
CULTIVATING COTTONII AND SPINOSUM: A “HOW TO” GUIDE

ERICK ASK

Acknowledgement

During the course of organizing, writing and rewriting the material that is the basis of this chapter, I received comments, ideas and suggestions from Epifanio “Jojo” Anoos, Jose “Pempey” Lagahid (Left), Recarte “Bong” Cay-an (Center), Made Simbik (Right), Rhodora Azanza, Ph.D., Mari Ask, M.D., Iain Neish, Ph.D. William Blakemore and Robert Stolarz. I wish to express my gratitude for their help.



Left: Jose “Pempey” Lagahid standing on the bow of a large Banca in his current stomping ground, the anajon reef of the Central Philippines. Pempey has worked with me since 1990 and is now a self employed seaweed trader.

Center: Recarte “Bong” Cay-an with the author in the waters of the Western Indian Ocean. Bong has been working with me since the early 90’s. Besides being a great field technician, he speaks eight languages and hasn’t met a problem yet that he couldn’t solve.

Right: Made Simbik has been associated with FMC for around 20 years and has played a major role in the development of the Indonesian seaweed industry, which produced over 60,000 dry tons in 2003. He is a wonderful man and my personal “guru rumput laut.”

In Memory

This chapter is dedicated to the memories of Dr. Maxwell S. Doty (left) and Kraft, 1997), Professor Emeritus University of Hawaii Botany Department, and Mr. Vicente Alvarez (right), first manager of Marine Colloids Philippines Inc. and namesake for *Kappaphycus alvarezii*. Their efforts (supported by students of Dr. Doty, employees and contractors of Marine Colloids and the Bureau of Fisheries and Aquatic Resources of the Philippines) laid the foundation for the commerci...al cultivation of tropical carrageenophytes, an industry that now employs over 70,000 families. They were also inspiring friends who greatly influenced my life.



The author, left, with Dr. Doty and the author’s father (1993). Dr. Doty and my father were talking about life in the Great Pacific Northwest of the United States pre and post -World War II. Dr. Doty grew up in rural Oregon while my father was born in Alaska.

Vicente “Vic” Alvarez (right) with the author and the 1942 Willy’s US Army jeep Vic used and bonded with in Indonesia (1993).

INTRODUCTION

Cottonii and/or spinosum farming have been introduced to over 25 countries over the last 33 years. However, only five to seven countries produce commercial volumes (over 1,000mt/year) for the carrageenan industry today (Ask et al., 2003). Analyzing this situation we find that:

1. Successful development of a cultivation industry is associated with the participation of carrageenan companies. These companies assure the project is market driven and at least the two largest companies provide their expertise in introduction of the cultivation industry.
2. Successful site selection is based on assuring that social, economic, political, logistic, demographic and environmental parameters make sense for cottonii and/or spinosum farming and that shipping costs to carrageenan plants are competitive.
3. Success follows projects that are properly funded, have timelines that allow for the inevitable setbacks, use experienced management and qualified field technicians and have a competent commercial structure.

The failed introductions were, for the most part, initiated by government fisheries departments, NGO's, donors, academics and even private companies with no formal relation to the carrageenan industry or experience. So, if you are reading this with the idea of creating a cottonii or spinosum cultivation industry, first talk to a carrageenan company about assuring a market and getting help with the development project as well as familiarizing yourself with farming and the commercial aspects.

1. SITE SELECTION (SITE SURVEY AND TEST PLOTS)

This section will provide information on selecting the correct site from an environmental perspective. Regarding the other parameters, briefly:

1. Social and Economic Concerns: The socio-economic parameter basically boils down to: is seaweed farming a more attractive livelihood than what villagers are doing now? Does it meet their social requirements? Do villagers have a need/use for cash and what is their daily income requirement?
2. Politics: Politicians and public servants can either greatly help a development project or severely hinder it. Knowing the key officials and what impact they will have on the project is quite important.
3. Logistic and Transport Costs: Logistics, communication, transportation and power are key to success and must be included in a complete survey.
4. Demographics: It is less costly and operationally easier to work in one village with a large population than numerous small villages with great distances between them. Smaller villages can adopt cottonii and/or spinosum cultivation after the larger villages are producing, assuring the commercial success of the industry.
5. Business models: Before beginning you must have a commercial model in mind that will protect your investment, treat farmers and farm workers fairly and allow for orderly development. This is far easier said than done.

Site Survey

The purpose of the environmental site survey is to determine which specific sites have the greatest possibility of meeting the physiological requirements of cottonii or spinosum and therefore ensuring a successful and prolific farm. The primary parameters to be concerned with are: water flow, temperature and salinity. Light, of course, is paramount but it is assumed to not be limiting given cottonii and spinosum's low $P_{\max}$ levels compared to what is available in the coastal tropical waters (a $P_{\max}$ of 200 vs. available light of over 2,000 $\mu\text{moles m}^{-2} \text{s}^{-1}$ on a shallow, sandy farm area). If the site is on a reef flat then the depth of water at low tide and associated seaweed species are also important.

To conduct a proper site survey, a few simple tools are needed. The experience of working in remote parts of developing countries, trying to travel light and realizing equipment will receive a lot of abuse and cannot be properly maintained or protected has taught me to go with the most inexpensive equipment that will still get the job done. Though I see a role for dataloggers, weather stations, depth sounders and so forth, it comes under the crop log heading where it is assumed a qualified person will oversee the equipment and be on station most of the time. Crop logging will be discussed later in this chapter. So for the survey I suggest the following tools:

- A. A salinometer (Figure 1.1)
- B. An alcohol thermometer (Figure 1.1)
- C. A photocopy of a nautical chart for that area, or at the very least a sketch of the area.
- D. A tide book (Figure 1.3)
- E. Book on identifying seaweeds, seagrasses and mangrove trees, if you already don't have that knowledge (Figure 1.4) (Calumpong and Meñez, 1997)
- F. A notebook and pen
- G. A bottle, a 5 meter string and a watch with a second hand (Figure 1.5)



Figure 1.1

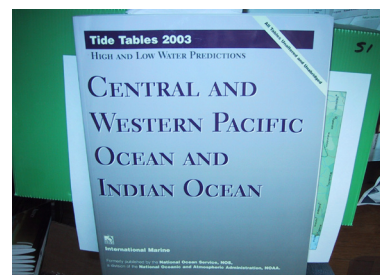


Figure 1.3

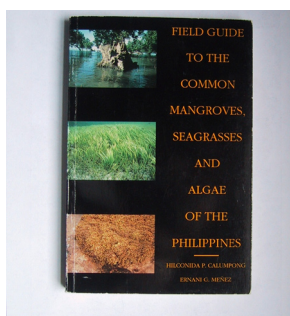


Figure 1.4



Figure 1.5

A survey begins by looking at a map, nautical chart or recalling from memory those sites which are believed to be suitable based on criteria such as: the sites are close to home, the waters are protected from large waves or the area is not being used for any other purpose such as fishing, reef gleaning or boat mooring. These sites should be marked on the chart or on a sketch map. The survey can then proceed by measuring the environmental parameters at these areas. Protocols for measuring each parameter are as follows:

Temperature

Take two readings, one in the early morning (assumed daily low) and the other in the late afternoon (assumed daily high). When reading a thermometer, make certain it remains in the water while doing so. Highs and lows must fall within the 23 to 30°C range. Exclude any site that is outside this range. If you feel the equipment will be safe, you can deploy a max-min thermometer that automatically reads the high and low temperature (Figure 1.6). Websites displaying water surface temperature data derived from remote sensors (satellites) also exist and give an indication of the seasonal temperature patterns. This site (http://www.osdpd.noaa.gov/PSB/EPS/SST/al_climo_mon.html) provides monthly mean water surface temperature data for the entire world from 1984 to 1998.



(Figure 1.6)

Salinity

Simple hydrometers sold by aquarium supply stores are accurate enough for this work and certainly a fraction of the cost of a refractometer (Figure 1.7). Exclude all sites outside the 23 to 38 parts per thousand (gm/liter, ppt or o/oo) range.



(Figure 1.7)

Exclude all sites 1 km or less from a river mouth. If the river is dry, assume you cannot farm at that site during the rainy season because the salinity will be too low.

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. This data is usually collected at nearby airports. Also, check <http://worldclimate.com/> for historical monthly averages of rainfall for towns near potential farm sites.

Wind speed/direction

Seasonal wind patterns are important since they can correlate with water temperature, nutrient and water motion changes. Airports also record this data as well as Pilot books such as those produced by the British Admiralty. For daily information, check:

<http://www.oceanweather.com/data/>, http://manati.wwb.noaa.gov/cgi-bin/qscat_day-1.pl and <http://english.wunderground.com>

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 cottonii or spinosum in low nutrient tropical waters, it is superior to find locations with high tidal water motion. Generally, winds in the tropics are seasonal and can be fickle so depending on wind to supply water motion, and subsequently nutrients, is not wise. In fact, it is assumed that much of the seasonal growth patterns of cottonii and spinosum farms can be attributed to wind patterns. Large die-offs of cottonii and spinosum have occurred when monsoon winds have changed, though direct correlation remains an assumption since it has not been thoroughly studied.

To monitor the water motion due to tidal activity, take a reading at exactly the time between high and low tide (check the tide book), when the tidal current is assumed to have the highest speed. This should also be done when there is no wind. The inexpensive way to take a reading is to fill a bottle with seawater so that it just barely floats and cap it in some manner. Tie a five meter string to the neck of the bottle. Place the bottle in the water by your person and record the number of seconds required for it to travel with the current the five meter distance. This should be done five times and the average recorded. It is important to develop an understanding of water flow patterns in the areas being studied so record the direction of the current on the sketch map. Taking water flow readings at five or so places in the general site location should give a profile of the tidal water flow patterns.

Though time consuming, letting half filled brightly colored bottles, or even fruit, like oranges, float around the area for a tide, and following them, is a very good way of gaining a deeper understanding of water motion over the proposed farm area.

Initially it is strongly suggested that the surveyor focus on sites with strong tidal currents and ignore sites where water motion is derived primarily from the wind. Wind driven water motion is a tricky matter best left to exploration after the farm is established. If, however, the surveyor wishes to try his or her luck, then wind driven currents should be measured at slack tide (at exactly high or low tide) in the same manner as that just described for tidal water motion. The bottle method measures horizontal laminar flow and does not take into account the up and down motion of wind driven waves. Therefore don't believe this is an extremely accurate approach, it is merely meant to give the site surveyor an indication of the current. Wind driven currents are helpful with floating cultivation methods (to be described later) since most wind driven current is near the surface. Again, winds cannot always be counted upon, therefore if using a floating method in an area with low tidal motion, be certain to know the seasonal and daily patterns of the wind.

For water flow, exclude sites where the time for the bottle to travel the 5 meters exceeds 25 seconds (water flow $< 20 \text{ cm s}^{-1}$) 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.

In reef flat environments, it is also important to take into consideration tides and associated species.

