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FEASIBILITY OF SEA CUCUMBER AND SEAWEED FARMING IN THE BAZARUTO ARCHIPELAGO-MOZAMBIQUE

Mission in BAZARUTO ARCHIPELAGO
MOZAMBIQUE: 20-25 November 2014

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INTRODUCTION

1. General Context

The Bazaruto Archipelago is a group of five islands in Mozambique, situated alongside the mainland city of Vilankulo. It comprises the islands of Bazaruto, Benguerra, Magaruque, Santa Carolina (also known as Paradise Island) and Bangue. The islands are administered by both the district municipalities of Vilankulo and Inhassoro of Inhambane Province. The Park supports various endangered marine mega-fauna such as Whaleshark, Manta rays, Leatherback turtle, cetaceans including Humpback whale, and the Dugong. Bazaruto's Dugong population is estimated at approximately 250 individuals, and it represents the largest remnant populations in Mozambique (Bandeira *et al.,* 2014), and the last viable population known in the Western Indian Ocean. The Park is Mozambique's oldest marine Protected Area and was proclaimed by Decree nº. 46 of 25th of May 1971 and its limits were revised by Decree nº. 39/2001 of the 27th November. The Park was created in order to protect Dugongs and marine turtles and their respective habitats. The Park covers a large expanse of ocean as well as the five islands of the archipelago with an area of 1430 $km^{2.}$

The Endangered Wildlife Trust is a South African Non-Profit Organization focussing on applying conservation of threatened species and ecosystem in southern Africa. Founded in 1973, the EWT implements conservation research and action programmes, supports biodiversity and ecosystem functioning and advocates the sustainable use of natural resources. It is affiliated to the Government of Mozambique by way of a support Partnership. The Partnership was developed in 2012 in order to provide technical, operational and financial assistance to the Bazaruto Archipelago National Park (BANP) with particular focus on (*i*) facilitating improved conservation management of the Park's marine environment, and (*ii*) stabilizing the Bazaruto Dugongs by mitigating major threats and strengthening existing structures. Based in Banguera Island, the mains activities of the Dugong Emergency Protection Project are to (*i*) enforce the law of dugong protection, (*ii*) help education and (*iii*) provide alternative livelihood for local communities. In line with (iii) above, the Manager of the project, Karen Allen- contacted experts from Madagascar in order to assess the feasibility of sea cucumber and seaweed farming in the Bazaruto Archipelago of Mozambique as an alternative livelihood for local communities.

2. History of sea cucumber farming in Madagascar

The sea cucumber hatchery and mariculture project was started in April 2000 in Toliara, on the south-western coast of Madagascar. The mariculture project produced tens of thousands of juveniles of the high-value sea cucumber *Holothuria scabra* (Jangoux *et al.*, 2001). The mariculture project arose from the widespread overexploitation of holothurian resources along the west coast of Madagascar (Conand 1998, Conand *et al.*, 1997). The successfulness of the project allowed the establishment of the first holothurian trade company “MHSA” (Madagascar Holothurie Société Anonyme) in 2008. This company is a tri-party partnership involving the Belgium University, IH.SM (Institut Halieutique et des Sciences Marines) and a Malagasy private company COPEFRITO SA (Eeckhaut *et al.,* 2008). In 2007, a pilot study to demonstrate the feasibility of holothurian mariculture in the villages (with local fishermen) was started. This was collaboration between IH.SM, Blue Ventures (NGO), Copefrito Company, the Women’s Association of Andavadoaka, and the village of Ambolimoke (Robinson & Pascal, 2009). In 2013, the company Indian Ocean Trepang was cretaed, which is a sea cucumber company of industrial level based in Toliara-Madagascar- whose aim is to produce 4.000.000 sea cucumber juveniles per year during the production phase.

3. Objectives and achievement of the mission in Bazaruto Archipelago National Park

The aim of the mission is to study the feasibility of sea cucumber farming in the Bazuaruto Archipelago of Mozambique, and to determine the environmental conditions that will allow the culture of seaweed. The overall aim is to provide alternative sources of income for fishing communities in the Bazaruto Archipelago National Park.

The specifics objectives are to:

- Assess the suitability of the site as well as infrastructure needed (hatcheries, feed, equipment, commercial buyers etc.) to build a successful livelihood project and,
- Develop the operational and community elements of the sea cucumber farming initiative under guidance and potentially- by way of a working partnership.

