Farming the Red Seaweed, *Eucheuma*, for Carrageenans

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The modern food industry requires 10 to 20 times more carrageenan than the wild seaweed crop provides. Part of this need is being met by the research and development reported here on the basic production ecology and agronomy of *Eucheuma*, a carrageenan-producing tropical seaweed. Other marine algae, such as *Chondrus crispus*, the "Irish moss" of temperate regions, produce variable mixtures of the different carrageenans. The genus, *Eucheuma*, can be divided (Table 1) into two groups of species producing, respectively, iota or kappa carrageenan.

Currently, something perhaps between 3000 and 4000 dry tons of *Eucheuma* reach the World market. Most of it goes to the United States with much smaller amounts going to the United Kingdom, France, or Denmark. Largely it comes from Southeast Asia, *e.g.*, the Philippines (Fig. 1) and Indonesia. Wildman (1971) provides both an interesting series of photographs and a variety of information on the *Eucheuma* industry. The World price might now be $350 (U.S.) per ton if the product were clean, rewashed, dry, and monospecific regardless of the species or kind of carrageenan contained. Deviations from these specifications may reduce the F.O.B. price one-half or two-thirds, but the value has nearly doubled in the past five years.

Table 1. The better known carrageenan containing *Eucheuma* species used commercially. The scientific names in parentheses are probable synonyms of those under which they are indented.

Kappa carrageenan ("cottonii" types)	Iota carrageenan ("spinosum" types)
E. cottonii	*E. spinosum*
(=*E. okamurae*)	(=*E. muricatum*)
E. striatum	(=*E. denticulatum*)
(=*E. nudum*)	*E. isiforme*
(=*E. edule*)	(=*E. acanthocladum*)
E. procrusteanum	*E. uncinatum*
E. speciosum	(=*E. johnstonii*)

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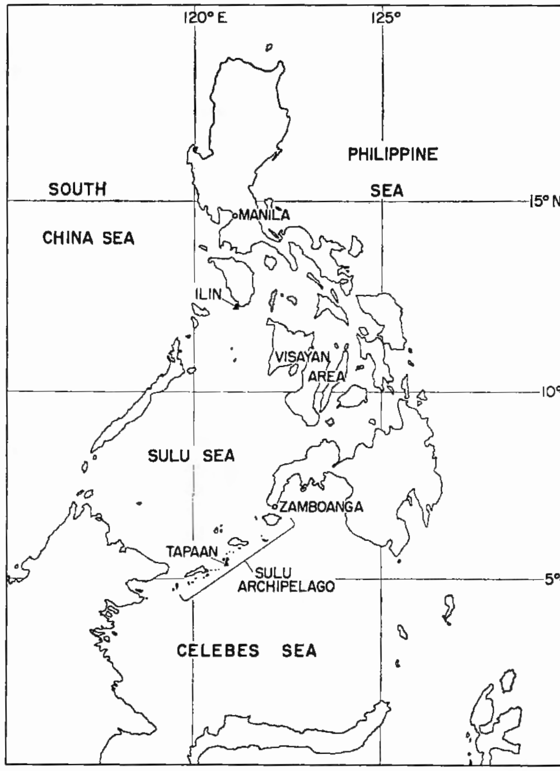
Micronesica 9(1):59-73. 1973 (July).



F g. 1. The Philippine *Eucheuma* farming and production areas.

Iota carrageenan is the principal component of the walls of *Eucheuma* species having a dense central axis of slender cells in the center of each branch. Likewise, these iota carrageenan-bearing species have (Fig. 2) regularly spaced spine-like branchlets on the margins of their flat fronds or in whorls on cylindrical fronds (*e.g.*, *E. spinosum*) when these are young. Later spines appear elsewhere and the primary spines may elongate into branches. The branches tend to be uniform in diameter from the base to tip or throughout any given segment. The characteristics of iota carrageenan (Stancioff and Stanley, 1969) include its being rather like a sugar solution, *i.e.*, hardly becoming really rigid as it thickens. Also it suspends quickly in cold water.