Low tide

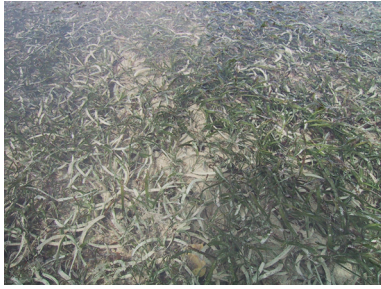
Use the tide book and determine at what date and time the lowest low tide of the month (springtide) occurs. Be present to observe the depth of the water at that tide. Never plant seaweed on a reef flat without first observing the full range of tides. For *cottonii*, exclude sites where farms may be exposed more than one hour on the lowest low tide while for *spinosum* three hours is the maximum exposure allowed (see figure 1.8).



Figure 1.8 For off-bottom farming, all potential sites must be viewed at low-low tide to determine if suitable for farming.

Associated species

The eelgrass genera *Enhalus* and *Thalassia* (figure 1.9), the red algae genera *Laurencia*, *Hypnea*, (figure 1.10), *Acanthophora* (figure 1.11) and some *Gracilaria* species (figure 1.12) are good indicators that *cottonii* and *spinosum* will grow in the area. Eel grass is also a good indicator that the bottom is suitable for wooden stake anchors. Introductory field phycology books for tropical areas with photographs are helpful for learning these seaweeds' and seagrasses' names and appearance. The mangrove genera *Avicennia* (figure 1.13) and *Rhizophora* (figure 1.14) also indicate a suitable salinity for *cottonii* and *spinosum* farming. This is especially useful during the dry season when it is difficult to judge the impact of nearby rivers that, at that time, have limited or no outflow.



Left: 1.9 *Enhalus* and *Thalassia* type eel grass beds indicate water temperatures and nutrient levels can be ideal as cottonii and spinosum cultivation sites.

Center: 1.10 *Hypnea* is also a good indicator for cottonii and spinosum farming.

Right: 1.11 *Acanthophora* is an indicator.



Left: 1.12 The presence of certain *Gracilaria* species assures that cottonii and spinosum will grow also.

Center: 1.13 *Avicennia* is a good indicator of salinity levels.

Right: 1.14 *Rhizophora* indicates suitable salinity levels, but *Avicennia* is more promising.

To answer other important questions about your sites, such as: does cottonii or spinosum grow? do herbivorous fish eat everything? or, do epiphytic algae take over?, you must put cottonii (or spinosum) in the water. This is formally entitled a “bioassay” and commonly called a “test plot.”

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 those remaining sites. Although something is known of the fundamental physiology of cottonii and spinosum and site surveys can be performed based on this knowledge, there is still much to be discovered. For now the only way to truly determine if cottonii or spinosum will grow in an area is to put it there for a reasonable period of time and see if it does indeed grow.

Though a test plot can be as simple as putting one propagule in a site and coming back a week later to see if it is still alive, a simple but more encompassing test plot is described below which will provide the farmer with more information.

A standard test plot consists of one five meter line with propagules attached every 20 cm and is merely designed to answer the question, “Does cottonii (or spinosum) grow at this particular location at this particular time?” The test plot will also give insights into herbivore and pest weed activity. Propagules should be in the 100 gm range, young, strong, well branched and with no sign of necrotic tissue (ice- ice) or epiphytic algae for both cottonii (figure 1.15) and spinosum.



1.15 A perfect *cottonii* propagule for a test plot.

It is very important to start with healthy propagules so that if they don't grow one can assume environmental factors are the reason, not initial propagule health.

In a reef flat location, create an off bottom test plot by placing two wooden stakes five meters apart as indicated in figure 1.16. You will need the following tools and materials:

1. One sledge hammer.
2. One digging bar.
3. One six meter twisted/braided nylon or polyethylene line (5-7 mm diameter).
4. Twenty five pieces of 15 cm long one mm braided twisted/braided nylon rope.
5. Twenty five healthy, well-branched propagules around 100 gm each.



1.16 Off-bottom test plot.

The digging bar is used to create a hole for the stake, then the sledge hammer is used to drive the stake into the bottom so that only 40 cm is visible.

The test plot line must be prepared before seeding. The 15cm long, one mm diameter nylon rope is first tied into Made Loops (pronounced “Maudie”) and attached to the main farm line every 20cm by inserting and wrapping around the line as depicted in Figure 1.17. Then the propagules are attached to the nylon line with the Made Loop by inserting them and using branching thalli to assure the plants will not fall out (Figure 1.18).

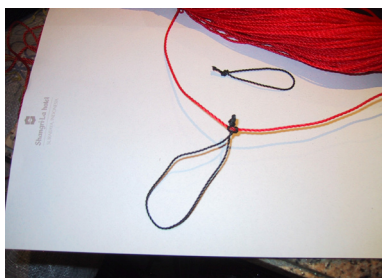


Figure 1.17



Figure 1.18

Mr. Made Simbik (see first page), of Bali, Indonesia, developed the Made Loop as part of the FMC BioPolymer No-Tie farm system development program. Although 15cm is

a general rule, the actual length and loop diameter should be modified to the diameter of the cottonii or spinosum branch (thalami). Also, please take note of the description in Section 2 on Broadcast spinosum farming.

And finally the line with propagules is attached to the wooden stake using the clove hitch knot diagrammed in Figure 1.19. This is important since it is easy to tie and remove. The use of loops on the mainline is discouraged since it can lead to the moving of stakes to tighten lines, thereby assuring varying line lengths and spacing of stakes creating anarchy in the farm area. Orderliness helps promote standardized farming practices necessary to achieve efficiency in the farming process and utilization of limited farm area.

For deep water areas you will use the “dancing bottle” test plot. This is simply a vertical rope with a large rock tied to one end for anchoring and a float on the other end. The top 2 meters of the line are seeded with 100gm propagules every 20cm and attached in the same manner as previously described using the Made Loop. This method allows you to see the difference in growth by distance from the surface (Figure 1.20).



1.20 Dancing bottles make excellent test plots for deeper water. They also indicate growth patterns as a function of distance from the surface, indicating at what depth rafts and long lines should be deployed.

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. For example, if the mass of the planted line was 2.8 kg, the number of plants on the line was 24 and the mass of a bare line was 0.07 kg then the mass per propagule would be $[(2.80 \text{ kg} - 0.07 \text{ kg}) / 24] = 0.11 \text{ kg}$ or 110 gm per propagule. Let the plants grow for 21 days, maintaining the plot by cleaning any attached debris, retying loose lines and bottles and replacing loose stakes twice weekly. Do not, however, replace missing propagules.

After 21 days, weigh the line and count the number of propagules on the line and perform the same calculation as above. For example if the mass after 21 days was 5.9 kg and the number of propagules was 21, then the mass per propagule would be $[(5.90 \text{ kg} - 0.07 \text{ kg}) / 21] = 0.28 \text{ kg}$ or 280 gm. If the mass has increased by 50%, in the example from 113 gm to 165 gm, then the daily growth rate is 2%*, ** and that is okay. If it has doubled, then you have a 3% growth rate and that is great. If there is little growth (below a 50% increase in biomass) then this probably isn't a good time to start planting at that locality. So, at this stage, it is possible to make a decision as to where to put the farm. However, the other test plots must be maintained because growth of cottonii and spinosum tends to be quite seasonal for each site and without test plots at

other sites, the farmer won't know where to move his farm if the seaweed begins dying at the original site.

* the standard growth equation is:

$$\% \text{ daily growth} = \frac{\ln(M_f) - \ln(M_i) \times 100}{\# \text{ days}}$$

where M_f = final weight and M_i = initial weight.

** Using the above growth formula, the following growth factor Table 1.1 has been created:

Table 1.1. Divide the harvest mass (M_f) by the Planting mass (M_i) to get your growth factor. Find the number that most closely approximates your number based on the grow out period (15 to 60 days). Go to the top of the column to get your approximate daily growth rate. Growth factors less than 1 indicate negative growth rates.

GROWTH RATE (%/DAY)											
	0	1	2	3	4	5	6	7	8	9	10
15 DAYS	1.00	1.16	1.35	1.57	1.82	2.12	2.46	2.86	3.32	3.86	4.48
30 DAYS	1.00	1.35	1.82	2.46	3.32	4.48	6.05	8.17	11.02	14.88	20.09
45 DAYS	1.00	1.57	2.46	3.86	6.05	9.49	14.88	23.34	36.60	57.40	90.02
60 DAYS	1.00	1.82	3.32	6.05	11.02	20.09	36.60	66.69	121.51	221.41	403.43

Eventually, with a few years of experience, the farmer will learn what locations have superior growth conditions for certain times of the year so that he is always at the best site for a particular season and test plots become unnecessary.

Presence of herbivore activity and pest weeds also play a role in deciding if the test plot indicates a good growing location or not. One has to develop a "feel" for these factors and that feel is developed through hands-on experience. Hands-on experience is gained through monitoring these factors over time.

Further Notes on Socio-Economics

I have often been said that seaweed farming is 10% phycology and 90% psychology. What this refers to is that when farming is introduced in an area, it is foolhardy to believe that villagers are just going to drop everything and start farming seaweed, no matter how well propagules on test plots grow. Undoubtedly the villagers are already engaged in various forms of livelihood and are using the sea in numerous ways. These livelihoods are known and tangible and when one lives marginally, one cannot very easily afford to give up the known, say fishing or reef gleaning, for the unknown, such as cottonii and spinosum cultivation. There may also be seasonal patterns to their livelihood and cultural or religious concerns that may prevent farming in certain areas at certain times. It is imperative that anyone who wishes to introduce cottonii or spinosum cultivation in a village first study the politico-socio-economic situation of the villagers to determine if, in fact, cottonii or spinosum farming has a future in the village. It is beyond this chapter's scope to fully discuss this topic, but below are a few questions that should be considered before a commitment is made to introduce cottonii or spinosum

cultivation as a livelihood alternative:

1. What are the other livelihood activities in the village and what time of the year do they take place? It could be that when the seaweed is just starting to grow well and demands attention, squid season arrives and everyone stops farming and goes fishing for two months.

2. Who performs those livelihood activities: men, women, youth or elders? It is important to know who will be available to farm cottonii or spinosum so that particular group can be targeted for training.

3. What is the daily income of a family in the village and would income derived from cottonii or spinosum cultivation be greater than what a family currently earns? Also, how does their income per unit work effort compare? Most likely no one will farm cottonii or spinosum if they can make more money at something else, especially if it takes less time.

4. How is the coastal area being utilized and would cottonii or spinosum cultivation conflict with those uses? Can management plans be developed to address all concerns? Water use conflicts can get nasty. Cut lines, poisoned propagules, arrest and threats of physical harm to farmers have been recorded in the past. Farmers can also find themselves zoned out of areas earmarked for tourism (Figure 1. 21). On the other hand, seaweed farm tourism has developed in Bali with three companies taking tourists to Nusa Penida and Nusa Lembongan daily. Seaweed farm tourism is also developing in Cebu, Philippines and Zanzibar, Tanzania.



1.21 These farmers were in the process of being displaced by tourism development (note heavy equipment in background creating a tourist beach). User conflicts need not necessarily arise. Seaweed farming has become a tourist attraction in Bali.

