1. BACKGROUND

A 1977 study by the author (Doty) had revealed promising potential fcr seaweed farming in Malaysia. Subsequently, the Middle Bank (between Kedah and Penang) was. entified as a principal source of seaweed.

Preliminary work had identified a red algal seaweed species *(Gracilaria sp.)* from the Penang area as desirable for its very clear agar. Another species, *Grad/aria cylindrica,* is also common in the Penang area. Both species occur on the calm protected inshore waters and gently sloping sea floor between Penang Island and the adjacent Middle Bank (Fig 1 .). There are about 1500 he.tares of such habitat. The,management of the wild crop and the farming of these two species app6ared feasible. They produced distinctive food grade agars with some sugar-gel reactivity. If either of the targeted species could be shown to be farmable, no greater success was desired for the year, as both produced readily marketable agars, though not of the highest quality. The attention of the Fisheries Research Institute at Glugor (GFRI) was drawn to this potential and to the expanding market for *Gracilaria* agars.

It was decided that the *Graci/aria* to be farmed should be the one that would bring maximum profit to the farmer. The species vary widely in their farmability and market value. The wholesale price of finished agars ranges from about US **$** 12.50 per kilogram for standard agar to $ 23.50 for microbiological grades and perhaps up to twice as much for the most expensive grades. The rate for seaweeds from which these are extracted runs upwards from at least US **$** 600 per tonne to perhaps $ 1600 per tonne at 18 per cent water (prices as of November 1984).

1.1 POTENTIAL CULTURE AREA

Farms are preferably situated on level ground for twO reasons. One is ease of working, which a sloped site does not offer; the other is that the environment over a level area is more likely to approach uniformity than a sloped or irregular area.

The terrain in the Penang area and the western shores of the Peninsular states of Malaysia is usually so gently sloped that it may be considered as level for our purposes. Figure 1 indicates the potential areas for *Grad/aria* farming in and around Penang Island. The Middle Bank is one such area. Since it is isolated from the island by water and not of interest to many people other than a few fishermen, this mud flat area is relatively free from site competition. All subtidal lands in Malaysia belong to the Government and while they cannot be either bought or sold, they can be obtained for farming on the same type of temporary occupation licence as that required for a kelong fish trap.

A minimum area of 1,000 hectares with farming potential may be required for an industry, but this figure will vary depending on site fertility. From hydrographic charts, aerial inspection and photographs, there seem to be at least 1485 ha of suitable area around Penang (Table 1).

The terrain in the Penang Island and Middle Bank region is characterized by very low slopes, on much of which *Gracilaria* may be grown. The values were derived from Admiralty Chart No.1366, the scale of which is 1: 60,000 (1 cm = 600 metres). The results are given in hectares.