Kappa carrageenan is the principal wall component of the anaxiferous *Eucheuma* species. While the principal species is *E. striatum*, in the trade the term "cottonii" is used for all kappa carrageenan producers of the genus. There is no dense central strand of slender cells; thus these species are said to be anaxiferous. The branchlets arise irregularly as protuberances near the branch tips; though sometimes they appear to be elongated longitudinally or arranged longitudinally in respect to one another. Branches are often seen that are swollen or much larger in diameter toward their apices than at their bases and callus-like collars or swellings are asso-

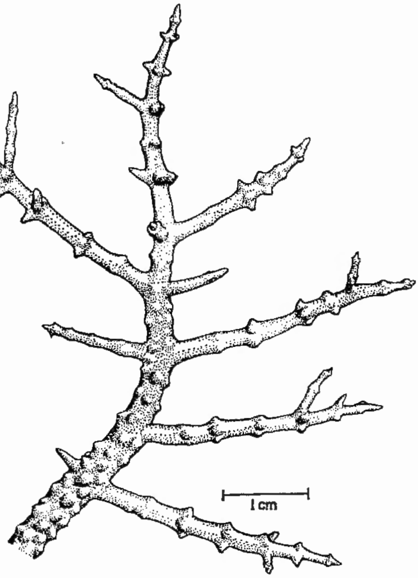


Fig. 2. A common form of *Eucheuma spinosum*. The whorled, regularly-spaced spines and branches as well as the regular diameter of the main axes are characteristic. The proliferations are of two sorts, primary proliferations which are tapered spines arising in regularly predictable places near the branch tips and secondary proliferations which are at first hemispherical but later may become cylindrical or grow out as branches. The secondary proliferations arise neither near the tips of rapidly growing thalli nor at regularly predictable places.

ciated with wound healing and branch regeneration. Sometimes the thalli may be flattened (Fig. 3) as is the species, *E. cottonii*, in its scientific sense. *Eucheuma procrusteanum* produces (Kraft, 1969b) erect flat blades from a branched basal cylindrical portion. Kappa carrangeenan makes (Stancioff and Stanley, 1969) a rigid gel that will retain its form without support.

There are exceptions to the above characterizations, but these involve a very small number of the species in the genus for which there are at least 42 specific epithets. These exceptional species of *Eucheuma* are not usually found in any quantity. It could be that more than one genus should be recognized. At present *Eucheuma* is usually recognized on the basis of the anatomy of the cystocarps, the seriate tetraspores and, in addition to the form of the individual species, by being both coarse and about the only noncalcareous tropical seaweed the branches of which are so rigid when alive they will snap in two when bent back on themselves.

Records of *Eucheuma* are as old as Linnaean botanical literature itself. It has long been used locally as a salad vegetable and, like *E. speciosum* in Western Australia during World War II, for its gel content. Agar agar is the Malay name for *Eucheuma* and some other seaweeds. Hesse's introduction of it to microbiology (Hitchens and Leikind, 1939) was apparently a first scientific use of kappa carrageenan from the cottonii *Eucheuma* species. The terms agar and agar agar are now

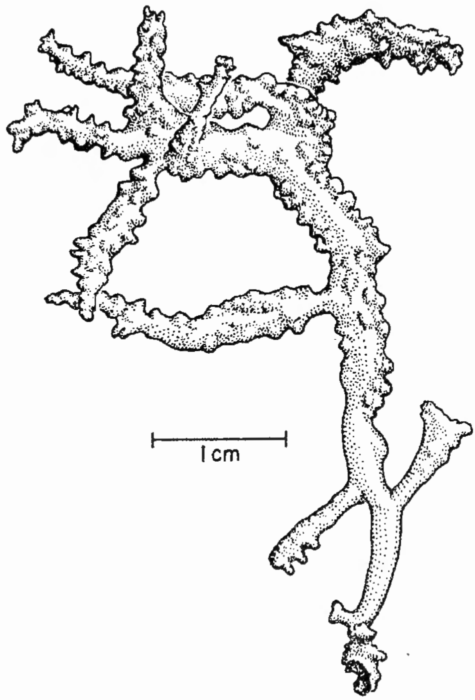


Fig. 3. A common form of *Eucheuma cottonii.* The branches are irregularly branched and their diameter or width is often irregular or flattened or sometimes conspicuously swollen above. The proliferations arise as protuberances near the branch apices and are hemispherical to cylindrical and do not appear at regularly predictable places. They may grow out as branches; often they are conspicuously marginal on flattened thalli.

applied in the Western World to a different substance from different algae.

