An Alternative Method of Bivalve Farming
Bweleo, Unguja

Sarah Wilkins
Academic Advisors: Dr. Narriman Jiddawi and Dr. A.J. Mmochi
Academic Director: Ben Miller
School for International Training
Zanzibar, Tanzania: Coastal Ecology Spring 2006

Table of Contents

Acknowledgments

This project would not have survived without the help of so many wonderful people. I'd like to begin by thanking my advisors, Dr. Narriman Jiddawi and Dr. A.J. Mmochi, for their help and support during the past month. Also, thank you to Dr. Flower Msuya for all her help—she was extremely supportive in lending me her ideas for this project.

Thank you to Ben Miller and Said Omar, my academic directors, for their guidance, support, and wisdom during these past 3 months.

I am very grateful to the SUCCESS (Sustainable Coastal Communities and Ecosystems) program for their financial contribution to this project.

Big thanks to Salum Hamad, my translator and guide, for all his help and hard work; and to BiAmina Khamis and BiFatuma Ramadhani for their determination, humor, insight, kindness, and help.

And finally, thank you to the people of Bweleo for warmly welcoming me to their village. I am especially grateful to all those who helped me with my project. Thanks to the seaweed farmers and fishermen, also know as "mamama and mababa chaza" (the mothers and fathers of chaza) who made this project a success.

Abstract

The effectiveness and suitability of an alternative method for bivalve farming was studied in Bweleo, Unguja. Bivalve farming contributes significantly to the local economy and diet of local peoples. Current methods of bivalve farming (including fence and stone culture) in the villages of Fumba and Bweleo have resulted in low yields due to a high risk of mortality. Water quality tests and field analyses, including bivalve growth and fouling, were measured in two rafts that were constructed to determine their effectiveness as an alternative method of bivalve farming. Informal interviews were also conducted with local farmers to gain background information on bivalve farming. Educational workshops and meetings were held in the community to gain feedback and provide information on the project. This report provides valuable baseline data on the feasibility and usefulness for this alternative method, as well as recommendations for continued practice.

Introduction

Bivalve farming in Bweleo, Unguja is currently at a pilot stage of development. In October 2004, the Institute of Marine Sciences, UDSM, initiated a bivalve farming project involving local fisherwomen. Farms were established in Bweleo, and the neighboring village of Fumba. This IMS project strives to educate women about the economic benefits of bivalve farming and the methodologies involved (Cohen 2005). Most recently, IMS has been involved with the implementation of a kiosk for women to sell their bivalves in the neighboring village of Fumba. The kiosk has yet to be opened due to an issue surrounding property rights.

Bivalves collected throughout the region have important economic benefits for local fisher people and significantly contribute to the diet of people throughout the region (Richmond 2002). This form of aquaculture has stimulated the local economy by providing sources of income for the women of Bweleo. For centuries, people have collected bivalves from the sea as an important source of protein. The foot or meat of the mollusk, is eaten in its natural state or with seasonings, and is considered a delicacy in many parts of the world. Bivalve aquaculture is practiced in the coastal regions of Asia, Europe, and South America, and is a significant animal protein. Today in Bweleo, bivalves are harvested on a small scale compared to other parts of the world such as Japan and Spain, and less time is spent on collecting bivalves than on seaweed farming (Cohen 2005). The next step in the IMS project is to upscale bivalve farming so that it is a sustainable economic alternative.

Methods of Bivalve Farming

Two forms of aquaculture are currently used in coastal regions throughout the world: intensive and extensive methods. Intensive methods involve the culturing of organisms in high densities within cages or pens. This method is costly, but if successful, can produce high yields. There is a low risk of predation involved, but high risk of environmental degradation (Richmond 2002). Intensive farms use food, fertilizer, and antibiotics to increase yields and often times build facilities on top of clear-cut mangrove stands. The potential for coastal pollution from pond effluent increases drastically as farming systems intensify (Tacon 2003). This form of aquaculture is used in the United States, Japan, India, and most recently Tanzania. The Institute of Marine Sciences became involved with this form of aquaculture in 1996. During this year, the institution started a research project on how to farm finfish, shellfish, and seaweed together in semi-intensive mariculture ponds. The project was successful at harvesting milkfish and rabbitfish, but unsuccessful at producing shellfish or seaweed (Dubi *et al.* 2004).

Extensive methods rely on farmed species being maintained in their natural environment and use a low density of wild caught or cultured organisms (Richmond 2002). This method requires no feeding strategy and is often times conducted on a small-scale, in and around rural coastal communities. Unlike intensive aquaculture, this form is less costly and produces lower yields. Over-harvesting and disruption of the intertidal zone has been observed in some unsustainable practices, but environmental impacts are few compared with intensive methods. These impacts have yet to be studied in the region.

Currently, two methods of extensive bivalve farming exist in Bweleo: fence and stone culture. Farms are constructed in the intertidal zone alongside seaweed farms. The spat (juvenile bivalves) are attached to hard substrate (stick or stone) and grown until they are ready to harvest (known as the culch stage). Recently, farmers have been facing increased bivalve die-offs in their farms due to predation and overexposure to sunlight (Cohen 2005).

This report explores an alternative method of extensive bivalve farming that incorporates designs from seaweed rafts used in Bagamoyo, Tanzania, and bivalve rafts built in other regions of the world such as India and Japan. Raft culture is considered to be one of the most suitable farming methods in sheltered bays and has proven extremely successful in the Galicia province of Spain (Persoone 1982). In parts of the South Pacific, Black-lip Pearl oysters (*Pinctada margaritifera)* have been successfully harvested from bivalve rafts (Ellis and Haws 2000).

Ecology of Mollusks

All of the mollusks mentioned in this report are bivalves, meaning they have two shells that house and protect their body parts (Figure 1) (Ellis and Haws 2000). The most common species of bivalve harvested in Bweleo include *Andara antiquata* (makorobwe), *Isognomom isognomon* (mamie chaza), and *Pinctada margaritifera* (chaza), commonly known as the Black Lip Pearl Oyster (Cohen 2005). Tides and currents play an important role in the development of bivalves, effecting stabilization, turbididity, nutrient availability, and the replenishment of clean, oxygenated water and plankton. The maintenance of high water quality is important to their health and survival. Mollusks tolerate a salinity range between 24 and 50%. If salinity levels fall below 15%, mortality will occur. The optimal temperature for mollusk growth is between 20 and 25°C. Below 13°C, hibernation is induced, and below 6°C, mortalities occur. Bivalves prefer clear waters and depths between 10 and 15 m, where silting is minimal (Garrido-Handog 1991). They are filter feeding herbivores that depend on plankton in the water column.

The development of bivalve from egg to substrate attachment requires approximately 15 days after spawning. Spawning occurs in 20 to 24 °C waters. Their survival is highly dependent on whether the larva can firmly immobilize itself onto a suitable substrate. Bivalves attach themselves to hard substrates via byssus threads located near their hinge or ligament (Figure 1). If overcrowding occurs, the spat will die from a lack of food and oxygen (Prytherch 1934). In tropical regions, the species *Pinctada margaritifera* prefers to spawn during the hot season from November to May with the young appearing during the cold, rainy season in April (Pouvreau *et. al* 2000). Growth of both *Pinctada margaritifera* and *Isognomon isognomon* can be observed by the extension of the layer known as the periostracum (Figure 1). This layer may be thick and dark, or thin and transparent, forming bristles or plates. *Pinctada m*. is often found with a thick, layered, and often fringed periostracum (Richmond 2002).

Biofouling and boring organisms also threaten bivalve health and survival. Boring organisms such as polychaete worms and sponges, and biofouling organisms such as other mollusks, barnacles and corals, can stunt growth and kill mollusks. Large predators include benthic fish and crabs (Garrido-Handog 1991). Farmers often protect their crop by removing the foulers before they can cause serious damage.

Figure 1. Bivalve morphology.

Study Area

Zanzibar is an archipelago comprised of the islands Unguja and Pemba, off the coast of Tanzania, East Africa (Figure 2). The shoreline surrounding Unguja is primarily fringing reef, making it a suitable region for fishing, seaweed farming, and small-scale bivalve farming (Fuentes 2005).

Bweleo is a rural village located approximately 15 km south of Zanzibar Town on the western side of Kiwani Bay (Figure 3). The shoreline is primarily coral rag with a long intertidal area including many seaweed farms. Approximately 30 meters away from shore, the substrate turns to a mud-sand consistency. Bweleo’s location is suitable for seaweed and raft-style bivalve culture due to it’s location in a sheltered bay, protected from strong waves and wind.

Bweleo is home to approximately 3,000 people, many of whom make their living from the sea. The local economy is dependent on fishing, although seaweed farming has most recently provided an alternative source of income for local women. Seaweed farming began in 1990 and has been successful in the village (Fuentes 2005). Bivalve farming began in 2003, but has been far less successful due to reasons explained in this report.

Figure 2. Map of Eastern Tanzania and Zanzibar. The islands of Pemba and Unguja (labeled Zanzibar island) are located just off shore.

(www.cia.gov 2006)

Figure 3. Map of Unguja Island. Bweleo is located southeast of Zanzibar Town (labeled Stone Town) on the western side of Kiwani Bay.

(www.matemwe.com/ images/zanzibarmap.jpg 2005)

Methodology

The data for this study was collected over the course of three weeks. An initial assessment of water quality was made during the first few days of research. The bivalve rafts (explained below) were then constructed and deployed during the end of the first week, and monitored during the second and third weeks. Meetings and informal interviews were also conducted in the community.

Site visits to existing farms were made to determine their physical structure and to interview farmers about current methods. A total of eight initial interviews were conducted with women farmers. An initial analysis of water quality was also conducted at 0.75m, 2.2 m, 3.75 m, 5 m, and 5.5 m to determine suitable areas for the implementation of two bivalve rafts. The parameters included depth, temperature, pH, turbidity, salinity, and dissolved oxygen. These measurements were taken during and directly before or after low tide; an important extreme that affects bivalve health.

Once two, new suitable sites were chosen for bivalve farming at 3.5 and 5 meters, the rafts were constructed. These rafts were modeled after those used in seaweed farming in Bagamoyo, Tanzania. Three sizes of manila rope were used in construction: 12 mm rope for the frame, 10 mm rope for the anchor lines, and 4 mm rope for the center lines and buoys (Figure 4). The frames of both rafts were 5 meters by 5 meters, and all four anchor lines 9 meters in length (refer to pictures in appendix F). In order to find the length of the anchor lines, the desired depth for deployment was added to 4 meters to account for tidal range, 1 meter for wave action, and 0.5 m for tying the lines to the anchors. A detailed list of instructions can be found in appendix D. Approximately 22 empty water bottles were tied to each raft to allow for buoyancy during fluctuating tides, and two bright orange “jerry can” containers added to aide in identification from the shore. The anchor lines were then attached to large rice bags filled with 50 kg of sand prior to deployment.

A total of sixteen bivalve cages were assembled with the help of men and women in the village. The stems of coconut leaves were chosen in the construction of the frames for durability, strength, and buoyancy in seawater (Figure 5). Pieces of coconut stem were lashed together with tai-tai, a plastic like rope used in seaweed farming. Cage size was approximately 30 cm x 25 cm x 30 cm. Nylon fishing net was then tied tightly to the frame with tai-tai and a small door fashioned for easy access to the bivalves. Both 9 mm and 6 mm netting were used for experimental comparison. The netting material prevents escapes and allows for filter feeding and respiration. Each raft housed eight cages: three containing *Pinctada margaritifera* (chaza), three with *Isognomon isognomon* (mamie chaza), and two with *Trapezium bicarinatum* (pomi) due to limited availability of the species. Each cage was labeled with the raft # and a letter indicating the species, stock density, and size of the bivalve (Table 1). Different stock densities and sizes were used to determine suitable environmental conditions. Bivalve farmers assisted in the collection and measurement of spats. Stones and panga shells (*Pteria chinensis*), were added to some cages to provide additional substrates for attachment. In addition to eight cages on raft one, three pocket-frame style cages (Figure 5) containing each species were constructed and installed for additional comparisons.

