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REPORT ON THE TRAINING COURSE ON SEAWEED FARMING

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United Nations Development Programme
Executing Agency
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PART I SUMMARY REPORT

REPORT OF THE TRAINING COURSE ON SEAWEED FARMING

1. BACKGROUND AND PURPOSE

The importance of seaweeds as a marine resource has recently been emphasized due to the increasing demand for them as food and raw materials in the manufacture of industrial colloids, e.g., agars, carrageenan and alginates which find varied uses in industries. In addition, the production of seaweeds through culture is now recognized as a very productive alternative source of livelihood and employment especially in developing countries in tropical Asia where a large portion of the shallow coastal fishery resources have been or are being depleted. With some exception, the present seaweed production in the tropics comes from the harvesting of wild stocks which if not regulated can result to the depletion of these stocks. Thus, it is necessary that culture and/or management of local stocks should be developed for the economic species to enhance and maintain their productivity.

The farming and gathering of economic species of seaweeds are labour-intensive form of activities which can help increase employment opportunities among the coastal communities and thus play an important role in enhancing their socio-economic conditions. The general ecology and productivity of shallow subtidal areas have been shown to greatly improve upon the introduction of seaweed farming. Additionally, the introduction of a management scheme for the gathering of local stocks shall also help conserve them.

The training of fishery extension workers, farm managers and future seaweed farmers in the practical methods of culturing economic species on *Eucheuma, Gracilaria* and *Caulerpa,* will promote further expansion of seaweed farming; on the inventory and assessment of local stocks of useful seaweeds shall promote and enhance the productivity and conservation of these species. It is for these reasons that this regional training was organized and implemented.

This training course was designed to develop and promote qualified expertise in seaweed farming to help in food production, provide cash crops and open new alternative employment to enhance the socio-economic welfare of coastal communities as well as offer practical training on seaweed farming and management of natural stocks of economically important seaweed species; improve technical knowledge about seaweeds and acquire practical skills in seaweed farming techniques, processing and marketing.

The course consisted of lectures and field training on the culture of *Eucheuma, Caulerpa* and *Gracilaria,* assessment and rational utilization of natural stocks of economic species such as *Sargassum,* post-harvest and quality control of the produce and field study visits to existing farms. Basic lectures on the biology and* ecology of seaweeds as well as methods on the identification and preparation of seaweed materials for research were also included as background information.

2. SPONSORS

The training course was sponsored jointly by the ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project (RAS/84/016) and the Regional Seafarming Development and Demonstration Project (RAS/86/024). The Bureau of Fisheries and Aquatic Resources (BFAR), Department of Agriculture and the Marine Science Institute (MSI), College of Science, University of the Philippines at Quezon City were joint hosts to the training course.

3. PLACE AND DURATION OF THE TRAINING

The training was implemented from May 2–21, 1988, All lectures and laboratory activities were conducted at the Marine Science Institute at Diliman campus of the University of the Philippines at Quezon City. Additional field practice were conducted at the Bolinao Marine Laboratory at Bolinao, Pangasinan, Luzon and at the farm of Marine Colloids (Philippines) Inc. at Danajon Reef, Northern Bohol. Additional field visits were made at the *Caulerpa* farm of Mr. Berame at Calawisan, Mactan Island, Cebu and the processing plant of Marine Colloids (Phils.) Inc. at Mandaue, Cebu.

4. PARTICIPATION

A total of 18 trainees from seven countries attended the course. Thirteen out of the 18 participants were from the ASEAN countries; Indonesia, Malaysia, Philippines and Thailand while three were from the Peoples' Republic of China, one from India and two from South Korea. Of the 18, twelve were supported by RAS/84/016 and the rest by the RAS/86/024.

The names, designations and addresses of the participants are listed in Annex 1.

5. PROGRAMME

The training programme consisted of lectures on the various aspects of seaweeds as a resource and methods of cultivation of economic species, field and laboratory demonstrations, field hands-on practice, and visits to existing farms and processing plant.

The list of the lectures/lecturers, practical exercises and details of the schedule of activities are found in Annex 2.

6. IMPLEMENTATION OF THE TRAINING COURSE

The training course was designed, planned and implemented by the Technical Director, Training Coordinator and the Training Staff. The Technical Coordinator was assisted by a number of technical staff and assistants. A complete list of the training staff, their designations and addresses are found in Annex 3.

The opening ceremony was brief. The Technical Director officially opened and gave the overview of the training course. Dr. E.D. Gomez, Director, Marine Science Institute gave a brief opening remarks (Annex 4); Mrs. M.N. Delmendo, Project Coordinator presented the participants; Mr. J.R. Montemayor, Assistant Director, Bureau of Fisheries and Aquatic Resources introduced the guest speaker and Mr. Tengku Ubaidillah, FAO Representative in the Philip-pines gave the keynote address. His opening address is in Annex 5.

6.1 Lectures and practical exercises

Basic lectures on the identification, biology, ecology and economic importance of sea-weeds were made as primary requirement in the training to provide the participants with adequate, background and baseline information, with the intention of bringing to a certain common level such knowledge among the participants because of their highly varied background on the subject. The participants were made to understand the different kinds and importance of sea-weeds (Lecture 4) as a resource; they were also taught how to recognize them (Lectures 5 and 13). In order to enhance the learning capability of the participants on the subject they were asked to familiarize themselves with the different representatives of sea-weeds (Practicum 1) as well as identify the seaweed specimens utilizing the keys and references (Practicum 2 and 3). The effects of the physico-chemical factors on the structure and distribution of seaweed communities was also discussed (Lecture 3) to enhance the perception and understanding of the participants on the ecology of the seaweeds.

Because the ultimate goal of the training was to produce and encourage expertise to go into resource development work on seaweeds, the environmental aspects of such development (Lecture 1) and the evaluation of the status of the resource and the potential areas for development (Lecture 2) were also emphasized in the lectures. In addition, they were also exposed and trained (Lecture 6 and Practicum 7) in the scientific method of sampling and assessment of natural stocks of economic species (Lecture 6), a basic requirement in natural stock management for conservation purposes.

The major coverage of the course dealt primarily with the potential target species for seaweed farming development (Lecture 7), the production of seaweeds through culture and gathering of natural crops (Lecture 8), the post-harvest practices and processing of seaweed products (Lecture 9), problems related to seaweed production (Lecture 10), the *Eucheuma* industry (Lecture 12), and the potentials of polyculture of seaweed with marine animals (Lecture 11). In order to develop and/or enhance the skills of the participants in the farming of seaweeds, hands-on field training in and/or study visits in operational farms of *Eucheuma* and *Caulerpa* (Practicum 4 and 5) and field demonstration on the field culture of *Gracilaria* (Practicum 6) were undertaken. The participants also made study visit to the processing plant for carrageenan (Field Visit 1) to observe the post-harvest handling and processing of *Eucheuma.* The discussion of farming of economic species such as *Eucheuma, Gracilaria* and *Caulerpa* dealt mainly on the selection of sites, methods of culture, management and problems associated with production. The list of lectures and practical exercises are found in Annex 2.

6.2 Field trips

A total of 11 days were spent on field trips to Cebu, Bohol and Bolinao, Pangasinan in which all the participants were required to attend. The first leg of the trip was a visit to Marine Colloids (Philippines) Inc. (MCPI) where the participants listened to the lecture on post-harvest preparation and processing of *Eucheuma* and an observation tour of the processing plant MCPI in Mandaue, Cebu. This was followed by the field trip to Danajon Reef, Northern Bohol where the *Eucheuma* farm of MCPI is located. The participants listened to a review lecture on the various stages in the farming of *Eucheuma* such as site selection, building of the farm, preparation of seedlings and planting, maintenance of the farm, and harvesting and drying. This was followed by hands-on practicum on these various activities. The rest of the time was spent in visits and hands-on training in different farms within the area.

The third field trip was conducted at Bolinao, Pangasinan. Field activities consisted of hands-on exercises on the field culture of *Gracilaria* and *Caulerpa* and the field exercise in the inventory and stock assessment of natural stocks of seaweeds. These activities were done on the reef fronting the Bolinao Marine Laboratory of the Marine Science Institute, University of the Philippines. Exercises on the collection and preparation of herbarium materials of seaweeds for research was also done utilizing the facilities in the laboratory. The list of practical exercises and schedule of field trips and major activities is in Annex 2.

6.3 Country/institution report

The participants of each participating country were required to submit and deliver a country experience report on seaweed resource development. The reports were delivered during two special evening sessions. The purpose of the country reports was to share with the other participants information on the seaweed farming and relevant activities from each of the participating countries. The country reports are included here as Part III of the report.

6.4 Discussions

A period of discussion was programmed after each lecture. The participants were encouraged to ask questions or clarifications on certain points of interest, comments and additional information on the topic in relation to their own country experience. The question and answer and discussion sessions were also done during the country/institution reports session.

A brief discussion or review of the methodologies and their significance and relevance to practical exercises were made prior to the actual field hands-on activities. During such review or discussion, the participants were made aware of the importance of these activities to seaweed production, management and conservation.

7. EVALUATION OF THE TRAINING COURSE

The evaluation of the training course was made during the last day of the training period. The participants were supplied with evaluation questionnaires for them to record their perceptions and opinions on both the technical and non-technical aspects of the training course. Some participants did not fully answer the questions. The results of the evaluation were pooled and are included in this report as Annex 6.

Examination of the evaluation results showed that as a whole the primary objectives of the training course have been achieved. A more detailed examination of the sectoral components of the evaluation results revealed some interesting insights on the conduct and the technical level of the training, the differences in the professional background, the individual idiosyncracies, and ability of the participants to communicate or understand English as the medium of instruction.

The large spread in the number of respondents to some questions relating to the technical level of training reflects the highly mixed representation among the participants.

8. CLOSING CEREMONY

The closing of the training course took place on May 20, 1988. Mr. Justo R. Monte-mayor, Assistant Director, BFAR delivered the closing remarks (Annex 7) while Dr. G.C. Trono, Jr., Technical Director delivered the closing statement on the training course (Annex 8). The graduates from the ASEAN and Non-ASEAN countries were presented by Mr. J.R. Montemayor. This was followed by the awarding of certificates. Mrs. M.N. Delmendo, Project Coordinator introduced the guest speaker, Dr. Herminio R. Rabanal, who delivered the keynote address (Annex 9). A representative of the participants gave a response to the training programme and impressions in the conduct of the course (Annex 10).

PART II
LECTURE AND PRACTICAL EXERCISES

Lecture 1
COASTAL RESOURCES OF ASIA-PACIFIC: ENVIRONMENTAL ASPECTS[1]

by
Edgardo D. Gomez[2]

ABSTRACT

This lecture was delivered orally. No hand-out was distributed.

As the most productive zone of the ocean, the coastal zone has been exploited heavily in the Asia-Pacific region. Being the closest to land and, therefore, the most accessible to man, the coastal zone and its resources are also the most vulnerable to pollution and other influences that result in the degradation of the coastal environment.

Recent studies in Southeast Asia have indicated same trends. The destruction of naturally productive ecosystems such as coral reefs and mangrove swamps continues as a serious concern. The disposal of wastes, particularly sewage, is a growing problem near many population centers, sometimes correlated with negative public health effects. While various pollutants such as oil and heavy metals are evident in some localized areas such as industrial centers, chlorinated hydrocarbons are more widespread and need to be monitored.

As a whole the region shows a growing awareness of marine environmental problems and some measures are being undertaken to address the concerns.

The environmental aspects dealing with contamination of marine environments and problems related to the development of the seaweed industry were discussed in general. Marine water pollution and levels of contamination in seaweeds were also discussed. Areas of research and development programmes towards appropriate management of the coastal resources in this region were given.

[1] The paper is not available; for inquires write to the author,

[2] Professor and Director, Marine Science Institute, College of Science, University of the Philippines Diliman, Quezon City, Philippines.

Lecture 2
STATUS OF SEAWEED PRODUCTION AND UTILIZATION IN ASIA

by

Gavino C. Trono, Jr.[1]

1. INTRODUCTION

Due to the archipelagic nature of many Asian countries, it is inevitable that a significant portion of the population is located along the coastal areas. The lives of the people in these areas are therefore, intimately associated with the sea and its resources. Due to their distance from urban and industrial centers, the people in the farflung coastal areas are not benefited by modern development.

Coastal areas in many Asian countries are characterized by well-developed coral reef which originally support rich fishery resources. The rapid increase in population and its concomitant increasing demands for fishery products, however, are exerting a tremendous pressure on the productivity of these resources. As a result, many of the coastal areas are at present experiencing the ill effects of overexploitation. Alternative sources of food and livelihood for the coastal inhabitants are therefore necessary.

With a few exceptions, the seaweeds are among the coastal resources which have not been developed in many countries in Asia. Many species of seaweeds with high economic value are found in the shallow reefs and bays. The principal genera of seaweeds presently being utilized in Asia are listed in Table 1. The production of seaweeds offer a good alternative as source of food and cash income for the coastal inhabitants.

[1] Professor, Marine Science Institute, College of Science, University of the Philippines, Diliman Quezon City, Philippines and Training Director, Seaweed Farming Training Course, 2–21 May 1988.

Table 1. Principal seaweed genera of economic potentials in developing countries in Asia

Country	General	Uses	Status of production
1. Philippines	*Caulerpa*	food	pond culture, wild crops
	Codium	food	wild crops
	Sargassum	alginate	wild crops
	Porphyra	food	wild crops
	Gelidiella	agar	wild crops
	Gracilaria	agar, food	wild crops
	Eucheuma	carrageenan, food	mariculture
	Hypnea	food	wild crops
2. Indonesia	*Gracilaria*	agar, food	wild crops
	Eucheuma	carrageenan	wild crops mariculture
	Gelidiella	agar, food	wild crops
	Hypnea	carrageenan, food	wild crops
	Caulerpa	food	wild crops
	Acanthophora	food	wild crops
3. Singapore	*Eucheuma*	carrageenan	wild crops
	Gracilaria	agar	wild crops
	Sargassum	alginate	wild crops
4. Brunei	*Gracilaria*	agar	wild crops
5. East Malaysia	*Porphyra*	food	wild crops
	Sargassum	alginate	wild crops
	Eucheuma	carrageenan	wild crops
	Caulerpa	food	wild crops
	Gracilaria	agar	wild crops
6. West Malaysia	*Gracilaria*	agar	wild crops
7. Thailand	*Gracilaria*	agar	wild crops
	Porphyra	food	wild crops
8. Vietnam	*Gracilaria*	agar	wild crops
	Sargassum	alginate	wild crops
9. Hong Kong	*Sargassum*	alginate	wild crops
	Porphyra	food	wild crops
10. Taiwan	*Gracilaria*	agar	pond culture
	Porphyra	food	mariculture
11. Sri Lanka	*Gracilaria*	agar	wild crops
	Porphyra	food	wild crops
12. India	*Gracilaria*	agar	wild crops, mariculture
	Gelidiella	agar	wild crops
	Sargassum	alginate	wild crops
	Hypnea	carrageenan	wild crops
13. Burma	*Gracilaria*	agar	wild crops
	Gelidium	agar	wild crops
	Sargassum	alginate	wild crops
14. Pakistan	*Gracilaria*	agar	wild crops
	Gelidium	agar	wild crops
	Hypnea	carrageenan	wild crops
	Porphyra	food	wild crops

2. WORLD SEAWEED PRODUCTION

Although there are no accurate data on the world production of seaweeds yet it is apparent that total world seaweed production is sizeable and will continue to increase in the future due to the expanding uses of seaweeds and seaweed products. Naylor (1976) estimated that approximately 1170 000 MT were produced in 1960 (Table 2). Production increased to approximately 2 400 000 MT in 1973 valued at US$765 million. The bulk of production was contributed by Japan, China, Korea, USA, Brazil, Norway and other countries in Europe. Except for the above mentioned countries in Asia, very little was contributed by the developing countries in Southeast Asia. India has been producing small quantity of seaweeds since 1960. Indonesia started producing in 1968 up to about the early part of 1970's to the present. The Philippines contributed very little from 1960 to about 1973 but her production significantly increased in 1974 up to the present. Thailand recorded very small production from 1967 to 1972 while Malaysia and South Vietnam did not produce any from 1960 to 1973.

Table 2. World production of seaweeds (1960 and 1973) and estimated value (1973)

Country	Production '000 tons wet weight		Estimated value[1] at first-hand sale US$ million
	1960	1973	1973
Japan	387	645	563.0
China	(250)	(700)	130.0
Korea, Rep. of	30	224	45.0
U.S.A.	(91)	(126)	1.9
Brazil	(1)	(103)	2.0
U.S.S.R.	(55)	(100)	5.8
Ireland	(69)	(44)	1.3
Norway	70	75	0.9
France	46	60	1.2
Spain	16	47	3.4
Canada	13	40	2.0
Mexico	16	37	1.0
U.K.	18	24	0.4
Chile	7	27	1.2
South Africa	(24)	(24)	1.0
Argentina	1	24	1.2
Portugal	(10)	(20)	1.5
Denmark	16	11	0.5
Morocco	17	8	0.4
Others	(35)	(47)	?
Total (approx.)	1 170	2 400	765.0

( ) Broad estimates of production

[1] Some figures, e.g., Japan, U.K., Argentina, Morocco are officially published data converted into U.S. dollars at average exchange rates for 1973; others, e.g., Korea, Spain are estimates based upon relative data for 1972; for a number of countries, notably China, U.S.S.R., U.S.A., Brazil, the estimates are broad indications calculated on the basis of the species composition of the harvest, uses of the weeds and unit production values elsewhere.

From: Naylor, J. 1976. Production, trade and utilization of seaweeds and seaweed products. FAO Fisheries Technical Paper No. 159.

3. STATUS OF PRODUCTION IN ASIA

Except for China, Japan and Korea where the seaweed industry is well established, the rest of the developing Asian countries are still dependent on wild seaweed crops. The Philippines may be cited as an exception, but actual farming is still limited to three species, namely: *Eucheuma alvarezii, E. denticulatum* and *Caulerpa lentillifera.* Indonesia is presently producing a certain amount of *Eucheuma.* Thailand is starting her *Gracilaria* culture project. The rest are still dependent on wild crops.

Production from wild crops is unreliable and is highly dependent on the natural growth of the species and the harvest rate exerted on the local stocks by the gatherers. Post-harvest methods used are generally antiquated resulting to the poor quality of the produce. In addition, the absence of a management programme for the naturally produced species often results to the depletion and/or destruction of their natural stocks. In contrast, the production of sea-weed species through farming is reliable. The rate of production can be programmed based on the demand. It is a very efficient way of conserving the local stocks. In addition, it is labor-intensive thus, offering more job opportunities to unskilled and otherwise underutilized labour force in the coastal areas. Seaweed farming is also a very good alternative in areas where small-scale fishing activities had become unproductive due to depletion of coral reef-associated fish species. Farm-produced seaweeds are generally of higher quality due to the application of highly improved post-harvest handling methods.

4. UTILIZATION OF SEAWEEDS AND SEAWEED PRODUCTS

Except in Japan, China and Korea where seaweeds and seaweed products are standard components of meals of the bulk of the population direct utilization of seaweeds as food in other Asian countries is limited to a small portion of the population along the coastal areas. Many species of seaweeds are eaten as vegetable salad and prepared in various ways. Seaweeds in general with the exception of some species are of low nutritional value due to their low protein content and generally hard-to-digest carbohydrates. However, they are important source of minerals, vitamins and roughage. Seaweeds are good food supplements and cannot totally replace the staple foods such as rice, fish and other cereals. Among those which are utilized directly as food are the following: *E. alvarezii, E. denticulatum,* species of *Caulerpa, Porphyra, Codium, Hypnea, Laurencia, Hydroclathrus, Acanthophora* and *Sargassum.*

Some genera of the brown algae such as *Sargassum* are also utilized as raw materials for the manufacture of animal feeds. At present, this genus is being harvested in commercial quantities for this purpose. A major portion of the local harvest is exported to Japan while the rest is used in the local manufacture of feeds. In India *Sargassum* is harvested in commercial quantities as raw material in the manufacture of alginates for their textile industry.

The most important use of seaweeds in Asia at present is as an item of commerce. The high demand for tropical seaweeds in the international market as raw materials in the manufacture of commercial products such as agars, carrageenans and alginates was the primary factor which influenced the development of farming technology for some seaweeds like *Eucheuma.* The farming of *Eucheuma* is a very productive small-scale industry which can be an alternative fishing activity in shallow coastal areas. During the 70's however, *Eucheuma* was sold in inter-national market in an unprocessed form due to the absence of processing technology. Asian countries buy the processed product (carrageenans) from foreign processors or suppliers at a much higher price for application in local industries. Today, a significant portion of *Eucheuma* produced through farming are sold in international market in treated (chips), semi-refined and refined forms. Portions of local produce of other seaweeds such as *Gracilaria, Gelidiella* and *Gelidium* are processed into crude agar which are sold in local markets in the form of dried agar bars. Except for *Caulerpa* production of other seaweeds is derived and is dependent up to now on natural stocks. Pond cultured *Caulerpa* are presently produced in the island of Mactan in Cebu. These are locally sold in open markets of Metro Manila, Cebu City, Cagayan de Oro City and Zamboanga City. Presently, a significant portion of the produce is exported to Japan and Okinawa in partially dehydrated (salted) form. All *Sargassum* processed in Central Visayas are exported to Japan while those in Northern Mindanao are locally utilized in the manufacture of feeds. A significant amount of *Gracilaria* and *Gelidiella* is exported while the rest is locally processed into agar bars. Production of other genera such as *Codium, Hypnea* and *Porphyra* is dependent on natural stocks and the produce is locally consumed.

The data on Philippine seaweed exported (Table 3) show that the volume of seaweeds presently exported had increased almost fifty times over that of the 1967 production. Starting as a minor sea product, seaweeds at present rank No. 3 among the fishery exports in the Philippines behind such pro-ducts as shrimps and tuna.

Table 3. Philippine seaweed export

Year	M.T.	Value (Pesos)
1967	674.5	351 989
1968	263.9	221 056
1969	427.6	447 908
1970	318.1	527 321
1971	339.8	675 504
1972	483.9	1 414 051
1973	1432.7	4 062 086
1974	5039.6	14 973 151
1975	4514.8	13 292 226
1976	3950.1	12 366 568
1977	6094.1	14 666 768
1978	13575.3	42 480 674
1979	16495.7	58 521 274
1980	13 191.3	55 647 616
1981	15 879.1	60 094 769
1982	16779.8	80 047 840
1983	17000.0	111 000 000
1984	10890.1	82 264 000
1985	28832.0	390 180 000
1986	27806.0	411 066 000

Source: Exports of fish and fishery product cleared by the Bureau of Fisheries and Aquatic Resources, by kind, quantity (in kilograms) and value, fisheries statistics, 1967–1980.

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Lecture 3[1]
SEAWEED ECOLOGY: INFLUENCE OF ENVIRONMENTAL FACTORS ON THE STRUCTURE, PHENOLOGY AND DISTRIBUTION OF SEAWEED COMMUNITIES

by

Gavino C. Trono, Jr.[2]

1. INTRODUCTION

The environmental conditions regulate the kind, nature, abundance and productivity of seaweed communities.

The stature of the community is reflective of the environmental conditions in the area.

Different kinds of species are found in certain habitats because environmental conditions are favourable to their development.

2. ENVIRONMENTAL FACTORS

The ambient ecological condition in a certain habitat is the result of the combined and synergistic effects of the various ecological factors. Some of these factors may exert modifying effects on the others. The understanding of the influence of these parameters on the nature, biology and distribution of seaweed is important in the evaluation and assessment of sites for mariculture purposes.

2.1 Salinity

Salinity is defined as "the amount of solid materials in grams contained in one kilogram of seawater when all the carbonate has been converted to oxide, bromine and iodine replaced by chloride and all the organic matter completely oxidized".

Most seaweed species cannot withstand . exposure to a wide variation in salinity regimes while others can. Those which cannot tolerate wide range of salinity regimes are known as stenohaline species while those which can are called euryhaline species. The effects of salinity on the structure of seaweed communities may be best illustrated by comparing the variety of species found in habitats which are influenced by freshwater (brackish) with those far from freshwater sources. Areas influenced by freshwater are generally characterized by low species diversity compared to reef areas not influenced by low salinity. The low diversity may be mainly due to the fact that only few species can thrive in habitats with highly fluctuating salinity regimes. For instance, certain species like *Glacilaria verrucosa* thrives very well in brackishwater areas while other species will die in such habitats.

2.2 Light and temperature

All photosynthetic plants require light as source of energy for the synthesis of organic products necessary for their normal growth and development. The different groups of seaweeds possess pigments of various types which enable them to adapt to different light conditions in the sea.

The quality and intensity of light change as it penetrates the water column. The change in light quality and intensity affects the distribution of the various species. The influence of light on seaweed distribution is best illustrated by their vertical zonation. In general those with pigments adapted for low intensities may be found in deeper areas while those adapted to full or bright conditions are found in shallow areas.

Heating of the water is a secondary effect of light which also affect the local distribution of seaweed species. Such effects, however, are limited to shallow intertidal areas or tidepools which become isolated and are not influenced by free water circulation. In such habitats, the temperature may become very high and can cause the exclusion of many species from the area. Such pronounced increase in water temperature takes place especially when low tides occur during the day. There is no significant change in water temperature in deeper areas where the water is constantly mixed by currents or wave action.

2.3 Substratum

Substratum provides mechanical support or attachment of the seaweeds. Seaweeds have different types of attachment organs adapted to various types of substrata. For instance, those species found in sandy-muddy habitats are generally characterized by fine and penetrating rhizoidal holdfasts while those in solid, hard or rocky substrates are characterized by strongly developed, branching or discoidal holdfast. Thus, the different types of substrate influence the composition and local distribution of seaweed species. The awareness of the role of substrates on the local distribution of seaweeds is thus, very important in inventory and stock assessment survey work.

2.4 Water movement

Water movement is an overall primary factor which controls or influences the nature or status of seaweed communities as well as modifies or moderates the extreme effects of other ecological factors. Water movement caused by waves and currents is important in aeration of the water, nutrient transport and mixing which prevents the rise in water temperature as well as light penetration. It also influences the amount of harvestable seaweed stocks. Waves are known to mechanically remove significant amounts of seaweed stocks. This effect is best illustrated by the tremendous amounts of drifted seaweed materials which accumulate along the beaches after storms. Wave-exposed areas are not good sites for the mariculture of seaweeds because of the destructive effects of waves on the farm. On the other hand, areas influenced by moderate currents are preferred sites for farming of certain species such as *Eucheuma* because currents are less destructive. Productive *Eucheuma* farms in the Philippines are characterized by moderate to strong currents. Loss of plants due to removal by currents can be significantly controlled by the construction of catchments at the lee-ward side of the farm.

2.5 Water depth

The water depth is another important factor which influences the local abundance and distribution of seaweeds. The upper limit of the vertical distribution of seaweeds is closely related to the upper tidal levels while the lower limit is limited by the amount of light which penetrates the water column. In general, most seaweed communities are well-developed starting from approximately plus or minus the 0 datum level to a few meters below this depth. The upper limit of vertical distribution of seaweed is influenced by the amount of exposure to air and sunlight during low tides and the inherent capacities of the species to resist dessication and the complications brought about by changes in salinity and water temperature during such exposure. The lower limit is generally related to the light conditions. Few species can thrive well in very low light intensities in deeper areas.

The understanding of the role of water depth in the vertical distribution and growth of seaweeds has a very important bearing in the selection of good sites for seaweed farms.

2.6 Biotic factors

One of the ever present factors which controls the marine vegetation are the associated animal life. Seaweeds and seagrasses are constantly being grazed upon by a host of animal grazers. These animals significantly control the amount of harvestable organic matter (biomass) in reef areas. Studies have shown that when grazing is controlled by the physical destruction or removal of grazers, luxuriant growth of seaweeds would follow.

Fungal and bacterial diseases are recognized as important biotic factors which influence the productivity of seaweed communities. These two factors are important considerations in the farming of seaweeds. Seaweed crops may be completely lost due to the destructive effects of these biotic factors. The presence of "weeds" is also one of the major problems in farms. These unwanted seaweed species compete with the crop plants for nutrients, space and light.

2.7 Other factors

Dissolved gases such as oxygen and carbon dioxide seldom become limiting factors to the growth and development of seaweed communities. These gases are abundant in the sea where there is continuous mixing of water due to the action of waves and currents. Oxygen comes from two major sources, i.e. from the atmosphere and as by-product of photosynthesis. Aeration of the water column is facilitated by waves and currents. Carbon dioxide which is a principal raw material in the production of organic substances through photosynthesis is present in abundance in the sea as dissolve gas or in the form of carbonate compounds. Another factor which seldom becomes limiting in the sea is pH. The buffered nature of seawater does not allow extreme fluctuation in pH values except in special types of habitats such as tidepools and isolated shallow lagoons especially during low tide regimes.

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Lecture 4 and Practicum I
AN INTRODUCTION TO THE SEAWEEDS: THEIR CHARACTERISTICS AND ECONOMIC IMPORTANCE[1]

by

Rhodora Azanza-Corrales[2]

1. INTRODUCTION

The primary producers or photosynthetic organisms in the marine environment are the algae and the seagrasses. Marine algae compared to the seagrasses and most terrestrial plants, are non-vascular and have simpler reproductive structures (Trainor, 1978). Seaweeds, unlike planktons, are macroscopic attached forms of algae.

This is a brief introduction to the major features of seaweed biology which are relevant to the understanding of the concepts and techniques in their resource management and culture. Economic benefits derived from these plants are also presented.

2. CYTOLOGY AND MORPHOLOGY

Aside from being useful as tools in seaweed taxonomy and nomenclature, knowledge of their cytological characteristics is important to appreciate the basic adaptations of sea-weeds at this lower level of organization. Thus, understanding at the higher levels of organization, e.g., organismic, population, community, etc., is facilitated.

The primary classification of the algae, i.e. at the division level is based on the following main criteria: (1) photosynthetic pigments, (2) food reserve, (3) cell wall components and (4) other important details of ultrastructure. It should be clarified, however, that classification is based on the combination of several characters (Annex A).

Except for the members of Cyanophyta, cells of most seaweeds are eukaryotic, hence, the structures where vital chemical processes occur are membrane-bound. To synthesize organic compounds with water and carbon dioxide in the presence of light as energy source, the seaweed utilize primarily chlorophyll a. Other major pigments are other chlorophylls, carotenoids and phycobilins. Photosynthetic pigments are contained in plastids generally discoid to ovoid in shape with less developed lamellae called thylakoids. These plastids or distinct containers of pigments are visible with light microscope in all seaweed divisions except in Cyanophyta. Blue green (Cyanophyta), green (Chlorophyta), brown (Phaeophyta) and red (Rhodophyta) seaweeds are so named because of their characteristic pigment combination (Dawes, 1981).

The biochemistry of their storage products and cell walls can also be used to differentiate seaweed groups. Starch (unbranched polymer of α l, 4 glucan as in higher plants) is the stored food in Chlorophyta while floridean starch (branched polymer of α l, 4 glucans and laminarin (polymer of β 1, 3 glucan) are found in Rhodophyta and Phaeophyta, respectively. Mannitol, an alcohol, found in many algae (Dawes, 1981) may be a common soluble food reserve in seaweeds. The basic component of the seaweed cell wall is cellulose (polymer of β 1, 4 glucan), however, other compounds as xylans (β 1, 3 linked) and mannans (β 1, 4 linked) can be found in coenocytic green algae. Patterns of cellular microfibril arrangement differentiate the various algal groups (Dawes et al., 1961; Dawes, 1966). Agar and carrageenan from some red algae and alginic acid from brown algae constitute the other (economically important) materials of their cell walls. Walls of many seaweeds have been known to have affinity for heavy metals which diffuse or are absorbed from the environment. Haug (1961) for example report that alginic acid has the following affinity for different metals: Pb>Cu> Cd> Ba> Sr> Ca> Co> Ni>Zn, Mn, Mg. This knowledge is important in choosing sites for culturing seaweeds. Culture or farming site should be far from sources of these pollutants which the seaweed can accumulate in their cells. Some (green and red) algae have calcium carbonate (Dawes, 1981), hence, are very important contributors to the calcium deposits in the marine environment.

The "thallus" (thalli, plural) refers to the seaweed's vegetative body with "roots", "stems" and "leaves" which are structurally and physiologically less differentiated unlike their counterparts in vascular plants. The thalli range from smaller simple filaments to the bigger forms with "holdfast", "stipe" and "blade". The holdfast which attaches the seaweed to the substratum can be: (1) a modified basal cell, (2) rhizoidal filaments or (3) multicellular organs which may be disc-like or a branched system. The structure which may be present or absent between the holdfast and the blade is the "stipe" that grows terminally through the activity of a single apical cell or a group of them called meristem (Trono and Fortes, 1988). The "blade" wherein most photosynthesis occur is generally thin and expanded, but may be filamentous or fleshy, branched or unbranched. Storage (and transport) of photosynthate is not localized in one organ or structure unlike in vascular plants where the stem usually performs this special function. Vascularization, i.e. presence of phloem and xylem is absent except in the temperate groups. Laminariales and fucales (Phaeophyta) where beginnings of these tissues are present (Morris, 1967).

3. GROWTH, DEVELOPMENT AND REGENERATION

Life begins normally for a seaweed as a spore or a zygote (or propagules/cuttings in culture). Germination, growth and development proceed after settlement and attachment in the substratum leading to the formation of adult or mature plant that can then undergo asexual or sexual reproduction (Lobban *el al.,* 1985). Evidences are mounting that aside from external factors as light, temperature, etc., internal ones as morphogenetic factors (like hormones) may be involved in processes that produce and maintain thallus integrity (Jacobs, 1985).

At some point/s in seaweed life, the thallus may be damaged or broken by natural factors (as strong waves, grazing by animals, etc.) or by human activity like the farming of economically important species. Healing is generally rapid or efficient which could be accomplished in 30 minutes in coenocytic seaweeds as *Caulerpa* (Dreher *el al.,* 1978) or within the second week in bigger thallus as in *Eucheuma* (Azanza-Corrales *el al.,* 1988). Wound healing is then followed or overlaps with regeneration or replacement of parts of redifferentiation of older adjacent cells to wounded area. This healing and regenerative capacity have been widely exploited in the culture of the abovementioned plants where vegetative propagation is the main technique in their production.

4. LIFE HISTORY AND REPRODUCTION

In the life cycle of more advanced members of green, brown and red seaweeds, there is an alternation of two or three isomorphic *(i.e.* some morphology) or heteromorphic (different morphology) somatic generations. The sporophyte (2N) produces spore through meiotic division, the meiospores (N) develop into gametophyte (N) where gamete formation is mitotic. Fusion of gametes (N) produce zygote (2N) which developes into the sporophyte completing the cycle. In advanced members of red algae for example in *Gracilaria,* a third somatic generation, the carposporophyte (2N) is produced "inside" the female gametophyte (N) after fertilization of egg by spermatia from male gametophyte. The carposporophyte produces carpospores (2N) in carposporangia which are released and germinate into tetrasporophyte (2N) that produces tetraspores (N) through meiosis. The tetraspores in turn develop into either female or male gametophytes (N), hence, completing the plant's life history.

From the abovementioned and other previous discussions, it is clear that seaweeds can multiply or proliferate in the dimensions of time and space through asexual and sexual means. Asexual method could be by 1) vegetative regeneration from fragments produced naturally or artificially, or 2) production of non-motile or motile spores produced in structures called sporangia. The former is called aplanospore produced in aplanosporangium and the latter is called zoospore formed in zoosporangia. Sexual reproduction is the fusion of gametes produced from simple or differentiated gametangia where in the latter, male gamete is produced from an antheridium while the female gamete from the oogonium. In the more advanced form of red and brown algae, fertile areas may be distinguished on the surfaces of the thalli. Spermatia (male gametes) may be aggregated in cavities called conceptacles, while tetrasporangia and/or female, reproductive structures may form distinct aggregations called sorus(i).

In some, specialized branches of spore production are called "receptacles" while in others portion of some branches are converted to fertile structures called stichidium (Trono and Fortes, 1988). Stalked or sessile cystocarps which contain the carposporophyte covered by a pericarp are formed on the surfaces of female gametophytes of red seaweeds as *Eucheuma* and *Gracilaria.* In Japan where seaweed culture is probably most developed, nets for *Porphyra, Laminaria* and *Monostroma* are seeded with spores indoor or in the laboratory. When the seedlings reach appropriate size and during appropriate time, the nets are transferred to the culture sites.

5. ECONOMIC IMPORTANCE OF SEAWEEDS

Man has a long history of seaweed utilization as direct sources of food, fodder, fertilizer and medicine. Various industries have used phycocolloids and other materials extracted from seaweeds for many purposes. World seaweed utilization has been reviewed by Levring *et. al.* (1969), Chapman (1970) and Bonotto (1976) as reported by Dawes (1981) who cited the brown and red seaweeds as the most dominant algae useful to man.

The following review of economic importance of seaweeds has been digested primarily from Dawes (1981) and Trono and Fortes (1988).

5.1 As direct source of food

Japan, China, Philippines, Korea and other Asian countries and Hawaii consume sea-weeds directly as food. They are mostly harvested from natural populations but mariculture of important species have been practiced specially in the first three mentioned countries. The species sold almost daily in the Philippines particularly in wet markets in Metro Manila are *Caulerpa lentilifera, C. racemosa, Eucheuma alvarezii, E. denticulatum* and *Gracilaria verrucosa. Porphyra* or "Nori" is a regular part of daily Japanese meal. The browns *Laminaria* and *Alaria* are also popular food items in Japan and Korea. Presently, the most expensive edible seaweed in Japan is *Monostroma* (Azanza-Corrales, personal communication). It is also farmed like the previously mentioned seaweeds but "Nori" remains the most extensively cultured.

5.2 Uses in medicine

Seaweeds have been variously utilized as medicinal herbs. Early Roman soldiers have used species to heal wounds, burns and rashes. Goiter and other internal disorders have been treated or prevented with sea-weeds by Chinese and Japanese. Agarophytes and carrageenophytes are good laxatives (Calompong, 1981). *Digenea simplex* has been reported to be a good vermifuge (Trono, 1973). Processed materials from seaweeds that are used in medicine and related areas are considered in item 5.4.

5.3 As fertilizer, fodder and fuel

Aqueous extracts mostly from brown seaweeds have been used commercially for agricultural purposes (Stephenson, 1974; Montano and Tupaz, 1988). Fertilizers from seaweeds result to increased crop yield probably due to the presence of growth promoting hormones (Bentley-Mowat, 1963). Other beneficial effects include increased resistance of crop to fungal and insect pests and increase water holding capacity of the soil (Mathieson, 1967). In Europe, seaweeds are dried and grounded to produce meals for animals. *Macrocystis, Sargassum* and *Gracilaria* are sources of fuel (menthane), production of which is a new-venture especially in the United States.

5.4 Sources of phycocolloids

Polysaccharides extracted from seaweeds (especially reds and browns) that can form colloidal or gel systems in water are called phycocolloids. *Alginic acid* is a polymer of D-mannuronic and L-guluronic acids and are derived from brown seaweeds. Alginates are used as emulsifier and stabilizers in the textile, paper, paint and food industries. They have been used to make surgical threads and whole blood substitutes for emergency transfusion. Half of the -entire world production of alginic acid comes from the harvesting of *Laminaria* in the North Atlantic. Other sources are *Eclonia* and *Sargassum* in the Pacific and Indian Oceans. Agar which chemically consists of agarose and agaropectin is a strong gelling phycocolloid mostly extracted from *Gracilaria, Gelidium, Gelidiella* and *Pterocladia.* The better quality agar is used as medium for culture of microbiological specimens. The food industry use them as protective gels in canned meat and stabilizers in many bakery products. They are also used in the sizing of fabrics, water proofing of paper and cloth and/or clarifying agent in the manufacture of wines, beers and coffee.

Carrageenan is a more sulfated (20—50 percent galactan) compound compared to agar which has lesser degree of sulfation (less than 5 percent). Presently, there are five major forms (k,,λ,,μ,λ, i) of carrageenan already known. They vary in the levels of sulfation and the ratios of galactose to 3,6 anhydrogalactose. Carrageenan is extracted from members of *Gigartinales,* wherein the different forms are distributed between the diploid and haploid phases. In *Chondrus, Gigartina* and *Iridaea,* K-carrageenan is found in the haploid plant and carrageenan in the diploid plant. *Eucheuma denliculatum* contains only K-carrageenan while *E. isiforme, E. alvarezii* and *E. uncinatum* carrageenan only. This phycocolloid is used mainly in dairy products because of its stabilizing effects with milk proteins. It is also useful in the production of toothpaste, diet foods, soups and confections. Other products with carrageenan as suspending or gelling agent are those from the cosmetic, paint and pharmaceutical industries.

Trono and Fortes (1988) report that "out of the total world production of 650 000 mt of seaweed in 1980, about 270 000 mt were used in the manufacture of phycocolloids, the rest were utilized as food in Asia. The Philippines contributed 84 percent of total world supply of carrageenan, Republic of Korea produced 62 percent of total raw materials for agar while 70 percent of materials for alginate production were from European countries, the United States and Canada".

Seaweeds, therefore, are very important not only for their biological roles in the marine environment but also for the economic benefits that they directly provide man.

[1] A lecture presented during the ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project and Seafarming Development and Demonstration Project (Joint Training Programme), University of the Philippines, Diliman, Quezon City, May 2–21,1988.

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ANNEX A

Simple Artificial Key to the Four Divisions of Seaweeds

1. Cells without distinct containers or plastids, reproduction purely asexual	Cyanophyta
1. Cells with distinct pigment containers or plastids, reproduction asexual and sexual	2.
2. stored food starch	Chlorophyta
2. stored food otherwise	3.
3. stored food laminarin	Phaeophyta
3. stored food floridean starch	Rhodophyta

Table 1. General features of the four seaweed divisions

Division	Pigments	Plastids*	Stored food	General morphology	Reproduction
1. Cyanophyta	chlorophyll a c-phycocyanin c-phycoerythrin	absent	cyanophycean starch	microscopic filamentous, form tufts	purely sexual
2. Chlorophyta	chlorophyll a chlorophyll b	present	starch	microscopic filamentous, to coenocytic, to various macroscopic forms	asexual. sexual
3. Phaeophyta	chlorophyll a chlorophyll c fucoxanthin	present	laminarin	freely branched filaments to macroscopic (giant kelps incl.)	asexual sexual
4. Rhodophyta	chlorophyll a chlorophyll d r-phycoerythrin r-phycocyanin	present	floridean starch	microscopic filamentous to various macroscopic forms	asexual sexual

* Container of photosynthetic pigment

Practicum 1
INTRODUCTION TO THE FOUR SEAWEED DIVISIONS

by

Rhodora Azanza-Corrales

Taxonomy deals with the identification of plants (or animals) using data and information from their morphology, anatomy, physiology, genetics and biochemistry. It involves the classification or ranking *(e.g.,* Division, Class, Family, etc.) of plants (seaweeds in this case) on the basis of their similarities and dissimilarities. Nomenclature, another aspect of taxonomy is the system of naming organisms.

This exercise will deal primarily on the classification of seaweeds at the Division level. It serves as an introduction to other practical work *(i.e.* identification of sea-weeds) by familiarizing the students with their morphological characters. Pressed and herbarium specimens of the more common representatives of the four divisions will be studied taking note specially of their root-like, stem-like and leaf-like structures. This will be useful in the recognition, collection and identification of these specimens.

As emphasized earlier in the lecture, the four seaweed divisions (Cyanophyta, Chlorophyta, Phaeophyta and Rhodophyta) are recognized based on their pigmentation, food reserve, cell wall composition and flagellation. To verify one's classification of an unknown or unfamiliar specimen, some simple biochemical tests (Hunt, 1978) could be employed.

For the guidance of the trainees, the following general characteristics of the four divisions have been included:

1. Cyanophyta (Blue-green algae)

Represented by bluish green to brownish, reddish or almost black-colored films or spongy tufts on intertidal rocks, other substrates as other seaweeds, the group has mainly freshwater and terrestrial forms. The marine members are mostly coccoid or filamentous forms of different sizes of colonies. They have lesser state of organization both at the cellular and organismic levels. Their pigments (chlorophylls, phycocyanin and phycoerythrin) are found in the cytoplasmic matrix and not in special containers called plastids. This feature can be verified even with the use of a light microscope. Reproduction is achieved by asexual method only, *i.e.,* by fission, spore formation or fragmentation.

The members are found mixed with other seaweeds. In certain months of the year, their over-growth has become a problem in some seaweed farms where they compete for light, space, etc. with the crop. *Lyngbya majuscula* (Trono, 1981 unpubl.) is a common "pest" in *Eucheuma* farms where they form tufts on nets, posts or on crops themselves.