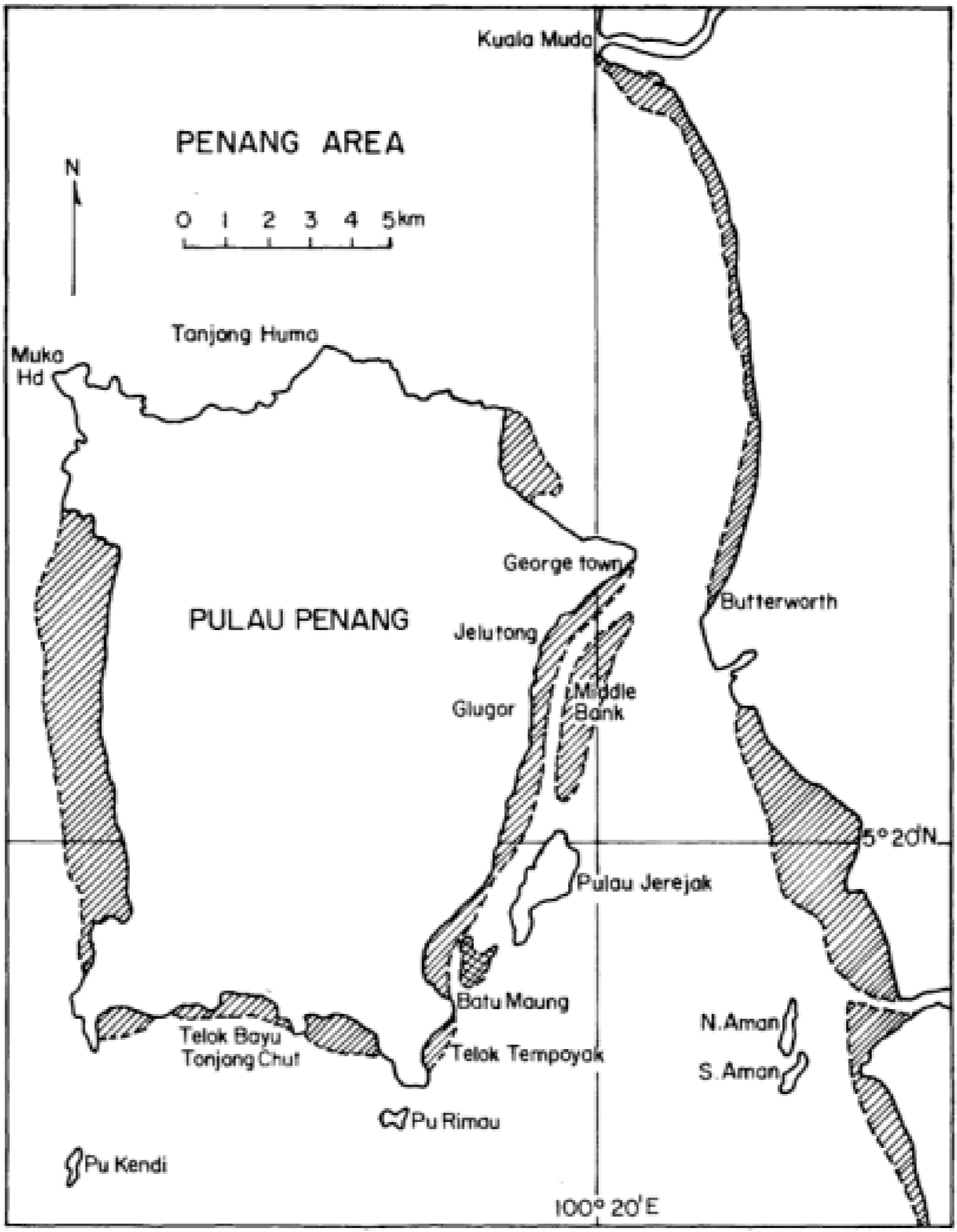


Fig. 1
Potential area, nearly 1,500 hectares, suited for mudflat Gracilaria farming around Penang island, Malaysia.

Table 1

Potential farmable area

	cm =	m =	(10000 m^2) hectares
West Penang Mud Flat (N)	10 x 1.5	6000 x 900	540
West Penang Mud Flat (S)	10 x 0.8	6000 x 480	288
GertakSunggul	2 x 0.5	1200 x 300	36
Telok Kumbar	2.5 x 0.8	1500 x 480	72
Telok Kapur	3 x 0.8	1800 x 480	86
Telok Tempoyak	3 x 0,5	1800 x 300	54
Batu Maung (N)	2 x 0.5	1200 x 300	36
Batu Maung (S)	3 x 0.8	1800 x 480	86
Tanjong Tokong (S)	3 x 1.5	1800 x 900	162
Middle Bank			125
		Total hectares	1485

There appears to be little use for these 1485 hectares of mud flats now. Most of the highly commercial cockle, *Anadara granosa* and other fin and shell fish are adjacent to the sites where the five most farmable *Gracilaria* species seem to thrive.

Although still subject to site testing, it would appear that Penang has the inshore area for a successful *Gracilaria* production industry. The outwash western shores of Peninsular Malaysia, when compared to Penang, are vastly more impressive area-wise for marine agronomy. However, they can be considered in this paper only in very preliminary way. The Kerian Bank on the shore of Perak State, (i.e. between Kuala Tangah and Tanjong Piadang), offers over 2000 hectares of potentially farmable mud rlat. Without question Malaysia has the necessary inshore area for a successful *Gradllaria* production industry or even an agar industry.

1.1.2 SITE SELECTION AND SITE CHARACTERISTICS

In Malaysia the bristle-like stipules of *Enhalus acoroides,* a sea grass, is the main substratum for *Gracilaria* aside from jetsam. In fact, the variation in the density of the wild crops of *Gracilaria* often appeared to be secondarily dependent on the density of the appropriate substratum.