The mission lasted 12 days (form Monday 17th to Friday 28th November) all trips included. However, the infield observation and assessment took only 4 days (Friday 21st to Monday 24th). Details are given at the Annex 01 of the present document as well as the boarding pass (Annex 02). The field studies were focused on (*i*) sites prospection, (*ii*) sediment sampling and physical and chemical analysis and (*iii*) discussion with authorities and local villagers.

METHODOLOGY

4. Study area and sites prospection

The area chosen for this feasibility study is around Benguerra, Bazaruto and Santa Carolina Islands (fig. 01). Before the field observations, discussions were firstly conducted with the EWT Project Manger who was familiar with the sites and the overall area. The discussions were focused on the analysis of suitable habitats in the Bazaruto Archipelago (overview of the Islands, existence of bay, etc.) and presence of suitable sites: muddy sediments, mangroves zone, sea cucumber, etc. After the discussions, it was decided to firstly conduct a fly-over of the Islands by light aircraft, especially the northern part of Benguerra Island, the western part of Bazaruto Island and around Santa Carolina Island.

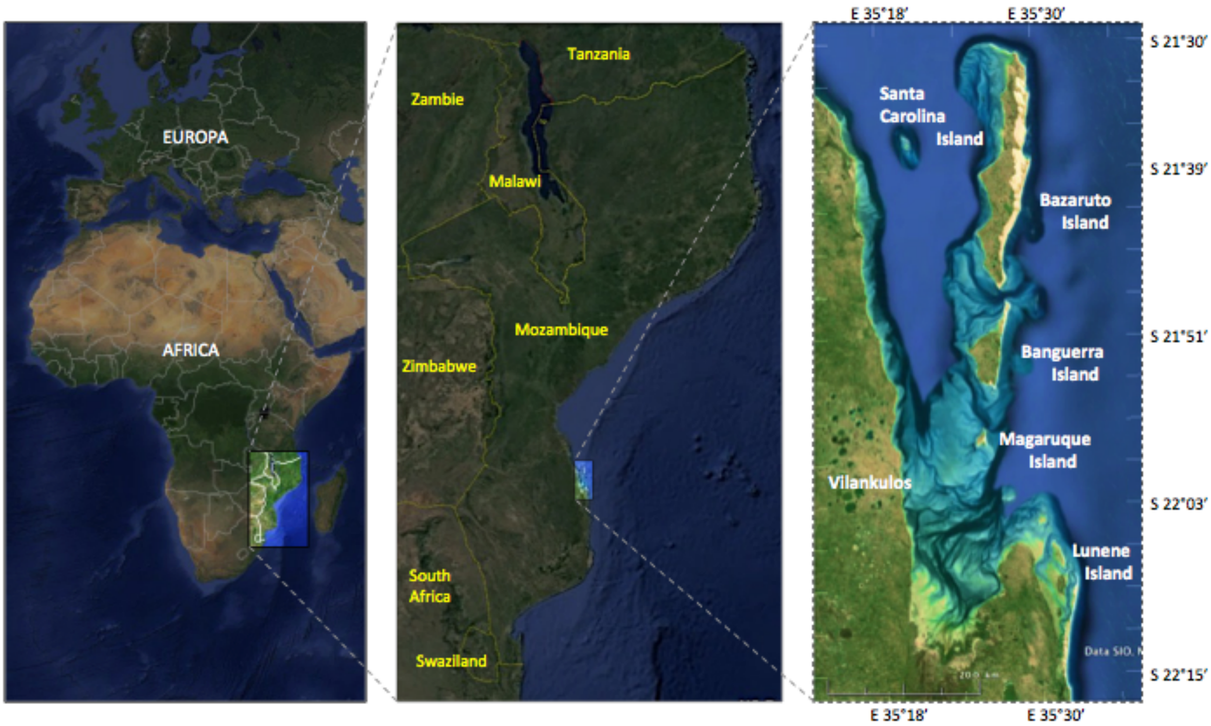

Figure 01. Map of the Bazaruto archipelago-Mozambique.

4.1. Fly-over by aircraft

The objective of the fly-over was to identify probable sites for sea cucumber farming before performing in-depth field observations by boat. The aircraft used is a small aircraft (two seats (fig. 02). These services were provided by Etienne Oosthuizen- Volunteer to the EWT project and owner of the aircraft. The flight was conducted during low tide at varying altitudes between 200 and 600 feet. The total flight time was 1 hour, 20 minutes- during with we used GPS to mark probable sites. These co-ordinates allowed us to return to the sites to perform *in* situ observation by boat days after.

Figure 02. Aircraft used for the aerial observation. On left: Dr Thierry Lavitra, and on the right: Pilot- Etienne Oosthuizen.

