Mauritius Research and Innovation Council

INNOVATION FOR TECHNOLOGY

Experimental Seaweed Farming at Albion

Final Report

February 2013

Mauritius Research and Innovation Council

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This report is based on work supported by the Mauritius Research and Innovation Council. Any opinions, findings, recommendations and conclusions expressed herein are the author's and do not necessarily reflect those of the Council.

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PROGRESS REPORT

1.0 Introduction

Seaweed and the plethora of commercial products derived from seaweed form the pillars of the economy of many countries, such as Japan, China, Indonesia, Philippines, among others. Seaweed derived products are essential in the food & beverage, pharmaceutical, cosmetics, agricultural and many other industrial sectors. The world market for the seaweed industry has an estimated total annual value of more than US$ 7 billion (FAO, 2010), growing at a rate of about 15% annually. The main importers are the developed countries, US and Europe. Major exporters include China, Japan, Indonesia, Philippines and some Latin American countries such as Chile and Peru. The absence of Africa as a major player in this market is recognized, though seaweed production and commercialization has been reported in Zanzibar and Madagascar to some extent. This is an indication of a potential African niche market.

Mauritius is a Small Island Developing State with limited land resources but with an extensive Exclusive Economic Zone of about 2.3 million km^2. Despite the reported presence of 435 species of seaweeds in Mauritius and Rodrigues and the potential market for seaweed derived products, no local research has been conducted to investigate the commercial exploitation of these resources. Hence the initiative of the MRC to set-up a research programme to investigate the potential of developing an economically, technically and environmentally viable seaweed industry in Mauritius and Rodrigues.

The National relevance of this programme is emphasized by section 195 of the Government Programme 2010-2015 which states that 'the Cultivation of Seaweed with a view to developing an Industry based on Value-added transformation of seaweed for human consumption, cosmetic application, medical and pharmaceutical research' will be conducted.

Development of small scale seaweed culture in Mauritius and Rodrigues is also mentioned under the project 2 (b) development of a comprehensive aquaculture development and management policy that builds on the Aquaculture Master Plan, Fisheries Master Plan for Mauritius, Rodrigues and the outer Islands, 2011.

A hands-on Training workshop on Seaweed Farming was held on the 7th – 11th of November 2011 for Stakeholders. This focused on the implementation of an experimental farm which occupied an area of $100m^2$ in the lagoon of Albion (refer to Figure 1 and Figure 2) and consisted of several methods of farming such as off-bottom farming and various rafts

The seaweed farms were implemented with the help of the participants of the workshop. The monitoring was carried out by Mr Koushul Narrain (Research Assistant) from the Mauritius Research Council from the 10th of November to the 21st of November 2011.

2.0 Objectives

1. To provide hands-on training workshop on seaweed farming to stakeholders
2. To set-up an experimental farm at Albion in collaboration with the local fisher groups
3. To cultivate *Gracilaria salicornia* in the experimental farm and monitor the growth rate over a period of one year.
4. To evaluate and adapt different farming techniques for local seaweed production
5. To build up local capacity in seaweed farming

3.0 Permits and Approvals required for experimental seaweed farming

Clearances have been obtained for Experimental Seaweed Cultivation from the following institutions - Prime Minister's Office, Ministry of Fisheries, Ministry of Housing and Lands, Beach Authority and Ministry of Environment and Sustainable Development.

The permit granted by the Prime Minister's Office to the MRC for seaweed farming and the support from other major stakeholders such as the Ministry of Fisheries, the Ministry of Housing and Lands, the Mauritius Oceanography Institute and the Beach Authority indicate the commitment of local authorities towards this program.

4.0 Project Description

The following activities have been undertaken to setup the experimental seaweed farm at Albion.

4.1 Scoping for site selection

The scoping for site selection was done in November 2011 with the consultant Dr F E Msuya of the Institute of Marine Science (IMS), Zanzibar. The site selection was also based on the reports of past experts and that the site was monitored by AFRC on a regular basis.

Another major reason for selecting Albion as the site for seaweed farming was its proximity to Albion Fisheries Research Centre (AFRC) where all logistic and technical support exist.

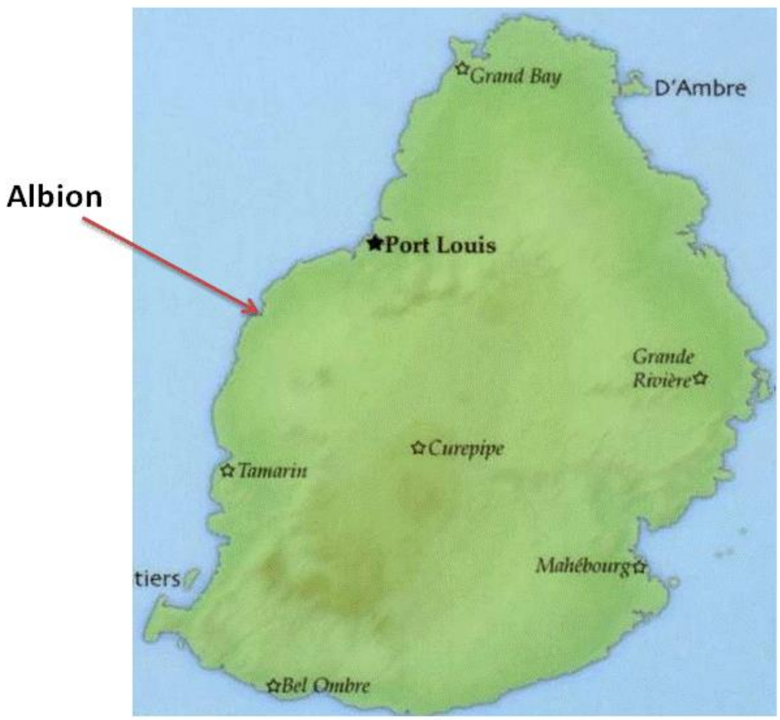


Figure 1: Location of Experimental Seaweed Farm in Albion.

4.2 Meeting with Fisher Groups

A meeting with the fisher groups was organized on 3rd November 2011 at the Albion Community Centre in collaboration with Ministry of Fisheries/ AFRC to inform them about the seaweed project of the Council.

Around 15 fishermen and the Officials of MRC and AFRC were present in the meeting.

Figure 2: Meeting with Fishermen of Pointe aux Sable region.

5.0 Bio-Assessment

The bio-assessment for the site was planned for first week of November 2011 along with the support from MOI, however, a shark was sighted in the area and a prevention order was issued by the Commissioner of Police barring entry into the sea.

In this scenario, the data obtained from the research paper on “The status of the marine environment of the Albion Lagoon, AFRC, 1999” was referred as a starting point to initiate setting-up of the experimental farm in Albion.

6.0 Workshop for setting-up of the seaweed farm

The Mauritius Research Council in collaboration with Ministry of Tertiary Education, Science, Research and Technology and the Ministry of Fisheries and Rodrigues organized a hands-on training workshop on "Seaweed Farming" at the Albion Fisheries Research Centre (AFRC) in Mauritius from 7th – 11^{th} November 2011. The seaweed expert, Dr. Flower E Msuya, from the IMS, Tanzania was the designated resource person for the training.

The purpose of the hands-on training workshop was to:

(a) Provide practical training to stakeholders and fisher groups in seaweed farming and

(b) Set up experimental farms in Mauritius.

The five-day hands-on training workshop included all skills involved from site selection to seaweed culture for setting up experimental seaweed farms, including farming methods, problem solving (both social and environmental), working with communities and management of a seaweed farm and so forth.

About 40 participants from Agricultural Research & Extension Unit (AREU), Board of Investment (BOI), Mauritius Oceanographic Institute (MOI), Mauritius Sugar Industry Research Institute (MSIRI), Ministry of Fisheries & Rodrigues, Ministry of Industry, Commerce and Consumer Protection, University of Mauritius (UOM), Private Sector and members of the fisher groups participated in the workshop in Mauritius.

Figure 3: Training Workshop Session at AFRC Conference Room Albion

7.0 Setting-up of an Experimental Seaweed Farm at Albion

The outcome of the workshop was to set-up an experimental seaweed farm in Albion, Mauritius demonstrating four cultivation techniques, namely, Off-bottom Culture, Bamboo Raft, Line Raft and PVC Raft with *Gracillaria Salicornia.*

Three (3) cultivation techniques; namely the rope, raft and off bottom methods were implemented using one seaweeds species, *Gracilaria salicornia*. Apart from the capacity building of the participants in seaweed farming, an important output of the workshop was the setting up of one experimental farm at Albion in Mauritius.

The experimental seaweed farm in Mauritius was jointly launched by Dr the Hon Rajeshwar Jeetah, Minister of Tertiary Education, Science, Research and Technology and The Hon. Louis Joseph Von Mally G.O.S.K, Minister of Fisheries and Rodrigues on **Thursday 10th November 2011** at the Conference Room of the Albion Fisheries Research Centre, Albion.

Figure 4: Seaweed Collection atPointe aux Piments.