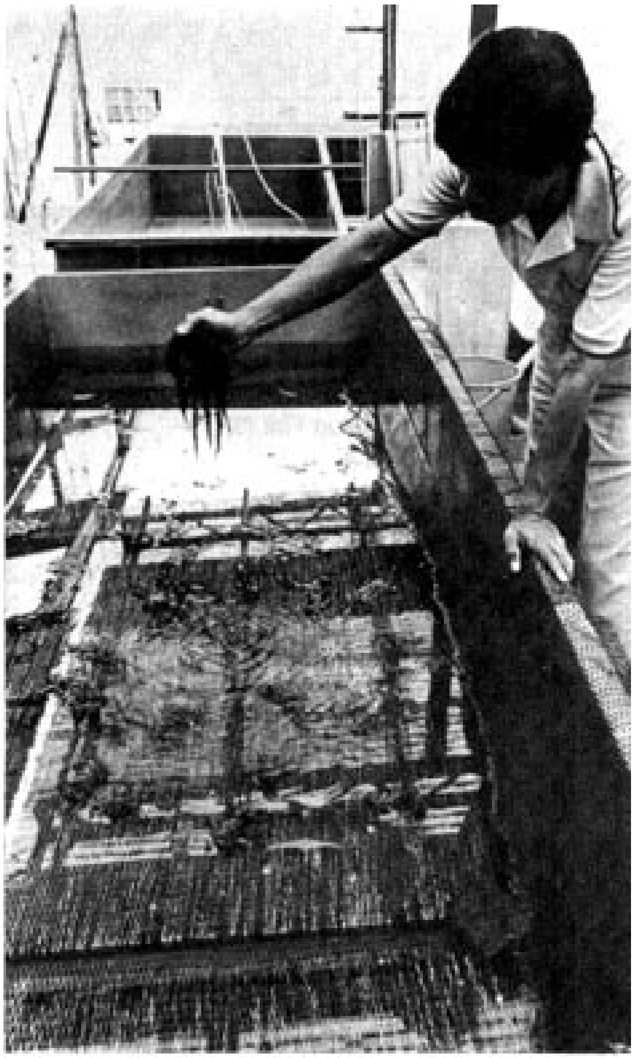
Almost any solid surface that projects at some season above bottom may ultimately have *Gracilaria* attached. However, some materials such as rubber, mangrove wood and concrete require a fairly lengthy leaching process to remove toxicity or induce other changes in their surfaces which will promote sethng of *Gracilaria,*

Two *Gracilaria* farming sites were easily accessible from Glugor. Two other sites may have yet greater potential for *Gracilaria* farming, but have not been tested, They are very large and south of Butterworth, Both these sites appear to have sizeable populations of under-employed small-scale fishermen. The four sites are described below. Of these, Middle Bank was selected as the site for the first pilot farm.

Several other site types such as ponds and rocky intertidal areas as well as other mud bottoms were considered briefly and rejected for the present and immediate future. The other areas considered and rejected were Pulau Sayak, Jelutong, Ban Merbok and Pulau Langkawi.

Middle Bank: The polluted water of the Middle Bank could be responsible for the abundance of *Gradilaria* species found there. However it is also possible that this conspicuous *Gracilaria* community was due entirely to the presence of adequate substratum materials, such as the bristle-like stipules of the common eelgrass, *Enhalus acoroides,* that is abundant there, and the jetsam accumulated at higher levels. The fertility of a site for *Gracilaria cyllndrica* in the shallow water on the Middle Bank may be due to the great opacity of the water as this species grows in much deeper water elsewhere in the world, The domestic pollution at Middle Bank may play a role as there were four