Once both rafts were deployed, the cages were fastened with tai-tai to the middle lines during low tide on 4/18/06 and 4/19/06. Bivalves were measured with a vernier caliper (a device used to measure bivalves) upon addition to the cages and approximately two weeks later on 5/2/06 and 5/3/06 during low tide to observe total growth. The bivalves are measured from hinge to widest or longest part of shell. The lines of seaweed, weighing 1 kilogram each, with 14 seedlings, were also added to each raft on 4/21/06. The species *Euchema striatum*, commonly known as cottoni, was used since it has been rather difficult to grow throughout Unguja. One week later, on 4/28/06, the seaweed was weighed again. A spring-weight scale was used to weigh the lines of seaweed with seedlings attached. Seaweed was added to determine if a polyculture was possible. It was also added to determine its effectiveness as a bio-filter, obtaining ammonia from the bivalve cages and exchanging oxygen in return. The condition of the rafts, bivalve establishment, and fouling was also recorded. Water quality was then monitored in each raft during low tide to observe environmental conditions.

Semi-structured, follow-up interviews were also conducted with bivalve farmers and fishermen to obtain additional information on farming, ideas for sustainable harvesting, and feedback on the project. During the last few days of research, a workshop was held in the village to provide the community with information gained from the project and to obtain valuable feedback. The goal of this workshop was to transfer knowledge about this alternative farming method in a form that is useful to people (Milliman 1996). A translator was used for all three meetings held in the village.

Table 1. Species, mesh size, stock density, and size range (cm) for each cage.

Raft #/ Cage #	**Species**	**Mesh size**	**Stock density**	**Size range**
1A	*Pinctada m.*	6 mm	15	0-2 cm
2A	*Pinctada m.*	6 mm	15	0-2 cm
1B	*Pinctada m.*	6 mm	20	2.0-2.5 cm
2B	*Pinctada m.*	6 mm	20	2.0-2.5 cm
1C	*Pinctada m.*	9 mm	25	2.6-3.5 cm
2C	*Pinctada m.*	9 mm	25	2.6-3.5 cm
1D	*Trapezium b.*	9 mm	16	0-2.3 cm
2D	*Trapezium b.*	9 mm	16	0-2.3 cm
1E	*Trapezium b.*	9 mm	8	2.3-3.5 cm
2E	*Trapezium b.*	9 mm	8	2.3-3.5 cm
1G	*Isognomon i.*	9 mm	10	0-3.5 cm
2G	*Isognomon i.*	6 mm	10	0-3.5 cm
1H	*Isognomon i.*	9 mm	15	3.6-4.5 cm
2H	*Isognomon i.*	9 mm	15	3.6-4.5 cm
1I	*Isognomon i.*	9 mm	5	4.6-6 cm
2I	*Isognomon i.*	6 mm	5	4.6-6 cm
POMI*	*Trapezium b.*	9 mm	10	0-2.3 cm
CHAZA*	*Pinctada m.*	9 mm	10	0-2 cm
MC*	*Isognomon i.*	9mm	10	0-3.5 cm

*indicates pocket-frame style cages added to raft #1

Figure 4. Bivalve raft structure.

Figure 5. Cage and pocket-frame structure.

Results

Initial Interviews

A total of eight initial interviews were conducted to gain background information on existing farms, problems facing these farms, and to gauge interest in building bivalve rafts. A detailed questionnaire can be found in appendix B.

Most of the farms were built in late 2004 or early 2005. Majority are fence and stone structures. Of the 42 farms built in 2004 and 2005, only 10 remain in operation. The farms were abandoned in December of 2005 due to a variety of problems facing the bivalves. These problems include decaying sticks, waves breaking sticks, bivalves leaving as adults, people taking the bivalves without permission, and overexposure to sunlight. The women mentioned that they no longer maintain their farms because they do not see the profit or have very little knowledge on how to farm.

Majority of the women have never harvested from their plots. A few have harvested once or twice from their farms for eating only. The most common species cultured among the women are *Pinctada margaritifera* (chaza), *Anadara antiquata* (makorobwe), *Isognomon isognomon* (mamie chaza), and *Trapezium bicarinatum* (pomi). All eight interviewees responded that they would be very interested in increasing productivity if a market or kiosk were available to them in Bweleo. In order to increase productivity, they would collect spats and add them to their farms. Majority expressed an interest in learning more about alternative methods of bivalve culture.

Initial Water Quality Parameters

Before constructing both rafts, an initial water quality assessment was conducted to determine two environmentally suitable sites for raft deployment. Measurements were made at 0.75 m, 2.2 m, 3.75 m, 5 m, and 5.5 m respectively (Table 2). Additional measurements were made in Safia Hashim's farm, a fence-stone structure located at 0.75 meters at low tide.

Table 2. Water quality parameters at five depths collected during low tide on 4/12/06 and 4/15/06.

Depth to bottom (m) at low tide	pH	Temperature (°C)	Turbidity (m)	Salinity (%)	Oxygen concentration (ppm)	Percent oxygen saturation (%)
0.75	8.22	29.7	0.75	35	5.2	83
0.75*	8.14	29.7	0.75	34	7.79	89.8
2.2	8.19	30.1	1.75	35	6.19	99.9
3.75	8.2	30.1	2.5	35	5.98	98.9
5	8.18	30.1	2.6	35	6.29	98.7
5.5	8.17	30	2.5	35	5.6	87.7

*indicates measurements made in Safia Hashim's farm
note: all measurements were made at the surface because the equipment was unable to reach the bottom.

From this data, it was decided to deploy the rafts at 3.5 and 5 m due to low turbidity levels, high oxygen concentrations, and stable temperatures. On the day of deployment, there were unusually strong waves, making it extremely difficult to locate 3.5 and 5 m. Despite the waves, the rafts were deployed at two different depths. Raft #1 and #2 were dropped at 2.8 m and 3.2 m respectively.

Meetings 1 and 2

On April 16th and 17th, 2006, two meetings were held in the village square to build the bivalve rafts. A total of 90 people arrived to help. A discussion about the project, and potential economic benefits were made prior to construction. Groups of both men and women gathered to listen to the instructions. After questions were answered, construction began (a list of materials and costs can be found in appendix D). To build two rafts, material costs totaled approximately 58,200 Tanzanian shillings. Financial support for both rafts was provided by the SUCCESS (Sustainable Coastal Communities and Ecosystems) program. It is a five year initiative in conjunction with the University of Rhode Island supported through a cooperative agreement with USAID (U.S. Agency for International Development). The program strives to help coastal communities improve their quality of life and physical environment through good governance. The program has an emphasis in Latin America and East Africa (www.crc.uri.edu 2006).

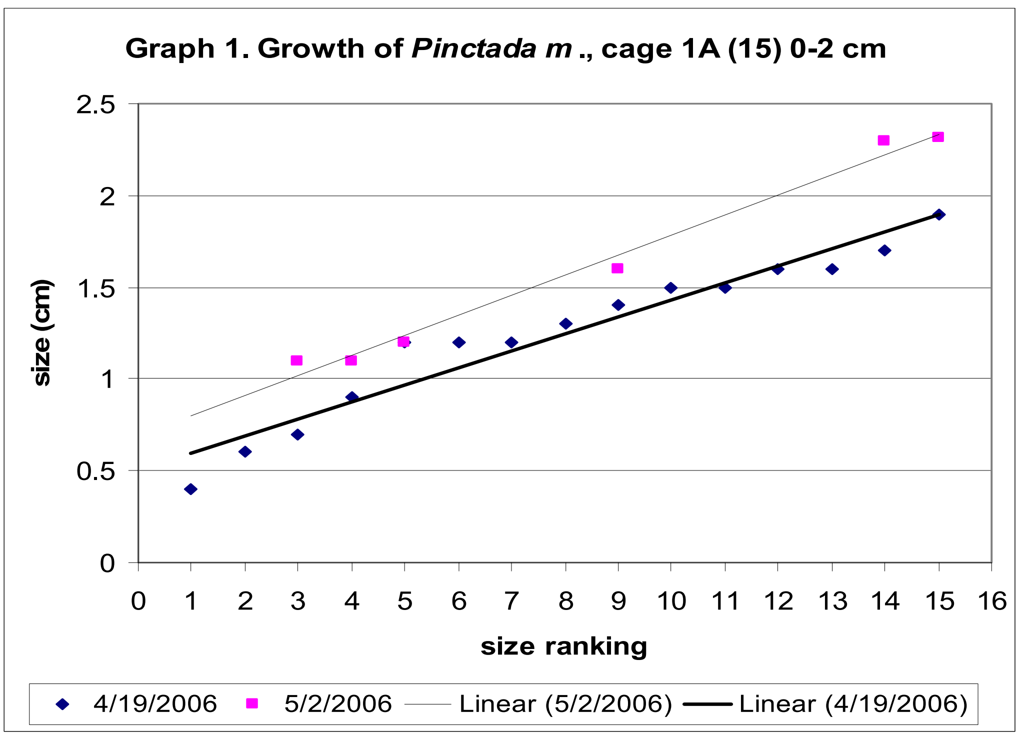
Raft Condition and Maintenance

The rafts were repaired and adjusted as needed once in the water. Raft #2, located at 3.2 m, was tangled by a boat on 4/27/06, a week after deployment. It was suspected that a boat carrying cows to Dar es Salaam, unable to see the raft at night, accidentally hooked the anchor lines. All four rice bags were found collided together, and the lines and cages extremely tangled. Both lines of seaweed on this raft were lost. Raft #1 did not face any problems and remained stable throughout the study. As a result of this disruption, two bright yellow buoys ("jerry cans") were attached for easy identification of both rafts.

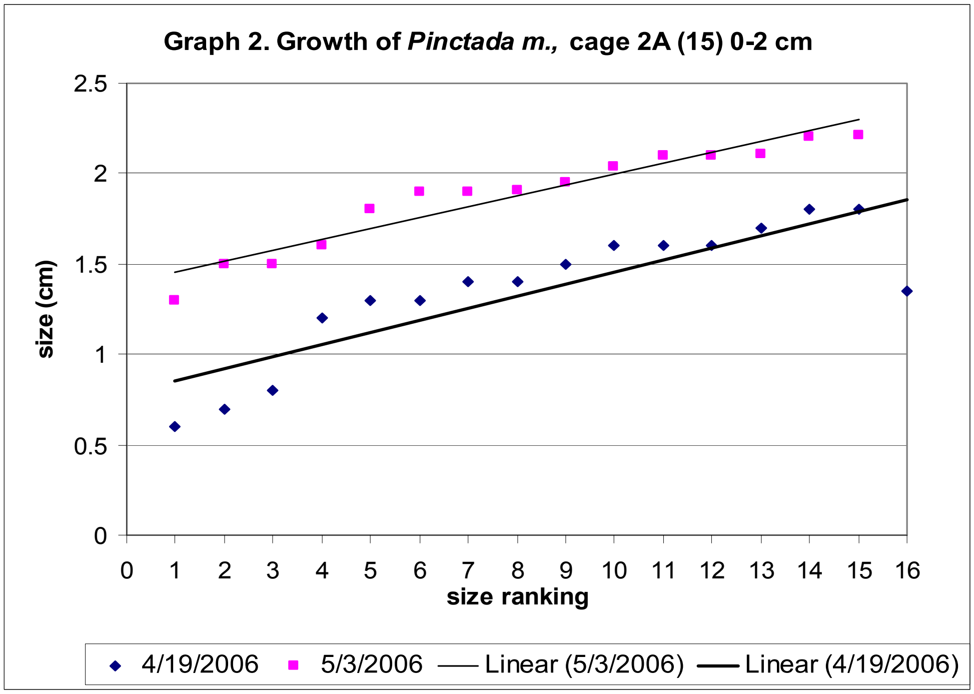
The rice bags were monitored on a regular basis to check for decay. All eight remained in tact during the study. As a result of currents and waves mixing sediment in the water column, all nineteen cages experienced some clogging. An un-identified plant/algal attachment was also observed clogging the netting on most cages (refer to appendix F for pictures). This attachment was quite difficult to remove. The cages were brushed off as soon as clogging became noticeable. Cages with 6 mm mesh netting clogged much faster than those with 9mm. Pocket-frame style cages also experienced less clogging than the other cages.