Figure 5: Seaweed selection at AFRC, Albion.

Figure 6: Implementation of Off Bottom Farm at Albion.

8.0 Experimental Seaweed Farming at Albion

The site plan

The site for the experimental farm at Albion is located in front of the Albion Fisheries Research Centre of the Ministry of Fisheries. The site is located approximately 50 meters from the shore line.

Figure 7: Satellite Imagery of Experimental Farm in Albion.

Initially only *Gracilaria salicornia* species was cultivated on four types of farming structures but due to problems encountered during the course of the experiment and invasive growth of *Padina* spp., the experiment was reinitiated with both *Gracilaria* and *Padina* species on PVC raft. This would be discussed in depth in following sections.

8.1 *Gracilaria salicornia*

Gracilaria salicornia is a red alga of the Rhodophyta division, Rhodophyceae class, *Gracilaria*les order, *Gracilaria*ceae family and in the *Gracilaria* genus. *Gracilaria* is one of the largest genera of seaweeds with over 150 established species. Increasing focus is being placed on this species due its importance in the agar industry as the main source of gelling phycocolloid "agar" in the world (Oliviera et al., 2000). It is used as a thickening agent and has applications in a vast number of industries such as in foods, cosmetics, textiles, brewing, paper and biotechnology.

Gracilaria also grown as fodder for abalone is highly valued in the world market. Recently several studies have successfully used *Gracilaria* species as biofilters (Chow *et al.*, 2001; Msuya and Neori, 2002). Moreover it is also a popular food consumed fresh in South East Asian communities of Philippines, Malaysia and Thailand. Together with *Laminaria*, *Porphyra* and *Undaria*, *Gracilaria* make up 93% of the total seaweed cultured currently.

Figure 8: *Gracilaria salicornia* and its classification

The *Gracilaria* species are characterized as remarkably resilient due to its resistance to extreme conditions; temperature, salinity and chemical treatments. The robustness and elasticity of this species enables them to adapt to both tropical and temperate climates. It adapts to large variations in growing conditions, such as freshwater dilution, increase in fertilizer concentration from runoff, as well as raised temperatures. Its high physical resistance promotes *Gracilaria's* global distribution which spans from the warm India Ocean water to the Pacific and Atlantic Oceans; from the coasts of Tanzania and Indonesia to the colder waters of southern Chile and the Atlantic coasts of Canada.

Gracilaria salicornia is characterized by its irregularly shaped solid brittle cylindrical branches, and in abundance exists in as large mats. It is a reef fringing seaweed which is abundant in areas of moderate water motion. Depending on its exposure to sunlight, *Gracilaria salicornia* varies in color from yellow to brown. Moreover it has a high growth rates and multiplies via fragments which consequently lead to it being labeled as ecologically invasive in Hawaii.

China, Indonesia, Viet Nam, Namibia, Thailand, India and Argentina are among the major worldwide producers of *Gracilaria*. However China remains the undisputed leader in aquaculture including seaweed cultivation. Overharvesting of wild *Gracilaria*, has given rise to the fear of depletion, which resulted in the pioneering of the commercial cultivation of *Gracilaria* species by Chilean entrepreneurs. Using the *Gracilaria chilensis*, a species native to the Chilean southern coast and having high quality agar, was successfully cultivated thereby contributing to making Chile as a major leader in *Gracilaria* production. Further developments to increase *Gracilaria* production has been the introduction of integrated multitrophic agriculture (IMTA). Co-culture of finfish and shellfish with *Gracilaria* offers several advantages such as *Gracilaria* improving the quality of water contaminated by cultured animals. It is noteworthy that despite the cultivation of *Gracilaria* has been engineered; the lion's share of the production still comes from the wild.

The future of *Gracilaria* production relies on the selection of species with faster growth rates and high agar content and quality. According to the FAO (2003), the most dynamic sector of the seaweed industry is the extraction of seaweed colloids with applications in almost every aspect of modern society. The protection on natural stocks of Gracilaria is crucial to prevent over-exploitation and the development of improved cultivation techniques is crucial for further development of the agarophyte industry. This consequently makes agarophytic *Gracilaria salicornia* species a crop with very high commercial potential and a promising future.

9.0 Farming Method for Gracillaria salicornia

Several types of farming methods were experimented in the Albion Lagoon for *Gracilaria salicornia*. These are as follows;

1. Off-bottom farm
2. Floating Rafts (Bamboo)
3. Floating Rafts (PVC)
4. Floating Rafts (Line)

1. Off-bottom farm

The off-bottom farm consists mainly of a 4mm diameter nylon rope of 10 metre length. Both extremities of this rope are tied to two 50 cm wooden pegs. The seaweeds are tied at an interval of 15 cm with the use of tie-ties (Rafia). Figure 8 shows the layout of the off bottom farms.

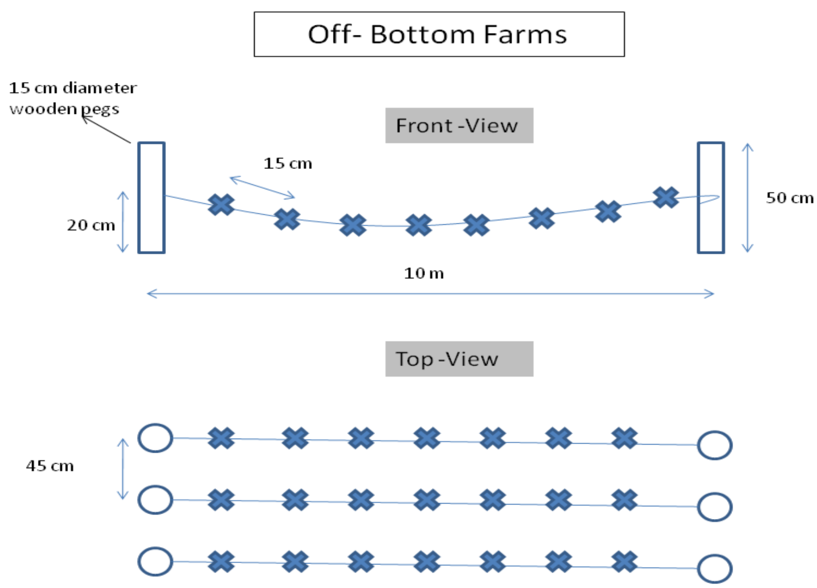


Figure 9: The Schematic representation of the off bottom farms.

The advantages

- The off-bottom technique has the advantage of being cheap and easy to implement. Furthermore it does not require specific skills to maintain.

The disadvantages

- This method can be implemented only in shallow waters and can hence only be implemented in the intertidal region of the lagoon which does not exceed one meter in terms of water depth.
- Considering the multiple user of the lagoon (i.e tourists and fishermen) this method proves to be disadvantageous as it is not visible at high tides and there is a high risk of being entangled in the lines. This increases the injury risk of this method to the public in general.
- Anchoring the pegs in the sea requires and sandy substratum. This method is suitable for Albion however for other region with rocky substratum it is not relevant.

2. Floating Raft (Bamboo)

The Floating raft structure consists of a more or less buoyant bamboo of 3 metre in length. The seaweeds lines are tied at an interval of about 30 cm (at each node). The seaweeds spacing in the line are 15 cm. The structure is anchored by tying them to blocks or stones of about 25 kg. The arrangement of the structure is shown in Figure 10.

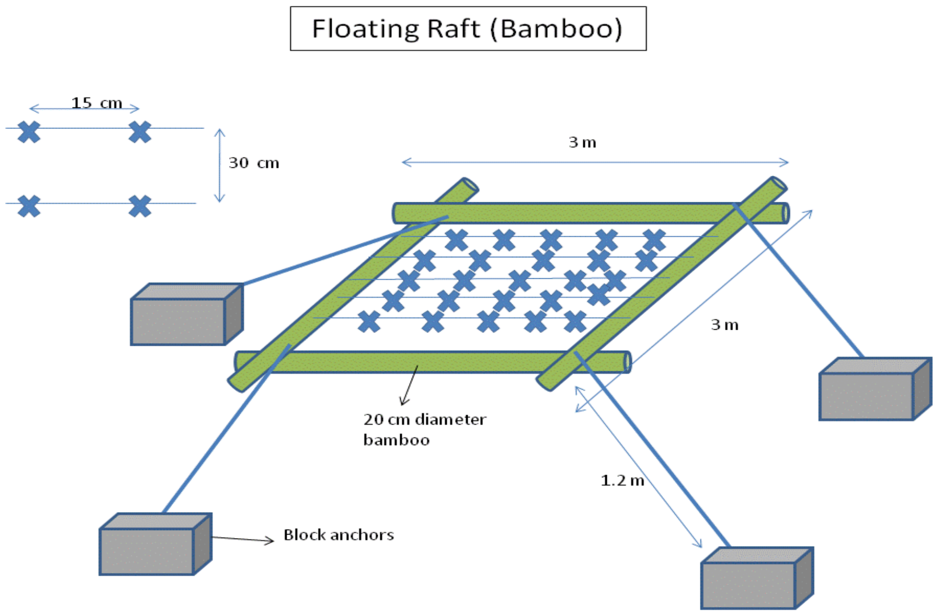


Figure 10: The schematic representation of the bamboo floating raft system.

