Seaweed farming in the Philippines

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ABSTRACT

The culture methods of the most economically important seaweeds in the Philippines farmed on a commercial basis such as *Eucheuma, Gracilaria* and *Caulerpa* are discussed. Culture methods for each species differ depending on the biology and ecophysiological requirements. Problems associated with seaweed farming include natural causes such as typhoons, aging effect or senescence, diseases and grazing.

Seaweed farming has greatly contributed to the socio-economic profile of the farmers and to the protection of the environment although long term changes in natural communities related to the introduction of pure algal stand are expected. More research on cultivars which are disease-resistant and have broader tolerance to environmental conditions in addition to new technology on seed stock production for mariculture in the Philippines are needed.

Keywords: *Eucheuma, Gracilaria, Caulerpa, polyculture, ecophysiological requirements*

INTRODUCTION

The use of seaweeds for human consumption, as sources of potash and iodine, and as fodder or manure was recorded as early as 3,000 B.C. (Doty, 1979a; Jensen, 1979; Chapman and Chapman, 1980). With the discovery of phycocolloids, seaweeds attained significance for their use in the brewery, chemical, pharmaceutical, textile and cosmetics industries (Mathieson, 1975; Hansen et al., 1981; McHugh, 1984). Recent trends in science and industry show potentials and new applications particularly for pharmaceuticals and biochemicals, bioenergy production or waste water treatment (Chapman and Chapman, 1980; Fralick et al., 1981; Hanisak, 1981; Lobban and Wynne, 1981).

These developments together with the traditional uses have accelerated the harvesting of algae from the wild. Massive harvesting has led to overexploitation and depletion of natural stocks as for example in Chile in the case of *Gracilaria* (Santelices and Lopehandia, 1981; Santelices and Ugarte, 1987), *Porphyra* in China

(Tseng, 1981a, b) and *Eucheuma* in the Philippines (Doty, 1979a).

Although the bulk of commercially utilized seaweeds is still collected from the wild stock, the yield, is still insufficient and unreliable to cope up with the growing demand for agar and carageenan in the world market. In many instances, the seasonal availability of algae has affected the market price. To solve these problems, cultivation of seaweeds has been thought of.

Since the early seventies, successful attempts in temperate and tropical areas were made to cultivate seaweeds in the sea, tanks and ponds (Doty, 1973; Shang, 1976; Ryther et al., 1979; Friedlander and Zelikovitch, 1984). From the early times up to the present, Asia remains to be the leader in mariculture. Japan and China were successful in the production of *Porphyra* (Okazaki, 1971 in Doty, 1979a) in 1736 and the Chinese in cultivation of *Gracilaria* (Shang, 1976). Seaweed farming in those countries actually started in the late fifties (Tseng, 1981a). The Philippines came into the maricultural scene with the successful cultivation of *Eucheuma* in the early seventies. From then on up to the present, much development in phycoculture in the Philippines has occurred. This paper reviews the development and status of seaweed farming in the country.

ECONOMIC USES OF ALGAE AND CULTIVATED SPECIES

Several algal species in the country are utilized in various ways either for human consumption, as organic or liquid fertilizer, medicine, raw material for the manufacture of commercial products and most important as sources of carrageenan, agar, and alginates (Trono and Ganzon-Fortes, 1988; Cordero, 1989; Veloso, 1990). Of the 350 economically important species listed by Trono and Ganzon-Fortes (1988), 60% are red algae followed by the brown algae (25%) and the green algae (15%). Only 10% of the natural and farmed products of seaweeds is utilized as food (Llana, 1990).

Despite the big number of economically important species, only a few species are commercially farmed in the Philippines. They are *Eucheuma denticulatum* (Burman) Collins and Harvey (= *E. spinosum*, source of iota carragegenan), *E. alvarezii* (= *Kappaphycus alvarezii*, cottonii of commerce and source of kappa carageenan) and *Caulerpa lentillifera*. Several strains of *Eucheuma* represented by the green and brown varieties are grown in seaweed farms (Trono and Ohno, 1989).