1. Rafia wound on frames ready for spore setting.



2. Spore setting. Tetraspore-bearing plants are placed on netting about 30 cm above frames.

3. Newly germinated spores.

4. Pilot farm layout at Middle Bank, Penang, Malaysia.

5. Transferring q,ore-bearing rafia to pilot farm.

6. Newly transferred rafla tied to stakes at 1-meter intervals.

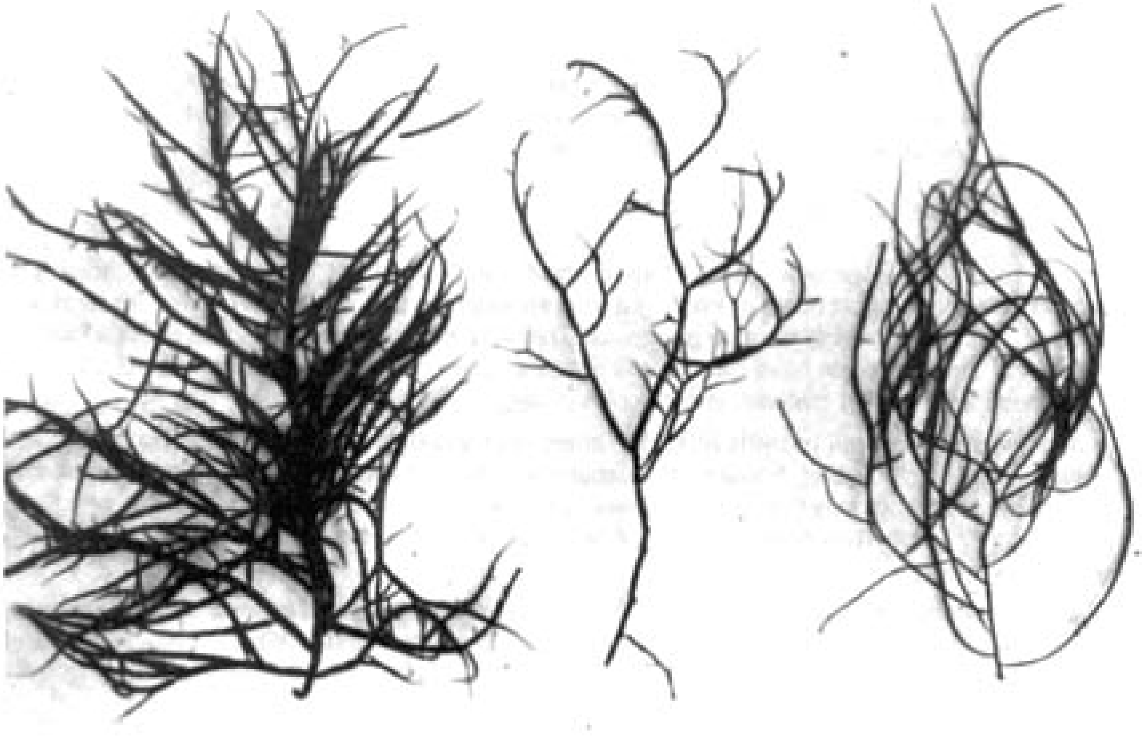
7. Maintenance work in progress.

8. Gracilaria after four months of growth.

9. Profuse growth of Gracilaria

4

10. Different forms of Gracilaria cylindrica.



species of *Gracilaria* on this site, plus one each of *Ulva* and *Hypnea.* All three genera are known to thrive in water with high nitrogen content.

1.1.3 FACTORS AFFECTING THE TARGETED SPECIES IN NATURE

To determine the nature of the aquatic elements in the environment and other factors affecting farmability, a wide variety of data was gathered. Monitoring was however cursory and dealt with the variations and qualities of the *Gracilaria* population.

Gracilaria is relatively insensitive to salinity variations of 20 to 34 per cent that occur in the Penang Straits or the site area. Some species may stand a few hours of nearly fresh water exposure such as might be found in fish ponds or in near-shore areas affected by fresh water spates during flood or storm periods.

Burial in sediment is not ordinarily disastrous for *Gracilaria* In some sites where it has a history of dominating seasonally, it is intermittently buried – at least the bases of the thalli are. Obviously burial would have to follow the arrival of the non-motile reproductory bodies which attach themselves to the bottom materials such as shell fragments or the stipules of *Enhalus.* In another project the consultants often found *Gracilaria* attached to small particles that could have been buried by the burrowing of animals or storm movement of the sediments.

The temperature records in published accounts indicate that this parameter provides no problems. However, the Ban Merbok temperatures were found to be distinctly lower than those on the mud flat near Glugor.

The fertilizing nutrients in the Penang Straits waters seem to be enough for *Gracilaria.* The uniform size and fertility as well as the dark coloured robust nature of the wild crop specimens support this hypothesis.

Secchi disk depths of 5 cm are almost a rule on Middle Bank, thus on-site work is restric d to brief periods during low tide.

The working time at sites within the elevations at which one finds wild crops of the two targeted species when the substratum or seaweed must be seen was worked out from data derived from the Malaysian Government tide tables for Penang which record levels in tenths of a metre. Over the 12-month period of 1984, the total was equivalent to 49.2 eight-hour days. This was in fragments from one to five hours long. These opportunites to work are concentrated during winter in the Northern Hemisphere. The period December through March has 50 per cent of the work opportunities and by far the greatest part of the 394 work hours for the year.

To make a living from *Gracilaria* in Malaysia, a farmer need not give up his usual occupation. Between September and April there are 34 daylight hours when the bottom substratum is exposed to air in the elevations through which the two targeted species of *Gracilaria* naturally thrive. During the rest of the year there are 45 hours (a man-week in a month) of suitably low tides. So a farmer or any member of his family can work part time.

1.1.4 SITE DESCRIPTIONS

1.1.4.1 *Telok Tempoyak* was identified as having some 50 hectares of potential farm area. It is located on the southeast coast of Penang arid is an example of a potentially rewarding farm site although it is not known to have large natural *Gracilaria* stands. However some *G.cylindrioa* as well as the "red" species have been found at this location in the past as isolated thalli attached to various forms of drift material, notably plastic bags.