2. Chlorophyta (Green algae)

Most green algae are found in the fresh-water and terrestrial habitats. There are only a few truly marine representatives. They are bright green to grass green in color due to the predominance of chlorophylls (a and b) over the other pigments. Plastids which are special containers of photosynthetic pigments are ovoid to spherical or assume various shapes. These chloroplasts can be made visible with light microscopy. Photosynthetic reserves in the green algae are stored as starch. Cell wall is made up basically of cellulose with calcification in the same genera.

The group is represented in the marine environment by microscopic, unicellular or macroscopic coenocytic to multicellular forms. The thalli vary from simple free filaments to definitely shaped forms with distinct blade, stipe and holdfast. The leaflike structure or blade may be a thin expanded structure as in *Ulva,* or pinnate as in some *Caulerpa* species or assume various forms. Other members may be highly calcified as *Halimeda.*

Reproduction in this group are sexual and asexual by formation of flagellated or non-flagellated spores. Fragmentation of thalli that leads to their regeneration is a means of vegetative multiplication which is utilized in the farming, for example of' *Caulerpa.*

Certain species of *Ulva, Monostroma, Caulerpa* and *Codium* are being utilized as food in the Philippines and other Asian countries.

3. Phaeophyta (Brown algae)

Almost all the members of Phaeophyta are marine forms. Major pigments found are chlorophylls (a and c) and fucoxanthin, a special type of xanthophyll which gives the algae the brown coloration. Plastids are present in their cells whose walls are made up of an inner layer of cellulose and an outer layer of algin. Stored carbohydrate reserves are principally laminarin and mannitol.

There are simple freely-branching filamentous representatives. Many genera form macroscopic highly differentiated thallus. Distinct blades, stipe, holdfasts are exhibited by the Laminariales and Fucales or giant kelps (like *Laminaria, Eisennia, Eclonia* and *Macrocystis.* These are found only in the temperate areas where they form seaweed forests that serve as habitats of other marine organisms. The beginning of anatomical differentiation or formation of a less differentiated vascular tissue has been observed in the kelps.

In the Philippines as in many other tropical waters, several species of *Sargassum, Turbinaria Padina* and *Dictyota* form the major component of the reef flora. The genus *Sargassum* which is distributed widely from the tropical to temperate areas, forms extensive vegetation or "beds" which are habitats for marine animals specially fishes.

Reproduction in the group is both sexual and asexual. Motile reproductive cells are laterally biflagellated except in Dictyotales. Vegetative propagation through thalli fragmentation may occur or formation and abscission of special reproductive structure called propagules may also be undertaken.

4. Rhodophyta (Red algae)

Except for a few species, the members of this group are mostly marine forms. Their color is variable from reddish-brown to reddish-green because of variation in the amount of pigments (chlorophylls and the phycobillins-phycoerythrin and phycocyanin). This phenomenon called "chromatic adaptation" is the plant's adjustment to available light quality (wavelength) and/or intensity (Lobban, 1985). The chloroplast in the red algae are generally discoid. Food reserve is floridean starch. The cell wall is made up of cellulose together with agar or carrageenan. Many red seaweed genera are economically important because of their phycocolloid content. Common sources of several types of carrageenan are *Eucheuma* and *Chondrus* while *Gracilaria, Gelidiella* and *Gelidium* provide varying quality of agar.

The reds represent the most complicated life history and reproduction among the algae. Spores whether asexual or sexual are non-flagellated. Vegetative reproduction through regeneration of fragmented thalli is quite common and widely utilized in the farming of certain species of *Eucheuma* and *Gracilaria.* The three life phases in the life history of most red algae are: 1) sexual phase consisting of male and female gametophyte, 2) the asexual phase — the carposporophytes attached to. the female plant producing carpospores, and 3) the other asexual phase tetrasphorophyte producing tetraspores.

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Lecture 5 and Practicum 2
HOW TO IDENTIFY SEAWEEDS: USE OF DICHOTOMOUS KEYS[1]

by

Edna T. Ganzon-Fortes[2]

As earlier mentioned, only through the practice of handling and distinguishing the seaweeds as they appear in nature or as pressed or preserved specimen can one develop the ease of identifying them.

For beginners, it is best to familiarize oneself with pressed herbarium specimens first before going to the field to collect fresh materials. In identifying a particular sea-weed species, the use of dichotomous keys is most useful because most seaweed literature provide it. However, seldom can one find a dichotomous key which include all seaweed groups or divisions. Most often, dichotomous keys are provided for only one division (i.e., one for Chlorophyta, one for Phaeophyta, one for Rhodophyta); and usually, keys are provided for major generic groups (e.g., a key to the *Halimeda* group, or *Caulerpa* or *Laurencia,* etc.). Therefore, before using a dichotomous key it would always require the identification of the division to which a particular species belong.

Especially when fresh, color may serve as the most convenient character to consider in identifying the particular division to which a seaweed species may belong. The green seaweeds (Chlorophyta) are almost grass green, although some species may be yellow-green or brownish-green. The brown seaweeds (Phaeophyta) are usually light to dark brown, yellow-brown, brownish-red, orange-brown but others may be bluish-green. Seaweeds that are colored red or purple, even in part, almost always belong to Rhodophyta. Some red species, however, may be colored brownish-red, or they may become yellow-brown, yellow-orange, or green in bright sunlight. In cases when group classification becomes difficult a simple biochemical test may be of help. To distinguish some reddish-brown or brownish-red seaweeds apart, immerse them in hot water maintained at 65 °C for a few minutes. Most brown seaweeds will turn green in 120 seconds but most red seaweeds will not turn green in 240 seconds. This is so because the hot water (65°C) dissociates the brown fucoxanthin pigments masking the chlorophylls, thus, allowing the green color to be observed. But in most seaweeds, the biliproteins (r-phycoerythrin) do not dissociate at this temperature, thus, retaining its color. A few red species, however, such as *Gracilaria* do turn green when immersed at 75 °C water as one will notice when they are blanched as required in certain recipes.

In our laboratory session, you will be given a set of dried seaweed materials to identify using dichotomous keys. These keys are only applicable to the species included in this exercise. They use morphological characters or traits that describe a particular genus or species to "split" or differentiate it/them from the other species or groups of species. For example:

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Key to the genera of Rhodophyta

1. Thallus calcified	2
1. Thallus not calcified	5

Look at the specimen and observe the presence or absence of the morphological character described which is calcification*.

* A seaweed is calcified when it is hard, brittle, or has chalky texture. To be sure, simply put a few drops of 10 percent Hydrochloric acid (HC1) to a very small portion of the thallus. If rapid bubbling results, this indicates the presence of calcium carbonate.

If the specimen is calcified, then proceed to number 2; if not calcified, then proceed to number 5.

2. Thallus crustose or rock-like	*Hydrolithon*
2. Thallus forming free branches	3

Look at the specimen again and observe its habit (general form). If it is rock-like, then it might be *Lithothamnium.* If the characters described fit your specimen, then it is it. But if it does not, then it might be a different species. On the other hand, if your specimen forms free branches, then proceed to number 3 of the dichotomous key; and so on until you arrive at the identity of the species in question.

Just be sure to confirm the identity of the species by checking if its morphological characteristics tally with the description of the species provided in the taxonomic hand-outs.

Take note that a scientific name is given to each specimen. This consists of two names, hence, a binomial — the first is the generic name (genus) and the second is the specific name (species). The first letter of the generic name is capitalized while the specific name is written in small letters, and both are italicized or underlined.

Example:	*Eucheuma*	*denticulatum*
	(genus)	(species)

Dichotomous Keys

A. Key to the genera of Chlorophyta

1. Thallus forming fan-shaped blades or segments	2
1. Thallus not forming fan-shaped blades or segments	3
2. Thallus composed of tiers of segments that are fan-shaped, kidney-shaped,or wedge-shaped	*Halimeda*
2. Thallus composed of fan-shaped blade	*Avrainvillea*
3. Thallus filamentous	4
3. Thallus not filamentous	5
4. Filaments branched,very fine	*Chlorodesmis*
4. Filaments unbranched	*Chaetomorpha*
5. Thallus club-shaped, occurs singly or in colony	6
5. Thallus not as above	7
6. Thallus vesiculate, not calcified, without a central axis and lateral branchlets when x-sectioned	*Boergesenia*
6. Thallus calcified, with central axis and lateral branchlets when x-sectioned	*Bornetella*
7. Thallus umbrella-like, without horizontal stolon	*Acetabularia*
7. Thallus composed of erect branches and horizontal stolon	*Caulerpa*

B. Key to the genera of Phaeophyta

1. Thallus composed of fan-shaped blades or segments	*Padina*
1. Thallus not as above	2
2. Thallus composed of strap-shaped branches	*Dictyota*
2. Thallus net-like	*Hydroclathrus*
2.. Thallus divided into "leaves", "stems" and with vesicles	3
3. Vesicles bone on stalks attached to the axes of the branches	*Sargassum*
3. Vesicles borne on the center of the bell-like leaves	*Turbinaria*
3. Vesicles borne on the central axes and with leafy triquetrous extensions	*Hormophysa*

C. Key to the genera of Rhodophyta

1. Thallus calcified	2
1. Thallus not calcified	5
2. Thallus crustose or rock-like	*Hydrolithon*
2. Thallus with free branches	3
3 Branches moderately calcified, flattened, not divided into segments by genicula	*Mastophora*
3. Branches highly calcified, divided into segments by genicula	4
4. Intergenicular segment sagittate	*Cheilosporum*
4. Intergenicular segments cylindrical	*Amphiroa*
5. Thallus distinctly flattened and frondose	*Halymenia*
5. Thallus not as above	6
6. Branches densely clothed with lateral branchlets	7
6. Branches not as above	9
7. Branchlets spinose	*Acanthophora*
7. Branchlets not spinose	8
8. Ultimate branchlets with distinct apical pit	*Laurencia*
8. Ultimate branchlets without apical pit	*Gelidiella*
9. Cross-section of branch shows cells at the center of the medulla distinctly large, 210–1 000 (commonly 400–700) microns in diameter	*Gracilaria*
9. Cells at the center of the medulla smaller, less than 200 microns in diameter; a core of thick-walled and very small cells may be present at the medulla of some species	*Eucheuma*

D. Key to the Seagrass species of Bolinao

1. Plants with ligule*(Family Potamogetonaceae)	2
1. Plants without ligule (Family Hydrocharitaceae)	5
2. Leaves terete, subulate	*Syringodium isoetifolium*
2. Leaves flat, thin	3
3 Leaves narrow, to 3 mm wide, each with one central vein	*Halodule univervis*
3. Leaves to 1 cm wide, with more than one vein	4
4. Leaf tip rotund, unserrated	*Cymodocea rotundata*
4. Leaf tip not rotund, serrated	*C. serrulata*
5. Shoots to 1 m tall, with black strands emanating from the base	*Enhalus acoroides*
5. Shoots with the strands	6
6. Leaves blade-like	7
6. Leaves strap-like	*Thalassia hemprichii*
7. Leaf blades to 1 cm long with less than 8 cross-veins	*Halophila minor*
7. Veins Leaf blades from 1.5–2.5 cm long, with more than 8 cross-veins	*H. ovalis*

E. Key to the species of *Caulerpa*

1. Erect branches simple and strap-shaped or blade-like	2
1. Erect branches bearing short branchlets (ramuli) of various forms	3
2. Erect branches narrow, slightly curved or spirally twisted upward	*C. serrulata*
2. Erect branches broader, not curved or twisted	*C. brachypus*
3 Erect branches feather-like	4
3. Erect branches not feather-like	6
4. Ramuli in the form of cylindrical pinnules	5
4. Ramuli in the form of compressed to flattened pinnules	*C. taxifolia*
5. Pinnules distichous-pinnately arranged on the erect axis	*C. sertularioides*
5. Pinnules distichous-pinnate or tristichously arranged on the erect axis	*C. cupressoides*
6. Ramuli peltate	*C. peltata*
6. Ramuli clavate, globose or spinose	7
7. Ramuli club-shaped, without distinct constriction between the head and stalk	*C. racemosa*

F. Key to the species *Halimeda*

1. Holdfast bulbous	2
1. Holdfast discoid, stupose, or rhizoidal	5
2. Segments compressed to flattened	3
2. Segments cylindrical and barrel-shaped	*H. cylindracea*
3 Segments large up to 2.2 × 2.9 cm, commonly flabellate with entire, undulate, or irregularly lobed upper margin	*H. marcoloba*
3. Segments smaller, cuneate, subcuneate, Suborbicular	4
4. Segments cuneate, subcuneate, flabellate to reniform and with ribbed surfaces	*H. simulans*
4. Segments broadly cuneate, cuneate and suborbicular, without ribs on the surface	*E. discoidea v.platyloba*
5. Thallus forming loose clumps, without stipe, and attached to substrate by rhizoids arising from segments that comes in contact with substratum .	*H. opuntia*
5. Thallus not as above	6
6. Segments with distinctly thick and wavy upper margin which becomes folded when pressed	*H. tuna*
6. Segments more or less uniform in thickness	7
7. Segments appearing "velvety" due to very broad diameter of surface utricles	*H. macrophysa*
7. Segments not appearing "velvety"	8
8. Segments with distinct or faint ribs on the surface	9
8. Segments without rib on surface	10
9. Basal segment single; upper segments, generally reniform with entire to very slightly undulate upper margins	*H. velasquezii*
9. Basal segments laterally fused; upper ones cuneate, subcuneate, etc., with trilobed, undulate, or deeply cleft upper margins	*H. incrassata*
10. Segments thick, glossy becoming concave upon drying	*H. taenicola*
10. Segments not as thick, not becoming concave upon drying	11
11. Segments abruptly decreasing in diameter from lower to upper portions of thallus; lower ones broadly cuneate to flabellate, upper ones narrowly cuneate to digitate	*H. discoidea f.subdigitata*
11. Segments not abruptly decreasing in diameter from base to apex of thallus, brittle, with dull, chalky surfaces	*H. fragilis*

G. Key to the species of *Gracilaria*

1. Branches compressed to flattened	*G. eucheumoides*
1. Branches terete to slightly compressed	2
2. Main branches not exceeding 2.5 mm in Diameter	3
2. Main branches more than 2.5 mm in diameter.	5
3 Branches constricted at bases	4
3. Branches not constricted at bases	*G. coronopifolia*
4. Lateral branchlets long and curved inwardly	*G. blogettii*
4. Lateral branchlets shorter not curved inwardly	*G. "verrucosa"*
5. Branches divided into clavate segments by deep constrictions	*G. salicornia*
5. Branches not divided into clavate segments by deep constriction	6
6. Lateral branchlets distinctly curved inwards and upward; obtuse	*G. gigas*
6. Lateral branchlets generally arcuate and attenuate	***G. arcuata***

* ligule — membranous appendage projecting from the summit of the leaf sheath.

Lecture 6 and Practicum 7
INVENTORY AND ASSESSMENT OF ECONOMICALLY IMPORTANT SEAWEED STOCKS

By

Miguel D. Fortes[1]

1. ECONOMIC SEAWEEDS IN THEIR NATURAL ENVIRONMENT

In terms of gross potential use and production, the Asia-Pacific region is one of the richest source of' natural seaweed products in the world. Such taxonomic diversity results directly from the varied conditions which are generated by equally varied topographical features such as deeply penetrating coves, coral and volcanic islands surrounded by wide, gently sloping reef flats, shallow continental shelves, and the enormous length of the total coastline. In addition, the numerous islands divide the waters into different seas connected by channels, passages and straits, making possible differential distribution of nutrients and compaction and composition of the substrate. These features ensure the constant availability of requirements that favor optimal relief for growth and development of the seaweeds.

The ecological factors that affect the biology of seaweeds in marine tropical waters may be, as Doty (1946) mentioned, primary or secondary. Primary factors are major phenomena, like monsoons and tides, observable as large-scale changes in the earth's surface, exerting their effects on considerably large areas and influencing a number of requirements of the seaweeds. The secondary factors, on the other hand, are those like temperature, light and grazing which are more limited and specific in their effects, generally subject to the fluctuations in the primary factors. In nature, however, these latter factor cannot (and should not) be isolated from one another because their effects are known to be interactive. The growth of a seaweed is more the resultant effect of several factors acting together, either synergistically or antagonistically, in the multidimensional niche of that species. If attempts are made to isolate the effects of individual factors, these are made for no other reason that a consideration of practicality and expense. For the purpose of this training/workshop, the latter view is adopted in the monitoring of the effects of selected field parameters on the performance of seaweeds.

2. NON-SCIENTIFIC AND SCIENTIFIC SAMPLING

Much of our knowledge on seaweed research is based to a very large extent, on samples. An administrator accustomed to dealing with complete censuses as bases of policies is suspicious of samples and is reluctant to use them. His choice of a farming technique is often determined by the "impressions" gathered from few encounters he has had with the technique in the course of a few years. He would differ from one who devotes 20 years to "trial-and-error" methods, "feeling" the best possible method for optimum seaweed production. But in a real sense, the two differ in that the former bases his conclusions on a much smaller sample of experience. In science and in human affairs alike, often we lack the resources in order to take a complete study of the phenomena that might advance our knowledge. This is the primary reason why investigators resort to gathering samples.

Non-scientific approaches to ecological studies may be in the form of:

a. a guess;

b. reliance on previous experience and/or memory;

c. the use of logic or common sense;

d. making "spot checks" and "judgment" surveys; and

e. taking a 100 percent survey.

Unfortunately, all these approaches are usually very biased even though not intentionally so. If sufficient data from previous experience or originally gathered by some-one else is available, it may be used as the basis for decision-making. But often, this is not so easy to secure, or if readily available, insufficient for the purpose. Thus, the need arises to collect primary or new data.

Values reported that "spot checks" may be accurate but one cannot be assured that the conclusions drawn from them are valid and reliable. It is risky when used as a basis for making programme-management decisions. With 100 percent surveys, their costs are prohibitive, the actual surveys very time-consuming and they are often physically impossible to conduct.

Scientific sampling is "..... the use of efficient and effective systematic methods of collecting, interpreting and presenting data in a quantitative manner to facilitate understanding". With these methods, bias inherent in the non-scientific techniques can be appreciably eliminated and the probability of being correct (or incorrect) ascertained. The principal advantages of scientific sampling as compared with complete enumeration in ecological studies are as follows:

a. Subjective and personal bias in the overall methodology is minimized;

b. Inasmuch as the conclusions will be based on just a few samples, precise quantitative statements can be made regarding how these samples closely reflect the whole population from where they were drawn;

c. The probability of being correct or incorrect can be estimated;

d. Since scientific sampling can give smallest number of samples needed to reflect the characteristics of a population, the method becomes more economical, efficient and effective; and

e. Compared to 100 percent survey, scientific methods are the more accurate and practical because there are many different sources of error in any enumeration of large amount of data. Hence, the smaller (but the more carefully controlled) the sample, the less chances of making mistakes.

3. SOME GENERAL GUIDELINES IN CONDUCTING A SCIENTIFIC FIELD STUDY

3.1 Clarification of objectives

It is often the case that your head office just wants "to know something about" or to be kept informed on the status of key areas in the project. There is really no "problem" and the request for you to study an area usually comes in the form of ambiguous formulae, focused on some observed details that seem to bother management. Get your guidance clear on what you are to study and once the objectives have been definitely stated, the need for the study becomes clearer.

The questions to be answered include: Why does management want to study? How important does the head office consider the need for answers? How accurate do the results need to be? When does management want the results? What is the budget limitation of the study?

3.2 Planning and organizing the study

There are many factors to consider in planning and organizing the survey. However, these can be categorized under two general headings, namely, administrative and technical. A serious consideration of funds, staff, equipment and administrative coordination is necessary before you go any further. Technically, once the problem is understood, formulate hypotheses to serve as possible explanations for the phenomenon to be encountered. This will lead to the right kinds of questions to be asked in order to resolve which of the hypotheses are correct.

Sometimes, questionnaires are important. The design and format of such materials are very significant in the accuracy in recording data. Master lists and a working schedule must be made available in order to complete the work in time for management's use. Also, an appropriate sample size must be determined as this will limit your time, money and personnel.

3.3 Selecting a sample

In sampling, one must know exactly the natural entity to be sampled. For example, if we obtain a collection of seaweeds from within a 0.25 m^2 plot, we must be aware that we have collected only a fraction of the entire vegetation. No single sampling technique can possibly give all the data required of a natural population or community. A given procedure can be best applicable only to certain species or group of species and not to others. This is the reason why the entity to be sampled must first be defined.

The population to be sampled (the *sample population)* should coincide with the population about which information is wanted (the *target population).* Conclusion drawn from the sample apply to the larger population.

3.4 Selecting a sampling procedure

There are several approved methods for drawing samples from a population, each of which has certain advantages depending upon the specific circumstances. If such item in the population is considered to have "equal importance" or where every point in that area is exactly like every other, you can perform either a SIMPLE or a SYSTEMATIC SAMPLING, the latter, useful especially if your population is arranged or lined up or along an environmental gradient. If on the other hand you know that the characteristics of the items in the population differ markedly, and it is possible to classify them you might want to select samples from each of these groupings in order to improve the validity of the survey. This more sophisticated approach is known as STRATIFIED SAMPLING. Finally, as plants may occur in clusters, it is possible to choose a number of clusters at random and measure the particular variable being studied on each of the units or individuals in the cluster. This method is called CLUSTER SAMPLING. Due probably to difficulties in field travel in some situations and/or in order to reduce travel time and cost, this technique may be the only practical means available to conduct the study.

The above sampling methods usually involve plots or quadrats of measured area. Hence, the results obtained using them are likely to be a function of the plot size. In *plotless sampling,* there is the advantage of not having to demarcate plots of a certain size or shape (hence, less laborious). The most popular of the plotless techniques are the POINT-QUARTER (QUADRAT) and WANDERING-QUARTER methods.

3.5 Conducting the study

Once the ecological entity has been defined and the sampling procedure chosen, one can do the actual sampling. How to obtain *representative samples* of the defined population is the next problem. Normally, statistical samples should be taken at random, in which case, you assume that each item in the population has an equal chance of being "picked" and that the occurrence of one individual in a sample in no way influences the inclusion of another. A sampling method is biased if it tends to underestimate a characteristic of the population or a community.

In a taxonomic sense, representative samples are those complete in parts (i.e. sample seaweeds to be collected should have fronds, stipes and holdfasts). Only such whole plants can facilitate correct and proper identification.

A single measurement is generally not enough to be used as basis of conclusions about an ecological characteristic. Replicates should be taken and from them, the mean of the statistical population can be estimated and the amount of error, determined.

In some instances, only portions of ecological samples or subsamples can be taken in the laboratory and studied. So long as the subsamples are taken randomly from the sample, they reflect the characteristics of the entire sample.

3.5.1 Quantitative assessment of abundance and production

Obviously, a large amount of error is inherent in using subjective means of describing vegetation. To at least minimize the error, ecologists resort to quantitative measures, with statistical considerations. Although unavoidably time-consuming, these methods give workers a more realistic picture of the structure and dynamics of a vegetation.

a) *Density (D)* — This is the count of the number of individuals within a series of randomly distributed sample areas (quadrats or plots). The method allows comparison of different areas and different species and is an absolute measure of abundance of the plants. Its disadvantage lies in the large amount of time involved in counting the individuals.

While density (often called *crude* or *absolute density)* is the number of organisms per unit total space or volume, much of the area or volume may not actually be colonized by the population. It is, therefore, more meaningful to speak of the number of organisms per unit of habitable space *(specific* or *ecological density).*

$$Di = \frac{n_i}{A}$$

where: D_i = density of species i;
n_i = total number of individuals of species i;
A = total area sampled

Often, it is more important to know whether a population is changing than to know its size at any one moment. In comparative studies, one generally wants to know the number of individuals relative to other populations. In such cases, *relative species density,* RD, is useful. It is the total number of individuals of a species expressed as a proportion (or percentage) of the total number of individuals of all species present:

$$RD_i = \frac{D_i}{TD} \times 100 \text{ percent}$$

where: RD_i = relative density of species i;
D_i = density of species i;
TD = sum of the densities of all the species

b) *Frequency (F)* — **Frequency is a measure** of the chance of finding a species with any one throw of a quadrat in a given area. Thus, if *Gracilaria* has a frequency of 0.1, then it should occur once in every 10 quadrats examined:

$$F_i = \frac{j_i}{k}$$

where: F_i = frequency of species;
j_i = number of samples (or smaller squares) in which species i occurs;
k_i = total number of samples (smaller squares) taken

The method is done simply by noting whether a species is present or absent in a series of randomly placed quadrats (or in the smaller squares within a quadrat). For example, if 43 quadrats out of a total of 90 contain *Gracilaria,* the frequency is 43/90 = 0.48. This is the same as saying that the probability of finding the seaweed in the sample is 48 percent.

Greig-Smith (1975) proposed two convenient forms of frequency, namely, *shoot* and *rooted* frequency. The former considers a species as "present" only when any part of the plant thallus overlaps into the quadrat. The latter measure considers a species as "present" when it is actually rooted within the sampled area.

The only advantage of frequency as a measure of abundance lies in the ease and rapidity with which an area can be sampled. Values obtained using this method are dependent on the size of the quadrat used, and the size and spatial distribution of the individuals inside the area sampled.

The relative frequency, Rf, is the frequency of a given species expressed as a proportion of the sum of the frequencies for all the species:

$$RF_i = \frac{f_i}{Tf} = 100 \text{ percent}$$

where: RF_i = relative frequency of species i;
f_i = frequency of species i;
Tf = total of the frequencies of all the species

c) *Cover (C)* — This is the proportion of the ground or the substratum occupied by the individuals or parts of the individuals of the species under consideration. It is an estimate of the area covered by the given species, expressed as a percentage of the total area, measured usually by taking a number of points from the sample area and determining at those points which species, if any, is covering the surface of the substratum. As this method involves visual estimates, it is prone to personal bias, as was discussed in relation to frequency ratings;

$$C_i = \frac{a_i}{A}$$

where: C_i = cover of species i;
a_i = total area covered by species i;
A = total habitat area sampled

The *relative cover* (RC) is the cover for a species expressed as a proportion of the total cover of all the species.

$$RC_i = \frac{C_i}{TC} \times 100 \text{ percent}$$

where: RC_i = relative cover of species i;
C_i = cover of species i;
TC = total cover of all species

As a rough and overall estimate of the influence or importance of a plant species in the community, the *importance value* (IV), may be useful:

$$IV_i = RD_i + RF_i + RC_i$$

Saito and Atobe (1970) utilized a more refined method in the estimate of seaweed frequency and cover. The method makes use of a 0.25 m^2 (50 × 50 cm) quadrat, divided into 25 small squares, each measuring 10 × 10 cm^2. This quadrat size of 0.25 m^2 was chosen by first comparing it with bigger quadrats, i.e., 0.5 m^2, 1.0 m^2, the values obtained fitted in a species-area curve.

The *frequency value* (F) of each algal species is determined by counting the number of small squares (10 × 10 cm^2) the species appears in the quadrat (qn), and this will be computed in percent using the formula:

$$F = \frac{qn}{25} \times 100 = 4 \times qn$$

Calculation of the species *coverage* (C) is done by assigning numbers to indicate degree of dominance or cover. The numbers 1, 2, 3, 4 and 5 are used as indices of species coverage in one small square of the quadrat as observed in the field. Each number has a corresponding percentage value when computed in the laboratory as tabulated below:

Index	Degree of cover (in one 10 × 10 cm)	% Equi. (C)	c/25
5	covering 1/2 to 1/1 of the substratum surface	75	3
4	covering 1/4 to 1/2 of the substratum surface	37.5	1.5
3	covering 1/8 to 1/4 of the substratum surface	18.75	0.75
2	covering 1/16 to 1/8 of the substratum surface	9.375	0.375
1	covering less than 1/16 of the substratum surface	4.6875	0.1875

The percent coverage (C) of each species is computed as follows:

$$C = qn \frac{c}{25} + qn \frac{c}{25} + \ldots.. qn \frac{c}{25}$$

where qn, is the number of small squares (10 × 10 cm areas) recorded as having a certain "c/25" cover (see above table occupied by the species.

Evaluation of the similarity or dissimilarity of the algal communities in two study stations is based on Frequency Index Community Coefficient (FICC) values computed as:

$$FICC = \frac{100B}{2A + B + 2C}$$

where: B = sum of the frequencies of the algal species common to both communities, A and C;
A = sum of the frequencies of the algal species present only in community A; (maldistributed species in community A);
C = sum of the frequencies of the algal species present only in community C; (maldistributed species in community C)

The advantage of the above formula over those of Jaccard's (CC_J) and Sorensen's (CCs) Community Coefficient formulae (cited by Brower and Zar, 1977) is that, not only are the total number of maldistributed and common species accounted for, but also their density as they occur in the field as measured in terms of their *frequency.* In other words, FICC involves quantification of the maldistributed and common algal species, whereas, CC_J and CCs account only for the number of maldistributed and common species without consideration of their density.

d) *Standing crop biomass* — This is the weight of existing species in a given area at any one time. Commonly, all the species within a plot are collected, sorted and dry-weighed. The result will give an estimate of the amount of matter produced by a species or a group of species in the area. Where there are large differences in the sizes of species present, standing crop biomass is an import-ant measure of "abundance":

$$B = (D)\ (TW/n)$$

where: B = the biomass;
D = density;
TW = sum of the weights of the individual organisms in a sample;
n = the number of individuals in the sample

Biomass for non-discrete, creeping (hence, non-individually countable) species is simply their absolute weights.

For organisms which vary greatly in moisture content, biomass should be expressed as dry weight rather than fresh weight. Biomass expressed as ash-free dry weight, nitrogen, carbon, or caloric content is useful in cases where the organisms vary in the amount of inorganic skeletal material,

e) *Growth rate (GR)* — This is a measure of how well a species is growing in a given area. Measurements of growth rates in seaweeds depend on their modes of growth, i.e., for *Ulva* and *Porphyra,* it is best to measure the change in area of an initial portion of a frond because they both exhibit diffused growth; for *Laminaria,* which grows by means of an intercalary meristem, growth rate is determined by getting the difference in the *length* of the frond after some time interval:

$$GR = \frac{\overline{AP}}{\overline{AT}}$$

where: GR = growth rate;
$\overline{AP}$ = mean of the change in the parameter used (area, length, weight, etc.)
$\overline{At}$ = mean change in time

f) *Productivity (P)*—This is the rate of organic matter production by organisms. In some cases, estimates of biomass may be useful to measure productivity:

$$P = \frac{B}{T}$$

where: P = gross biomass productivity;
B = standing crop biomass;
T = turnover time

Biomass is usually expressed as units of weight per area (or volume) of habitat, and productivity, as units of weight per unit area (or volume) per unit time. Hence, the turnover time is the number of time units (days, months, years) required to produce as much biomass as is present at the time of measuring the standing crop. .

3.5.2 Determination of other ecological parameters

From the above basic ecological measures, others can be determined to reflect some of the structural aspects of the community not explicit in density, frequency, or cover. Indices of species diversity, dominance and similarity of dissimilarity give better insights on the structure of the community in comparison with other communities or relative to a change in time. For example, the degree of influence of a fertilizer on the floral composition of a seaweed community may be assessed by monitoring the change in the diversity of the community. Physically-stressed habitats are generally less diverse than biologically-controlled ones.

a) *Species diversity* — Species diversity is a measure of the number of species (the* *variety* component) and the relative abundance of the individuals of each species (the *evenness* component). There are a number of diversity indices proposed, each one with its own defined usefulness depending upon the nature of the community in question. Some of the more popular ones are: Shannon-Wiener Index (H'), Brillouin's measure (H) and Simpson's (D).

b) *Ecological dominance* — This is a measure of the degree of control by a species or species groups of the energy flow and the environment of all the other species. A more popular index of dominance is given by Simpson (1949).

$$C = (n_i/N)^2$$

where: C = dominance index;
N_i = importance value for each species (i.e., number, weight, etc.);
N = total of importance values

c) *Similarity/dissimilarity* — Often after knowing the seaweed flora of two or more communities, you ask the question: How similar (or dissimilar) are the communities in terms of the species present? Or you may want to compare the species composition of the same community at two different times. In such instances, indices of similarity or dissimilarity may be useful:

(i) Jaccard's coefficient (CC_J):

$$CC_J = \frac{c}{S_1 + S_{2\text{-}c}}$$

(ii) Sorensen's coefficient (CCs):

$$CC_S = \frac{2c}{S_1 + S_2}$$

where, in both (i) and (ii), c = number of species common to both communities S_1 and S_2.

The index of dissimilarity is 1 - CC_J or 1 - CCs

4. SOME SELECTED PHYSICO-CHEMICAL PARAMETERS

The particular condition that characterizes a natural habitat is the result of myriads of factors, interacting with one another to create an overall, highly specific and prevailing effect that maintains the ecological integrity of the ecosystem as a whole. These factors have . been conveniently classified as biological and physico-chemical factors. Biological factors are active, energy-requiring interrelations among the biotic components, exerting their effects directly on the species, populations, or communities themselves. It is often difficult to directly and immediately determine the degree of effect of these factors. Thus, grazing pressure, pests and diseases, and direct human impact are primarily biological in nature.

Physico-chemical factors, on the other hand, are abiotic factors in the environment that are directly or indirectly and immediately measurable using specific devices and instruments. Under natural conditions, it is impossible to isolate them and pinpoint separately their effects.

There are two important considerations in dealing with ecological factors: factor interaction and factor compensation. Factor interaction emphasizes the fact that "... high concentration or availability of some substance, or the action of some factor other than the minimum one, may modify the rate of utilization of the latter" (Odum, 1971). Sometimes organisms are able to substitute, in part at least, closely related substances for one that is deficient in the environment. Such factor compensation emphasizes the fact that organisms are not just "slaves" to the physico-chemical environment; they adapt themselves so as to reduce the limiting effects of the physical and chemical conditions of existence. Thus, seaweeds with wide geographical ranges almost always develop locally adapted populations ("ecotypes") that have optima and limits of tolerance adjusted to local conditions.

Table 1 gives some ecologically and "operationally significant" factors *(sensu* Odum, 1971) which are known to influence the biological attributes important in the management of seaweed resources. The influence of each of these factors is the subject of another lecture in this course and need not be emphasized here. Their determinations in the field deserves some attention since one factor may give widely differing results depending upon the type of instrument used, the time and place of determination, and the purpose of the investigator. For comparison purposes, field methodologies have to be standardized and intercalibrated.

5. MONITORING: PURPOSE AND NATURE OF THE PROCESS

The primary purpose of the monitoring process is to gather data, adequate and accurate enough to be useful in the prediction and control of major trends in certain biological attributes for management purposes. Hence, monthly monitoring of the growth rate or biomass of natural stocks of the brown seaweed *Sargassum* aims to pinpoint the temporal and spatial peaks and troughs in its organic matter production, as well as those factors that have considerable influence On this attribute. The information generated could be the key in the prediction and control of future production trends in order to sustain yield at an optimum level.

To monitor an ecological factor is to regularly observe, determine and record the changes that occur in that factor as a result of heterogeneity in time and space. However, certain major requirements should first be satisfied before the process is undertaken.

a. The "operationally significant" factors should be known, i.e., those factors which most likely have considerable influence on the biological attribute in question;

b. Temporal and spatial changes, in those factors should be sufficiently covered within the predetermined intervals of operation;

c. The operations should be repeatable and can be carried through at least the time span of a complete life cycle or development of the species or community in question;

d. The data to be generated should come from sufficiently large sample sizes for statistical purposes; and

e. No major technical or administrative problems should be expected to seriously interfere in the course of the operation.

In the Philippines many research projects fail because these are poorly conceived. Their objectives while sound and clearly expressed are more often "sidetracked" at the completion of the project. The data gathered, when validated are unreliable, hence, risky when used as basis for policy decisions. The problem lies primarily in major defects in the monitoring process (if ever such process is made an integral part of the project objectives). The factors chosen for monitoring purposes are dictated either by the availability or type of instruments at hand, or by the literature which more often than not espouses techniques dismally unsuitable under local conditions. To compound the problem, the study intervals chosen, while scientific in intent, decidedly become a function of the irregular and delayed releases of the necessary support funds. The results are wide gaps in data unacceptable for statistical analysis and interpretation.

Baseline data that relate to the biology and ecology of target seaweed species for culture either do not exist, or are poorly known. This is due to the lack of directly relevant literature materials which remains as the major handicap in the conceptualization and implementation of the acceptable experimental design and procedure. Sample sizes and the chosen intervals along transects or through time periods are often arbitrary and dictated by convenience without regard to the natural structure along habitat gradients, seasonal dynamics of the vegetation, or much less, to statistical considerations.

6. SPECIFIC CONSIDERATIONS IN THE MONITORING OF THE SELECTED PARAMETERS

Serious technical, logistical and administrative considerations must be made before any monitoring activity is planned and implemented. These aspects of management have varying degrees of effects on the project objectives. Government agencies mandated to perform general livelihood tasks more often lack the specific technical expertise and the necessary library support to design efficient and acceptable monitoring activities. Their meager research funds, if there exist, are normally tied up with other unrelated office projects and it becomes virtually impossible to transfer funds for a project of lower priority rating. On the other hand, academic and private institutions whose substantial research funds are committed to a particular and specific purpose, enjoy the big advantage of focusing all efforts, time and the monetary allotment to that specific project. Hence, in these institutions, one finds adequate library acquisitions and the necessary equipment and facilities to even extend positively the project activities beyond those expected, and with much better reliable results. This problem varies from agency to agency, public or private, and it is beyond the scope and responsibility of the present training/workshop to deal lengthily with such administrative aspect.

Table 1 lists some biological attributes or parameters that are known to be significantly associated with seaweed culture or management objectives. These parameters are matrix-correlated with operationally significant biological, physical and chemical factors that are known to considerably influence the status of the parameters. The degree of effects of the factors are, for convenience, categorized into low (L), medium (M) and high (H). The degree of effect is low when it is short-term, localized, and does not cause a significant negative shift in the observed trend in the parameters; it is medium when the effect is medium-term, affecting a sufficiently large percentage of the total area or activity, and a degree change above or below its level causes a significant shift in the trend; the degree of effect of a factor is high when it affects negatively a very large percentage of the area or activity, causing a major adverse shift in the trends of the parameters.

Table 1. Matrix table emphasizing the degree of correlation between the biological attributes and some ecological factors of the coastal seaweed environment. L — low; M — Medium; H — high.

	BIOLOGICAL ATTRIBUTES								
	Density	Frequency	Cover	Diversity	Biomass	Productivity	Hectarage	Seasonality	Zonation
Grazing pressure	L-M	L-M	M-H	M	H	L-M	L	L	M-H
Pests and diseases	L-M	L	L-M	M	M	M	L	L-M	L
Direct human impact	H	H	H	M-H	H	M-H	H	L	H
Temperature	L-M	L	L	L-M	M-H	M-H	L	M-H	L-M
Salinity	L-H	L-M	L-M	M	M-H	M-H	L	M-H	L-M
pH/En	L-M	L-M	L-M	L-M	L	M	L	M	L
Nutrients	M-H	M	M	M	M-H	M	M	M-H	L-M
Water movement	M-H	M	M	M	M-H	M-H	M-H	M-H	M-H
Light	L-M	L-M	L-M	M	M-H	M-H	L	M-H	M-H
Tides	M-H	L-M	M-H	M	M-H	M-H	M-H	M	M-H
Toxic substances	M-H	L-M	L-M	M	L-M	M	L	L-M	L-M
Substrate	M-H	M-H	M-H	H	M-H	M-H	M-H	M	H

For exploratory management purposes, most of the factors that correlate with the biological parameters at the M-H and H levels should ideally be monitored. Monitoring of those factors that correlate at the L and L-M levels, on the other hand, may be postponed for a future date when conditions favor their inclusion in the monitoring process. For example, at an experimental farm of the red seaweed, *Eucheuma,* management would be better advised to monitor seedling density, biomass and seasonality as these parameters are affected by urchin or fish grazing, harvesting or "poaching" (direct human impacts), water temperature, salinity and movement, nutrients, tidal exposure, submersion and the possible inflow of toxic substances. On the other hand, if the purpose of management is simply to increase hectarage in a natural community, the factors to be considered in the monitoring process would principally be the direct influence of the activities of the inhabitants, water movement, tides and certain features of the substrate.

It should be noted that the degree of effect of the ecological factors may be species-specific and/or site-specific. More detailed studies are required to pinpoint the causal factors in the observed changes in the production and growth of local seaweeds. This could be done through both laboratory and field experiments. In the Philippines, it is a "rule of thumb" to utilize available foreign information that probably could be useful in the management of a related species.

Among the ecological factors, six emerge as decidedly the more important, as far as their effects on seaweeds under tropical conditions are concerned. These are: direct human impact, nutrients, water movement, light, tides and substrate. Unplanned or uncontrolled collection or harvest, damage wrought by plying boats and coastal development activities (e.g., marinas, ports) affect the seaweed communities not just through direct physical decimation or removal, but also the quality, quantity and availability of nutrients, water flow and circulation, and the amount of light available via increase turbidity and siltation. Tides have been mentioned earlier as a primary factor affecting the fertility of tropical coasts since their diurnal fluctuations affect most other factors in the marine environment. The rapidly increasing industrialization in the Philippines indicates that the shallow coastal portions where seaweeds abound will not in the years to come, improve its productivity in relation to the level where it is now. The prevailing wrong attitude of the people is such that the marine resources including seaweeds are viewed as inexhaustible, easily replaceable with the minimum time and effort. Compounded by their low income, these people turn to the sea as an alternative means to acquiring their basic necessities, but in the most destructive way.

There are other specific considerations associated with. the monitoring process. Basic to science, all activities must have controls. Regularly monitoring the effects of stipe cutting in the growth rate and biomass of *Sargassum* must, by comparative necessity, include a similar set of activities on uncut plants. Data generated in this way give useful information on the advantage or disadvantage of the introduced variable (i.e., cutting), the result inevitably becomes an index of profit or loss left for management decisions. Fortes (1981) emphasized the usefulness of describing habitats in terms of the biological composition and interactions, not in terms of the physico-chemical factors.

For initial field exploratory purposes, monthly or bimonthly sampling may be done, especially if one intends to follow the phenology and production potentials of seaweed species. But once information on the parameters are established, it is not always practical and much less scientific, to do sampling outside the natural phenological cycle of the species. Hence, if a species has a turnover time of 60 days, it would be advisable to sample once every two months. In addition, each country has its own set of meteorological conditions to which local seaweeds directly or indirectly respond physiologically, structurally or through differential species occurrence or composition. In the Philippines, the coastal parts of Regions I and III, and the western sections of Regions IV, IVA and VI belong to the First Climatic Type (Figure 1). These areas are characterized by two pronounced seasons, dry from November to April, and wet during the rest of the year. The north and eastern coasts of Region V, the eastern coast of Region VIII, northern Region X, and the entire eastern portion of Region XI belong to the Second Climatic Type. These areas are characterized by the absence of a dry season, with a very pronounced maximum rainfall from November to January. Coastal Aparri (Region II), Romblon, the eastern halves of Panay (Region VI) and Negros and Cebu (Region VII), eastern Palawan (Region IV), the mid-northern part of Region X, and western Zamboanga (Region IX), belong to the Third Climatic Type. These areas have relatively dry season from November to April and a wet season during the rest of the year. The eastern coasts of Region II, Mindoro and Quezon (Region IV), north-western Samar and western Leyte (Region VIII), northern Cebu and the whole of Bohol (Region VII), northwestern coasts of Region X, Cotabato, eastern Davao del Sur (Region XI), Pagadian, the southern islands of Region IX and the coastal portions of Region XII belong to the Fourth Climatic Type. These areas are characterized by rainfall that is more or less evenly distributed throughout the year.