Other seaweeds have great potential for mariculture e.g. *Gracilaria* sp. and *Gelidiella acerosa* for their agar content (McLachlan and Bird, 1986; Santos and Doty, 1983), *Sargassum* for its alginate content and use as fertilizer and feed (Llana, 1990; Ricohermoso, 1990) and *Porphyra*.

MARICULTURE OF EUCHEUMA, GRACILARIA AND CAULERPA

Eucheuma Culture

History

Much had been written on the history and development of *Eucheuma* farming although techniques had been introduced around 25 years ago (Parker, 1974; Doty and Alvarez, 1975; Doty, 1978; 1979a; Lim and Porse, 1981; Lim, 1982; Trono and Ganzon-Fortes, 1988; Veloso, 1990). The proper technology of *Eucheuma* cultivation came only after a long, slow process of trial and error since the biology of *Eucheuma* was then unknown. Several experimentations based on technology in other seaweeds done by various private and government institutions with vested interests on seaweeds and seaweed products were performed in selected sites throughout the country in the early sixties. Trial experimentations on the proper cultivation techniques of attached *Eucheuma* using lines such as the use of the net, raft and monoline methods or of unattached thalli as in pen planting were done (Doty, 1978). Studies on the suitability of planting techniques such as the depth of the attaching net or lines from the sea bottom, planting distances between cut thallus, seedling weights and tying materials were also made. Researches on artificial fertilization using different fertilizer types, durations of fertilization and methods were performed to a lesser extent. Strain selection of *Eucheuma* for seedstock and type of cultivation techniques suitable in the selected sites were also started (Lim, 1982).

Commercial production of *Eucheuma spinosum* was started in the Southern Philippines (Sulu and Jolo) in the early seventies (Doty, 1979a; Lim and Porse, 1981). Due to many problems associated with seaweed farming such as the lack of knowledge on the requirements of algae, seasonality of produciton, and political unstability of the area, new production sites e.g. in Danajon Reef, Bohol were developed (Lim and Porse, 1981; Doty, 1983). At present, several farms have been established in the Danajon Reef area and other parts of the country, e.g. Palawan and Mindoro and more areas have been identified as having potential for seaweed farming (Malig, 1990).

Farming and Culture Method

Preparation of an algal farm(*Eucheuma* or any other species) involves several activities, namely: 1) selection of sites; 2) preparation of materials; 3) clearing of the planting area; 4) staking; 5) installation of monolines or nets; 6) preparation of seedlings; and 7) planting.

Areas where wild *Eucheuma* are naturally found or where the environmental factors are favorable to its growth are considered as primarily suitable for *Eucheuma* farming (Table 1). In

Table 1. Environmental factors suitable for *Eucheuma* culture.

Factors	Range/characteristics
Substrate	corals, coarse sand, rocky
Salinity	30-34 ppt
water movement	
current velocity	20-40- m/min
water depth at low tide	45-90 cm
at high tide	210 cm
clarity of water	clear
light intensity	moderate to high
nutrients	moderate to high

many cases, pilot studies are necessary to determine the suitability of the area.

The materials needed for planting are purchased and prepared in advance with the cost varying with the culture method preferred (net, raft or the monoline method) and the farm size. A small farm uses less initial capital for starting the farm than medium or large farms. Table 2 shows an approximate list of materials needed.

Table 2. Approximate list of materials needed for one-ha seaweed farm (taken from Veloso, 1990).

Quantity		Description
1,100	pcs	mangrove stakes, 5 cm. dia. 75 cm. long
30	kg	nylon monofilament #200
10	rolls	plastic straw
4	pcs	iron bars
4	pcs	bull hammers
1	unit	seedling container
1	unit	motorized banca
7.5	tons	fresh seedlings

The site selected for planting must be initially cleared of other seaweeds, seagrass and animals such as sea urchins and starfishes to ensure pure *Eucheuma* stand (monoculture) and the absence of grazers which may affect the productivity of the farmed seaweed.