5. Are the villagers comfortable in the sea? Believe it or not, in some parts of the world people who live near the seashore don't swim or fish and have many taboos against entering the sea.

6. What religion do the villagers practice and do they have any beliefs that would conflict with the cultivation of cottonii or spinosum? It could be that the best farm site is just off the beach from a religious holy site. The Shaman may be enraged that you are defiling this holy area and place a curse on you. Based on personal observation I assure you that curses are to be avoided.

7. How much do the villagers value consumer goods, cash and cash crops? Do they only work for a minimum, daily required, income or do they want to continuously increase their daily income to "get ahead." Knowing what motivates villagers is absolutely vital information.

8. What is the political situation in the village? Who has the power and influence? Are they liked and respected by the villagers? Would that person or group want to try cottonii or spinosum cultivation?

9. What support or hindrance can the national or regional government provide? Does the government wish to promote new livelihood projects or have they zoned the beachfront property for hotel development?

10. Are the necessary materials for farming available locally? Can nylon lines be purchased in the local hardware store?

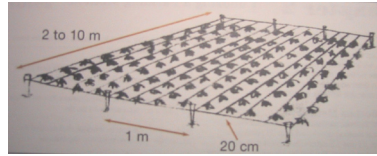
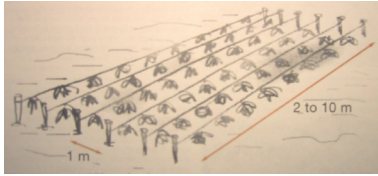
One can see then that there is much more to growing cottonii and spinosum than just photosynthesis. Understanding the politico-socio-economics of the village one wishes to introduce cottonii and spinosum cultivation into is not just important, it is absolutely necessary for successful technology transfer. Even then success is not guaranteed. Developing a new livelihood in a village is a very fluid undertaking. Circumstances and assumptions change daily and nothing is certain making it difficult to develop step-by-step guidelines. Success is based on so many factors it is mind-boggling and veterans of this sort of work may have ten stories of failure for every one of success. With experience however, one gets a feel for this work and success rates increase dramatically. This is why it is crucial that the project manager be experienced in successful seaweed cultivation development. If the project manager is a novice, the project merely pays for his/her education and is usually left with a failure at the end of the project period. This is bad for the villagers, for the cultivation industry and for the project country.

2. CHOOSING A FARMING METHOD

Once a site has been chosen, the next step is to decide upon a farming method to promote among potential farmers. There are three methods using the Made Loop, each with its own variations. In this chapter all three methods are described and the factors used to determine which method is appropriate for a particular site will be explained. In addition, a description of the Broadcast method for spinosum will be provided. Due to the current (July, 2004) limited market for spinosum and the efficiency of the Broadcast farming method, promoting spinosum farming at this time is unwise.

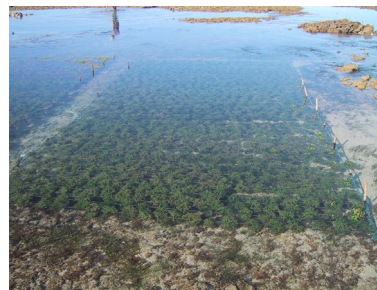
Off-Bottom Method

The Off-Bottom method was the original commercial farm method developed over 35 years ago. Figures 2.1 and 2.2 depict the typical designs of Off-Bottom farms. The former shows the extensive style with one meter space between lines while the latter shows the newer, intensive approach with lines tied every 20 cm on the end line. The latter may not be appropriate for areas with low water motion because the density would be too high for available nutrients and waste material removal. Basic construction, including appropriate knots, has been described in the section on test plots. Figures 2.3 and 2.4 depict extensive and intensive farms ready for harvest. Figure 2.5 depicts an off bottom farm under construction: pounding in stakes and laying out the seeded lines.



2.1 Older style Off Bottom farm design with stakes one meter apart, nylon lines 2 to 10 meters long and propagules tied every 20 cm on the nylon lines. Length of lines depends on water motion. In violent water motion, it is best to have shorter lines to prevent tangling and lost lines and stakes.

2.2 The newer style high density Off Bottom farm design with stakes still one meter apart but end lines are added allowing spacing of 20 cm between nylon lines. Again, nylon lines are 2 to 10 meters long and propagules are tied every 20 cm on the nylon lines.



2.3 A well managed and maintained low density Off Bottom spinosum farm.

2.4 A high density Off Bottom cottonii farm at low tide.

2.5 Constructing an Off Bottom farm. One family member pounds stakes into the sandy subtidal while others string out seeded farm lines.

Terms-

Propagules: The individual plants tied to the lines with plastic straw.

Made Loop: The 1mm line tied into a loop permanently tied to the line that is used to hold the propagule.

Lines: The braided or monofilament line to which the plants are attached with tie-tie.

Stakes: The bamboo or wooden stakes used to anchor the entire structure to the bottom.

End lines: The heavy braided rope or rubber lines used as tying points for the lines on a high density farm.

When and why to use this method-

Use on reef flats with near bare water at low spring tide (the lowest low tide of the month). Generally such an area can have heavy water motion from breaking waves at high water and therefore the farm structure (stakes, end lines and lines) must be strong and tied tightly. The propagules must be tied tightly as well to prevent loss. For cottonii, having more than two propagules per tie-tie is discouraged due to high

loss from strong water motion. Water motion is primarily due to tidal action but can be violent at high tide when large waves break over the reef edge. Also, with violent water motion the suggested ten meter lines may have to be shortened up to two meters to prevent anchor failure.

Raft Method

Rafts are used primarily in Indonesia, particularly Madura and Bali. Like a high density Off Bottom farm, lines should be tied 20 cm apart. It is important to weigh down the raft so that plants are submerged. In Bali, near the subtidal, smaller rafts are used (figure 2.6) while in Madura long bamboo poles are used to create the roughly 8 m x 8 m structure and are lashed together with nylon line (figure 2.7). One or two anchors can be used. Rafts are towed by local motorized fishing boats to and from the shore for harvesting and replanting (figure 2.8).



Left 2.6 Raft farming on the reef flat in Bali using small rafts.

Center: 2.7 Raft farming on coastal waters in Madura using large rafts. Once planted, this raft will be towed out to deeper waters for grow out.

Right: 2.8 The coastal waters in front of villages are quite busy with raft planting and harvesting as well as fishing boat moorage and maintenance.

Terms-

Propagules: Same as for the Off Bottom method.

Made Loop: Same as for the Off Bottom method.

Lines: Same as for the Off Bottom method.

Raft: The bamboo structure to which lines are tied.

Anchor line: The heavy line used for anchoring the raft.

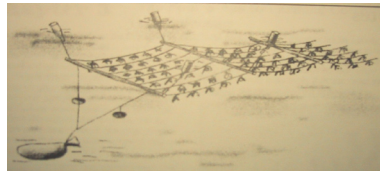
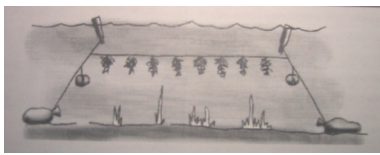
Anchor: The cement block or bag of sand used to hold the raft in permanent position.

When and why to use this method-

In calm deep waters (< 7 meters) such as bays, channels and some reef flat areas. Strong wind driven water motion during most of the day is important because tidal water motion may be insignificant. Heavy wave action will destroy rafts.

Long Line Method

Long lines are primarily used in southern Philippines and Sabah, Malaysia, though they are growing in popularity throughout the countries where *cottonii* and *spinosum* are cultivated. Sketches of two long line systems are given in Figures 2.9 and 2.10. Sand bags, rocks or wooden stake anchors are used and little 0.3 to 1 kg rocks are attached to keep tension in the anchor line. Floats are situated so that the lines are 20 to 40 cm below the surface. It is important to experiment with depth. The *cottonii* propagules depicted in Figure 2.11 clearly indicate the importance of depth on growth rates. Besides possible changes in growth rate, there are two other very important reasons. First, it prevents exposure of the plants to air and direct sunlight and second, it keeps the lines below drifting garbage, such as dead *Sargassum* or plastic bags.



2.9 Sketch of extensive long line system. Individual lines are spaced two meters apart. Long lines, as the name implies, can be up to 100 meters long, with floats tied on every 5 meters.

2.10 A sketch of the intensive, more space efficient Long Line system. This system uses sandbags or wooden stakes as anchors and bamboo as floating spacers. The bamboo or wood poles are placed about five meters apart and in this case are denser than water so that floats are used to keep the structure 30 cm below the water's surface. Small rocks are placed on the anchor line to maintain tension during low tide. The lines could be up to 100 meters long with the same anchoring system on the opposing end.

2.11 The *cottonii* propagules on the left and the center were grown 30 cm from the surface while the one at the top right was grown one meter from the surface. The farmer should experiment with depth.

With the older method, lines are spaced 2 meters apart. The newer system, the intensive long line system, allows lines to be placed 20 or 30 cm apart, but it would not be appropriate for sites with low water flow due to limiting nutrients and build up of waste material around the plant. In addition, heavy wave action may damage the more intensive method.

Long line farms, like the raft method, have the advantage of not being dependent on the tide for planting, maintenance and harvesting. However, boats should be used to work these farms (Figures 2.12 and 2.13).



2.12 Long line farming in deep water really requires a boat to work and maintain the farm.

2.13 This Malagasy farmer easily cleans lines and replaces missing propagules from his boat.

Terms-

Propagules: The same as for the Off Bottom method.

Made Loop: The same as for the Off Bottom method.

Line: As with the previous two methods, the propagules are attached to the line with tie-tie, however, for this method the line can be 100 meters long.

Float: The Styrofoam or plastic bottles used to float the line just below the surface.

Anchor line: The line from the anchor to the first float.

Anchor: The cement block or sand or rock filled sack. Usually 30 kgs. Wooden stakes are more common.

When and why to use this method-

In deep waters (< 7 m) but over large areas. Waters are generally more exposed than that for the raft method and water motion is both tidal and wind driven. Long lines can be used in the same areas as rafts but rafts could not stand up to heavy wave action like long lines can in more exposed locations.

Note:

The farm dimensions given in this chapter are merely suggestions. Each site is unique and the technician should, initially, experiment with depth, spacing of propagules, size of propagules and spacing of lines to find an optimum for that unique site. This should also be done seasonally since optima change with both locations and seasons.

Also, it is always superior to use wooden stakes over sand bags as anchors because they are less expensive and environmentally friendly. However, there should be a tree-planting program as part of the project to assure the sustainable supply of wooden stakes.