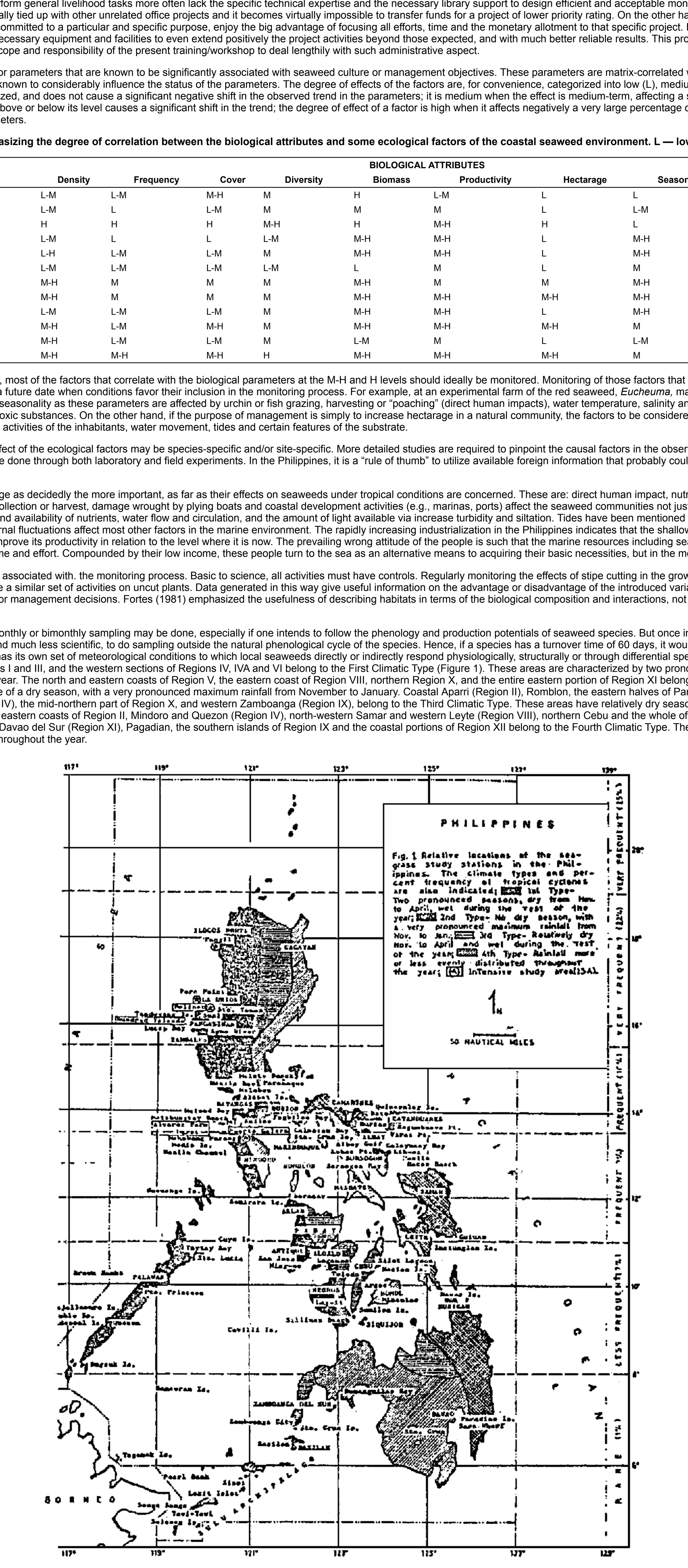

Figure 1. Relative locations of the seagrass study stations in the Philippines

Hence, in terms of climatic types, factor-monitoring could also be location-specific. So long as the major seasons of a climatic zone, and the period (month) when they occur are known, management is well advised to monitor during months representing these seasons. Two but intensive samplings would be minimum for Pangil (Ilocos Norte), Bolinao (Pangasinan), Batangas, western part of Mindoro, the entire western Panay and Negros, and the entire stretch of north-eastern, northern, western and south-western Palawan. One sampling would be representative of the dry season (from November to April) and another, representative of the wet season (May to October). Field monitoring in the other parts of the country should be spread evenly throughout the year. Contingency alternative monitoring periods are required in the more northern parts of the country where the frequency of tropical cyclones is highest.

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Lecture 6 and Practicum 7
INVENTORY AND ASSESSMENT OF ECONOMICALLY IMPORTANT SEAWEED STOCKS(continue)

7. DATA PROCESSING AND INTERPRETATION

Once the data are available, they should first be organized and systematized to facilitate the statistical procedures used in data analysis. It should be emphasized that it is only by means of *statistical methods* that: (a) characteristics of sets of data can be quantitatively described and summarized; (b) conclusions about large sets of data, using only samples of them can be drawn; and (c) relationships between sets of data established. Hence, in the present paper, simple statistical manipulations will be frequently encountered but for no other reason that the fact that a good ecological work requires them.

An understanding of some basic statistical concepts is needed at this point:

a. Statistical population — the entire set of data about which we wish to draw conclusions. (For example, a population of *Gracilaria).*
b. Statistical sample — a portion of the statistical population.
c. Parameter — in statistics, it is a measure that describes or characterizes an entire population of data. (For example, density or frequency of *Caulerpa).*
d. Statistics — descriptive measures derived from sample data taken from the population. (For example, mean and median).

7.1 Descriptive statistics

Although we cannot directly measure a parameter of a population, we can describe, for example, the density of a seaweed population by using the:

a) Mean — this is a measure of the central tendency of a population and is computed as:

$$\bar{X} = \Sigma X/n$$

where: $\bar{X}$ = sample mean; ΣX = sum of all values of X in the samples; n = number of data in the sample

The sample mean is a reasonable estimate of the population mean only when the former is obtained at random from the entire population.

b) Median — this is the middle measurement in a ranked data. If there are an even number of data, the median is the mean of the two middle measurements.

c) Range — a measure of how variable the gathered data are, the range is simply the difference between the largest and the smallest measurement. The big disadvantage in using the range to describe dispersion of sample data is that it tends to underestimate the population range.

d) Standard deviation (s) — this is a mea sure of how the data are dispersed relative to the mean. For this reason, it becomes very useful in statistics:

$$s = \sqrt{s^2}$$

where: s = sample standard deviation; s^2 = sample variance

e) Variance — this variance is:

$$s^2 = SS/DF$$

where: SS ("sum of squares") $= \Sigma(X - \bar{X})^2$; DF ("degrees of freedom") = n — 1

f) Standard error — we ask the question: How precise is our estimated mean? If we have replicates of, for example, the cover of *Caulerpa* taken from a population, each sample will have a different mean and how the sample means vary from each other can be measured by the *standard deviation of the mean* or *standard error* (SE).

$$SE = s/\sqrt{n}$$

where: s = standard deviation; s^2 = number of data in the sample

g) Confidence interval — with a known standard error, we can set a range, with a stated level of confidence, within which the population mean lies:

(1 — α)confidence interval for population *mean*, $\mu = \bar{X} + SE$

where: α = significance level; $\bar{X}$ = sample mean; SE = standard error

The value of t is obtained from a statistical distribution known as "Students' t", a portion of which is given below:

DF	α= 0.10	α= 0.05	α= 0.02	α= 0.01
1	6.31	12.71	31.82	63.66
2	2.92	4.31	6.96	9.92
3	2.35	3.18	4.54	5.84
4	2.13	2.78	3.75	4.60
5	2.01	2.57	3.36	4.03
6	1.94	2.45	3.14	3.71
7	1.89	2.36	3.00	3.50
8	1.86	2.31	2.90	3.36
9	1.83	2.26	2.82	3.25
etc.	etc.		etc.	etc.

7.2 Selecting statistical sample size

In general, the greater the value of n = (number of data ion the sample), the smaller the amount of error and the more precise the estimate of the population mean. This is evident from the formula for SE above. From this relationship, we can determine the number of data (n) required to estimate the population mean with a specified precision.

7.3 Comparing statistical populations

Phycologists may often ask the question: Are the mean seaweed biomass of, for example, two apparently similar portions of the shore, the same? Are they the same in two different seasons? The community coefficients (CC_J and CC_S) discussed above give only the relative degree of similarity between the communities. They do not tell us whether that difference is a result of habitat — specific conditions or of other factors.

The more common tests to compare statistical populations are: two sample (or t-) testing, multisample testing (analysis of variance, ANOVA) and non-parametric testing.

The first two are applicable only in instances where the populations being compared have equal variances and each population is composed of data which conform to the "normal distribution". For example, lengths, weights, heights and rates can be compared using t-testing and ANOVA. But percentages or proportions, densities, pH and other data measured on a non-linear scale should not be subjected to the above tests. Instead, they are analyzed using non-parametric or distribution-free methods.

7.4 Qualitative description of study site

This aspect of the study should be considered in terms of:

7.4.1. Location — specific municipality where it is located; describe in relation to major bay(s) in the vicinity; use bathymetric or topographic maps, with compass bearings;

7.4.2. General physiographic setting — reckon in terms of:

a. type of shoreline; general features of the reef
b. dominant substrate
c. in relation to major natural or artificial structures
d. dominant associated flora and fauna
e. major curent patterns; wave exposure
f. dominant associated activities of local inhabitants
g. specific disturbances of the habitat

7.5 Quantitative description and summarization of data

This portion of the study is to be done at both the station- (i.e., specific transect) and site- (i.e., considering all transects) levels.

7.5.1. Biological parameters

a. species composition
b. mean species relative frequency (RF%) for both seaweeds and seagrasses
   - specific or in relation to its community
   - general or in relation to both communities
c. mean species relative cover (RC%) for both seaweeds and seagrasses
   - specific
   - general
d. mean species biomass (dry wt.: wet wt. difference, gm/m^2) for both seaweeds and seagrasses
   - total per community
   - total for both communities
   - wet wt.: dry wt. ratios — for each species
e. species diversity
f. community similarity

7.5.2 Physico-chemical parameters

a. mean temperature (°C) per station, surface and bottom; overall mean for site (surface and bottom)
   - min-max thermometer reading
   - temperature profile
b. mean salinity (‰) per station; overall
   - salinity profile
c. mean dissolved oxygen (mg/l) per station; overall
   - DO profile
d. mean light intensity ($\mu E\ mol^{-1}\ sec^{-1}$) per station; overall
   - light intensity profile
e. bottom type and contour per station; overall

7.6 Objective assessment of differences and relationships of the sets of data

This aspect of the study would primarily deal with:

a. correlation and regression
b. statistical tests
c. graphical presentations (i.e., histogram, curves, 3-dimensional structures, pie-diagrams, matrices, etc.).

7.7 Drawing conclusion from the data

This aspect of the study is almost solely dependent on the experience and knowledge-ability of the worker. Relevant information available from the literature and data obtained from measurements of environmental variables are very useful at this point. But they are so only to the extent of supporting and/or supplementing the primary findings just made. So long as the interpretation of results and the conclusions drawn from the data have conformed to the steps outlined above, in a form that is easily comprehensible, and they answer the basic questions posed before the survey was conducted, it is fairly reasonable to assume that a "good job" is almost done.

The important questions to answer at this point include:

7.7.1. Basic considerations

a. Which species or species group was dominant? Least dominant?
b. What do the trends in the parameters suggest?
c. Which physico-chemical factors had apparent control over the observed trends?
d. Were there indications of species/community interactions (positive or negative)?

7.7.2. Management considerations

a. Which species or species group had the best potential for culture or intensive study?
b. If the study were carried monthly through a year's duration.
c. What could be the most important issues in the conservation and optimum utilization of the seaweed resources at the site?
d. What are the major problems and limitations?

CONCLUSIONS

To monitor a parameter that controls the development of seaweeds, whether it be in the field or in the laboratory is to regularly gather, determine and record changes in that parameter through time and space. The process becomes impractical and untenable when too many factors are considered. Hence, only the operationally significant factors should be included in the monitoring process. Factor-monitoring could be species and/or site-specific.

A serious consideration of technical, logistical and administrative support should be made before any attempt to monitoring is undertaken. The failure of many research projects lies in their being poorly conceived, often the monitoring component is so defective, or management is not outwardly supportive of the project objectives. The lack of government emphasis on seaweed research evidenced by the lack of equipment, library facilities and personnel incentives, remains as a primary obstacle to the development of the seaweed industry in the Asia-Pacific.

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Lecture 7
THE TAXONOMY OF COMMERCIALLY IMPORTANT SEAWEEDS IN THE PHILIPPINES AND TROPICAL ASIAN-PACIFIC REGION

by

Gavino C. Trono, Jr.[1]

1. INTRODUCTION

The utilization of seaweeds as items of food and as raw materials for industries highlights the economic importance and potentials of these fishery resources. The increasing contributions of the seaweed industry to the foreign trade as well as the utilization of a number of species as food in some Asian countries have emphasized the need to develop the large but untapped potentials of these resources in the region.

In the Philippines, seaweed and seaweed products have gained prominence as the number three fishery export behind shrimps and tuna during the last five years. More-over, seaweed farming and/or gathering of natural stocks have become a productive alternative or additional source of livelihood among the coastal populations who are not at all benefited by industrial developments. The relevance of the seaweed resources to the economic welfare of the artisanal fisher-men and their families has been emphasized recently because of the degraded conditions of many of the shallow coastal fishing areas in the country. At present, thousands of fishermen and their families in Tawi-tawi, Sulu and Central Visayas are gainfully engaged in the farming of seaweeds. Seaweed farming has become a major industry in these places.

One of the basic problems which prevents the rapid development of the seaweed resources in the Philippines and in the other developing countries in the tropics is the lack of information on the identities of economically important species of seaweeds. The taxonomy of seaweed species has been identified as "the greatest single obstacle in the progress of seaweed aquaculture and natural products chemistry in the Pacific. Taxonomy is the hidden, natural products chemistry in the Pacific. Taxonomy is the hidden, but important foundation of the superstructure of aquaculture and mariculture, whether of mollusks, crustaceans, fish or seaweeds..." (Sullivan, 1985).

The taxonomy of seaweeds of commercial value is in many cases not known. The correct scientific names attached to commercial species are tremendously important because the quality of the phycocolloids derived from them are so divergent, i.e., the gel properties are very different depending on the species. The prices, for instance, of local species of agarophytes differ significantly because of the differences in the agar quality they contain. Buyers/processors need to know the kind and quality of the product they are buying, e.g., *Gelidiella acerosa* commands a price many times higher than *Gracilaria "verrucosa"* because of the better gel it contains. The correct name attached to a seaweed is thus, very important because it provides the clue to the identity of the species which is used as basis for determining the value of the product.

2. THE TAXONOMY OF THE COMMERCIALLY IMPORTANT SEAWEEDS IN THE PHILIPPINES

2.1 The Philippine agarophytes

The agarophytes are agar-producing sea-weeds which belong mainly to several genera in the Rhodophyta. Included in this group are the genera-*Gracilaria, Gelidiella, Beckerella, Laurencia, Gelidium* and *Pterocladia*. Of these genera *Gracilaria* and *Gelidiella* are commercially utilized. The other genera are not economically utilized for various reasons, e.g., *Beckerella* although has great potential because of its large size is not a common species; *Laurencia* is common and appear to have large naturally produced biomass but except probably for one species, the quality of the agars of the several large species are not known and thus, have not been commercially utilized; *Gelidium* and *Pterocladia* although well known for their good quality agars, their representative species are too small for commercial utilization. In addition to these genera, there are probably other species which are not yet known.

These genera are also found in the tropical Asia and Western Pacific countries.

2.1.1 The genus *Gracilaria*

The genus *Gracilaria* belongs to the Family Gracilariaceae, Order Gigartinales. This genus is fairly well known in the Philippines. Abbott (1985) listed some 17 species based on records available (refer to Annex A). However, except for seven species namely, *G. arcuata, G. "verrucosa"* the identities of the other species have to be verified. It would appear, however, that several of these binomials are names which have been misapplied to these taxa.

The genus *Gracilaria* is characterized by plants that generally have fleshy and succulent, and in one species cartilaginous thalli which consist of a holdfast, and cylindrical to compressed or foliose branches. The thallus grows by means of a group of apical cells and is multiaxial in construction. The thallus is basically filamentous but the filaments become compact to form pseudo-parenchymatous tissue. The tetrasporangia are cruciate and occur generally in the cortex of the mature thallus.

The gametophytes are dioecious. The female thallus when reproductive forms a fertile structure called the cystocarp. The fertile male thallus produces the spermatangia in cavities called the conceptacles. The conceptacles are mainly limited to the outer cortex and may be one of general forms, namely, pot-shaped, cup-shaped and saucer-shaped. In first type the cavity is deep with a narrow opening; in the second the opening has the same diameter as the diameter of the conceptacle while in the last type, the conceptacle is shallow. Although the male plants are not commonly collected, the type of conceptacle it possesses is diagnostic of the species and so these are very important.

The key and descriptions of the eight species of *Gracilaria* are contained in the paper by Trono, Azanza-Corrales and Manuel (1983), a copy of which is appended. Reports of other species are found in the literature but I feel that these need verification.

2.1.2 The genera *Gelidium, Pterocladia, Beckerella* and *Gelidiella*

These are genera under the Order Gelidiales. The first three belong to the Family Gelidiaceae and the last to the Family Gelidiellaceae. These are characterized by generally tough and wiry thalli (dried) with a distinct apical cell at the tip of the branch.

Key to Genera:

1.	Presence of rhizines or thick walled rhizoidal filament in the cortex and/or medulla	2
1.	Absence of rhizines in cortex and/or medulla	*Gelidiella*
	2. Cystocarp unilocular	*Pterocladia*
	2. Cystocarp bilocular,	3
3.	Thallus large, branching regularly pinnately branched, branches with distinct midribs	*Beckerella*
3.	Thallus small, branching irregular, branches without midrib	*Gelidium*

2.1.3 The genus *Gelidiella*

The genus *Gelidiella* is represented by several species but except for *G. acerosa*, these are small and thus, are not utilized in the manufacture of agar. Only *G. acerosa* is presently harvested from natural stocks for agar processing.

The thallus of *G. acerosa* consists of cylindrical stolon from which erect and decumbent branches arise. The branches are cylindrical and bear pinnately arranged determinate branchlets. In fertile materials, tetrasporangial stichidia are borne near the tips of the determinate laterals. No gametophytes are known. This species is pantropic and therefore found in most tropical countries.

Other species of *Gelidiella* which have been reported in the Philippines are:

1. *G. myrioclada* — Tuft forming habit, erect branched well-branched; very small — 1–1/2 cm tall.
2. *G. tenuissima* — With creeping stolon attached by small hapters at regular intervals.
3. *G. adnata* — With creeping stolon attached by rhizoids along the entire ventral side of the stolon. Erect branches simple. Tetrasporangial stichidia stalked from the stolon.

2.1.4 The genus *Gelidium*

The Philippine *Gelidiums* are not well known taxonomically. There are, however, reports of four common species in the Western Pacific area and the South China Sea region. But undoubtedly these species are also present in the Philippines and other countries in tropical Asia and Western Pacific Region.

1. *G. crinale* — Small species like the other three below but is quite distinctive from them that the branches are mainly cylindrical to subcylindrical in contrast to other which have compressed to flattened branches.
2. *G. pusillum* — Branches compressed to flat; turf forming.
3. *G. divaricatum* — Branches compressed to flat, not forming turf, the main branches broader than the laterals.
4. *G. puchellum* — Branches compressed to flat, not forming turf, main branches and laterals same in width.

2.1.5 The genus *Pterocladia*

Like *Gelidium* this genus is not well known taxonomically in the Philippines. So far very few unreliable reports are available in the literature. The reports are based mainly on the morphology of the materials. The similarity between this genus and *Gelidium* has been emphasized, i.e., these two are morphologically very similar. The distinction lies mainly on the structure of the cystocarp, e.g., *Pterocladia* has a unilocular cystocarp while in *Gelidium* it is bilocular. Thus, reports on the species of *Pterocladia* which do not include the information on the type of cystocarp are always doubtful.

2.1.6 The genus *Beckerella*

Only one species of *Beckerella, B. scalaramosa* has been reported in the Philippines. The thallus consists of stoloniferous axis from which erect branches arise. The main branches are flattened/compressed and percurrent. Branching is pinnate. This species has only been reported from Bulusan, Sorsogon, Southern Luzon growing on the coralline wall of deep tide pools.

2.1.7 The genus *Laurencia*

The genus *Laurencia* is one of the more common components of seaweed communities on reefs in tropical areas. The genus is easily recognized by the form of its determinate branchlets which are generally clavate in shape with a single pit at the tip from where tufts of uniseriate hairs called Arichoblasts arise.

Although the genus is taxonomically relatively well known in the Philippines, this is not at present being utilized as raw materials for the manufacture of agar because the quality of the colloids is not known. Among the many species, only *L. flexilis* has been reported as possessing good quality agar.

The paper of Saito (1969) is a major paper which covers the taxonomy of the genus in the Philippines, a copy of which is appended. Among the species which have been reported here are *L cartilaginea, L flexilis, L japonica, L majuscula, L mariannensis, L obtusa, L. papillosa, L parvipapillata, L subsimplex* and *L. tronoi*.

2.2 The carrageenophytes

The carrageenophytes are carrageenan-producing seaweeds. The genera *Eucheuma* and *Hypnea* are two important genera of carrageenophytes which are abundant in the Philippines and in the tropical Asia and Western Pacific. More recently *Acanthophora spicifera* has been reported to contain iamba carrageenin which is not produced by either *Eucheuma* or *Hypnea*. At present, the most important of the many genera of carrageenophyte is *Eucheuma* which is at present the main base of the seaweed industry in the Philippines and Indonesia, although the latter is producing only a few thousand tons of this seaweed recently. The development of the culture technology for this genus has boosted tremendously production in the Philippines to an estimated 60 000 MT in 1987.

2.2.1 The genus *Eucheuma*

The genus *Eucheuma* belongs to the Family *Solieriaceae* of the Order Gigartinales. Of the more than two dozen species known in the world, seven species of *Eucheuma* are present in the Philippines. These are *E. denticulatum (E. spinosum), E. procrusteanum, E. cottonii, E. striatum, E. arnoldii, E. gelatinae* and *E. alvarezii. Eucheuma alvarezii* and *E. denticulatum* are the species presently produced through mariculture in the Philippines and Indonesia. *E. alvarezii* and *E. gelatinae* are also cultured in Hainan Island in China.

The thalli of *Eucheuma* are very cartilaginous, may be prostrate or erect in habit and consist of cylindrical to compressed branches except in one species whose thallus is a thick and flattened blade (*E. procrusteanum*). Gamophytic and sporophytic thalli have been reported for many species. Fertile female thalli develop distinct cystocarps which appear as mammillate structures. The male thalli, however, appear to be uncommon.

Key to Philippine species of *Eucheuma*

1. Thalli prostrate	2
1. Thalli erect	3
2. Thalli segmented; branches compressed with marginal and ventral spines; axiferous	*E. gelatinae*
2. Thalli not segmented; branches cylindrical, mottled, fused with each other at certain portions to form crust (erect, branches may be present); anaxiferous	*E. cottonii*
3. Thalli may or may not be segmented: segment(s) of flattened blades	*E. procrusteanum*
3. Thalli consisting of generally cylindrical branches	4
4. Determinate branchlets in form of whorled simple or branches spines	5
4. Determinate branchlets coarse, irregularly arranged spines	6
5. Determinate branchlets distinctly arranged as simple whorls of spines, at the distal portions of the branches	*E. denticulatum* = (*E. spinosum*)
5. Determinate branchlets arranged as compound discrete whorls of branched spines or covering the entire branch completely: anaxiferous	*E. arnoldii*
6. Main axes not percurrent, roughened by presence of secondary coarse determinate spinose branchlets; branching close with angular axis: branches uniform in diameter but abruptly tapered to the tip; axiferous, medullary core of axial hyphae absent in branches less than 5 mm in diameter	*E. striatum*
6. Main axis percurrent generally (or may be obscured) smooth and cylindrical with only indeterminate branches interrupting; branching open with generally round axis; branches larger at their bases (inflated) and tapering towards the apices; axiferous, medullary core of axial hyphae persistent in at least 10 cm below the tip of any indeterminate branch less than 5 mm in diameter	*E. alvarezii*

Brief descriptions of the species

1. *E. alvarezii* — Thallus erect, large; main axes percurrent or may be obscured by secondary axes; axes and branches cylindrical; branching open with rounded axils; diameter of branches larger at base and tapering towards the tip: axiferous, the medullary core of axial hyphae persistent to at least 10 cm below the tip of any indeterminate branchlets less than 5 mm in diameter; kappa-carrageenan producing species.

2. *E. arnoldii* — Thallus erect, "coral-like" in appearance; branching irregular; branches anaxiferous with compound whorls of simple and/or branched spines, or these may cover the entire distal portion of the branches to obscure the whorled arrangement of the determinate branchlets; kappa-carrageenan producing species.

3. *E. cottonii* — Thallus prostrate, attached to the substrate by hapters at ventral parts of the branches; branches become fused with each other at certain portions to form crust-like mass; semi-erect branches may be formed in plants growing in habitats less exposed to strong wave action; dorsal portions of the branches generally "mottled" in appearance; anaxiferous, kappa-carrageenan producing species.

4. *E. denticulatum* — Thallus erect, branching from the main axes irregular; branches cylindrical characterized by the presence of regularly whorled determinate branchlets (spines); whorled arrangements of spines in the older portions of the branches is obscured by the development of adventitious spines; axiferous, the core of axial hyphae persistent throughout the branches; iota-carrageenan producing species.

5. *E. gelatinae* — Thallus prostrate, attached to substrate by hapters from the ventral side of the thallus; branches segmented, flattened; with spines at the margins and the ventral surface of the branches; axiferous, with many filamentous medullary filaments extending throughout the segment; kappa-carrageenan producing species.

6. *E. procrusteanum* — Thallus erect, of a single flattened blade or may be segmented consisting of several flattened blades; anaxiferous.

7. *E. striatum* — Thallus erect, axes not percurrent roughened by presence of spinose determinate branchlets; branching close, branch axils angular; branches generally uniform in diameter and abruptly tapered to the apices; branches partly axiferous, medullary core of axial hyphae present in main branches not less than 5 mm in diameter.

2.2.2 The genus *Hypnea*

The genus *Hypnea* belongs to Family Hypneaceae, Order Gigartinales. Although many species are listed in Philippine literature, it is not generally well known. No monographic studies on the genus has been done for the Philippines and other Asian countries. Many of the binomials cited in the literature for the Philippines appear to have been misapplied.

The thallus is generally fleshy and crispy. Like most species of *Gracilaria* the branches collapse when pressed between fingers. Branching is irregular, the branches are generally cylindrical or slightly compressed at certain portions; monoxial with apical cell very prominent at the tips of the branches/branchlets. Determinate branchlets simple or branched, mostly spine-like. Both the gametophyte and sporophytic generations are large and of the same form (isomorphic). Fertile female plants produce prominent cystocarps while the tetrasporophytes produce tetrasporangia in swollen stichidia on the determinate branchlets (spines); tetrasporangia are zonate.

Key to species:

1. Plants forming thick dense clumps/mats	*H. pannosa*
1. Plants erect, free or forming loose clumps	2
2. Main axes percurrent cylindrical clothed with long, simple or sometimes branched cylindrical determinate branchlets	*H. valentiae*
2. Main axes not percurrent, determinate branchlets fine to coarsely spinose	3
3. Main branches less than 0.5 mm in diameter, determinate branchlets (spines) gradually tapering to a sharp tip	*H. esperi*
3. Main branches cylindrical or slightly compressed at certain portions; more than 0.5 mm in diameter; determinate branchlets mainly simple and abruptly pointed	4
4. Branchlets slightly compressed; with stellate (star-shaped) branchlets in addition to simple spines	*H. cornuta*
4. Branchlets cylindrical with "cervicorn" (antler-type) branchlets in addition to simple spines	*H. cervicornis*

Brief descriptions of the species

1. *H. cervicornis* — Plants forming loose clump; branching irregularly alternate; branches cylindrical; determinate branch-lets mainly simple abruptly pointed at the tip (spines). The presence of "cervicorn" branches/branchlets is a distinct feature stichidia pedicellate, swollen and borne mostly at the middle portions of the spinose branchlets.

2. *H. cornuta* — Plants forming loose clump; branching irregularly alternate; branches slightly compressed; determinate branchlets mainly simple sharp spines; the presence of stellate branchlets in addition to the simple forms is a distinct character of the species.

3. *H. esperi* — Plants small, forming loose clump; branching irregularly alternate; branches fine, less than 0.5 mm in diameter; determinate branchlets gradually tapering to a sharp tip. Tetrasporic stichidia are found at the tip or just below the tip of the branchlets (spines).

4. *H. pannosa* — Plants form dense thick mats; branching irregularly alternate to somewhat pinnate to irregularly divaricate; branches fused with each other at some parts, slightly compressed or subterate with many short, stout spinose ultimate branchlets; tetrasporangial stichidia saddle-shaped, formed on one side of the spinose branchlet.

5. *H. valentiae* — Plants erect, forming loose tuft; branching lax, irregular alternate the percurrent main axis and cylindrical branches covered with relatively dense, long, slender, cylindrical determinate branchlets which are simple or branched. The tetrasporic stichidia form swollen bands around the determinate branchlets a short distance from or very near the base, or occasionally forming swollen cap at the tip of very short branchlets.

2.2.3 The genus *Acanthophora*

This genus belongs to the Family Rhodomelaceae of the Order Ceramiales. Two species are known in the Philippines. *A. spicifera* and *A. muscoides*. Recent study showed that *A. spicifera* contains iota-carrageenin.

The thallus of *A. spicifera* is fleshy and like *Hypnea* the branches collapse when pressed between fingers. The thallus is erect, the branching is irregular and the main axis is percurrent. Determinate branches are spirally arranged/attached along the main axis at regular intervals The determinate laterals bear spirally arranged spines.

Both gametophyte and tetrasporic thalli are commonly collected. The female thallus bears distinct urn-shaped cystocarps while the male thallus on the other hand forms tetrahedral sporangia at the swollen tips of the spines.

2.3 The Philippine alginophytes

The alginophytes are alginate-bearing seaweeds. The known alginophytes belong mainly to the genera *Sargassum, Turbinaria, Hormophysa, Cystoseira* and *Hydroclathrus*. The genera *Sargassum* and *Turbinaria* are proven raw materials for the manufacture of alginates in some Asian countries. The last three genera and several others have been listed as potentials for the manufacture of alginates but the potentials of *Hydroclathrus, Cystoseira* and *Hormophysa* over the two others are higher because of these are available in large quantities from natural stocks. These genera are also common components of seaweed communities in Asian countries and Western Pacific.

The genera *Sargassum* and *Turbinaria* belong to the Family *Sargassaceae* and *Hormophysa* to the Family *Cystoseiraceae* of the Order Fucales: *Hydroclathrus* on the other hand belongs to the Family *Scytosiphonaceae* of the Order Dictyosiphonales.

2.3.1 The genus *Sargassum*

The genus *Sargassum* is very difficult and may be considered a nightmare among the taxonomists. Very little is known about this large genus in the Philippines. It is, however, a very common component of seaweed communities and is distributed widely in the country. More than 30 binomials (names) for *Sargassum* have been listed in the literature (Velasquez, Trono and Doty, 1975) but the correctness of more than 80 percent of these names are suspect.

The difficulties in the taxonomy of this genus stem mainly from the fact that this is a very polymorphic genus. *Sargassum* is perennial and the primary growth and the succeeding growth (2nd year) phases are entirely different. In addition, the old binomials which have been applied to the different taxa were based only on portions of a thallus or of a growth stage of thallus of a taxon. As far as I am aware, the only authoritative work on Philippine *Sargassum* is that of Ang (1987) although the work was limited only to the *Sargassums* in Calatagan, Batangas and includes seven species.

Key to the species reported from Balibago, Calatagan, Batangas:

1. Axis of erect branches terete or slightly compressed leaves arise in all directions	2
1. Axis of erect branches strongly compressed; leaves distichous, alternative	*S. binderi*
2. Leaves generally not undulate, or undulate only in those of the lower order of branches; vesicles numerous, those associated with higher branches very small, up to 4 mm in diameter	3
2. Leaves thick, strongly undulate; vesicles few, large, up to 10 mm in diameter	7
3. Vesicles, generally spherical, or slightly compressed, mutocous, apiculate or sometimes winged, receptacles subcymose to racemose,	4
3. Vesicles, consistently ovate to oblong, mutocous or sometimes apiculate; receptacles cymose	*S. cinctum*
4. Female receptacles mainly trigonous to triquetrous, slightly to strongly twisted	5
4. Female receptacles mainly flat or compressed at base becoming triquetrous towards tip, no twisting	6
5. Female receptacles irregularly serrate or dentate, triquetrous and strongly twisted; leaves clavate, obovate to oblong, with average length/width ratio between 5 to 10	*S. siliquosum*
5. Female receptacles smooth or slightly dentate, trigonous and occasionally twisted, leaves ovate, obovate to elliptical, with average length/width ratio between 5 to 10	*S. paniculatum*
6. Terminal branchlets smooth; receptacles with subtending bracteal leaf	*S. ilicifolium*
6. Terminal branchlets muricate; upper half of female receptacles dentate	*S. baccularia*
7. Leaves with thickened edges, terminal or apical ones with edges double	*S. crassifolium*
7. Leaves with edges not thickened	*Sargassum sp.*

The binomials included in the above key are considered as correctly applied binomials to the *Sargassum* species. In addition, the following are also considered as good species: *S. polycystum. S. cristaefolium, S. polycystum* differs from *S. siliquosum* by its ramifying (branching) holdfast in contrast to the non-branching holdfast of the latter, other morphological characteristics as the size and shape of the leaves, the presence of numerous, small floats in mature plants and the rough or muricate nature of the primary branches are quite identical. They also differ in the type of habitat, i.e., *S. polycystum* grows in the inner protected portions of the reef where water movement is minimal while *S. siliquosum* thrives in habitats exposed to relatively strong waves/currents.

Sargassum cristaefolium (= *S. duplication*) appears to be similar in appearance to that of *S. crassifolium* based on their morphology. The two species differ on the nature of the "duplicate leaves". In *S. cristaefolium*, the large relatively thicker leaves are duplicated at their tip portions, i.e., the "double" apical portions involves the distal portion of the blade in contrast to *S. crassifolium* where the "double" apical portions of the leaves only involves the edges of the apical margin of the leaves as indicated by the double rows of teeth.

Detailed descriptions of the different species are found in the paper of Ang and Trono (1987).

2.3.2 The genus *Turbinaria*

The genus *Turbinaria* (Family Sargassaceae, Order Fucales) is one of the brown seaweeds which is as common as the genus *Sargassum*. It is also one of the major components of seaweed communities although it is not as abundant (biomass) as the latter. This genus is quite well known in the Philippines. It is represented by the following species: *T. ornata; T. decurrens; T. conoide* and *T. luzonensis*. The first three species are well known and widely distributed in the tropical Asia and Western Pacific Region.

The thallus of *Turbinaria* is fleshy and consists of rhizomatous or haptercid holdfasts from which a simple or branched erect axis arise. The leaves are of different forms depending on the species, i.e., may be triangularly obpyramidal, turbinate or peltate in shape. The truncate top of the leaves is in most species, with thin expanded blade-margin in which a vesicle is embedded. *T. luzonensis*, the expanded margin is very much reduced or lacking. Except for the few varieties, the leaves of *Turbinaria* possess air bladder or vesicle immersed in the swollen distal portion of the leaves.

Like in *Sargassum* the gametangia are produced in conceptacles embedded in the receptacle.

Brief description of the species:

1. *T. ornata* — Thallus coarse, dense and fleshy. Leaves large distinctly turbinate with terete stalk. Distal marginal blade moderately expanded and often reduced in one side; thick, rounded to triangular from top view; margin of the blade with coarse teeth; in the center of the blade is the vesicle, on top and around it is a crown of teeth. The teeth are absent in some varieties. Receptacles is branched, racemose and attached on the stalk of the leaves.

2. *T. conoides* — Thallus lax, to more than meter long; stipe or axis branching; leaves numerous, stalked, the distal marginal blade thin and well-developed, generally triangular in top view, the margin sharply dentate; the body of the leaves abruptly inflated due to the presence of a prominent vesicle.

In most materials, the leaves are campanulate in form with well-developed vesicles.

Receptacles : are attached near the base of the stalk of the leaves.

3.*T. decurrens* — Thalli mainly short; compact; erect stipe unbranched. Leaves distinctly triangular from the top view, the distal end abruptly cut, the distal blade very much reduced to a sharp, thick minutely dentate margin. The lateral faces of the leaves are separated by sharp dentate ridges extend to the distal end of the leaves. Vesicle small, deeply embedded in the leaf.

Receptacle racemose, dense and attached to the base of the leaves.

4. *T. luzonensis* — Thallus small to 10 cm tall. Erect axis simple or with few laterals. Leaves small, sharply inflated towards the distal end with well-developed vesicle. Distal marginal blades absent or very much reduced to a narrow ridge which may be sparingly toothed. Top view of vesicle is rounded to slightly triangular. Receptacle racemose and attached at the base of the stalk of the leaves.

2.3.3 The genus *Hormophysa*

This genus *Hormophysa* (Family Cystoseiraceae. Order Fucales) is also a common component of seaweed communities usually mixed with *Sargassum* and *Turbinaria*. It is represented by only one species, *H. triquetra*.

The thallus is large, bushy and fleshy and grows up to 40 cm tall. It is attached to the substrate by a discoid holdfast from which erect axes arise. The branches are foliaceous and segmented, the segment commonly with centrally disposed oblong vesicle embedded inside. The segments are more distinct in fertile materials and the narrow or reduced blade make the segments distinctly tri-ridged. The segments especially towards the distal portions of the fertile thallus are triangular in cross-section with the ridges extended into thin narrow blades. In sterile materials, segments especially at the basal portion, have broadened, well-developed blade. The margin is serrate to dentate.

2.4 Seaweeds utilized as food

Seaweeds have long been utilized as food by people living along the coastal areas in the country. These are prepared as fresh salad vegetable or blanched in boiling water and prepared into salad. Others are used as vegetables mixed with fish or meat. Some are also prepared into dessert gels.

A large number has been listed as food but the following species are commonly utilized:

Chlorophyta (greens)
- *Caulerpa lentillifera*
- *C. peltata*
- *C. racemosa*
- *Codium edule*
- *C. intricatum*
- *Enteromorpha clathrata*
- *E. flexuosa*
- *E. intestinales*
- *Monostroma nitidum*
- *Ulva lactuca*

Phaeophyta (browns)
- *Colpomenia sinuosa*
- *Hydroclathrus clathratus*
- *H. tenuis*
- *Sargassum* spp. (young shoots)
- *Spathoglossum* sp.

Rhodophyta (reds)
- *Acanthophora spicifera*
- *Asparagopsis taxifolia*
- *Catenella impudica*
- *Eucheuma* spp.
- *Gelidiella acerosa*
- *Gracilaria* spp.
- *Gratiloupea filicina*
- *Halymenia durvilleai*
- *H. dilitata*
- *Hypnea* spp.
- *Laurencia* spp.
- *Porphyra crispata*
- *Scinaia hormoides*

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Annex A
LIST OF COMMERCIALLY IMPORTANT SEAWEED SPECIES

Species	Uses
1. *Chlorophyta* (greens)	
Caulerpa lentillifera	human food
C. peltata	human food
C. racemosa	human food
Codium edule	human food
C. geppii	human food
C. intricatum	human food
Enteromorpha clathrata	human food
E. flexuosa	human food
E. intestinales	human food
Monostroma nitidum	human food
Ulva lactuta	human food
U. reticulata	human food
2. *Phaeophyta* (browns)	
Colpomenia sinuosa	human food; source of alginate
Hydroclathrus clathratus	human food; source of alginate
H. tenuis	human food; source of alginate
Hormophysa triquetra	source of alginate; human food; animal feeds
Sargassum baccularia	source of alginate; human food; animal feeds
S. binderi	source of alginate; human food; animal feeds
S. cinctum	source of alginate; human food; animal feeds
5. crassifolium	source of alginate; human food; animal feeds
S. cristaefolium	source of alginate; human food; animal feeds
S. illicifolium	source of alginate; human food; animal feeds.
S. paniculatum	source of alginate; human food; animal feeds
S. polycystum	source of alginate; human food; animal feeds
S. siliquosum	source of alginate; human food; animal feeds
Spathoglossum sp.	human food
3. *Rhodophyta* (reds)	
Acanthophora spicifera	human food
A. muscoides	
Asparagopsis taxiformis	
Beckerella scalaramosa	source of agar
Catenella impudica	human food
Eucheuma alvarezii	source of carrageenan; human food
E. arnoldii	source of carrageenan; human food
E. cottonii	source of carrageenan; human food
E. denticulatum	source of carrageenan; human food
E. gelatinae	source of carrageenan; human food
E. proscrusteanum	source of carrageenan; human food
E. striatum	source of carrageenan; human food
Gelidium crinale	source of agar
G. divaricatum	source of agar
G. puchellum	source of agar
G. pusillum	source of agar
Gelidiella acerosa	source of agar; human food
G. adnata	source of agar
G. myriocladia	source of agar
G. tenuissima	source of agar
Gracilaria arcuata	source of agar
G. coronopifolia.	source of agar; human food
G. eucheumoides	source of agar; human food
G. gigas	source of agar
G. salicornia	source of agar
G. verrucosa	source of agar; human food
Grateloupea filicina	source of agar
Halymenia durvilleai	human food
H. dilitata	human food
Hypnea cervicornis	source of carrageenan; human food
H. cornuta	source of carrageenan; human food
H. esperi	source of carrageenan; human food
H. pannosa	source of carrageenan; human food
H. valentiae	source of carrageenan; human food
Laurencia cartilaginea	source of agar; human food
L flexilis	source of agar
L japonica	source of agar
L majuscula	source of agar
L marianensis	source of agar
L obtusa	source of agar
L papillosa	source of agar
L parvipapillata	source of agar
L subsimplex	source of agar
L tronoi	source of agar
Porphyra crispata	human food
Pterocladia spp.	source of agar
Scinalia hormoides	human food

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Lecture 8
PRODUCTION OF ECONOMICALLY IMPORTANT SEAWEEDS THROUGH CULTURE AND HARVESTING OF NATURAL STOCKS[1]

by

Gavino C. Trono, Jr.[2]

1. PRODUCTION OF SEAWEEDS THROUGH CULTURE

1.1 Pond culture of Caulerpa

Several species and varieties of *Caulerpa* are presently utilized as food in the form of fresh vegetables in many areas of the Philippines. These are mainly produced through gathering of natural stocks. Only *C. entillifera* is commercially cultivated in ponds. The culture of this species started in the early 1950s on the island of Mactan, province of Cebu, Central Visayas. The accidental introduction of *C. lentillifera* with some other seaweed species to fishponds as fish food initiated its formal cultivation. The high demand for this alga on the local markets in metropolitan Cebu was a major factor contributing to the success of its commercial production. The species is preferred because of its delicate, light, taste, soft and succulent texture. It is also a fast growing species.

The pond culture of *C. lentillifera* was started by a fish farmer in 1952 utilizing his fishponds with milkfish and shrimp. At the beginning, *Caulerpa* was a secondary crop to fish and shrimp but later, because of the marginal production of fish and shrimp compared to the high production of *Caulerpa*, the farmer shifted to Caulerpa as his major crop and milkfish and shrimp became secondary crops. Interviews made among farmers revealed that some 80 to 100 hectares of ponds are presently used for the culture of *Caulerpa*. Although the commercial culture of Caulerpa in ponds started more than two decades ago, it has not been successfully transferred to other parts of the Philippines as yet, with the exception of a small production pond in Calatagan, Batangas so that the bulk of the fresh supply of *Caulerpa* in Metro Manila and some bigger towns in Central Luzon still comes from Mactan, Cebu. Although local consumption statistics are not available, it is probably safe to assume that several tons of *Caulerpa* are transported to Metro Manila from Mactan, Cebu every month. This seaweed is always available on the local markets any day of the week. The statistics of the Bureau of Fisheries and Aquatic Resources showed that in 1982 some 827 tons of *Caulerpa* was exported to Japan and Denmark in fresh, brine-cured or salted form.

The present cultivation utilizes the traditional fish and shrimp culture ponds. However, results of recent studies (Trono, 1986, in press) have shown that water management is a primary factor in the productivity of *Caulerpa*, the culture of which would require a flow-through system to facilitate water exchange. Thus, some modification of the traditional ponds such as the introduction of control gates has to be made. Unlike pond fish culture where water exchange is relatively infrequent, (e.g. once a week or a fort-night) pond culture of *Caulerpa* requires more frequent water exchange in order to maintain the necessary level of nutrients for growth and development. Some of the more progressive farmers in Mactan, had through experiences, learned the importance of proper water management and achieved higher production through the introduction of some form of a flow-through system by providing both entry and exit gates for each pond compartment.

The development of a new area into *Caulerpa* ponds consists of several stages, namely, site selection, pond construction, planting of the ponds, maintenance of the culture, harvest and post-harvest activities. Fishponds with marginal production are usually preferred because initial investment for their conversion to *Caulerpa* ponds is low and usually the location of these unproductive fishponds fits the ecological requirements of Caulerpa culture, that is they are far from sources of freshwater and pollution.

1.1.1 Site selection

The following factors have to be considered when selecting sites for pond culture of *Caulerpa*.

a) The area must be near to the source of unpolluted seawater supply. *Caulerpa* is consumed fresh thus, it must be grown in areas free from both communal and industrial pollution. Bacterial contamination of the crop should be avoided. *Caulerpa* may absorb pollutants such as heavy metals and toxic chemical which it can accumulate with deleterious effects to the consumers.

b) The site must be far from sources of freshwater such as rivers and streams. *Caulerpa* is a stenohaline marine alga and will die even in slightly brackish seawater when salinity drops below 30 ppt.

c) The elevation of the pond bottom must be at or just a little above the zero tidal level. This is necessary in order to enhance proper water management in the ponds.

d) The site must be protected from the destructive effects of wind and waves. A buffer zone of mangroves or coral reef is necessary.

e) The substrate must be loamy-muddy, however, very deep, soft mud must be avoided.