Planting *Eucheuma* can either be submerged (bottom) or the off-bottom (floating) and different methods (broadcasting, rock-and-anchor, wood or bamboo anchor, net, cage or monoline) can be used (Doty, 1979b; Lim, 1982; Veloso, 1990). Three culture methods (net, raft and monoline) have been tried for *Eucheuma*, but the latter is highly recommended and often used by farmers since it is the cheapest and easiest method (Trono and Ganzon-Fortes, 1988; Shemberg Marketing, Dept. of Agriculture, Doty, 1979a).

If seaweed farming is introduced at the beginning stage, the net method is recommended since it gives the most intensive production (Deveau and Castle, 1976; Doty, 1979a). However, it is labor intensive and had long been abandoned in the Philippines. In this method 2.5 x 5 m nets with a diagonal meshwork of 25 cm bar length or 127 intersections of net materials are laid horizontally parallel to the water. The net margins are 110-130 and the meshwork of 80-100 lb-test monofilament nylon or of polypropylene lines. The latter material is usually recommended because it is stronger than the former. The nets are supported by 6-8 cm stakes made of mangrove driven into 30-60 cm deep sediment. There are usually 800 net units/ha (Doty, 1979a).

Rafts made of bamboo poles and mangrove stakes with single nylon lines measuring 1.8 x 2.7 m or 1.9 x 2.5 m accomodating about 84 plants were initially tried in the raft method. Later, the single layered raft was improved to the double layered raft consisting of 6 bamboos, 2 mangrove stakes and a single nylon line and this was then considered ideal (Lim, 1982). The monolines are attached to the bamboo poles from end to end and the whole system is connected to wooden stakes which are driven deep into the substratum. Additional buoys are sometimes used to allow support for floating. There are usually 40 rafts per hectare. This method is best for areas with weak water movement. Plants grown in rafts were observed to be hardly grazed, have dependable production rates, and high daily growth rates (DGR) (Lim, 1982) probably due to the influence of water movements which kept the algae floating. However, seaweeds mature early apparently due to higher metabolism and utilization of tissue nutrients for growth coupled with slow nutrient replenishment from the surrounding waters. In addition, the raft occupies much space, restricts movement in the farm, and the anchor lines are frequently entangled. The method is labor intensive for maintenance hence not highly recommended.

In the monoline method, the bamboo or wooden stakes driven into the substrate ca. 0.6 m deep are spaced 10 meters apart and the rows are one m apart. Nylon filament is stretched between the stakes about 0.3-0.5 m above the bottom. The monolines are placed parallel, diagonal or perpendicular to the direction of the current depending on the current velocity (Lim, 1982; Veloso, 1990; Trono, 1988). In areas with relatively strong current, 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.

A modification of the fixed monoline or bottom monoline used in areas of deep waters utilizes bamboo poles with monolines which are attached to posts spaced 3-5 m apart and 30-50 m between the monoline. The raft system maybe 30-50 m long. This modification is otherwise known as floating monoline method.

A *Eucheuma* farm using the monoline method consist of units or modules made of 38 monolines. Each monoline is planted with 35-36 plants while one module contains approximately 1000 plants thus, a hectare has 35,000 to 36,000 plants.

Eucheuma cuttings or seedlings are secured usually from the Sulu seas or other places such as Palawan, Bohol, Leyte and Zamboanga. Extra care is taken to select good quality and healthy-looking thalli shown by strong firm branches and bright colors. Transport of cuttings from the source to the planting site is necessary to prevent algal stress due to temperature gradient and dessication.

The cuttings are tied to the monolines at 25-30 cm apart using soft plastic straw. The seedlings are allowed to grow and are harvested after 2-4 months when the weights have reached one kilogram.