Commercial crops of *Eucheuma* are harvested in water rarely more than a half meter deep at low tide. Some species have been found in water over 25 fathoms deep. Some, *e.g.*, *E. serra*, seem to be principally intertidal. Indeed, most of the Southeast Asian crop appears between the lowest level to which the tide descends and the level where the longest single exposure to air is not over about one hour.

Limestone-rich substrata where there is little coelenterate coral seem to favor both the sprawling *E. spinosum* and the erect *E. striatum.* The prostrate *E. "cottonii"* types are usually draped over solid limestone. However, they may be on rocks nearly buried in mud as at Tandjung Pasir Laba, Singapore. *E. arnoldii* lives in close association with finger coral which it simulates in form and color.

Among the other observed field relationships are some concerning form or occurrence. For example, at higher intertidal levels the "cottonii" types become heads or crusts with few discrete branches being apparent. These thalli may come to weigh a few kilograms. As deeper water is reached, the species tend to be more discretely branched, more slender and, *e.g.*, in the case of *E. striatum* at Quiniluban in the Northern Sulu Sea, the thalli may be (Kraft, 1969a) over a meter tall on bottoms nearly two meters lower than low tide level. In shallow water on one thallus of *E. striatum*, there may be olive green, vinaceous purple, and rather tawny branches of similar form and size all at the same time.

The wild crop of *Eucheuma* will vary around 50 to 1500 grams per square meter in areas attractive to wild crop harvesting. Of course, most of the sites visited in the tropics will have no *Eucheuma* at all. In exceptional places a large outrigger canoe has been loaded with a few hundred kilograms of *Eucheuma* in "an hour" at one place. Panagatan Cay in the Northern Sulu Sea yielded about 25 dry weight tons of *Eucheuma spinosum* from an area of much less than one square kilometer the first time it was harvested. This indicates a live weight of several kilograms per square meter in this nearly pure stand.

One learns to improve his likelihood of finding new *Eucheuma* communities. However, thus far the criteria for finding *Eucheuma* crops are largely subjective feelings developed from experience. On the other hand, in watching the bottom while being towed behind a boat (a practice referred to as "trolling for sharks"), one learns that *E. striatum* is often localized on reef areas just on the deep-water side