Recently numerous thalli growths at Telok Tempoyak have been observed attached to *Enhalus* bristles. At this site, however, *Enhalus* grows sparsely in isolated patches. But given enough suitable substratum, it seems likely that both *Gracilaria* species would become abundant in this bay. One advantage of Telok Tempoyak is that *Ulva reticulate,* a pest at the Middle Bank, has not been seen here.

This is the second and more unlimited of the seemingly desirable sites directly attached to Penang Island itself. It can grow a lot of seaweed as it has large inter and sub-tidal areas at the right elevations. The site is regularly fished by seining or the use of 'butterfly nets" which drag over the bottoms. The short post and line method adopted for the first pilot farm effort could not be used here. The use of V- or J-rafia would allow such fishing to continue, yet possibly provide the ncreased substratum that would lead to harvestable crops. However, during the tenure of the one-year project only elementary testing and monitoring could be done

1.1.4.2 *Kuala Muda* might well be considered a typical example of the mud-outwash shores extending along most of the western coast of Peninsular Malaysia. The partly inter-tidal clean sand beach edging the shoreline rapidly deteriorates into a mud-substratum that extends at a gradual slope into deep sub-tidal water. According to marine charts, the width of this inter-to sub-tidal mud bottom varies considerably from point to point, For example, the area just north of Sungei Muda in Kedah is shown as extending from 0.3 km to nearly 1 km from the shoreline. At many places south of Butterworth the mud shallows extend beyond the 3 km width line before the bottom drops into deeper water.

The contours of these inter-tidal mud areas are influenced by the many rivers and streams that empty into the Penang Straits and must thus experience considerable fluctuations in the salinity of the water over them, depending on the extent of rainfall experienced inland. Fortunately *Gracilaria* is an algae that is known to tolerate salinity fluctuations within certain limits and farming this genus near such fresh water outlets as Kuala Muda (literally "the mouth of the Muda River") could therefore well be possible.

1.1.4.3 *Pulau Aman:* Little is known of this site other than the extended mud-bank shown on marine charts and the reported existence of thriving fish-cage culture systems there. If correct, this location could be ideal and provide the desired facilities for continued experimentation of fish-cage GOMPU design development, with the added advantage of being able to outplant material close to a fish-cage seedling production unit. This would facilitate monitoring the crop without the transportation problems encountered in work at the Jelutong fish cage for Middle Bank outplantings.

1.2 Species and their agar quality

To facilitate selection of additional species which might be profitable to farm, attempts were made to locate and consider as many as possible of the agarophytes in Penang's flora. Of the 10 species provisionally identified as belonging to *Gracilaria* only the following five deserved to be reported upon, although three of these may still suffer from doubtful identity. The five are comparatively more abundant than the others. Some may not truly belong to the genus *Gracilaria* but their classification will not matter to agar producers so long as they produce a good agar that can be cultured economically.

1.2.1 GRACILARIA CYLINDRICA

Gracilaria cylindrica is the most common species seen on Middle Bank, and at Telok Tempoyak is found attached to debris or the stipules of *Enhalus* on the mud flats. Santos and Doty (1983) provide a photograph of typical portions which show the gently falcate nature of many branches below where they may become rebranched – the often broadly blunt branches and the cylindrical, differently coloured, thread-like basal portions. While significantly distinct, it has often been confused with the much more slender species *G.blodgettii* by some taxonomists who may not have seen both entities.

A description of the agar of *G. cylindrica* grown on Middle Bank is already available (Doty, Santos and Ong, 1982) and there have been enquiries about the extent of its availability, its agarose content and clarity. As would be expected from its gel strength (Table 2), the agarose content of *G. cylindrica* is not remarkable. However, the agarose is sometimes very strong when taken from fresh samples (Table 3) but has been significantly weaker when isolated from older samples.

Table 2

Examples of the qualities of the Agars extracted from two of the *Gracilaria* species common in Penang area

(CAW = Clean anhydrous weed; CAY = Clean anhydrous yield;
MT. = Melting temperature; G.T. = Gelling temperature)

Gracilaria spp Sample No.s & date collected	PH of extrac-tion	Agar yield %CAW	Agar yield %CAY	1.5% gel strength g/cm²	MT. (°C)	G.T (°C)
G. cylindrica						
28421	8.0		39.71	32	85.6	29.5
(unlimed)	12.0		31.56	547	87.5	34.5
5. V. 77	13.0		31.97	605	86.5	34.2
28422	8.0		42.86	236	85.5	29.5
(limed)	12.0		29.27	779	88.5	36.0
	13.0		30.77	905	88.5	35.5
G. "red" spp						
31624	12.0	49.80	29.60	63	79.0	38.0
28. VI. 76	13.0	49.80	31.33	42	78.5	39.3
26631						
(unlimed)	12.0	60.00	34.72	97	80.0	39.2
29. X. 76	13.0	60.00	35.18	93	80.0	37.5
26632						
(limed)	12.0	58.25	31.24	93	80.5	39.2
29. X. 76	13.0	56.60	34.50	105	80.0	37.8
26635						
(unlimed)	12.0	43.55	26.29	108	79.0	37.5
24. XII. 76	13.0	43.55	28.70	126	78.0	37.5
26636						
(limed)	12.0	40.18	31.86	99	80.0	37.6
24. XII. 76	13.0	38.65	29.95	116	77.0	37.5