4.2. In-field observation by boat

The in-field observations ware performed over 3 days (22-24th November). Sampling was conducted along the west of Bazaruto Island (two bays) and at the western and eastern shores of Santa Carolina Island. Each in-field observation proceeded for between 4-5 hours (travelling included) and was conducted during the low tide. For each site, the following parameters were measured and recorded: (*i*) salinity, temperature, visibility of the seawater, (*ii*) water depth and (*iii*) observed fauna and flora species. We noted seawater temperature at each site using a data logger, but mean medium-term temperature readings were not recorded since the data logger became exposed at the spring low tide.

5. Sediment sampling and treatment

Sediment sampling and treatment were carried out at two bays along the western shore of Bazaruto Island (fig. 03). For each bay, 4 sediment samples were taken (collected form different points). The top 5 cm layer of sediment was collected. Four replicate samples were collected at each bay. For each sample, our laboratory (in Toliara) analysed the granulometries as well the organic matter content.

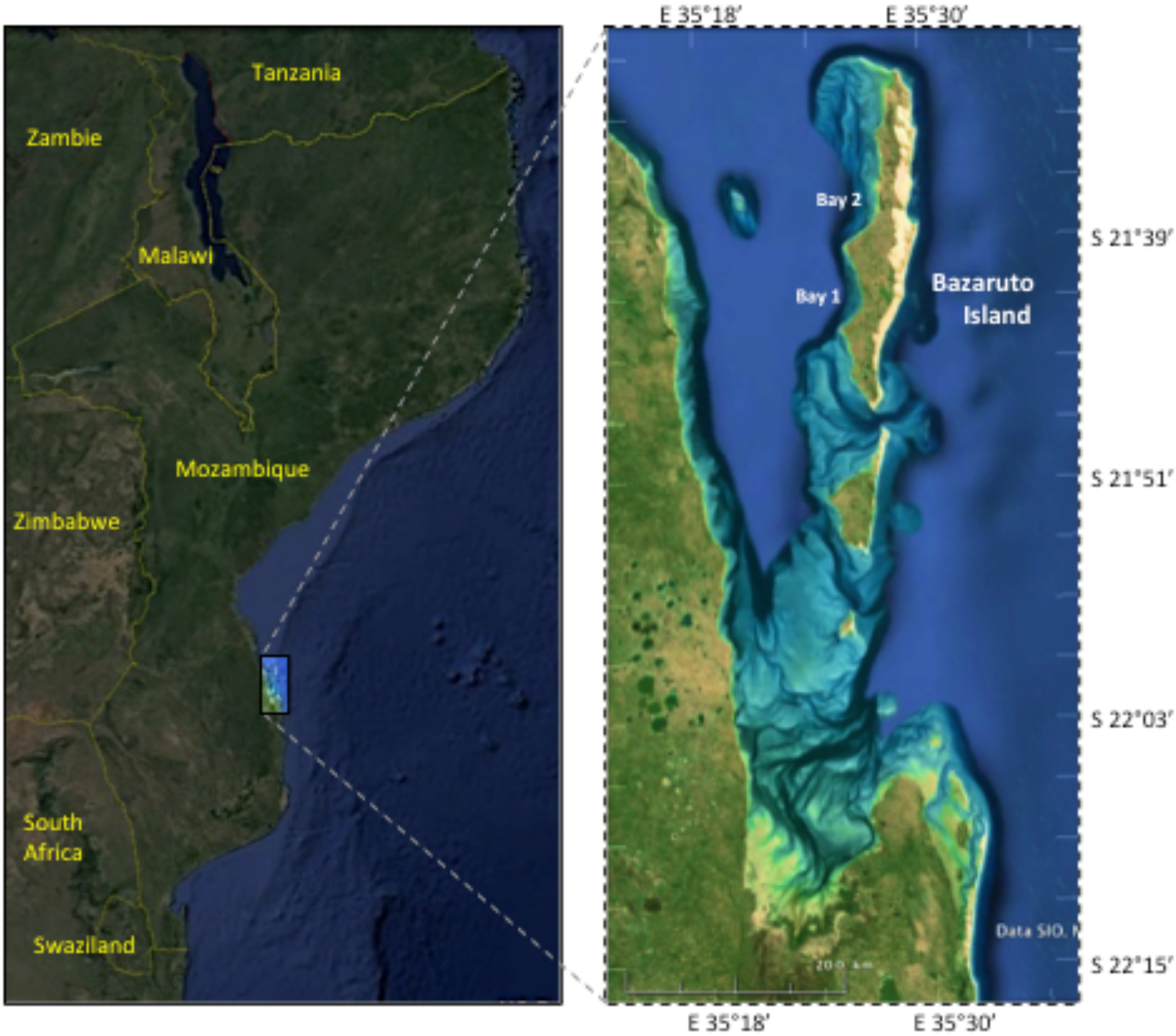

Figure 03. Map of Bazaruto Island-Mozambique, depicting both bays where sampling took place.