The advantages

- This method is cheap to implement and is an eco-friendly method.
- It is also a proven method used in other countries such as Tanzania, Indonesia and India

The disadvantages

- Bamboo is not ready available at the site of farming and thus transport cost to bring the bamboo poles to the site outweighs the initial low cost of production.

- The bamboo rafts do not have a long lifespan in seawater. During the course of this experiment it was noticed that shrinkage of the bamboo raft occurred at approximately 3 month after implementation and thus resulting in breakage of raft.
- Special skills is required to tie build the raft. As such special type of knot arrangement is required for this type of raft. Also a considerable amount of rope is used only in tying the raft together. It is to be noted that any mistake or loosely tied pole result in the lost of the totality of the structure.
- It is difficult to arrange to the correct diameter of bamboo (20cm< diameter< 35cm) in Mauritius. Diameter is an important feature in the bamboo raft as it would be this which would determine the buoyancy of the raft. Too much floatability will increase the frequency of breakage due to interaction which surface current and strong waves

3. Floating Raft (PVC)

The PVC floating raft system is a novel system which has been developed in Mauritius during the workshop. PVC pipes used in conventional plumbing system are joined together with 90^{o} elbow fitting so as to make a square shape arrangement. This arrangement hence acts as floats and the seaweed lines are tied 50 cm below these floats on the anchor lines. In this way, the seaweeds are always submerged and are at optimum depth at all times. This system is anchored by using four 25kg anchor blocks. The arrangement is illustrated in Figure 11.

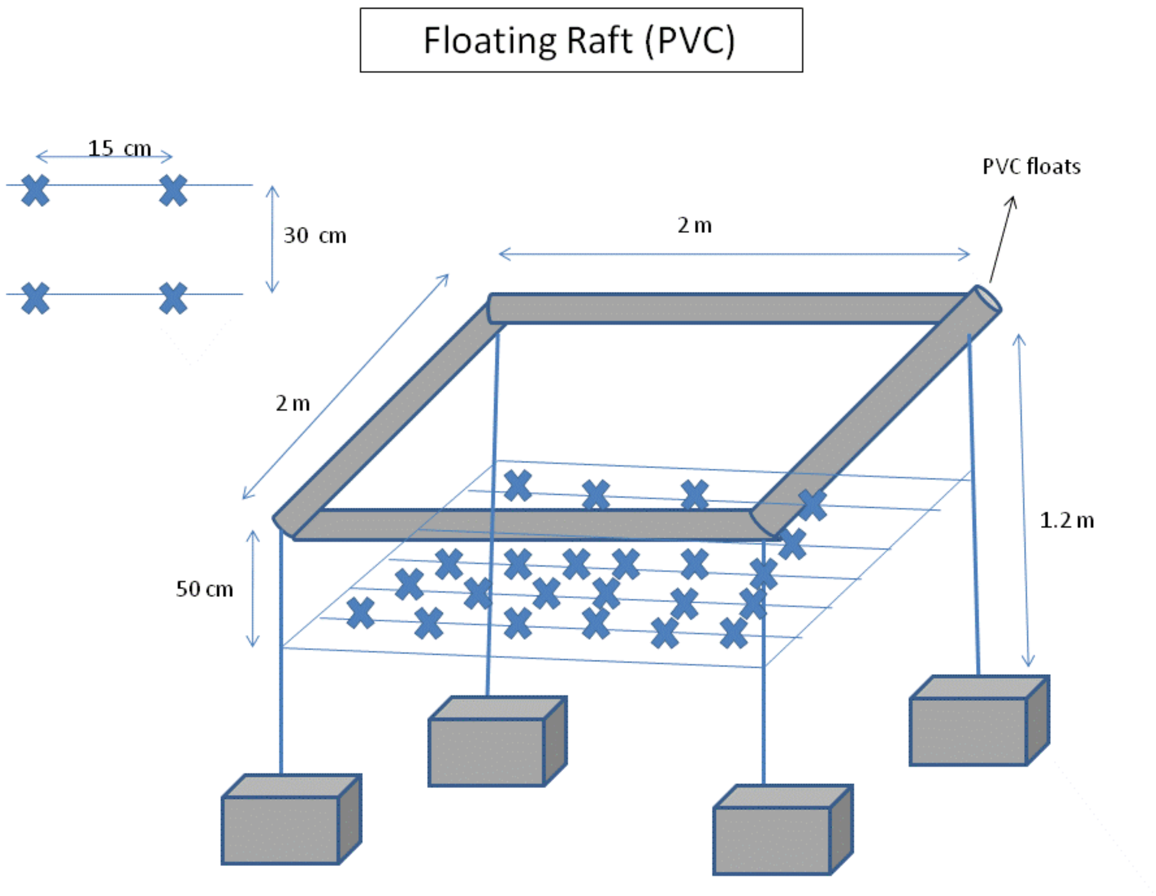


Figure 11: The schematic representation of the PVC Floating Rafts.

The advantages

- PVC is a material which is readily available in Mauritius and more specifically near the sites of cultivation.
- Mounting a PVC raft is a very easy process where only fitting and gluing is involved. Hence no special skills are required. As such it is less time consuming than other methods of cultivation
- PVC is a very durable and resistant material in seawater. It showed no sign of disintegration during its exposure to seawater and sun.
- PVC raft can be modulated to any size up to a maximum of 9m X 9m which is the common maximum available length of PVC piping.
- The overall weight of the structure is very low as compared to other techniques. This confers the structure to a very good floatability and implementation at sea does not require a large number of staff.
- Due to the colour of the PVC it is a very visible structure at sea and hence requires no extra buoys for signalization.
- Even in case of water infiltration, the integrity of the structure remains and hence no further cost is required when repairing the rafts.
- A pipe being smooth on the surface limits the amount of fouling as compared to other farming techniques.

The disadvantages

- Due to the light weight of the structure it experiences the effect of surface tension which may bring about deformation and breakage of the raft.
- It requires very careful gluing as if the fitting are not airtight, water infiltration occurs. Furthermore with time it has been observed that there is gradual deterioration of the glue with seawater. Hence regular maintenance is required. In addition, silicone cement has to be applied to maintain air tightness.
- Fouling and subsequent shell accumulation on the PVC pipes in the long run can cause puncture of the pipes.

- It requires a certain amount of investment due to the price of the PVC pipes, fittings and glue.

4. *Floating Raft (Line)*

The floating Raft (Line) also known as the line raft consist of a 20 metre 8-mm rope tied in a square shape of 5 metre by 5 metre. To each extremities of this square are tied a floating buoy which may consist of normal floating buoys or empty plastic 20L gallons. The seaweeds lines are tied at a depth of 50 cm below the floating line. The anchors are tied to the system at an angle of about 30°. The arrangement is illustrated in figure 12.