Bivalve Health

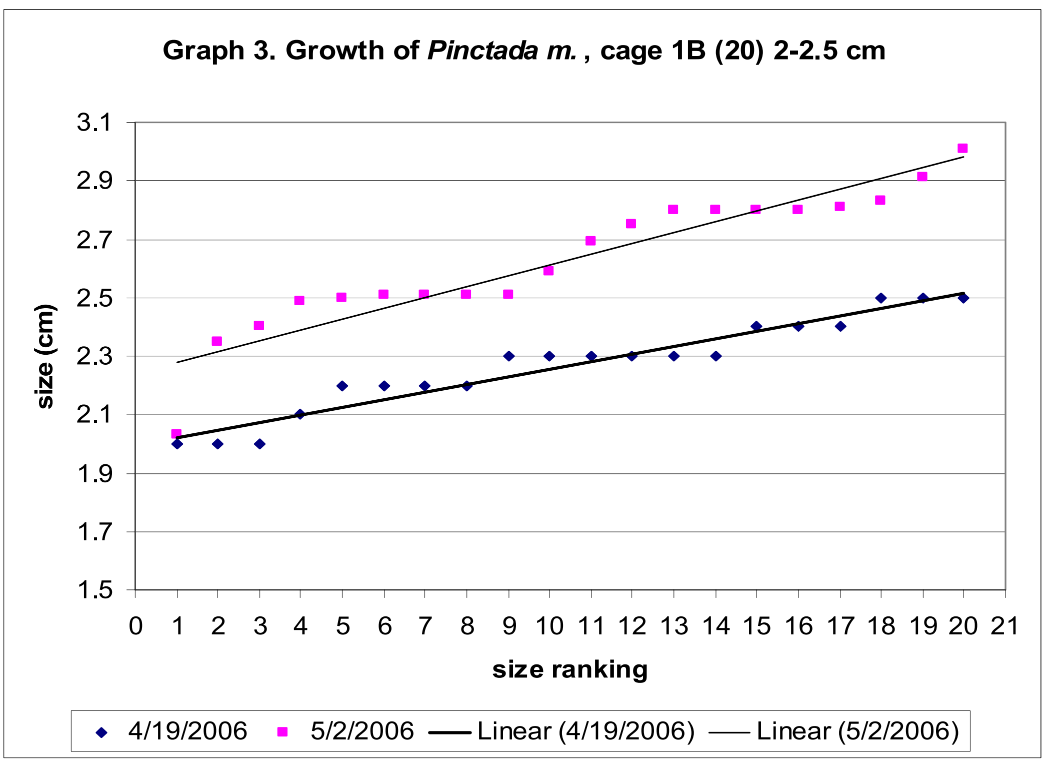
The bivalves were monitored frequently to check for fouling and mortalities. Final measurements of the bivalves were made approximately two weeks after the cages were tied to the rafts on 5/2/2006 and 5/3/2006, with the exception of the species *Trapezium bicarinatum*, which had to be re-measured on 4/24/06 due to confusion in the data. A graph for each cage was made to observe growth trends (Graph 1 – Graph 19). The title of each graph contains the species name, raft and cage number, stock density in parentheses, and size range in centimeters. The bivalves were ranked in order of increasing size (cm) within individual dates, and dates plotted against each other. The space between the two trend lines indicates growth. Mortality and fouling is discussed below each graph.



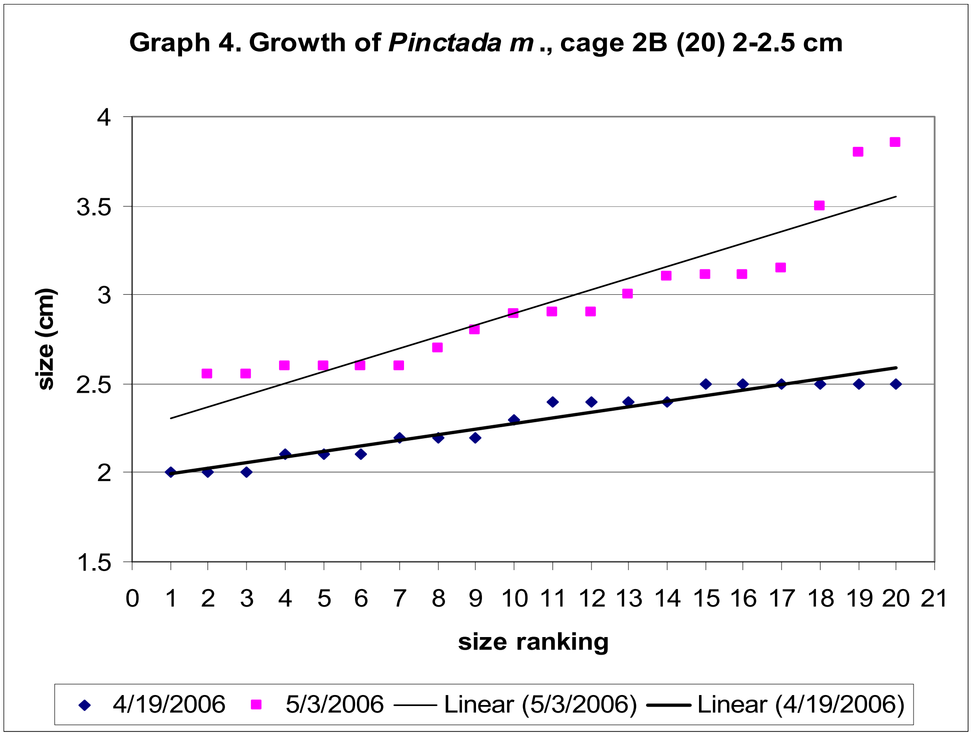
Graph 1: Nine individuals were lost in this cage through an identified hole in the netting. No fouling or mortalities were recorded.



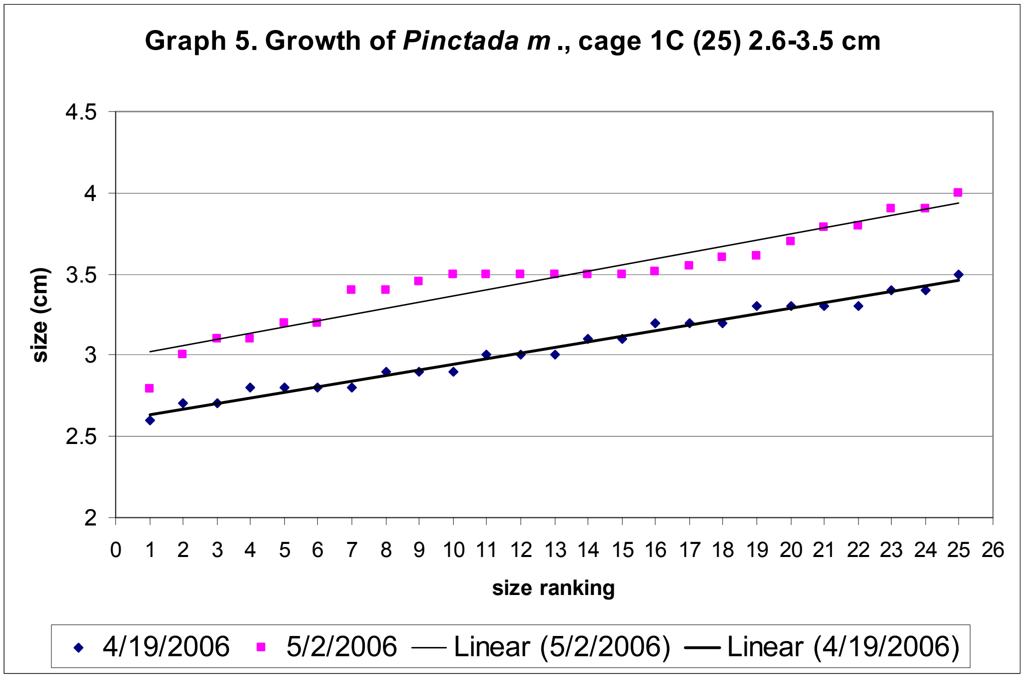
Graph 2: One death was recorded during the first week (1.7 cm in size). Barnacles were identified on another individual.



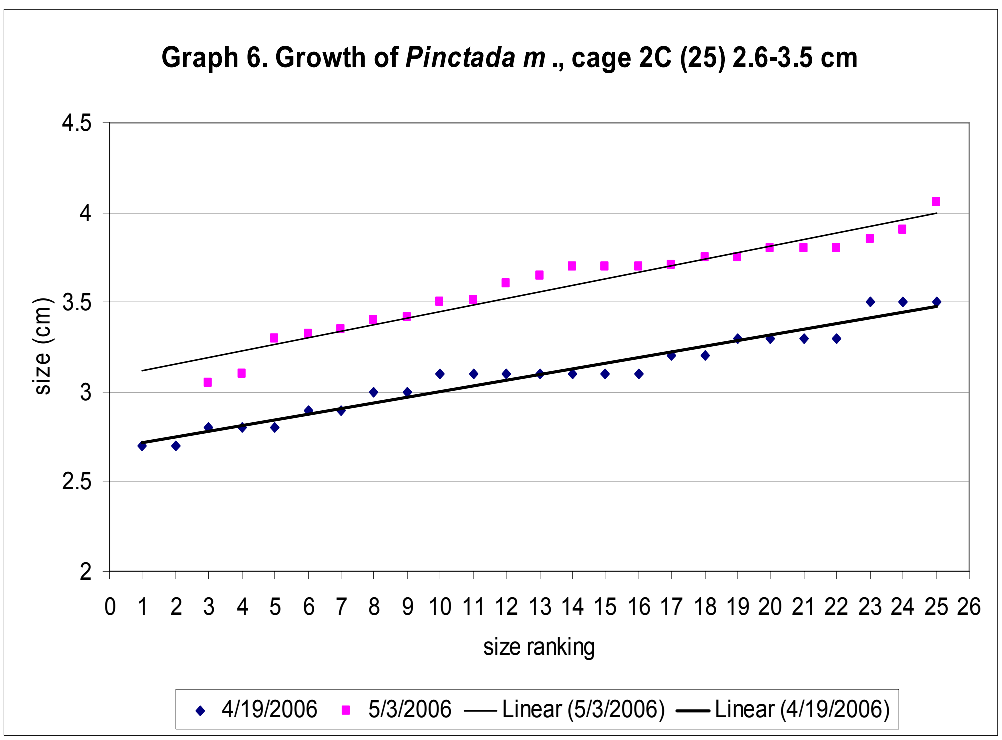
Graph 3: One small mollusk was found attached to one individual. Others displayed red, purple, and black periostracum growth. The spat of *Trapezium b*. was also recorded attached to a few individuals.