Broadcast spinosum farming

Beginning in the mid-1990's Filipino spinosum farmers off the Northeast coast of Bohol Island in central Philippines, long a large spinosum producing area, began experimenting with Broadcast farming. In this method, they make pens or corrals of old fishing nets and let the spinosum just tumble around on the sandy bottom. Corrals can be as large as 30 m x 30 m. There is no planting, maintenance, culling, tying... and the nets are second hand so they are free. The only labor involved is diving down (usually in 1-2m of water) to scoop spinosum into net bags (Figure 2.14). These are then loaded onto boats or bamboo rafts (Figures 2.15 and 2.16) and taken to the beach where the spinosum is dried. The product is quite clean and, of course, free of tie-tie and other plastics (Figure 2.17 and 2.18). The advent of Broadcast spinosum farming took place because the spinosum strains adapted to the free-tumbling conditions. This production method was so successful that it changed everything about the spinosum market. Production rose causing prices to drop. Then production never declined since, unlike Made-Loop farms, the farms are always in production whether someone is harvesting or not. Actually, the Broadcast farms are now the raw material warehouse for the end users of spinosum, whether they are carrageenan processors or the fresh (Filipino) or

dried (China) direct food market. More applications for the iota carrageenan derived from spinosum or other markets for spinosum would be VERY welcome to provide an outlet for all this production.



Left: 2.14 Broadcast spinosum farmer in the central Philippines harvesting with a bag net. Notice he has diversified his income and has a floating Longline cottonii farm above his Broadcast spinosum farm.

Center: 2.15 Broadcast spinosum farms loading harvest onto a large outrigger boat ("Banca") in the central Philippines.

Right: 2.16 Broadcast spinosum farmer with harvest loaded onto a bamboo raft for trip to the village for drying.



Left: 2.17 Broadcast spinosum is quite clean. Besides now sand and rocks, there are also no tie-tie.

Right: 2.18 Broadcast spinosum freely rolling around the bottom of a farm. It is very clean and healthy.

3. THE FOUR STEPS TO FARMING COTTONII

Below are specific protocols for the four steps in the cultivation process designed to keep growth rates and yields high. Most health related problems of cottonii and spinosum on a farm are caused by stress. For this reason it is extremely important that measures are taken to reduce stress by handling the plants very gently throughout the cultivation process. In other words, "healthy plants don't get sick." Once this attitude is adopted, i.e. that the plants are precious and should always be treated with care, the protocols should be second nature and appear as common sense.

1. Planting

Planting is the act of taking lines with propagules tied to them with the Made Loop from the beach to the farm site and tying those lines to whatever structure is there: stakes if Off Bottom, bamboo poles if a Raft, and floats and anchor lines if using the Long Line system. Usually boats are used to do this. The clove hitch knot used to fasten the line to the stake or bamboo is depicted in [Figure 1.19](#). Below are a few points to keep in mind when teaching farmers proper techniques for planting seeded lines in the water.

Sun damage: When planting, keep lines below the water surface to prevent tip damage from exposure to sunshine. This is especially important with rafts and longlines (Figure 3.1).



Left: 1.19 Clove hitch knot for attaching farm line to wooden stake for Off Bottom method. This knot can also be used for attaching lines to horizontal bamboo for the raft method.

Right: 3.1 Sunlight bleached and killed these tips, the growth portion of the plants. The plants should be in deeper water.

Rain damage: When transporting lines ready for planting to the field do not allow them to be exposed to sunshine and rain. Keep them covered with plastic and pour seawater on them every 15 minutes to keep them fresh. Rain and direct sunshine kill the propagules.

Gasoline (Petrol): When transporting lines ready for planting to the field using a boat, make certain there is no gasoline or other toxic substance in the bottom of the boat. These toxic substances kill the propagules.

Crushing: When the lines ready for planting are in the boat, do not walk on them because this damages the propagules.

Tie tightly: When using a line system, always tie lines tightly to the stake, end line, bamboo of the raft or anchor of the long line so they do not become untied during the course of the grow out.

Handle Gently: When at the farm site, gently set the lines, seeded with propagules, into the water. Do not throw them because this may cause propagules to fall off the line.

Inspect: Inspect the stakes, end lines, rafts, anchor lines and anchors to make certain they are strong and will last the grow out period without falling apart or being destroyed. Replace them if there is any doubt about their integrity and strength.

2. Maintenance during grow-out

Maintenance can be defined as all activities that take place from after tying the propagule to the farm structure (planting) until just before untying them (harvesting). Maintenance is absolutely crucial during the grow-out period and regular maintenance is usually what sets successful and mediocre farms apart. Productive farmers are in the water every day doing maintenance work.

Inspect and Repair Regularly

Teach the farmers to schedule regular inspection and repair trips, visiting each line at least twice a week. If plants are dead or dying, harvest them and replant with young, clean, well-branched and strong propagules. If plants have sediment, shake them. If lines are untied, retie them. If stakes are loose, replace them. If anchors are lost, replace them. If rafts are destroyed, replace them. If propagules are lost, replace them with young, strong, well-branched and clean propagules. The farm should be clean, orderly and straight. The goal of every farmer should be to have a farm that looks like that depicted in Figure 3.2, with no lost plants, no sick plants, no broken or loose lines and stakes. Figure 3.3 depicts a poorly maintained farm with twisted lines and broken stakes. Fortunately for the farmer, the plants are still growing, though some have been lost. Remember, dead, missing and sick plants don't grow and are only taking up valuable space and time. Also, broken stakes, lines and rafts are unproductive and are wasting space so repair or replace them.



3.2 A healthy farm with no missing plants, no pest weeds and healthy growth.

3.3 A poorly maintained farm. Though the plants are healthy, the stakes have come loose and the lines are twisted.



Herbivores

There are four types of herbivore damage, which are listed in Table 3.1 and discussed in detail below.

Table 3.1 Types of Herbivore Damage	
Type of damage	Type of herbivore
1. Tip nipped	Various fish, particularly adult Siganids.
2. Pigment picked (cortical layer is missing and branches are white)	Juvenile Siganids.
3. Thalli are “planed” with cortical layer missing and thalli have a flat surface.	Sea urchins, particularly <i>Triplonustes gratilla</i> .
4. Almost entire plant is missing, except a bit around the tie-tie.	Green turtles <i>Chelonia midas</i> .

A. Nipped Tips: It has been observed that adult and juvenile rabbitfish (Siganidae) are the primary perpetrators (see figures 3.4 and 3.5). Filefish (Monacanthidae), cowfish (Ostracidae), triggerfish (Balistidae), surgeonfish (Acanthuridae), parrotfish (Scaridae), porcupinefish (Diodontidae) and pufferfish (Tetradontidae) have been observed eating tips but usually just when farms are placed by coral heads, which is a good argument against placing farms near coral reefs.



3.4 Type of rabbitfish (family Siganidae).

3.5 A school of rabbitfish swarming over a raft farm eating all the tips.

Tip nipping is a serious form of damage since tips are the growth portion of the plant and fish can literally devour all the tips on every plant for a quarter hectare of farm in a few days (see Figures 3.6 and 3.7). It can take a week or more for the wound to heal and a new tip to grow. This new tip may then be eaten soon after it protrudes from the thallus. The farmer can monitor this by tagging a branch with nipped tips and observing if they are eaten again. Numerous anti-herbivory devices have been tried but no entirely successful and practical system has been developed. Anti-herbivory devices can be divided up into five groups, which are listed below with examples



3.6 Voracious rabbit fish leave no tip un-nipped. Note that the perpetrators are in the background. It can take up to a week for the tips to heal and start growing again.

3.7 Constant tip nipping leaves an obviously healthy cottonii plant stunted and the farmer frustrated.



3.8 This farmer uses a net pen to protect his seedstock during the high grazing period. The plants depicted in Figure 3.7 came from outside the net pen.

3.9 Fishermen in Southeast Asia and the Western Indian Ocean construct fish traps to catch rabbit fish and place them in the high subtidal.

1. Physical: use barrier nets, gill nets and traps (Figure 3.8 and 3.9).
2. Chemical: use compounds produced by other algae that deter grazers or compounds which are lethal to herbivores.
3. Electrical: simulate the electrical signal produced by predators of tip nippers to scare them away.
4. Audio: broadcast the sounds of tip nipper predators or sounds that are annoying to tip nippers.
5. Visual: use scare lines or models of predators.

Farm location may play a role. Most tip nippers live near the bottom where they can quickly find refuge from predators. This usually makes Long Lines and Rafts less susceptible than the Off Bottom method but it is not certain. In bays, especially, floating systems can be quite susceptible. Siganids will attack plants on floating systems and filefish actually live amongst the plants they are eating. The latter five fish families mentioned above tend to live near the reef edge, around the corals and may not bother farms planted on the reef flat and in deep waters, but this is certainly site specific. Having test plots at various parts of the reef area should give an indication as to which tip nippers are present and where they will and will not feed.

Other comments-

- Keep in mind that some of the tip nippers are dangerous to human beings and should be handled carefully. This is particularly true of Siganids, which have a toxic spine, and sea urchins.
- It has been observed that extreme tip nipping, when farms are decimated, is a seasonal occurrence. This is probably due to reproductive cycles and population changes since no tip nipper is migratory. Siganids, for example, have been noticed to reproduce during rainy season and tip nipping by Siganids appears a month or two after rainy season. This is followed by a decline in tip nipping, which has been attributed to predation on the Siganid population.
- Herbivorous fish have been seen to travel in feeding groups" made up of different species. They also feed primarily at dawn and dusk to avoid predators.
- Tip nipping damage can look very much like tip damage from stress (Figure 3.1), especially when plants have been introduced to a new area and are experiencing an adaptation period. To distinguish the two forms of damage and thereby identify the root of the problem, remember that both leave flat tips but tip nipping leaves a clean cut with teeth marks and no ice-ice whereas dead tips from stress leave a rounded end with ice-ice. You may need a magnifying glass to see teeth marks.

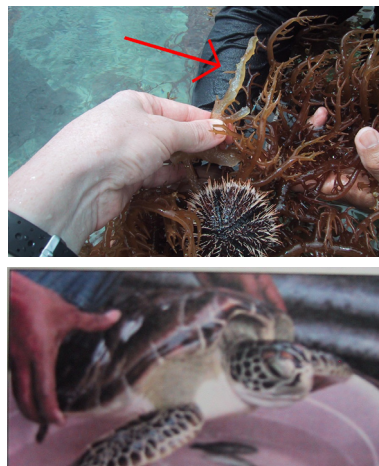
B. Pigmented Layer Picked: Juvenile Siganids (rabbitfish) move in schools and can attack plants voraciously, removing the entire cortical layer of a plant (all the pigmented cells) in a very short period of time as depicted in Figure 3.10. These fish travel in schools and feed at dawn and dusk. At this stage the only defense is to plant enough seaweed to give them indigestion, as it were.



3.10 Pigment pickers like the juvenile Siganids remove the pigmented and nutritious layer of the thalli, leaving just the white unpigmented cells exposed. Note that the tips have also been nipped on this propagule.

This problem occurs after rainy season and since this family of fish is not migratory, it is assumed the problem is due to the population rise of juveniles. The decrease in pigment picking is attributed to predation on juvenile Siganids and their growing into adults, becoming tip nippers. All this is based on casual observation and further study is certainly necessary.

C. Planed thalli: Like pigment pickers, sea urchins, primarily *Tripneustes gratilla*, (Figure 3.11) also remove the cortical layer but dig deeper creating a planed surface (Figure 3.12). This occurs on Off Bottom farms and can be easily controlled by destroying the sea urchins or harvesting them for their gonads, if a buyer exists in the area. To destroy them, use a one meter long pointed stick, walk or swim around the farm and stab the urchins in their center. Place the destroyed urchin in a bag since the needles are still dangerous. Be careful not to puncture yourself while walking in the intertidal and handling the sea urchins.