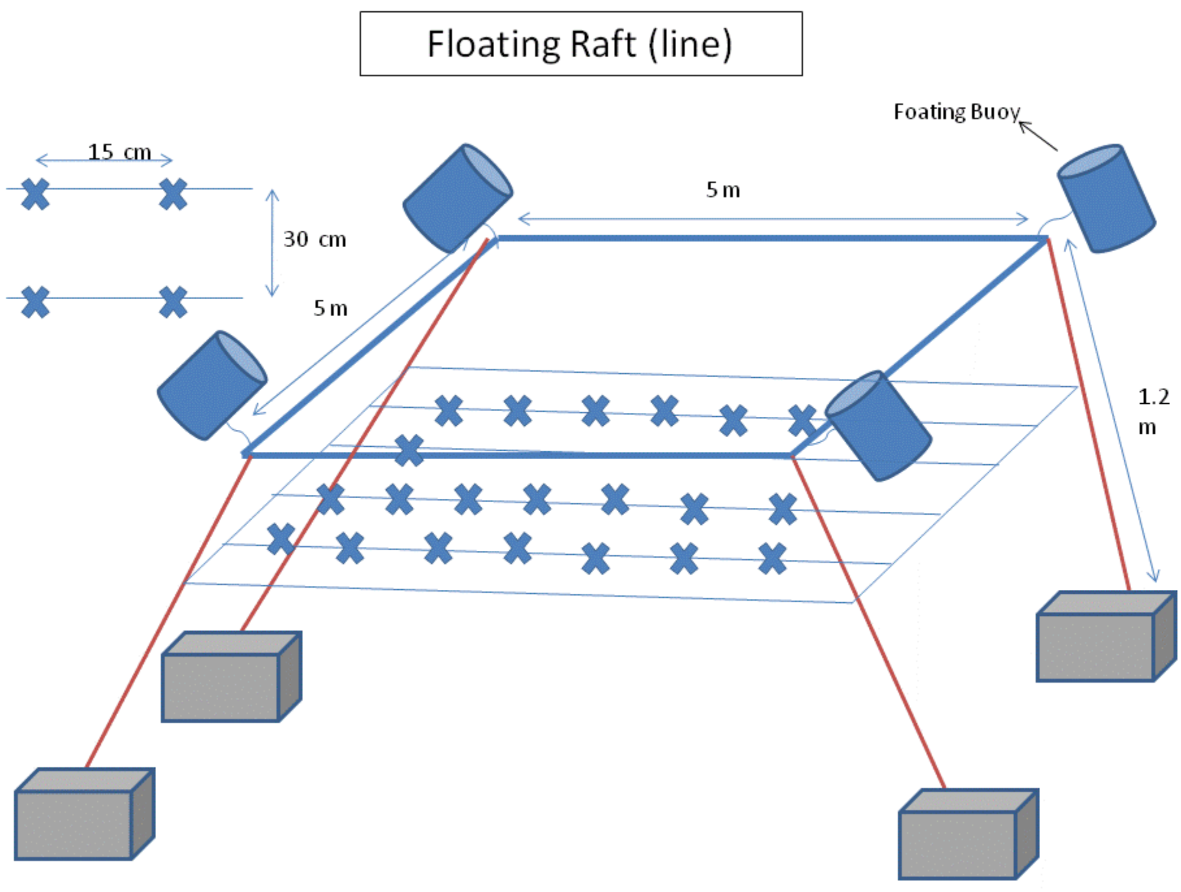


Figure 12: The schematic representation of the floating line rafts.

The advantages

- The floating line raft method does not require much material to be constructed. The main constituents are ropes. It is hence cheap to make.
- There is infinite possibilities concerning the length and size of the raft as this depends wholly on the length of rope available.

The disadvantages

- Constructing the floating line raft requires a lot of time and labour. As such it requires a minimum of four persons to be constructed.
- Considering the complexity of such a structure and the dependencies of each constituent, a slight breakage in the structure will result in the lost of the integrity of the whole structure.
- This farming method relies to a great extent on the floating buoys or 20L gallons. Hence the weight of the seaweeds in the structure is a determining point for the number of floats required. However, this type of structure does not allow adaptability to net-bag farming due to the added weight.

5. *Net bags*

Following problem of fish grazing of *Gracilaria salicornia,* the method of net bag farming was adopted. This technique is very easy to adapt upon the current farming techniques. It consists of placing the seaweed inside the net-bags and tying the net bag to the culture lines on the PVC raft. Initially net bags of hydroponic grade were used but it had a high price. Then an alternate solution was found by using onion bags as net bags as shown in figure 13 below.

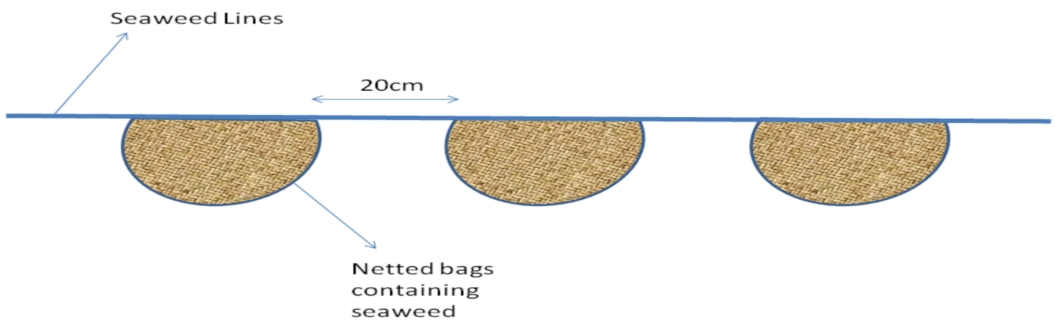


Figure 13: Schematic representation of floating Onion Net bags.

<u>The advantages</u>

- The onion bags are very cheap to obtain. Also used onion bags of good quality can be obtained freely from onion growers or sellers.
- This technique reduces the amount of labour hour required to implement a seaweed farm and also in maintenance.
- The net bag provides a protected environment for the seaweed to grow. Apart from protection from predation it offers a structure which can resist rough sea condition and reduces seaweed breakage.
- In the case of *Gracilaria salicornia*, it has been observed that the net bags tend to replicate the natural environment for the optimal growth of the seaweed.

<u>The disadvantage</u>

- The net bags tend to favour more fouling as compare to the culture line method.

10.0 PadinaSpecies

Padina spp. cultivation was more of a fouling effect; which was noticed on the initial *Gracilaria salicornia* farms. On 16th January 2012, it was observed that *Padina* spp. was growing on the raft structure and block anchors. Since *Padina* spp. has been identified by the Council as commercially viable seaweed it was decided to maximize on this fouling phenomenon to cultivate this seaweed. Hence, the *Padina* spp. was allowed to invade and grow on the farming structures and the anchor blocks. Furthermore, another experimental structure consisting of concrete blocks were laid on the seabed to allow further *Padina* spp. to attach to the porous surface of the blocks through their holdfasts.

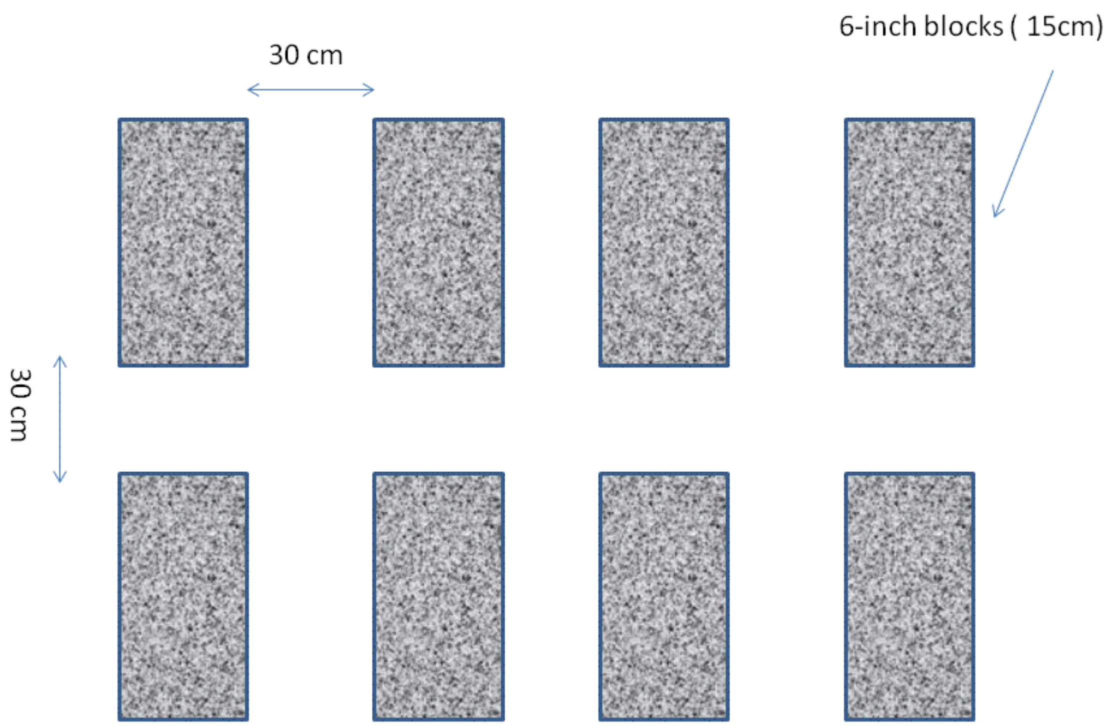


Figure 14: Schematic representation of *Padina* spp. growing on concrete blocks.

However this type of cultivation depends upon the seasonal bloom of *Padina* spp. which occurs in the summer season.

11.0 Monitoring of the Experimental Farm

The methodology for monitoring the water parameters was as followed:

Readings for salinity, temperature, pH and dissolved oxygen were taken at three selected sites in the proximity of the seaweed farm. Below is the GPS map of the seaweed farm and the selected sites at Albion.

Figure 15: GPS map for the three selected point for water parameters monitoring.

Table 1: GPS coordinates of selected point for water parameters monitoring.