1.1.2 Pond construction

The maintenance of good water quality in the ponds through proper water management is dependent on the proper design of the ponds. The traditional layout of ponds for milkfish and shrimp production does not provide the necessary water exchange required in *Caulerpa* culture. *Caulerpa* ponds may be divided into compartments of 0.10 to 0.25 hectare and should have a flow-through design, that is each of the compartments should be provided with individual entrance and exit gates positioned in such a way that the water could easily be changed and circulated during the draining and flooding process. Peripheral or diversion dikes may also have to be provided to divert runoff water from the ponds during rains.

1.1.3 Planting of the ponds

The ponds are drained to a depth of 0.3 meters to facilitate planting. During the early development of the culture broadcasting was used to seed the ponds with *Caulerpa* cuttings. However, this technique was found to be inefficient because the "seeds" were not uniformly distributed on the pond bottom which resulted in uneven growth of the crop. An initial stocking rate of 1 000 kg per hectare under favourable weather conditions can produce a good crop in about two to three months.

The farmers have evolved some practical ways of seedling the ponds to ensure uniform distribution of the "seeds". Planting is done by burying into the mud one end of a handful of *Caulerpa* cuttings at about one meter intervals. Uniform planting is facilitated with the use of guidelines or the planted areas are marked by pieces of bamboo. After planting, the ponds are flooded to a depth of about 0.5 to 0.8 meter. Flooding is done slowly to prevent the newly planted cuttings from being uprooted. The newly planted ponds are inspected a day or so after planting and the barren areas are replanted to ensure uniform growth. The pond water is changed only several days after planting to make sure that the cuttings have well rooted and could not be carried away by water currents.

1.1.4 Water management

Proper water management is a key factor in the successful pond culture of *Caulerpa*. Ideally, the pond water must be changed in only every three to four days at the start of the growing period in order to avoid strong water currents which may uproot the seedlings. The frequency of water exchange is increased to every other day at about the third week after planting especially when the plants start to form a thick growth on the pond bottom. Frequent water exchanges provide fresh supply of nutrients for the normal growth and development of *Caulerpa* thus, it will eliminate the need for fertilizer application.

In general, the water in the ponds is maintained at a depth where the *Caulerpa* is visible from the surface of the water. Thus, the depth would vary depending on the transparency of the pond water to provide enough light for the plants. However, adjustments in water depth should be made to avoid perimeter dikes from collapsing during spring tides when the tidal amplitudes are extreme. During rainy days, the pond water should be maintained at a slightly greater depth to reduce the possibility of a dilution below 30 ppt. *Caulerpa* will die when the salinity goes below this level thus, the entire crop might be lost. After heavy rains, the pond water should be immediately drained and replaced by fresh seawater to ensure that the salinity is maintained at or above 30 ppt.

Fertilization may not be necessary as long as frequent water exchange can be granted. However, fertilizer has to be applied especially one or two weeks before the harvest, when a large biomass has already been produced and the plants appear to be pale in color (that is light green or yellowish). The sufficient rate of fertilization is about 16 kg per hectare. Nitrogen fertilizers have produced very good results. The plants regain their healthy color a few days after application. The fertilizer may be broadcasted but past experience has shown that wrapping the fertilizer in many layers of gunny or plastic bags and suspending these in strategic places in the pond at a level where the bags are just about half submerged in water, produces very good results. The fertilizer is applied right after water exchanges. The pond water should not be exchanged for several days after fertilizer application.

Weeding is an important activity which is done regularly to remove other seaweed species and associated organisms growing in the pond. Weeds compete with *Caulerpa* for space, light and nutrients. The weeds and the associated organisms should be removed before they take over as dominants. The presence of the weeds results in decreased production and low quality of the product and adds extra labor cost to sort them out before the product is sold in the market.

The dikes and gates of the ponds must be continuously maintained to grant efficient water management. This is especially critical during the monsoon season when strict and efficient water management is required to avoid extreme dilutions due to heavy rains.

1.1.5 Harvesting and post-harvest activities

Depending on the growth rate of the plants the crop may be harvested two months after the initial planting, when the plants form a relatively uniform carpet on the pond bottom. The plants at this stage are of high market quality, light grassgreen in color, soft and succulent in texture. Older plants though high in biomass are of lower quality because they are tougher in texture and their lower portions near the bottom are pale or colorless. The paling of the basal portions of the fronds is caused by self-shading when the plants become older and form a very thick carpet.

During the early stages of farming, the crop was completely harvested and the ponds were replanted afterwards. Harvesting was done by uprooting the plants from the pond bottom. The farmers, however, discovered that more crops could be produced during a growing season if partial harvesting is done, that is a sizeable amount (20–25 percent) of the crop is left in the pond to serve as seedstock for the next crop. Harvesting in this case is made in such a way that the leftover of the crop is more or less uniformly distributed in the pond. Barren areas are then replanted to ensure uniform stand. This practice has drastically reduced production costs by savings made in labor costs for replanting. The sizeable amount of seedstock left in the pond also results in a much shorter growing period and farmers claim they can harvest every two weeks after the first harvest during the optimal growing season (dry season).

Harvested seaweeds are thoroughly washed in seawater to remove the mud and other uncleanlinesses. They are then sorted, unsuitable thalli and other seaweed species are removed. The clean seaweed is placed in bamboo baskets. The side and the bottom of the baskets are lined with banana leaves or other seaweeds such as Sargassum which are also placed on the top of the filled baskets. The baskets are placed under the shade where they are allowed to drip before transportation to the market. The product can stay fresh for four or five days.

Caulerpa destined for export to other countries (such as Japan) is exported as a fresh product or in brine-cured or salted form. The seaweed is first thoroughly washed several times in seawater. Then thalli of good quality are selected. The clean seaweed is first completely drained of water, packed in styrofoam boxes provided with aeration holes on the upper side or cover of the box, taped and sent to its destination by air cargo. A large portion of *Caulerpa* exported to other countries is either brine-cured or salted. The latter two forms can be kept for longer periods and may be transported by surface cargo.

1.1.6 Progress and problems

While *Caulerpa* farming has been proven to be a profitable venture, it has not developed to a large-scale industry as yet. Important factors which have hindered the development of *Caulerpa* farming are the low local demand for *Caulerpa*, the use of traditional (extensive) fishponds for its culture, lack of technology transfer to other areas and untapped local potential demands. At present, the distribution of *Caulerpa* produced in Mactan is limited to Cebu City, Metro Manila and probably some cities in the southern Philippines. Only a small fraction of the population in these cities consumes *Caulerpa*. In general, people who buy *Caulerpa* are those who have been used to eat this seaweed long before they migrated to the cities. Majority of city residents do not eat seaweed of any kind. The sharp rise in the price (up to P22 per kg retail price in Metro Manila) may have also contributed to the decrease in demand for this seaweed.

Many of the farmers in Mactan still use the traditional fishponds for the production of *Caulerpa*. This is the reason why their production per unit area is quite low. In contrast, experimental ponds of the University of the Philippines using a flow-through system (Trono and Denila, 1986, in press) produced between 12 to 15 tons per hectare per year despite the very low production during the rainy months of July to October. As it was pointed out earlier, the layout of the traditional fishponds does not grant the necessary water exchange for a productive *Caulerpa* pond. This is the main reason why farmers using the traditional fishponds achieve very low yields compared to some of the more progressive ones.

The distance of the growing areas from market outlets is a factor limiting supply in areas far from Mactan, for instance in Metro Manila, contributing to high retail prices of this seaweed. The problem is due to the fact that culture techniques of this seaweed has not been transferred to other areas as adequate information on the technology and feasibility of *Caulerpa* production is still missing. The construction of new farms in areas with high potential demand for *Caulerpa* will be critical in the development of this industry. Recent studies (Trono, 1984, unpublished) have shown that the population in northwestern Luzon province consumes a sizeable amount of local seaweed species which include *Caulerpa* as a top favorite. The natural beds of *Caulerpa* in Bolinao, Pangasinan which serve as the main source of this seaweed for the population centers in the area are now depleted. A part of the imported *Caulerpa* from Mactan, Cebu finds its way to these big population centers in Pangasinan and La Union but transport is expensive. The population of the two Ilocos provinces in the north are also known to utilize local seaweeds for food. The development of *Caulerpa* culture in Pangasinan or La Union would, therefore, be very feasible because the local demand for the product is high and the area, also well known for its fish and shrimp aquaculture have ample pond facilities for seaweed culture.

1.2 The culture of Eucheuma

During the early 1960s, the Indonesian archipelago was the main source of dried *Eucheuma* for the American carrageenan industry. The supply of dried seaweed came from harvesting natural stocks. The advent of political problems in the mid-sixties had drastically affected the supply and the American company was forced to locate new resources. The Philippines was a natural choice because *Eucheuma* also abound on the shallow reef areas of the country. Thus, gathering of wild stocks started and after three to four years of intensive harvesting the easily accessible reefs supporting natural stocks of *Eucheuma* became depleted. Measures to control overexploitation of stocks did not succeed because of the tendency of the seaweed collectors to remove everything they found. In the late sixties, the annual production of a few hundred tons of dried seaweed was maintained by locating new stocks in far-flung areas but this resulted in high production costs. By now it became apparent that the harvest from natural stocks cannot satisfy the increasing demand of the industry and efforts to develop the culture of this seaweed were initiated. The initial activities and problems encountered in the development of *Eucheuma* culture have been described by Doty (1973), Doty and Alvarez (1973), Parker (1974) and Trono (1974). By now *Eucheuma* culture has grown to a medium size industry producing some 20 000 to 25 000 tons of dried *Eucheuma* during the past five years from about 6 000 to 7 000 hectares of family farms in the southern Philippines and Central Visayas where not less than 20 000 people are directly involved in farming. The industry was estimated to be producing some 300 million pesos in 1983.

1.2.1 Species under cultivation

A recent report on a new species has resulted in a total of seven species now reported from the Philippines. These are *Eucheuma cottonii, E. arnoldii, E. procrusteanum, E. gelatinae (= E. serra), E. striatum, E. denticulatum (= E. spinosum)* and the newly described E. alvarezii (Doty, 1985). The taxonomy of these Philippine *Eucheumas* and of those reported from other parts of the world has been reviewed by Doty and Norris (1985). At present two species, namely, *E. denticulatum* and *E. alvarezii* are the main species under cultivation, although a third species, *E. striatum*, may be occasionally found mixed with these two in some farms. *E. denticulatum* earlier referred to in the literature on seaweed farming as *E. spinosum* is an iota-carrageenan producing species and is known as the "spinosum type" of commodity. *E. alvarezii* referred to earlier as *E. striatum* is a kappa-carrageenan producing species and is called the "cottonii type" of commodity.

1.2.2 Methods of cultivation

The farming of *Eucheuma* had undergone through some changes in two major areas, that is in culture techniques and in its organization and management. Different methods of cultivation were tried in the past from the very simple bottom culture to the more sophisticated types using some form of' a support system such as the raft method, the fixed off-bottom method, the tubular net method and the monoline method. The change in the organization and management was a shift from the highly organized "hacienda-type" or company farms to individual family farms.

In the bottom culture cuttings of *Eucheuma* are attached to pieces of corals and arranged on the bottom into plots of uniform sizes. While this method is easy to practice, it is not very productive. The plants are easily attacked by benthic grazers or are easily displaced when the area is affected by even a moderate water movement.

In the raft method, a pair of 2.5 to 5 meters monofilament nets with mesh size of approximately 30 cm are attached and stretched to a 6 × 6 meters bamboo raft. Cuttings of 50 to 100 grams are tied to the intersections of the nets. The rafts are anchored to the bottom. Approximately 225 to 300 plants can be planted on such a raft. The raft method is not used at present for commercial purposes as the costs of materials, labour and maintenance are quite high.

In the tubular net method, the planting material is placed on a strip of monofilament netting (2 cm mesh, 12–15 cm wide and one to two meters long) mounted on a seeding board. The edges of the netting are laced with a nylon braided string to form a tube with the cuttings inside and the ends of the tube are closed by tying these with the nylon string which also serve as a support. The seeded tubes are then attached either to a raft or to wooden stakes. Harvesting is done by pruning the branches of the plants outside the tubing. This method has also, high material and maintenance costs and is not very productive. It was not adopted in the commercial production.

In the fixed off-bottom culture method, the monofilament nets (as described above) are stretched horizontally above the bottom and their corners are tied to wooden bipods or tripods which serve as supports. Four modules consisting of two hundred nets each form a hectare where approximately 102 000 cuttings can be planted. This method grants an intensive type of farming but was later replaced by the monoline method presently used in both small family farms and large company farms. Although productivity of the fixed monofilament nets vs relatively high costs of materials and maintenance and the difficulty in planting and harvesting were the factors which caused the farmers to shift to the simpler, cheaper and easy to maintain monoline method. This latter method is an extensive type of farming where only 34 000 to 35 000 cuttings are planted on a hectare.

1.2.3 Site selection

Unless it is in an area already having *Eucheuma* culture, any attempt to open new areas for farming should be preceded by careful site selection. Reconnaissance survey of reef areas should be made and potentially good portions of the reef should be identified and subjected to intensive in situ growth rate studies. The following general guidelines could be used in the preliminary evaluation of sites. Reefs far from freshwater sources are preferred because *Eucheuma* is a stenohaline marine alga and salinities below 30 ppt may have adverse effects on it. The area should be protected from the destructive effects of wave action thus, the presence of buffer zones is necessary to minimize these effects.

Areas which are about two to three feet deep with coarse sand to coralline substrate and subject to a moderate water current have been found to support good *Eucheuma* farms. Water movement in general favors the growth of *Eucheuma* by facilitating rapid nutrient absorption. It also prevents extreme fluctuations in other ecological factors (temperature, salinity, pH, dissolved gases, etc.), which can adversely affect the growth of plants. The firm substrate is essential for the support system and also reflects the existence of water movement in the area. Portions of the reef characterized by soft substrates such as fine sand or silt are generally not good for *Eucheuma* farming. Water depth at low tides is also an important factor because it affects the cost of farming. Areas with a depth of two to three feet at low tide are ideal. Deeper areas are hard to cultivate as the construction of the support system, the planting and harvesting in deeper water will entail higher costs in labor and materials. Reef areas supporting natural stocks of *Eucheuma* are good potential sites.

After a site have been identified, test planting of the desired species is recommended. Test plots consisting of a few monolines planted with 50 to 100 test plants each are constructed at different strategic locations of the area. The size of the seedlings and the culture method of the test plots follows the farming practices except for the small size of the plots which is about two by five meters. The growth of the test plants is monitored at weekly intervals and their daily growth rates determined. Areas supporting daily growth rates of two to five percent are potentially good sites. Although two to three months long monitoring of the growth rate may be enough to start a small family farm, it is advisable that the development of a commercial size farm should be based on a whole year-round monitoring, considering the possibility of problems associated with the seasonality in the growth of *Eucheuma*. This precautionary step should be strictly observed if the site is in a newly opened area. However, if adjacent areas are already being farmed, short-term growth monitoring will suffice. In general, areas in which the test plants double their size within 30 days or less are productive areas.

1.2.4 Construction of the support system (the monitoring method)

The development of the farm starts with the clearing of the site of seagrasses, seaweeds, large rocks and corals. The area is then divided to smaller sections of 1/4 of a hectare or smaller. The following is a brief description of the monoline method presently used by farmers.

Construction of the support system starts with drilling holes in the bottom with the use of a pointed iron bar (two inches in diameter) and a heavy sledgehammer. Then pointed mangrove stakes about two inches in diameter and 60 to 80 cm long are firmly driven into the holes using the sledgehammer. The wooden stakes are arranged in rows at one meter intervals and the distance between the rows is 10 meters. A loop is made at one end of the monofilament line (180–200 lbs test nylon) and it is attached to a stake. The line is then strongly stretched and its other end is firmly attached to the opposite stake in the next row. The distance of the monofilament line from the ground is approximately 0.3 to 0.5 meter depending on the depth of the water during low tides. The monolines may be positioned parallel with or crosswise to the direction of the current depending on the strength of the current. In areas where the current is relatively strong, the monolines are arranged parallel to the current and an extra stake is placed midway between the original rows of stakes to provide extra support for the monoline. The shorter the distance between the rows of stakes, the stronger the support system, but a reduced distance will result in additional costs. Adjustments in the construction of the support system may be made to adapt to the needs of a specific area. One thousand pieces of 10 meters long monolines will make a hectare of farm.

1.2.5 Preparation of seedlings

Seedlings of the selected species or variety are acquired from the nearest source. These are transported to the farm site in the shortest possible time and protected from exposure to sun, rain and wind. If the seedlings are in transit for longer periods, they should be occasionally soaked with clean seawater. Experiences have shown that for long distance transport of seedlings the use of styroform boxes with quarter-size holes at their upper sides to facilitate aeration is the most efficient method. The seedlings should be drained of excess seawater before being placed in the box and covered. They must immediately be placed in seawater upon arrival to the farm site.

"Seeds" for planting are prepared by tying SO to 100 grams bunches of cuttings with soft plastic tying materials commonly called as "tie-tie". The bunches are then tied at 20 to 25 cm intervals to the monolines already stretched in the sea. Maintenance and management of the farm are facilitated by planting on a unit area basis that is a farm unit should be fully planted before proceeding to the next one. The plants are ready to be harvested when they are about one kilogram in size or bigger. The time required to grow *Eucheuma* to harvestable size vary depending on the ecological conditions. Seasonality in growth is a common phenomenon in some areas of the Philippines.

1.2.6 Maintenance of the farm

The maintenance of the farm consists of weeding, repairing the support system, replacing lost plants and removal of benthic grazers. Other species of seaweeds grow in close association with *Eucheuma* as epiphytes or on the monofilament lines and stakes. These compete with *Eucheuma* for nutrients, light and space. They also add to the "drag" on the line in areas with a strong current which result in breakages and losses of plants. Grazers such as sea urchins and starfishes have been demonstrated to consume significant amounts of seaweed resulting in severe losses of biomass. Maintenance is a necessary component of farming which significantly influences production. In areas characterized by strong currents, a retaining fence made of nylon nets with approximately 10 cm mesh size should be constructed at the leeward side of the farm to catch thalli washed out by the current. In northern Bohol, about a fourth or a third of the daily harvest consists of these washed-out materials.

1.2.7 Harvesting

The present practice of farmers is to harvest the whole plants and to replant the farm with new cuttings. The best plants from the harvest are used as seeding material for the next crop. This practice has replaced the pruning method formerly used by farmers in which the plants at harvest were pruned down to a 100 grams bunch or so to serve as the "seed" for the next crop. The objective ' was to save on planting cost as well as on tying material. This old practice, however, was found to be inefficient because the bunches left behind were old portions of the thalli which grew slowly thus, it took a longer period to produce the same amount of biomass after the first harvest. In addition, the "tie-ties" lasted only for one growing season anyway. But most importantly, the built-in mechanism of "seed improvement" by selection which is a big advantage of the present practice was not possible with the former method of harvesting.

1.2.8 Drying of the product

Drying is an important post-harvest activity which affects the quality of the product. The harvested crop is spread on drying platforms usually made of bamboo slots, cleaned of foreign materials such as old tie-ties, weeds, marine animals, nylon lines, etc., and spread uniformly under the sun to dry. This drying method has been slightly modified recently to minimize the loss of material and facilitate drying. The platform is now first lined with fine mesh braided nylon net and the crop is spread on top of it. The plants are regularly turned over to facilitate complete sun-drying. The drying crop should be protected from rains. Before the onset of a rain the crop is first piled up into a heap by just pulling the lining net to one part of the platform and then covered by a water-proof sheet. The product is dried in two to three days during a hot, sunny weather. The dried product should not contain more than 30 percent moisture. The dried material is tightly packed in nylon bags and stored in dry areas before shipment to buying centers.

At present *Eucheuma* is exported in three forms as dried, raw seaweed, as alkali-treated chips or as a semi-processed powder. Export of the last two forms appears to be the trend among the big exporters. This reflects the preference of these semi-processed products by big processors of pure carrageenan and by the pet food and canning industry. By importing semi-processed products such as alkali-treated chips, the processors of carrageenan are receiving good quality raw materials and they can avoid pollution problems associated with the disposal of wastes. The semi-processed powder form is directly utilized in pet foods and by some canning industries, a cheap substitute to the pure carrageenan.

1.3 The culture of Gracilaria

Although several species of agarophytes belonging to the genera *Gelidium, Pterocladia* and *Gracilaria* have been reported to be commercially produced through some form of farming in several countries such as Japan, China, Republic of Korea, Vietnam, India and the Philippines, it is in Taiwan where the production of *Gracilaria* through pond culture has achieved a high degree of success. Here, an average of 12 000 tons of dried *Gracilaria* was produced during the past few years (Chiang, 1981).

The genus *Gracilaria* is characterized by the alternation of three somatic generations, the sporophyte, the gametophyte and the carposporophyte stages. The last one is microscopic and it is parasitic on the female gametophytes thus, the gametophytic and sporophytic stages are the macroscopic forms used as planting materials in the pond culture. Although the reproductive potential of *Gracilaria* through spores is high, vegetative propagation by cuttings is presently used in the pond culture because of the very high regenerative capacity of the plant and the simplicity of the method. However, "hatchery produced" seedlings from spores have been demonstrated to be superior in the open field culture of Gracilaria (Doty, 1986).

Out of the several species of the genus presently used (e.g., *Gracilaria chorda, G. edulis, G. verrucosa, G. lichenoides, G. compressa* and *G. gigas*) *G. verrucosa* is the most popular due to its ability to adapt to a wide range of ecological conditions, its higher production rates and better gel quality. The culture of Gracilaria started in 1962 in southwestern Taiwan. Production in ponds is primarily influenced by three ecological factors, namely; salinity, light and temperature. High production is recorded during the months characterized by . higher temperatures and growth is slow during winter. High light intensity exerts adverse effects on the growth, therefore, control of light conditions is practiced by adjusting the water depth in the ponds. Salinity of 15 to 24 ppt appears to be optimal for growth. The increase in salinity during the summer months is controlled by the addition of freshwater thus, farms need to be located near freshwater resources.

1.3.1 Site selection

The success in pond culture of *Gracilaria* is highly dependent on the selection of appropriate sites. The following criteria are recommended in the selection of sites for pond culture.

- the site should be located near seawater and freshwater resources;
- the area should be protected from strong winds;
- the pond bottom should be at or near the zero tide level; and
- the pH of the water should be slightly alkaline, e.g., 8.2 to 8.7.

Gracilaria is a eurythaline species and can grow in brackish water under a wide range of salinity. A salinity range of 15 to 24 ppt have been found to be optimal. Salinity rises during the sunny months due to evaporation losses reaching values as high as 35 ppt or drops to as low as 8 ppt during the rainy season were shown to be detrimental to the crop. The maintenance of optimal salinity in the ponds requires readily available freshwater and seawater supply. The ponds should be located in areas protected from strong winds because there is a tendency for *Gracilaria* to accumulate the leeward side of the pond. The formation of thick heaps of *Gracilaria* in one side of the pond has adverse effects on the growth due to shading.

Water management is greatly influenced by the tidal changes in relation to the elevation of the pond bottom. Ponds located in areas where the bottom is at or a little above the zero tide level can easily be managed as water exchange is easy.

1.3.2 Culture ponds

The average size of ponds for the culture of *Gracilaria* is about one hectare or smaller. Smaller ponds are easier to manage than larger ones because in large ponds *Gracilaria* tend to accumulate at one side due to the influence of winds. Pond management is also easier when *Gracilaria* is polycultured with shrimp and/or crab. Provision of entrance and exit gates also facilitate proper water management.

The depth of the ponds vary from 50 to 80 cm clayish loam, silty loam or sandy loam. It was observed that *Gracilaria* easily gets buried in ponds with sandy bottom due to the effect of wind. This problem, however, could be resolved by increasing the depth of the water during windy periods. In larger ponds wind breaks consisting of bamboo slots are installed perpendicular to the direction of the wind to prevent the seaweed being transported to one side of the pond.

1.3.3 Culture method

The following method is generally followed in the pond culture of *Gracilaria*. The ponds are dried for several days, water is then introduced. Healthy stocks are selected as planting materials. These are generally characterized by their elastic feel to touch, reddish brown color, brittle texture, they must have stout and well-branched thalli and must be free of dirt and extraneous materials. The planting material is transported from its source to the pond site early in the morning to prevent its exposure to the sun. During long distance transport, it is frequently sprinkled with seawater and perforated bamboo or plastic pipes are inserted into the bottom of the heap to provide aeration. The plants must immediately be placed in the water of the pond upon arrival. The planting material is then cut into pieces and is broadcasted uniformly on the bottom of the pond. Stocking is usually made with 5 000 to 6 000 kg stocking material per hectare in April.

1.3.4 Pond management

The water is maintained at a depth when the surface is approximately 30 to 40 cm above the heap of the algae. However, the depth is increased to cover the algae by 60 to 80 cm during the warm summer months to prevent a significant rise in the water temperature. Water depth is also increased during the cold winter months to avoid temperature drops below 8°C which is lethal to Gracilaria.

Frequent exchange of water is necessary to maintain the optimum temperature of water in the ponds. The water is changed every two to three days. About 50 to 75 percent of the pond water is used to be drained and replaced with fresh seawater.

Fertilization with either organic or inorganic fertilizers is used to enhance the growth of *Gracilaria*. Weekly application of three kilograms of urea per hectare is sufficient. Fermented pig manure may be applied at a 160 to 180 kg per hectare dosage two to three days after the exchange of the water.

1.3.5 Harvest and post-harvest activities

The harvesting season starts in June and extends to November. The crop may be harvested every 10 to 40 days manually or by using scoop nets. The frequency of harvests is primarily dictated by the market price and the season. The crop is thoroughly washed in pond water to remove the silt, sand, pieces of shells and other extraneous materials such as snails and other algae. The clean *Gracilaria* is spread uniformly on bamboo screens or plastic sheets for drying. An average wet to dry ratio of 7:1 is generally attained.

Standards set by the Bureau of Standards in Taiwan for the export of dried *Gracilaria* require that the product should not contain more than 1 percent of mud and sand, not more than 1 percent shells and not more than 18 percent other seaweed species. Moisture contents should not exceed 20 percent. Dried *Gracilaria* is then packed into sacks of 100 kg weight for export or sold to local processing plants. Ten to twelve metric tons of dried *Gracilaria* are produced in a hectare of pond.

1.3.6 Polyculture with shrimp and/or crab

Polyculture with shrimp (Penaeus monodon) and/or crab (Scylla serrata) is mainly done in Ping-tung Prefecture in southwestern Taiwan. Stocking material for a hectare of farm consists of 4 000 to 5 000 kg of *Gracilaria*, 5 000 to 10 000 crab and 10 000 to 20 000 shrimp. Crushed trash fish and snails are generally used as feed for the crab. Crabs are harvested after three months, the shrimp often after four to seven months. Survival rates as high as 80 percent for crabs and 80 to 90 percent for shrimp has been documented making this polyculture one of the most profitable methods in Taiwan. The net income from polyculture has been proven to be three times as much as from monoculture.

2. NATURAL PRODUCTION OF COMMERCIALLY IMPORTANT SEAWEEDS

The "non-farmable" species as used in the present context are those which by the very nature of their small size, slow growth and regenerative capacities and/or determinate growth cycles do not easily lend themselves to the conventional way of farming through mass production through the use of cuttings or spores, e.g., *Gelidiella acerosa, Gelidium spp., Sargassum sp.*, and *Acanthophora*. Their production depends primarily on the availability of naturally produced stocks as influenced by harvest pressures during the preceding season. Production of some of the species is highly seasonal depending on their growth cycles as influenced by environmental conditions. Their harvestable stocks are also significantly controlled by monsoons.

Because their growth cycles are highly dependent on the environmental conditions in their habitat and to a large extent to the degree by which these are influenced by man's exploitive activities, their production, therefore, is highly unreliable. The need to manage and conserve their natural stocks is of prime importance in order to assure to a certain extent their continuous production as well as to prevent overexploitation.

The design of a sound management and conservation scheme for non-farmable species depends primarily on the availability of information on the various aspects of their biology, e.g., reproduction and growth cycles, growth rates, their regeneration and recruitment capacities and their production potentials; The above information are necessary in the formulation of guidelines for the management of the natural stock of the target species. These information can provide answers to questions such as where the species is abundant, how much to harvest per unit area, when to harvest, how many times can the stocks be harvested in one season, what kind of harvest method is best for the species. Furthermore, production can be safely forecasted. These available information is most important in quoted contracts which may be entered into by the farmer, fishermen, or exporter. The gathering of these basic information on the species to be managed requires basic skills in methodologies for field sampling and data gathering.

Thus, it is of prime importance that any plan to exploit natural stocks of seaweeds must be preceded by intensive biological studies to determine seasonality in biomass production, reproduction, regeneration and recruitment. These information are necessary in determining the best possible time of harvesting and amount of harvestable stocks.

Production of non-farmable species can be enhanced by the application of some agronomic techniques with the primary aim of protecting the natural stocks from over-exploitation. The application of harvest techniques which are the least destructive is one way of assuring the fast recovery of stocks. For instance, harvest by hand picking (pulling) is more destructive than pruning. The removal of the whole plant from the substratum by hand picking reduces the capacity of the stocks to regenerate. Renewal of stocks through regrowth from basal portions left after pruning is very much faster than recruitment of new thalli from spores.

The removal of unwanted species (weeding) may enhance the growth and development of target species through eradication of competitors for space, light and nutrients. The clearing of the substrate also enhances the opportunity for recruitment by spores. Studies have shown that recolonization of bare substrates results to the increase in population density of the target species.

The eradication of grazers in reef areas being managed for wild crops contributes to the enhancement of production in reef areas. Sea urchins, starfishes and fishes like siganids are well-known seaweed grazers whose destructive effects on seaweed crops can be minimized.

The harvesting of seaweed crops from natural stocks is labour-intensive. Seaweed gathering for cash crops, therefore, offers an opportunity to optimize the utilization of the minimally used labour force in coastal areas. Methods being employed in the harvesting of natural stocks vary depending on the species, its size, abundance and the habitat where these are found. In tropical areas, most of the wild crops are found in shallow rocky portions of the reef or in shallow bays. In reef areas where harvestable crops are closely associated with other species, selective harvesting through hand picking and/or pruning are the most common methods of cropping. In shallow bays, the gathering of *Gracilaria* is done by hand, or with the use of rakes. In some instances semi-mechanized method is employed utilizing trawl-like equipment attached to a slow-moving motorized bancas. In deeper areas, diving and hand picking or the use of pruning tools are employed. Scuba is a convenient equipment now used in some countries for gathering wild stocks in deeper areas.

In wave-exposed areas where hand picking is hazardous, the gathering of seaweed crops is mostly dependent on drift materials which accumulate on the shore especially after some heavy surfs.

[1] Reproduced as hand-outs for this training from the paper entitled "Seaweed Culture in the Asia-Pacific Region". RAPA Publication 1987/8, pp. 15–25 and from Report on the Training Course on *Gracilaria* Algae, SCS/GEN/81/29, pp. 45–46.

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Lectures 9 and 12
SEAWEED INDUSTRY IN THE PHILIPPINES

by

Maximo A. Ricohermoso[1]

ABSTRACT

The Philippines is one of the few countries in the world that has successfully grown marine algae (seaweeds) in substantial commercial quantities. Among marine and fisheries product exports, seaweeds and seaweed products now ranks third after shrimps and tuna. Compared to shrimps and tuna, however, seaweeds provide greater direct economic benefits to a greater number of our people.

Eucheuma seaweed species dominate the Philippine seaweed industry. *Sargassum, Gracilaria, Gelidium* and a few other species are commercially important, limited information is available thus, this paper will deal more on *Eucheuma*.

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1. EXISTING RESOURCES

1.1 Eucheuma cottonii and Eucheuma spinosum

Eucheuma cottonii and *Eucheuma spinosum* are the main commercially cultivated seaweeds in the country. Estimated harvest in 1986 was about 45 000 metric tons for both species with an estimated export value of about P500 000 000 ($25 000 000). The country's export of *Eucheuma* materials has been growing at an average rate of 30 percent per year during the last five years (Table 1).

Eucheuma is now cultivated and the main source of livelihood of about fifty thousand coastal-dwelling ocean farmers and fishing families in Tawi-Tawi, Sulu, Zamboanga de Sur, Sacol Islands, Palawan and Cuyo, Danajon reef of Central Visayas, Southern Leyte and other reef areas in the country. *Eucheuma*, of the red algae category is one of the most important raw material for carrageenan, a colloidal substance used as an essential. gelling agent, stabilizer or emulsifier in various food, personal care, Pharmaceuticals and industrial products worldwide.

Gracilaria and *Gelidium* are the raw mate-rials for agar which has major applications in food, pharmaceuticals and culture media for clinical and research laboratories.

Sargassum, however, finds major application only in animal feeds in Japan due to its lower alginate extract.

Caulerpa, known as "lato" is a green algae finding its place among sea food delicacies for local and foreign consumers.

Using present cultivation technology, the country could easily produce seventy to eighty thousand metric tons of *Eucheuma* annually.

1.2 Gracilaria, Gelidium, Sargassum and other species

Although known to be growing abundantly all over the coastal and reef areas of the country, there is no adequate inventory data on *Gracilaria, Gelidium, Sargassum, Porphyra* and other commercially important seaweeds. As late as the 1960's, *Gracilaria* and *Caulerpa* were harvested in Manila Bay and were important livelihood sources of coastal dwellers along the bay from Bataan to Cavite. Pollution, unfortunately, had already wiped out these important marine resources in the area.

2. EXISTING TECHNOLOGY

2.1 Cultivation and post-harvest processing

Cultivation technology of *Eucheuma* is adequate for the current needs of the industry. The present *Eucheuma* farming utilizes the monoline system which is easily adaptable to either bottom or floating methods, depending upon suitability of farming site. *Eucheuma* through this method is harvestable in 45 or 60 days.

Drying and storage are very important aspects of *Eucheuma* post-harvest handling. Poorly dried harvests and improper storage results to highly degraded produce.

Eucheuma harvests are simply dried under the sun, commonly in an extended platform beside the farmer's house. More often, however, the seaweed is left to dry over the sand in a make-shift mat of coconut leaves or nylon nets. This drying method yields low quality materials due to excessive sand and other foreign matter contamination.

3. PROCESSING AND END-PRODUCTS EXTRACTION

Raw material exports is now less than 50 percent of the total *Eucheuma* harvest, accounting for 38 percent of the export earnings of the seaweed industry in 1986. Local seaweed processors utilize more than 50 percent of Philippine *Eucheuma* harvests in the manufacture of carrageenan products, generating about 62 percent of the foreign exchange earnings last year.

Raw materials for export are sorted, foreign matters removed, redried and baled. Standard moisture content for raw *Eucheuma* export is 38 percent. Farmers deliveries range from 40 to 50 percent moisture.

Eucheuma processed product exports from the Philippines are either kappa or iota-carrageenan blended materials ready for use in their respective applications. These are manufactured either through extractive or non-extractive method. The dried seaweed material is cooked in an alkali solution to a desired modification level, washed, dried (either solar or mechanical) ground and blended to customers specifications. Rigid quality control is observed starting from the raw material to the finished product phases of the process. This *Eucheuma* processing technique, although well known and used in the U.S. and Europe in the earlier stage of carrageenan technology was initiated in the Philippines by Japanese chemists sometime in 1977 in a joint venture with a Cebu based Filipino company. The method since then has undergone several revisions. The Philippines is now the leading world supplier of carrageenan manufactured through the non-extractive method.

The extractive (refined) carrageenan processing method also involves alkaline cook of seaweed raw materials plus the more highly sophisticated and technically advanced KCL (potassium chloride) or alcohol extraction system. A newly built extraction, plant initially relying on Japanese technology is now operating in Cebu at 500-metric tons annual rated capacity.

Agar processing system has been an established technology in the country as evidence by the existence of agar manufacturing plants. The method simply involves pasting the raw materials, washing and drying either solar or mechanical. Agar locally known as "gulaman" is usually marketed in agar bar or strip form.

Sargassum processing involves sorting, cleaning, drying and grinding. Fishermen deliver *Sargassum* material at a 30 to 40 percent moisture content. The local processor-exporter redries the materials at 14 to 18 percent and milled to about 10 mesh.

4. MARKETING

Except for a minor local usage, *Eucheuma* harvests of the country is totally destined to the export market either in raw or carrageenan form. Raw *Eucheuma cottonii* material exports in 1986 was about 19 300 metric tons (Table 1) with an estimated value of US$7 720 000 (₱154 400 000).

Eucheuma spinosum was about 1 886 metric tons (Table 1), value estimated of US$1 037 000 (₱20 740 000).

The major use of Philippine *Eucheuma* harvests are the processing plants in Denmark, France, Spain, U.S.A., Korea, Japan, Argentina, Taiwan (Table 1), China (PROC) used to buy and remain potential big users of *Eucheuma* materials.

Table I. Philippine seaweed (*Eucheuma* sp.) industry profile December 31. 1987

Farm harvests

	Percent share	Metric tons	Seaweed farmers Direct economic benefit
Tawi-Tawi[1]	60	22 800	₱114 000 000
Sulu	12	4 500	22 500 000
Zamboanga	10	3 720	18 600 000
Palawan	9	3 600	18 000 000
Central Visayas	7	2 600	13 000 000
Others	2	1 000	5 000 000
Total	100	38 220[2]	₱191 100 000

Exports - raw materials + seaweed products

		Metric tons	US$ value	Percent
Raw materials				
E. cottonii	15 130			
E. spinosum	2 651	17 781	6 223	26
Seaweed extracts carrageenan		5 836[3]	17 508	74
Total		23 617	US$23 731	100

Typical seaweed farming family annual income

		Low	High
Average area cultivated		2 500 sq m	5 000 sq m
Annual harvest		6 000 kg	12 000 kg
Average price (₱/kilo)		5.00	5.00
Gross income		₱30 000	₱60 000
Expenses:			
Labor[4]			
Nylon lines (100 k × ₱l00)	₱1 000		
Plastic straw	500		
Wood stakes (1000 × ₱0.20)	200		
Banca	1 000		
Daily subsistence:			
1 bag rice/mo, at ₱350	4 200		
Miscellaneous: (Fuel, etc.)	6 000	18 900	18 900
Net income		₱11 100	₱41 000

[1] Tawi-Tawi provides about 60 percent total Philippine *Eucheuma* seaweed harvests.

[2] *E. cottonii** — 36 300 mt;
*E. spinosum*** — 1 920 mt, average price is ₱5.00/kilo.

[3] One kilo carrageenan extract is equivalent to 4.5 kilos raw.

[4] Assume the family provides own labor.

NOTE: * Correct botanical name is *Eucheuma alvarezii*.
** Correct botanical name is *E. denticulatum*.

Private sector investments

Company	Plant	Location	Annual capacity (mt)	Investment (P)
Deltagen/Biocon	Crude carrageenan	Mandaue City, Cebu	400	₱10 000
Manwealth	Raw material	Mandaue City, Cebu	3 000	5 000[1]
Marcel	Crude carrageenan	Zamboanga City	1 500	15 000
	Refine carrageenan	Metro Manila	200	25 000[2]
	Raw material	Zamboanga City	6 000	5 000
MCPI	Crude carrageenan	Mandaue City, Cebu	2 000	30 000
Corporation	Refine carrageenan	-do-	500	50 000[3]
	Raw material	-do-	6 000	4 000
SHEMBERG	Crude carrageenan	Mandaue City, Cebu	2 000	25 000
	Refine carrageenan	-do-	400	60 000
	Raw material	-do-	6 000	5 000
Others	Crude carrageenan	Zamboanga City/Palawan		
	Raw material	Tawi-Tawi	10 000	10 000
	Total			₱244 000

[1] Owners are from Tawi-Tawi.

[2] Construction in progress.

[3] Designs in progress.

Carrageenan product export in 1986 is about 4 500 metric tons with an estimated value of US$14 400 000 (₱288 000 000), providing approximately 62 percent of the foreign exchange earnings of the seaweed industry. Usage of Philippine Semi-Refined Carrageenan (SRC) has been limited and unfairly restricted to pet foods, personal care and industrial application since it was banned as an acceptable additive in human foods during the recent meeting in Rome of the Joint FAO/WHO Experts Committee on Food Additives at the instigation of MARINALG, an association of carrageenan manufacturers from the industrialized countries.

Refined carrageenan from the Philippines was introduced into the market last year. About 100 metric tons of refined carrageenan has been exported to Europe and Japan.

Sargassum exports were mainly ground products for animal feed component in Japan. About 700 metric tons was exported in 1986 with an estimated value of $200 000 (₱1 400 000). China and Indonesia are providing formidable competitions.

5. POTENTIALS FOR DEVELOPMENTS

Eucheuma-based industries appear to be maturing. The 1986 large volume increase over the previous year was mainly due to inventory positioning of the foreign buyers as a hedge for a perceived political instability of the country last year. There is, however, potentials for *Eucheuma* as a fresh processed table food item similar to Nori or Wakami for both the local and international consumers.

Gracilaria and *Gelidium* have plenty of room for developments. *Gracilaria* is now successfully grown in Taiwan and efforts are underway in Thailand. The Philippines has suitable sites and technology is available.

Sargassum and other brown seaweeds have bigger potentials as animal feed component. *Sargassum* is abundantly available and cheap. Local feed millers could use *Sargassum* with very little processing.

A bright potential also is in the horizon for a polyculture system in the seaweed farms. Technology for growing mollusk and other marine species such as abalone, giant clams and cucumber are now emerging and compatible with seaweeds farming.

6. NEEDS/PROBLEMS/ISSUES AND RECOMMENDATIONS

The various sectors of the seaweed industry have formed together into an industry association in 1985. The common issue which the industry association is trying to resolve are wide variations in quality and stiff fluctuations in prices of the harvests.

As the industry matures, price of the produce remains at lower level thus, reducing the farmers income. Polyculture of seaweeds together with other marine species, therefore, needs adequate attention.

Majority of individual seaweed farms are still without license or concession from the Bureau of Fisheries and Aquatic Resources. The industry association is assisting the government on this aspect. BFAR should accelerate processing of applications.

The Philippines used to be the only *Eucheuma* farming country in Southeast Asia. In 1986, Indonesia started shipping in commercial quantities cultivated *Eucheuma* seaweeds at a very competitive price. *Eucheuma* farming in Indonesia was initiated by the major European and U.S. carrageenan manufacturers as a reaction to an attempt by the defunct Batasang Pambansa to create a Seaweed Industry Commission and as a hedge to earlier worsening political condition. The damage has been done, however, learning from this lesson, the government should now be more promotive rather than regulative on the industry.

Seaweed processing and exporting companies find Mandaue City (Cebu) the ideal place for their plants due to conducive investment climate and availability of comparatively better infrastructure facilities such as:

a. Local and international shipping ports
b. Communications: Telephone, telexes, etc.
c. Power and water
d. Banking facilities and government offices
e. Peace and order

7. INDUSTRY PROBLEMS

7.1 High variable raw material quality due to lack of post-harvest facilities.

7.2 Low farm productivity resulting to uncompetitive prices.

7.3 Excessive shipping and handling costs from the farming regions to the processing plants due to inadequate ports and transport facilities.

7.4 Lack of power and water facilities in the farming regions.

7.5 Lack of banking and communication facilities in the farming regions.

7.6 Peace and order threats in the farming areas.

7.7 Unruly competition both in local and international markets.

7.8 Emergence of Indonesia as a strong competitor in the world market.

Lecture 10
PROGRESS AND PROBLEMS IN SEAWEED CULTURE

by

Gavino C. Trono, Jr.[1]

A review of the status of seaweed culture in the region shows that the degree of success and the resolution of the associated problem are highly dependent on the availability of basic information on the general biology, physiology and genetics of the species concerned and on the application of this knowledge to the development of their culture techniques. The great successes in seaweed culture achieved in such countries as Japan and China are generally attributed to achievements in controlling the biological cycle and satisfying the physiological requirements of the species both in the laboratory and in the field. Thus, in countries where culture systems or technologies are highly sophisticated, production itself becomes much less of a problem than the monitoring and the control of the culture in order to produce high quality crops to make the industry cost effective. On the other hand, in the countries where these basic informations are not yet available, the development of culture techniques in order to enhance production is the major concern.

Although the major seaweed producing countries are well-known for the cultivation of many species of seaweeds, this review will be limited only to species cultivated as major crops in these countries because of the limited informations available on the minor species.

1. PORPHYRA CULTURE

Several species of the genus *Porphyra* (in Japanese: nori, in Chinese: zicai) are presently cultured commercially in Japan, China, Republic of Korea and to a limited extent in Taiwan. Although the basic culture methods are quite similar as the techniques generally used are primarily based on those developed in Japan, they may differ in certain details because of differences in the requirements of the cultured species and local conditions.