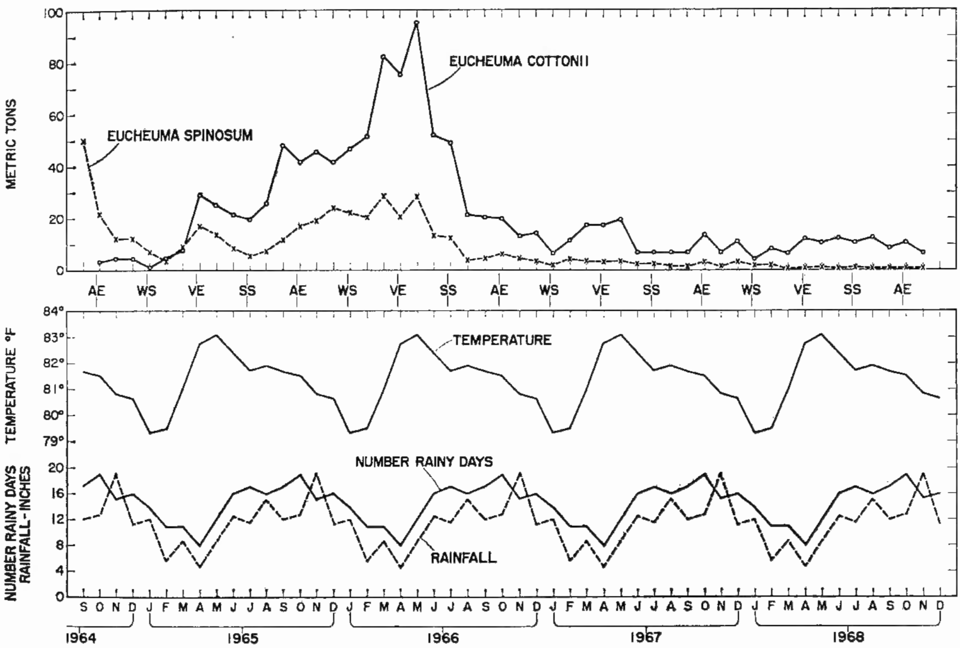


Fig. 4. The shipments of dried *Eucheuma* from one company in the Visayan area of the Philippines (upper portion) and related climatic data (lower portion). It is thought that during the 1964–1966 period these amounts were over 90 per cent of the *Eucheuma* exported from the Philippines. The values have been serially averaged in groups of three. The sun's position in reference to the winter (WS) and summer (SS) soltices and vernal (VE) and autumnal (AE) equinoxes is given between the separated crop and climatic plots.

of the reef flat coelenterate corals and in the pathways the water follows. No measurements have been made that would, *e.g.*, allow us to judge whether the causal factors here are inherent with such an area being the pathway water takes in moving onto or off of the reef. Perhaps the sharp variability in temperature with tidal change at such sites is a factor and in such habitats 24-hour temperature variations of over four degrees Celsius have been measured.

Eucheuma spinosum, on the other hand, is characteristic of habitats where there is a constant passing of water from the sea. Thus it would seem there is likely to be little daily temperature variation in its habitat. The substratum is usually rich in dead finger-corals, generally fragmented and often covered with prostrate algae. The most dense stands have been found in slight depressions in such substrata but usually not in water deeper than one meter at the time of the lowest tides.

Most *Eucheuma* species are attached by small basal discs a very few millimeters in diameter. These are nearly always torn from the substratum when the harvester picks the thallus. *Eucheuma speciosum* is unique for the genus in having a large disc-like or crustose base a few centimeters in diameter from which commonly as many as 25 to 50 erect branches arise. In this case at least the natural harvesting by storm action usually removes only the erect branches. Likewise, in the case of *Chondrus crispus* and some other commercial seaweeds, new fronds spring forth from a basal crust. In these latter cases the harvesting practices often improve the beds by destroying the weed species while the crustose bases of the commercial species such as *Chondrus* may expand so as to come to form nearly a 100 per cent cover.

Early experience with an intensification of wild crop procurement about 1966 in the Philippines indicated (Fig. 4) an area may not remain productive long without effective measures to prevent its decline. The result of such destructive harvesting of *Eucheuma* in the Ryukyus and Southeast Asia has led to reduction of the harvest at some sites below the level of profitability. Given a year or two of nonharvesting some beds have again become profitable.

Very few concessionaires or harvesters have been able to control harvesting such that their *Eucheuma* resources have continued to be profitable over the years.

Table 2. Estimated annual harvest values for Panagatan Atoll in the Northern Sulu Sea. Unseasonal weather during 1971 reduced the opportunities to harvest during that year. In 1969 planting was begun.

Year	Tons dry weight	
	Estimator A	Estimator B
1966	25	25
1967	—	35
1968	97	40
1969	111	90
1970	35	100
1971	37	47

In Malay areas anything on the reef is free to the finder. Thus introducing the logical practice of taking some and leaving some is ineffective as a conservation measure. The places with sustained yields (Table 2) over the years are those with some natural control of the harvests. One such is Panagatan, an atoll in the Philippines. At this site weather permits harvesting as a rule only during November and again in April and May. In November at this site there are a few harvesters, but the weather is too wet for drying to be feasible. In April and May and till the typhoon season, which begins in June as a rule, there may be a hundred harvesters and the weather is good for dry:ng. Though the seas are calm from January until June, the early part of this period is wet, later until November the water is too rough. Unfortunately most harvest sites are not so protected by seasonal weather.