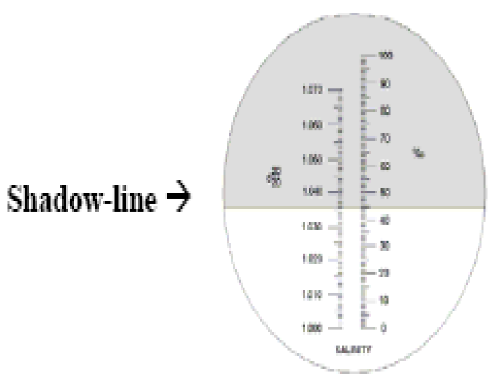
Selected points for water parameters	**Latitude**	**Longitude**
Raft		
Measure Pt1	S 20°12.922'	E 057°24.107'
Measure Pt2	S 20 °12.893'	E 057°24.118'
Measure Pt3	S 20 °12.856'	E 057°24.121'

Equipment used for water parameters:

1. Refractometer was used for salinity determination
2. HACH portable probe meter was used for pH, temperature, dissolved oxygen and electrical conductivity (EC) measurements.
3. HACH portable probe DO6

Procedures:

1. Salinity measurements



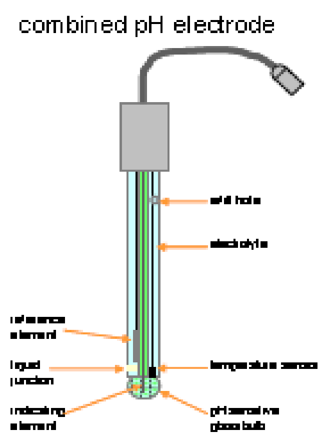
The salinity refractometer measures the refractive index of the samples and displays the results in parts per thousand (ppt).

- Calibration of apparatus:
    - Few drops of distilled water are placed on the entire prism.
    - The cover plate is closed and the adjusting screw is rotated so that the shadow line (light/dark boundary line) evens up with zero line.
    - The prism is cleaned with a piece of tissue paper after the zero adjustment.

- Sample preparation and reading:
    - Few drops of sample liquid (seawater) are placed on the measurement prism and enough liquids were added in order to cover the entire prism (liquids were spread on the entire prism and no air bubbles were allowed)
    - Sample was allowed to remain on the prism for approximately 30 seconds and the salinity concentration was read under a light source through the eyepiece.

      The salinity concentration is determined by the intersection of the boundary of the light and dark fields (known as the shadow-line) on the printed scale.
    - Once a reading has been taken, the prism is rinsed with some distilled water and wiped dry with a clean cloth and placed in a safe and dry environment.

2. Measuring temperature, dissolved oxygen (DO), pH and conductivity with multi-probe, portable meter.



- The protective cover of the probe is removed first
- The probe is washed with distilled water and blotted dry.
- The instrument is turned on (the power key ‘**Φ**’ is pressed).
- The ‘√‘ key is pressed to begin measuring
- The probe is placed in the sample liquid with sensors submerged.

- Some time is given for the reading is allowed to stabilise
- The readings are then recorded (temperature: **°C**, DO**: %**, Electrical conductivity: **mS/cm**)
- The instrument is switched off and is cleaned with distilled water and dried with soft tissue only by contact (without rubbing) before storage.

Note: All measurements were taken in-situ. Apparatus were calibrated before taking the first reading.

12.0 Results and Discussions

12.1 Physico-chemical parameters

The data on water quality was obtained from AFRC, which is the regulatory body monitoring the lagoons of Mauritius on a regular basis (every month) for about 10 sites identified for aquaculture.

The physico-chemical parameters for sea water quality at Albion as obtained from AFRC for the period May &July 2012 are presented in the table below:

Table 2: Physico-chemical parameters for sea water quality at Albion as obtained from AFRC for the period May &July 2012.

Date	Station	Temperature °C	Salinity ppt	pH	DO mg/L	COD mg/L	NO_3^- - N mg/L	PO_4^{3-} mg/L
May-12	1	28.5	32.2	8.0	7.0	1.1	<0.1	0.05
	2	28.5	34.4	8.0	6.5	1.5	<0.1	0.04
	3	25.5	34.5	8.1	7.0	0.6	<0.1	0.08
Jul-12	1	25.5	35.0	8.4	7.7	0.4	<0.1	0.09
	2	25.5	35.5	8.6	10.7	0.5	<0.1	0.03
	3	25.0	35.0	8.5	10.7	0.7	<0.1	0.01

Water quality data were also collected by the MRC. The physical parameters (Dissolve oxygen, pH, Temperature, Electrical conductivity and salinity) for Albion were measured at a weekly basis from January 2012 till August 2012 for the first cycle and the same parameters were recorded in Albion during July 2012 to November 2012 for the second cycle. The Parameters ranges are summarized below in Table 3 and the trends are shown in Figures 15 – 17 for cycle I and Figures 19 – 21 for cycle II.

Table 3: Physical parameters range from May to August 2012 (Cycle I) and July to November 2012 (Cycle II). Data include Salinity, Temperature, pH and Dissolved Oxygen.

Parameters Range at Albion for 2012		
Parameters	**Range (Jan-Aug)**	**Range (Jul-Nov)**
Salinity (ppt)	27.0 - 37.4	26.0 – 35.0
Temperature (°C)	23.7 – 28.2	23.0 – 28.2
pH	7.5 - 9.0	8.5 – 9.0
DO (%)	76.5 - 130.1	Not Recorded

The range for salinity, temperature and pH were in the range of that established by the AFRC throughout the growth period of the seaweed in the farm.

12.2 Cycle I: (Jan-Aug 2012)

Salinity trend

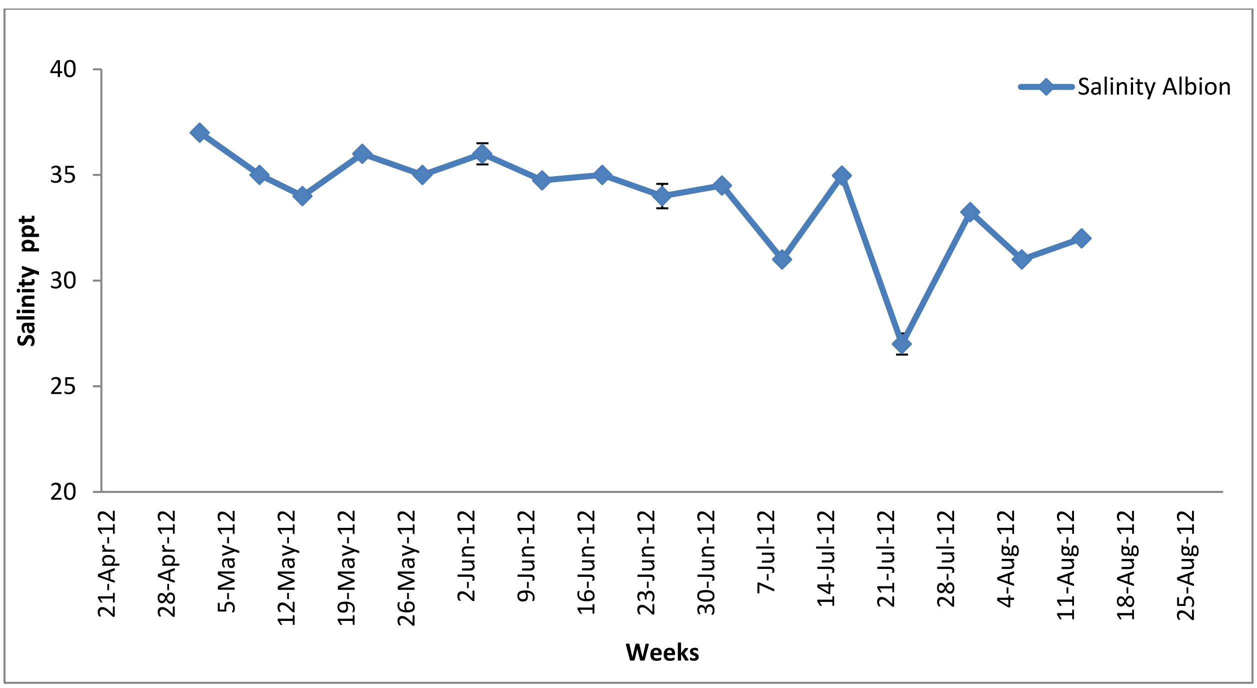


Figure 16: Shows salinity trend in Albion from May to August 2012. Data represent Mean ± SD.

The salinity trend at Albion was within the normal range (according to AFRC values). There was a sudden drop in salinity on the 21st July 2012 due to a high influx of fresh water on that day which was caused by heavy rainfall.