Table 3

Properties of agarose from Malaysian *Gracilaria cylindrica*
All the seaweed samples were treated with alkali to pl-1l3

(CAY = Clean anhydrous yield; G.S. = Gel strength; MT. = Melting temperature;
G.T. = Gelling teplperature; AG = Anhydrogalactose)

Sample	CAY % in relation to seaweed	G.S. 1.5% gel 9/cm2	MT. 1.5% soln	G.T. 1.5% gel	Ester Sulp-hate %	3, 6-AG %
28421						
(unlimed) from agar	13.90d	1220*	92.0	36.0	0.35	48.13
28422						
(limed) from agar	10.38	1220*	92.0	35.0	0.45	48.35
28422						
(limed) from seaweed	16.33	1220*	91.0	35.5	0.255	48.49

* No higher measurement could be made with the marine colloids gel tester and its 1 cm2 plunger with the particular scales being used.

In the absence of sizeable samples, the market advantages of its unusual clarity or agarose could not be explored. However, selling *G. cylindrica* on the expanding food grade market may not be a problem.

1.2.2 GRACILARIA TEXTORII

Often called the flat species, *G. textorii (Fig 1)* is found only at the Middle Bank. growing on debris at the deepest inter-tidal levels and seems to be farmable. It has been found naturally established on some of the farm lines reported upon below. Under natural conditions it grows on muddy shores at slightly lower levels than do the two species which were eventually selected for farming in this project. Its farming can be an additional crop for deeper areas adjacent to, or intermingled with, those on which the other two are being farmed.

The gel characteristics, the nature of the male structures and the general morphology of this species led the consultants to conclude that this species. classically treated as a member of the genus *Gracilaria,* should be classified otherwise.

The peculiar nature of the *G. textorii* gel and the lack of sample size have made satisfactory chemical analytic work impossible during the project year.

1.2.3 GRACILARIA ("SLENDER SPECIES")

This is the "slender" *Gracilaria* species of earlier reports. It is found on the deepest inter-tidal and possibly sub-tidal mud flat debris. The bases of the few examples collected were buried in a few centimetres of mud. Only known from the Middle Bank, this "slender species" grows at the same low inter-tidal or highest sub-tidal elevations as G *textorli* or lower than it. It was discovered too late in the year and in quantities too small for any study to be done. The form is that of some depauperate specimens seen that were named G *lemaniformis* but when alive the fronds were weak and not elastic. But this does not indicate that its agar is not desirable. There is a possibility that this species could be a slender form of G *cylindrica* arising in low light conditions from vegetative reproduction by the propagule-like branches of the G *cylindrica* thalli growing at higher elevations and higher light conditions nearby.

1.2.4 GRACILARIA ('RED SPECIES')

This is one of the two most common species of *Gracilaria* found on the intertidal mudflats at Middle Bank, Telok Tempoyak, Batu Maung and on the inter-tidal rocks at Tanjong Chut as well as Pulau Jerejak. It is predominant on fish cage rafts at Jelutong.

The cavities in which the male structures are born are compounds which, among other things, led Chang and Xia (1976) to establish the genus *Polycavernosa.* While this species is well illustrated by Chang and Xia's figures of *P. fastigiata,* the Penang material is often larger, especially on Middle Bank, and may represent a similar, but yet formally undescribed species. Since it is suspected that the differences may be environmentally induced, these forms are being taken as representing a single specific entity rather than as several genetically and taxonornically discrete specific entities.

The "red" *Gracilaria* species has been investigated only superficially with respect to the chemistry of its agar. The agar has some sugar reactivity (Table 4), though not outstanding. In the case of one sample, a 1 per cent solution was very viscous with or without any other combination of sugar and lime. As the concentration of sugar was increased the gel became clearer and, while whitish at low sugar concentrations, it became noticeably yellow, indicating a reaction between the sugar and the agar.

In the case of a limed sample, when 250 gms of sugar was used the gel was even more viscous than an unlimed sample. Otherwise it is a good food-grade agar and while this is a readily marketable grade, food-grade agar is not in great demand and therefore fetches relatively low prices.