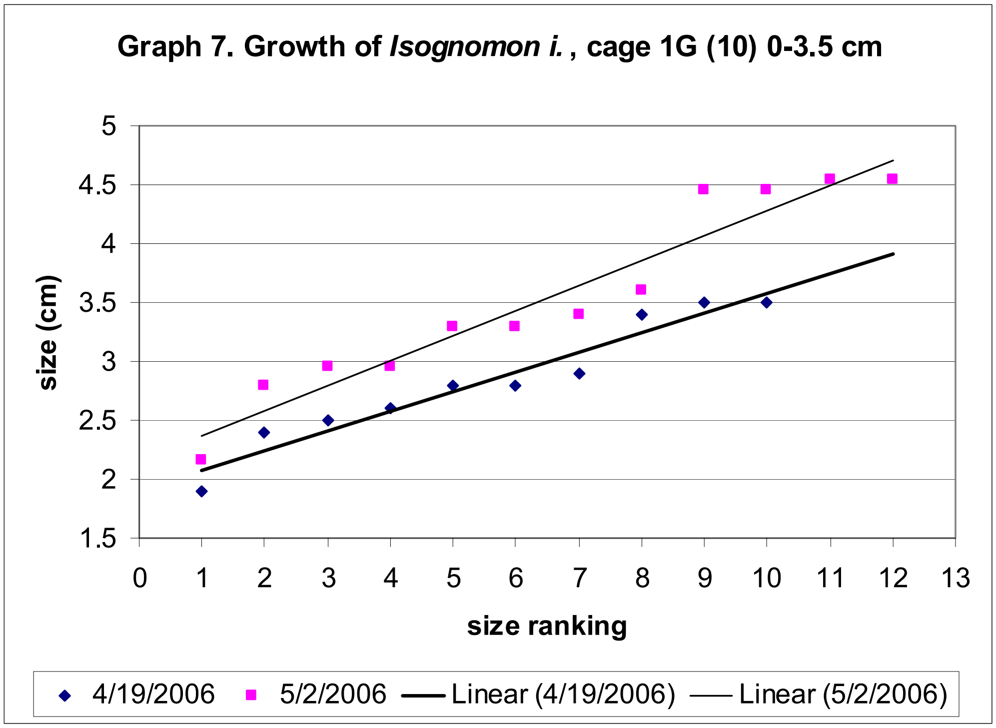
Graph 4: One death was recorded during the first week (2.6 cm in size). Many small *Pinctada m.* spats were also recorded attached to the shells of individuals inside this cage.



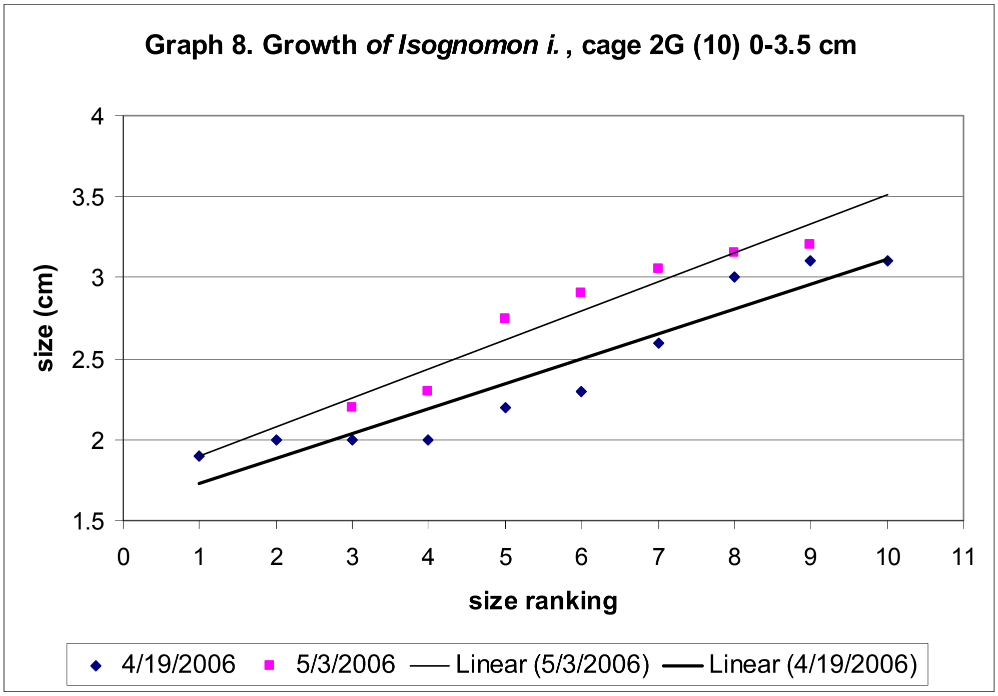
Graph 5: One death occurred inside this cage during the first week (2.7 cm in size). Many small spat, ranging in size from 1 mm to 6 mm, were attached to individuals inside the cage. A tiny crab was also found on one individual.



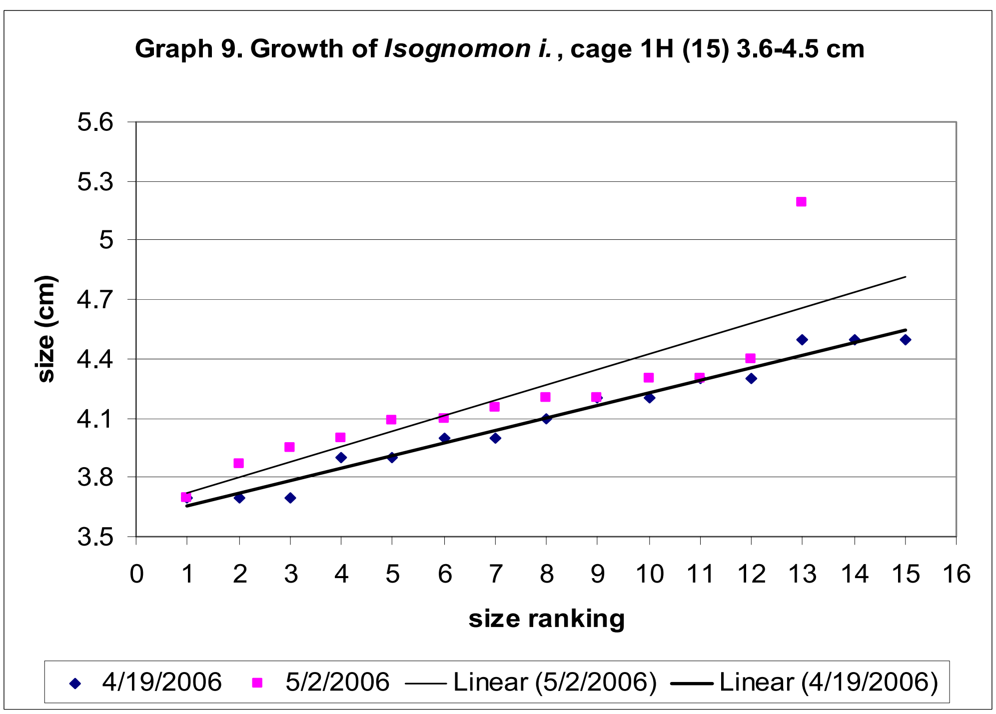
Graph 6: Two mortalities occurred inside this cage (2.9 cm and 3.2 cm in size). Three individuals had barnacles attached, and three had small spats attached to their shells. Many exhibited large white to red periostracum growth.



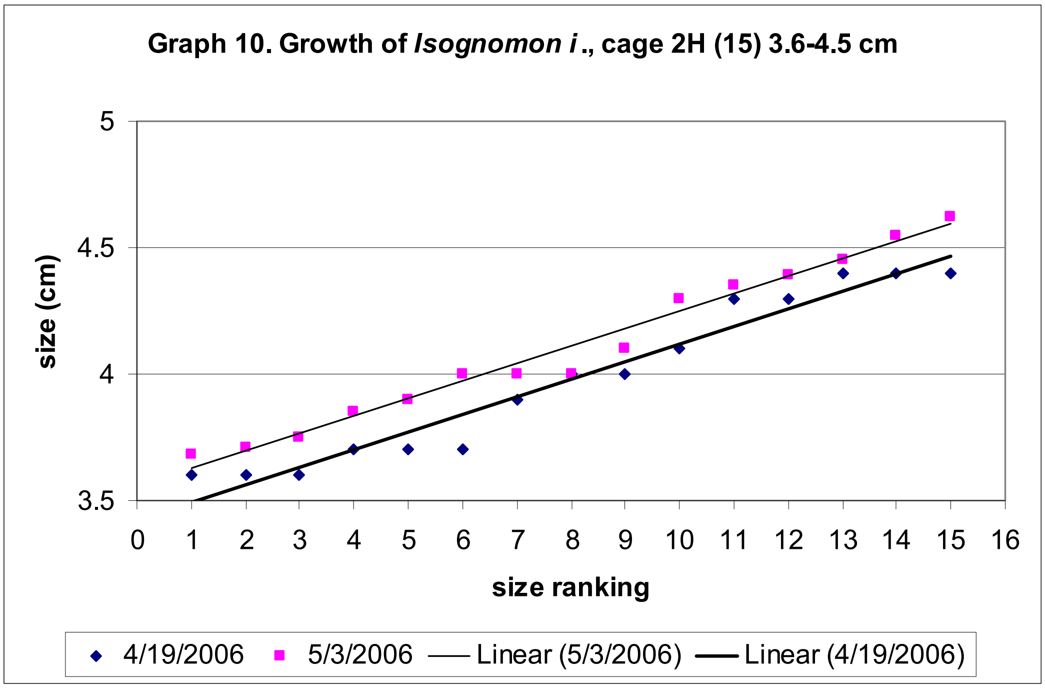
Graph 7: Two extra bivalves were found inside the cage on 5/2/06, for unknown reasons. A large black sponge was also observed attached to an aggregation of *Isognomon i.* inside the cage.



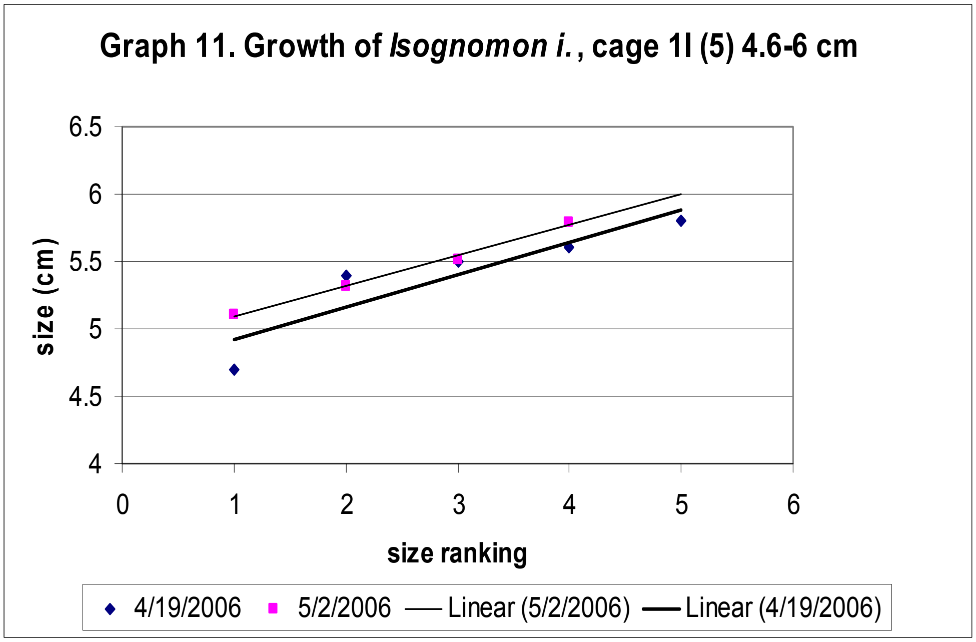
Graph 8: There were two mortalities inside this cage (1.99 and 3.05 cm). Seaweed, algae, and coral were attached to three individuals.