Temperature trend

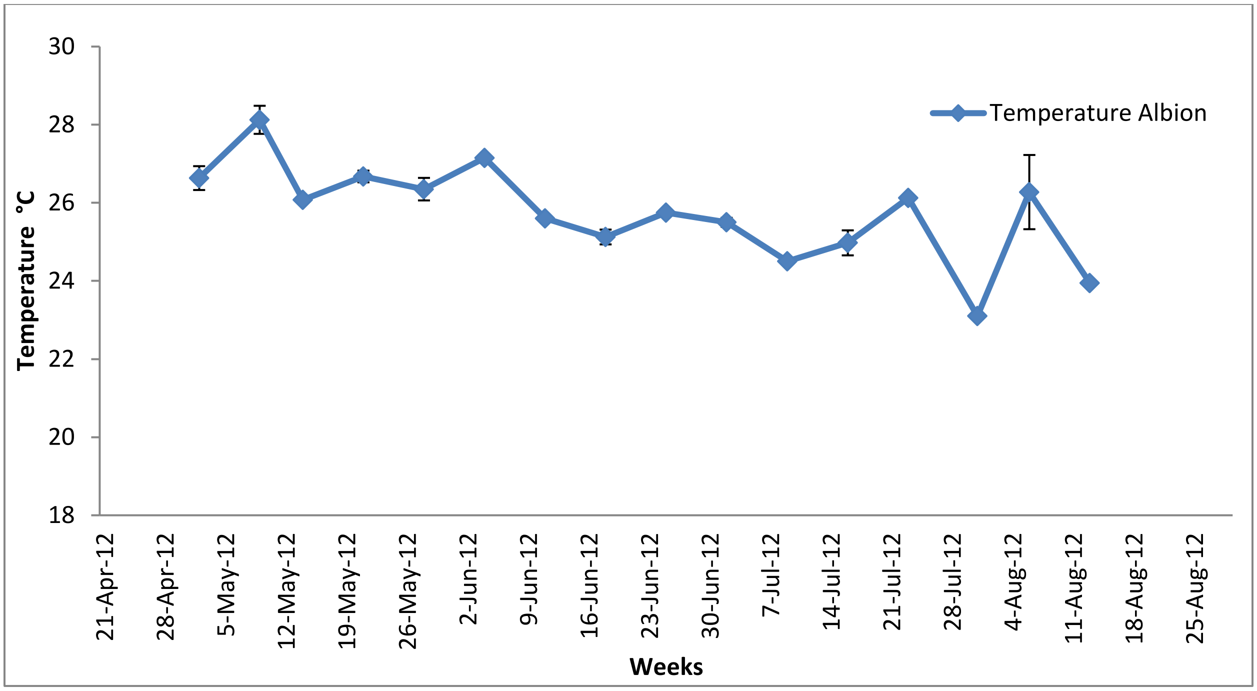


Figure 17: Shows Temperature trend in Albion from May to August 2012. Data represent Mean ± SD.

The temperature trend at the site showed a gradual drop which correlated with the change of seasons; from summer to winter. The temperature ranged within the established set of parameters of AFRC and also falls into the international parameters range for optimum seaweed growth.

pH trend

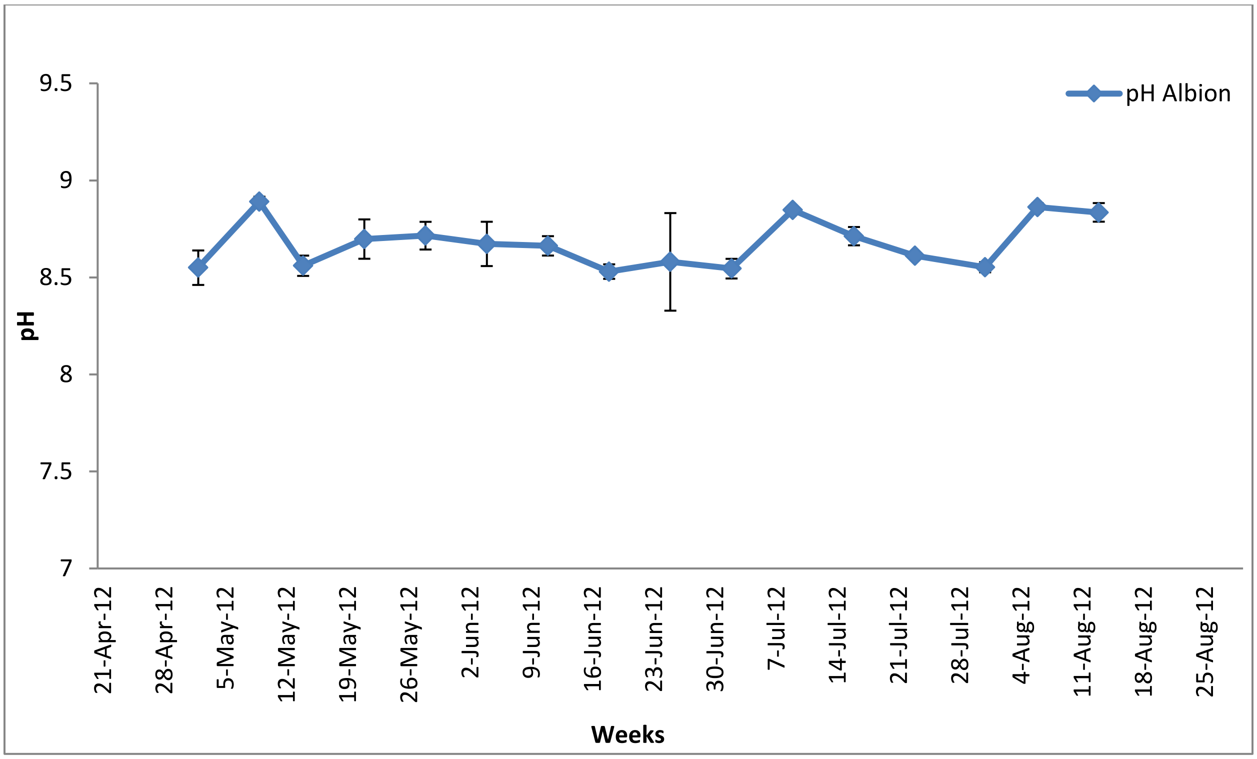


Figure 18: Shows pH trend in Albion from May to August 2012. Data represent Mean ± SD.

From the above graph, the coastal waters of Albion appeared to be very much alkaline. The pH values ranged between 8.4- 8.7 throughout the growing stages of the seaweed. The pH recorded at the working site corresponds accordingly to the AFRC physico-chemical parameter guidelines.

12.3 Cycle II: (Jul-Nov 2012)

Salinity trend

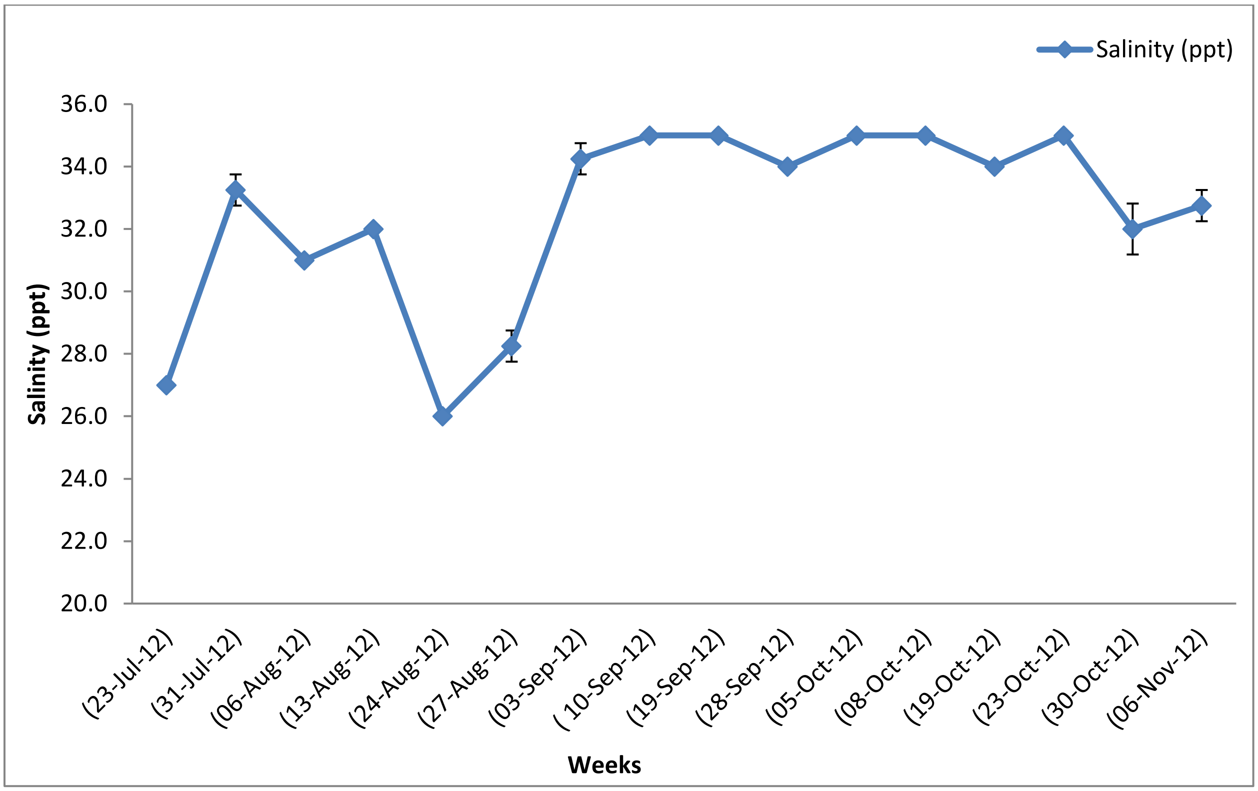


Figure 19: Shows Salinity trend in Albion from July to November 2012. Data represent Mean ± SD.