3.11 The sea urchin *Tripneustes gratilla* is a common herbivore for Off Bottom farms. These animals can be harvested and there is a market for them.

3.12 The sea urchin *Tripneustes gratilla* "planes" the thalli leaving a flat but rough surface as indicated by the red arrow.

3.13 The green turtle, *Chelonia mydas*, is a voracious herbivore but also an endangered species. Please tell farmers not to harm it!

D. Almost entire propagule is gone. The Green turtles, *Chelonia mydas* (Figure 3.13), can be a voracious herbivore, consuming entire plants and destroying lines and stakes. Since these animals are endangered, it is best to move to areas without turtles. If the problem persists, put up large, colorful barrier nets around the farm. Please do not harm these animals.

Pest Weeds

Though there appear to be a lot of non-Eucheumoid algae growing on the farms, only six types have proven to be problematic. Five are large macro-algae and the sixth is not actually a particular species but a number of epiphytic filamentous algae (EFA) which grow from the cortical layer of the cottonii (not yet observed in spinosum) and basically stop the plant from growing.

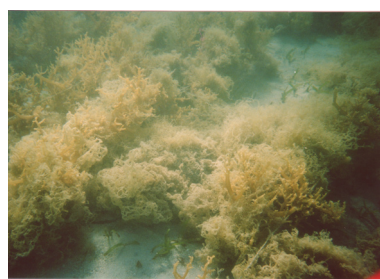
A. Large Algae (*Enteromorpha*, *Ulva*, *Chaetomorpha*, *Hypnea* and *Hydroclathrus*): The first three are green algae (Chlorophyceae) the fourth is a red algae (Rhodophyceae) and the last is a brown alga (Phaeophyceae). They all cause a similar problem, which is to smother the cottonii and spinosum, making it difficult to harvest the plants and forcing the workers to spend an inordinate amount of time cleaning the harvest (see Figures 3.14 to 3.18). Also, while in the water, these pest weeds rob cottonii and spinosum of nutrients and sunlight, perhaps slowing growth. All tend to be seasonal and it is important to record their seasonal pattern so that their appearance is not unexpected (see section on Crop Logging). Also, at least *Enteromorpha* and *Ulva* are known to sporulate on full and new moons so that patchiness of these populations will be noticed on large farm areas. It is important to clean the farms of these weeds by hand immediately upon seeing them, placing them in sacks and taking them to the beach. They will only increase in biomass and spread spores if left on the farm.



3.14 *Enteromorpha* smothering a cottonii plant. The longer it is left on the farm, the longer and more entangled it becomes and the more spores it releases.

3.15 *Enteromorpha* covers the entire lines on this farm.

3.16 *Ulva* has a leafy morphology and attaches to the line or tie-tie, growing over cottonii plants. These farmers should have a sack or basket to put the *Ulva* in, once removed from the farm.



3.17 *Chaetomorpha* has a wiry morphology and entangles and grows over cottonii plants.

3.18 *Hydroclathrus* also entangles itself in cottonii and spinosum plants and is time consuming to remove. It's also larger and heavier than the green pest weeds.

B. Epiphytic and Endophytic Filamentous Algae (EFA) Also considered seasonal, EFA is a serious threat to the health and productivity of a farm. The first signs are hair like protrusions of filamentous algae on the thallus of cottonii (Figure 3.19). Bumps then form where the filament is embedded in the cortical (outer) layer of the cottonii. Eventually, after about one month, the EFA dies and leaves the plant covered with bumps (Figure 3.20). Growth stops and no new branches or tips form. The only solution is to manage around it by harvesting all these plants and replant with new, clean propagules from a non-infested site.



3.19 Hair-like projections from tiny bumps in the cortical layer of the cottonii plant are the first signs of EFA.

3.20 After the EFA dies, the cottonii is left stunted, poorly branched and with bumps all over its thalli.

Other Problems

A. Ice-ice: Ice-ice is a term used to describe tissue that has lost pigment and turned white (like ice). However, it is NOT a disease, it is a sign of an underlying problem. Ice-ice occurs when the plant is stressed, perhaps by high temperatures, low salinities, exposure or toxic substances. To determine if this problem is due to changing environment or poor handling of propagules, determine first if this problem is spread over the entire farm, or just a few lines. If the former, the weather may have changed or there may have been a toxic spill (oil from a boat or agricultural herbicides from a near by river) and you must find a new site. It would also be wise to monitor the temperature and salinity to see if levels are too extreme (Section 1). If the latter is the case, and only a few lines have plants showing ice-ice, then some aspect of the protocol was not followed for those few lines.

B. Microbes: Microbes, such as fungus, bacteria and microscopic animals have been known to attack damaged areas of spinosum (figure 3.21) and cottonii. Since microbes attack damaged areas, it is very important to teach farmers to follow cultivation protocols to ensure their plants are not stressed and therefore less susceptible to attack.

C. Animals: During the course of his travels the author has seen numerous life forms attached to the cottonii or spinosum thalli such as tunicates, squid and nudibranch egg cases, sponges and barnacles. However they have never been present in numbers to be considered a serious problem to production. This does not mean that they won't be problematic in the future, however, and their biology, life history and impact on plant health should be studied.



3.21 Fungus infestation of a cottonii propagule requires that there first be weak and dying tissue for the fungus to attach to and begin growing. This will then cause that portion of the branch to weaken further until it finally breaks off and is lost.

3. Harvest

Harvesting is defined as the act of untying lines from farm structures and transporting them to the beach, usually done by carrying them or floating them (Figures 3.22 to 3.29), though more unique methods are used (Figure 3.30). The goal of the harvesting process is to transport all harvested plants from the farm to the sorting area on the beach with 0% loss or damage.



3.22 This Balinese farmer carries his harvest suspended between a pole over his shoulder in a very traditional, if inefficient, manner. This is fine if you don't have far to walk.

3.23 This Balinese farmer carries her harvest on her head. Also traditional and fine if you don't have far to walk.

3.24 These Malagasy farmers are using a fiberglass catamaran specifically designed to carry harvested seaweed from the farm to the beach. A catamaran also a large, stable work area though you'll need infrastructure to build, repair and maintain non-traditional water craft.



3.25 This resourceful Zanzibari spinosum farmer uses what's available to increase his efficiency. In this case it is an old life raft.

3.26 These enthusiastic Malagasy farmers use a more traditional water craft, a dugout canoe, to transport their harvest to shore.

3.27 Filipino farmers have created these purpose built bamboo rafts to transport their harvest to shore. Simple, inexpensive and using local materials are usually the correct ingredients to solving problems in developing countries.



3.28 Filipino farmers use traditional paddle bancas to transport their harvest. These outrigger canoes can't carry very much harvest.

3.29 These resourceful farmers in Tanzania have put floats inside bags to tow their harvest to the beach. This is far more efficient than carrying the load on their heads, especially since the distance from farm to drying area may well be over a kilometer on the east coast of Africa.

3.30 Farmers in Lombok, Indonesia use their horse carts to transport their harvest to the shore.

Below are guidelines that the farmers should be taught to follow to make certain that no harvest is lost and that harvested plants used for propagules will be in optimum condition. Figure 3.31 shows ideal sized planted and harvested cottonii plants and this can work for spinosum as well. The plants are large, bushy and healthy at harvest. When split, these plants will make excellent propagules as well.



3.31 The line on the left is newly planted and that on the right is ready for harvest. This was a six week grow-out period.

A. Careful removal from the farm: Gently untie the lines from the farm and pull them into the boat or net bag.

B. Careful transport: Make certain there is NO gasoline or oil spilled in the boat because these are toxic to cottonii and spinosum. You may want to line the boat with a plastic sheet. Also, cover the plants with a plastic sheet to protect them from sun or rain. Pour sea water on them every 15 minutes during transport. Finally, do not step on the plants or place heavy objects on them that will crush them.

C. Careful unloading of boat: When removing cottonii or spinosum from the boat and taking it to the working area, handle the cottonii or spinosum gently so that no plants are lost.

Grow Out Period

A very important question often asked is “What is the most appropriate grow out period?” This is a complicated question to answer because there are a variety of factors to be considered, primarily biological, logistic and economic. Let’s first look at the question from a biological point of view.

Over one hundred years ago a German scientist named Verlhust developed a logistic equation to describe population growth (Harper, 1977):

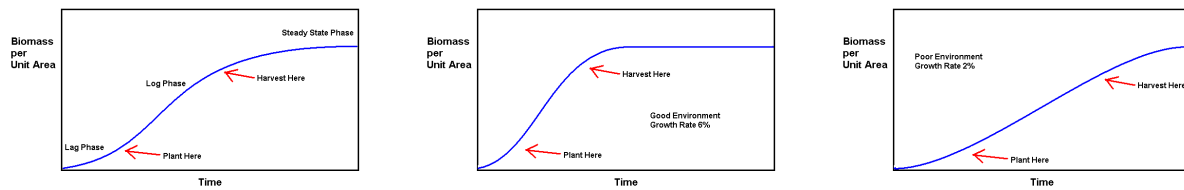
$$dB/dt = r \times B \times [(C - B)/C]$$

where B = biomass, t = time, r = relative growth rate and C = carrying capacity

He found that when measured, a population of bacteria in a Petri dish or unicellular algae in a jar grew in a sigmoid fashion with three phases (see Figure 3.32). Initially cells begin dividing, but since there are so few to begin with, a lot of dividing has to take place before a significant population exists. This is called the “lag phase.” Then, once a critical population exists, every time the population reproduces huge quantities are created. This is called the “log phase.” And finally, limiting factors such as space and nutrients work to control the population and it reaches the “steady state phase” or the carrying capacity.

Although the equation is not very applicable to a population in the wild because of factors like competition, predation and natural calamities, it does work well for a cottonii or spinosum farm for three reasons: First, these plants reproduce vegetatively,

avoiding the complications brought about by sexual reproductive cycles. Second, they are grown as a mono-crop, and third, the farmer keeps competition and predation to a minimum.



3.32 The sigmoid growth curve indicating the three phases. Given the great increase in biomass per unit time during log phase, it is best to plant at the beginning and harvest at the end.

3.33 Good environmental conditions give high growth rates and that means shorter grow out periods.

3.34 Poor environmental conditions give low growth rates and that means longer grow out periods.

So, looking at Figure 3.32, it is obvious that one should plant at the beginning of the log phase and harvest at the end of it. Farming during lag or steady state phase is a waste of time because biomass increase per unit time is so low compared to log phase. But the question still remains, how long should the grow-out period be?

That depends on the growth rate (r in the equation), which, in turn, depends on environmental factors like temperature, nutrient availability, light, water flow and salinity. Under good environmental conditions (Figure 3.33), the optimum grow out period would be shorter than during poor conditions (Figure 3.34). So, one would expect to have different grow out periods during different seasons.