5.1. Granulometric study

For the granulometric study, each sediment sample of an approximate amount of 200g (dry weight) was firstly rinsed with distilled water and dried in an oven at 60°C for 48h (fig.04).

The total dry sediment was passed through six sieves (fig. 05) with decreasing pore sizes (2000, 1000, 500, 250, 125 and 63 μm). The granulometries of the sediment was determined by dry-sieving and was expressed in weight percentages. Also, each part of the sediment was observed in order to record the existence of fauna and flora/ organisms.

Figure 04. A: Drying sediment in an oven at 60°C. B: samples inside the oven.

Figure 05. Sediments treatment. A. Rinsing; B. sieving.

5.2. Organic Matter content

Sediment samples were oven-dried for 48 h at 60°C and sieved in order to remove large particles (mesh size, 4 mm). The dried sediment (ca. 50 g; $n = 4$) was then weighed using precision balance (fig. 06A), transferred into a muffle furnace and carbonized at 450°C for 4 h (fig. 06B). After the sediment cooled to ambient temperature, samples were re-weighed and the organic-matter content was determined as the ash-free dry weight.

Figure 06. Analysis of sediment sample (weighting and carbonisation). A: Precision analytical balance; B: Muffle furnace.

RESULTS

6. Sediment analysis

6.1. Granulometries.

There is a similarity of the sediment grain-size for the two sites (Bay 1 and bay 2 of Bazaruto Island). The first observation is the absence of argil and silt (<63 microns) for the sediment and a low amount of fine sand (<250) <20% in both sites. In comparison- Toliara-Madagascar sea cucumber farms exhibit a 1% argil and silt composition of the sediment, and the fine sand (<250 µm) comprises 43% the sediment (Lavitra, 2008). The Bazaruto Island sediment is composed especially of medium size sand (250-500 µm), which comprises 75 to 83% of the sediment.

Table 01. Granulometries of sediment in two bays of Bazaruto.

	Bazaruto Island 1st Bay		Bazaruto Island 2nd Bay	
Grain size (microns)	**Average**	**Standard deviation**	**Average**	**Standard deviation**
>2000	3,15	1,23	3,49	3,47
2000-1000	1,90	1,15	2,80	1,02
1000-500	0,49	0,38	1,02	0,36
500-250	74,87	11,76	82,54	4,41
250-125	17,28	10,96	9,60	4,22
125-63	2,30	1,28	0,55	0,12
<63	0,00	0,00	0,00	0,00

6.2. Organic Matter

A very low organic matter content is observed in the sediment collected at Bazaruto Island. They are 0,57% +/-0,10 and 1,10% +/-0,29 respectively for the first and the second bay (tab. 02 A and B). In comparison, it should be mentioned that organic matter content is of 2-2,5% in sea cucumber farming sites of Toliara-Madagascar (Lavitra, 2008).

Table 02. Organic matter content in the sediment samples.

A. At 1st bay of Bazaruto Island

	Bazaruto Island 1st Bay					
	Sample 1	Sample 2	Sample 3	Sample 4	Average	Standard deviation
Empty capsule (g)	0,85	0,63	0,92	0,88		
Sediment (g)	15,37	15,41	15,16	15,02		
Capsule + Sediment	16,22	16,04	16,08	15,90		
C+S after carbonisation	16,13	15,95	16,01	15,80		
O M content (g)	0,08	0,10	0,07	0,10		
O M rate (%)	0,54	0,63	0,45	0,68	**0,57**	0,10

B. At 2nd Bay of Bazaruto Island

	Bazaruto Island 2nd Bay					
	Sample 1	Sample 2	Sample 3	Sample 4	Average	Standard deviation
Empty capsule (g)	0,52	0,75	1,08	0,69		
Sediment (g)	15,02	15,08	15,19	15,38		
Capsule + Sediment	15,54	15,83	16,26	16,07		
C+S after carbonisation	15,42	15,68	16,10	15,84		
O M content (g)	0,12	0,15	0,16	0,23		
O M rate (%)	0,83	0,99	1,06	1,51	**1,10**	0,29

7. Assessment of sea cucumber farming sites in the Bazaruto Archipelago

From an analysis of the map and discussions with the EWT Project Manager, the island's western coasts were omitted from the assessment owing to unfavourable environmental conditions- wind, waves and current. In addition, these sites are deep and the sediment is too sandy. Observations and samples were limited to favourable and probable environments presenting suitable farming site conditions.