There was a sudden decrease in salinity on the 13th and 24th of August 2012 due to high fresh water input which was discharged from the nearby drain. The salinity got back to normal for the whole farming period and still remains in the set of values prescribed by the AFRC as shown in Table 2.

Temperature trend

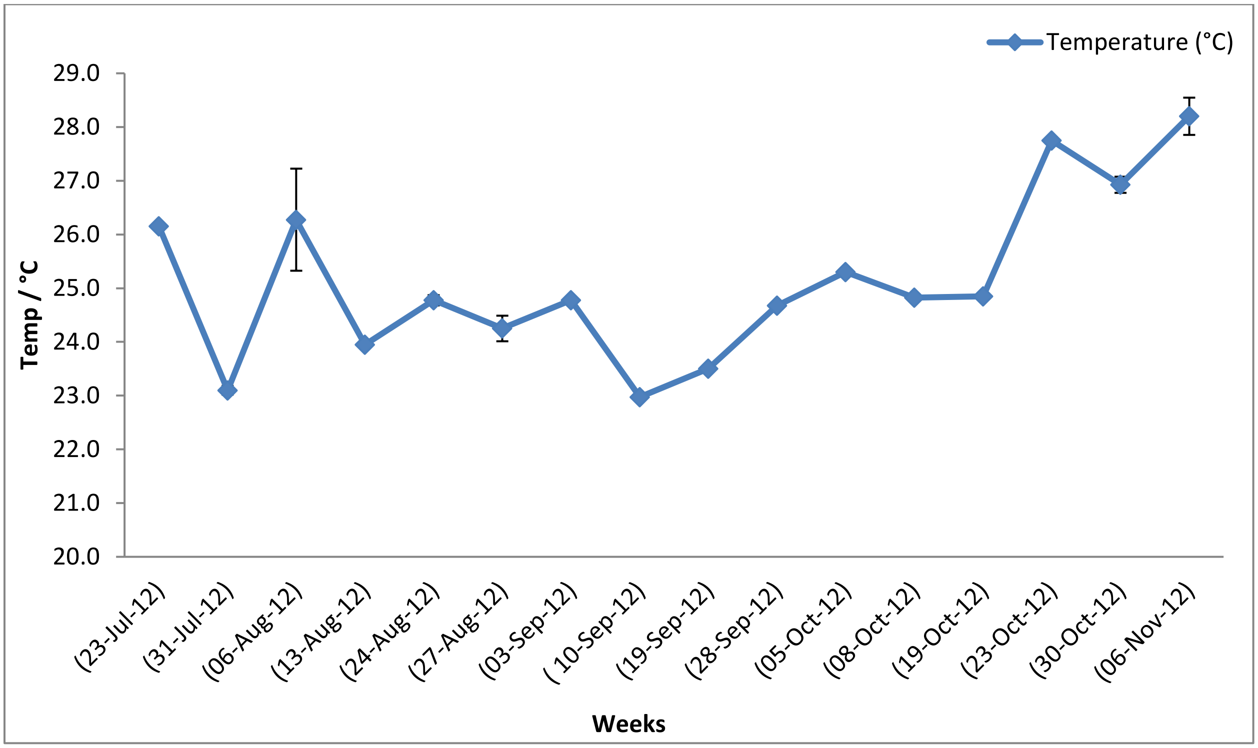


Figure 20: Shows Temperature trend in Albion from July to November 2012. Data represent Mean ± SD.

The temperature fluctuated during the first farming period and caused a sudden drop on the 31st July and 13th August; which may be due to the high fresh water input. Also on these two specific days, the cloudy weather which prevailed caused minimum sunlight penetration thus, less contact with the sea surface leading to less evaporation which made the water colder. Also, the trend of the temperature showed an increase throughout the farming period as the season was shifting from winter to summer thus, an increase in the sea water.

pH trend

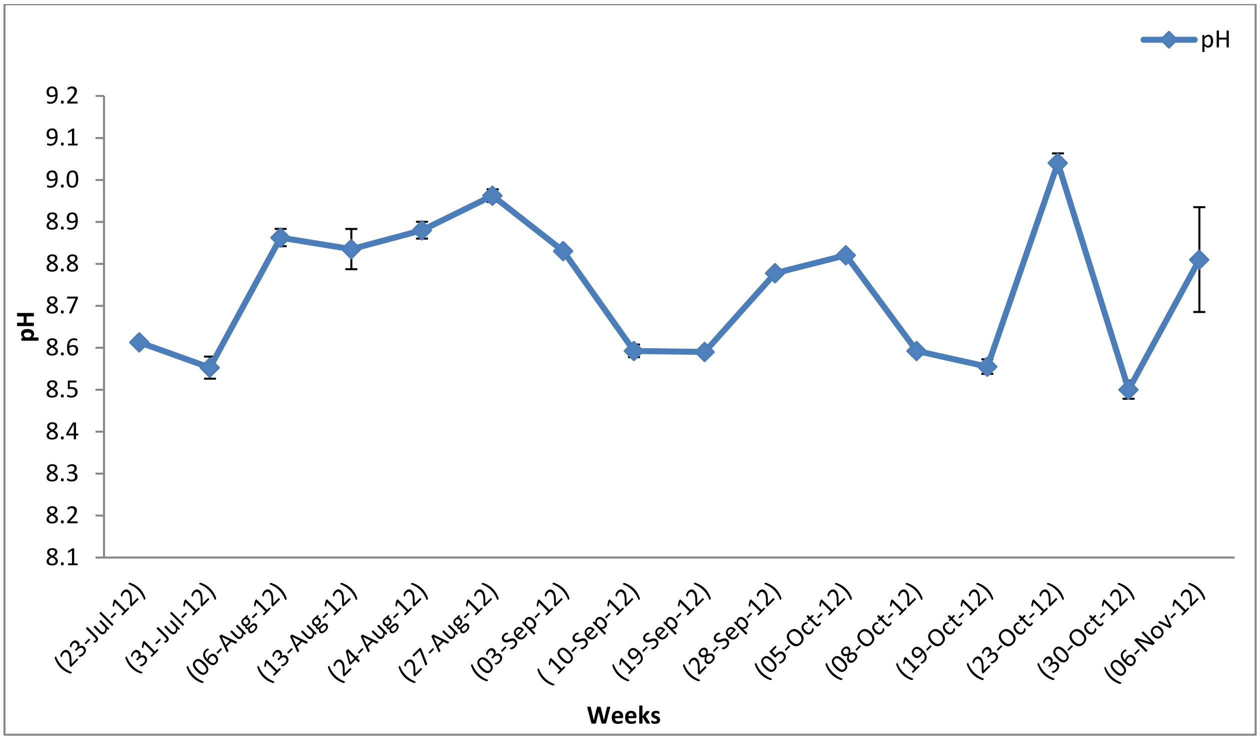


Figure 21: Shows pH trend in Albion from July to November 2012. Data represent Mean ± SD.

A much higher pH was observed in the second cycle (from July to November) than that recorded by the AFRC. Also, the pattern of the graph shows the up and down pH variation which indicates the variation of the alkalinity of the water in turn. The high salinity gradient recorded during this period can be the cause of these pH variations in the water. Also, the highest pH recorded was on the 23rd of October whereby the salinity was at its highest concentration for same.

12.4 Growth Cycle

Cycle I

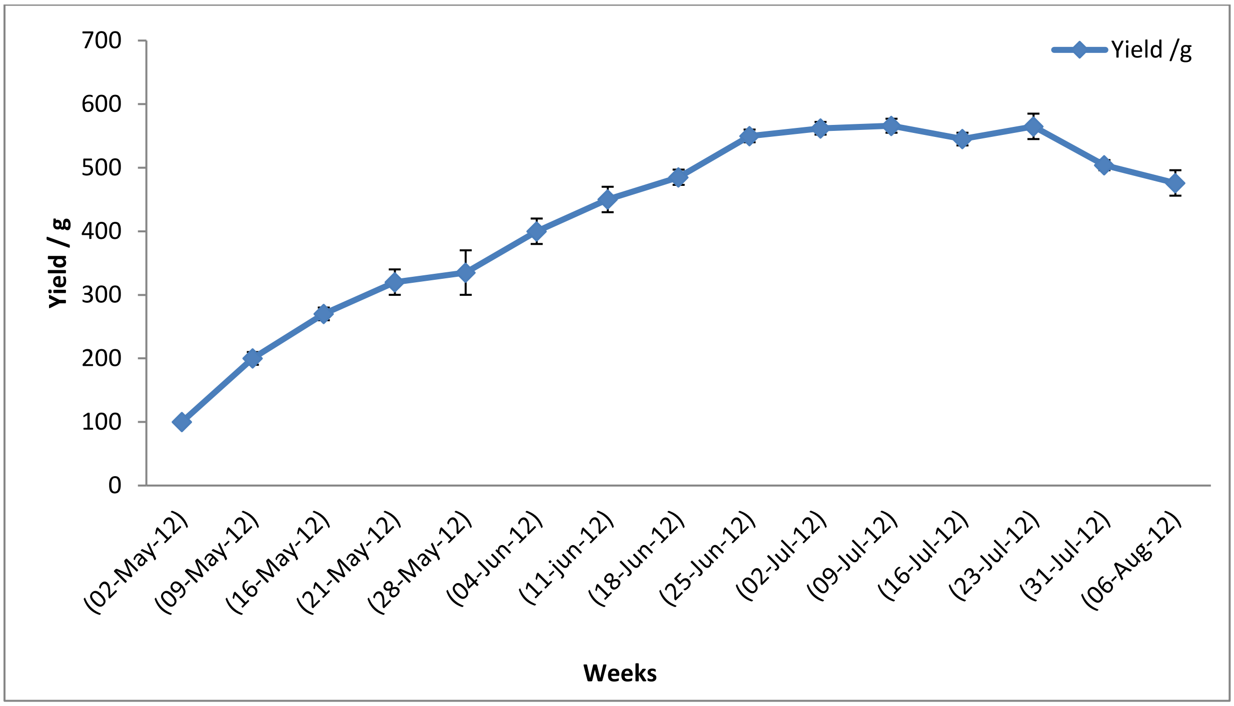


Figure 22: Shows growth of *Gracilaria salicornia* for cycle I in Albion from May to August 2012. Data represent Mean ± SD.