Table 4

Sugar reactivity of agar from the Penang "red" *Gracilaria* as determined from extracts of limed and non-limed seaweed samples

Sample number	Per cent sugar in 1.0% agar					
	0	10	20	30	50	75
32255						
(unlimed) G.S. g/cm²						
Top gel	42	76	131	154	265	444
Bottom gel	25	42	72	97	168	328
32267						
(limed) G.S g/cm²						
Top gel	67	107	65	106	171	227
Bottom gel	37	82	44	102	143	137

1.2.5 GRACILARIA ("TENDRILLED SPECIES")

This is a "tendrilled" species It grows on a wide variety of substrata such as debris on the mud flats, on granite boulders or attached to other biological living materials such as large animals. This species has some of the characteristics of a *Sebdenia* but if its gel is determined as a desirable agar, it is possibly farmable. The nature of its agar is not known.

1.3 Farmability of Penang "Gracilaria" species

Data on the handling weights of four of the above five species after different types of processing are given in the hope that future gel analysis will show the extent of the profitability of their farming (Table 5). It is suggested that the nature of the gels of all the potentially farmable Penang species be obtained along with the developing of pre-export treatments that will bring out their most desirable market qualities.

The wild crops of the two most abundant species of *Gracilaria* were sampled to get a preliminary estimate of their standing crops and predict their potential production. These two were *Gracilaria cylindrica* and *G.* (Polycavernosa) *fastigiata.* The identity of the latter is provisional and hence in this text it is often referred to as the "red" species, since under some conditions it dries red whereas *G. cylindrica* dries black. The wild crop density of these species is unknown.

Regarding the mass of the two *Gracilaria* species, 20 mature wild crop thalli of the coarser, 6. *cylindrica* had a mean wet weight of 59.7 g (rounded to 60 g). The same number of the more slender *Gracilaria* sp. (the "red" species) had a mean live weight of 40.6 g.

Preliminary calculations of possible harvests were made using the above mean thallus weights, the general growth rate figure of 3.5 per cent a day and line spacings (planting densities) equal to or lower than 150 juvenile thalli per metre which is considered as sparse growth on lines. Using such values, one metre of line was shown to have potential for producing at least 10 kg of live *Gracilaria* per crop. This would provide about 1 kg of dry *Gracilaria* for first sale. This result encouraged continuation of the work on these two species, though only one sampling of the thalli had been drawn for each species.

While not yet established, it is understood that one might expect a major difference between the gel qualities of farmed and wild crop. Pond farmed *Gracilaria* usually has less gel strength. A significant amount of the research carried on in Taiwan has been towards selecting wild strains which, when grown in fish ponds, produces gels with suitably high gel strengths. The present project could not go this far in respect to either the Ban Merbok ponds (BOBP/REP/20) or the open mud flats.

Earlier exploratory visits on a different FAO project relating to farming a seaweed of a different kind first revealed the significant population of the *Gracilaria* species on Middle Bank. It was easily accessible and free of adverse site competition. Middle Bank also had sufficient area, low slope, water quality and currents favourable to *Gracilaria* growth. Thus in the end, *Gracilaria cylindrica* and "red" *Gracilaria* were targeted for the preliminary work that could be done in one year. The farmability of other species should also be tested. The results of such work could then be used as a guide to selecting those species for farming which produce the scarcest and the highest priced gels.

Table 5

Wild harvest handling weights of *Gracilaria* species from the Middle Bank, Penang.

Handling process and terms	*G. cyl* No. 1155(a)	*G "red"* No. 1155(b)	*G. text* No. 1183	*G. "slender"* No. 1193
Total live wt. 20 thalli (g)	1194.30	812.10	–	–
Mean live wt. (g)	59.70	40.60	–	–
Limed wet wt. (g) (Includes the lime)	621.00	383.00	870.00	510.00
Limed dry wt. (g)	51 .85	36.40	86.64	59.68
Limed dry/wet wt. (%)	8.35	9.50	9.96	11.70
Limed oven dry wt. (g)	45.92	30.46	69.32	–
Limed dry/oven dry (%)	11.44	16.04	20.00	–
No-lime wet wt. (g)	621.00	383.00	820.00	500.00
No-lime dry wt. (g)	57.51	36.93	70.10	47.82
No-lime dry/wet wt. (%)	9.26	9.64	8.55	9.56
No-lime oven dry wt. (g)	53.70	34.52	60.87	–
No-lime oven dry wt. (%)	6.62	6.52	13.17	–
Males	4	4		
Females	8	20		
Tetrasporic	21	12		

1.4 Production technologies

The selection of methods was aimed principally at evolving an industry that will provide small-scale inshore fishermen with an alternative or supplementary means of employment. At the same time alternative approaches that would preserve both environmental quality and traditional fisheries were also kept in mind.