In Japan the success achieved in the nori industry in the past two decades has been due to significant improvements in the production techniques and the development of genetically superior strains. The development of highly productive strains of *Porphyra tenera* and *P. vezoensis* through selection and the extension of fast growing and disease resistant populations has resulted in maximum production. Although efforts to produce fast growing, high quality and disease-resistant varieties through hybridization have been undertaken in the past, there has not been any success to date in producing hybrid strains of *Porphyra* (Imai, 1982). The difficulty has been attributed to the inherent characteristics of the alga such as the low number of chromosomes and the occurrence of fissions in the succeeding generations of thalli. These characteristics are not favorable to hybridization. In cases where hybrids were produced, problems were encountered in their culture.

Very significant developments have been achieved in the production of *Porphyra* during the past few years in Japan. Among these are:

a. the expansion of the use of freezing techniques in storing hibi nets seeded with “young buds” for the lengthening of the production season and/or for back-up stocks for replacing diseased nets;

b. the development of the floating and raft type support systems which facilitated the expansion of the production to deeper and open waters (the original fixed support system limited the production areas to protected, shallow bays); and

c. the development of culture techniques of free living *Conchocelis* and the physiological control of conchospore release had made the seeding of the hibi nets very efficient.

Although these improvements in the culture techniques have tremendously contributed to the success of *Porphyra* production, these advances have also resulted in problems affecting both the farmers and the government. Overproduction which is generally accompanied by low quality has resulted in lower prices. The introduction of improvements in culture and fertilization techniques and the mechanization of post-harvest operations resulted in increased costs of production thus, decreasing the net income of the farmers. The expansion of the nori industry has also resulted in serious problems in the management of coastal areas and brought about a conflict in their utilization for other aquaculture ventures and/or for other purposes. In Japan increasing industrial pollution in protected bays is also becoming a major problem.

In China the knowledge on the biology of *Porphyra haitanensis* and *P. vezoensis* and on the physiological requirements of these species (especially in relation to the mass culture of *Conchocelis),* and the development of techniques in enhancing conchospore production, the timing of their release, improvements in the nursing of young seedlings, the expansion of production to open; less fertile areas using the semi-floating and floating raft support systems together with the development of fertilization techniques using pumps have increased significantly the production of *Porphyra.*

Because the *Porphyra* industry in China is relatively young and smaller in magnitude as the nori industry in Japan, it has not yet encountered serious problems related to overproduction and management. Opportunities for the expansion of production in China are great because of the availability of suitable coastal areas for this purpose. At present the emphasis is on increasing production through improvements in the culture techniques and on the solution of problems related to weeds and diseases.

Although the culture of *Porphyra* is practiced in the Republic of Korea too, very little information is available in the literature on the subject. According to Saito (1978) the slow development of the industry may be primarily due to its dependence on the export markets (that is Japan's) demands. As can be surmised from Saito's report, the local demand for nori has not developed as yet, therefore, production is still low utilizing mainly old techniques.

The development of *Porphyra* culture in Taiwan is only at its initial stage. The lack of information on the biology of the local species *(Porphyra dentata* and *P. angusta)* has been one of the major constraints in its development. However, progress has been attained in the development of culture techniques for the mass culture of *Conchocelis* and conchospore formation under artificial light and temperature conditions. The seasonality of production due to weather conditions and the long period between the development of *Conchocelis* and conchospore formation are two of the major problems confronting the development of local *Porphyra* culture in Taiwan.

2. UNDARIA CULTURE

The *Undaria* genus (in Japanese: wakame) is cultivated in Japan, the Republic of Korea and China but it is in Japan where its commercial cultivation has almost equal importance to the nori industry.

The thorough knowledge of the biology and the physiological requirements of the two species presently cultured has resulted in the development of culture techniques which made possible the highly successful *Undaria* industry of Japan today. The understanding of the physiological requirements of *Undaria* seedlings, that is their temperature, light and nutrient requirement, resulted in the highly controlled tank culture of seedlings in both private and government nurseries. The problems of disease, epiphytism and grazing which seriously affected production earlier have been resolved by the culture of seedlings in nursery tanks. The readily available seedlings have encouraged the expansion of production to deeper and wave-exposed areas through the development of the raft support system. Improvements in the natural production of *Undaria* through the management of local stocks have also contributed to an increase in its total production.

The improvements in culture techniques, however, have resulted in overproduction of low quality products which seriously affected the net income of farmers. The application of support systems designed for deeper and open sea conditions has also added to the cost of production.

The introduction of the culture techniques from Japan has also resulted in a significant increase in *Undaria* production in the Republic of Korea. The use of nursery-produced seedlings has increased production from culture which has been estimated to con-tribute 17 to 18 percent to Korea's total production. However, because the projected increased increase in local demand and exports did not materialize, the oversupply resulted in low prices.

3. LAMINARIA CULTURE

The rapid development in culturing *Laminaria* (in Japanese: kumbu, in Chinese: haidai) in China has been attributed to important successes in the resolution of production and quality related problems. The development and application of raft culture has extended production to relatively deep, open seas. The problem of low nutrient supply was resolved with the development of spraying and soaking method of fertilization. The problems of sporeling supply and those of epiphytes and weeds which hinder the normal development of young *Laminaria* plants in the field were resolved when the temperature requirements of the gametophytes and the young sporophytes was determined. This knowledge became the basis of the low temperature method of culturing summer sporelings under controlled, indoor conditions. The availability of hatchery-reared summer sporelings in early autumn provides a significant ecological advantage for the crop over the competing weed species. The introduction of this method has resulted in a 30 to 50 percent increase in the total production (Tseng, 1981). Aside from decreasing the weed problem, the use of the summer sporelings has lengthened the production period by two to three months and benefitted also workers because planting can now be done in autumn when the water temperature is relatively warm.

The problems of low productivity and inferior quality of the product were resolved through the development of highly productive strains with high iodine content through hybridization. Additionally, the understanding of the etiology of diseases provided a basis for the application of preventive measures. Production areas have been expanded towards the southern parts of China through the development of warm-water strains. The success in the development of long distance shipping techniques rendered the sporelings and matured *Laminaria* available to farther growing areas.

4. GRACILARIA CULTURE

Although the monoculture and polyculture of *Gracilaria* (in Chinese: jiangli, in Tagalog: gulaman) in ponds became a very successful aquaculture venture during the past decase in Taiwan, not all the problems are solved as yet. According to Chuch and Chen (1982) one of the most pressing problems which restrains the rapid expansion of this venture is the serious competition in the utilization of coastal areas with other aquaculture methods such as finfish and shrimp culture. The southwestern part of Taiwan where *Gracilaria* culture has been found to be the most successful is fully utilized for these other aquaculture ventures. This problem was partly resolved by the development of a polyculture of *Gracilaria* with shrimp and tilapia. The latter species are successfully for weed control in the ponds by controlling other seaweed species such as *Enteromorpha* and *Chaetomorpha.* Another problem which adversely affects this venture is the seasonal variation of the agar quality in the production. Among the ecological factors which have significant influence on the quality the most important ones are temperature and daylight regimes. The development of strains adapted to different growing areas is a major step toward the resolution of this problem.

5. EUCHEUMA CULTURE

Although the culture *Eucheuma* (in Tagalog: gozo) has become a major aquaculture industry since the accidental discovery of fast growing varieties, it has also been going through some critical times ever since its initial success in the early 1970s. These problems stem mainly from two major areas of concern, namely; fluctuating prices related to a weak marketing system and the biological problems associated with production.

The highly fluctuating prices are attributed to a buyers market, where prices are usually determined by a few major buyers/exporters (Hollenbeck, 1983). The farmers whose individual production is small, do not have the capability to influence the local prices of the seaweed. Despite the presence of a number of traders which made the local market somewhat competitive, the *Eucheuma* wholesale market is still dominated by the buyers and prices continue to fluctuate significantly. One of the primary reasons for the unstable prices is the fact that production is concentrated in one major area of the Philippines and any political instability in this area induces speculation on the amount of the expected supply, affecting ultimately the local prices. In addition, there is a tendency among buyers to acquire their stocks in the shortest possible time (ADB/FAO Report, 1983). Increased production is stimulated by buyers through increasing the local prices, these encourage the farmers to overproduce which in turn results in lower prices. Opening up other production areas to prevent speculation and enhancing the capability of the farmers to influence pricing through the formation of cooperatives would increase incentives to production and stabilize prices.

The fluctuation of production brought about by the seasonality in the growth of different varieties, weather disturbances (e.g., typhoons), the occurrence of the So-called “ice-ice” disease and the general decline in the productivity of the cultured varieties have adversely affected the industry, in many occasions resulting in the economic dislocation of farmers. The growth of the different varieties has been demonstrated to vary with the seasons of the year (Trono, 1985, unpublished). Months characterized by low light intensities and warmer water temperatures (June to October) are generally very productive for all the varieties in contrast to months characterized by high light intensities and cooler temperatures (December to February). However, *“spinosum”,* varieties tend to recover better than *“cottonii”* varieties during the following months characterized by higher light intensities and warmer temperatures (March to June). The general practice of the farmers of selecting the best looking plants from their harvest to be used as planting material for the next growing season (without considering their inherent seasonality in growth) appears to have further contributed to the slow but continuous decline in the productivity of the different varieties in the farming areas of northern Bohol, central Philippines. The studies of Trono *(loc. cit.)* also demonstrated that the low quality of the *Eucheuma* product (which manifests in a low yield of pure carrageenan) is directly related to the health of the crop during harvest. Healthy crops have high recoverable carrageenan content.

Although there are no conclusive evidences, the occurrence of “ice-ice” disease appears to be preceded by conditions of low nutrient regimes. Uyenco *et. al.* (1981) showed apparent positive correlation between low concentrations of phosphates and the occurrence of the disease. The relationship between the incidence of blooms of other algae with the occurrence of the disease is not well understood. The problem of low production associated with the seasonality in growth may be resolved through proper management such as the planting of the appropriate varieties during certain months of the year. The requirements for such a scheme that is the availability of the appropriate varieties, however, seems to be a formidable, problem which has to be resolved first. Trono *(loc. cit.)* proposed the establishment of seedling banks in areas having different oceanographic conditions from those in Danajon Reef farms but accessible to the local farmers.

The solution of the disease problem by developing resistant strains through hybridization appears to be slow due to the lack of basic informations on the sexuality of the different varieties. Although the present work on “seed selection” (based on varietal growth performance tests) may result in the production of physiologically superior varieties, the solution of the problem of enhancing growth and resistance to the disease through genetically improved strains is still paramount. The application of genetic engineering methods such as protoplast fusion may be the ultimate solution.

The expansion of production areas to other parts of the Philippines has been constrained by the minimal support to the efforts in locating appropriate sites for farming and is compounded by the unavailability of the right varieties to be utilized for field testing. Although some general criteria for site selection are available, these are mainly guidelines to narrow the choices to a manageable number of sites and the final decision whether to develop a given site to farms should depend on the results of actual field tests using available varieties. The presence of natural population of the species to be cultured is a good indicator of the potentials of an area.

The lack of appropriate varieties and predation are two of the most important problems generally encountered during the initial stage of the development of an area. Although effective control of large and slow moving grazers (such as sea urchins) can be achieved, it is almost impossible to control fast swimming grazers (such as rabbitfish) especially when they graze during the night. The varieties presently used in two major farming areas in the Philippines that is in Sulu and Northern Bohol appear to have developed peculiar ecological characters over the many years they have been cultured in these areas and as there is no information on the physiological requirements of these varieties, the success of introducing these to new areas sometimes becomes a matter of a hit-and-miss process.

6. CAULERPA CULTURE

Problems encountered in the culture of *Caulerpa* are mainly the seasonality of the production and the low local demand for the product. Being a stenohaline marine alga, its growth is easily affected by lower salinities brought about by rains during the monsoon season. This problem, however, could be minimized by the incorporation of a flow-through system when constructing the ponds to facilitate proper water management, that is maintaining the salinity above 30 ppt. The development of consumer demand has been constrained by high prices in areas far from the center of production. The introduction of *Caulerpa* culture in areas where it is popular with local people will result in lower prices within the reach of the consumer.

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Lecture 11
POLYCULTURE OF SEAWEEDS WITH MARINE ANIMALS

by

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1. INTRODUCTION

The rearing of desirable aquatic organisms under controlled condition for their socio-economic benefits is “aquaculture”. Of the different types of “water culture”, “mariculture” or “seafarming” seems to be less developed compared to freshwater and brackishwater culture. These efforts are geared towards the replacement of traditional, almost unmanaged, harvest of natural populations with the most economical culture techniques that will increase production and improve the quality of selected organisms.

Marine organisms presently being commercially grown in “monoculture” (i.e., culture of single species) include: a) finfish, b) shrimp, c) prawn, d) oysters, e) mussels, f) clams, g) scallops, and h) several species of seaweeds. Of the abovementioned, some fishes, shrimps and prawns are the organisms which are sometimes cultured with sea-weeds. Polyculture is a system of rearing two or several compatible animal/s and/or plant species. It remains to be fully utilized in most countries. Perhaps only Japan has made significant advances in this regard. Aside from practical purposes of saving time and space, the system allows for energy or food partitioning or budgeting among the different organisms cultured. Hence, input of nutrient into the system may become unnecessary or may be minimized through proper timing and control of the levels of production of each species involved. To attain this end, the roles of organisms in relation to each other (or ecological niche) should be clear to the culturists. The biology of the organisms involved should also be well studied or defined. For example the roles of seaweeds in relation to the omnivorous, carnivorous or herbivorous animals need to be clarified. How and when the animals will affect the productivity and reproduction of the seaweeds should also be considered. All the basic information must be gathered to effectively manage the more complicated polyculture system.

This lecture presents existing or developing polyculture systems of seaweeds with marine animals in the ASEAN and Asian countries. Polyculture using a) ponds and b) open sea systems are covered. Suggestions are made on the use of other marine organisms for future polyculture systems, Culture of seaweeds incidental to or in relation to culture of fishes are likewise considered.

2. POND POLYCULTURE OF SEAWEEDS WITH MARINE ANIMALS

In developing ponds for polyculture, a decision must be made on what major product is desired. Fish and crustacean culturist do not necessarily desire to produce seaweeds as a crop. On the other hand, seaweed culturists may raise some animals in their ponds as a by-product or secondary product. More often, however, the animals are raised as a management tool in the control of undesirable weed species.

2.1 Gracilaria pond culture
(After Chen, 1976)

Japan, China, Korea, Vietnam, India, Philippines and Taiwan have been practising *Gracilaria* pond culture usually with shrimp *(Penaeus monodon),* crab *(Scylla serrata)* or milk-fish *(Chanos chanos).* Doty and Fisher (1986, as cited by Trono, 1986), reports that hatchery produced *Gracilaria* seedlings from spores are more superior in open field culture. The *Gracilaria* species used for culture are: a) *G. “verrucosa”,* the preferred species in Taiwan, b) *G. lichenoides, c) G. gigas* and d) *G. compressa.*

Chen (1976) enumerated the following ideal pond culture conditions of *Gracilaria*: a) the rectangular pond, one hectare in size, should not be exposed to strong wind, the long axis perpendicular to the direction of prevailing winds; a windbreak may be constructed on the windward side, b) sufficient tidal flow to change water, c) sandy loam bottom, d) pH of 6–9 preferably 8.2 to 8.7, and e) fresh water available to avoid above normal salinity.

2.1.1 Culture method

Cuttings of *Gracilaria* can be broadcasted to grow on pond bottom planted in nets fixed on poles, or tide to monoline systems as is being done in Burma. Sporelings can be grown on adobe or cement blocks added to the substratum as in Bacoor, Cavite, Philippines. Average water depth is 60–80 cm. Water is changed once every two to three days and fertilization with 3 kg urea or 120–180 kg fermented manure from pigsties when new water is introduced. The stocking materials and time of harvest for a hectare of farm are as follows (Trono, 1986):

Organism	Stocking material (kg)	Time of harvest
1. *Gracilaria*	4 000 to 5 000	after 3 mos.
2. Crab	5 000 to 10 000	3 mos.
3. Shrimp	10 000 to 20 000	4–7 mos.

Milkfish which can be stocked at 500 to 1 000/ha can control the green algae *(Enteromorpha* and *Chaetomorpha)* which may be “pests” on *Gracilaria*. Other weeds include *Acanthophora* and *Bangia.* After the green algae are gone, the milkfish will eat *Gracilaria*. When this begins to happen they should be netted at the water inlet where they congregate.

Many *Gracilaria* farmers stock *Penaeus monodon* or *Scylla serrata* to utilize fully the pond space and for additional income. Net income from this type of polyculture is three times as much as monoculture of the seaweed. Annual production of dual *Gracilaria* is about 10 000 to 12 000 kg. Drying rates is 1.7. The criteria for maintaining the quality of export may be summarized as follows: not more than one percent mud and sand; not more than one percent of mollusc shell; and not more than 18 percent mixture of other seaweeds: total not more than 20 percent foreign materials. The moisture must not exceed 20 percent. The dried seaweed is packed in 100 kg gunny sacks for export or local sale.

Penaeus monodon tolerates up to 30°C and 10–35 ppt. The stocking density in nursery ponds is 300 000 to 500 000 fry/ha. Later, stocking density is reduced to 10 000 to 12 000 juvenile/ha in grow-out ponds as in polyculture with *Gracilaria*. “Lab-lab” which is the scum or crust of microbenthic algae that may grow naturally in ponds (on poles or attached to macrobenthic algae such as *Gracilaria*), serves as feed to the shrimps. Ricebran, dead fish or other protein sources can be ground with “lab-lab” for feeding. Small-scale production of shrimps is usually achieved in this polyculture with *Gracilaria*.

2.2 Caulerpa pond culture

To date, the Philippines is the only country known to be cultivating *Caulerpa* in ponds. The more popular species being cultured in Mactan Island, Cebu and lately in Batangas is *C. lentillifera*. Production of this and other edible *Caulerpa* species, however, remains to be dependent upon natural stocks. Trono and Denila's (1987) experiments on pond culture of *C. lentillifera* have shown that: a) there is seasonality in production under farmed and natural conditions; b) seasonality seems to be influenced by salinity primarily and temperature and light intensity secondarily; c) production is better in ponds than in open natural conditions; and d) water management is an important factor for successful farming.

Their experiments have also shown the following growth rates and increase in biomass production in *C. lentillifera* in pond culture.

Stocking density	Growth rate	Percent increase
100 g/m^2	15.16 $g/m^2/day$	940 percent
250 g/m^2	19.78 $g/m^2/day$	478 percent
500 g/m^2	32.00 $g/m^2/day$	376 percent

The conditions in the experimental fish-pond about 1/4 of a hectare size were as follows: a) muddy substratum; b) temperature range of 22.5 to 37.5°C; c) salinity range of 23–36 ‰ (lowest in August highest in March of 1982); and d) light intensity range of 4 500–10 000 lux. Plants were produced by vegetative regeneration of stocks coming from Mactan Island, Cebu.

Although most of the fish and/or shrimp culturists (in Mactan, Cebu) have apparently shifted to monoculture of *Caulerpa*, some have retained small-scale production of these animals. With proper management, this polyculture system can be continued or enhanced.

3. OPEN SEA POLYCULTURE OF SEAWEEDS WITH MARINE ANIMALS

Eucheuma, Porphyra, Undaria and *Laminaria* are the seaweed genera which have been successfully cultured in nets or monolines attached to poles in the “open sea”. Systems for their monocultures have been outlined by Trono (1986). Details of their culture techniques are not considered in this paper since they are fully covered by the other lectures.

3.1 Possibility of Eucheuma polyculture with giant clam, abalone or lobster

Eucheuma monoculture in the Philippines is quite extensive. Existing farms are found in Southern Philippines (which has the greatest production), Central Visayas and Batangas. Most of the farmers utilize about one hectare (per family) wherein 10 meters long one meter apart monolines are fixed on the substratum of reef areas. About 35 *Eucheuma* (30 to 50 g/bunch) cuttings are tied at 20 to 25 cm interval per monoline. Since harvesting of whole plants are usually done monthly when replacements or replanting are done, spaces between mono-lines could be unproductive or useless. Limited numbers of giant clams which do not feed on seaweeds could then be cultured in these areas. Their shells can be substrates to the spores and sporelings of this genus whose thalli have been recently found with tetraspores and carpospores even in farming conditions. However, weeding of other seaweeds that may also grow on the clams should also be done.

Giant clams of the genus *Tridacna* and *Hippopus* have been successfully spawned in various laboratories in the Pacific. As a consequence, several species are now being farmed in Australia, Philippines and several countries in South Pacific. Interest in these “self-feeding” bivalve is growing because of its economic value.

Abalones which are herbivores could also be cultured to a limited extent in unproductive sites in a *Eucheuma* farm. Care and attention should be given so that they will not negatively affect production of sea-weeds. If the primary concern is abalone culture, the organism being quite expensive and in demand as food especially in Japan and Korea, seaweed beds could be maintained or developed for their shelter and protection. Ohno (1987) has been doing experiments to produce seaweed beds from artificial substrates (reefs) for various stages of abalone culture in Japan. In other ASEAN countries like the Philippines, existing sea-weeds beds could be utilized for this purpose.

Spiny lobsters could also be grown in sea-weed beds in the open ocean. It has been found that the planktonic larvae swim into shallow coastal waters to seek shelter in seaweed beds, particularly among those members of Rhodophyta. The juvenile lobster forage on these seaweed (and sea-grass) beds for molluscs and crustaceans. Since availability of feeding areas has been found to limit growth of the young lobsters, special types of artificial structures to generate seaweed: beds are also being built and tested in Japan (Ohno, 1987).

4. CULTURE OF SEAWEEDS IN RELATION TO FISH CULTURE

Seaweeds are now being deliberately grown or cultured in the open sea in order to expand, develop or conserve fishing grounds. In Japan, a “National Scale Fishing Ground Engineering and Development Program” was launched in 1976. Among others, the programme consists of submersion of artificial reefs and breakwaters and creation of seaweed beds and forests. All of these have been done in connection with a “marine ranching program” that will enhance marine fisheries production within the country's territorial limits (Yamane, 1987). These artificial reefs made of cement blocks or steel are used as substrates to develop seaweed beds and forests where other marine organisms could be grown as discussed in the preceding paragraphs. Sea-weed beds or forests made up of *Sargassum, Laminaria* or *Eisennia* could serve as spawning or nursing areas for fishes (Ohno, 1987; Tsukidate, 1987). Tsukidate (1987) reports that about 50 spp. of fishes belonging to 23 families have been found along *Sargassum* masses. These fishes belong more commonly to the following genera: *Sebastes, Sebasticus, Hexagrammos* and *Seriola.* Floating or sub-merged seaweeds serve as attachment of microalgae which can be: a) food for fish, b) substrate for their eggs, and c) spawning ground (Kimura, 1987). Japanese fishermen usually catch fishes along or adjacent to floating *Sargassum* masses (Tsukidate, 1987). Other marine animals found in the seaweed *(Sargassum)* beds are polychaetes and molluscs at their larval, young and adult stages (Tsukidate, 1987; Ohno, 1987).

In other Asian countries where seaweed beds still flourish, conservation and management of their stocks need to be done or started soon. This is not only to protect the seaweed species from overexploitation but also to maintain these sites as fishing grounds. Polyculture of suitable fishes in available or newly created seaweed beds can be done in countries other than Japan which has initiated the programme.

Incidental culture of seaweeds in cultivation sites of some fishes has also been observed. In the cage and pen culture of yellowtail *(Seriola quinqueradiata)* in Japan, luxurious growth of *Hypnea* and *Gracilaria* has been noted. The culture of seabass *(tales calcarifer)* in Thailand has also yielded growth of some *Gracilaria* species.

Fish Attracting Devices (FADs) can also have overgrowths of certain seaweed species. They can be used as structures for seaweed culture. The Philippine “payaw” which makes use of bamboo poles and leaves of terrestrial plants can utilize seaweeds in order to attract fishes more effectively, and culture these marine plants at the same time.

The (over) growth of seaweed species in fish culture areas and FADs can be developed, maintained and controlled to generate secondary products.

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Lecture 13 and Practica 3
FIELD AND LABORATORY TECHNIQUES IN THE COLLECTION, PRESERVATION AND PREPARATION OF MARINE BENTHIC ALGAE FOR HERBARIUM AND FOR IDENTIFICATION

by

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1. INTRODUCTION

To be able to effectively acquaint one's self with the seaweeds, one must experience the collection of the specimens in the field and their preparation in the laboratory for the herbarium. Only through the practice of handling and distinguishing the plants as they appear in nature or as pressed or preserved specimens, can one develop the ease of identifying them. By carefully comparing the specimen with the taxonomic description of the species in the literature may lead to the right identification of the species.

2. COLLECTION OF SEAWEED MATERIALS

The following are the usual supplies and materials necessary for seaweed collection:

- plastic bags, small bottles or vials, net bags or pails
- knife (or any scraping material)
- labelling materials (pencil, pentel pen, hard paper or plastic card)
- facemask, snorkel, glass bottom
- booties or rubber shoes

The best time for collecting the seaweeds is during the hours of the falling tide. It is best to go to the collection site one to two hours before the time of the low tide (minus tides are the best times) as predicted by the tide table. This is to allow the collector considerable amount of time to observe the algae in their natural habitat, to record such observations and to collect the specimens.

When collecting, be sure to remove the complete plant (including the holdfast) from the substrate and put this in the plastic bag together with the label which include the place, date of collection, kind of substrate of habitat. Be sure to gather only what is needed for conservation purposes. Delicate or small materials should be placed in separate plastic bags (small) or vials. Many specimens can be removed from their substrates by hand but those closely adhering to rocks such as crustose or mat-forming species may be removed with the help of a knife or any scraping material to secure the complete holdfast. However, those species which may adhere so closely to the rocks can be removed with the rock using a geologist's pick or any similar instrument. For the epiphytic species, this could be collected with a portion and the host plant.

3. PRESERVATION AND TRANSPORT OF SEAWEED MATERIALS

Things needed are the following:

- five to 10 percent solution of commercial formalin of sea water
- pails with cover or styrofoam boxes
- labelling materials
- large plastic bags (sack size)

Prepare five percent solution of commercial formalin in sea water. Prepare a stronger solution of 10 percent if the specimens to be fixed could not be processed immediately. Remove all animal components, rocks and other foreign materials from the collected seaweeds. Before addition of the formalin, drain the water from the plastic bag. The formalin should then be poured to the seaweed materials inside the plastic bag in amounts just enough to fill the bottom of the bag. Additional formalin may be added if the materials are bulky or fleshy. The fumes of the formalin.would be enough to fix and preserve the algal materials. All these materials should be properly labelled with information on the place and date of collection, name of the collector and pertinent observations on the character of the habitat written on quality paper or any substitute using indelible ink or pencil. Label also the plastic bags using pentel pen.

For transport of the plastic bags containing the preserved algal materials, these should be placed in large styrofoam boxes or barrels or in two to three layers of good quality large plastic bags (approximately 0.6 × 1.0 m in size) properly tied with rubber band to prevent any leakage of formalin.

4. HERBARIUM TECHNIQUES AND PROCEDURES

Things needed:

- basin with a flat bottom
- galvanized sheet (approximately 31 × 24 cm size)
- forceps
- dissecting needles
- mounting sheets (preferably two-ply velum paper cut into ¼ and ½ sizes)
- paper cutter
- data notebook
- pencil
- driers: cheese cloth, blotters, old newspapers
- ventilators: corrugated aluminum sheets, corrugated cardboards
- wooden pressers
- strings or any tying material

Upon returning to the laboratory, ready the above materials for preparation of sea-weeds for the herbarium. It would be convenient to work on the individual collecting bags. Dump specimens contained in each bag into a flat-bottom basin containing fresh water to wash off excess formalin and other foreign materials, i.e., sand, pieces of shell, etc. Sort out the seaweeds according to species. Assign a collection number to one species collected in one area at one time. This number should be recorded in a data notebook together with the information on the name of the species, date and place of collection, name of collector and other pertinent ecological data. This same number should be written on the mounting sheet carrying the particular algal species. In mounting, place the paper on top of a flat galvanized sheet and immerse both in a basin of clean water. Arrange the specimen on the mounting sheet while under water to simulate their natural habit, especially when this is of the filamentous type. Then lift the galvanized sheet carefully from one side to allow the water to drain off gradually and to leave the specimen spread out and undisturbed. Final arrangement of the specimen may be made when out of the water with the use of forceps and dissecting needles.

Place the mounting sheet with the specimen directly on top of the newspaper which is spread out on the blotter resting on a ventilator. Cover the specimen with a cheese cloth. Then, place another newspaper and blotter on top of the cheese cloth. Add another ventilator on top of the pile. The same process is repeated for the rest of the mounted specimens until a sizeable pile is made. This pile should then be stacked between two wooden pressers. Enough pressure should be applied to the pile while tying it tightly.

The whole stack is left to dry in an oven-dryer under temperature of 65–70°C for 24–32 hours (continuous) or three to four days if oven is “on” only during daytime, depending on the thickness of the pile. If an oven-dryer is not available, frequent changing of the driers (such as the wet blotters, newspapers and cheese cloth) must be done until drying is complete.

For the crustose algal species, these should be dried directly in the air, then kept in small boxes of suitable size. Articulated, calcareous algae that are so fragile/or so three-dimensional as to suffer badly from pressing should also be air-dried and kept in boxes. (Be sure to provide labels to each species in the same way as the mounted ones). They should, however, preferably be soaked for several days or weeks in a formalin solution containing 10 to 40 percent glycerin before being dried and kept in small boxes. Glycerin retains the flexibility of the genicula and prevents fragmentation.

All seaweed specimens (mounted or in boxes) should be provided with labels containing the following information: collection number, name of species, place and date of collection, collector/s and other pertinent ecological data if available. For those materials which do not stick to the mounting sheet use gum arabic glue or any substitute. Keep the seaweed exsiccatae materials (dried herbarium materials) in a cabinet.

5. PREPARATION OF SLIDES OF MARINE BENTHIC ALGAE FOR IDENTIFICATION

5.1 Whole mounts

Microscopic forms of benthic algae especially the epiphytes are always mounted wholly. To prepare temporary mounts, carefully wash the specimen on a petri dish by changing the fresh water several times until the sand or mud particles are removed. Then transfer the specimen to a clean glass slide. Stain it with one percent aqueous aniline blue by adding one to two drops of the stain, acidifying it with one drop of one percent HC1 after about a minute, and then washing it with a drop or two of distilled water. Excess acidified stain and water may be blotted off with tissue paper. Add a drop of glycerin or 45 percent Karo syrup with phenol to the specimen before putting the cover slip. Apply nail polish to seal the edges of the cover slip.

5.2 Cross-section mounts

The sections of the branches may be used for anatomical studies. The freezing micro-tome, if available, is one of the most useful equipment for preparation of sections. However, free hand sectioning may be easily substituted for the microtome although the sections may not be as good. Skill in making sections can be developed through practice.

For materials which are foliose, good sections may be produced by cutting a piece of the blade, then folding this several times and placing it between two glass slides in such a way that a part of the specimen is exposed beyond one end of the upper slide. Use the upper slide as a guide for cutting. Be sure to use new razor blades. The plane of cutting should be tilted towards the far end of the material in such a way that several cuts could be made before the upper slide is slid back a little to expose more of the materials for further cutting. Many of such sections should be made and only the thin ones can be separated from the rest using a dissecting microscope.

For those materials with cylindrical or flattened branches, the same technique can be used. One to several of the branches (depending on the diameter) should be placed between two slides as discussed above.

The sections are stained with aqueous aniline blue using the same procedure described for the “whole mounts”.

5.3 Squash mounts

Materials which are soft and basically filamentous in construction easily lend themselves to this special technique. These may also include those materials which are slightly calcified. These are first decalcified using 10 percent HC1 solution right on the slide. Then remove excess acid using tissue paper as absorbent material. Wash the specimen with distilled water by adding drop by drop of the liquid. Blot off excess liquid with tissue paper.

The same procedure described for the “whole mounts” is followed when staining the squash mounts.

All slides should be labelled; include the collection number, name of the species and structure emphasized in the slide.

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STATUS OF SEAWEED CULTURE IN INDIA

by

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1. INTRODUCTION

In India, Gulf of Mannar, Gulf of Kuteh, Palk Bay, Lakshadweep and Bay islands are the important areas having considerable natural resources along the 6 100 km long coast line of the country.

About 680 species of seaweeds belonging to the groups *Chlorophyta, Phaeophyta, Rhodophyta* and *Cyanophyta* occur naturally in varying degrees of abundance in shallow bays, lagoons and coastal areas which offer suitable substrata for their growth and propagation.

Apart from their utility as a source of food, food derivatives, vitamins, proteins, etc., seaweeds provide the raw material for many agar and algin-based industries. The exploitation of carrageenophytes such as species of *Hypnea, Acanthophora, Laurencia,* etc. has yet to make a beginning in the country as these are available in sizeable quantities.

In view of the constant demand for the seaweeds, research programmes on seaweed resources and their culture were taken up by the Central Marine Fisheries Research Institute, and Central Salt and Marine Chemicals Research Institute at Mandapam at their Regional and Field Centre, respectively, and various other research organizations belonging to the State Fisheries Departments/Universities. As regards sea-weed farming, experiments were mainly carried out on species of *Ulva, Gelidiella acerosa, Gracilaria edulis, Gracilaria corticata, Gelidiopsis variabilis, Gelidium pusillum, Hypnea musiformis, Acanthophora spicifera, Hormophysa triquetra, Cystoseira* sp. and species of *Sargassum.*

The experiments were mainly conducted by the method of vegetative propagation. Some trials were made with spores as well. An appraisal of different techniques adopted were as follows:

1.1 Culture of Gelidiella acerosa

Bhanderi (1974) cultured the apical region of the *Gelidiella acerosa* by inserting these fragments in a string and suspended in a seawater aquarium at Port Okha, Gujarat. He observed a linear growth of 0.01 cm/day and an increase of 0.01 g/day in weight. Krishnamurthy *et al.* (1975) conducted some experiments with 2 cm fragments of *G. acerosa* in a lagoon on the southern side of Krusadi Island. After four months, the fragments grew to full sized plants of about 10 cm in length with seven to eight branches.

In the same area Subbaramaiah *et al.* (1975) carried out experiments on 2 cm length fragments of *G. acerosa* fastened to a nylon string at fixed intervals and the seeded string was wound round a rope kept submerged in coastal waters. The maximum growth attained was 6.6 cm and the rate of production was 3.13 g/m/month (wet). The total production of seaweed was 421 g/m (wet) in a year.

Experimental field cultivation of *G. acerosa* using submerged coral stones as the sub-strata was done at Ervadi (Patel *et al.*, 1979). An annual yield of 115.83 g/m^2/day (dry) on overall basis was obtained which was 33 times over the seed material. Patel *et al.* (1980) reported a maximum yield of 122 g/m^2 (dry) in one of their six monthly harvests made in January 1979 from the field cultivation of *G. acerosa* at Ervadi.

1.2 Culture of Gracilaria edulis

Raju and Thomas (1971) cultured *Gracilaria edulis* by long line rope method in a sandy lagoon in Krusadi Island. Fragments of 1 cm and 2.5–3 cm length were used for planting and they grew to a length of 35–40 cm in about five months period. Three harvests were made at the end of 5, 8 and 10-1/2 months and the total harvest during the year was about 3.5 kg per 1 m length of rope.

Krishnamurty *et al.* (1975) carried out cultivation of *G. edulis* in a lagoon in the Krusadi Island. Fragments of 2.5 cm length were introduced in the twists of the ropes which were tied to bamboo poles planted to the sea bottom. In about five months period, the plants attained a length of 30 cm and the average weight of plant was about 300 g. A total of three harvests were made in a period of 10 months.

1.3 Culture of other red algae

Bhanderi (1974b) recorded a linear increase of 0.02 cm/day and an increase of 0.07 g/day in weight in his culture experiments on *Gracilaria corticata* in seawater aquarium. In experiment with *Gelidiopsis variabilis,* he obtained a linear increase of 0.12 cm/day with an increase in weight of 0.04 g/day.

Mairh and Sreenivasa Rao (1978) cultured *Gelidium pusillum* in the laboratory under free floating conditions and using nutrient enricher and obtained maximum fresh weight and full size within three to four months. Rama Rao and Subbaramaiah (1980) cultured *Hypnea musciformis* and obtained four fold increase in 25 days.

Thivy (1964) conducted culture experiments in ponds at Porbandar by attaching small plants of *Sargassum cinctum, S. vulgare* and *S. wightii* to coir nets with the help of tape. The plants grew to a height of 15–52 cm for an initial 5–10 cm length within 40 days.

Bhanderi and Trivedi (1977) made an attempt to study the possibility of culturing *Hormophysa triquetra* by vegetative propagation in an aquarium. The fragments gained seven times (fresh weight) over the initial weight at a rate of 0.333 g/day.

2. SEAWEED CULTURE EXPERIMENTS AT CENTRAL MARINE FISHERIES RESEARCH INSTITUTE (CMFRI)

The Central Marine Fisheries Research Institute at its Regional Centre at Mandapam conducted culture experiments especially with *Gracilaria edulis* and *Gelidiella acerosa.* In seawater aquaria *Gracilaria corticata* (Umamaheswara Rao, 1973) was cultured which showed an increase in length from 1.8 to 5.5 cm in 90 days. Experiments with *Gracilaria edulis* in 0.5 m^2 coir nets yielded very good results. The average height of the plants varied from 14 to 16 cm at the end of two months and the fragments gained a weight of 213 and 257 g, respectively. Experiments conducted in 4 × 2 m size coir rope nets yielded 4.4 kg (fresh weight) of seaweed per square meter in 80 days (Umamaheswara Rao, 1974a).

The culture experiments were conducted by introducing fragments of the seaweed into the twists of the coir ropes which in some cases were fabricated in the form of nets of different sizes which in turn were tied to wooden poles fixed in the coastal waters.

Experiments conducted in the submerged floating condition (Chennubhotla *et al.*, 1978) proved to be more beneficial than that at subtidal level.

The cultivation was attempted at slightly deeper water, i.e. 3–4 m depth on HDP rope nets to avoid intensity of sedimentation and grazing by fish. The yield obtained was about four times the initial weight after 70 days. Chennubhotla *et al.* (1977c) cultured *G. acerosa* by tieing small fragments along with substratum (coral piece) to the coir ropes in the net. One frame was introduced with 0.9 kg and the other with 1 kg seed material. A yield of 2.5 and 3 kg were obtained, respectively after 76 days.

Experiments conducted by keeping the *G. acerosa* seeded coral stones kept in cages were introduced in 2 to 4 meters depth. The growth of the seaweed was found to be very luxuriant.

The culture was attempted by fastening fragments of *G. acerosa* to coral stones with the help of iron nails, reached harvestable size after five months and 1 kg of seed material yielded 3.1 kg of full grown plants.

Fragments of *Sargassum wightii* obtained from the basal portion of plants with holdfast were inserted in the twists of the coir ropes and cultured in inshore waters of Gulf of Mannar at 1 m depth in mid-water level. An average growth of 15.5 cm was recorded from an average initial length of *7.7* cm within 60 days (Chennubhotla *et al. 1976,* unpublished).

Cultivation of *Acanthophora spicifera* was carried out on 2 HDP rope nets in 60 × 30 m sized ponds which are connected through a feeder canal to the sea. An average yield of 22.615 kg (wet weight) was obtained after 45 days from the two nets which was found to be 3.6 times the initial seed material. The remnants were allowed to grow for the second harvest which was made after 35 days. An average yield of 14.4 kg was obtained in the second harvest (Chennubhotla *et al,* unpublished).

Experiments on *Ulva lactuca,* pre-treated with ascorbic acid were cultured in the sea-water of different salinities in the laboratory. It was observed that the trials with 18 percent salinity boosted up the production to eight times in 92 days (Chennubhotla *et al,* unpublished).

2.1 Culture of spores

The number of spores produced by an alga is enormous. In nature only a small number of spores grow to mature plants since viability, settlement and development of these spores are controlled by hydrobiological factors such as water movement, tidal exposure, water temperature, competition for space and predators or grazing organisms. When the spores are raised into germlings on suitable substrata in the laboratory or nursery and then transplanted to the field, a high rate of germlings grow to harvestable size plants. Some work in this direction of culturing the spores of economically important seaweeds was carried out in recent years.

Subbaramaiah *et al.* (1967) cultured germlings of *Ulva lactuca.* The germlings were kept growing in attached or in a free floating condition in petridishes containing sterile sea-water which was changed once a week. In two months time the germlings differentiated into cylindrical plants with 2–3 branches arising from the basal cells. The floating plants were found to be longer (1.25–1.7 m) and produced branches while the attached ones were shorter (0.75–0.83 m).

The effect of different culture media on growth and sporulation of laboratory raised germlings of *Ulva fasciata* was given by Oza and Sreenivasa Rao, (1977). Kale and Krishnamurty (1967) studied the effect of plain seawater, Erdschreiber seawater and artificial seawater medium (modified ASP-6) on the growth of germlings of *Ulva lactuca* var *rigida.*

Mairh and Krishnamurty (1968) observed 100 percent germination of spores of *Cystoseira* and subsequently 94 percent of their survival. The germlings survived and grew to young and healthy plants under experimental conditions. Chauhan and Krishnamurty (1967) cultured the oospores of *Sargassum swartzii* in petridishes lined with filter paper. They developed into germlings and some of them grew for a period of five weeks. Experiments were also conducted using different substrata such as coral pieces, shells, granite stones, nylon threads and rough stones. Some of the oospores attached to the substrata developed into healthy germlings while a large number did not survive. Continuous illumination of the culture experiments with a light intensity of 600–800 lux, 23–26°C temperature and circulation of a thin stream of filtered sea-water were found favourable for healthy growth of germlings. Chauhan (1972) observed the survival of germlings in *Sargassum swartzii* for about six months under the controlled laboratory conditions. Of the eight different substrata used, the concrete blocks, bricks and filter paper were found to be good substrata as they retained 84.55 percent, 78.42 percent and 62 percent of the germlings, respectively. The filtered seawater and enriched seawater were found to be most suitable culture media for the growth of germlings. The use of media like ASP-6 and ASP-12 did not give good growth of germlings. Continuous illumination was found to be more beneficial than 18 hours photoperiod.

Raju and Venugopal (1971) made an attempt to allow the oospores of *Sargassum plagiophyllum* to settle on a concrete substratum with a view to find out the time required for the appearance and growth. The concrete cylinders were lowered in *Sargassum* beds. Observations revealed that the appearance of *Sargassum* germlings on the cylinder took 10 months and another eight months to grow to maturity. Observations after one year revealed that there were a number of new plants which had germinated from the spores within the year and some had regenerated from persisting holdfasts. There appear to be potentiality for regeneration for a third year in a few plants. Umamaheswara Rao and Kaliaperumal (1976) maintained the oospores of *Sargassum wightii* in a medium of seawater enriched with agar and found that 47.6 percent of germlings were in healthy condition at the end of 60 days. Krishnamurthy *et al.* (1969) raised the germlings of *Gracilaria edulis* and *G. corticata* on a nylon fabric from carpospores under laboratory conditions. They were transferred to the sea. After four months, young plants appeared and they took another four months to attain maturity and develop reproductive structures.

Chennubhotla et al. 1977 (unpublished) conducted laboratory culture experiments on the viability, germination growth of germlings of *Turbinaria ornata* and *Gracilaria edulis* under controlled temperature of 18±2 and light intensity of 4 K lux. The spores of *T. ornata* were found to be viable even after a period of two months, but growth of germlings was not satisfactory. Carpospores of *G. edulis* were allowed to germinate and parenchymatous stage of development was noticed.

It is understood that UNDP/BOBP Programme at Madras has embarked on culture of seaweeds by tetraspores in Mandapam-Vedalai area. This may throw light on the aspect of spore culture in the natural environment.

2.2 Environmental factors in relation to seaweed culture

In the Central Marine Fisheries Research Institute, the culture experiments were conducted in different seasons of the years from 1976 to 1985 continuously. Although there were variations with respect to the quantity of seed material introduced, the yield rate showed fluctuations during certain seasons. In order to understand these variations, relevant environmental data were collected from the inshore waters where culture operations were carried out.

The average values of each environmental parameters such as surface temperature, salinity, O_2 and nutrients during each culture operation were compared in relation to biomass increase and duration of culture period (Table 1). It was observed that no single environmental parameter could be pinpointed as responsible for variation in production. At best it could be inferred that a complexity of environmental factors operating in a dynamic inshore area may be responsible for seasonal variation in the yield of seaweeds. The Gulf of Mannar and Palk Bay experience contrasting seasonal changes ' in wind velocity and direction and wave action. The solar radiation in the region, rainfall, transport of inorganic and organic material into the region are some of the factors Other than those observed parameters.