Also, notice that the sigmoid growth curve indicates a rough optimum planting density: the beginning of the log phase.

Since each site is unique, it is advisable to teach the farmer to determine the carrying capacity for her site. This can be done by planting a 5 x 5 meter plot during the best growth season with 50 gram propagules every 20 cm and weighing the plants every two weeks until there is no longer an increase in biomass. The mass at this point can be assumed to be the carrying capacity.

A second factor influencing grow out period is logistics. A farmer has limited resources, e.g. labor, boat, drying area and farm area. The farmer knows how many lines his family is capable of managing in one day and he knows how much farm area he has. Therefore he must decide how long of a grow out period he wants so that he can comfortably run all the gear on the farm during that grow out period.

Besides limited resources, another logistic factor is pest weeds. Pest weeds require attention because if they are left on the gear they become problematic at harvest time and the farmer will find herself spending an inordinate amount of time cleaning pest weeds off her harvested cottonii or spinosum. She may find it wiser to shorten her grow out

period during pest weed season so that she harvests before the pest weeds become problematic.

And finally, economics also play a role in determining an optimum grow out period. Economics relates to the limited resources of the farmer, mentioned previously. Biologically it would make sense to shorten grow out periods during the high growth season, but this requires the farmer to buy more resources: perhaps hire some people, buy a few more boats, build a storage house for dry seaweed and lease land for drying. The purchased resources will only be used for two or three months when there is high growth, after that it may sit idle. It could be that his additional costs of production outweigh the gain in producing more seaweed so it would be more economical to stick with the longer grow out period even though plots go beyond log phase into steady state phase.

It is beyond the scope of this booklet to fully analyze the economics of farming. But every farmer should be encouraged to attempt to understand this factor, as well as the biological and logistical factors, when determining her own optimum grow out period. Remember, the bottom line is that there is no universal optimum grow out period. It depends on the unique time and place of cultivation and the farmer's circumstances.

4. Stripping harvested lines, Culling and Seeding propagules

Once the harvested lines reach the beach, the first order of business is to strip the lines of the harvested plants. With the Made Loop this is easily done using a Line Stripper. Line Strippers are wooden planks with 3cm diameter holes through which the lines are pulled. Farmers can pull more than one line through the hole at a time and the harvested plants simply pop off as they break when they hit the hole and cannot pass through (Figures 3.34.1 and 3.34.2). The harvest is then culled. Culling is defined as removing healthy, young and strong plants from the harvest to be used as new seedlings, more appropriately referred to as "propagules." With these propagules the cleaned farm lines with Made Loops can then be seeded, that is attaching the propagules to the farm lines with the Made Loop.

In some areas farmers choose to do all their line stripping, seedling selection and line seeding at the farm site. In this case it is possible to put up line strippers at the farm. For example in the central Philippines the line stripper is on a raft (Figure 3.34.3).



3.34.1 A Line Stripper is a plank of wood with a 3 cm hole in it though with the harvested line passes. The plants pop off when the hit the hole. Note that in this photo four lines are stripped at once, increasing efficiency.

3.34.2 One farmer who simply holds the line and walks away from the stripper is using this free standing Line Stripper.

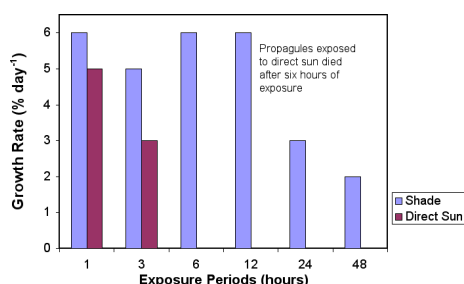
3.34.3 A line stripper on a bamboo raft in the central Philippines.

Characteristics of a Good Propagule

Teach the farmers to always try to plant healthy, young and strong propagules with many tips. The farmer should avoid using the poor propagule if possible. Planting sick, old or stressed seedlings wastes time and money. If propagules are sick, old or stressed, they will not grow well and may even die.

Exposure of a Propagule

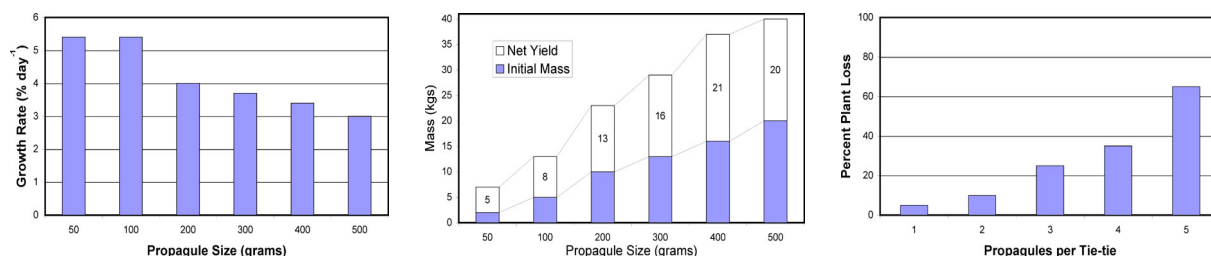
When harvesting and replanting cottonii or spinosum, always return the seedlings to the sea as soon as possible. Exposure to air and sunlight stresses the propagules and the more stress the propagules receive, the longer it takes for them to recover and grow. (see Figure 3.35) If they are exposed too long, they will dry and die. As a rule, the maximum exposure times should be six hours of shade or one hour of direct sunlight. If long periods out of the water are required, the farmer may wish to rig a pump and hose to pump seawater from the beach and spray the propagules every 15 to 30 minutes. Farmers sometimes harvest in the afternoon, tie propagules in the evening and plant in the morning, with no apparent impact on the health of the propagules.



3.35 Cottonii propagules of different sizes grow at different rates.

Size of Propagule

Teach the farmers to use an appropriate propagule size. It has been shown that smaller propagules have higher growth rates than larger propagules (see Figure 3.36) but larger propagules per tie-tie have a bigger net yield per unit effort of tying propagules onto the lines (see Figure 3.37). However, having large propagules is not always practical. First, after culling, propagules may be broken into small sizes, e.g. 50 grams, and secondly, in areas with strong water motion, large propagules may break and be lost. The farmer must experiment a little bit to decide what is appropriate for his location.



3.36 Cottonii propagules of different sizes have different net yields. There were 40 propagules per treatment and the grow period was three weeks.

3.37 For cottonii, more than two propagules per tie-tie leads to high percent plant loss.

3.38 Exposure results for cottonii. It is best to be cautious, never exposing your plants to more than one hour of direct sun or six hours of shade.

For cottonii it is also important not to tie more than two propagules per tie-tie. It has

been found that having three, four and five propagules per tie-tie leads to plant loss (see Figure 3.38). In the case of spinosum, tying up to seven propagules per tie-tie is common practice. For spinosum, tie the propagules tightly and with cottonii, keep the tie-tie a bit loose.

Handling Propagules

The farmers should always handle the propagules with care. Teach the farmers not to step on them, crush them, or throw them. Since culling and tying of propagules is usually done on land, the work area should be clean with no gasoline or toxic substances on the floor. If outdoors, the work area should have shade and a plastic sheet covering the ground (Figure 3.39).



3.39 In order not to stress their cottonii plants, these farmers are culling and tying in the shade and have a tub of sea water with which to wet the propagules every 15 minutes.

4. POST HARVEST HANDLING

The farmers must clearly understand that the goal of post harvest handling is to take the harvested wet cottonii or spinosum through the drying process so the final product to be baled is:

1. clean
2. free of sand, tie-tie and other foreign material
3. shaken to remove external salt
4. dry to 30% moisture content
5. purplish/brown colored indicating it was not rained upon or stacked too thickly during the drying process

Historically, numerous drying methods have been used, but most do not allow the previously mentioned goals to be met. Examples are on the ground methods (see Figures 4.1 to 4.3) and tables (Figure 4.4 to 4.5). Today only drying tables and drying racks for bare cottonii and spinosum detached from farm lines should be used. On the ground methods usually allow for a lot of contamination from sand and foreign material and people and animals walk on the drying seaweed. Hanging methods, where the seaweed is still attached to the line, keeps the line out of production and the direct sunlight with UV light on the line destroys its integrity, greatly shortening its useable life span.



4.1 Drying in the sand is the absolute worse thing a farmer can do. Sand sticks to the seaweed, animals and people walk on it and all sorts of garbage gets into the harvest. This should NEVER happen.

4.2 This Zanzibari farmer is drying his cloves along with his cottonii. At least the cloves get a woven mat. The cottonii is still in the dirt. Completely unacceptable!

4.3 These Balinese farmers are drying on the ground but at least they are using plastic sheets and the farm houses surrounding the drying area protects the plants from wind driven debris and sand.



4.4 These are excellent local made tables in Pemba, Tanzania. What is important here is to assure trees are being planted so table construction does not lead to deforestation.

4.5 These Malagasy farmers not only have tables, but cover their drying cottonii with plastic sheets during rains storms.

4.6 This is the best drying platform, from Sulawesi, Indonesia. A nice clean surface and a “pup tent” to protect the plants during rain squalls and still allow air to flow over the plants.

Tables should also utilize a “pup-tent” frame (Figure 4.6) so plastic sheeting can be placed over the tables during rainstorms. The pup-tent design allows air to flow over the plants preventing condensation that can bleach them.

Mechanical dryers: Mechanical dryers are not used. The benefits of being able to dry during the rainy season are apparent and FMC BioPolymer, along with other processors and suppliers, have put effort into designing mechanical dryers. If you are interested you can contact FMC BioPolymer. Protocols for the post harvest handling process

Teach the farmer the following protocols:

1. Don't let the cottonii or spinosum sit on the beach. Move it immediately to a clean, sand free area and begin drying it.

2. Keep dogs, chickens, other animals and children off the cottonii or spinosum when drying.

3. When untying harvested plants from the lines, remove ALL tie-tie. This is extremely important. It is best to use the knots outlined in Chapter 1 so that tie-tie is permanently attached to the line and cottonii and spinosum can be removed with a simple pull of

one end of the tie-tie. Knots that require cutting the harvested plant free should NOT be used.

4. Have plastic tarps nearby to cover drying seaweed in case of a rainstorm. Rain is bad for the buyer as well as the farmer. The farmer loses weight in the form of salt and the buyer may be getting substandard cottonii or spinosum. Keep the rain off the drying seaweed!!! It should take no more than three sunny, hot days to reach 30% moisture content (M.C.). With experience the farmer will be able to know moisture content by squeezing the plant. This is a good skill to develop since it saves time and frustration when bickering with the buyer of the cottonii and spinosum.

5. When drying is completed, place the seaweed in clean bags and transport to the buying area. When transporting, make sure the product stays dry and clean. This can especially be a problem when transporting the product in a boat or truck. In both cases the bags should be off the floor and covered with a sheet of plastic.

6. If the cottonii or spinosum cannot be transported to the buying station right away, then the sacks of dried cottonii or spinosum must be stored in the farmers house or work-shed. The farmer should be certain the roof and walls are waterproof and the sacks of dried seaweed should be stacked on wooden slats, allowing air to circulate under the sacks.