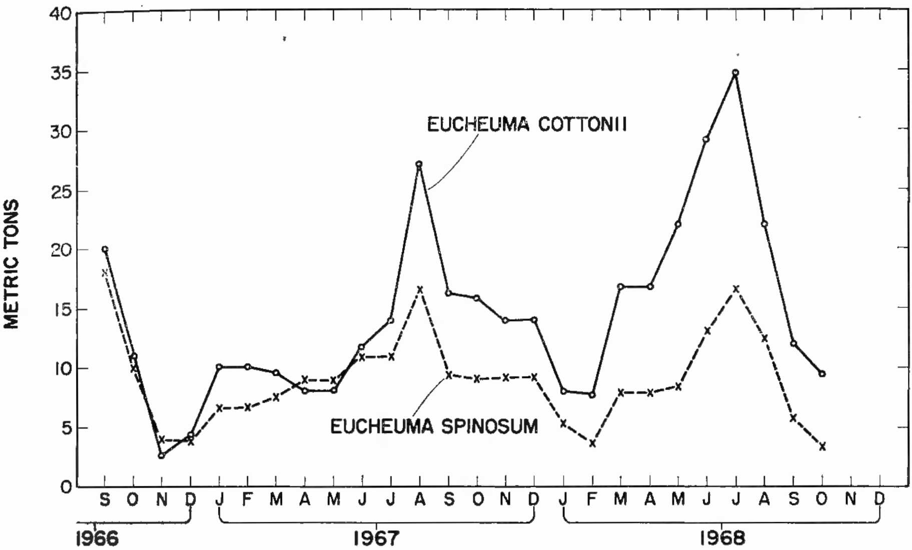


Fig. 5. The shipments of dried *Eucheuma* from one company in the Northern Philippines representing about 80 per cent of the nation's exports of this product for the period shown. The values have been serially averaged in groups of three.

The exporting of production from the harvesting of wild crops is (Fig. 5) certainly seasonal. Searches for causes of such seasonality (Figs. 4 & 5) have been fruitless when sought objectively in the field. Random sampling of 16 sites in the most southern Philippines over a period of 36 months has failed to reveal seasonality of the crop in its natural communities. No seasonal changes in growth rate were found when wild thalli were brought in at monthly intervals and reared by a uniform method at a field laboratory.

However, the reported seasonality remains to be explained. The live seaweed is presumed to be harvested at least two months before being shipped. It has been shown (Doty, 1971a) that environmental factors at least one or two months before a harvest are influential in determining the size of other tropical seaweed crops. If one studies the climatic data in Figure 4 for the Visayan and Sulu areas from which most of the Philippine crop comes, it is seen the warmest period is in April and May immediately following the clearest skies (fewest rainy days and least rain) and the brightening of the light with the higher noon sun angles of spring. This is three months before the shipping peak and could represent the time there is a maximum combination of harvesting and crop available. The minimum in crop shipped appears in the northern winter months following in the same way the minima in the same climatic events. There are other seasonal events that play a role such as rice planting and harvesting and religious periods. While unappraised, their effects would appear to have some significance.

Since a concession system exists for marine products on reef areas in the Philippines, developing farming of *Eucheuma* on concessions has seemed the efficient way to offset seasonality and the effects of harvesting. The benefits of farming would include production of a crop of predictable size; which is, within limits, at least as important as producing a less expensive crop. Research and development toward this end was thus begun as a cooperative effort between the University of Hawaii, Marine Colloids (Philippines) Inc., and the Philippine Fisheries Commission. A laboratory was provided by the Commission at Zamboanga along with several technicians. Others were employed as needed. Mr. Ernest Loveland served from 1967 to 1970 as superintendent of the operations at Zamboanga. The principal financial support initially was provided by Marine Colloids, Inc., Rockland, Maine, and later by the U. S. Sea Grant Program.

Experiments were carried out at Zamboanga using *Euchuema striatum* and *E. spinosum* to develop information of agronomic value. These involved measuring the growth rates of *Eucheuma* thalli as a function of the variation of different environmental variables. At the same time different possible physical methodologies were evaluated for possible use in farming practice.

Experiments revealed that the brighter the light the faster *Eucheuma* grows. Any desiccation appears detrimental. The variations in salinity and seasonal temperature normally anticipated in fully marine Philippine situations seem not to be of significance. *Eucheuma* survives well out of water, if kept wet, shaded and at near-sea temperatures. Thus, it can be moved from place to place. For experimental purposes five-kilogram lots have been taken to Hawaii successfully from as far south in the Philippines as the Sulu Archipelago.

The *Eucheuma* planting material, or "seed," has come to be pieces of thalli. Variously the seed has been broadcast on what appeared to be favorable bottoms, lashed to stones on the bottom, semiconfined in open baskets, tied to stakes, nets and lines at different constant distances from the bottom, or suspended a constant distance below the surface on floating systems. These last two methods are referred to, respectively, as constant-level and constant-depth plantings or farms.

