Association of the United Kingdom,90*(2), 215-223. doi:10.1017/S0025315409990518

Appendix A: Maps of Study Location

<u>Appendix B:</u> Calculation of Farm Areas

First Farm

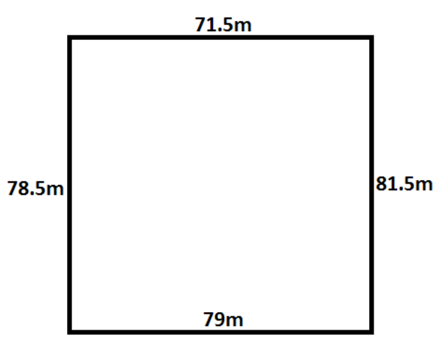
The area of the first farm was approximated by breaking it into three sections: A, a rectangle; B, a quarter-circle; and C, a rectangle. The dimensions of section A are taken directly from the farm diagram presented earlier. The radius used for section B was 22.6 meters, which is the average of the lengths of its two linear walls (as shown in the earlier diagram). The height of section C was taken from the earlier diagram, and the width used was 23.35 meters, which is the average of the lengths of the two walls running horizontally in the diagram.



Section A:	Area = (width)(height) = (37.5m)(30m)	= 1,125m^2
Section B:	Area = (0.25)(π)(r^2) = (0.25)(3.14)(($22.6m)^2$)	= 401m^2
Section C:	Area = (width)(height) = (23.35m)(8.5m)	= 198m^2
Total:		= **1,724m^2**

Second Farm

The second farm is roughly rectangular. It has four straight sides, but the corners are not exactly 90º angles. However, for the purpose of estimating its area, it was assumed to be a rectangle.



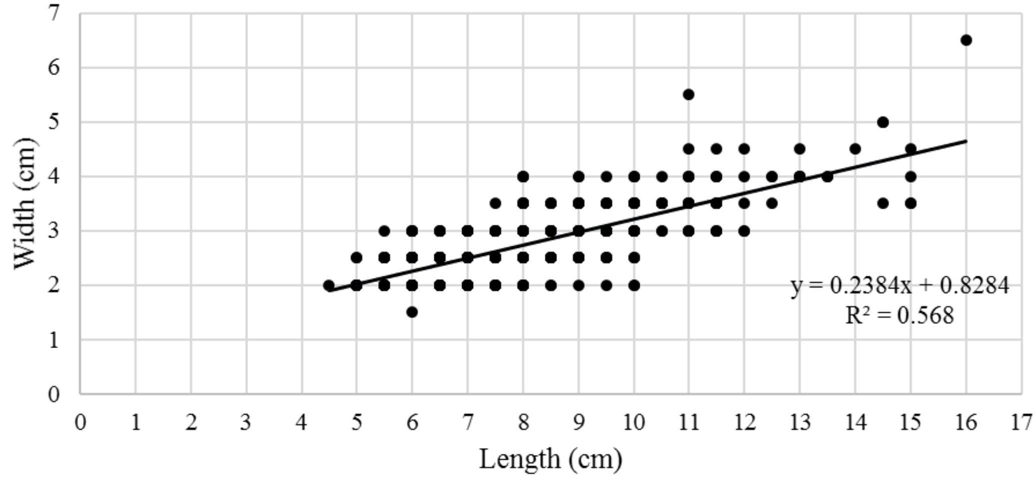
To approximate the dimensions of the rectangle, the lengths of each pair of parallel sides were averaged.

Width = (71.5m + 79m)/2 = 75.25m
Height = (78.5m + 81.5m)/2 = 80m

Area = (width)(height) = (75.25m)(80m) = **6,020m^2**

Appendix C: Length-Width Relationship

The width of each individual at the widest point was measured on seven of the eight sampling occasions to obtain a length-width relationship. Length and width had a moderately strong, positive correlation ($R^2 = 0.568$), but there was considerable variation in the widths observed for a given length.



Appendix D: Variation in Length

To better understand the variation in the size of individual sandfish, a small experiment was conducted in which the same individuals were measured repeatedly. First, an individual was selected, picked up, and measured to the nearest half-centimeter (time=0). Then, the sea cucumber was set down, and the stopwatch was started. Measurements were then taken every minute for the next four minutes, without picking up the sea cucumber, resulting in a total of five measurements per individual. This procedure was repeated for 12 individuals.