Seaweeds are either fully harvested by removing the whole monoline (Veloso, 1990; Trono and Ganzon-Fortes, 1988) or by alternating pruning and full harvesting (Lim, 1982) which is also done in Indonesia (Adnan and Porse, 1987). Full harvesting is resorted to when the twines have deteriorated. During the initial *Eucheuma* farming, selective harvesting of seaweeds (mature parts are removed while leaving young alga) must be done. This should be the practice until a self-producing farm is established (Doty, 1979a).

In the Philippines, either from the algal farm or in the wild, harvesting of seaweeds is done manually using knife or sickle. It is devoid of any form of mechanization since labor is cheap. In other countries like Europe, mechanical trawls, cutters and rakes are used (Briand, 1991).

In algal farms flat-bottomed wooden bancas are used to harvest and transport seaweeds to the drying station or farm house. Plants removed from the line or still attached are spread out on drying mats and bamboo platforms. In the absence of a drying platform, drying is done on cemented floors or on sandy beaches lined with coconut leaves. Sun drying to about 30-35% moisture content usually takes about 2-5 days depending on the amount of irradiation.

Dried seaweeds are packed in jute sacks and plastic bags and are stored for further transport and processing.

Gracilaria Culture

Gracilaria species are found worldwide at the intertidal and shallow-subtidal areas, in various habitats such as sandy and muddy sediments and in marine and brackish waters. The algae are unattached or attached to soft and hard substrate such as pebbles, rocks, corals and shell fragments (Trono and Azanza-Corrales, 1981; Trono and Ganzon-Fortes, 1988). They occur in waters of various salinities and temperature. Laboratory studies have shown their eurythermal and euryhaline characteristics (Hoyle, 1978, Bird and McLachlan, 1986) although it is generally a warm-water genus.

In the Philippines, several species of *Gracilaria* are observed and *G. coronopifolia* is the most common followed by *G. salicornia* and *G. verrucosa* (Trono et al., 1983; Orosco and Yamamoto, 1989; Largo et al, 1991).

Members of this genus are highly tolerant of rich nutrient regimes and are capable of luxury uptake of nutrients are thus suggested as sources of biomass for wastewater treatment and methane production (Hanisak, 1981; DeBusk and Ryther, 1984). They are among the most productive seaweed species as exemplified by unattached *Gracilaria tikvahiae* in intensive culture under rich nutrient conditions and constant agitation giving 44 g dry wt $m^{-2}d^{-1}$ (Lapointe and Ryther, 1979).

The above-mentioned characteristics of the species make them suitable for artificial culture in various environments especially in the Philippines where these are abundant.

The present supply of *Gracilaria* species in the country solely depends on wild stocks, its production is nonsustaining for commercial purposes. Despite its potential for mariculture, farming techniques for this genus in the country are still in the preliminary stages (Trono, 1981; Largo et al., 1989; Hurtado-Ponce, 1990; Largo et al., 1991). In the absence of a developed technology in the Philippines, cultivation techniques from other countries are described below.

Culture Methods

Mariculture of *Gracilaria* is presently done in ponds, tanks, raceways and flow-through systems in Taiwan and Florida (Shang, 1976; Lapointe and Ryther, 1978; Chiang, 1981; Edding et al., 1987; Hanisak, 1987) and in open waters such as in Malaysia and Chile (Santelices, and Doty, 1989).

Open ocean cultivation: Cultivation and development of techniques for open waters are similar to those performed for *Eucheuma*, namely: rope, net or raft methods. These involve the attachment of the algae to lines which are suspended either in the surface, subsurface waters or near the bottom. In contrast, bottom planting without using lines is done. In all these methods, vegetative (fragmentation) and spore propagation are utilized, with the former is more common.