Once dried, it is important to shake the seaweed salt (KCl) off the plants to bring it down to about 30% of dried weight of the dried plant. This can be done by the farmer, shaking or beating the plants. A little bit of vigorous shaking can release a surprising amount of salt (Figure 4.7). For suppliers, using a rice thresher makes more sense (Figure 4.8).



4.7 The plant on the left was shaken for just a short while and released quite a bit of seaweed salt (KCl).



4.8 A seaweed exporter in Indonesia uses this rice thresher to remove excess seaweed salt.

5. WATER SAFETY

The marine environment is foreign to us and therefore if one is going to work in this environment, one must take special precautions to ensure one's safety. These precautions include knowing what the dangers are and preparing for them. Preparation includes knowing what animals are dangerous and how to avoid them and treat the injuries they inflict, how to swim well, what safety equipment to keep on a boat and how to plan trips to the sea. There are numerous books on the topic that can be referred to but basically:

1. Be careful of rabbit fish, which have venomous spines and the sea urchins that may

- be eating the cottonii or spinosum farms.
2. Reef flat farmers should, as soon as financially possible, purchase and wear solid soled shoes to protect them from urchins, stone fish, blue spotted rays, barnacles, oysters and other dangerous animals on the reef flat.
 3. Raft or long line farmers working from a boat should have and wear a personal floatation device (PFD), maintain their water craft and tell family and friends when they go to sea and what to do if they do not return on schedule.
 4. Farmers who spend a lot of time in colder waters should obtain a wet suit, when financially possible.
 5. All farmers should know how to swim.

Some useful websites include:

1. Boating safety (including an on-line course!). <http://www.uscgboating.org/>
2. Health, especially in developing countries, and this includes problems with sun and heat. <http://www.tripprep.com/scripts/main/default.asp>
3. Dangerous marine animals and how to treat the wounds they inflict. <http://www.marine-medic.com/index.html>

6. BRIEF BACKGROUND ON SEAWEED, EUCHEUMAS AND CARRAGEENAN

Background on Seaweed

First, some definitions: "Algae" (singular "alga") are photosynthetic plants without roots stems or leaves. Algae are usually separated into two groups: the microscopic group called "phytoplankton" or "microalgae," and the algae you can see with your unaided eyes called "macroalgae." Macroalgae that live in seawater are called "seaweed."

There are four types of seaweeds: Blue-green, Red, Green and Brown. Each type is a phyla and to give some perspective as to how different these phyla of seaweeds are, all terrestrial plants, from pine trees to ferns, belong to one phyla. Therefore, the study of algae, or "phycology," is an extremely broad field.

Numerous characteristics distinguish the four phyla of seaweeds but primarily they are: photosynthetic pigments, storage material and numbers of membranes. Each phyla has a variety of species, some range from microalgae to seaweeds. These species vary widely in reproductive strategies, lifecycles, morphology and natural habitat.

There are around 50 species of commercial algae out of a total species number of nearly twenty thousand. Some uses of commercial algae are: phycocolloids (agar, carrageenan and alginate), human food, food for fish and shellfish hatcheries, pigments and proteins, fertilizer and soil texture and cosmetic/therapeutic purposes. Some of these species are cultivated and others are harvested from the wild.

Eucheuma crop ecology

Most eucheuma type seaweeds (including cottonii and spinosum) naturally grow on the reef flat and reef edge environment. As a wild species they are subjected to environmental pressures that determine their success. In a farm environment,

environmental pressures also exist and determine the biological success of the cottonii and spinosum on the farm. The study of the interactions the spinosum and cottonii have with their environment is called eucheuma crop ecology. Currently eucheuma crop ecology is not very well established. It is important to develop this area of study so that eucheuma farming can develop into a more scientific based activity allowing proactive farming methods that ensure higher yields and more successful farmers. Interactions with the environment are commonly divided into three primary categories biological, chemical and physical. These in turn have specific topics, for example:

Biological

1. herbivores
2. competition for space with other seaweeds
3. epiphytes

Chemical

1. nutrients
2. pollutants
3. phycochemicals

Physical

1. temperature
2. salinity
3. water flow
4. light
5. wind vector

A clearer understanding of the crop's interactions with these environmental parameters should lead to improved cultivation practices that will provide higher productivity.

Morphology

It has long been known that many seaweeds have phenotypic plasticity. This means that if the environment changes they adapt, sometimes dramatically changing their physical appearance. For instance, *Chondrus crispus*, a red algae from the north Atlantic, growing in its natural habitat, a rocky, sub-tidal wave washed environment, is leaf like with a very distinct base and attachment structure. But when cultivated in a tank, unattached, it forms a ball. Likewise, when fish graze algae such as certain species of *Gracilaria*, another genus of red algae, biting off the tips of the thin, cylindrical branches, the plant responds by forming many new branches on the thallus with the missing tip so that after a few weeks the plant has a bushy appearance.

Cottonii has numerous "morphotypes," or different looking types (Doty, 1985). There appear to be at least three different color types, commonly known as: green, olive green and brown (Figure 6.1 and 6.2). In addition, nutrient and light levels can change the intensity of these colors (Figure 6.3).



6.1 The three color variants of cottonii (green, brown and olive green).

6.2 A new color variant of spinosum (deep red?) alongside a more typical brown variety...

6.3 This plant depicts how self-shading leads to higher pigmentation (darker color) to compensate for the lower light levels it obtains, while the exposed thalli are lighter in color since they need a lower density of photosynthetic pigments to obtain the light needed to drive photosynthesis.

Cottonii also has a few different morphotypes based on shape. These are: alvarezii, ajak-assi, buaya and sakol, also called "flower" and originally called "dichotomous" (Doty, 1985) (Figure 6.4).

As stated previously, these plants have morphological plasticity, and will change their appearance when grown in different environments, e.g. buaya will change to alvarezii or an olive green will have new thalli that are brown.



6.4 Sakol variety (green) next to alvarezii variety (brown).

6.5 Green and brown spinosum varieties.

6.6 Spinsum

Morphological plasticity is also present in spinosum. Color types include green brown and olive as well as an additional bright red variety (Figure 6.2 and 6.5) and structural types exist, but, like cottonii, can change with the environment in which they are cultivated. Some morphotypes look surprisingly like cottonii and have confused buyers (Figure 6.6).

Lifecycle

The cultivation of cottonii and spinosum is vegetative and does not involve lifecycles. This makes cultivation comparatively simple but raises concern over genetic variability and the ability of the crop to withstand a decimating microbial attack.

Traits like high growth rates and high carrageenan yield may diminish over time and would be the major reason to begin and maintain a strain selection program. Microbial attacks are certainly a concern but keep in mind this has yet to occur since cultivation began over 25 years ago. In addition, there are numerous plant and animal species that reproduce asexually and are quite successful.

In the wild, *cottonii* and *spinosum* would pass through a typical red alga triphasic lifecycle consisting of the tetrasporophyte (diploid), the gametophyte (haploid) and the carposporophyte (diploid).

It is important to note that cultivated varieties of *cottonii* and *spinosum* have been introduced in tropical waters of the Pacific, Atlantic and Indian oceans by researchers, government officials and industry representatives. In some places indigenous varieties exist but have proven inadequate for cultivation. Incidence of introduced varieties for commercial cultivation going wild and out competing other marine plants, including native varieties of *cottonii* and *spinosum*, have never been recorded nor witnessed by the author, who has travelled extensively. It is important to note that when plants break off a farm, other farmers or reef gleaners will pick them up because they have value. For an extended discussion of introduction, read Ask, et al. (2003).

Carrageenan

Carrageenan is a gum, like starch, which is part of the cell wall structure of the carrageenophyte. The extracted and processed carrageenan is primarily used as a food ingredient. There are basically three types of commercial gum derived from marine algae: Carrageenan, agar and alginate. The first two are produced by certain red algae (Rhodophyceae) and the latter is extracted from certain brown algae (Phaeophyceae).

Carrageenan, in turn, is divided into three types: lambda, iota and kappa. Lambda does not gel, iota forms a weak gel and kappa forms a very strong gel. *Spinosum* produces iota carrageenan and *cottonii* produces kappa carrageenan. Commercially, lambda carrageenan is extracted from temperate species of red algae though certain tropical species also produce it.

7. COASTAL RESOURCE MANAGEMENT AND COTTONII AND SPINOSUM FARMING

Coastal resource management in developing countries is challenging. On the one hand growing populations in coastal areas are putting huge pressures on the environment (Figures 7.1 to 7.3) from over fishing to destructive fishing, coral harvesting, sand harvesting, reef gleaning and deforestation of coastal hills and mangrove forests. On the other hand government may lack the financial, human and logistic resources to manage and control these activities. Currently the ideas of village-based management and valuing resources in a way that preserves and enhances them are rising to prominence. In this context *cottonii* and *spinosum* farming can play a valuable role and be an important tool for the coastal resource manager, like marine protected areas and eco-tourism. Specifically, seaweed farms have major benefits for the coastal environment and villagers and should enhance the abilities of the coastal resource manager to achieve his or her project goals.



7.1 A densely populated island in the central Philippines puts great pressure on the coastal environment.

7.2 Seaweed farms are placed right in front of this large population village on an island off the coast of Tanzania.

7.3 These farms are placed right in front of a highly populated village where human activity has already had major negative impact. The farms are improving the coastal ecosystem through nutrient absorption, providing primary production and habitat to marine organisms and providing a sustainable livelihood to the villagers as opposed to dynamite fishing and reef gleaning.

Environmental Benefits

1. Absorb nutrients from urban and agricultural runoff, protecting corals from nutrient driven wild seaweed blooms and improving water quality.
2. Provide primary production. If not more than 10% of the farms are eaten by herbivores farmers can survive and the farms enhance the marine ecosystem and fish stocks for local fishermen. Greater than 10% can negatively impact farmers' income.
3. Provide habitat. Fish (adults and juveniles), invertebrates and other algae live in and around cottonii and spinosum farms, enhancing the marine environment and fish stocks for local fishermen.
4. Promote stewardship mentality. The farmer's wealth is directly tied to water quality and farmers will fight to maintain superior water quality levels.
5. Alternative sustainable livelihood. Farming of cottonii and spinosum is usually taken up by people who have depleted their natural marine resources through over fishing, dynamite and cyanide fishing, reef gleaning, coral harvesting, sand harvesting, slash and burn farming on coastal hills causing siltation and so forth.

Farms are rarely placed in remote and pristine areas because these areas don't make commercial sense due to increased domestic shipping costs, difficult logistics as well as demographics. You need a lot of people to produce a commercial volume of cottonii and spinosum and large villages have usually had a large negative impact on their nearby marine environment. In these areas seaweed farming certainly has a positive impact on the coastal environment.

Social Benefits

1. In many cases women farm cottonii and spinosum which gives them their own income. This usually translates into better food, clothing, health and education for the family.
2. Cottonii and spinosum farming is a cottage industry so children can be looked after while doing on shore farm work (preparing materials, drying seeding...), keeping the family together.
3. Since it is a sustainable and lucrative livelihood, it prevents migration to urban areas and helps prevent the social ills which arise from people moving to large urban

centers with high unemployment: crime, homelessness, prostitution, squatting, loss of self respect and dignity as well as the loss of local culture and when youth leave the society.