By way of initial observations made from the aircraft, four sites at Bazaruto Island were recorded as potential farming sites. Whilst performing ground-truth checks, only 2 of the 4 sites were diagnosed as suitable, and all further tests were conducted at Bay 1 and Bay 2.

7.2.1. Bay 1:

Bay 1 yielded salinity of 35% and the water depth was 0,5m. 95% of the site was covered by seagrass, and the most common and dominant species was *Thalassodendrum cilliatum.* Within the site, we observed high concentrations of sand oyster *Pinctada imbricata*. Other species observed included sea urchin *Tripneustes gratilla* and *Toxopneustes pileolus*, sea cucumber *Holothuria sp* and some coral species such as *Pocillopora sp*. The seawater was very clear, indicating the absence/low quantity of particles in suspension and low organic matter content (0,57%). The seagrass cover (very high >95%), in combination with the absence of silt and argil, the low amount of fine sand and the organic matter content in the sediment allows us to deduce that Bay 1 of Bazaruto Island is not a preferable site for sea cucumber farming.

7.2.2. Bay 2:

Our first impression of Bay 2 was that this would be a better site for sea cucumber farming. The salinity measured 37% and the depth was 0,5m. Our first observation was the presence of many organisms and muddier sediment as compared to Bay 1. We observed the presence of at least 3 species of mangrove in close proximity to the site (fig.10). Unfortunately, our second and follow-up visit to this location showed that the tide receded completely from this bay at spring low tide (fig. 11A), and the data logger that we used to record seawater temperature variation was emerged (fig. 11b) during this same tidal phase.

Figure 10. Mangrove species present in the site. A: *Avicenia marina* and *Sonneratia alba*; B: *Ceriops tagal.*