In the line method using rope or nets, thalli are entwined or inserted between coir rope or filaments at some interval and the lines are stretched between stakes driven into the bottom (Raju and Thomas, 1971). In some method the thalli are tied into the lines or nets which are attached to stakes (Smith et al., 1984) or floated in low rafts as is used in China (Tseng, 1981a; Ren et al., 1984). Since the net method requires intensive labor this has been replaced by economically feasible methods.

Bottom planting is done by sticking cuttings or thallus into the sandy or muddy bottom by a forked planting tool (Santelices and Doty, 1989) or held by sand-filled polyethylene tubings (Pizarro and Barrales, 1986). By the time the tubings have disintegrated underground, thallus have already formed. This method is successfully used in Chile (Santelices and Doty, 1989).

Propagation using spores is developed in other countries, i.e. Malaysia and Hawaii (Santelices, and Doty, 1989). This requires nursery units made of various materials provided with suitable substratum ready for spore shedding and are covered with nets. Fertile thalli are laid on the nets; kept under water and allowed to shed spores. After 1-3 days, the substrate with attached spores are ready for outplanting in the field. The chance for spore survival greatly depends on the planting site thus, prelimnary field studies on the area is a prerequisite.

Pond cultivation: Pond cultivation of *Gracilaria* in commercial scale is well developed in Hainan, Taiwan, and Hawaii. The procedure is similar to the pond culture of *Caulerpa* which includes the drying of the pond for several days, introduction of water, and seeding by broadcasting (Chiang, 1981).

Ponds are usually small (< 1 ha) for easy management and located in areas where freshwater and seawater are available. Ponds are 50-80 cm deep with either sandy, loamy sand or silt bottoms.

In the ponds, the physico-chemical parameters favorable to growth of the species are: water salinity of 8-25 x 10^3, temperature of 20-30 °C, pH of 6-9 but preferably 8.2-8.7 and water depth of 30-40 cm. No specific data on the nutrient situation in the culture ponds is available. However, high nutrient concentrations is probably necessary for high growth rates of pond cultivated species because artificial fertilization using pig or chicken manure made the polyculture system of cultivation together with milkfish successful (Shang, 1976; Chiang, 1981; Santelices and Doty, 1989).

Harvesting of the algae from both attached and unattached cultivation techniques is done by pruning using bare hands or scoop nets or rake.

Studies in the Philippines: Preliminary studies on open sea cultivation of *Gracilaria* species in the Philippines showed feasibility and potential of using methods similar to that of *Eucheuma* culture, that is, utilizing bamboo raft, net, monoline (vertical and horizontal), cage and open basket (Largo et al., 1989; Hurtado-Ponce, 1990; Largo et al., 1991). Growth rates of algae cultured using different methods were varied depending on the species and depth of planting. However, the raft and monoline techniques already gave good results. Raft planted thalli of *G. salicornia* and *G. coronopifolia* exhibted better growth rates than those planted by the bottom-monoline method.

The addition of artificial hard substratum using adobe and hollow cement blocks for cultivation of *Gracilaria* as done by the Bureau of Fisheries and Aquatic Resources showed potential as culture technique for natural spore recruitment (Trono and Ganzon-Fortes, 1988).

Monoculture pond cultivation of *Gracilaria* species in netted cage gave lower mean daily growth rates (1.44-4.29%) than the open water cultivation, (4.95-10.02%), depending on the species (Largo et al., 1989). Such differences in growth rates can be attributed to different hydrographic features of the areas such as prolonged insulation of the relatively stagnant waters and higher temperature in the pond.

Caulerpa Culture

History

The potential of *Caulerpa lentillifera* commonly known as "lato" in Visayan for pond culture was discovered by chance by the family of Mr. Juancho Berame in the early fifties in Barangay Kalawisan, Mactan Island, Visayas (TECHNOPACK-CV-CIRRD, 1991). At present a hundred fishpond operators in the area and its surrounding places, culture *Caulerpa* species or "lato" in ponds and have supplied the needs of the country and for exports. Despite the success of *Caulerpa* farming in the Visayas, this has not been duplicated in other areas of the country although pilot studies are ongoing.