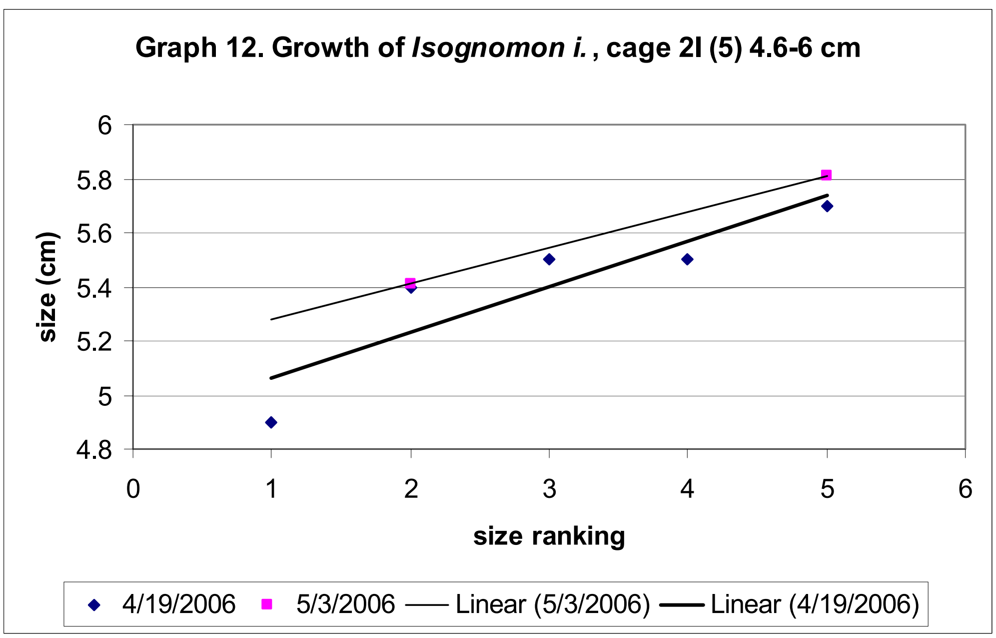
Graph 9: Two individuals were lost from this cage and coral found attached to the shells of others. Sponges were also very common and a few spat of *Pinctada m*. found attached to shells.



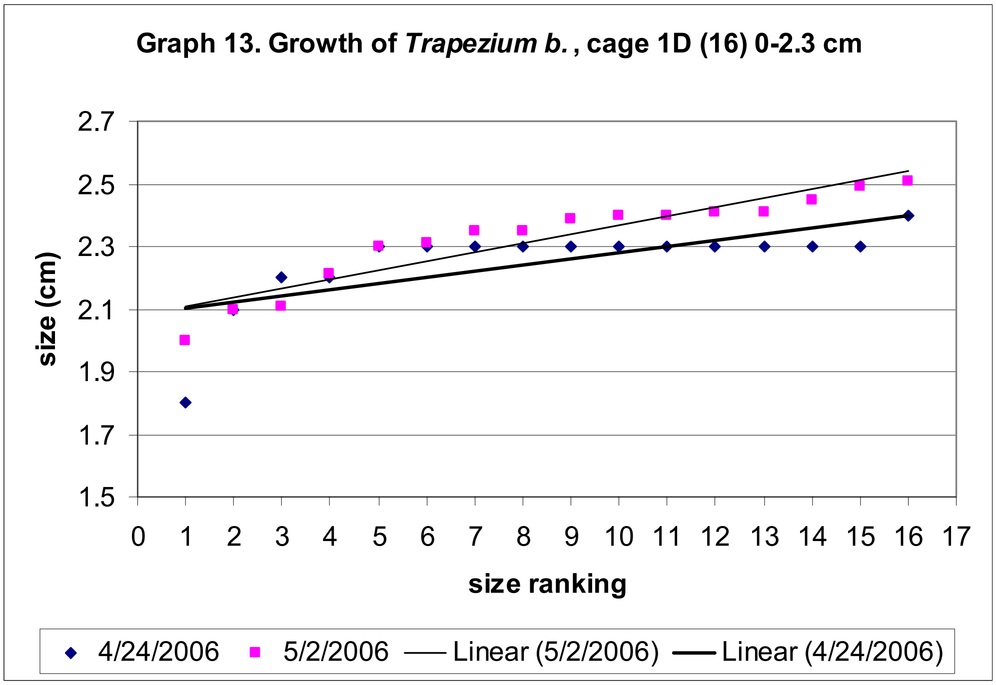
Graph 10: Fouling by corals, mollusks, and sponges was a problem in this cage. Seaweed and algal attachments were also very common.



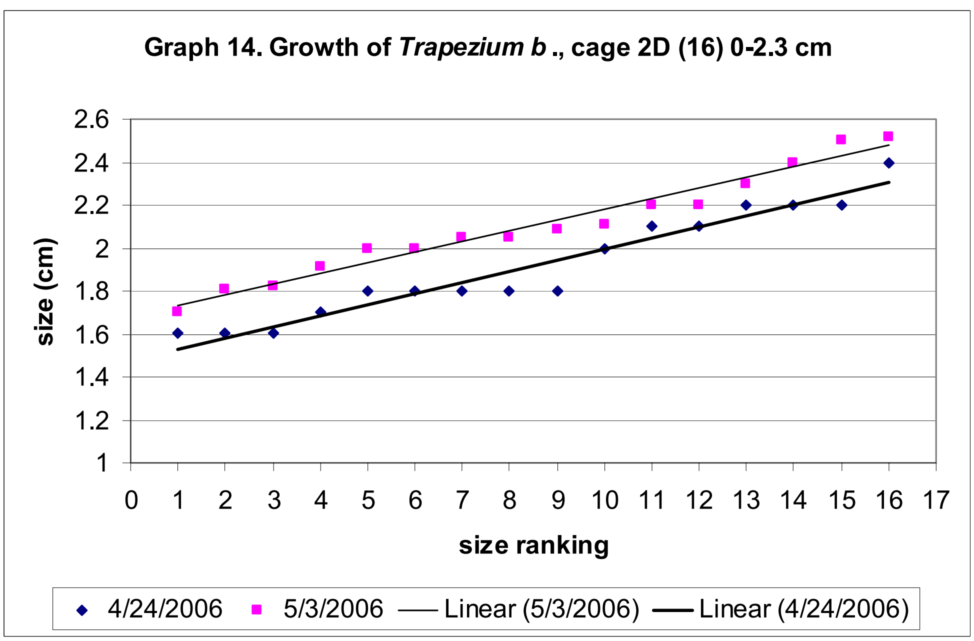
Graph 11: One individual was lost and another was found with a mollusk attached to its shell.



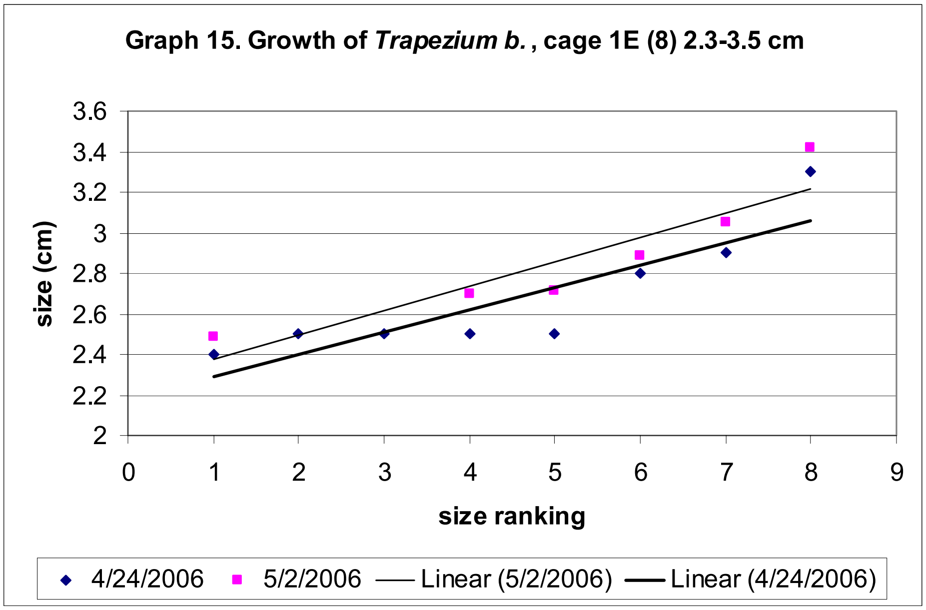
Graph 12: Three individuals were lost from this cage. No fouling or mortalities were recorded.



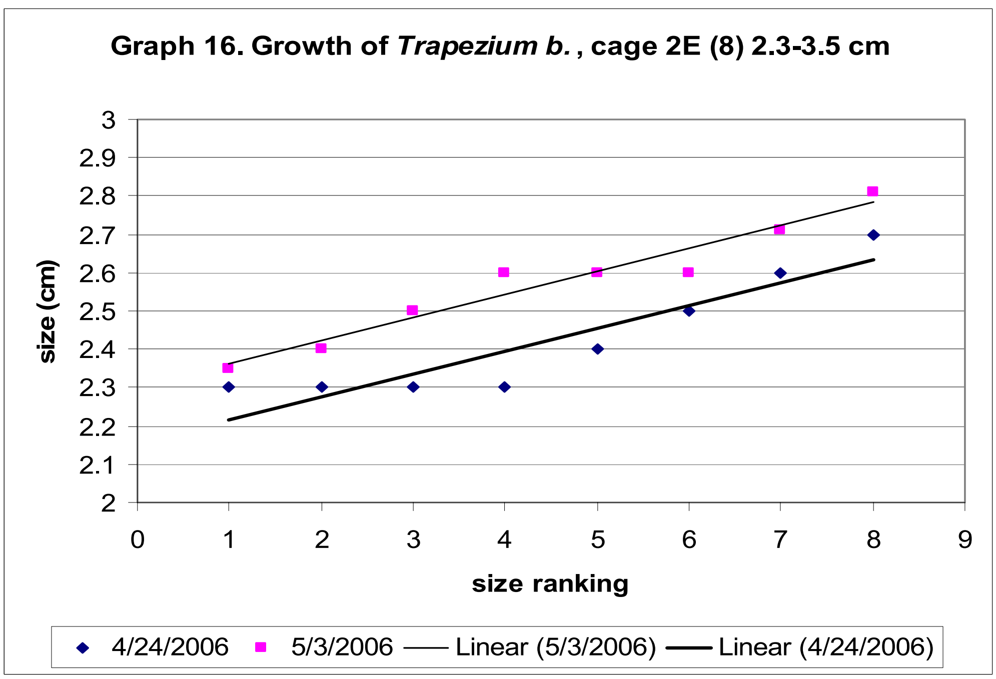
Graph 13: One individual was observed with a coral attached to its shell and another with sea grasses.