Plantings on bottoms have commonly failed ultimately due to grazing, largely by sea urchins and siganid fishes. Likewise, other types of planting are often completely destroyed by grazing. In Palau this would seem to be an overriding problem. Failures otherwise have largely been due to storm damage or socio-political problems.

Successful *Eucheuma* farming has resulted from the Philippine pilot experiences. It embodies methods designed to achieve optimal longterm growth, mass production efficiencies and remain within the material as well as the manipulatory and managerial skill levels available. Through installation of a series of demonstration units in the Philippines and Micronesia, largely by Mr. Robert DeWreede, the introduction of this farming method was sought. However, it was soon realized that the socio-political characteristics of Southeast Asia and the Central Pacific would prevent rapid development of indigenous farm production. Thus, pilot farms for *Eucheuma striatum* were established on a wholly-owned basis in the Northern Sulu Sea and in the Sulu Archipelago. In the Sulu Archipelago where there are rarely storms these farms have produced well.

Growth rates of *Eucheuma*, especially on the near-surface constant-depth pilot farms, are (Doty, 1971b) usually slow the first week, then hit a maximum for two or three weeks followed by a steady decline for six to ten weeks until a plateau is reached or death overcomes the thalli. The organic nitrogen content of thalli grown just under the surface declines in a parallel fashion. The seed materials coming from natural beds on the sea bottom have developed in less bright light than that to which they are exposed just under the surface. The change in dry-weight-to-nitrogen ratio obtaining in such surface-grown thalli is perhaps similar to that leading to flowering and death of annual plants when forced by bright light. To obtain indefinite high growth rates, we assume a balance is necessary between light intensity, water quality and water motion.

In practice now, constant-level plantings are used. They are positioned just below low tide level. This level has been chosen as a compromise on light intensity and it is the level at which one often finds the highest standing crops of *Eucheuma spinosum* and *E. striatum* in nature. Experiments have shown such plantings when at least a half meter above the bottom survive the surface chop of local storms and much of the grazing that often destroys bottom plantings is avoided. In the southern Philippines the principal grazer on such off the bottom plantings is a small *Tripneustes*-like sea urchin which can be readily removed.

The constant level is attained by lashing the seed *Eucheuma* at the mesh intersections of special nets. The nets are held in place on support wires extending between braced mangrove posts. This adaptation of the common Japanese system for production of the seaweed *Porphyra* was first tried by Mr. William Anderson (Marine Colloids Inc., Rockland, Maine) in the Northern Sulu Sea. Such a support system using nylon monofilament for the nets and 14-gauge galvanized wire is expected to last up to three years with maintenance.

The nets and net support system now conform to a set of conventions developed to enable the farmer to contract or pay for their construction on a piece-work basis. Each net is constructed of nylon monofilament, 80-1b-test for the meshwork, 100-1b for the border. The meshwork used at present is square, 25 cm on a side and runs diagonally within the 2.5 by 5 meter outline. Thus, there are 127 planting sites per net. Except in dimensions and being monofilament they are not unlike those (hibi) used for cultivating *Porphyra.* In fact such hibi have been used for *Eucheuma* experimentally.

Using fist-sized 50 to 150 gram seed pieces about 10 kilos of *Eucheuma* is required to plant one net. In practice the seed is lashed to a net by tying a 1 cm by 30 cm strap of soft polyethylene tying material around it so the weed can neither fall out nor move from its position at an intersection of the monofilament meshwork. These "ties" are loose enough that there is little restriction of water movement around the seed segments. All sorts of algae grow on these ties so they are accepted as being nontoxic.

The support system now in use is developed in modules to hold 200 nets. The support wires run parallel to one another, 5 meters apart, and it is recommended they follow reef contours at right angles to tidal current flow rather than being grouped more efficiently in respect to space and material in a square 50 meters on a side. Four such 2500 square meter modules make a one-hectare farm. This size and arrangement has been developed in the light of its being of a size manageable by one enterprising farm family. It also would seem to lend itself to economical plantation management.