Average Length (cm)	Range in Length (cm)	Range as Percentage of Average Length (%)
6.2	1	16.1
6.5	1	15.4
7.1	0.5	7.0
7.5	1.5	20.0
8.2	2	24.4
8.7	1	11.5
9.5	1.5	15.8
11.0	1	9.1
14.8	3	20.3
15.3	2	13.1
18.6	1.5	8.1
21.8	2	9.2
		Average = 14.2

Appendix E: Photographs Documenting Poor Health

Sandfish with cuts:

Sandfish with discoloration:

Appendix F: Summary Sheet for Farmer

Summary of Study Results

Farm near the Fish Market:

The temperature of the water is not a concern. Temperature at the farm was between 25ºC and 36ºC during low and mid tides. Majongoo mweupe can acclimate to temperatures of at least 33ºC, but temperatures above 39ºC may be dangerous. They grow faster at higher temperatures.

The salinity of the water was not measured successfully, but this would be useful information to know in the future.

The shallow depth of the water, and the absence of water in some areas, is a concern. Repairing the holes in the walls would be a good first step to address this issue. Future farms should be located in deeper water, where the farm will not become dry.

The type of seagrass found at the farm is an important species for majongoo mweupe larvae. This may help reproduction to occur successfully at the farm.

Other studies have shown that majongoo mweupe grows well on sand and muddy sand, but they do not grow well on mangrove sediment. Any sediment that is added to the farm probably should not be taken from mangrove areas.

The average length of the sea cucumbers is 7.86 centimeters. Most of the sea cucumbers are around 6 to 8 centimeters long. The minimum length is 4.5 centimeters, and the maximum length is 16 centimeters. A few sea cucumbers were also seen that were 20 centimeters long. Majongoo mweupe are able to reproduce when they are longer than 16 to 17 centimeters, so only a few individuals are reproducing now.

There are about 15,700 sea cucumbers at the farm. The total weight of all the sea cucumbers is about 421,500 grams. This also means there are 244 grams per one square meter. This is a concern. Each different area has a limit for the weight of sea cucumbers that can live there. Other studies have said that this limit can be as low as 250 grams per square meter, or it can be higher than 940 grams per square meter. We do not know what the limit is here at this farm. However, the sea cucumbers must grow a lot more before they are ready, and this will probably cause the weight to surpass the limit. If the weight is higher than the limit, the sea cucumbers will stop growing. This means that with 15,700 sea cucumbers at the farm, it will not be possible for many of them to reach a large, harvestable size. The number of sea cucumbers should be reduced, otherwise they will probably stop growing before they are big enough.

About 2.23% of the sea cucumbers have cuts (from crabs). About 15.92% of the sea cucumbers have discoloration (usually on the bottom, and usually blue). This means that 18.15% of the sea cucumbers are unhealthy in some way. The unhealthy sea cucumbers are smaller than the healthy sea cucumbers. It may be helpful to reduce the number of crabs, maybe by trapping or catching them. Other studies have said that the aggressive, green crab with the colorful claws, is a big problem for sea cucumbers. Because the smaller sea cucumbers have more problems, it may be helpful to separate the smaller sea cucumbers and use extra effort to protect them. The discoloration may be caused by cuts from crabs, but it may also be caused by low salinity or a fungus or bacteria. Having fewer sea cucumbers may help prevent the diseases from spreading from one sea cucumber to another.

Farm in the Mangrove Area:

It should be noted that this farm was only studied for two days, while the first farm was studied for many more days.

The temperature of the water is not a concern. The temperature is cooler and less variable compared to the first farm. Temperature at the farm was between 28ºC and 33ºC at low tides.

The depth of the water is not a concern. It is good that the farm does not become dry at low tide.

The type of seagrass that is important for the larvae is also found at this farm.

The average length of the sea cucumbers is 11.72 centimeters. The minimum length is 8.5 centimeters, and the maximum length is 15.5 centimeters.

There are about 11,850 sea cucumbers at the farm. The total weight of all the sea cucumbers is about 894,500 grams. This also means there are 149 grams per one square meter. This is probably not a concern. This amount of weight per area is much lower compared to the other farm. The sea cucumbers can probably continue to grow more without reaching the weight maximum. However, be careful about putting too many sea cucumbers here, or the same problem as the first farm could occur.

About 3.23% of the sea cucumbers have cuts. About 3.23% of the sea cucumbers have discoloration. This means that 6.45% of the sea cucumbers are unhealthy in some way. It is unknown whether the healthy sea cucumbers are different in size from the unhealthy ones.

Ideas of Community Members:

All of the people I talked to thought sea cucumber farming was a good idea. People said the farm is good because it will increase the number of sea cucumbers outside the farm, it makes harvesting easy, it can be used to educate people about sea cucumbers, it can be an example for other people to start farming sea cucumbers, it can supply sea cucumbers to other farms, it creates jobs, and it can be used as a tourist attraction.

Some people said they were concerned about crabs, and about theft of the sea cucumbers. Some people were concerned that the sediment is too shallow and said that more sediment should be added to the farm.