Pond Culture

Caulerpa prefers basic soil which is soft, loamy and muddy, and waters with a narrow range of salinity (30-35 x 10^3) since it is a stenohaline species (Trono and Ganzon-Fortes, 1988). The plant grows best at water temperature range of 25-30 °C. Unlike *Eucheuma* and most macroalgae which require considerable water movement for growth, *Caulerpa* thrives best in relatively stagnant waters. In the pond, considerable changes in the physico-chemical factors such as light, salinity, temperature and pH are observed but these are within the tolerance limit of *Caulerpa* (Horstmann, 1983). Among the environmental factors affecting the productivity of the algae, nutrient situation in the pond and the nutrient requirements of the algae have not been thoroughly studied. The plant apparently does not require very high nutrient concentration which may promote growth of undesirable algal species and epiphytes and reduce the productivity of the farmed species.

The suitability of the culture sites and pond designs are based on the above mentioned knowledge on the general growth requirements of *Caulerpa*.

"Lato" is grown in ponds either in monoculture or polyculture together with milkfish production. The ponds for monoculture are prepared similar to milkfish ponds but without rearing ponds. Each pond, is so constructed for easy access to clean seawater and are provided with dikes and gates to regulate water level in the ponds.

For easy planting, the algal pond is drained of water to a depth of 0.3 m. The algal cuttings, selected from healthy individuals or from the wild stocks, are either thrown into the pond (broadcasting method) or the stolons pressed into the substratum (sowing method) at regular distances and intervals. Broadcasting is less laborious than the latter, but it results in uneven distribution of the seaweed.

After planting, the ponds are filled with water not less than 0.6 m and are maintained with 1.0-1.5 m of water (TECHNOPACK-CV-CIRRD, 1991). After 45 days the plants become ready for harvest by hand and selective pruning. Some plants are retained in the pond to serve as seedlings for succeeding planting in bare areas in the pond.

Besides the pond cultivation of *Caulerpa* in pure stands, polyculture with milkfish similar to the brackish pond polyculture cultivation of *Gracilaria* was tried by pond operators in the Visayas with success. It has been observed that ponds are converted from polyculture to monoculture of either *Caulerpa* or milkfish depending on the seasonal production of the farmed species.

Open Sea Cultivation

Cultivation of *Caulerpa* species in open waters was reported in Siquijor Island (TECHNOPACK-CV-CIRRD, 1991), but the technology has to be thoroughly studied yet.

Post-harvest procedures of *Caulerpa* include packing of the harvested seaweeds in wicker baskets lined with jute sacks, leaves and interspersed with other seaweeds for further transport. The algae for export is salted at 1:5 ratio.

The above discussion clearly shows the cultivation of unattached *Caulerpa* in ponds is less labor intensive and is therefore more manageable than open water cultivation of attached *Eucheuma* or *Gracilaria*. Despite these advantages, the technological advancement of *Caulerpa* farming remains to be tapped for use throughout the country.

PROBLEMS ASSOCIATED WITH SEAWEED FARMING

Seaweed farmers are faced with problems basically similar to those experienced by land farmers. These problems are loss or reduction of crops due to typhoons and other phenomena associated with physiological and biological factors such as senescence/aging effect and ice-ice (Doty, 1971; Doty and Alvarez 1975; Trono and Ganzon-Fortes, 1988).

Typhoons are unpredictable and uncontrollable thus the only way for seaweeds mariculture to be successful is to select areas which are not exposed to typhoon path. Otherwise, collection or harvesting of the remaining seaweeds after a storm will always be resorted to. Another alternative is seasonal planting and harvest of the macrophyte as is presently used by some seaweed farmers.