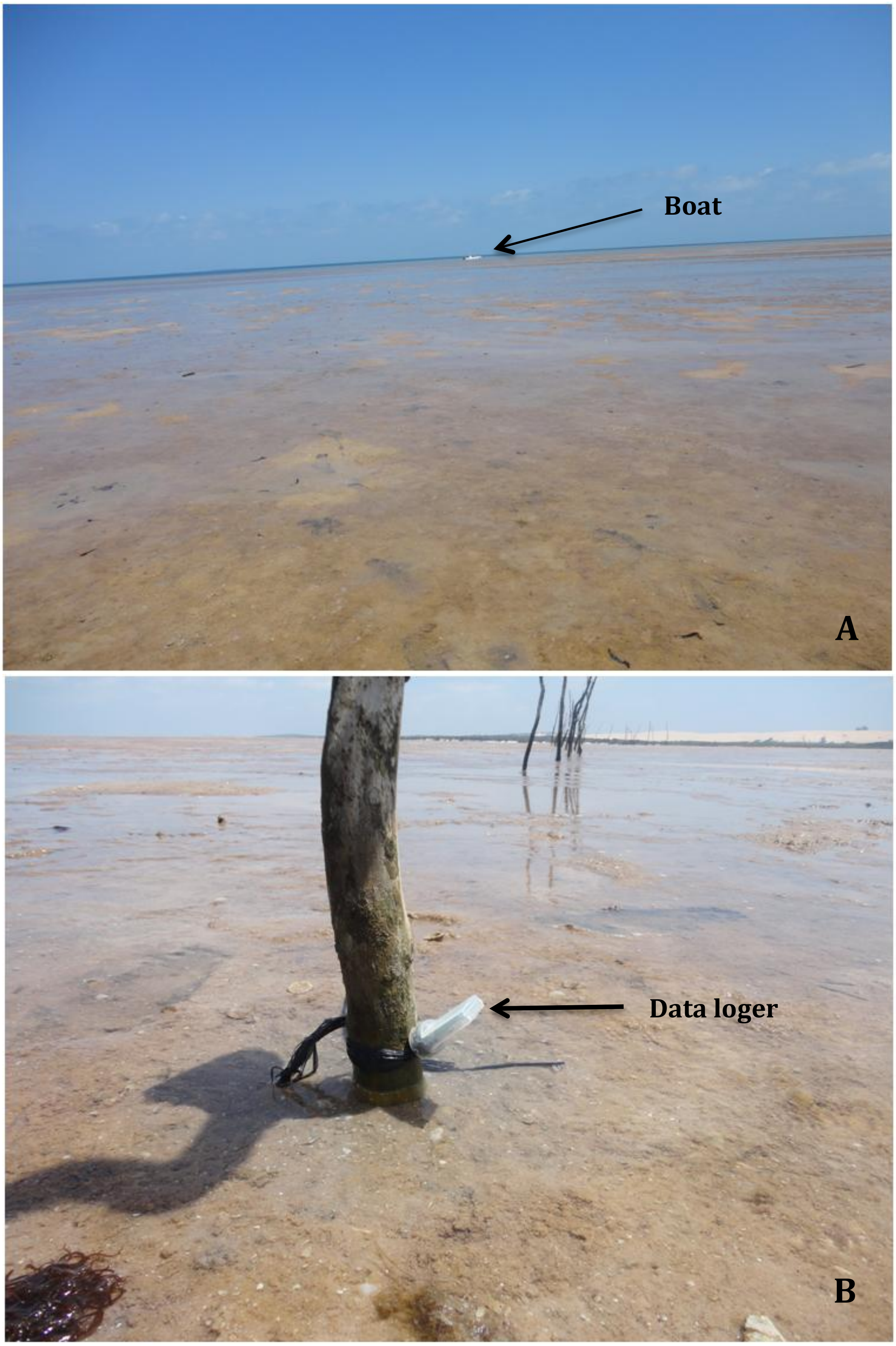

Figure 11. The 2nd bay of Bazaruto island during the 2nd visit. A: Photo showing that there was no water at al on the site. We had to keep the boat far away form the site. B: Photo showing the data logger exposed out of the water.

7.3. Santa Carolina

Also known as Paradise Island, Santa Carolina is a site better-suited to tourism than aquaculture. Many tourists frequent this site daily to enjoy the incredible cultural richness of this island, and to visit its reefs for snorkelling. The Santa Carolina site inspection was scheduled in order to observe the diversity of sea cucumber species present in the area.

Waves and current at the eastern part of the Island was minimal, while the sediment is very sandy and white in colour. The water depth varies according to the distance form the coastline: 0,3 to 1m during the low tide. We found many live corals and a high diversity of fish at this location. Only 2 species of sea cucumber were observed here: *Holothuria atra* (0,5 individual/m^2) and *Stichopus chloronotus*.

The Island's western shore habitats and species richness are distinct. The presence of seagrass (dominated by *Thalassodendrom ciliatum*) and also seaweed: *Sargassum latifolium*, three species of sea cucumber: *H. atra*, *S. Chloronotus* and *Holothuria edulis*, and *H. edulis* was found in deeper water (2m).

Figure 12. Sea cucumber species present in Santa Carolina Island.

A. *Holothuria atra*
B. *Stichopus chloronotus*
C. *Holothuria edulis*

8. Overview of fishing activities in Bazaruto Archipelago and the perception of villagers about sea cucumber and seaweed farming/ Alternative Livelihoods.

The Park is inhabited by the Vahoka ethnic group and more recently- by the decedents of the mainland-based Tsonga tribe. The estimated local population of the National Park is approximately 5,000 people, and the average household size is 8 persons per dwelling. The local island residents are almost all fishermen or practice some form of marine resource harvesting. As the islands are part of the National Park, the mainland-based fishermen (i.e. from Vilanculos) are prohibited to fish inside the Park. Only the local population (from the islands) is allowed to practice subsistence fishing, and commercial fishing is forbidden. The use of gill nets and spear guns are not permitted within the National Park.

8.1 Meeting with villagers and discussion with BANP Staff

Discussions with villagers on Bazaruto Island was carried out by focus group method (fig. 07). The following groups were invited to the focus-group meeting:

- The Bazaruto Archipelago National Park Authorities;
- All staff of BANP and
- The fishermen living around Sitone Focal village.

The meeting took place on Saturday 22 November after the fishers had harvested and sorted their yields (from 3 to 5h pm). The discussion focussed on two main topics: (*i*) the overview of the fishing and fisheries and (*ii*) sea cucumber and seaweed farming. The meeting was conducted in the local language of Xihoka, and translations were made into Portuguese so that the EWT project manager could translate the discussions to Dr Thierry Lavitra.

8.2. Fishing methods

The primary marine resource harvesting methods employed within the Park are (i) beach seine netting, (ii) hand-line fishing and (iii) collection of bivalves and crustaceans.

Figure 07. A: Feasibility Assessment team and Local Community Leaders. B: Discussions with local community by focus-group method.