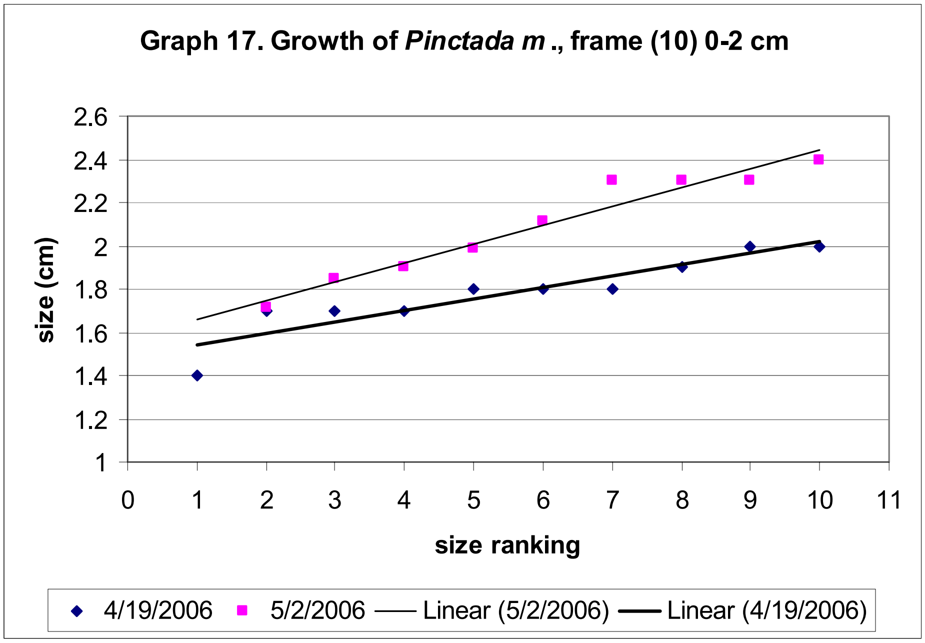
Graph 14: Algae and seaweed were found attached to four individuals, and a sponge attached to another.



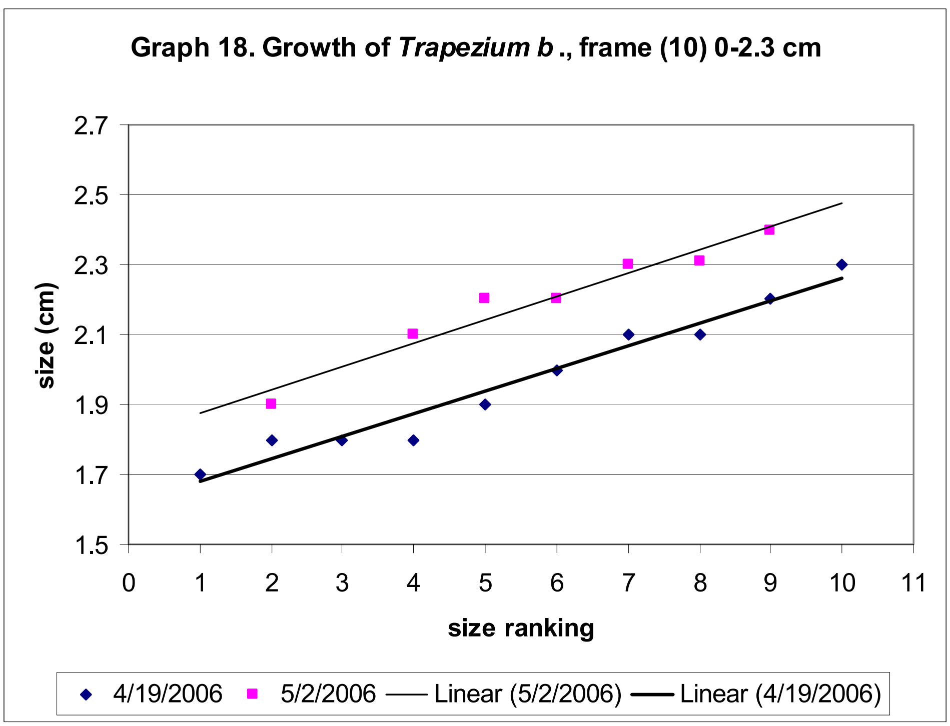
Graph 15: One death occurred in this cage during the first week (2.6 in size). Another was lost. No fouling was recorded.



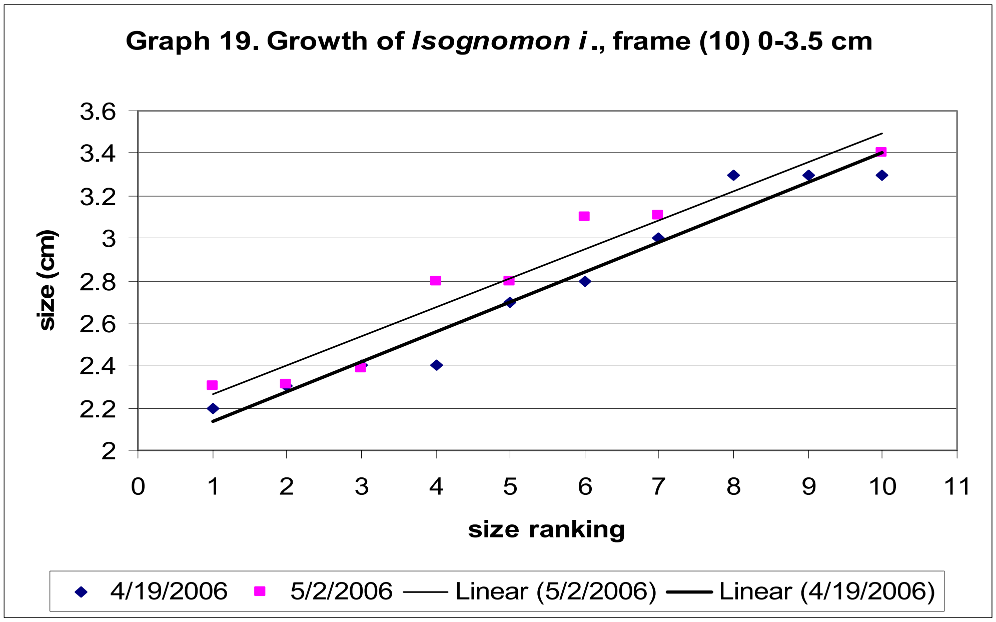
Graph 16: No mortalities were recorded in this cage. One individual had a seaweed/algal attachment on its shell.



Graph 17: Individuals were recorded successfully attaching to stones and shells inside this cage. One individual was lost.

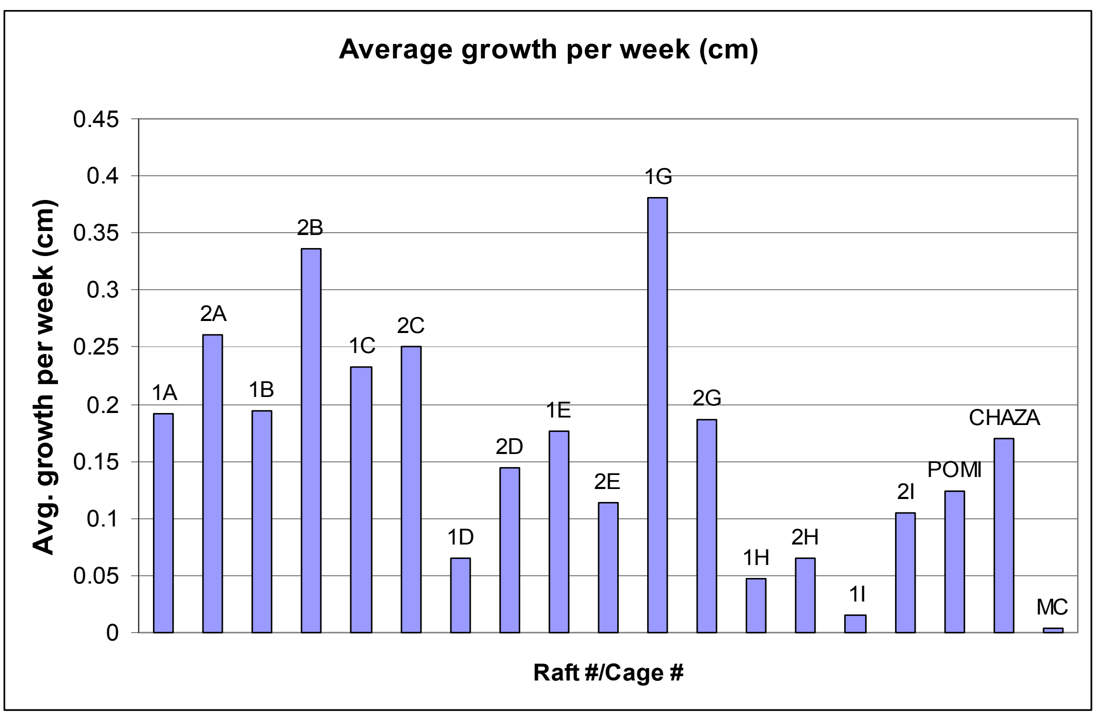


Graph 18: Three individuals were lost in this cage. No fouling or mortalities were recorded.

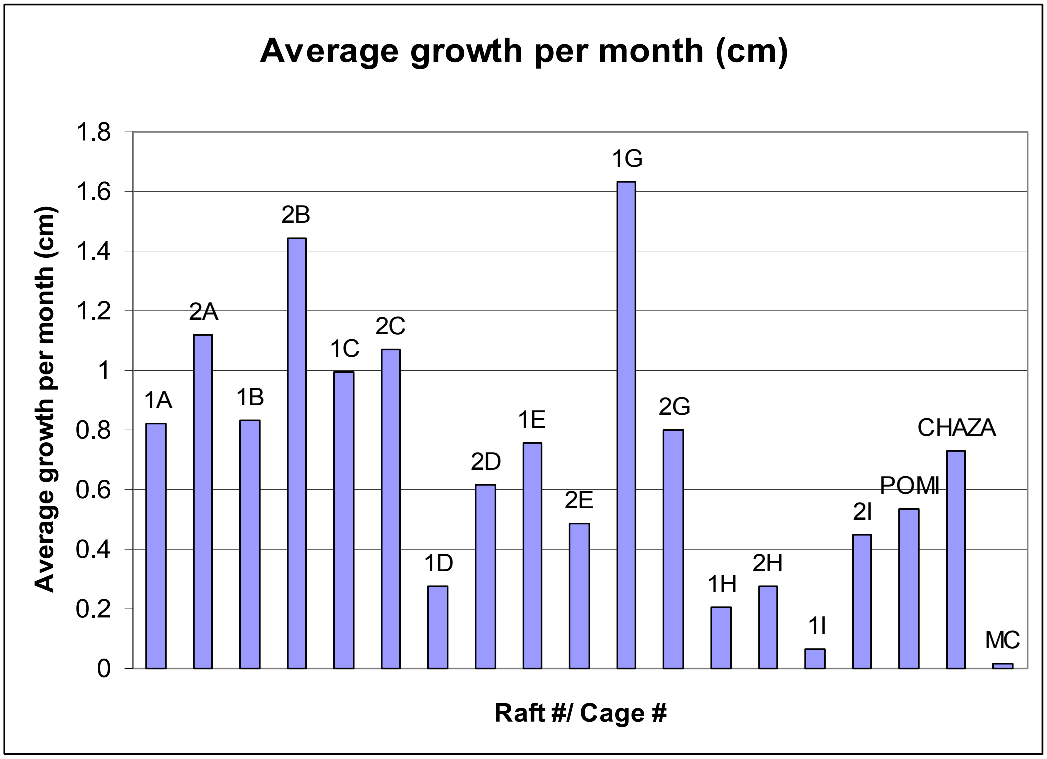


Graph 19: Some of the measurements taken in this cage on 5/2/06 had to be rejected due to a reduction in size (which is impossible even if the bivalve is dead). The tops of shells on many were observed broken.

Graph 20. Average growth per week for individuals in all cages.



Graph 21. Average growth per month for individuals in all cages.