Aging effect or senescence is characterized by general thinning and weakening of the distal portions of branches, and pale discoloration of the plants. This may be associated either with a decrease in the nitrogen content or in the ratio between carbon-nitrogen content of the tissue (Doty, 1971), or algal metabolism have simply overutilized the tissue capacity for growth. This leads to slowing down of growth in the affected algae. This usually occurs during periods of very high light intensity (Doty, 1971) to which *Eucheuma* is said to be sensitive. Senescence has not only been observed in *Eucheuma* but also in other macrophytes such as *Gracilaria* and *Sargassum* (Santelices and Doty, 1989; Ang, 1985). So far, no control has been suggested against aging which is a natural physiological process.

On the other hand, ice-ice phenomena is characterized by discoloration of branches, dissolution of affected parts, and later the removal of soft parts. Occurrence of the ice-ice in the seaweed farms is observed during the months of

November up to January and March to May (Lim, 1982). Ice-ice was previously reported to be caused by bacteria (Lim, 1982), but this has not been thoroughly studied. On the contrary, ice-ice is said not to be a disease but rather a stress reaction to environmental factors (Santelices and Doty, 1989). Ice-ice appears during periods of low light, low water motion and low water nutrients e.g. phosphates (Uyenco et al., 1981; Santelices and Doty, 1989). Low water motion apparently influences the availability of nutrients or micronutrients to the farmed algae. Nutrient deficiency leads to symptoms of stress and diseases similar to higher plants. In addition this phenomenon occurs during periods preceding or coinciding with algal blooms (Trono and Ganzon-Fortes, 1988). The presence of microscopic algae apparently leads to competition with the macrophyte for the available low nutrient concentration in the seawater.

The problem of competition for available nutrients and space does not only come from microorganisms but also from other algal species epiphytic to the farmed seaweeds such as *Enteromorpha* and *Chaetomorpha*.

Another problem of seaweed farmers is the grazing of farmed seaweed by siganids (rabbit fishes), starfishes and sea urchins. Prevention of grazing involves periodic removal of grazers in the area.

PHYSICO-CHEMICAL FACTORS NECESSARY FOR SEAWEED CULTURE

For successful mass cultivation of seaweeds, the biology and the ecophysiological requirements of the crop plants in relation to the physical and chemical environment must be known.

Changes in light and temperature with seasons as occurring in temperate waters are less significant in the tropics where the factors vary little (Doty, 1971). Conditions, however, may be harsh on the surface water especially during noontime and summer months which may lead to photoinhibition and bleaching. Any factor that negatively influences the process of photosynthesis and the rate of reaction affects the primary production of seaweeds as shown by low biomass and low growth of seaweeds. However, tropical seaweeds generally tolerate high temperature and light intensity but they may be under physiological stress.

Illumination reaching bottom planted seaweeds may be reduced due to turbidity caused by silt, discharges and agitation of the bottom sediment. This may lead to low productivity of the farmed seaweeds. Therefore, the presence of clear water and the type of substratum in the chosen site is important in open ocean farming except pond farmed species such as *Caulerpa*. Illumination of algal undergrowth may be affected by shading from upper level thalli as observed in farmed species of *Eucheuma*, *Gracilaria*, and *Caulerpa*. In a vertical rope culture of *Gracilaria*, inner growing thalli were darker than those found on the surface (Hurtado-Ponce, 1990). Regular pruning in both attached and unattached cultivation prevents shading of algae in the understorey.

Water movement acts chiefly on diffusion of nutrients between the water and algae thus steepening the gradient directly surrounding the thallus, and facilitates nutrient uptake. In many cases, considerable water movement removes epiphytes attached but also cast away the poorly attached algae if too strong. For some species which survive in floating form, strong water movement may be advantageous form of dispersal under natural environment but this is a disadvantage for farmed species. Excessive water movements may also cause dislocation and tearing of thalli affecting in turn the shape and form of the algae. Thus, the cultivation technique for a specific seaweed must be designed to allow enough water motion in order to facilitate nutrient diffusion and cleanse the algae from sediment particles.