8.2.1 Beach seine Netting

Beach seine netting constitutes the main fishery within the park. It has been practiced for many years. Beach seine netting requires from 6 - 22 fishermen to work together. The length of nets vary, but the commonly used net measures 100m (fig. 08 A). Typically, the community are actively engaged in fishing activities for about 5 hours each day and their harvests consist of small pelagic and baitfish species (fig. 08 B).

Figure 08. A: Beach seine. B: Nets and small fish caught.

8.2.2 Bivalve and crustacean harvesting

Children and women mostly practice this form of resource harvesting during the low tide. The sand oyster *Pinctada imbricata* (fig. 09) constitutes the main harvest while Blue swimming crab *Portunus pelagicus* are also common. The women usually treat the oysters by smoking them, and these are sold for about 150 Mzn/Kg ($4/ Kg).

Figure 09. Sand Oysters *Pinctada imbricata.*

8.3. Perceptions on Yield

The Islanders explained that fishing is not easy and that the catch has diminished. According to the community- yields have declined during the last 20 years. The entire harvest is used for subsistence, and excess is seldom available to sell.

8.4. Perception of sea cucumber/ seaweed farming as an alternative livelihood

8.4.1 Limitations of Fishing

- Catches/ yields have decreased
- Harvesting takes place only at low tide
- Fishing at night is forbidden
- Owners of the nets and the fishing boats gain the largest part of the yield, and what remains is barely enough for a family's consumption.

8.4.2 Limitations of Farming

- since the Islands became a National Park, intensive farming has beenprohibited.

Based on the above limitations, a critical need exists for fishermen to be provided with alternatives in the tourism, transport, and aquaculture industries. It should be mentioned that none of the villagers were familiar with sea cucumber farming and had no notion that this aquaculture industry provided profitable alternative livelihoods for fishing communities elsewhere in the western Indian Ocean. While unknown to them, the community expressed interest in exploring sea cucumber and seaweed farming as an alternative income-generating opportunity, and any other suggestions that EWT may be able to provide them with.

CONCLUSION

The local communities of the Bazaruto Archipelago National Park require urgent support to identify and develop alternative income-generating opportunities. Since sea cucumber farming was deemed unfeasible, our recommendation is to pilot a seaweed farming project at either Bay 1 or Bay 2 of the Assessment site. Based on our experience, *Kappaphycus alvarezii* would be advised as the most suitable commercial species, and farming of this seaweed species is much requires limited investment to establish the farming plots.

RECOMMENDATIONS

10. Technical Recommendations

The details of how to prospect sites, the importance of carrying out test plots and the technical culture of *K. alvarezii* are presented below:

10.1. Materials Required to prospect farming sites

- Salinometer
- An alcohol thermometer: 23 to 30°C
- A nautical chart for that area or at the very least a sketch of the area.
- A tide book
- Reference materials to identify seaweed, seagrasses and mangrove trees,
- A notebook and pen
- A plastic bottle attached to a 5 meter string
- A watch with a second hand

10.2. Indicators to measure

Temperature: Take two readings, one at the daily low tide and the other at the daily high tide. When reading the thermometer, make certain it remains in the water while doing so. Temperatures must fall within the 23 to 30°C range.

Salinity: Simple hydrometers sold by aquarium supply stores are accurate enough for this work (and are a fraction of the cost of a refractometer.) Exclude all sites outside the 23 to 38% range. Choose a site far from a fresh water source.

Rainfall: It is important to know the rainfall pattern and amount- since this can impact coastal salinity as well as solar drying of the harvest.

Wind speed/direction: Seasonal wind patterns are important since they can correlate with water temperature, nutrient and water motion changes.

Water motion: Water motion is primarily driven by two factors, gravitational pull of the moon (tides) and the wind. Since water motion is extremely important to growing seaweed in low-nutrient tropical waters, it is important to select locations with high tidal water motion/ velocity. This can be measured by dropping the plastic bottle into the current whilst holding onto the end of the string that is attached to the bottle-neck. The bottle will travel along the current, and the string will tension. Exclude sites where the time for the bottle to travel the 5 meters exceeds 25 seconds (water flow < 20 cm s-1) at maximum tidal flow.

Siltation and Turbidity: This is a somewhat paradoxical topic. On one hand *cottonii* and *spinosum* can grow very well in turbid (muddy) waters such as off mangrove forests. On the other hand, certain siltation causes decreased growth. At the site selection stage, test plots can be used to determine if the site is suitable.