Water Quality Assessment

Water quality parameters were measured frequently within both rafts during the second and third weeks. The parameters were measured on seven days during the study period: 4/23, 4/24, 4/25, 4/29, 4/30, 5/2, and 5/3. The second raft was measured less frequently than the first due to boat disruption that occurred on 4/27/06. A table was created for each parameter (Tables 5-9), as well as one table describing the weather conditions on each date (Table 4).

Table 4. Weather conditions for each sample date.

	4/23/06	4/24/06	4/25/06	4/29/06	4/30/06	5/2/06	5/3/06
Weather conditions	Calm, light rain before measurements	Sunny, with strong current, Storm approaching	Clear, sunny, strong current Clouds on horizon	Calm, cloudy, rain	Sunny, few clouds, water cloudy	Sunny, light breeze	Sunny, calm

Table 5. pH in both rafts during all seven dates.

	4/23/06	4/24/06	4/25/06	4/29/06	4/30/06	5/2/06	5/3/06
Raft #1	8.10	8.16	8.20	8.14	8.19	8.24	N/A
Raft #2	8.20	8.12	8.13	N/A	N/A	N/A	8.23

Table 6. Temperature (°C) in both rafts during all seven dates.

	4/23/06	4/24/06	4/25/06	4/29/06	4/30/06	5/2/06	5/3/06
Raft #1	29.1	28.8	29.3	27.6	28.3	28.4	N/A
Raft #2	28.9*	28.9	29.3	N/A	N/A	N/A	28.9

* measured at 2.4 m, the rest of the data was measured at 1 m

Table 7. Salinity (%) in both rafts during all seven dates.

	4/23/06	4/24/06	4/25/06	4/29/06	4/30/06	5/2/06	5/3/06
Raft #1	34	35	35	34	32	34	N/A
Raft #2	35	35	34	N/A	N/A	N/A	34

Table 8. Turbidity (m) in both rafts during all seven dates.

	4/23/06	4/24/06	4/25/06	4/29/06	4/30/06	5/2/06	5/3/06
Raft #1	3.75	3	3	2	N/A	2.75	N/A
Raft #2	5	3	2.75	N/A	N/A	N/A	3

Table 9. Oxygen concentration (ppm) and saturation (%) in both rafts during all seven dates.

	4/23/06	4/24/06	4/25/06	4/29/06	4/30/06	5/2/06	5/3/06
Raft #1	4.7 ppm 75.7%	5.78 ppm 90.1%	6.25 ppm 99.5%	6.57 ppm 98.9%	6.80 ppm 105.2%	7.45 ppm 115.8%	N/A
Raft #2	5.7 ppm 93.3% *	6.5 ppm 95%	6.29 ppm 102.6%	N/A	N/A	N/A	7.43 ppm 115.1%

* measured at 2.4 m, the rest of the data was measured at 1 m

Seaweed Health

Both lines of *Euchema striatum* tied to raft #1 on 4/21/06 were weighed after one week of growth on 4/28/06. Both lines of seaweed were lost in raft #2 due to boat disruption. Total growth can be seen in Table 3. Seaweed on raft #1, on ropes #1 and #2, gained 1.2 and 2 kg in one week respectively. Some epiphyte attachment (a disease that affects seaweed growth) was seen, but not fully monitored or recorded.

Table 3. Growth of *Euchema striatum* during one week.

	Weight (kg) on 4/21/06	Weight (kg) on 4/28/06	Growth (kg)
Raft #1	Rope #1: 1.0 Rope #2: 1.0	Rope #1: 2.2 Rope #2: 3.0	Rope #1: 1.2 Rope #2: 2
Raft #2	Rope #1: 1.0 Rope #2: 1.0	N/A	N/A

Follow-up Interviews

A total of seven interviews were conducted on 4/26/06 with fishermen and bivalve farmers involved with the project. A detailed questionnaire can be found in appendix E.

All of the fishermen interviewed had never been involved with bivalve farming before this project began, but were very interested in continuing this method of cultivation. Many mentioned how they can divide the days of bamvua (spring tide) into fishing and "chaza" farming days. The rafts can be protected through the attachment of large, bright buoys to warn passing boats. One man mentioned that communication with other fishermen and community members will be important to raft protection. Men and women can successfully work together by dividing jobs equally. Men are able to monitor the rafts and deploy them, while women can collect the spats and measure them on a regular basis. Most had little to no idea about the biology of bivalves. A few mentioned how they live on hard substrates and that they "eat from the water." All believe that a kiosk would be a good idea and that women can sell the bivalves they harvest to other villagers or migratory fishermen. A few mentioned the potential value of owning a refrigerator to keep bivalves for later sale. Some mentioned that the environment can be protected by designating appropriate zones for collection and coordination with spring tides.

All of the women bivalve farmers interviewed have been involved with cultivation for three years since the IMS project began. Most of them have been collecting since they were young. Within seasons, bivalve numbers fluctuate. During the cold, rainy season, numbers increase, and during the hot, dry season, numbers decline. Overall, numbers have decreased. They believe this is due to an increase in the number of people collecting bivalves in the village.

Most of the bivalves collected from the wild are sold in the village in groups of 10-20 for 50 Tanzanian shillings each. During one week of spring tide, they are able to earn 5,000-8,000 Tanzanian shillings, and for one month approximately 10,000-16,000 Tanzanian shillings. They collect pomi, makorobwe, and mamie chaza for sale. All of the women interviewed believe that a kiosk would be a very good idea and that a freezer would be particularly helpful in storing harvests for later sale. Men and women can work together by dividing responsibilities. Women can collect spats, measure them, and clean the cages, while men can handle the difficult work such as deploying the rafts and swimming. The women knew very little about bivalve biology except that spat appear during the rainy season and that they feed from the water. They also knew that chaza live on rocks and grass, pomi live stuck in the substrate, and that makorobwe and mamie chaza live in soft mud or sand. In order to protect the environment, they believe that people should avoid taking small bivalves that will deplete future stocks, and that the bivalves should be harvested only when adults. Days for harvesting and days for resting should be determined prior to implementation. They also believe that working together with the Government and Department of Fisheries will be important in protecting the marine environment.

Final Meeting

A final meeting was held in the village on 5/1/06 to provide the community with feedback on this project. Dr. Narriman Jiddawi, Dr. A.J. Mmochi, and Salum Hamad from IMS attended to aide in translation and to answer questions. A total of 36 people were in attendance, including chair people from most bivalve groups (refer to appendix A). The meeting focused on the biology/ecology of bivalves, reasons for building rafts, seaweed addition, what was found through the research (bivalve and seaweed growth, interviews, and raft construction), how to measure bivalves, socio-economics involved, and environmental considerations. Recommendations were also made for continued practice. At the end of the meeting, a discussion was held with the people. A common concern among many women was that they are unable to swim and access bivalve rafts in deep water. It was agreed that SUCCESS will help fund the addition of 14 new farms (fence structure) to be built in deeper water (ie. Safia Hashim's farm, 0.75 m). SUCCESS will also help fund 10 bivalve rafts after these 14 farms have been established.

Discussion

The people of Bweleo have demonstrated tremendous interest in exploring this alternative method of bivalve farming. This was especially apparent during all three meetings held in the village. For example, Safia Hashim (mentioned earlier in this report) decided to cover her fence-stone farm in fish netting to avoid escapes. As a result, the bivalves in her farm have remained healthy and are growing well. Another fisherman expressed interest in deploying rafts near Miwi Island in Kiwani Bay to harvest pearls from *Pinctada m.* The community was very receptive to the information given during the last meeting and helpful in providing feedback.

All 171 bivalve farmers have been organized into groups of five (see appendix A) and are ready to begin cultivation. Both leaders of bivalve farming, Amina Khamis and Fatuma Ramadhani have requested help from TASAF (Tanzanian Social Action Fund), under MACEMP (Marine and Coastal Environmental Management Project) for seaweed farming. During the project, they decided to extend this request to bivalve farming. Their organizational efforts have proven extremely helpful to the community of farmers because it allows them to communicate effectively and work together to increase production and protect marine resources.

The interviews revealed a great deal of valuable information on the future of bivalve farming in Bweleo. Past methods have been unsuccessful due to a lack of knowledge on where and how to effectively cultivate bivalves. One interesting result was that men and women can successfully work together on cultivation. Men are able help in the deployment of the rafts, repairs, and swimming. Women can be responsible for collecting spats, measuring bivalves, and cleaning cages. During the final meeting, it was also recommended to the women that rafts can be deployed in 1-1.5 m deep water at low tide. This means that women can easily access their farms to clean the cages, remove foulers, and measure the bivalves without having to swim.

The size and structure of the rafts was successful. The addition of large, bright buoys was effective at deterring large boats and for easy identification from shore. It is unknown how long the rice bags will last, but it has been recommended that they are removed and replaced with a sand-cement mixture less prone to decay. The data also revealed that pocket-frame style cages clog less than cages, most likely due to a difference in surface area exposed to particles in the water column. Pocket-frame style cages also utilize fewer materials and cost less to produce.

Bivalve health and survival varied greatly between species. Many bivalves were lost between measurements due to holes in cages that should have been repaired. Individually, cage 1G, containing *Isognomon i*., demonstrated the highest average growth per week/month, and cage 1I, containing *Isognomon i*., the lowest average growth per week/month (Graph 20 and 21). It is unclear as to why this species had both the highest and lowest growth rates among all cages. Cage 1G contains two extra individuals, which may have distorted the average (Graph 7).

Overall, *Pinctada m*. demonstrated the highest growth rates, with the least amount of fouling. The distinct red, purple-black growth of the periostracum on many of the bivalves indicated good growth. The attachment of spat to other individuals within the cage was also an indication that recruitment occurred. This may be a result of the cold-rainy conditions favorable for spat attachment in the month of April (Pouvreau *et. al* 2000). The high number of mortalities in this species can most likely be attributed to stress encountered during the first week. The environmental change from wild to cage may have been enough to kill these individuals. The average growth per month for

Pinctada m. ranged from 0.89 cm to 1.44 cm (Graph 21). For *Isognomon i*., this average ranged from 0.063 cm to 1.63 cm and for *Trapezium b*. from 0.27 cm to 0.75 cm. *Isognomon i*. experienced the most fouling overall, with sponges, mollusks, and corals most commonly attached. The large variation in average growth for this species was also an indication of unreliable growth rates.

The results showed no relationship between stock density and size of bivalve. The discontinuity between cages 1A- 2I (graphs 20 and 21) were an indication that stock density did not influence overall growth rates. Future studies may be able to determine survival and growth rates with larger stock densities. In addition to this, the size of mesh used on each cage did not significantly influence growth rates. This was highly dependent on the species and cage condition.

Raft #2 had higher average growth rates than raft #1, even though it was tangled by a boat. This might be explained by the fact that bivalves grow better in deeper water (Garrido-Handog 1991). Since raft #2 was situated at a deeper depth than raft #1, it was exposed to less sunlight at low tide. The species *Trapezium b.* was determined to be the second most reliable species to use in raft culture because it demonstrated steady growth rates and little fouling. Overall, the pocket-frame style cages experienced less fouling than cages. Again, *Pinctada m.* demonstrated the highest growth rates and *Isognomon i.* the lowest growth rates. The frame containing *Isognomon i.* had extremely little growth, most likely contributed to fractures found in some shells.