2.3 Survey of seaweed resources

The surveys conducted in various maritime states of India have revealed that the resources of seaweeds along the coasts can be put around 1 lakh tonnes. The break-up figures are as follows:

Stn.No.	Area	Annual yield in tonnes (fresh weight)	References
I	Tamil Nadu	22 044	Subbaramaiah *et al.* (1979a)
II	Gujarat	20 000	Chauhan and Krishnamurty. (1968) Bhanderi and Trivedi (1975) Sreenivasa Rao *et al.* (1964) Chauhan and Mairh (1978)
III	Maharashtra	20 000	Untawale *et al.* (1979)
IV	Lakshadweep Islands	8 000	Subbaramaiah *et al.* (1979b)
V	Goa	2 000	Dhargalkar (1981)
VI	Kerala	1 000	Chennubhotla *et al.* (1987)
		73 044	
VII	Unexplored areas	27 000	
	Total	100 000	

The seaweeds along the Indian coast are mainly harvested by small- as well as large-scale industrialists by engaging divers. Seaweed collection is an occupation by itself and offers employment to rural population. There are a number of agents who deal directly with the collection and supply of seaweeds to the industries. The methods of collection of seaweeds are very crude at present and hence extension work is very essential to educate the people in collection and management of the natural beds in a judicious way.

3. ECONOMICS OF SEAWEED CULTURE

In view of the importance of marine algae as a source of food, fodder fertilizer and . pharmaceutical compounds, augmentation of this resource by different methods has to be undertaken. The economics worked out by the Central Marine Fisheries Research Institute indicate that at least a minimum of Rs 500/- per month accrues to the farmer by taking up cultivation in one hectare area.

Culture experiments conducted in the inshore coastal waters from 1972 to 1986 in Gulf of Mannar and in Palk Bay have revealed that on the culture frames the agarophyte *Gracilaria edulis* reaches the maximum length (harvestable size) within three months while in nature it takes 4 to 5 months time.

These studies have further indicated that the minimum period for the seed material to reach harvestable size is two months for *G. edulis* and that the length of the algae at the time of harvest would be 20 to 25 cm. The suitable period for carrying out the culture operations are October to April in Gulf of Mannar and May to September in Palk Bay.

Harvesting is done by hand picking or by cutting the crop with sickles leaving the basal portions to the net for regeneration. One kilogram of seed material of *G. edulis* yields an average of 3 kg/m^2 of net after 60 days of growth. In one-ha area of nets (i.e. 1000 nets) 30 tonnes of fresh *G. edulis* could be harvested. Based on the above studies, the economics of culture of *G. edulis* has been worked out for a hectare area and details are given below.

For the cultivation of *G. edulis* in one-ha area, 1 000 coir nets of 5 × 2 m size are used. Two thousand casuarina poles of 1.5 m height and 10 000 kg for fresh seed material (for initial introduction) are required. The cost of 2 000 casuarina poles is Rs 6 000/-(approximately) and the cost of 1 000 coir rope nets is Rs 33 000/- including charges for fabrication. The seed material will be collected for the initial introduction from the natural beds and from the cultured crop for the subsequent seeding. Wages for seeding harvesting and maintenance of the farm for four persons at the rate of Rs 10/- per day for 360 days work out to Rs 14 400/-. The total expenditure for one year would be Rs 54 000/- including a miscellaneous expenditure of Rs 600/-. The estimated cost is arrived at on the assumption that a minimum of four harvests could be made in a year. A total of 120 tonnes (fresh weight) of crop could be obtained from the four harvests in a year when the yield is 3 kg/m^2. If the seaweed is dried (75 percent moisture) and marketed at a rate of Rs 2 000/- per tonne, the net profit would be Rs 6 000/-for one year.

If the harvested seaweed is dried and converted as agar, the profits will be around Rs 100 000.

3.1 Predators

At Mandapam, the culture frames were often the target of attack by certain fishes like *Siganus javus* and *S. canaliculatus.* The crabs, *Thalamita crenata* and *T. integra* caused extensive damage to growing parts of the seaweeds by merely clipping them with their Chelipeds as they crawl about amongst the seaweed (James *el al*., 1980). The problem of predators can be solved to a great extent by enclosing the cultivation area with latticed fence or a net of a suitable mesh size.

3.2 Effects of hormones on the seaweed growth

Studies on this aspect are very limited. Oza (1971) has found that low concentrations of IAA progressively stimulated the growth of *Gracilaria corticata* while higher concentrations were found to be lethal. Raju (1971) conducted experiments on the effect of hormones and fertilizers on the photo-synthetic carbon assimilation in *Ulva fasciata, Sargassum* sp. and *Gracilaria corticata.* The photosynthetic uptake of C^{14} was found to be maximum in *G. corticata* followed by *U. fasciata* treated with gibberrellic acid. In *Sargassum* maximum effect on photosynthetic C^{14} assimilation was observed in plant supplied with ammonium sulphate. Tewari (1975) found that Chlorflurenol in hormonal range increased the fresh weight and the number of proliferations. But the elongation growth was found to be inhibited. Chauhan and Joshi (1979) reported that Indole-3-acetic acid at the concentration of 10^5 proved a stimulant on the growth of *Sargassum swartzii* germlings than the other concentrations tried. The 10^{-3} to 10^{-6} M concentration of gibberettic acid helped in increasing the length of pseudophylls of the sporelings.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Attempts have to be made to simplify the seaweed culture technology so as to reduce the cost of production and to make the technology economically viable.

4.2 The seaweed farmer and his family members or some families jointly have to undertake on cooperative basis, the cultivation of seaweeds and extract agar.

4.3 The cultivation of seaweeds is beset with problems such as grazing by fish in the sea and hence some times the yield in the crop and thereby the production may come down from the expected level. Hence, some attempt should be made to find out the methods of controlling the grazing of the crop by fishes and other predators.

4.4 In order to enable the fishermen or landless labour to undertake the seaweed cultivation, the government or some funding agencies may offer credit facilities with subsidies under the programmes such as IRDP, DPAP, etc. which will be of immense use to them.

4.5 Use of hormones and fertilizers must be tried in the culture fields or the seed material may be pre-treated with hormones.

4.6 Evolving of hybrid varieties of sea weeds by genetical methods may be given due consideration.

4.7 Transplantation of commercially important exotic species like *Eucheuma* and *Caulerpa lentillifera* will be attempted in Indian waters in suitable locations.

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Table 1. Data on seaweed production and related environmental factors in Gulf of Mannar and Palk Bay, Southeast Coast of India

Year	No. of days of culture operation	Initial weight to seed material (in Kg)	Final weight (kg)	Average gain of seed (kg)	Mean values of hydrological data: Surface Temperature (°C)	Salinity (%)	O_2 ml/l	PO_4ug-at/1	NO_3	Sio_6	pH
1976	40	0.90	4.00	0.0775	28.6	29.16	4.57	0.29	0.49	12.59	8.2
Gulf of Mannar	30	1.00	4.30	0.1100	27.7	32.79	4.65	0.45	0.53	8.25	8.2
1977											
Gulf of Mannar	88	34.	162.17	1.4565	27.3	30.31	4.38	1.55	0.15	0.73	8.13
1979	60	1 800.	4.70	48.3300	29.68	32.03	4.59	2.78	12.10	3.65	8.18
Gulf of Mannar											
1980	90	6.65	16.17	0.1058	29.48	35.29	4.59	0.59	3.13	6.36	8.20
Palk Bay	70	560.	733.70	2.4814	28.69	31.76	5.17	0.82	9.85	18.11	8.10
1984–85											
Gulf of Mannar	60	2.4	7.50	0.0850	27.3	30.00	4.95				7.9
1985											
Gulf of Mannar	55	1.80	9.50	0.1400	29.3	29.72	5.51	0.12	0.44	60.00	7.4

THE DEVELOPMENT OF SEAWEED CULTURE IN KEPULAVAN, SERIBU, JAKARTA

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1 INTRODUCTION

Kepulavan Seribu lies north of Jakarta. Most of the coastal waters in Kepulavan Seribu is suitable for seaweed culture, e.g., Pari Island, Laneang Island, Panggang Island, etc. There are many species of seaweeds which have economic value that can be cultivated such as *Eucheuma, Gracilaria, Gelidium* and *Hypnea.* But most of the market demand preferred on *Eucheuma* mainly. The other species are under research by Department of Agriculture.

In Kepulavan Seribu, seaweed culture is not the source of the main income but only a secondary activity to fill spare time. So, the production is still low and not managed as a business.

We began culturing *Eucheuma cottonii* since October 1986 using seedlings from Bali.

There are two culture methods in Kepulavan Seribu:

a. OFF bottom method; and
b. Floating method.

1.1 Area

Kepulavan Seribu has a high potential for producing seaweed but at the moment only about 1.5 ha have been planted to *Eucheuma cottonii.* -

1.2 Production

The *Eucheuma cottonii* production in Jakarta is still low till January 1988, the wet production is only 300 mt. We hope in the long run seaweed culture will be projected as tradeable goods to fulfill the demand of international market. On the other hand, it means increasing fishfarmer's income.

1.3 Marketing

The most important problems in seaweed marketing is the very low market price compared with the production cost. The farming site is too far from Jakarta. The other problem is the collector does not buy the *Eucheuma* product on a regular basis. To overcome these problems the government advised the farmers to join in cooperatives. The collector/exporter must buy the *Eucheuma* product from the cooperative.

On April 1988 the exporter in Jakarta exported about 20 mt dried product from the Kepulavan Seribu to Hong Kong.

Since seaweed is tradeable commodity and source of foreign currency, it is reasonable that the government of Indonesia pushing up seaweed production by applying new methods and technology.

REPORT ON EUCHEUMA CULTURE PRODUCTION IN BALI PROVINCE, INDONESIA, 1987

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1. INTRODUCTION

Bali Province has a coastline of about 470 km. It consists of several islands, namely: Nusa Penida, Nusa Lembongan, Nusa Ceningan, Nusa Dua, Pulau Serangan and Pulau Menjangan. Most of the coastal areas in Bali Island are characterized by growing reefs, particularly by sandy bottoms which gradually slopes toward the sea.

2. PRODUCTION

The production of *Eucheuma* culture in Bali Province is about 73 899.40 mt. These production has been produced from an area of 179.1 hectares and has come from three different places namely:

a) Badung	5 070.00 mt
b) Jemberana	39.40 mt
c) Klungkung	68 790.00 mt
	73 899.40 mt

3. MARKETING

Most of the seaweed production from Bali Province were mainly marketed to the other districts especially in Java (Surabaya and Jakarta), with the exception of *Eucheuma* which are generally marketed for export to other countries.

4. PROBLEMS

The problems of the *Eucheuma* culture in Bali Province are as follows:

a. The plants are grazed by small fishes and are affected by heavily rainfall in the culture site.
b. *Eucheuma* plants are being disturbed by different species of seaweeds such as *Ulva* species which cause the main branches of the plant break down.

CURRENT SITUATION OF SEAWEED AQUACULTURE DEVELOPMENT IN KOREA[1]

[1] Reported by Mr. Jung Jin-Tae, Staff, National Fisheries Research and Development Agency, Republic of Korea.

1. INTRODUCTION

1.1 Geographic characteristic of Korean coast

The surrounding waters of Korean peninsula has special environmental characteristics according to the eastern, western and southern coasts.

The first, is the eastern coast characterized by a sudden drop in water depth, the surf is strong, many submerged rocks/reefs, and the coastline is monotonous without irregular curves; the current is more influenced by the Liman cold current than the Tsushima warm current; seaweed culture of this area is possible to place long line rope structure for sea mustard and sea tangle.

The second, the southern coast, is characterized by severe curved coastline as fiord, and there are many islands including many inlet bays. The current is influenced strongly with Tsushima warm current. The rising and falling tidal wave as well as moderate water depth is adequate to place various cultural structure such as hanging, long line rope and bamboo raft type. There are many species of cultural organisms. Therefore, this coastal area has become the center of culture in Korea, and almost all of the major seaweed culture such as sea mustard and laver is centered on this area.

The third, the western coast, is characterized with many isles including complicated coastline, though this phenomena is relatively smaller than the southern coast. There is a long stretched shallow water with a broad tidal land. The high tidal wave of ebb and flow is well known worldwide. Consequently, the laver culture has been practiced since long ago, and floating net culture system of laver is now under extension. Koreans enjoyed seaweed as daily food from ancient time, and could do seaweed culture easily owing to such rich marine environmental benefaction.

1.2 The sea current and water masses

There are correlation between the sea currents of Korean adjacent sea and that of Pacific Ocean especially the current of Korean waters is mainly influenced by Tsushima warm current which is the branch stream of Kuroshio current originating from eastern Philippines and is flowing upwards to the western Pacific through the eastern China Sea. Therefore, the characteristic of currents and water masses in accordance with the three sides of Korean waters is characterized as follows: (a) in the southern coast, the Kuroshio current forms the West Sea (Yellow Sea) warm current flowing into the western sea through the southern part of Jeju Island; (b) in the eastern coast, the Tsushima current forms the Korean east sea warm current, and this is faced with the Liman cold current, the North Korea cold current flowing downwards with lowered temperature by cold weather and thawed ice during winter; and (c) in the western coast, the Yellow Sea warm current flowing in through western Jeju Island as the branch stream of Tsushima current flowing upwards to the northwestern coast of China during April to August. The strength of , this current is relatively weak comparing to the China coastal line waters flowing downward by forming cold current. Consequently, the two kinds of currents are forming a reflux in the central part of Yellow Sea, and Yellow Sea bottom cold current is going downward as a result (Figure 1).

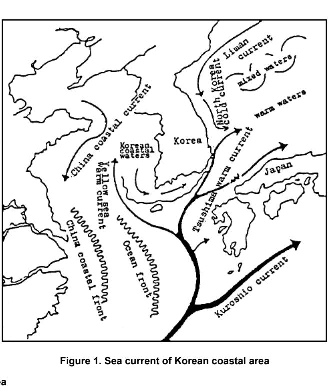


Figure 1. Sea current of Korean coastal area

1.3 The distribution of water temperature in surrounding waters of Korea

The seasonal variation of sea surface temperature in Korean waters ranges from 5 to 27°C in general (Figure 2). The sea surface temperature (SST) in Korean waters depends not only on incoming radiation but also on heat advections by winds and ocean current as mentioned above. The heat advection by the Asian monsoon decreases the mean SST and increases the annual range of SST, while the heat advection by warm currents such as Tsushima current and the Yellow Sea current increases the mean SST and decreases the annual range of SST. Also, it is shown that the higher mean SST and smaller range of SST in the East Sea (the sea of Japan) than in the West Sea (the Yellow Sea) resulted mainly from the fact that the heat advection into the East Sea by the Tsushima current is more pronounced than that into the West Sea by the Yellow Sea warm current. On the other hand, the maximum SST in the neighbouring sea of Korea occurs between mid-August and early September (Figure 3).

1.4 The distribution of seaweed (algae)

The algae distributed in Korean coastal area is predominant in the temperate zone flora (this flora occupied over 70 percent of the total amount of algae). In accordance with the different coasts the situation of flora is classified as follows:

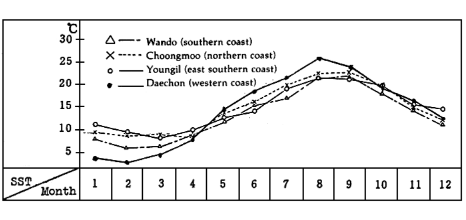


Figure 2. Monthly variation of SST according to the major cultural areas

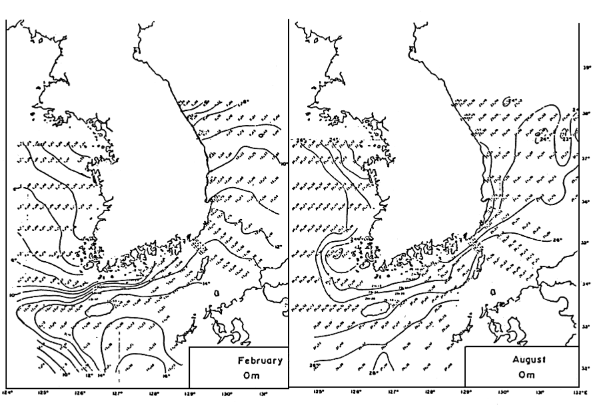


Figure 3. Mean oceanographic chart of the adjacent sea of Korea (SST)

1.4.1 East coast

Although there are predominant family of northern seaweed flora than any other coast resulting from the influence of cold current, it is shown that the central part of the eastern coast is also distributed with the family of temperate zone flora nearing about 70 percent among total seaweed flora.

1.4.2 West coast

Although the distribution of the family of temperate zone flora reaches about 71 percent among total seaweed flora and is poor in the northern flora, owing to the weak cold current as the special tidal land is broad, the algae is distributed only to the surrounding coast of isles so the flora of seaweed is poor.

1.4.3 South coast

The family of temperate zone flora occupies about 70 percent among total seaweed flora, and there are many large and small islands as well as severe curved coastline in the geographical condition. Many, subtropical temperate zone algae is distributed in the coast of Jeju island. It is general characteristic in Korean coast belonging to the temperate zone that the algae after reaching highest growth during spring (from March to May) is declining during summer.

Now, the algae showing abundant distribution in Korean coast in accordance with life cycle are as follows:

a. The annual plants (in common name) Laver, sea mustard, green laver, the family of Gulf weeds and others.
b. The perennial plants (in common name) Hijiki, Irish moss (Rock moss, carrag-heen), seaweed cava, tangle (kelp), agar, seaweed tenella, *Zostera marina* (scientific name), and others.

1.5 Major culturing seaweed

Here, the major algae being cultured now in Korea are as follows:

1.5.1 Laver (*Porphyra* spp.)

This is the major algae cultured as well as sea mustard, and the history of culture is the oldest one. The culture area stretches from southern coast to the eastern coast, and the center of culture is located in Wando, Shinan, Hadong, etc. in southern coast and Seochon, Anmyundo, etc. in western coast (Figure 4).

1.5.2 Sea mustard *(Undaria pinatifida)*

This is one of the most cultured alga and is distributed all along the coastal areas. There are abundant, good quality *Undaria* in the eastern coast growing in natural state. The technique of artificial seeding was introduced in Korea in 1962 and the production amounted to 300 thousand tons in 1986; the center of culture area is Wando in the southern coast and Ilgwang, Kijang in neighbouring Pusan (Figure 4).

1.5.3 Sea tangle *(Laminaria)*

This is generated abundantly in the north eastern coast going upward to latitude of 38° parallel line. The culture of this species is practised a little in the east southern coast.

1.5.4 Hijiki *(Hijikia)*

Although this is found almost all over the Korean coast, the culture of this species is practised only in Jeju island including Wando of southern coast.

1.5.5 Agar *(Gelidium* spp.)

Although the Gelidiaceae is found all over the Korean coast, the production of this alga is from natural algae collection until now. But recently, because the price of raw material as agar products is high, the culture of *Gelidium amansii* is under experiment in southern coast.

1.6 The status of shallow sea culture in Korea (Figure 5)

Korea has shown rapid progress in marine cultural fisheries from the late 1960's. Although the total amount of maricultural production attained 19 thousand tons, only 4.1 percent was part of the total Korean fisheries production in 1962. The production of 947 thousand tons in 1982 has shown about 50 percent increase compared to that in 1962 and which occupied 25.9 percent of total Korean fisheries production (Table 1 and Figure 6). On the other hand, the development of culture areas which reached about 100 thousand hectares in 1986 showed occupying about 55 percent in total possible maricultural area that is estimated about 183 thousand hectares. This maricultural fishery has made such a rapid progress due to great influence by decreased fisheries resources in offshore and curtailment in deep-sea fishing that resulted from 200 miles economic zone by the coastal states along with increased demand of sea food as a provisions nowadays. Consequently, the extension service in mariculture with supply of artificial seeding in governmental basis as well as the activation of license system in private cultivation area has acted effectively to the rapid progress of mariculture in Korea.

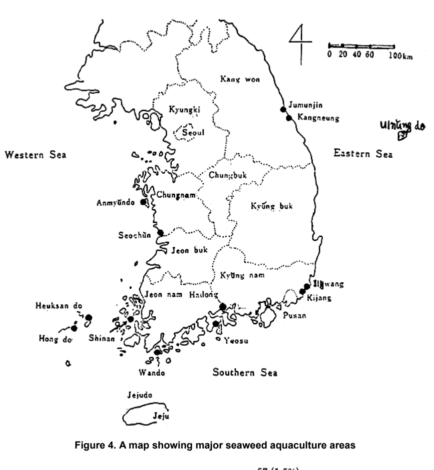


Figure 4. A map showing major seaweed aquaculture areas

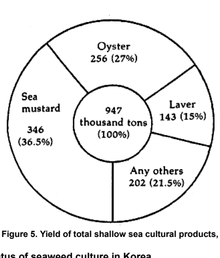


Figure 5. Yield of total shallow sea cultural products, (1986)

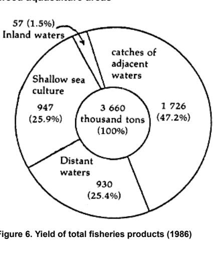


Figure 6. Yield of total fisheries products (1986)

1.7 The status of seaweed culture in Korea

The major seaweeds cultivated in Korea are laver, sea mustard, kelp including hijiki and green laver which is now under extension stage (Figure 7). In Table 2, it is shown that the culture of laver has been under continuous increase, and sea mustard under stagnation without fluctuation, but the kelp under decreasing state from 1980 to 1986 in accordance with the areas. It has shown that the amount of products in laver and sea mustard, the highest amount of which recorded in 1986 have been varied with relative high amplitude through the years. The important problems faced from now on is that: How to keep stable production by preventing natural disaster in marine environment along with how to minimize fluctuation in production by strengthening the regulation concerning the license of private cultural area. Consequently, as shown in Table 3, the two species occupy an important position in Korean seaweed culture.

Table 1. Annual yield of aquacultural products in Korea

(unit: thousand tons)

Year/Yield	1962	1970	1980	1981	1982	1983	1984	1985	1986
Total fisheries product	470	935	2 410	2 812	2 644	2 793	2 910	3 103	3 660
Total cultural product*	18	119	541	701	596	644	678	788	947
Composition ratio	4.1	12.7	22.4	24.9	22.9	23.1	23.3	25.0	25.9

*Total cultural product = Total marine cultural product

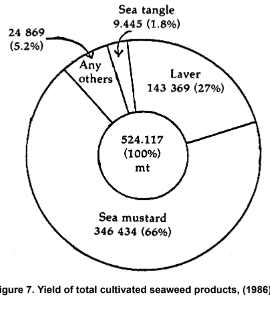


Figure 7. Yield of total cultivated seaweed products, (1986)

2. CULTURE OF PORPHYRA SPP. IN KOREA

2.1 Development of cultural technique

The original cultural method of laver reportedly began in 1623 on Kwangyang Bay (adjacent to the estuary of Sumjin river) in central southern coast of Korea and this was preceded 50 years than Japan. The original cultural method is now obsolete and extinct (except Kwangyang Bay); Korea was involved in placing bundles of leafless branches of bamboo, or other trees at or just above the mean water level located well away from brackishwater during September to October. Since then, this was improved as a fixed semi-floating type that was made of split bamboo rattan and fixed with pole on either or both sides in the 1630's on Wando island of Jeonnam Province (in accordance with this principle, movable type fixed with pole on both sides to place split bamboo rattan in parallel with the sea surface was improved by Japan). But it was later in 1962 that artificial production of monospore and culture of conchocelis filament was practised in Korea. Owing to this technical development, the technique of nursery nets storage and floating net cultural system was introduced in Japan, and free living conchocelis culture method was dispersed during 1970's. As a result, annual laver production was attained over 23 × 10^8 sheets of dried products from 1979 (Figure 8). Since 1980 the annual production has been kept over 30 × 108 sheets, and over 62 × 108 sheets of dried laver was produced in 1986 while annual production of 1987 decreased to 34 × 108 sheets resulting from bad condition in marine environment. Consequently, it has shown that the harvest of cultivated laver depends greatly on the influence of the marine environment condition in Korea until now.

Table 2. The annual cultivated area (licensed) of seaweed in Korea

(unit: ha)

Year/Areas	1962	1971	1980	1981	1982	1983	1984	1985	1986
Total cultivated	19 156	46 670	78 573	85 561	83 825	88 465	89 557	96 885	101 189
Total seaweed cultivated	5 316	17 016	28 584	35 369	37 275	43 578	47 661	51 547	54 008
Total laver cultivated	730	13 459	20 593	25 144	27 256	33 355	37 953	42 011	44 451
Total sea mustard cultivated	271	2 960	7 590	9 445	9 253	9 530	9 116	8 944	9 009
Total sea kelp cultivated	-	-	237	291	241	125	32	50	50

Table 3. The annual yield of seaweed products according to major cultural species

(unit: mt)

Year/Division	1962	1971	1980	1981	1982	1983	1984	1985	1986
Total shallow sea	18 106	147 221	540 564	701 065	596 316	643 798	628 321	787 571	946 965
Total seaweed	6 054	48 818	527 880	383 063	314 535	347 227	383 661	377 461	524 117
Total laver	4 247	34 801	56 274	80 490	79 784	87 963	136 484	109 819	143 369
Total sea mustard	804	11 103	196 147	294 622	225 045	237 128	230 188	256 436	346 434
Total sea kelp	-	-	940	1 963	3 987	11 606	7 927	11 796	9 445

2.2 Characters of laver

There are about 10 kinds of species cultivated in Korea. Among them: *P. tenera, Kjellman* and *P. yezoensis* are more important cultural species than others.

a) Phylum: Rhodophyta
Class: Bangiophyceae
Order: Bangiales
Family: Bangiaceae

b) Size and shape

Length of fully grown frond of *P. yezoensis* varying from 15 to 36 cm, and that of *P. tenera* from 17 to 35 cm, sometimes up to 1 m.

c) Color

Fronds very dark purple.

d) Life cycle (Figure 9)

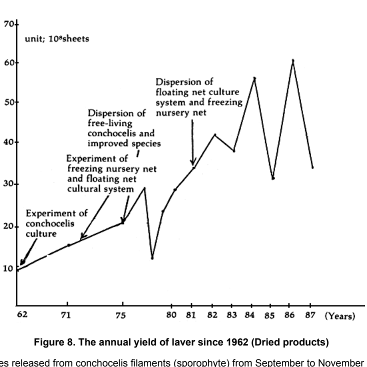
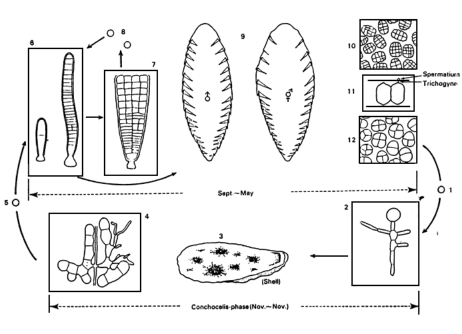


Figure 8. The annual yield of laver since 1962 (Dried products)

Life cycles of both species are the same. The algae germinate from spores released from conchocelis filaments (sporophyte) from September to November and appear as small germlings of 1 mm in length from mid to late October, when the water temperature drops to 22°C. The germlings grow rapidly to fronds (gametophyte) 15 to 20 cm long, or more, by mid to late November and flourish during winter in waters of 3 to 8°C. In April, fronds of the algae wither and disappear by May when the water temperature rises to 14°C.

Germlings of 150 μ to 1 mm in length form a large number of neutral spores during the period between late September and early November. These neutral spores also germinate and grow into fronds. When germlings grow into fronds of 3 to 5 cm in length in November, sexual reproductive organs are formed on the fronds. These organs continue to release fertilized carpospores until the fronds disappear in May. Released carpospores attach to shells on the sea bed to germinate and become conchocelis filaments. Conchocelis filaments bore into the shell and grow in the pearl layer of the shell to form colonies of 1 cm in diameter by August to September when they start -to release spores called conchospores.

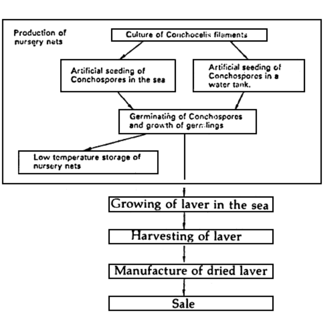
Generally speaking, the characteristic of laver in the life cycle and ecology differ from almost all of the agricultural cultivated species in the side of carrying out accessory reproduction by asexual spores given off by the young thalli. The growing of laver into fronds is a result of repeating complicated process of life cycle such as: (1) carphospore 2) ⇁) conchocelis rosa 3) ⇁) conchospore (monospore) 4) ⇁) germling (young thalli) ⇌ (5) neutral spore (monospore) 6) ⇁) fronds of thalli. The process between (4) and (5) differ from any other cultivating species, that is, germling germinated from carposhore form neutral spore, in return, this neutral spore germinate germling. After repeating this process many times, germling grows into fronds of thalli.



1, Carpospore;
2, Conchocelis;
3, Conchosporangium;
4. Parasporangium;
5, Conchospore;
6, Germination of Carpospore;
7, Discharge of Monospore;
8, Monospore;
9, Leafy thali (Gametophyte);
10, Antheridium;
11, Carpogone;
12, Cystocarp.

Figure 9. Life cycle of laver

e) The process of laver culture (Figure 10)



2.3 Cultural technique in genera

2.3.1 Culture of conchocelis filaments

This is carried out by placing oyster shells either loose or stung on wires, in indoor tanks in the early spring and adding chopped thalli. The conchocelis plants are then cultured in the tank until the artificial seeding of conchospores begins in October.

a) Culture by oyster shell

This starts from collecting the thalli during December to mid-January. The thalli is cold stored until March to April before conchocelis culture begins, thalli is dried in dark place until the moisture contents are about 20–30 percent. The conchocelis culture begins with inputting carpospore solution into the oyster shells, and the method of inputting carpospore solution is either by hanging the stringed oyster shells into the concrete tank perpendicularly, or by placing the shells loosely into the plastic container filled with sea water (Figures 11 and 12).

(i) Preparation of carpospore solution

Put the cold stored thalli into the container filled with sea water (10 g dried thalli per 1 liter of sea water) The thalli which release carpospore after two to six hours had elapsed, show change of water color. The carpospore solution prepared is put into the culture tank filled with sea water, and the carpospore bore into the shells after one week elapsed and grow into conchocelis filaments.

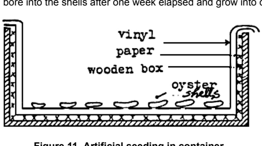


Figure 11. Artificial seeding in container

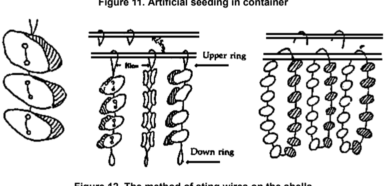


Figure 12. The method of sting wires on the shells

Monthly process of conchocelis culture after inputting carpospore solution is shown below.

Month	Process	Water temperature control
From February to March	Attaching of carpospore solution into oyster shell	From 10 to 15°C
From mid-march to April	Growing of conchocelis filaments	From 16 to 24°C
From May to June	-do-	Forming the sporangium From 18 to 25°C
From July to August	-do-	Proliferation of sporangium (carpospore being liberated) control under 28°C
September	Maturing of conchocelis filaments Monospore collection with conchocelis bearing shells	

b) Culture of free living conchocelis

This method was introduced in 1975 for the first time in Korea and over 30 percent of total culturists now in Korea is adopting this method. This method is to grow the nurtured free living conchocelis filaments, after planting it into the oyster shell in May until it may be used in monospore collection.

But recently, it was found out that the free living conchocelis release spore by forming carposporangium without substrate and monospore collection by free living conchocelis without substrate has been possible.

2.3.2 Artificial seeding of conchospore

This is to collect either the monospore (conchospore) released from conchocelis filaments, or neutral spore germinated from germling (young plant). The method is divided into: (1) natural spore collection with nets in the sea which is practised in timely season; and (2) artificial collection of spore in the sea or in the tank with oyster shells bearing matured conchocelis.

a) Natural spore collection in the sea with nets

This is to set up culture nets to the seashore in the fall to collect released conchospore in natural state when water temperature is about 22°C. Whatever collecting device is used, catching of monospores is best when the water temperature is 22 to 23°C. After a storm is considered to be a particularly good time as are in the second to fourth days, after the first or fifteenth of each lunar month. The western coast of Korea is not concerned with the lunar month where it is practised everyday in the morning during the period.

b) Artificial seeding of conchospores in the sea

This is carried out by placing conchocelis-bearing oyster shell cultured in indoor tank, beneath the spore collecting nets which is spread horizontally in the sea with supporting pole, and the nets and conchocelis bearing shells are kept as is for the seeding period of three days.

c) Artificial seeding of conchospore in concrete water tank

This is to place the mature conchocelis-bearing oyster shells on the bottom of concrete tank, and conchospores released from the conchocelis filaments attached to the twine of the nets dipped into the tank. The release and attachment of spores is induced by stirring the water in the tank. Nets are of the same quality as those used in the sea, and it is set one upon another up to 30 to 50 layers in thickness. The laver net are knitted with twigs of palm, etc. and the stretched mesh size of the net is 30 cm, the length is 18 m, and the width is about 1.5 m. There are several methods for seeding the spores into the nets. The device is classified as follows: (a) rotary type (Figure 13); (b) vertical movement type (balance type); (c) running water type (belt conveyor type); and (d) bubbling type, etc.

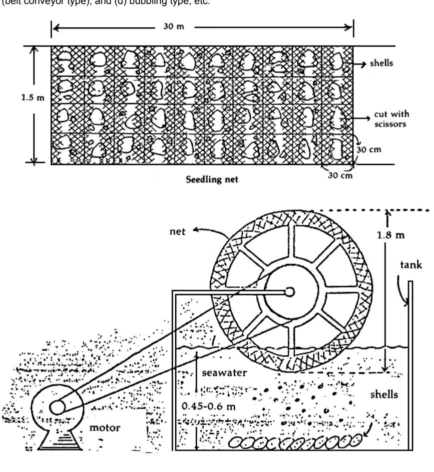


Figure 13. Porphyra seed collector in indoor tank (rotary type)

2.3.3 Correlation between timely artificial seeding and growing of laver

At the start of September, every culturist is careful of practising timely spore collection along with placing the nursery nets in the sea. Generally, there is poor annual harvest when sea water temperature drops with the coming fall. Meanwhile, in the late reduction of sea water temperature, artificial seeding was also late along with placing of nursery nets and showed rich annual harvest. After all annual harvest is correlated with timely seeding (spore collection) along with placing culture nets in the cultivation grounds. Harvesting of grown laver usually begins in November, and takes about 40 to 60 days from the start of growing to harvest time. Therefore, after 40 days had elapsed the amount of thalli in the cultivation grounds reaches its peak, and the growing rate of thalli is suddenly fast. If the water temperature is lowered fast, the artificial seeding and placing of the nursery nets in the sea is hastened. Consequently, the amounts of thalli reached its peak rapidly. If the growing rate of thalli is fast as much as the nutritive salts in sea water is demanded the higher discharge of waste material from the thalli is shown. If the growing rate is slowly decreasing or there is stagnation and the sea water temperature tends to be more upward with the result of stratosphere phenomena without convection of current, the supply of nutritive salts will be slow along with the elimination of waste material discharged from the thalli. A decreased harvest in cultivation grounds will be shown. In addition, if the wind and rainfall is less, the stronger the effect will be. Also, when the laver become activated in photosynthesis under the water temperature of 15 to 16°C, the demand of nutrient salts become highest in this time than any other season. Meanwhile, the peak time in growing rate of thalli coincides with the optimum water temperature of 15 to 16°C, and also the convection of current is weakened at that time. As a result, the thalli's growth is impaired with the imbalance between the demand and supply of the nutrient salts. Such a phenomena causes disease and the laver finished its life cycle.

a) Optimum sea water temperature in artificial seeding at the sea.

When the monospore collection is carried out in the sea by placing conchocelis-bearing shells beneath the collecting nets, the most important factor to decide the period is the sea water temperature. Although the conchospore filaments release spore from 26°C in water temperature, it is done well under 24°C. In the releasing of spore from germling (young plant), this temperature has no problem in considering the attaching diatom, etc. on the nets. However, the; optimum water temperature is 22.5°C in general. If the nursery net is placed over 23 °C in order to harvest thalli as soon as possible, the result will fail in collecting spores or the attached green laver, diatoms, etc. and will result to poor harvest.

b) A comparison between harvest and marine environment

As mentioned above, harvest is correlated with marine environment such as water temperature, light, specific gravity of water, sea current, - and the condition of rainfall, etc. (Table 4). Disease of laver is occurring frequently during November to December with the result of long stagnation of high water temperature. Such a disease occurs in ebb tide when stagnation of sea current, warm temperature along with no wind continue temporarily.

2.3.4 Germinating of conchospores and growth of germling

The laver nets seeded with conchospores in the sea or in the tank are spread in the sea with the cultural structure to await spore germination. To increase the passage of sea currents on the surface of nets twines, only up to five nets are stacked upon each other for germination. The nets are set at a level which keeps the net exposed to air for about four hours a day to get rid of undesirable algae. About 15 to 20 days after seeding, the germling of laver become visible on the nets. The germling grows to 2–3 cm in length after 40–50 days after seeding and the nets are ready for use as nursery nets. The density of germlings is several hundreds per cm of net twine. The nets are either placed in the sea for cultivation, or stored in freezer for use in later months.

2.3.5 Growing of laver plants

The growing season of laver fronds lasts from November to early April. Cultivation ground should be located in the sea with as much nutrient salts and sea Water movement as possible. Waves and wind are desirable to secure rapid water exchange as long as the cultural structure is not destroyed. The nursery net of which the germling grows to 2–3 cm in length is spread in the surface layer of the sea horizontally to grow the laver fronds.

Table 4. Analysis of harvest in comparison with marine environment during October 1–December 31

Year	Production*	Duration of water temperature(22–24°C)	Stagnation of water temperature(14–15°C)	Storm days	Rainfall (mm)
1986	63 × 108 sheets	52 days	Nov. 12–Nov. 16 (5 days)	17 times (49 days)	12 times (81 mm)
1987	35 × 108 sheets	66 days	Nov. 16–Dec. 29 (19 days)	7 times (11 days)	4 times (14 mm)

*Production: Total national yield of dried laver (1 sheet = 24–30 g)
Source: District: Central southern coast of Korea (Wando)

2.4 The structure for growing laver

There are many types of man-made structures for growing laver such as old fashioned type of placing only bamboo bundles or any other trees at or just above the mean water level, now obsolete and extinct except at the estuary of Sumjin river, to floating net culture system fixed with anchor, developed lately. But the major type now in use is classified as movable type with pole and floating net culture system. The structure which was used from the old days in Korea and is used until now is classified as follows.

1) According to materials

- Bush clover 'hong' — Now obsolete and extinct
- Reed-bundle 'hong' — Now obsolete and extinct
- Bamboo 'hong'* (bamboo bundle; split bamboo) — Now obsolete but this occupied 6 percent among total structures (in 1987)
- Net 'hong' (natural fiber; synthetic fiber) — This occupied 94 percent among total structures (in 1987) and almost all of the net is synthetic fiber

* 'Hong' means the cultural structure of laver

2) According to structure types

- Fixed type; placed bamboo bundles, oak treet, etc. — Obsolete and extinct except at the estuary of Sumjin rive/river/Kwang-yang Bay
- Movable type fixed with pole
  - semi-floating type — Being used now only by few culturists
  - floating type
    - elevator type fixed with pole; being used in western coast in which high tidal wave between ebb and flow is
    - fixed with pole on either side; both western and southern coast
    - fixed with pole on both sides; coast of Shinan area
- Floating net culture system fixed with anchor

2.5 Any other technical problems

2.5.1 Developing floating net culture system for an effective use of cultivation grounds

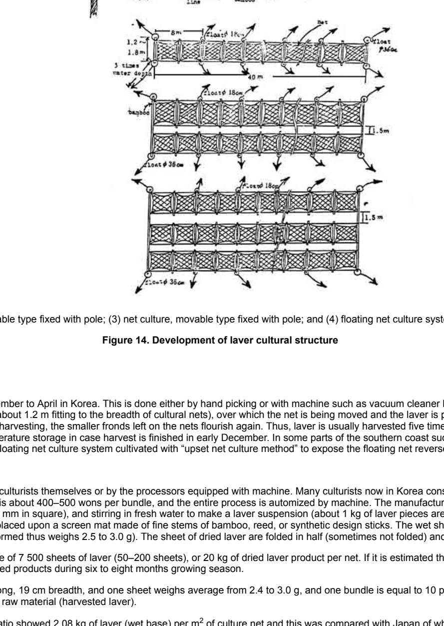
The laver is cultivated in shallow sea by placing the man-made structure with culture nets and the net9 should be exposed to air two times a day. This is necessary to stop disease and keeps stable growth of laver with good color, and control the fertilization of diatoms, green lavers when the fronds grew in some estimated length. It is helpful to cultivate without exposure to spur the growth of algae plants. The floating net culture system aiming at fast growth of laver was developed in Japan and was introduced in 1972 in Korea. But the practical use of this floating net culture system was begun from 1981. According to fisheries regulation, the floating net culture system is distinguished from any other man-made structure in water depth. It is designated to be placed under 10 m water depth. Any other structure such as movable, floating but fixed with pole type is designed under 7 m in water depth. After all, the difference between floating net culture system and other structure fixed with pole type is only 3 m gap in water depth. If the floating net culture system increase, we are faced with problems that not only the shallow cultivation ground under 10 m in water depth will become narrow if it is occupied with floating net culture system but also, it will be difficult to observe the intervals of placing the structure over 500 m, and will bring up the problem of high intensive culture. Finally, in order to develop the cultivation ground more effectively, it is necessary to develop the floating net culture system by correcting the fisheries regulation concerning the depth in which the floating net culture system is designated now "under 10 m" and to place the structure "under 20 m" in water depth in the future.

2.5.2 Utilizing cold-stored nursery nets and extending the cultivation period

When sea water temperature rise at night in the cultivation ground, the algae take physiological injury, and in case of severe injury, the thalli falls out from the nets. But if such phenomena of rising in sea water temperature occur during early mid-November, it is necessary that the nursery nets be stored in freezer. Generally, the nursery net germinated in autumn can be stored in a freezer for one to two months for cultivation in later months. Nursery nets attached germling of 1–3 cm in length withdrawn from cultivation ground, follows dehydration with air drying in dark place or (dehydrated in centrifugal) to reduce the moisture content to 30–40 percent, and be stored in -20°C freezer (usually stored until early December, this is called cold-stored nursery nets). In December when the oceanographic condition becomes favourable, the nursery net is placed on cultivation area, and the germlings of 1–3 cm in length begins growth again. Owing to the artificial seeding developed, it is faster to place laver nets on the cultivation area. As a result, harvest of grown laver begins from early November. The thalli to be annuated declines in quality with the curtailment of cultivation period and shows various diseases. Yet, many culturists now in Korea has not been equipped with freezer for cold storage of nursery nets except some industrialized culturists. Finally, they are faced with the problem of how to supply the cold storage system of nursery nets effectively for small-scale fisheries.

2.5.3 Arrangement of cultivation grounds and high intensive cultivation

The standard of placing cultural structure in cultivation grounds is regulated now in Korea by the law of the Ministry of Agriculture, Forest and Fisheries, to keep the ratio between the area of covering culture nets and licensed cultivation ground to be 20–25 percent in case of floating net culture system, and 20–30 percent in case of any other culture structures (Figure 14). Under this law regulating the standard of placing culture structure in cultivation ground, it is not designated specially to the difference between the floating net culture system which could be placed offshore and any other structure fixed with pole type which could be placed only on seashore. Therefore, the problem is that the floating net culture system which is expanded from now on will cover almost all of the offshore cultivation ground. The cultivation ground of estuaries/shore will be disturbed by sea current. Consequently, in order to keep laver from disease resulting from the sea current disturbance, it is necessary to lower the standard ratio of placing culture structure in cultivation ground. In case of floating net culture system, the ratio which is now 20–25 percent (covering culture nets area/licensed cultivation area) is to be 10–15 percent in general, and in case of any other structures the ratio of 20–15 percent, in general to be 20 percent on the offshore, and to be 15 percent on the estuaries/shore.



(1) placing pine trees/bamboo bundle; (2) bamboo culture, movable type fixed with pole; (3) net culture, movable type fixed with pole; and (4) floating net culture system (ladder type)

Figure 14. Development of laver cultural structure

2.6 Harvesting and processing

2.6.1 Harvesting

Harvesting of grown laver fronds usually begins from early November to April in Korea. This is done either by hand picking or with machine such as vacuum cleaner like a machine attached with a rotating knife or other type of machine attached with long rotating knife (the length of knife is about 1.2 m fitting to the breadth of cultural nets), over which the net is being moved and the laver is picked up (Figure 15). But until now in Korea, harvest is done almost all by hand picking. After thinning the density of laver by harvesting, the smaller fronds left on the nets flourish again. Thus, laver is usually harvested five times from each net until growth declines and the net is then replaced by a new nursery net which has been kept in low temperature storage in case harvest is finished in early December. In some parts of the southern coast such as Kohung Peninsular of Jeonnam Province, harvesting is done possibly nearly 10 times from each net by developing the floating net culture system cultivated with "upset net culture method" to expose the floating net reversely sometimes.