The growth of *Gracilaria salicornia* had a gradual increase throughout the farming period from May to June 2012. The seaweed reached its maximum growth in July and start decreasing by the end of June. Only 1 raft of 9x9m was used for the first cycle at Albion and showed to have very good yield. The harvest was done and a total average of 3400g of *Gracilaria salicornia* was obtained. The growth of cycle I was believed to be optimal because of its good water quality and due to the use of juvenile buds obtained from the wild.

Cycle II

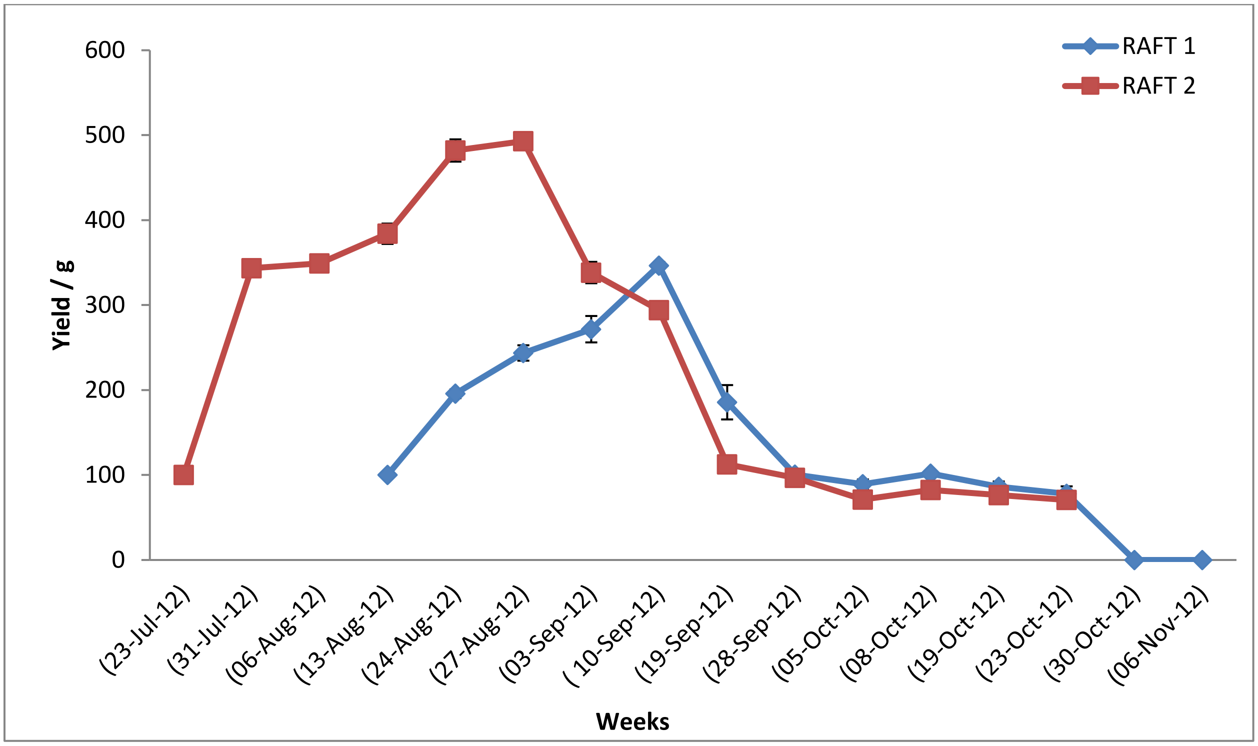


Figure 23: Shows growth of *Gracilaria salicornia* for cycle II in Albion from July to November 2012. Data represent Mean ± SD.

Cycle II started on July 2012 for Raft 2 and August 2012 for Raft 1. For both the same initial weight of *Gracilaria salicornia* was used for seedlings (100g). It was noted that there was a sudden decrease in the growth at the end of August and September. It was observed that the *Gracilaria salicornia* started to degrade drastically until no more *Gracilaria salicornia* was present in the cultivation bags. It was recorded also that no wild *Gracilaria salicornia* was present in surrounding waters of the farm. Thus, the decrease of the seaweed can be related with its natural degradation during this particular period. The sudden decrease can also be corresponded to the transition from winter to summer whereby, the increase in temperature played an important role in the degradation. It is also believed that the degradation can be due to the same buds used from the previous harvest, thus, weakening the species resistance to changes in parameters of the water.

12.5 Harvesting

Gracilaria species

A total of **3400g** of *Gracilaria salicornia* was harvested after cycle I of growth.

Padina Species

A total of **4300g** of *Padina* spp was harvested after a 4 months cycle I of growth.

13.0 Problems Encountered and Lessons Learnt

Numerous problems have been encountered during the course of the experiments. These are described below.

<u>Presence of Shark</u>

In November 2011, a dead whale drifted to the shores of Albion, at about 200 metres from the farming site. This dead carcass attracted a number of shark and other marine predators which triggered a restriction notice from the National Coast Guards. Hence it was not possible to monitor the farm during a period of 2 weeks.

<u>Fish grazing</u>

On the 21st of November 2011, it was observed that all the *Gracilaria* species on the culture lines had been disappeared from the lines. It was also noteworthy that when the ties were open only a small piece of *Gracilaria* remained (i.e the piece of *Gracilaria* enclosed by the tied raffia). Hence it was hypothetically suggested that the seaweed had been grazed by fish.

Moreover following discussions from members of the Technical committee for seaweed farming it was found that the period of November-December was the spawning period for fish and these normally invade the lagoon and feed on seaweed present. Furthermore discussion with fisher group of that region, allow finding that *Gracilaria salicornia* was at times used as baits in fish cages and is known to attract certain types of fish. Thus this confirmed the hypothesis of fish grazing.

Solutions for this problem were to either cover the whole structure with fishing grade nets or use of net bags. The problem with covering the whole structure was that it was a costly solution and a special permit was required for purchase of fish grade nets, which would have considerably slow down the project.

Net bags were a cheaper alternative as net bags of hydroponic grades were available off the shelves and were at a cost of about Rs.150. However, once implemented, these types of bags did not resist the seawater and constant abrasion from harsh weather conditions. These net bags disintegrated and let out all the *Gracilaria salicornia.*

From discussions with fisher group, it was found that onion bags were already used in fishing cages and boats and were very resistant to seawater and harsh weather conditions. Another benefit that was highlighted was that used onion bags (linen bags) were available free of cost or at a very cheap price. In some cases it was found that the lifecycle of onion bags in seawater exceeded one year.

Hence the onion bags were evaluated in farming conditions and found to be a very good material to use as net bags. In the course of this experiment 25kg onion bags were used.

<u>Water Infiltration in PVC Raft</u>

- Overcomed by gluing Fittings and pipes with high pressure PVC Glue then by PVC Concrete
- Finally Sealed with silicon
- This arrangement is allowed to dry for 8 hours

<u>Surface Tension and Resistance to rough sea conditions</u>

- Being a floating structure a PVC raft experiences surface tension. This is exacerbated during rough sea conditions and raft gets dismantled
- Overcome by Cross sectional tying of raft so that overall pressure is balanced

Gracilaria salicornia bleaching

- Direct exposure to sunlight causes discoloration and die-off of *Gracilaria* spp.
- In the wild, best quality of growing *Gracilaria* is found under rock in shaded area
- Solution to replicate the natural conditions for growth was to use net-bags and lower the supporting lines

14.0 Conclusion

It is observed that growth of *Gracilaria salicornia* was at its optimum during Cycle I than Cycle II. As the transition of winter to summer occurs, the yield of *Gracilaria salicornia* decreased. It is believed that *Gracilaria salicornia* grows better within cool environment and that new buds should be used instead of mature ones obtained from previous harvests.