Associated species: The eelgrass genera *Enhalus* and *Thalassia*, the red algae genera *Laurencia*, *Hypnea*, *Acanthophora* and some *Gracilaria* species are good indicators that *cottonii* and *spinosum* will grow in the area. The mangrove genera *Avicennia* and *Rhizophora* also indicate a suitable salinity for *cottonii* farming.

10.3. Test Plots

After surveying sites and excluding those that had at least one environmental parameter that was outside the range specified, the next step is to place test plots at the remaining sites. The only way to truly determine if *K. alvazerii* will grow in an area is to place it there for a reasonable period of time and see if it does indeed grow.

After tying propagules to the line, weigh the entire line and then count the number of plants on the line. When weighing, let the plants drip dry for 30 seconds to get rid of water. Also, weigh a comparable length of dry line without propagules. Record these numbers in a field note book, then calculate and record the mass per plant.

The standard growth equation is:

$$\textbf{\% daily growth} = \ln(Mf) - \ln(Mi) \times 100 / n^b \text{ days}$$

Where Mf = final weight; Mi = initial weight and n^b days = number of culture days

Importantly, the daily growth rate is must exceed 2%

11. Technical culture

11.1. Off-bottom method

The general approach is to suspend a series of lines of 10m in length between two posts, which are usually made of wood. This technique is best suited for lagoons, where there is relatively shallow water at low tide and for small-scale initiatives. The lines are regularly checked and the seaweed harvested during the two spring tide periods each month, at which time the farmers can work on foot, and is therefore a technique particularly suited to women farmers. Following each harvest, the seaweed is dried on land for a few days before sale.

Figure 13. Off Bottom culture

11.2. Long Line Method

This method is commonly used in used in the southern Philippines, Sabah, Malaysia and Madagascar though they are growing in popularity throughout the countries where *K. alvarezii* is cultivated. This technique involves the use of line of up to 50m in length, anchored at each end and with floats attached every 10m or so to support the line This technique is usually employed in water of between 4 and10m and farmers therefore require access to some sort of boat to access the plots. However, as a result of the necessity of a boat the farmers can access the plots at all times, except for during bad weather. Sand bags, rocks or wooden stake-anchors are used and small rocks (0.3 to 1 kg) are attached to keep tension in the anchor line. Floats are situated to ensure that the lines are 20 to 40 cm below the surface.

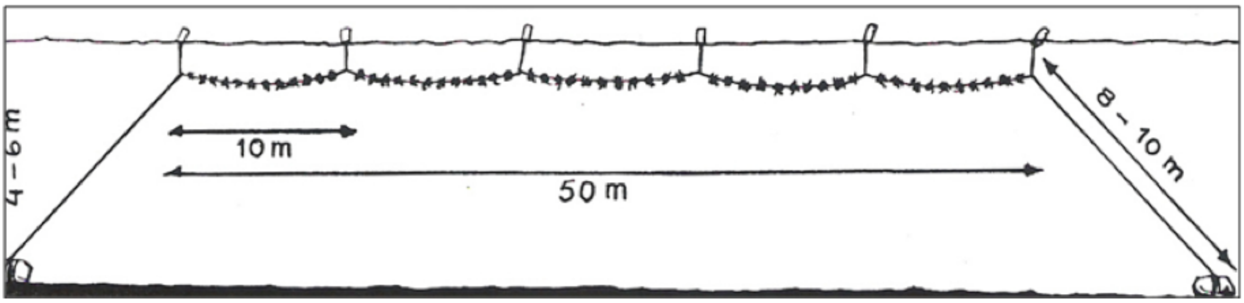

Figure 14. Long line system

11.3 Harvesting

Seaweed is fast-growing and they are ready for harvest in 40 – 60 days. For floating and fixed off-bottom farming, the seaweed can be harvested by removing the entire monolines together with the plants from the stakes or from the main support lines. This procedure makes it easy and convenient to select good seedling materials for the succeeding cropping. By using the broadcast method- the plants are pruned and small sections are left to enable re-growth.

11.4 Drying

The proper solar drying of seaweed is crucial. This is because it determines the quality of the final product and thus its price. Eight to ten kilogram wet-weight of seaweed will yield one kilogram dry-weight after about three-days drying. It is necessary to pay attention during this process because farmers are paid by weight and so it's in their interests to sell seaweed before it is fully dehydrated. Properly dried seaweed will be prickly when crushed in the hand. International buyers require a product with a 30% moisture content and of a high standard of cleanliness and quality. This can be achieved only by drying on a drying table (fig 15), to avoid contamination with animal droppings, for example, which may contain fecal colliform bacteria. Drying seaweed directly on the ground should be avoided at all costs.

Figure 15. Seaweed drying.

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