2.6.2 Processing

The harvested frond is processed into dried laver sheets by the culturists themselves or by the processors equipped with machine. Many culturists now in Korea consign to the processor. The mechanical drying is expensive, 800–1 000 wons per bundle of dried product, but the basic cost is about 400–500 wons per bundle, and the entire process is automized by machine. The manufacturing process begins with washing the laver fronds in sea water, followed by chopping the washed laver into small pieces (10–15 mm in square), and stirring in fresh water to make a laver suspension (about 1 kg of laver pieces are placed in 20 liters sea water and stirred). The resulting suspension is spread within a small rectangular wooden frame placed upon a screen mat made of fine stems of bamboo, reed, or synthetic design sticks. The wet sheet of laver formed on the screen is dried in nature or hot air chamber (40 + 1°C) and then peeled off the screen (the sheet formed thus weighs 2.5 to 3.0 g). The sheet of dried laver are folded in half (sometimes not folded) and packaged together for marketing.

One 1.8 7times; 40 square meter culture net produce an average of 7 500 sheets of laver (50–200 sheets), or 20 kg of dried laver product per net. If it is estimated that one fourth of intensive cultivation is covered by laver net, this amounts to 100 nets/ha producing a total of 20 000 kg of dried products during six to eight months growing season.

The standard size of one sheet of dried laver product is 21 cm long, 19 cm breadth, and one sheet weighs average from 2.4 to 3.0 g, and one bundle is equal to 10 piles which consists of 10 sheets, so one bundle equals to 100 sheets. The yield of dried product is 600–800 g per 10 kg of wet raw material (harvested laver).

In accordance with Fisheries Statistics in 1986, the production ratio showed 2.08 kg of laver (wet base) per m^2 of culture net and this was compared with Japan of which was calculated 3.17 kg/m^2 of culture net.

2.7 Marketing

Almost all of the processed laver is now consumed in domestic market. There are some differences in marketing routes according to the districts. The marketing routes now in Korea is shown in the following figure (Figure 16). As shown in the figure, either the producers/culturists themselves deal with wholesale/retail dealers directly, or is dealt through the consignment of Local Fisheries Cooperative Association (LFCA). However, over 90 percent of culturists are processing dried products by the processor equipped with machine, and about 10 percent of culturists are processing laver by sun dry method until now.

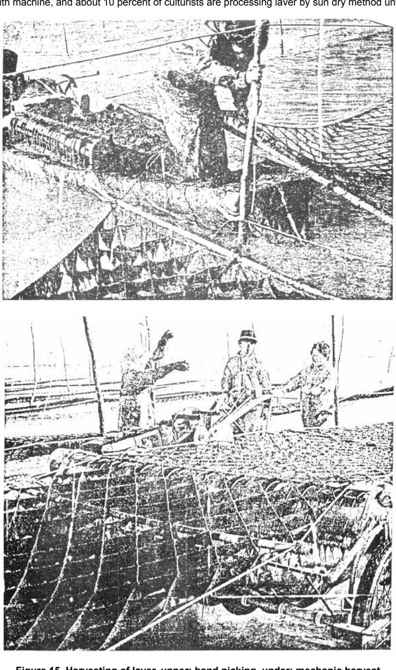


Figure 15. Harvesting of laver, upper; hand picking, under; mechanic harvest

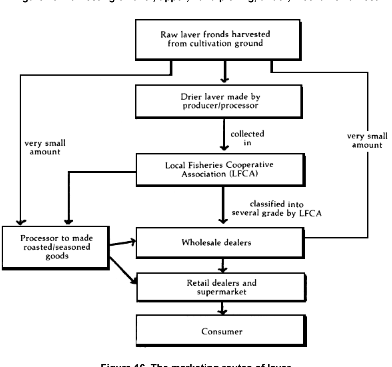


Figure 16. The marketing routes of laver

The consumer's price is about 3 to 5 thousand wons per bundle.

The harvesting of laver frond begins from November and finishes from March to early April, therefore, the dried product is necessary to be stored for a long time. In case the moisture content of the product after processing is about 10–12 percent, it should be dried again so that the moisture content would be 5 percent before storage. The moisture content of over 10 percent brings about changes in color, taste, etc. for long time storage of over two months.

Dried laver is usually sold as a set of 10 sheets packaged, and this weighs approximately 24–30 g and is called pile.

2.8 The problem of laver industry in Korea

Recently, the laver culture industry of Korea has shown remarkable increase in production due to the technical development such as artificial seeding, supplies of culture nets' made of synthetic fibers, floating net culture system including improved culture species (such as *P. tenera* Kjellman form, *Tamatsuensis mura*, and *P. yezoensis*). Almost all of the products are consumed in domestic market. Yet, the production is unstable annually because of variation in marine environment along with deficiency in cold storage system for the storage of nursery nets. On the other hand, expanding of culture areas with culture nets placed has given increase in production, and consequently, the change in processing from manual harvest to sun drying to mechanical harvest and mechanical drying. Therefore, expenditure for purchasing of mechanics as well as equipments inputting into the cultural structure enhanced inevitably the cost of final products. But in the side of customer, the price is keeping 3 000 to 4 000 wons per bundle or 12 000 wons/kg of dried products. The processor is also faced with the problem of "how to make the consumer's price stable and how to lower the basic cost without damage to the culturist through the development of various products as low cost".

3. CULTURE OF UNDARIA PINATIFIDA IN KOREA

3.1 Development of culture technique

Sea mustard, brown algae belonging to the genus *Undaria* is a cold water algae occurring widely in temperate zone, for the whole life cycle, a temperature of 10 to 20°C is suitable. The ecological condition of this algae is restricted in estuaries and other brackishwater region which typically occurs in open sea situation with inflow of water from rivers influence greatly the growth of this algae. This algae grows all along the Korean coast except at higher latitude over 40°C parallel in western coast.

It has been an important foodstuff along with laver from old days in Korea. What is more, it is cheaper than laver and has become a necessary food for soup cooking especially for a pregnant woman.

The history of culture by artificial seeding lately from 1963 in Korea and the culture method before then was extremely primitive. Inputting stone only at suitable depth for attachment of young plants or weeding algae competing with sea mustard for existence is done by brushing the rock or reef for the attached fertilized eggs from spermatozoa on the substrate during late fall of every year. From 1967, cultivation by floating rope type method was developed. The culture product reached over 100 thousand tons (wet) annually from 1970 especially in 1974, the amount of culture product was 180 thousand tons (Figure 7). With the decreased consumer's price resulting from over production as compared to the domestic demand, the production decreased. But owing to the exportation to Japan with blanched-salted products that developed from 1975, the culture production has began to increase again. Now, the annual yield of culture product is being kept on about 200–300 thousand tons. On the other hand, natural harvest which was 28 thousand tons in 1972 (the production ratio between natural harvest was 28:29 in 1972), decreased under 6 thousand tons per annum which is harvested only in the eastern coast. Now cultivation of sea mustard is occupying over 60 percent among total yields of seaweed culture and the major culture areas center on Wando of Jeonnam district and Kijang, Ilgwang near Pusan of Korean southern coast which produce over 80 percent among total yields of sea mustard in Korea.

3.2 Characteristics of sea mustard, Undaria pinatifida

There are three kinds of species; *Undaria pinatifida* (Harvey), Suringar, *U. undarioides* (Yendo) Okamura and *U. peterseniana* (Kjellman) Okamura. Of these species, *U. pinatifida* is the most widely distributed and favoured for consumption.

a) Phylum: Pheophyta
Class: Pheophyceae
Order: Laminariales
Family: Alariaceae

b) Size and shape

Maximum 1–2 mm in thallus length, grows larger in east than south.

c) Color

Fresh fronds is dark brown to greenish brown but when cooked (boiled) the color is turning brighter to brownish green to green.

d) Life cycle and ecology

Undaria pinatifida is an annual plant which grows on rocks and reefs at a depth of 1 to 15 m in places facing the open sea or near open seas influenced by warm ocean currents. When the 10 days average of water temperature rises above 14°C in April in the southern part of Korea, the discharge of zoospores begins from the sporangium formed on sporophylls at the base of the fronds. The discharge of zoospores continues until the temperature reaches 23°C peaking at 17 to 22°C.

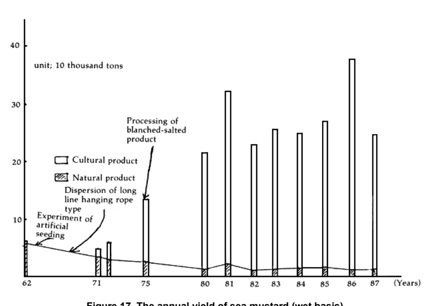
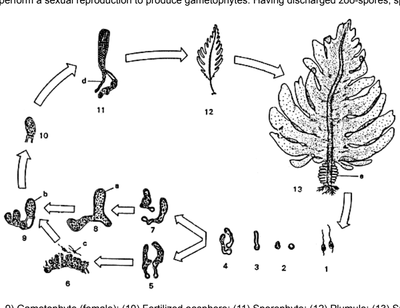


Figure 17. The annual yield of sea mustard (wet basis)

The discharged zoospores are 9 μ in length and locomotive with flagella. They drift in the sea with the water current, adhering to any substrate they contact by chance. Zoo-spores germinate on the substrate and grow to gametophytes at water temperatures up to 24 °C. They stop growing at temperature higher than 24 °C and form resting gametophytes with thicker cell walls to tolerate the high temperature (Figure 18).

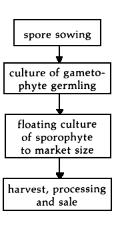
Gametophytes are microscopically small bodies which perform sexual reproduction when mature at water temperatures of around 20°C in October. Spermatozoas discharged into the sea from the male gametophyte fertilized eggs formed on the female gametophyte. The fertilized eggs germinate into sporophytes which grow well at temperatures lower than 17°C. Sporophytes grow fast in winter to form large edible fronds. In the spring, the sporophytes form sporangium on sporophylls at the base of frond to perform a sexual reproduction to produce gametophytes. Having discharged zoo-spores, sporophytes wither and thus, finish the year long life of the plant.



(1) Zoospore; (2, 3, 4) Germination; (5, 6) Gametophyte (male); (7, 8, 9) Gametophyte (female); (10) Fertilized oosphere; (11) Sporephyte; (12) Plumule; (13) Sporophyte; (a) Oogonium; (b) Oosphere; (c) Spermatozoid; (d) Rhizoid; (e) Sporophyll.

Figure 18. Life cycle of Undaria

e) Process of culture



3.3 Culture technique

The life history of *Undaria pinatifida*, as of other brown algae is rather complex and involves an alternation of generations between sexual and asexual form. The asexual form or sporophyte is the obvious macroscopic plant of which the fronds of the main thallus are used as food.

The sporophyte phase grows during the winter months when the temperature is between 10 and 15°C. The cultivation of *Undaria* begins with collecting sporophyll, which was left on the culture structure for use of spore sowing after finishing harvest of plant (sporophyte) from December to May.

In nature during winter months, the sporophyte develops asexual zoospore and these are released from sporophyll in spring and early summer when the water temperature rises above 14°C. After a brief planktonic life, the zoospore settle and adhere to a solid surface (stone, shells, etc.) and germinate to produce the macroscopic sexual plant, the gametophyte.

Germination of zoospore and growth of the gametophyte occurs between water temperature 15 and 20°C.

3.3.1 Artificial spore production (spore sowing)

In order to do spore sowing, first of all, the mature sporophytes (the plants) are brought into the laboratory and placed in concrete/plastic tanks. Into these tanks are placed rectangular plastic/wooden frames (generally 40 × 50 cm^2) around which is wrapped 90 cm of approximately 1.6 m/m diameter braided cotton strings (frame with strings for collection of zoospore) (Figure 19).

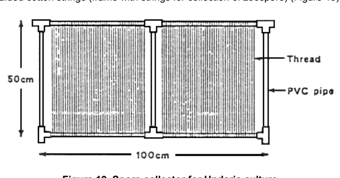


Figure 19. Spore collector for Undaria culture

The zoospores are released from the plant and attach to the strings in late spring or early summer; the gametophytes ultimately the young sporophytes develop on the strings during the summer and early fall.

In carrying out artificial sowing the useful method is as follows: after drying the sporophylls collected in culture area in dark place for one to several hours, place them into the tank filled with sea water. Then the sporophylls start discharging zoospores within 5 minutes which lasts about 20 to 30 minutes. Now, take out the sporophylls in the tank. After 30 minutes have elapsed from the start of inputting it into the tank, place the spore collector (the plastic/wooden frame wrapped with string to collect the zoo-spore) into the tank. After 30 minutes have elapsed the spore collector is taken out from the tank (being the strings of spore collector are attached with zoospore in full) and are transferred to sea water or cultural tank for culture of gametophyte germlings.

The suitable amount of sporophylls used in spore sowing is about 3 kg (wet basis) per 1 km of string length or is estimated 10 individuals per 200 meter in length of strings.

The sea water in the tanks should be controlled to keep the water temperature under 20°C and specific gravity over 1.020.

3.3.2 Culture of gametophyte germling

There are two methods to culture germlings: one is to culture them in the sea by hanging spore collector from a raft; and the other is to culture them in indoor concrete tanks (the suitable capacity of the culture tank is to fill 1 ton of sea water, and the strings of the spore collector is about 300 meters in length); the culture of gametophyte germlings starts by putting the spore collector into the tanks. In Korea, the culture of germlings is carried out in indoor concrete tanks. The spore collectors with attached zoospores are hung vertically in the tank where zoospores germinate on the strings of the spore collector.

In this germling culture, the water temperature, light and water flow should be controlled according to the growing stages carefully and also, in some cases nutrient salts such as sodium nitrate and sodium phosphate are added to the water to stimulate the growth of germlings. Gametophyte ' enter a resting stage over 25 °C in summer. During the resting stage, germlings are kept in still water and the temperature should be controlled under 28°C. Over that temperature the germling is easy to be killed and also it is very important to control the light in accordance with the water temperature (in southern part of Korea the sea water temperature upwards over 25°C in August, and the growth of gametophyte continues until early August, and from mid-August the gametophyte begins resting. In case of this, supply of nutrient salt is necessary). When the water temperature drops below 23°C in autumn, the gametophyte can resume their growth, and the light conditions of waters tanks are increased to 2 000–4 000 lux. Gametophyte matures at water temperature of 20°C and sexual reproduction takes place. When fertilized eggs germinate as sporophytes, lighting is increased over 5 000 lux, and the exchange of water and addition of nutrient salts are effective to accelerate the growth of sporophytes.

If the growth of sporophytes is not efficient, tank water should be cooled to 20°C, or spore collectors should be hung in the sea.

Conditions of water temperature and light in accordance with the growing stages is shown (see table below).

3.3.3 Floating culture of *Undaria* sporophytes

In September or November, the sporophytes grow to 100 to 1 000 μ in size, attach the strings of the spore collector and are ready for further culture in the sea. Thus, floating culture of *Undaria* has begun in autumn, from September to November when the water temperature drops below 20°C. The culture ground should be located where temperature is below 15°C since the *Undaria* grows well at water temperature below 15°C and the specific gravity should be above 1.025.

Before the main culture of the sporophyte (young thalli) by floating rope culture system, the spore collector is hung to the main rope of culture structure for about two weeks until the young thalli grows to 0.5–1 cm in length. After that, strings covered with young thalli (sporophytes) of *Undaria* are wound around the main or branch line of the floating rope type culture structure placed in the sea.

3.3.4 Harvesting

Undaria fronds are harvested from a boat with a knife in cultivation ground from December to May. There are some differences in harvest period between the east southern part and the central southern part, in accordance with the oceanographic condition of water temperature and sea currents (Figure 20). Generally, the central part of southern coast finish in April, but the east southern part continues until end of May. Nowadays, the disease of thalli by the appearance of *Harpacticoida* has given great problems in cultural area especially from March. The damage resulting from the *Harpacticoida* reached over 20 percent decrease in total annual harvest in recent years.

Growing stage	Water temperature	Light	Month
Sporophylls form sporangium	not concerned with special temperature		April–July
Sporangium discharge zoospore	14 to 22°C (opt. 17 to 20°C)		April–July
Zoospore germinate gametophyte, growing of gametophyte	17 to 20°C (growth stop at 23°C)	2 000–6 000 lux	May–July
Resting of gametophyte	25 to 30°C	500 lux	July–August
Maturing of gametotophyte and germination of germling	drops under 20°C	1 000 lux	September–October
Growing of germling	17 to 10°C (opt. 15°C)		October–November
Growing fronds of thallus	13 to 5°C (opt. 10°C)		November–April

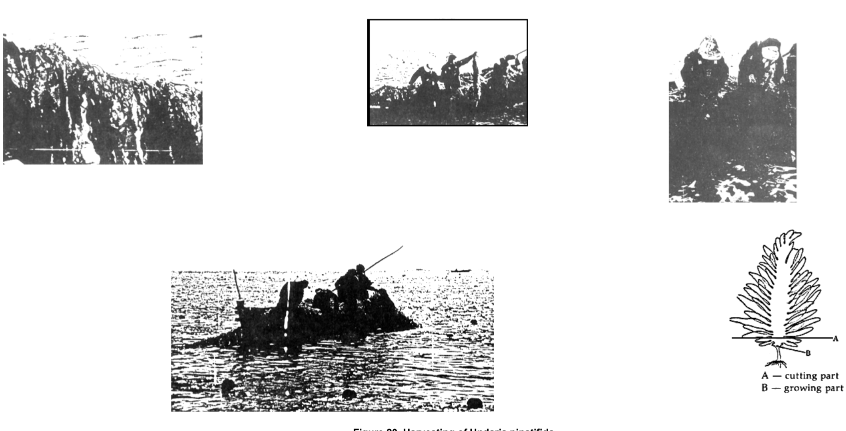


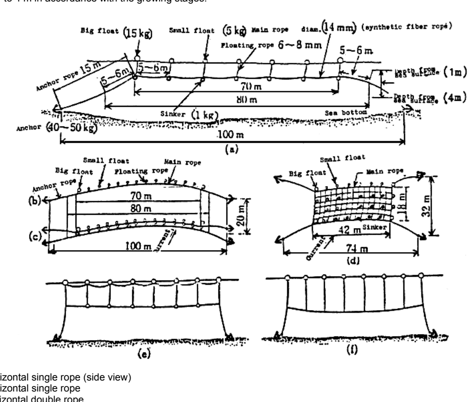
Figure 20. Harvesting of Undaria pinatifida

3.4 The floating culture system of Undaria pinatifida

In the cultivation of *Undaria*, the culture method now in Korea mainly consists of the floating rope type or hanging rope type.

The main lines of the culture structure are 1 to 3 cm in diameter and 70 to 80 m long; in case of long line rope type, it is composed of synthetic fibers (or strong rubber for continuous use) which are kept afloat and are fixed at suitable intervals in the sea with anchors.

In the floating rope method, branch lines are hung from the main lines. The strings covered with young thalli (sporophytes) of *Undaria* are either wound around the main or branches lines or cut into short pieces, several centimeters long and inserted between the strands of main or branch lines (Figure 21). The method of winding around the main line is popular. The water depth at which the main line should be set 1 to 5 m below the surface. The depth from the sea surface should be controlled from 1 to 4 m in accordance with the growing stages.



(a) Horizontal single rope (side view)
(b) Horizontal single rope
(c) Horizontal double rope
(d) Rectangular assembling rope
(e) Suspending horizontal single rope
(f) Single rope hanging

Figure 21. Floating culture method of Undaria

3.5 Processing

Grown fronds in market size in cultivation ground is harvested by cutting the strips nearing the sporophyll with knife on boat and the harvest is only through hand picking. Meanwhile, natural grown *Undaria* is harvested by diving which is practised now in Korea only in the eastern coast of Kangwon province. After harvesting, *Undaria* is processed as sun dried product, blanched-salted product, or cut type product, etc. General processing type practised now in Korea are as follows:

a) Sun dried product

The fronds of sea mustard rewashed with fresh sea water after harvesting and they are cut into two similar halves by removing the midrib or cut into small size by removing the end part of thalli and are dried in the sun or in a hot air dryer. The yield from raw material (fronds) is about 10 percent.

b) Blanched-salted product

Raw material fronds are heated soon after harvest at 90–98°C for about 40–60 seconds and cooled quickly with water. Then the fronds now vivid green, are mixed with salt in a ratio of 3:10 (w/w) in a machine. They are preserved in a tank for one to two days, then packed in a bag to remove excess water. The product is stored in a cold room at -10°C for sale. This product is a major commercial form of *Undaria* at present and much of them is exported to Japan.

c) Cut products

The blanched-salted product is desalted by washing with fresh water, centrifuged to remove excess water, then cut mechanically into small pieces and dried in a rotary type of flow-through drier. These cut fronds are stored into uniform sizes by sieving any faded fronds (if present) which are removed and then appropriate amounts are packed in a bag of plastic film for sale. But now the processing of this type is treated easily with hand by fishermen themselves, that is, to be sun dried after desalting the blanched-salted product (used as raw material without storage or packing in the plastic bag), except industrialized processing company.

3.6 Marketing

The *Undaria* harvested by fisherman follows the marketing chain as shown in Figure 22. In reference, the price of cultivated *Undaria* is 10 thousand wons per 100 kg after harvesting. Now a small amount is sun dried by culturists/fishermen themselves and is marketed to consumer through wholesale/retail dealers in domestic market. Only the blanched-salted product made of good quality fronds are exported to Japan. Generally, this product for export finishes in March because of good quality in fronds of thalli and the price of raw material (harvested fronds), which is used on this product kept on about 120 thousand wons per 100 kg after harvest last year. The standard of this product is regulated as to the moisture content which is under 63 percent, the midrib should be removed thoroughly and the contents of salts from 25 to 40 percent. The yield of the product from the raw material is about 40 percent. The products for export are packed in wooden boxes and the unit of package is 15 kg per box. Consequently, the other products made by culturists/fishermen/processors are sold to domestic market through the marketing channel as shown in Figure 22. However, the cooking method is simple, that is almost all of them are cooked for soup.

3.7 The problems of Undaria industry

Undaria is the most productive shallow sea culture species in Korea. Although the total production reached 350 thousand tons in 1986 with developed culture technique, the income of culturist decreased in general, owing to the stagnation in price. Also, disease caused by the *Harpacticoida* in cultivation area resulting from intensive cultivation is now a serious problem. The damage led to an estimated decreased harvest of about 20 percent of the total possible production in 1987. What is more, the reason why this gives a serious damage to *Undaria* culture is that the disease of the fronds by this microorganism mainly occurs in March when the harvest of good quality fronds reaches the peak. There is no special counter measure to keep the fronds from this damage. The only preventive measures are: (1) controlling culture process thoroughly from spore sowing to the growing stage according to the growth of thalli; (2) preventing the intensive cultivation (controlling the intervals of culture structure between the main ropes of which is now 2–3 m to be 3–5 m; and (3) keeping marine environment from pollution, etc. On the other hand, as the processed products of *Undaria* is only consumed for soup so the price between producer and consumer is limited domestically. Consequently, in order to increase the consumption in the domestic market a higher grade product should be developed in participation with the industry such as instant foods as *Undaria* tea, powdered product, seasoned product, fish pasted product, *Undaria* noodle, etc.

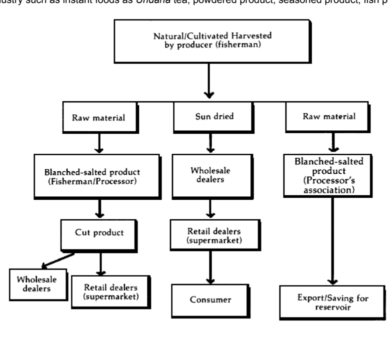


Figure 22. The marketing route of Undaria

SEAWEED FARMING IN EAST MALAYSIA

by

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1. INTRODUCTION

Sabah and Sarawak are two states in East Malaysia which have a potential of producing seaweeds. There are several seaweed species found growing on reefs in Semporna area, south of Sabah and in Banggi Island of the South China Sea in Kudat area, north of Sabah. The major seaweed species found are namely: *Sargassum, Eucheuma, Caulerpa, Gracilaria, Hypnea, Padina and Hydroclathrus.*

2. EUCHEUMA FARMING

Eucheuma culture was developed in Semporna area which has a greater number of coastal inhabitants. It was started in May 1986 which was done by the Fisheries Department Personnel and four fishermen with their families involved. The aim of the Fisheries Department is to farm *Eucheuma* as a source of seed stock and to attract the fishermen to involve themselves in farming in order to increase their income. As for the information gathered, there was no actual data collected.

3. SITE SELECTION AND PRODUCTION

An estimate of about 1.5 hectares of suitable site was planted with *Eucheuma* striatum for the initial seedlings which consisted of 30 000 plants with an average weight of 250–300 grams per plant. The farmers were able to plant four hectares in October 1987. There were six families who started to culture *Eucheuma*. The total number of fishermen involved in planting *Eucheuma* at present are 10 families which cover an area of 10 hectares. This does not include the Fisheries Department *Eucheuma* farm.

The production of *Eucheuma* in 1987 amounted to 400 metric tons wet weight. Some were consumed as food and others were exported as dried material. The total *Eucheuma* production as reported does not include the wild stock harvested by the fishermen and as far as I know there was no record available.

4. METHODS OF CULTURING SEAWEEDS

Two methods of farming were employed namely:

4.1 Semi-raft method

Semi-raft method is applied only in the lagoon area where the depth of the water is between 10–20 feet deep and the width is about 200–500 ft. Pegged stakes are placed on opposite sides of the lagoon with floats tied to the monoline at a depth of 3 ft from water surface.

4.2 Bottom method

This method is also called stake and nylon line method. It is cheaper compared to the other method for it is made up of two stakes and a monofilament nylon No. 200 lbs and 15 meters long. Stakes are pegged one meter apart from each other and 15 meters long. A 15-meter nylon line can be planted with 40–50 plants with a distance of 30 cm from each plant.

5. PROBLEMS ENCOUNTERED

When the culturing started, we encountered some problems as follows:

5.1 **Fish predators** that graze on the plants. The fish was identified as *Siganus* sp.

5.2 **Epiphytes**

5.3 **Environmental factors** such as salinity, light and temperature, water movement and water depth which affects the growth rate of the *Eucheuma* and other seaweed species

5.4 **Marketing.** Since seaweed farming is still being developed in our country marketing of the product is also a major problem to the East Malaysian seaweed farmers.

6. RECOMMENDATION

In the future, more efforts in research on other seaweed species should be carried out by the Fisheries Department.

SEAWEED INDUSTRY OF THE PHILIPPINES

by

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1. INTRODUCTION

The Philippines is blessed with abundant aquatic resources which provide food and livelihood to many Filipinos. Seaweeds are one of these resources which are found in lagoons and reef areas all over the country. The country is one of the few in the world which has pioneered the farming of these plants in substantial quantities.

Seaweeds are good sources of colloidal material which are used as gelling agents, emulsifer, food stabilizers, pharmaceutical, cosmetic and industrial products. It also constitute an important food item, fertilizer and animal feed.

In 1966, seaweeds was the only negligible item of the country's economy. Export at that time amounted to only 800 mt. But with the development of seaweed farming in 1973 foreign revenues had increased to almost fifty times. Since then what was considered a minor sea product is now generating ₱466 732 486 (32.2 thousand mt) for the country and now the third fishery export of the Philippines.

2. EXISTING SEAWEED RESOURCES

Production of seaweeds in the Philippines is dependent on harvest of natural stocks except for *Caulerpa* and *Eucheuma* which are produced through mariculture. Limited information are available on other commercially important seaweed such as *Gelidium, Sargassum,* etc.

Among the different seaweeds found in the country, *Eucheuma* dominates the industry. *Eucheuma* alvarezii (cottonii type) and E. denticulatum (= spinosum type) as "gozo" are the species commercially cultivated in the country. *Eucheuma*, a red alga is an important source of raw material for carrageenin, a colloidal substance used as gelling agent, stabilizer or emulsifier in food, cosmetics and other products. *Gracilaria* or "gulamang dagat" are raw materials for agar which are used for food, pharmaceuticals and culture media for research laboratories.

Gracilaria is harvested in Manila Bay and provides income to coastal communities in Bataan and Cavite. Unfonately, it is of inferior quality due to pollution surrounding these areas. Gathering of *Gracilaria* is also undertaken in Buguey, Cayagan and sold at ₱2.00/kg. These are marketed in Manila and gathering is undertaken only as secondary to farming.

Sargassum, a brown seaweed containing alginate is known as "samo". It can also be used as food and in pharmaceuticals. Sargassum industry developed in Misamis Oriental in 1978. This seaweed grows abundantly in shallow coastal waters in the country. It is used as insect repellant and feed supplement for poultry and livestock. Harvesting is by hand picking during . the months of January–June.

Caulerpa known as "lato" or "ar-arosep" is utilized as vegetable salad and sold both in the foreign and local markets. About 400 hectares of ponds are utilized in *Caulerpa* farming in Mactan, Cebu. Retail price in Metro Manila markets range from ₱20–22/kg.

Hydroclathrus or "balbalolong" is used mainly as a food item in Pangasinan and sold at ₱80.00/can.

Other species such as Codium (pokpoklo), Porphyra (garnet), Digenea simplex (bodo-bodo) and Gelidium are also utilized in the country but very little information is available on their usage and production.

3. SEAWEED EXPORT

Seaweeds exported to other countries come in dried and treated form; fresh or salted or as seaweed meal powder. *Eucheuma* produced through farming are sold in the international market in treated (chips) semi-refined and refined forms. A portion of the local produce of *Gracilaria* and Gelidiella are processed into crude agar which are sold in the local market in the form of dried agar bars.

A small amount of *Caulerpa* is sent to Japan in dehydrated (or salted) form. *Sargassum* is processed in Central Visayas and exported to Japan. A significant amount of *Gracilaria* and *Gelidiella* are exported while the rest is locally produced into agar bars for food. Production of *Codium* and *Porphyra* are dependent on natural stocks and are consumed locally.

Major bulk of dried seaweeds goes to Denmark. Japan is the biggest importer of salted seaweeds and seaweed meal. The total export of seaweeds of the Philippines increased from 16 890 tons in 1982 to 32 293 tons in 1986. The breakdown of this export product in kgs, value and destination is shown in Table 1. Seaweed is the third largest export item of marine product of the Philippines.

4. CULTIVATION AND POST HARVEST PROCESSING

The present farming of *Eucheuma* utilizes the monoline or bottom and floating methods.

Seaweed farms range from 2 500–5 000 sq m. There are about 100 seaweed farms in Bohol province and an estimate of 3 000 farms in Tawi-Tawi, Sulu in Mindanao. It has been reported that there are approximately 2 500 ha of *Eucheuma* farms in the Tawai-Tawi and Sulu areas (Smith, 1987). Farmers use 10 m nylon lines. Seaweed cuttings weighing about 150–200 g are attached to these lines with the use of plastic straw. These are suspended and attached to wooden stakes. The distances between lines is at least one meter. Seaweed farming manuals are available from the ASEAN/UNDP/FAO Project based in Manila.

In the floating raft method, the monolines are attached to a rectangular bamboo raft.

The best months for growing are from November to July with March to May as peak growth months.

Harvesting is undertaken after 45 days. The harvested seaweed is sun dried for three to four days.

One kilogram of dry seaweeds require 6–9 kg of fresh seaweeds.

Table 1. Export of seaweeds, 1982–1986

Year	Dried/Treated		Fresh		Salted		Kelp meal powder		Total	
	Quantity (kg)	Value (₱)	Quantity (kg)	Value (₱)	Quantity (kg)	Value (₱)	Quantity (kg)	Value (₱)	Quantity (kg)	Value (₱)
1982	16 073 947	82 418 082	173 890	2 172 649	–	–	532 008	456 749	16 779 845	85 047 480
1983	15 594 056	108 332 508	149 331	2 559 185	1005	22 155	910 075	1 058 680	16 654 467	111 972 528
1984	10 255 505	81 238 046	400	6 300	-	-	634 250	1 019 692	10 890 155	82 264 038
1985	23 749 056	364 474 804	803 358	15 796 444	131 183	791 736	4 124 626	8 691 137	28 808 223	389 744 121
1986	29 182 896	455 572 060	166 145	3 186 057	77 470	388 148	2 866 393	7 587 221	32 292 904	466 733 486

Year	Kind	Quantity (kg)	Value (₱)	Major destination	Quantity (kg)	Value (₱)
1982	Fresh	173 890	2 172 649	USA	1 783 815	19 468 271
	Treated	654 475	6 037 468	Spain	1 658 340	6 089 624
	Dried	15 419 472	76 380 614	Denmark	6 687 101	17 473 431
	Kelp meal	532 008	456 749	France	2 874 500	6 945 260
				Japan	1 538 596	6 460 127
	Total	16 779 845	85 047 480			
1983	Fresh	149 331	2 559 185	France	3 155 360	10 109 068
	Treated	633 026	15 157 992	USA	2 374 789	18 594 731
	Dried	14 961 030	93 174 516	Denmark	5 705 225	22 883 123
	Salted	1 005	22 155	Japan	1 859 835	7 375 255
	Kelp meal	910 975	1 058 680	England	1 004 550	35 624 853
	Total	16 654 467	111 972 528			
1984	Fresh	400	6 300	Denmark	3 360 317	28 716 904
	Dried	10 217 505	80 023 546	France	1 528 050	4 924 947
	Treated	38 000	1 214 500	Hong Kong	1 272 706	4 046 005
	Kelp meal	634 250	1 019 692	Japan	631 750	918 752
	Total	10 890 155	82 264 038			
1985	Dried/treated	23 749 056	364 474 804	Denmark	9 887 301	99 084 429
	Fresh	803 358	15 796 444	Japan	5 379 808	49 146 789
	Salted	131 183	791 736	France	4 088 043	32 085 938
	Kelp meal	4 124 626	8 691 173	USA	2 261 883	30 806 381
				United Kingdom	2 299 947	101 327. 651
	Total	28 808 223	389 744 121			
1986	Dried/treated	29 182 896	455 572 060	Denmark	12 532 440	108 739 116
	Fresh	166 145	3 186 057	France	4 145 698	35 138 008
	Salted	77 470	388 148	USA	3 646 455	55 890
	Kelp meal	2 866 393	7 587 221	United Kingdom	2 550 156	128 412 659
				Japan	3 998 661	50 970 009
	Total	32 292 904	466 733 486			

MARINE PHYCOCULTURE IN CHINA

by

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1. INTRODUCTION

In China, the seaweed with commercial importance are mainly *Laminaria, Undaria, Porphyra, Gelidium, Gracilaria, Eucheuma* and *Macrocystis.*

Laminaria is the most important economic seaweed in China. Mariculture of *Laminaria* on artificial floating rafts started in 1952 and the production increased steadily until 1980 when the highest yield of 252 907 tons of the dry product was produced. In recent years, the cultivation area and total yield of *Laminaria* declined because the culture of shellfish developed so quickly that the farmers prefer cultivating shellfish to *Laminaria*. Annual yield of *Laminaria* keeps over 200 000 tons.

Undaria is cultivated by the same raft method as the *Laminaria* and is often mix-planted with the latter on the same floating raft in Qingdao and Dalian. The annual production keeps only a few thousand tons. It is usually used for feeding abalone and some are exported to Japan. *Porphyra* is mainly cultivated in Jiangsu, Zhejiang and Fujian province. It is used for food and extraction of agar. *Gracilaria* and *Eucheuma* are mainly cultivated in Guangdong province also used for extracting phycocolloid.

Now let me introduce the productive procedure of *Laminaria*. The culture of other brown algae such as *Undaria* and *Macrosystis* are almost similar to *Laminaria*.

The productive procedure of *Laminaria* include mainly four steps: (1) culture of *Laminaria* sporelings; (2) cultivation of sporelings in the sea and transplantation; (3) cultivating methods of *Laminaria;* and (4) harvesting and processing.

1.1 Culture of Laminaria sporelings

The first is collecting zoospores onto the seeding cords. To do this, *Laminaria* fronds with mature sporangial sori are subjected to partial drying in the air and then placed in a small container with seawater. The liberated zoospores will soon attach themselves to the substratum, the seeding cords. The gametophytes and early sporophytes are cultured in water of 8–10°C in glass-house for three months. After that the juvenile sporophytes can reach 2–3 cm long.

1.2 Cultivation of sporelings in the sea and transplantation

When the water temperature has already dropped to about 20°C, we can remove sporeling cords to the sea from glass-house and hang them on the floating raft. In a month or so the sporelings will have grown to juveniles of 10–15 cm long or more. These juvenile sporophytes have to be brought to the transplanting room and placed in tanks filled with seawater. Since they grow on the cords so thickly, they have to be thinned. The best way in our experience is to remove them from the original sporeling cord and insert them in the twists of the kelp ropes, generally, with about 30 juveniles to each rope of 2 m.

1.3 Cultivating methods of Laminaria

There are two basic floating raft kelp cultivation methods. One is hanging kelp rope (also called single-raft) cultivation method. Another is horizontal kelp rope (also called double-raft) cultivation method. The floating-raft, floating line is about 60 m long floated at the surface by buoys generally made of glass or plastics and anchored terminally by anchoring lines to wooden pegs driven into the sea bottom. Each kelp rope has about 30 kelps twisted in it and is about 2 m in length. In the single-raft method, the kelp ropes are hung down from floating line and weighted down by a small piece of stone. In the double-raft method, the end of two kelp ropes are linked or tied together, the other ends are tied to floating lines, respectively. The hanging kelp rope method has the advantage of better water movement but has the defect of uneven growth of the kelps. The horizontal kelp rope method has the benefit of more even growth of the kelp. However, it has the defect of being more resistant to water motion. Generally speaking, the single-raft method is better adapted to comparatively clearer water regions and the double-raft method to turbid regions with lower water transparency such as the Zhejing coast.

2. HARVESTING AND PROCESSING

Harvesting takes place when the fronds are mature. The time for harvesting is important to kelp farmers. Since the *Laminaria* is sold in the market on the basis of dry weight, and since the wet weight to dry weight ratio changes from month to month, the criterion for selecting harvest time should take into consideration the highest per unit area production rate plus the lowest wet-to-dry ratio.

Table 1 shows the results of an experiment conducted on the quantity and quality of the production on kelp drop at different dates.

From the table, it is readily seen that mid to late June is the best time for harvesting. It is, therefore, recommended harvesting begins in mid-June and continue until late June or early July in North China. In harvesting the *Laminaria,* the kelp ropes are detached from the floating line and collected in small boats, many of which are retowed in a long line by a motor boat. When the boats reach the wharf or shore, *Laminaria* are transported to land and dried under the sun.

Table 1. Production quality and quantity per kelp rose at different dates

Harvest time month/day	Production in wet weight (kg)	Production in dry weight (kg)	Wet weight dry weight ratio
4/25	21.8	2.2	10:1
5/10	24.4	2.7	9:1
5/26	24.6	3.1	7.9:1
6/11	22.0	3.3	6.6:1
6/29	17.6	3.1	5.7:1
7/14	14.5	2.9	5:1

3. UTILIZATION AND MARKETING OF LAMINARIA

Most of the *Laminaria japonica* produced in China is used for food. Besides its role as a "health" vegetable in China, *Laminaria* is also important as raw material to be processed for its algin, mannitol and iodine content in a special programme for the comprehensive utilization of *Laminaria*. Recently, the kelp produced in China has also been employed in the processing of synthetic feed use in mariculture. Formerly, the kelp was sold in the market only in the crude dried form, but recently small package of shredded and seasoned forms with different flavours have appeared in the market and are very well accepted by the people.

GRACILARIA CULTURE IN THAILAND

by

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ABSTRACT

Thailand exports dry seaweed (approximately 20 to 200 tonnes), most of which are of the genus *Gracilaria*, which can be processed to agar. At the present time, Thailand has no agar processing industries and therefore, agar has been imported (around 200 to 300 tonnes/yr valued at 50 to 100 million baht). The major producing areas are the southern region of Songkhla Lake and the shallow mud-flats in Pattani Bay. Production is mostly from natural beds. Two methods of culture are practiced: pond culture with a production of approximately 6 442.5 kg/ha/yr; and polyculture in seabass *(Lates calcarifer* Bloch) cage with a production of approximately 100 kg/cage/yr (1 cage = 10 × m^2). Mostly dry seaweed is exported to Malaysia.

1. INTRODUCTION

Thailand exports seaweed at quantities ranging approximately between 20 to 200 tonnes/yr (dry weight) valued at 4 to 10 million baht (HAI, 1986). Most of the seaweed exported are of the genus *Gracilaria*. Major export markets are Japan, West Germany, Hong Kong and Malaysia. In view of this and due to the absence of processing plants, Thailand has been importing agar at quantities ranging between 200 to 300 tonnes/yr at a value of 50 to 100 million baht. Some of the production is utilized and consumed in Thailand, but the bulk is exported; in 1984 seaweed exports totalled around 8.4 tonnes valued at 1.5 million baht (HAI, 1986).

Gracilaria species are found in shallow mudflat areas. They can propagate by sexual and asexual reproduction. They can be eaten in fresh form or dried for export (Plate 1). At present, eight endemic agarophytes are found in Thailand, four species belonging to the genus *Gracilaria* and four to *Polycavernosa, G. tenuistipitata* var. *liui, G. firma, G. irregularis, G. salicornia, P. fisheri, P. changii, P. fastigiata* and *P. percurrens* (Abbott, LA. 1987). The major producing areas are the southern region of Songkhla Lake and the shallow mudflats in Pattani Bay (Figures 1, 2 and 3).

2. CULTURE TECHNIQUES

Thailand does not produce large quantities of seaweed. Harvest is mostly from natural beds. The Department of Fisheries is conducting research and investigating the feasibility of mass propagation of a number of seaweed species especially *Gracilaria* sp. (Sirikul and Singthaweesak, 1987; Tachanaravong et. al., 1987).

The culture methods practiced in Thailand are as follows:

2.1 Long line

Raffia and polyethylene lines were used as materials for the long line culture method in an experimental culture farm; the results obtained were not satisfactory (Plate 2).

2.2 Pond culture

Farmers collect young *Gracilaria* sp. from natural grounds and transfer them to earthen pond with a water level of around 0.5–1.0 m (Plate 3). The exchange of water depends on the tide. The average production level obtained in 1985 was 1 030 kg/rai/yr (1 rai = 1 600 m^2) (Tookwinas *et. al,* 1987).

2.3 Polyculture in seabass cages

Seabass *(Lates calcarifer* Bloch) farmers harvest *Gracilaria* that naturally collects and grows on the cages. They grow on the polyethylene net and on the bottom of cages. Production levels range between 50–100 kg/100 m^2/yr.