Table 3. Material list for a one-hectare farm and its costs at Ilin, Mindoro Occidentale, Philippines. "Fixed costs" are adjusted to a "per year" basis and are those estimated or experienced in pesos at a time when the U.S. dollar was worth 6 pesos. Maintenance is included in these figures as needed to achieve the predicted life expectancies but not that in Table 4 required to keep the farm operating.

Item	Initial cost	Depreciation	Interest	Fixed cost
Module support system	947.00	947.00	22.41	975.41
Laborers' quarters	1000.00	200.00	30.00	230.00
Farm manager's quarters	700.00	140.00	21.00	161.00
Drying house	446.50	89.30	13.40	102.00
Boat	2000.00	400.00	60.00	460.00
Net units	3664.00	916.00	109.92	1025.92
Miscellaneous equipment	271.92	195.92	8.14	204.60
Totals	9030.00	2889.00	265.00	3160.00
	($1505.00 US)			($526.00 US)

The initial costs of installing and maintaining a constant level one-hectare farm in the Northern Sulu Sea region (Table 3) have been only roughly developed thus far. The initial $1505 US cost has been calculated to be amortizable with allowances for 6 per cent interest and depreciation to $526 per year. There has been no opportunity for one person to gather all the cost figures nor has there been, as yet, an opportunity to either repeat observations at one place or determine the reliability of the estimated depreciation rates.

Table 4. The operating costs of a one-hectare farm for one year. These values are only partially as experienced at Ilin, Mindoro Occidentale, Philippines. In part they have had to be estimated from operations elewhere.

Item	Costs	Manhours
Labor:		
Selecting & obtaining seed	1574.80	[a]
Planting	1016.00	2,032
Weeding & module maintenance	6240.00	16,640
Harvesting	1900.00	760
Drying, washing & redrying	320.80	128
Packaging & baling	532.80	240
Shipping	2930.40	
Materials:		
Plastic ties (tie-ties)	1056.64	19,800
Totals	15,571.44 ($2600 US)	39,600[b]

[a] Varies wildly.
[b] Total in manhours.

The operating or variable costs per year (Table 4) run to $2600 US dollars. Such items as "seed" costs are very unpredictable and those at some sites, *e.g.*, Sibaton and Tapaan Islands, nil. Shipping costs are also extremely variable but fixed for a given location, in this case, Ilin in the Northern Sulu Sea. Labor itself is highly variable. The minimum wage by law for industrial workers is 6 pesos and for agricultural laborers 2 pesos per day in the Philippines. However, the degree to which subsistence is provided, the way time at work is calculated and local customs prevent any hard figure being obtained.

The overhead costs of $3284 (Table 5) seem excessively high. At the most

Table 5. Overhead costs for a one-hectare farm for one year. The values given were projected from the totals paid out for these items during a four-month period.

Item	Pesos
Farm manager's salary	3600.00
Farm foreman's salary	2160.00
Miscellaneous boat rentals	480.00
Plane fares, transportation	2591.88
Per diem, allowances	6900.00
Communications	1216.80
Freight, air cargo, handling charges	840.00
Representation expenses	462.00
General repairs to boat	131.00
General repairs to nipa houses	77.38
Fuel and oil for boat	1245.00
Totals	19,706.00 ($3284 US)

advanced farm, at Tapaan in the Sulu Archipelago, these costs have been far lower for several reasons. First the manager, Mr. Baltapa Anjail, served as the foreman on the job initially with little outside supervision. Secondly, the methods have been more stable during operation of this farm and less travel, per diem and communication have been needed.

Returns from the farms are as yet poorly known. They have been in operation for only about one year. Those put into operation earlier, *e.g.*, in Micronesia and, in the Philippines, at Cucarayan Inlet, Sibaton, Caluya and Punta Arena, were abandoned for one reason or another and thus not much in the way of a crop was recorded from them. Most often the crop on the abandoned modules was grazed away, stolen, lost to storms or used as seed for another type of planting elsewhere, and no final measurements of its quantity were made.

Growth rates on the farms have average 1.5 to 5.5 per cent per day. In the case of the most advanced farm at Tapaan such persisted through the first harvest period and an average of 2.3 through the second. The first partial harvest of one module at Tapaan was of some 5891 kilograms; assuming it to dry 8 to 1, this is equivalent to 736 kilograms of shipable dry weed. About 50 grams of the live weight of each thallus harvested was left as seed. Second harvests of one module produced 7921 and another 10,800 kilograms with perhaps 100 grams being left as seed in each case.