It was difficult to find a trend in some of the water quality data, since the data was similar for most days (Tables 5-9). pH in both rafts ranged between 8.10 and 8.20. The temperature ranged between 28 and 29.3 °C in both rafts. On 4/29/06, the lowest reading was measured at 27.6°C in raft #1, most likely due to the cloudy, rainy weather conditions. Salinity held constant between 32-35% in both rafts. A slight increase in oxygen saturation and concentration was also observed in both rafts. This could be a result of seaweed adding oxygen to the water within the rafts. In raft #1, the percent saturation increased from 75.7% to 115.8% between 4/23/06 and 5/2/06. In raft #2, percent saturation also increased, from 93.3% to 115.1% between 4/23/06 and 5/3/06 (Table 9). Turbidity was greater on days proceeding heavy rains. On 4/29/06, the visibility was reduced from 3.75 meters in raft #1 (measured on 4/23/06) to 2 meters (measured on 4/29/06). In raft #2, visibility was reduced from 5 meters (measured on 4/23/06) to 3 m (measured on 5/3/06). This increase in turbidity may have caused additional cage clogging. Despite this, it was determined that both rafts provided suitable environmental conditions for bivalve health mentioned earlier in this report.

Although the health and condition of *Euchema s*., or cottoni, was only studied briefly, raft conditions were suitable for growth. The species grew quite rapidly during one week, gaining 1.2 to 2 kg in weight. A polyculture involving both bivalves and seaweed was thus proven possible. Despite the species' success, it is still unclear how seaweed preformed as a bio-filter. Epiphyte attachment should be studied to determine the health of the species. Fish were also seen congregating around the lines of seaweed and cages, most likely using the raft for shelter. It was suggested during the final meeting on 5/1/06 that local dema traps be placed under each raft to harvest the fish that congregate nearby.

Conclusion

Bivalve raft culture in Bweleo, Unguja has yet to be proven effective for all three species until a harvest is made. *Pinctada m.* survived well under cage conditions and has the potential for use in additional rafts. A polyculture with both bivalves and seaweed is also possible. With the help of SUCCESS, women will be able to continue harvesting bivalves from fence and raft structures in water unexposed at low tide (1-1.5 m in depth). Zonation for sustainable bivalve harvesting should also be determined to ensure that the marine environment is protected and has time to recover.

The people of Bweleo have demonstrated extraordinary enthusiasm in learning about this alternative method of bivalve farming. Although the lack of a kiosk in Bweleo remains discouraging, the people seem determined to make an initiative once a harvest is made.

Recommendations

- Raft monitoring should be continued for at least three months to see if this method is successful at harvesting full-grown, healthy bivalves.
- Those conducting additional scientific studies should mark individual bivalves with a pen so they can be accurately measured during each spring tide. Cages should be clearly marked to avoid confusion.
- Pocket-frame style cages should be used more frequently because they experience less clogging and fouling. They also require fewer materials and can be constructed for less money than cages. The frames can be built larger with more panga shells and rocks added for attachment.
- A fish net larger than 9 mm should be used for cages to avoid clogging. Fouling organisms should be removed on a regular basis.
- A project focused on determining temporary "no take zones" will be important for the protection of future stocks and the marine environment. For example, the intertidal area could be divided into two zones: A and B. Zone A can be harvested for one season and left to recover during another. Zone B can be left fallow during harvest time in A and become productive when A is recovering.
- Additional lines of seaweed can be added to the rafts.
- Rice bags should be filled with a sand and cement mixture to avoid decomposition.
- Farms can be established at 1-1.5 meter deep water for easier access and maintenance. Deeper depths are always preferred though.

References

Cohen, Ilana, 2005. *Mollusk Collecting and Bivalve Farming: Economics and Strategies in Two Zanzibari Villages.* Independent Study Project: SIT, Zanzibar, Tanzania.

"Current CRC Projects: SUCCESS." 2006. www.crc.uri.edu, Coastal Resource Center: University of Rhode Island, RI, USA

Dubi, A.M., A.J. Mmochi, N.S. Jiddawi, M.S. Kyewalyanga, F.E. Msuya, Z. Ngazy and A.W. Mwandya. 2004. *Development of Integrated Pond Culture of Finfish, Shellfish, and Seaweed in Tanzania.* The Institute of Marine Sciences, Zanzibar, Tanzania.

Ellis, Simon, and Maria Haws, PhD. 2000. *Producing Pearls Using the Black lip Pearl Oyster (Pinctada m.): Aquafarmer Information Sheet*. CTSA Publication no. 141, The Oceanic Institute: Hawaii, USA.

Fuentes, Angelica, 2005. *Seaweed Health and Production in Bweleo, Unguja.* Independent Study Project: SIT Zanzibar, Tanzania.

Garrido-Handog, Leda. 1991. *Pearl Oyster Farming and Pearl Culture Training Course*, training manual #8, Central Marine Fisheries Institute, Regional Seafarming Development and Demonstration Project: Tuticorin, India.

Jiddawi, Narriman and Aviti Mmochi. 2005. *Integrated Seaweed and Shellfish Farming on Zanzibar: A Pilot Project, DRAFT Report to the McKnight Foundation*. Institute of Marine Sciences, Zanzibar, Tanzania.

"Map of Tanzania." <www.cia.gov> 2006.

"Map of Unguja Island." < www.matemwe.com/ images/zanzibarmap.jpg> 2005.

Milliman, John D. 1996. *Integrating Research and Education with Public Outreach at Coastal Laboratories.* Virginia Institute of Marine Science: College of William and Mary: Gloucester Point, Virgina. Biology, pp. 278-285.

Persoone, G. and P. Sorgeloss. 1982. *Perspectives in Mariculture Technologies.* Laboratory for Mariculture and Artemia Reference Center: State University of Ghent, Belgium, vol. 307, no. 1499, pp. 363-375.

Pouvreau, Stephanie, G. Aline, J. Tiapari, F. Lagarde, M. Garnier, and A. Bodoy. 2000. *Gametogenic and reproductive effort of the tropical blacklip pearl oyster, Pinctada margaritifera, cultivated in Takapoto atoll (French Polynesia)*. Aquatic Living Resources 13, vol. 1, pp. 37-48.

Richmond, Matthew D, ed. 2002. *A guide to the Seashores of Eastern Africa and the Western Indian Ocean Islands.* Sida/Dept. for Research Cooperation, SAREC ad the University of Dar es Salaam.

Ryther, J.H. 1981. *Mariculture, Ocean Ranching, and other Culture-Based Fisheries.* Woods Hole Oceanographic Institute: Woods Hole, MA. Bioscience, vol. 31, no.3, pp.223-230.

Tacon, Albert G.J. and I. Foster. 2003. *Aquafeeds and the Environment: Policy Implications.* Aquaculture, pp. 181-189.

APPENDIX B: List of Interviews

Date	Interviewee(s)	Age	Translator
4/13/06	Msimu Ali	N/A	Yussuf Hashim
4/13/06	Mashavu Azizi	N/A	Yussuf Hashim
4/13/06	Mwnamkuu Hamisi	N/A	Yussuf Hashim
4/13/06	Shinuna Haruna	N/A	Yussuf Hashim
4/13/06	Mwajuma Hassan Bakari	N/A	Yussuf Hashim
4/13/06	Amina Khamis	43	Yussuf Hashim
4/13/06	Mwatum Juma	N/A	Yussuf Hashim
4/13/06	Mwanaisha Makame	N/A	Yussuf Hashim
4/13/06	Fatuma Ramadhani	45	Yussuf Hashim
4/26/06	Asha Ali	52	Salum Hamad
4/26/06	Amina Khamis Fatuma Ramadhani	43 45	Salum Hamad
4/26/06	Ramadhani Mwinyi	35	Salum Hamad
4/26/06	Khamis Muhammed	31	Salum Hamad
4/26/06	Heri Musa	36	Salum Hamad
4/26/06	Saidi Majid	24	Salum Hamad

APPENDIX C: Questionnaire for initial interviews
4/13/06

1.) What is your name and when did you build your farm? What is the physical structure of your farm?
2.) What kinds of bivalves do you farm?
3.) How many times have you harvested since you built the farm?
4.) What, if any, are problems that face your farm?
5.) Do you maintain your farm (clean it, remove foulers, etc)? If yes, how?
6.) If there were a market in Bweleo for bivalves, would you be interested in increasing productivity?
7.) How could productivity be increased?
8.) Are you interested in learning more about raft culture? Are you interested in helping to construct two for this project?

APPENDIX D: Instructions on how to build a bivalve raft.
* refer to Figure 4

Materials and Costs (for two rafts)

Material	**Quantity**	**Approximate cost (TSH)**
12 mm rope	100 yards	17,000
10 mm rope	100 yards	13,000
4 mm rope	100 yards	2,700
9mm + size nylon fishing net	4-5 meters	10,000 – 20,000
50 kilo rice bags	8	1,200
Tai-tai	1 roll	1,500
Coconut stems	as much as is needed	N/A
Scissors	1	N/A
Shazia (large sewing needle)	1	N/A
Empty water bottles	44	N/A
Candle	1	N/A
Bright yellow buoys ("jerry cans")	4	2800
		TOTAL: ~58,200

Instructions- for 1 raft

1.) Measure and cut two 10 meter pieces from the 12 mm rope for the frame.
2.) Fold both in half and make a figure 8 knot.
3.) Tie the remaining ends together to make a square.
4.) Burn the ends together with a candle flame
5.) Measure and cut four pieces from the 10 mm rope for the anchor lines. The length of these lines can be determined using this equation:
  X m = depth at low tide for the implementation of bivalve raft
  4 m = tidal range
  1 m = wave action
  + 0.5 m = for tying to rice bags
  = **Length of anchor lines**
6.) Tie all four anchor lines to the frame tightly and burn with a candle flame.
7.) Next, cut 5 lines @ 5 meters each from the 4 mm rope. Tie these across the frame in 0.75 m intervals. Make sure to tie these lines tightly to the frame
8.) Cut 16 lines @ 1 meter each from the 4 mm rope and tie to the loops where the anchor lines are fastened to the frame. Attach an empty bottle to the end of each line.
9.) Cut an additional 5 lines @ 0.5 meters each from the 4 mm rope and tie to the middle lines. An empty water bottle should be attached to each middle line.
10.) Add two bright yellow "jerry can" buoys to two alternating corners of the raft.
11.) Once all these steps have been completed, the raft is ready to be deployed. This should be done during low tide in the desired depth. Rice bags should be filled with sand and tied just prior to deployment.
12.) Seaweed and bivalve cages can then be added during the following days at low tide.

APPENDIX E: Questionnaire for follow-up interviews
4/26/06
*Please note that two different questionnaires were devised due for differing levels of involvement between male fishermen and female bivalve farmers.

Questions asked to fishermen:

1.) What is your name, age, and how long have you been fishing?
2.) What kind of involvement, if any, have you had with bivalve farming before this project?
3.) Do you have interest in continuing this method of bivalve farming? If yes, how could you fit this into your daily schedule?
4.) How can men and women successfully work together on this method of bivalve culture?
5.) How can the rafts be protected from boat disruption and tampering?
6.) What do you know about the biology of bivalves (their habitat, diet, and reproduction)?
7.) How do you feel about the potential implementation of a kiosk in Bweleo? What are your ideas?
8.) How can the environment be protected and productivity increased at the same time?
9.) Do you have any feedback, comments, or questions on this project?

Questions asked to bivalve farmers:

1.) What is your name, age, and number of year farming seaweed, cultivating bivalves, and collecting wild bivalves?
2.) What has been your involvement with bivalve farming to date?
3.) Since you began farming, have bivalve numbers increased or decreased? Why?
4.) Do you culture bivalves or just use them for food?
5.) Do you sell or eat the bivalves collected and the bivalves cultivated?
6.) When are the bivalves sold? Where are they sold? In what quantity and for how much? How much do you make in a week or a month? Who purchases the bivalves?
7.) How can men and women successfully work together on this method of bivalve culture?
8.) What do you know about the biology of bivalves (their habitat, diet, and reproduction)?
9.) How do you feel about the potential implementation of a kiosk in Bweleo? What are your ideas?
10.) How can the environment be protected and productivity increased at the same time?
11.) Do you have any feedback, comments, or questions on this project?