Economic Benefits

1. Cottonii and spinosum farming puts cash into the villages. This money flows through the economy as coastal dwellers buy food from inland farms and clothing and household goods from urban areas, spreading the benefits.
2. The more a farmer grows, the more he or she can earn.
3. In many islands and coastal areas, eucheuma has become the crop with the highest total export earnings. In some cases, this has occurred within less than five years of being introduced.
4. Since in many countries no one owns the coastal area, establishment of cottonii and spinosum farms becomes instant land reform.

8. CROP LOGS

An enhanced test plot system (see Section 2) run by the developer is a crop log. Crop logs provide a clear picture of what is happening on the farm as well as other sites by monitoring cottonii or spinosum parameters (growth rate and percent plant loss) against environmental parameters (water temperature, salinity, wind speed/direction, herbivory, pest weeds, debris). Proper crop log programs should use data loggers and sensors to monitor water temperature, rainfall and wind speed/direction while other parameters are monitored by a technician. Figures 8.1 to 8.6 provide a crop log data sheet representing one year's worth of farm data for one location. As you can see, this one page has a tremendous amount of information about what is probably driving production (growth rates) at any given time of the year. It also allows the identification of seasonal patterns that over a few years should allow you to promote pro-active farming practices.

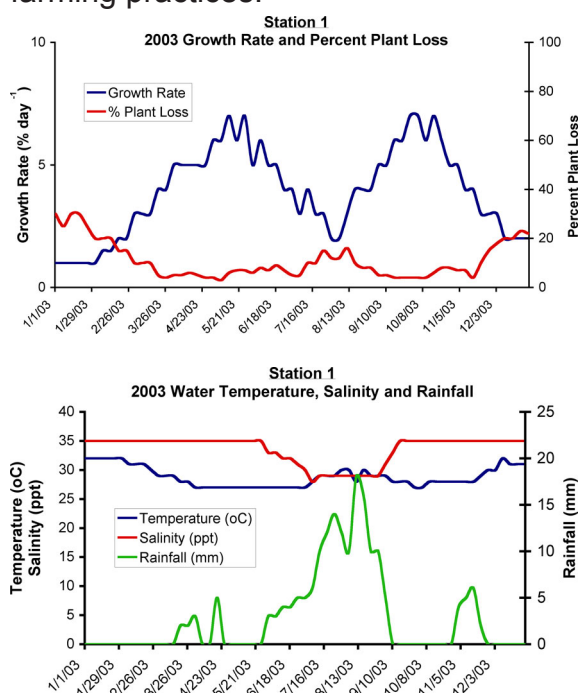


Figure 8.1 Growth rate and % plant loss.

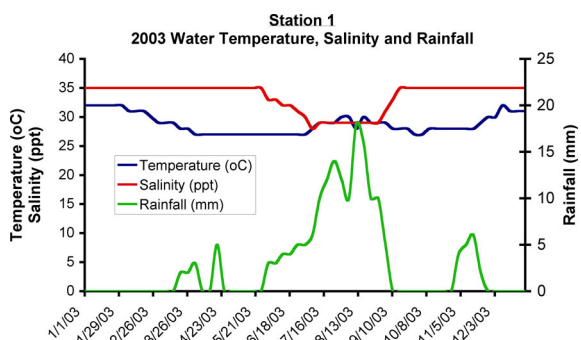


Figure 8.2 Water temperature, salinity and rainfall

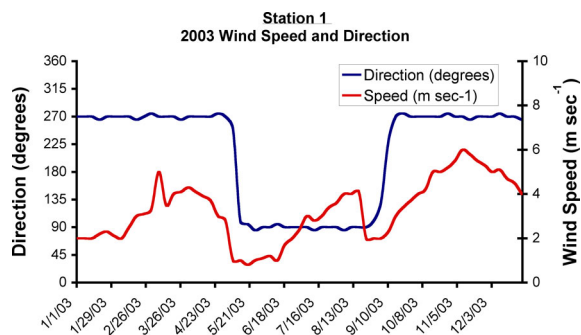


Figure 8.3 Wind speed and direction.

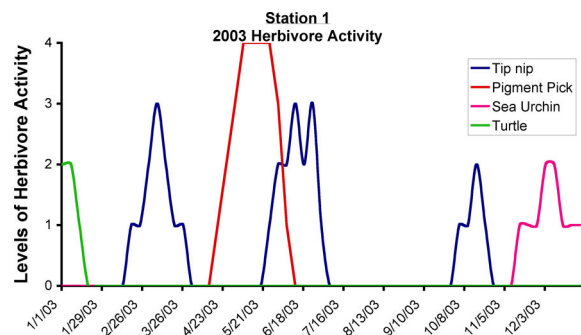


Figure 8.4 Herbivore activity.

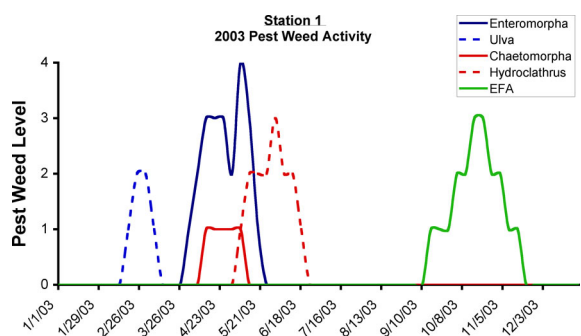


Figure 8.5 Pest weed activity.

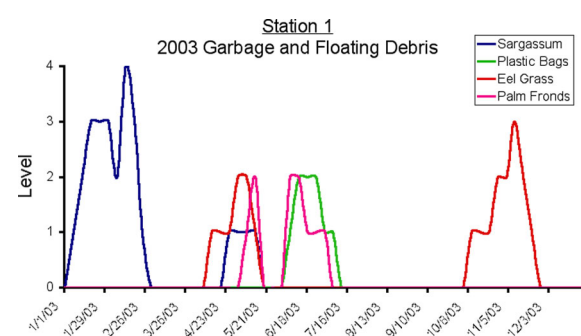


Figure 8.6 Garbage and floating debris.

To conduct a crop log, monitor growth rate and plant loss as you would with a test plot. In addition, monitor wind speed/direction and rainfall by either getting the data from a weather station, such as those at nearby airports, or buying your own station with data loggers (Onset produces relatively economical and easy to use weather stations and waterproof temperature loggers - www.onsetcomp.com - while Aquatic Ecosystems Inc. - www.aquaticeco.com - is a great source of monitoring and survey equipment). If you don't have funds, then a simple manually operated rain bucket, alcohol thermometer for water temperature and plastic aquarium salinometer will suffice.

Use Tables 8.1 to 8.3 to monitor herbivory, pest weeds and garbage/debris on a fuzzy scale. You decide what is "a little," "a lot" and so forth. Also, you may want to track plant color, as an indication of nutrient status (though color may also be a factor of light levels as indicated in figure 6.3). Use Chart 8.1 for that.

Finally, with digital cameras being so inexpensive, you may find it quite useful to take pictures of your crop log plots, and plants from those plots, every week to have a visual crop log indicating plant health, herbivory, pest weeds and color.

Tables 8.1 to 8.3 Code sheet for Crop Log Data Sheet.

Herbivores

Type	Type #	Level	Level #
Tip Nipping	1	None	0
Pigment Picking (cortical layer)	2	A few	1
Cortical layer planed	3	Some	2
Whole branch eaten	4	A lot	3
		Entirely	4

Pest Weeds

Type	Type #	Level	Level #
<i>Enteromorpha</i>	1	None	0
<i>Ulva</i>	2	A few	1
<i>Chaetomorpha</i>	3	Some	2
<i>Hypnea</i>	4	A lot	3
<i>Hydroclathrus</i>	5	Entirely	4
EFA	6		

Garbage and Floating Debris

Type	Type #	Level	Level #
Floating <i>Sargassum</i>	1	None	0
Plastic bags	2	A few	1
Dead Eel grass	3	Some	2
Palm fronds	4	A lot	3
		Entirely	4

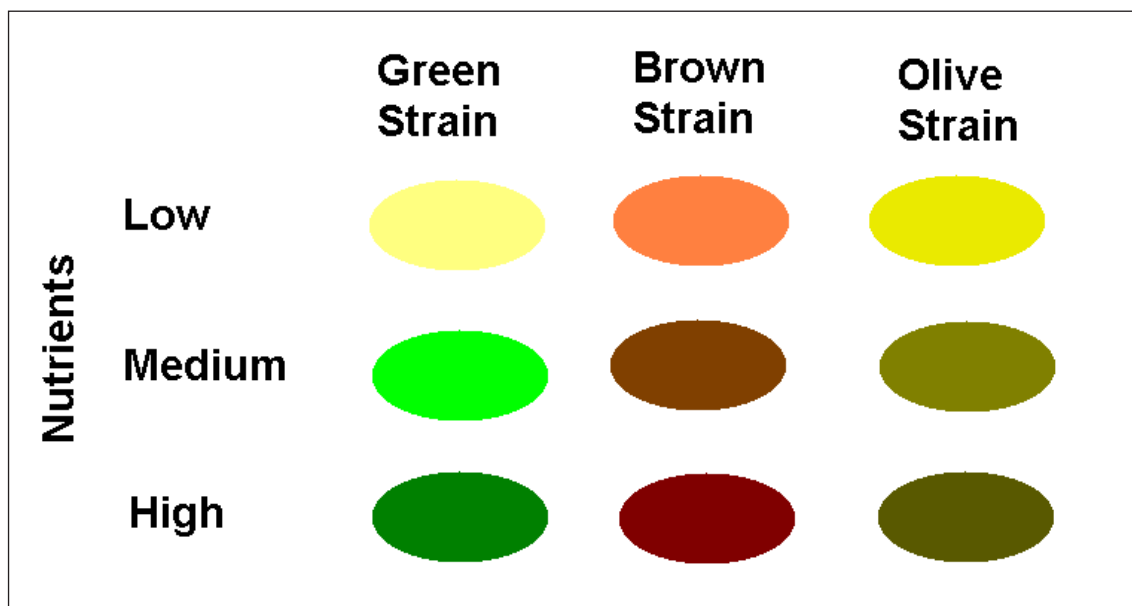


Chart 8.1 Color chart for three color variants.

9. VIDEO CLIPS

Meet the farmers



Zanzibari woman tells why she became a cottonii farmer.



Malagasy matriarch tells why she enjoys farming cottonii.

Seaweed tourism



Tourists can easily visit seaweed farms near Bali and receive lectures on farming from well qualified tour guides. Here a group of Americans learn all about Balinese seaweed farmers and farming.

Environmental benefits



Juvenile fish use a Tanzanian cottonii farm as a nursery.

Farming



Maduran family planting their raft.



Tanzanian farmers harvesting and seeding lines.



Daily activities at a Balinese farm area.



Post harvest activities at a Balinese farm area.



Tanzanian farmers seeding lines.

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