It is calculable that the first harvest of one module could have yielded between one and two tons of dry weed per hectare more had the harvesting procedure been different. The second yielded an average of about 6 tons of dry (unwashed) weed per hectare. Operating procedures have been revised to achieve, hopefully, such a harvest every two months. If six such harvests can be made per year possibly 36 tons per hectare per year will be produced. For this uniform, high class, clean *Eucheuma* a price of over $250[2] per ton F.O.B. Manila seems reasonable. On this basis, even with the excessive current overhead, or two-thirds the realized production rate, the list of costs and returns in Table 6 indicates profitability.

Table 6. Annual per hectare Ilin and Tapaan returns conservatively projected at 30 tons for one year in U.S. dollars.

Budget item	Ilin costs	Tapaan costs	Returns
Farm installation	526	1047	
Farm operation	2600	1648	
Overhead	3484	1874	
Crop Value			9000
Total	6410	4569	9000

The management plan effected appears (fide Mr. Henry Parker of Marine Colloids, Inc.) to be producing but little over 10 tons of dry weed per hectare at

[2] As much as $300 to even $400 was paid for small lots of wild harvest *Eucheuma* in the 1970–71 period.

Tapaan instead of the 30-odd tons that seem feasible. Elsewhere in the Philippines at least one private farm is producing at about the 30-ton level. The importance of continuous operation and high maintenance, as in truck gardening, would seem to be imperative and thus industry, initiative and management are critical on the part of the farm operator.

Growing *Eucheuma* would be very profitable for people who would do it with no supervision from outside. This would reduce the costs by one-half. It should be noted that the foreman's wage is also included at Tapaan but he serves as a working foreman there. Ideally the foreman would be the farmer himself, and as such his wages should perhaps not be subtracted from his profit.

From the industrialist's point of view the ability to obtain a higher quality crop that is free of foreign matter doubles the value of the weed. Likewise it is

Fig. 6. A thallus of *Eucheuma striatum* weighing over 5 kg and grown on a farm in three months from an initial "seed" size of 50 grams.

desirable that the unpredictable (Fig. 4) and seasonal (Fig. 5) variation in the crop, and the small crops of "bad years" be offset. Farming would be justified if these ends were met though the cost might not compete alone or might be the same as for wild weed.

Control of the crop will lead to improved varieties. For example, it has been observed that under farm conditions, some thalli grow twice as fast as others. According to Mr. Vicente B. Alvarez, Manager of Marine Colloids (Philippines) Inc., under farm conditions thalli have been measured (*e.g.*, Fig. 6) as growing from 50 g to near 5 kg in three months. Thus, as soon as operations become stable, the use of these as seed is expected to double the yield.

Some slower growth observed in the centers of modules may be offset by fertilizer. In fact, there is the feeling that with the right fertilizer concentrations, productivity can be enhanced by elevating the crop to brighter light conditions or, on the other hand, success can be had under conditions of lower water motion. In this latter situation there would be less maintenance to do on the supporting structures and less storm loss. Finally with complete control of growth and the growing areas, genetic improvement and capital-intensive methods can be expected to produce still more carrageenan more cheaply.

In conclusion let us consider the probable useful dry matter and monetary returns from a *Eucheuma* farm in comparison to other productivities. The 30-odd tons of dry *Eucheuma* that it seems likely we can produce per hectare per year is (Westlake, 1963) in line with other estimates of dry matter productivity in tropical shallow marine waters. Such *Eucheuma* will be worth significantly over $250 per ton. In Mauritius sugar is profitable at 3.5 tons per hectare per year. In Hawaii the mean productivity[3] during 1970 was 11.23 tons of sugar per hectare per year. After all the care and processing it takes, it is only worth[4] $187 per ton. Yet, to tropical agriculturists, sugar is considered an attractive crop. It requires good soil and must compete with many other possible uses for the land. *Eucheuma* is a crop of tropical reef flats which are of little use in today's economies, and it provides an income to a group of people not otherwise aided by the current development programs. On a given area *Eucheuma* farming can provide over three times the dollar return sugar produces.

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