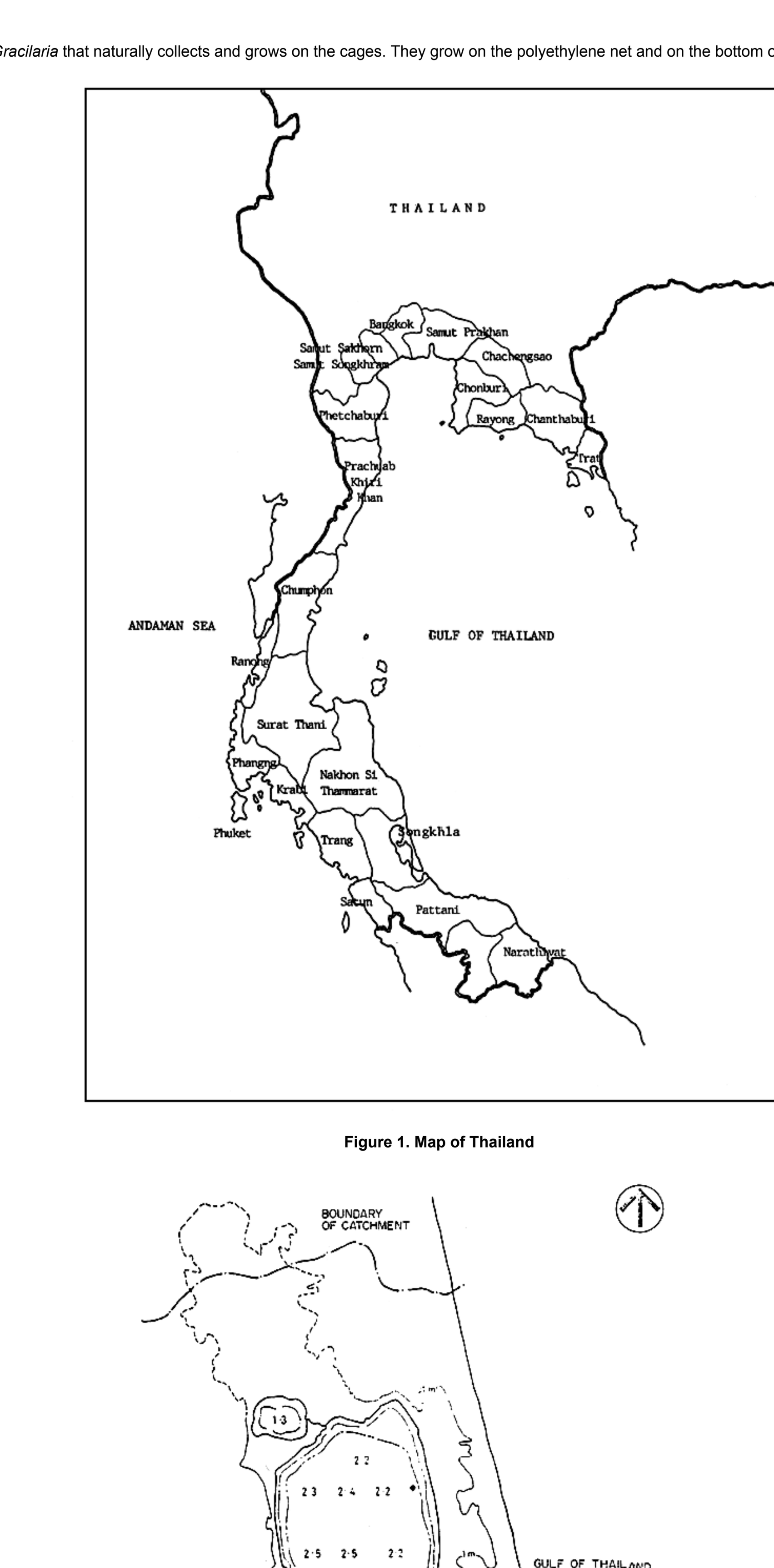

Figure 1. Map of Thailand

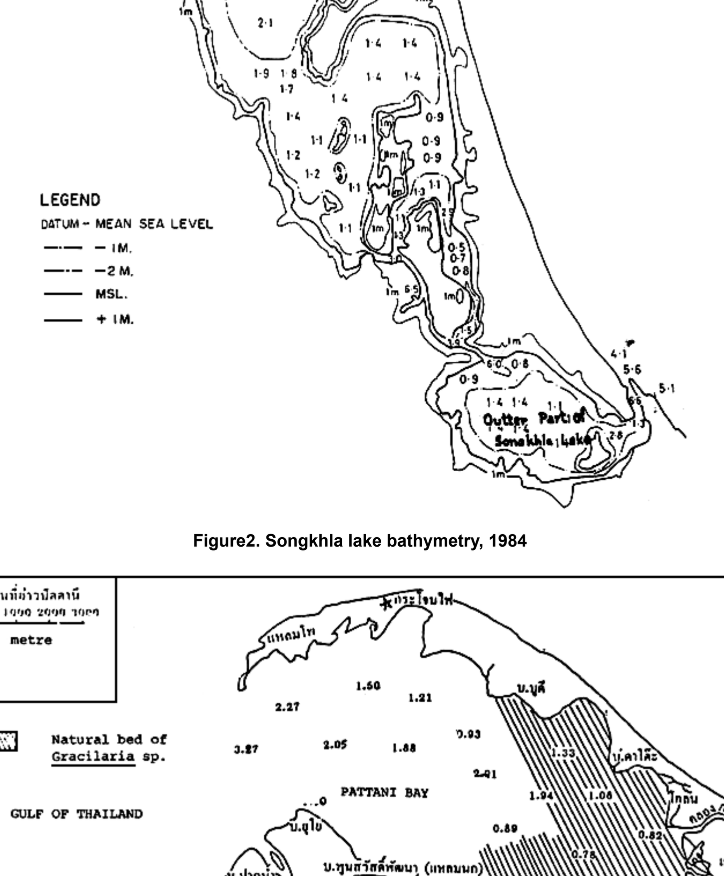

Figure2. Songkhla lake bathymetry, 1984

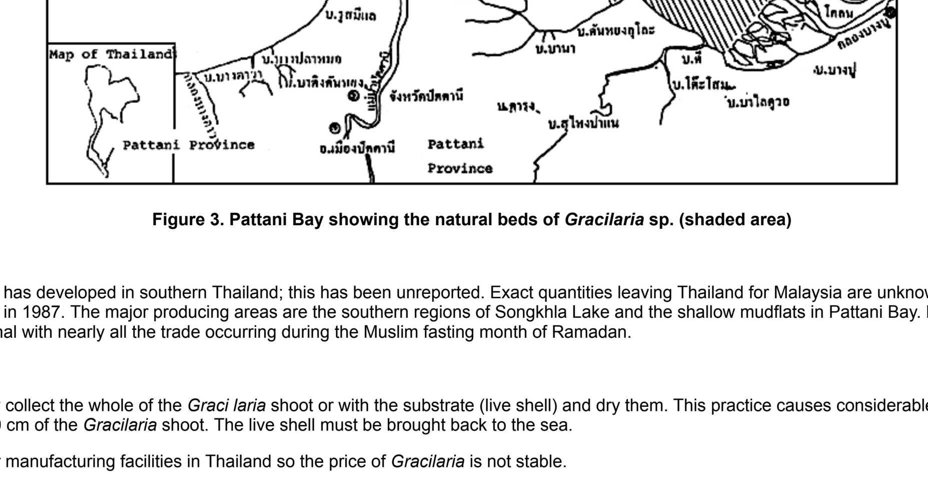

Figure 3. Pattani Bay showing the natural beds of *Gracilaria* sp. (shaded area)

3. MARKETING

An export market for dried, wild harvested *Gracilaria* has developed in southern Thailand; this has been unreported. Exact quantities leaving Thailand for Malaysia are unknown but are estimated to range from 30 to 50 tonnes annually at a value (first sale) of 1.8–3.0 million baht in 1987. The major producing areas are the southern regions of Songkhla Lake and the shallow mudflats in Pattani Bay. Price was in the range of 30 to 90 baht per kg. The market appears to be fairly limited and highly seasonal with nearly all the trade occurring during the Muslim fasting month of Ramadan.

4. PROBLEMS

4.1 Farmers who harvest from natural beds normally collect the whole of the *Graci laria* shoot or with the substrate (live shell) and dry them. This practice causes considerable damage to the natural stocks of *Gracilaria*. They must be harvested by cutting, leaving around 5 to 10 cm of the *Gracilaria* shoot. The live shell must be brought back to the sea.

4.2 There are no commercial or industrial-scale agar manufacturing facilities in Thailand so the price of *Gracilaria* is not stable.

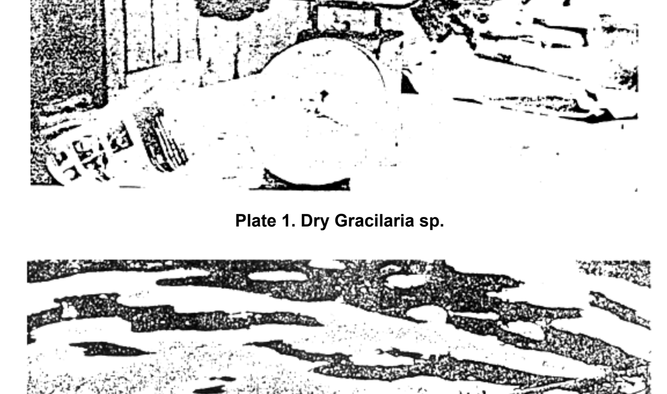

Plate 1. Dry Gracilaria sp.

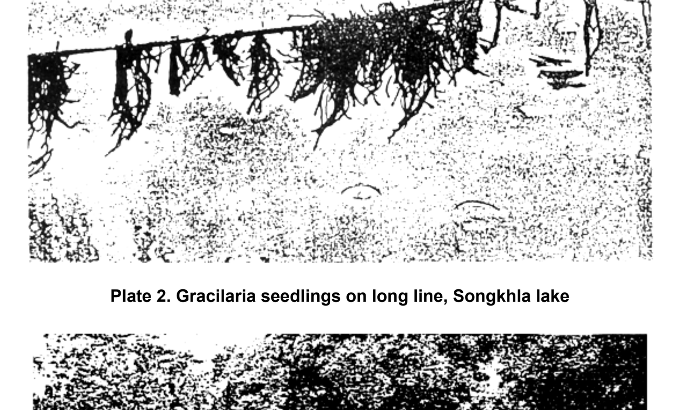

Plate 2. Gracilaria seedlings on long line, Songkhla lake

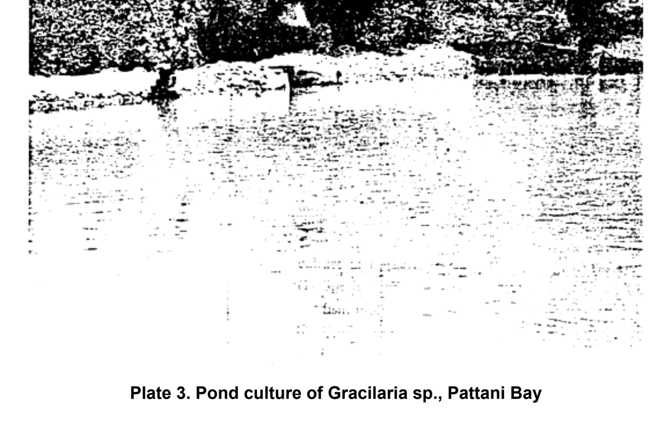

Plate 3. Pond culture of Gracilaria sp., Pattani Bay

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PART IV
ANNEXES

Annex 1
LIST OF PARTICIPANTS

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	2.	Ms. Leonora D. Rivera Fishery Technician Seafarming Section, Fish Propagation Division Bureau of Fisheries and Aquatic Resources Arcadia Bldg., 860 Quezon Avenue Quezon City, Metro Manila
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	5.	Mr. Gregorio Clave Seaweed Farmer Anda, Pangasinan
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Non-ASEAN countries		
PEOPLE'S REPUBLIC OF CHINA	1.	Mr. Wang Feijiu
	2.	Mr. Cai Zulin
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REPUBLIC OF KOREA	1.	Mr. June Chang-Su
	2.	Mr. Jung Jin-Tae Contact Address: Dr. Byung Ha Park, Director Department of Aquaculture Fisheries Research and Development Agency 16, 2-GA, Namhang-Dong Youngdo-Gu, Pusan Republic of Korea
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Annex 2
LIST OF LECTURE TOPICS AND CORRESPONDING LECTURERS, PRACTICAL WORKS, FIELD VISITS AND DETAILS OF THE SCHEDULE OF ACTIVITIES

A. LECTURE TOPICS	LECTURERS
1. Coastal Resources of Asia-Pacific: Environmental Aspects	Dr. Edgardo D. Gomez
2. Status of the Seaweed Production and Utilization in Asia and Western Pacific Region	Dr. Gavino C. Trono, Jr.
3. Influence of Environmental Factors on the Structure and Distribution of Seaweed Communities	Dr. Miguel D. Fortes
4. Introduction to Seaweeds: Their Characteristics and Economic Importance	Dr. Rhodora A. Corrales
5. How to Identify Seaweeds	Dr. Romeo Modelo
6. Inventory and Assessment of Economically Important Seaweed Stocks	Dr. Miguel D. Fortes
7. The Taxonomy of Commercially Important Seaweeds in Tropical Asia/Western Pacific	Dr. Gavino C. Trono, Jr. and Dr. Romeo Modelo
8. Production of Economically Important Seaweeds through Culture and Harvesting of Natural Stocks	Dr. Gavino C. Trono, Jr.
10. Post-Harvest Practices/Processing and Utilization of Seaweed Products	Mr. Maximo Ricohermoso
10. Seaweed Diseases and Other Problems in Seaweed Culture	Dr. Gavino C. Trono, Jr.
11. Potential for Polyculture of Seaweeds with Milkfish/Crustaceans	Dr. Edgardo D. Gomez
12. *Eucheuma* (Seaweed) Industry	Mr. Maximo Ricohermoso
13. Field and Laboratory Techniques in the Collection, Preservation of Marine Benthic Algae for Herbarium and for Identification	Dr. Romeo Modelo
B. PRACTICAL WORKS	
1. Introduction to the Representatives of the our Division of Seaweeds	Dr. Rhodora A. Corrales
2. Identification of Seaweeds	Dr. Romeo Modelo
3. Field and Laboratory Techniques in the Collection, Preservation and Curation of Seaweeds	Dr. Romeo Modelo
4. Demonstration on Field Culture of *Eucheuma*	
5. Demonstration on Pond Culture of *Caulerpa*	
6. Demonstration on Field Culture of *Gracilaria*	
7. Assessment of Natural Stocks of Seaweeds	
C. FIELD VISIT/TRIPS TO PRODUCTION SITES ANDPROCESSING PLANTS	
1. Visit to Processing Plants in Cebu/Mandaue	

Schedule of Activities

Date/Day	8:00–9:00 A.M.	9:00–10:00 A.M.	10:00–10:30 A.M.	10:30–12:00 N.N.	1:30–3:00 P.M.	3:00–3:30 P.M.	3:30–5:00 P.M.
2 May (Mon)	Registration	Opening Ceremonies	Break	Course Orientation	Lecture 1	Break	Lecture 2
3 May (Tue)	Lecture 3		Break	Lecture 4	Practicum 1	Break	continuation
4 May (Wed)	Lecture 3		Break	Lecture 5	Practicum 2	Break	Practicum 2 (cont'd.)
5 May (Thu)	Lecture 6		Break	Lecture 6 (cont'd)	Lecture 7	Break	Lecture 7 (cont'd.)
6 May (Fri)	Lecture 7		Break	Lecture 8	Lecture 8	Break	Lecture 8 (cont'd.)
7 May (Sat)	Lecture 10		Break	Lecture 11	Lecture 13	Break	Lecture 13 (cont'd.)
8 May (Sun)	Leave for Cebu						
9 May (Mon)	Field visit to Mactan, Cebu					Practicum 5	
10 May (Tue)	Leave for Bohol		Field visit to Bohol			Practicum 4	
11 May (Wed)	-do-						
12 May (Thu)	Field visit to Cebu/Mandaue						
						Lectures 12 and 9	
13 May (Fri)	Field visit to Cebu/Mandaue						
14 May (Sat)	-do-					Leave for Cebu for Manila	
15 May (Sun)	Field trip to Bolinao, Pangasinan						
16 May (Mon)	Practicum 6						
17 May (Tue)	and						
18 May (Wed)	Practicum 7						
19 May (Thu)	Back to Manila						
20 May (Fri)	Assessment/Evaluation of Training and Closing Ceremony						
21 May (Sat)	Depart for Home						

Annex 3
LIST OF TRAINING STAFF

Corrales, Rhodora, A., Ph.D. Assistant Professor, Marine Science Institute, College of Science, University of the Philippines, Diliman, Quezon City

Fortes, Miguel D., Ph.D. Associate Professor, Marine Science Institute, College of Science, University of the Philippines, Diliman, Quezon City

Gomez, Edgardo D., Ph.D. Professor and Director, Marine Science Institute, College of Science, University of the Philippines, Diliman, Quezon City

Modelo, Romeo, Ph.D. Associate Professor, College of Arts and Sciences, De La Salle University, Taft Avenue, Manila

Trono, Gavino C. Jr.,[1] Ph.D. Professor, Marine Science Institute, College of Science, University of the Philippines, Diliman, Quezon City

Ricohermoso, Maximo, President, Seaweed Industry Association of the Philippines, Mandaue City, Cebu

[1] Served as Training Director of the Course

Annex 4
REMARKS OF DR. EDGARDO D. GOMEZ
PROFESSOR AND DIRECTOR MARINE SCIENCE INSTITUTE, COLLEGE OF SCIENCE
UNIVERSITY OF THE PHILIPPINES
TRAINING COURSE ON SEAWEED FARMING
2–21 MAY 1988

Mr. Tengku Ubaidillah,
Mr. Justo R. Montemayor,
Mrs. Medina N. Delmendo,

Project Coordinator,
Fellow Guests and Participants:

We are gathered here this morning to open the Regional Training Course on Seaweed Farming. This occasion brings us together to recognize the fact that more and more people are aware of the importance of seaweeds and more and more agencies have been addressing this particular problem to maximize the spread of knowledge on seaweeds. We are now beyond the stage of collecting wild seaweeds and we are exerting efforts in facing and searching for new species that might be produced in this country and many countries are enjoined in this effort. In Asia seaweeds transplantation has the greatest potential and biotypes where seaweeds may be found are abundant. We are gathered here today to open this training course so that a number of participants from the ASEAN and non-ASEAN countries can learn the different methods of seaweed culture, exchange ideas, share problems and share time and effort to solve these problems so that later on in going back home to be able to train others on the culture of different types of seaweeds.

The Marine Science Institute is about to put all systems to this important exercise. I would like to be apologetic simply because we are not in the very fast stage of growth. At the moment we cannot offer you the best facilities. We are making available to you the facilities that we presently have to make your training worthwhile and you may see our laboratory which is not only devoted to marine seaweeds. We are at the present time constructing the headquarters and hope some of you will have the chance to work and see our laboratory. I understand you are going to our Marine Laboratory in Pangasinan.

We have been constructing the laboratory two years ago with a total expense of about ₱2 million. Now, the costs have been doubled and we have just known that the Secretary of Budget has approved our funding to complete our Complex consisting of the laboratory, administration building, dormitory and housing of our staff. When you go to Pangasinan, you will see what is happening there. There are many projects that we are undertaking. I hope you will have a chance to see the location.

Let me just pass on these two or three ideas that pertains to seaweed since you will be lectured in the class. I would like to say that in your effort to develop this marine resource in your respective country, let me point out that effort can only be obtained if there is a sincere dedication on the participant to obtain results to come up. Too often we make some effort to make the project see through. In our project there is that interest of the staff. I have noticed that this has been successful since the staff is willing to make some extra effort, some sacrifice. It is not just an eight to five o'clock hour work. It is difficult to work earlier than eight o'clock in the morning and finish beyond five o'clock in the afternoon and work on Saturdays. But perhaps if you want to see results, we could try to develop a work ethic that will meet the challenge. The second point is the present resource development in the environment. We will talk on this later in the day. In our effort to develop this resource, we forget the conservation of our environment. Too often we are trying to develop our production without due regard to environment. If we are to make our marine resources productive, we should take into consideration the impact of the various habitats of environment.

I would like to welcome all of you in this particular training and hope you will find this course very profitable when you go back to your respective country.

Annex 5
ADDRESS OF MR. TENGKU UBAIDILLAH
FAO REPRESENTATIVE MANILA
TRAINING COURSE ON SEAWEED FARMING
2–21 MAY 1988

Sponsored by the ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project
and
Seafarming Development and Demonstration Project

On behalf of FAO I would like to welcome you all to the Philippines. It is always a pleasure to me to receive and to join fellow workers in Fisheries, because I have spent almost 30 years of my life in the service of Fisheries. Although I have a broadened scope of work now, I am still serving fisheries as one of my areas of concern. Small-scale fishermen is still the target group we are directing our rural development efforts.

General Information

Seaweed farming has a fairly recent development in Asia except that of *Porphyra* known as Nori to the Japanese which was reported to have started in 1596 in Hiroshima Bay. The discovery that the pole and net devices installed to catch fish were fouled by this algae led to their use in culturing *Porphyra*. In China the farming of this species was initiated about 200 years ago (Trono, 1986).

In the Philippines the culture of *Eucheuma* started in 1970. Other countries in the region do have seaweed farming activities but these are mostly at the earlier stages of development.

FAO considers that the culture of seaweeds is one of the activities which has positive socio-economic impact on the coastal fishing communities. It is also compatible with coastal environment management which offers positive income-generation to small-scale fishing communities. Seaweeds are used for human consumption and industrial applications.

Of the world production of seaweeds for use in the manufacture of industrial phycocolloids, Asia produces 50 percent of those used for agar, 46 percent of those used for carrageenan and 40 percent of those used for alginates. These extracts come from red and brown algae.

In general, the brown seaweeds mainly grow in temperate waters while the red seaweeds in warm tropical waters. The latter group of seaweeds are used in the production of agar and carrageenan. The cultivation of these species is therefore, of great interest to the developing countries particularly in Southeast Asia.

Seaweed farming or "mariculture" became popular in 1970 when the culture of *Eucheuma* species was initially developed in the Philippines. *Eucheuma* is a source of carrageenan. This extract is mainly used as a stabilizing and gelatinizing agent in food, in toothpaste, cosmetic products and in solid air fresheners.

The international demand for carrageenan increased over the last two decades. Harvesting of the wild stocks, therefore, became intensive and the farming techniques developed for its production somehow minimized the depletion of natural stocks. The Philippines in 1972 produced only less than 20 tons of *Eucheuma*. However, the Philippines succeeded in increasing its total annual production of seaweeds to over 167 000 metric tons in 1985. The farming of seaweeds is replacing the traditional seaweed collection done in the past. It is placed as third marine product for export.

There are other species of seaweeds which are being cultivated such as *Gracilaria, Caulerpa, Porphyra, Undaria* and *Laminaria.* These species are mainly used for food. The techniques of farming will be given in this training course which the participants hopefully would assimilate in the next three weeks of training activities.

Other uses of seaweeds besides food and industrial applications are animal feeds and fertilizers. Brown seaweeds are used in the production of animal feeds as sources of iodine and other trace elements. They are also used as organic fertilizer and source of certain hormones.

The demand for brown seaweeds have been increasing due to their uses as source of animal feeds and fertilizers in the last 30 years. It developed in Ireland and Norway. However, the prohibitive cost of drying due to high cost of oil led to the drastic decline and collapse in the manufacture of these products. In the tropical region such as Southeast Asia where reasonable supplies of these brown algae (e.g., *Sargassum)* are found and climatic conditions for open air drying is feasible should exploit this resource and develop a similar industrial application on a commercial scale. Developing countries could perhaps revive the European market for these applications by supplying the market with dried seaweeds or establish processing facilities themselves.

The socio-economic benefits which the small-scale fishermen households derive from seaweed farming is one of the over-riding factors which justifies the organization of this training course. Government technicians and seafarmers alike are given the opportunity to obtain training so that they may serve as the instruments of development and expansion of seaweed farming in the region.

In the Philippines, a number of studies have shown that sizeable portions of coastal populations (coastal fishermen and their families) are gainfully employed full-time in seaweed farming particularly in the southern and central regions of the country. It provides the fishing households with cash income which enable them to narrow the gap between their needs and what is avail-able to them from time to time.

Status and potentials of seaweed farming development

Most countries in Asia have already started to develop their seaweed resources and they are in various stages of development.

In countries where seaweed cultivation has become an industry, efforts are concentrated in studies on how to reduce production costs, development of high quality products and regulation and management of the industry.

In countries where exploitation of seaweeds has just started, research and development thrusts are directed towards expansion of production areas and identification of seaweed sites or areas suitable for seaweed farming. On the other hand, in places where production depends on wild stocks collection and harvesting, development efforts are geared towards identification of new sea-weed grounds for exploitation and protection of stocks from overharvesting.

The role of FAO in seaweed farming development

Recognizing the socio-economic impact of seaweed farming on small-scale fisheries development, FAO through the financial support of the UNDP is promoting the exchange of technical information and sharing of practical experiences among developing countries through training. This training course is one of them. Through the auspices of the two Regional FAO/UNDP Projects, i.e., the ASEAN Regional Small-Scale Coastal Fisheries Development Project and the Regional Seafarming Development and Demonstration Project, this Training Course on Seaweed Farming is organized.

This course is designed to give you the essential technical knowledge about seaweeds and hands-on training on farming techniques, harvesting and processing.

On behalf of the FAO, I would like to thank the Government of the Philippines through the Bureau of Fisheries and Aquatic Resources and the Marine Science Institute of the University of the Philippines for hosting this training course. I am sure that the participants will acquire the knowledge they need and benefit greatly from this training course in the furtherance of seaweed farming in their respective countries.

I wish each one of you a pleasant stay in the Philippines and success in your endeavor.

Annex 6
POOLED RESULTS OF THE TRAINING

I.	UNDERLINE THE ANSWER THAT SUITS YOU BEST.					
	A.	Objectives				
		1. Were you aware of the objectives of this training course?				
			Fully			8
			Partially			10
			Not at all			-
	B.	Mechanics				
		1. How do you rate the time schedule?				
			Very satisfactory			1
			Satisfactory			6
			Fairly satisfactory			6
			Not satisfactory			5
		2. The training facilities?				
			Excellent			1
			Good			7
			Fair			7
			Poor			2
	C.	The training course activities?				
		1. Do you feel the activities of the training course were:				
			Interesting			2
			Stimulating			1
			Informative			12
			None of the above			1
	D.	Methodology				
		1. How would you rate the teaching methods used in this training course?				
				Very effective	Effective	Not effective
			Lectures	5	10	3
			Work assignment	1	11	3
			Field trips	5	7	6
			Case studies	1	7	4
II.	THE FIELD TRIPS					
	1.	Are you satisfied with the organizational arrangements for the field trips (such as transport, accommodations, etc.)?				
				Cebu	Bohol	Bolinao
			Completely	6	4	1
			Very	6	6	3
			Fairly	3	2	2
			Not very	3	4	7
			Not at all	-	2	4
	2.	What opportunity did you get to discuss professional issues with the personnel working at the site(s) of the field trip?				
				Cebu	Bohol	Bolinao
			A great deal	1	5	-
			Enough	9	8	6
			In-between	8	2	4
			Not enough	-	3	6
			None	-		1
	3.	How important was this field trip in relation to the whole training activity?				
				Cebu	Bohol	Bolinao
			Very important	5	10	4
			Fairly	10	4	4
			In-between	2	2	6
			Not very	1	1	4
			Not at all		1	-
	4.	How much did this field trip added to your professional knowledge?				
				Cebu	Bohol	Bolinao
			A great deal	4	9	2
			Quite a lot	8	4	5
			In-between	4	2	5
			Not much	1	2	5
			Nothing	-	-	
	5.	How great was the value of the field trip in helping you become better acquainted with your colleagues and the staff members?				
				Cebu	Bohol	Bolinao
			Very great	5	5	3
			Great	4	7	4
			Fair	5	3	6
			Little	3	3	3
			Not at all	1	-	1
	6.	Was the technical information received during the field trip satisfactory?				
				Cebu	Bohol	Bolinao
			Very	4	6	
			Fairly	8	7	9
			In-between	3		7
			Not very	4	3	3
			Not at all	-	-	
	7.	Did you get practical hints which will be of use to you in your own work?				
				Cebu	Bohol	Bolinao
			A great deal	3	3	1
			Many	2	6	
			Some	12	8	11
			A few	1	1	2
			None at all	-	-	

III	UNDERLINE THE ANSWER THAT SUITS YOU BEST.			
	1.	How do you rate the amount of time made available for this course?		
			Far too much	1
			Too much	3
			Just right	13
			Too little	1
			Far too little	-
	2.	How do you rate the instructional level of the lectures for this subject?		
			Far too high	3
			Too high	1
			just right	11
			Too low	1
			Far too low	2
	3.	How do you rate the balance between lectures and discussions/practicals?		
			Far too many lectures	1
			Too many lectures	1
			Just right	15
			Too many discussions/practicals	-
			Far too many discussions/practicals	-
	4.	How do you rate the quality of the presentation of the lectures for this subject?		
			Excellent	3
			Good	7
			In-between	4
			Poor	2
			Very poor	2
	5.	How do you rate the value of the discussions for deepening your understanding of this subject matter?		
			Essential	1
			Very useful	9
			In-between	7
			Not very useful	1
			Useless	-
	6.	How do you rate the importance of this subject matter for your own work?		
			Very high	2
			High	7
			In-between	8
			Low	1
			Very low	-
	7.	How do you rate the relevance of the background material to the subject matter treated?		
			Very high	-
			High	4
			In-between	13
			Low	1
			Very low	-

IV. QUESTION/ANSWERS						
1.	What is the quality of the meals?					
			Diliman	Cebu	Bohol	Bolinao
		Very good	3	4	4	1
		Good	5	6	8	4
		Passable	8	6	5	5
		Poor	1	2	1	5
		Very poor	-	-	-	3
2.	What is the quality of the accommodation?					
			Diliman	Cebu	Bohol	Bolinao
		Very good	1	6	-	-
		Good	12	7	4	2
		Passable	2	4	6	4
		Poor	-	-	6	6
		Very poor	1	1	2	6
3.	How suitable is the lecture hall?					
			Diliman			
		Very good	6			
		Moderately	10			
		Somewhat	2			
		Not very	-			
		Not at all	-			
4.	Describe the transportation facilities?					
			Diliman	Cebu	Bohol	Bolinao
		Very good	9	7	8	6
		Good	7	7	5	4
		Passable	2	4	3	4
		Poor	-	-	1	3
		Very poor	-	-	1	1
5.	Describe contacts with the staff members					
			Diliman	Cebu	Bohol	Bolinao
		Very good	3	5	7	1
		Good	11	7	5	6
		Passable	3	5	3	6
		Poor	-	1	2	3
		Very poor	1	-	-	1
6.	How much opportunity are you given for private study?					
		A great deal	2			
		Enough	9			
		Some	2			
		Little	2			
		Far too little	2			
7.	Describe the duration of the sessions					
				Lectures	Practicals	Field work
		Far too long		2	1	1
		Too long		5	4	6
		just right		10	6	7
		Too short		1	5	3
		Far too short		-	1	1
8.	Describe the size of the group					
		Far too large		-		
		Too large		-		
		Just right		18		
		Too small		-		
		Far too small		-		
9.	How much free time is there?					
			Diliman	Cebu	Bohol	Bolinao
		Far too much			5	2
		Too much	1	1	2	5
		Just right	9	11	7	6
		Too little	5	4	2	3
		Far too little	3	2	2	2

V.	QUESTIONS/ANSWERS. PLEASE UNDERLINE YOUR ANSWER.					
	A.	The group of participants				
		1.	The size of the group for the purpose of the activity was:			
			Far too big	1		
			Too big	2		
			Just right	14		
			Too small	1		
			Far too small	-		
		2.	The composition by professional qualifications was:			
			Far too mixed	1		
			Too mixed	1		
			Just right	15		
			Not mixed enough	1		
			Not nearly mixed enough	-		
		3.	The composition by nationalities represented was:			
			Far too mixed	-		
			Too mixed	2		
			Just right	14		
			Not mixed enough	2		
			Not nearly mixed enough	-		
	B.	Contacts				
		4.	Professional contacts with the lecturing staff were:			
			Very good	2		
			Good	9		
			In-between	6		
			Poor	1		
			Very poor	1		
		5.	Professional contacts with the other participants were:			
			Very good	3		
			Good	12		
			In-between	2		
			Poor	2		
			Very Poor	-		
	C.	The duration of the activity				
		6.	The duration in regard to the programme covered was:			
			Far too long	1		
			Too long	2		
			Just right	13		
			Too short	2		
			Far too short	-		
		7.	The duration in regard to your own requirements was:			
			Far too long	1		
			Too long	1		
			Just right	11		
			Too short	4		
			Far too short	1		
	D.	Lecture and practicals				
		8.	The balance of time given to lectures and time available for discussions/practicals was:			
			Very good	1		
			Good	8		
			In-between	6		
			Poor	3		
		9.	The presentation of the lecture was:			
			Very good	3		
			Good	8		
			In-between	3		
			Poor	2		
			Very poor	2		

	10.	The presentation of the practicals (including trips) was:				
			Diliman	Cebu	Bohol	Bolinao
		Very good	2	4	7	1
		Good	11	7	4	4
		In-between	2	4	3	6
		Poor	1	3	4	5
		Very poor	-	-	-	2
E,	Relevance					
11.	The relevance of the background material was:					
		Very high			-	
		High			4	
		In-between			15	
		Low			-	
		Very low			-	
12.	The relevance of the field trip(s) to the activity was:					
				Cebu	Bohol	Bolinao
		Very high		3	3	2
		High		6	4	3
		In-between		7	9	8
		Low		1	1	3
		Very low		1	1	2
13.	The overall relevance of the activity to your own work was:					
		Very high			2	
		High			4	
		In-between			11	
		Low			1	
		Very low			-	
F.	Organization and facilities					
14.	The quality of the meeting rooms was:					
			Diliman	Cebu	Bohol	Bolinao
		Very good	3	3	2	2
		Good	13	10	6	5
		In-between	2	3	5	5
		Poor	-	-	3	1
		Very poor	-	1	1	4
15.	The quality of the accommodation was:					
			Diliman	Cebu	Bohol	Bolinao
		Very good	4	7	2	1
		Good	10	9	9	4
		In-between	2	1	1	4
		Poor	-	-	4	4
		Very poor	-	1	2	5
16.	The quality of the laboratory facilities was					
			Diliman	Bolinao		
		Very good	8	4		
		Good	3	7		
		In-between	4	5		
		Poor	2	1		
		Very poor	-	1		
17.	The opportunity for private study was:					
			Diliman	Cebu	Bohol	Bolinao
		Ample	1	-	-	1
		Enough	8	10	10	9
		In-between	3	4	4	4
		Too little	1	1	1	1
		Far too little	2	1	1	1
G.	The activity as such					
18.	The theoretical level was:					
		Far too high	3			
		Too high	1			
		Just right	14			
		Too low	-			
		Far too low	-			
19.	The practical level was:					
		Far too complicated	-			
		Too complicated	-			
		Just right	16			
		Too simple	2			
		Far too simple	-			
20.	The amount of theoretical lecture was					
		Far top much		1		
		Too much		2		
		Just right		13		
		Too little		1		
		Far too little		1		
21.	The amount of practical work was:					
		Far too much		1		
		Too much		-		
		Just right		14		
		Too little		3		
		Far too little		-		
22.	The programming of the activity was:					
		Far too rigid		2		
		Too rigid		2		
		Just right		9		
		Too lax		3		
		Far too lax				

		Par 100 tax		-		

Annex 7
CLOSING REMARKS OF MR. JUSTO R. MONTEMAYOR
ASSISTANT DIRECTOR
BUREAU OF FISHERIES AND AQUATIC RESOURCES TRAINING COURSE ON SEAWEED FARMING

I would like to welcome you back to Manila. It is very evident that you have really gone out to work in the field as shown by your dark, tanned complexion. The saying that "black is beautiful" applies to each one of the participants on account of your sun brunt skin.

It is our sincere hope that each one of you not only gained theoretical knowledge about seaweeds, but most of all acquired the practical know-how on seaweed farming which is the main objective of the course.

I understand that you were able to see for yourselves the seaweed industry activities in Cebu, Bohol and Leyte. You were also given the opportunity to practice what a seaweed farmer does in seaweed fanning. While it is not possible to see and observe the whole cycle of farming seaweeds, it is hoped that the exposure you made in the seaweed farms had given you adequate knowledge and hands-on experience. These, hopefully, would enable you to apply what you have just learned during the last three weeks from our country to your respective countries.

We are indeed very happy to be part of this learning process. We, in the Philippines do not profess to know everything about seaweed farming but we just happened to develop this industry ahead of the ASEAN countries in Southeast Asia and the Pacific. Hence, hosting this training course is indeed an honor and privilege.

In the course of your training activities you might have encountered some difficulties, the Project Coordinator, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, the Bureau of Fisheries and Aquatic Resources, with the cooperation of the Marine Science Institute, tried their best to arrange the training programme as easy as possible. On the other hand, there are not adequate comfortable facilities in rural areas where seaweed farming could best be observed and practiced. We therefore, beg to apologize for the inconveniences you encountered which did not meet your expectations during the period of your training.

In closing, I would like to congratulate each one of you for successfully completing the training period and wish you all the best of luck and success in your seaweed farming development. Perhaps in the future we could meet again not to train, but to exchange experiences and information to know the progress each country made on seaweed farming and production.

Till then, good luck and good bye.

Annex 8
CLOSING STATEMENT OF DR. GAVINO C. TRONO, JR.
TRAINING COORDINATOR
TRAINING COURSE ON SEAWEED FARMING

Up to the first half of the 1980's the developmental efforts in aquaculture were mainly centered on finfishes, crustaceans and mollusks. It was only very recent when the seaweed resources were recognized as an area of high potentials for development. The recognition of the importance of seaweeds as a fishery resource and as an alternate source of livelihood for coastal populations in developing countries in Asia have been the driving force which made possible the holding of this training programme. This training course was designed to develop/promote qualified expertise in seaweed farming to help in food production, provide cash crops and open new alternative employment to enhance the socio-economic welfare of the coastal communities as well as offer practical training on seaweed farming and management of natural stocks of economically important seaweed species.

The training programme consisted of basic lectures and hands-on field training on the culture of *Eucheuma*, *Caulerpa* and *Gracilaria*, and the assessment and rationale utilization of natural stocks of economic species such as *Sargassum*. The services of experts were employed to deliver high quality information on the different subjects for the purpose of enhancing the learning capabilities of the participants. The physical facilities of Marine Science Institute were made available for the training to further improve the learning environment.

The programming of the training activities within a three-week period has out of necessity been quite hectic, but it was felt that such arrangements were reasonable in order to avoid wastage in time and funds.

The learning process in an exercise such as this training is significantly influenced by two major factors; by the capabilities of the training instructors to convey/communicate the information which are to be learned by the. participants, and the ability, interest and discipline of the participants to learn what are being taught to them. In a very heterogeneous group of this sort, the background on the subject matter and the ability to comprehend the medium of instruction are additional factors which further influenced the learning process. From the Training Director's perception most of the "small" problems encountered during the conduct of this training stemmed from these factors. The failure of several of the participants to observe discipline has also been identified as one contributory factor inimical to the learning process.

Notwithstanding these constraints, the training staff believes that the objectives of this course has been achieved based on the quality of the information being conveyed to the participants and the expertise and all-out effort rendered. The ultimate measure of the success of this training programme, however, will only be known a few years from now and such is mainly dependent on you, the participants. This is the challenge which the training staff and the sponsors are directing you. We strongly encourage you to answer this challenge. Your failure to come up to this challenge will mean a tremendous loss in our efforts, time, energy and funds on our part. It is now your ball game.

In order to help your meet this challenge please let us know of the additional assistance which you may require. On my part and I am sure also from the members of the training staff, it has been a pleasure and a rewarding experience to have at least been able to influence your thoughts and future activities towards the need to develop the seaweed resources in your countries.

Thank you.

Annex 9
THE IMPORTANCE OF SEAWEED RESOURCES AND THE NEED FOR SEAWEED TRAINING[1]

by

Dr. Herminio R. Rabanal[2]

[1] Talk delivered during the Closing Ceremonies of the Training Course on Seaweed Farming, sponsored by the ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project and the Seafarming Development and Demonstration Project held at the University of the Philippines Campus, Diliman Quezon City, Metro Manila, Philippines, 21 May 1988.

[2] Consultant (Aquaculture), 8 Basilan Road, Philamlife Homes, Quezon City, Metro Manila, Philippines.

I understand that today you have just successfully completed your training on the culture and rational utilization of seaweeds. I greet you and commend you for completing this very valuable training course. Eight years ago in April 1981, the FAO/UNDP-South China Sea Fisheries Development and Coordinating Programme, a predecessor of the ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, one of your sponsors, initiated a training course on *Gracilaria* algae patterned along the same lines as your course and practically using the same expertise and more, in this course.

I can see from your course outline that you covered more species of the economic seaweeds than the first course. You also have wider area and much more diversified practical activities. It is to the credit of the organizers of your course and the wise counsel of your instructors that this has happened.

The seaweeds as I am sure you have now realized are very interesting groups of living plants. They have great variety in size from very microscopic to giant plants of the oceans. They live in a great variety of environments from slightly freshwater as in the *Gracilaria* to strictly marine forms like the *Sargassum*. They may also occupy very shallow areas and may tolerate intermittent drying-up while others occupy the sea bottom down to medium depths which can be reached by sunlight. Some require very clear water while others can tolerate slightly turbid waters. There are those that can grow in stagnant areas but most of them would require some amount of current in their natural environment. As they inhabit very varied environments, one of the most interesting characteristics of the seaweeds is their ability to synthesize varied substances that are peculiar, interesting, some useful while others can be powerful poisons to other organisms.

It is the last named characteristic — the attribute to form unique substances, that has made many species of seaweeds useful and of high economic value today. I must, however, remind you that this training can be considered only as a scratch on the surface with regards to the culture and utilization of economic seaweeds. I am sure that your instructors have emphasized to you that there is a lot more to know about seaweeds. There are many more species of seaweeds for which we have no knowledge of while there are only few that we know a little of such as the ones you dealt with this course. Very little is still known of the many more useful substances from many other kinds of seaweeds that have not yet been discovered or we know very little of.

It is with this realization that there are many seaweeds we do not know yet and there are many more useful substances from seaweeds still undiscovered, that underscores the usefulness and need for the course that you have just completed. It is also for this reason that your sponsors have required your respected institutions in your respective countries some knowledge about yourselves and that you have some involvement or will have such involvement of seaweed work in your respective countries. It must be borne in mind that if this training is to be of some use at all, some of you should come out in your respective countries in the not too distant future to provide some form of leadership to initiate, if you have not yet initiated, or to expand, if you have already started, the seaweed work in your respective institutions. I trust that you will make full use of the knowledge that you have just acquired.

In this connection, I would like to inform you that in the course of my aquaculture work in the global scope but more especially in the Asian region, I am very pleased and I enjoyed my visits and exchanges of information with fisheries people in your respective countries. In the People's Republic of China where I had the opportunity to visit the coastal areas to help formulate a coastal aquaculture project, I saw the vast coastal and marine resources in that country. It is of interest to mention at this point that the Chinese art of seaweed processing dates from prehistoric times. In India where I had occasion to visit some years back particularly the tropical southern portion of the country, relatively advanced research and development work on seaweeds have been going on for sometime. In Indonesia, the archipelagic nature of that country favors a great variety and quantity of marine resources including that of the seaweeds. Seaweed work composes a part of an ongoing foreign-assisted seafarming project for that country. It has been sometime since I had the opportunity to visit the Republic of Korea, but at the time of my visit that country has achieved very advanced techniques in the culture of the economic seaweeds present along its coasts. Malaysia is one other country which has big potentials for the utilization of natural seaweed stocks and for the culture of many economic species. In fact multilateral technical assistance projects on seaweed culture have already been initiated in that country. With regards to the Philippines, initially, natural stocks of economic seaweeds were overexploited so that today this country has to depend on culture to produce the seaweeds that it exports. Unfortunately, it seems that this country is overconcentrating in the culture of only limited group of economic seaweeds and has not diversified in this activity. Thailand likewise has many natural seaweed areas and has high potential for the culture of many economic species. That country in fact hosts the FAO/UNDP Regional Seafarming Development and Demonstration Project, your other co-sponsor for this training. In addition, we could have also expected participants from the Pacific islands countries where seaweed utilization and farming also has very high potentials.

Of course, it should also be realized that mutual exchange of knowledge and information in this field can be very useful. The many friendships and acquaintances that you have formed in this training should be kept and constantly refreshed in the years to come. Whether you realized it or not, I am sure that you have also contributed some knowledge, no matter how little, when you described to your co-participants and to your instructors your own work and experiences before you came here. It is therefore, hoped that you will maintain your contacts and benefit from the exchange as you progress in your future work.

In closing, I would like to express the hope that you have gained something useful during your participation in this course. I hope that you did not work yourself out, but you have also some occasion to see many beautiful sights in this country. If you have not, however, you better stay for some more days, or arrange to come back sometime. I hope you enjoyed your stay in the Philippines and best wishes and good luck to you in your future endeavors.

Annex 10
IMPRESSIONS OF THE PARTICIPANTS OF THE TRAINING COURSE ON SEAWEED FARMING
2–21 MAY 1988

by

Dr. V.K.S. Chennubhotla
(Participant from India)

On behalf of all the participants of the above programme, I wish to state that the training programme was informative and interesting to us. After an initial orientation course on general aspects of seaweeds, the team left for Cebu.

With the kind courtesy of the President of Marine Colloids Philippines Incorporated, the team have stayed in the farm house located at Bohol. This has given all the participants an excellent opportunity to see the actual farming of *Eucheuma*, harvesting and processing the same for extraction of the phycocolloid, the carrageenan.

Other features of interest of the programme were the *Caulerpa* farming in ponds in Mactan Island, Lapu-Lapu City and the demonstration of the *Gracilaria* farming technique that is followed in Chile.

The participants are of the opinion that these economic species can be hopefully transplanted in their countries in suitable areas. Some of the participants are of the view that the training programme can be further improved by the faculty staff in developing more rapport with the participants by treating them as colleagues and not as students. The field programme arranged by the Project Coordinator in Cebu was excellent. It really gave the participants the practical exposure to seaweed farming and processing. The President of the Seaweed Farming Association of the Philippines was very accommodating and the hospitality he gave to the participants was very warm indeed.

All the participants wish to place on record the excellent care taken by Mrs. Medina N. Delmendo, Project Coordinator, RAS/84/016, on the participants and in conducting the course smoothly.

I take this opportunity to thank FAO/UNDP/BFAR/DAF/MSI/NACA for arranging this training programme and for successfully conducting the same.

Thank you.

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