A number of approaches to farming methods for *Gracilaria* in Malaysia were considered and discarded. For example, vegetative transplants, used successfully in respect of larger seaweeds like *Macryocystis* and *Eucheuma* and even *Gracilaria* itself. Another approach was tried with *Eucheuma;* tying loose thalli to lines and allowing them to grow. The local *Gracilaria* species appeared to be too small and fragile to be successfully cultured in this manner. The plan finally adopted and described below has two phases – hatchery/nursery and outplanting/rearing.

In nature *Gracilaria* reproduces by spores that are either diploid or haploid. While in some species vegatative reproduction does take place and it is usually easy to get cuttings to grow, this can be successful commercially only where herbivores are controllable and there is little water motion. This is the method usually used in Taiwan for pond production of *Gracilaria* In the Taiwanese method there is no hatchery stage. A different method is used historically in Japan for a wide variety of seaweeds. Basically spores of the seaweeds are held on nets or twine in a hatchery and then the sporelings are outplanted on the nets, lines or other materials for growth to harvest size. This method has not been used for *Grad/aria* other than in Hawaii for plantings to restore wild crop production.

The nursery or hatchery stage is preferred where there is water movement which will carry the spores or vegetative cuttings out of the farm area, or where there are herbivores that would consume too many of the young *Gracilaria* thalli before they reach harvestability. It was chosen in the present case and the host agency's experimental tanks were used. The approach used was to set viable spores of the *Gracilaria* on materials upon which they would grow to maturity and then outplant them to farm sites where they could be protected and nurtured further until they grew to harvestable size.

2.0 METHODS AND MATERIALS

2.1 Spore Collection. Simple routines, materials and methods were developed for *Gracilaria* Outplanting Material Production Units (GOMPU). To date all three major types of GOMPU – hatchery type, fish-cage type and field type – have been used. They differ largely in the way the lines are exposed to the spore sources. The first two were remote from the farm area, while the last was a part of the farm itself.

Each GOMPU type has its advantages and disadvantages, but the advantages of special nurturing of the most juvenile stages for *Gracilaria* outplanting material far outweigh the disadvantages. A major advantage of the remote hatchery and fish-cage GOMPU is that work can be done with them during high tide periods when on-site farming routines are severely limited or completely prevented by the very high water turbidity along Western Malaysian shores.

Otherwise, there are three main advantages of the hatching and fish-cage GOMPU5:

a) greatly improved spore survival
b) relatively uniform spore setting
c) control over what species or variety is planted in the production system.

Obtaining very high spore densities means there will be far more juvenile thalli on a given length of line than can survive as adults. When outplanted it is believed higher densities enhance the natural selection of genera suited to the outplanting site and thus give the farmer a better crop. One can expect to count 150 juvenile thalli surviving beyond the two and a half centimetre height stage on each metre of heavily spore-set rafia.

Central to standardization of the remote GOMPU operations was the use of synthetic rafia, wound the short way around 60 cm x 90 cm frames with approximately 1 cm spacing between lines to permit spores to settle on them on the underside of the frame during the spore settlement process (Fig. 2). Each frame holds about 100 metres of rafia. The frames are made of about 2.5 x 5 cm wood slats or 19 mm polyvinyl chloride pipes. The latter have holes drilled in them to admit water so that they do not float.

Experimentation in spore settlement was sought on a variety of locally available materials which might, with adaptation, be inexpensive or of no cost to the farmers. Experiments included spore settlement on *Anadara* (cockle) shells, rubber discs or squares cut from discarded tyres, rubber strips from old inner tubes, coconut shells and husks, *Nipa* fronds, mangrove branches or twigs, and plastic strips.

For the pilot phase of this project, the most useful data for comparing spore setting techniques were counts of the number of thalli attached to given lengths of the experimental and control sets of lines. These counts when obtained at intervals for the same planting were taken as measures of survival. Such comparisons of larger *Gracilaria* thalli made on the basis of differences in length at successive measurement periods were termed as "growth" or similarly on the basis of "weight change" as "production". Production in terms of mass per unit of time was the measure of "productivity". Counting can be conducted while the thalli are microscopic, long before they can be weighed without fear of damage. When the thalli are visible to the naked eye or large enough to be harvestable, it is impractical to count them or use length; so weight is used. Section 3 describes comparative results of the three spore collections method. In appraising the pilot farm results, only weights per unit of line or block (Table 10) were used.