Besides the physico-chemical factors mentioned above, nutrients in particular play an important role in mass production of seaweeds (Ryther and Dunstan, 1971; DeBoer, 1979, 1981; Tseng, 1981; Lapointe, 1981; Gerard, 1982b). This particularly applies to tropical marine environments where nutrient levels in offshore waters are usually extremely low (DeBoer, 1981; Dawes, 1987). In shallow inshore waters, nutrients may be higher but still lower than those in temperate waters (Dy, 1984; Rosales-Apao, 1991).

Intensive artificial fertilization of algae in seaweed farm to supplement low existing nutrient at the farm sites had been done in China for Laminaria farm (Tseng, 1981). It helped seaweed production and had been successful. Fertilization by spraying with liquid fertilizers on pellets, diffusion from clay pots or soaking before planting (Tseng, 1981) was observed to boost algal production. Preliminary studies under laboratory and field conditions on the use of fertilizers (inorganic and organic) in the Philippines showed improved growth and development of *Eucheuma* and other seaweeds (Lim, 1982; Gaulberto, 1984; Orosco, 1984; Rosales-Apao, 1991). However, the practical application in algal farms in the Philippines have been limited due to cost and labor associated with the methods of fertilization. Another deterrent to the commercialization of fertilization in open water seaweed cultivation is the faster diffusion and removal of the fertilizer by relatively strong water current.

At present existing farms rely on available nutrient concentration in the proposed site and thus this is an important consideration in the selection of farm sites. The seasonal variation in nutrient levels in the seawater is important in seasonal farming. In some cases, planting areas are transferred whenever nutrient levels in synergistic action with other environmental conditions become unfavorable in order to obtain high growth rates of farmed species.

In pond farms using polyculture with fish, artificial fertilization is not needed due to the recycling of organic wastes. Such method of mariculture is more effective and realistic (Kinne, 1984 cited in Dawes, 1987).

IMPACT OF SEAWEED FARMING TO THE ECOSYSTEM

The presence of manmade seaweed farms either in open water, or enclosed ponds or embayments changes the natural ecosystems, i.e. in levels of trophic structure to the modification of communities. Long term changes in natural communities due to introduction of pure algal stand and control of undesirable flora and fauna in the seaweed farm are expected. This will apparently alter the natural food web of the organisms in the marine environment. Such removal of natural populations may result in more stress related disturbances or diseases as occurring in monoculture terrestrial farming (Dawes, 1987).

On the other hand, such changes in the ecosystem caused by developing seaweed farms in coral reef areas may be advantageous in protecting the coral reef environment. The rampant dynamite blasting and cyanide poisoning in fishing and coral reef areas destroy the fishes, other invertebrates, zooxanthellae and algae. However, the development and presence of seaweed farms in the coral reef areas are claimed to deter the indiscriminate destruction of the reefs' inhabitants.

In the final analysis, long term effects of seaweed farming to the ecosystem may either be positive or negative but such may take a long time to be felt and realized.

SOCIO-ECONOMIC IMPACT

The success of seaweed farming especially that of *Eucheuma* in addition to natural harvesting in the Philippines has been recorded in detail (Ricohermoso, 1990; McHugh and Lanier, 1984). Seaweed ranks third among the fisheries and marine products exported to other countries such as Denmark, Japan, France, Korea, and USA.

Carrageenan product export was 4,500 metric tons in 1986 and about 5,800 metric tons in 1989 providing 62% of earnings of the industry for 1986 (Ricohermoso, 1990). The world's prices of carrageenan have changed from US $3.00 to US $5.5 in 1982 and stabilized at US $9.00 to 11.00 per kilogram (Dept. of Agriculture).

With the success, seaweed farming in the country, has a great socio-economic impact to the population. The impact is best seen among the coastal populace in Sulu areas where seaweed farming is a major source of livelihood. The standard of living of farmers has improved in the past years (Alih and Toring-Alih, 1985; Alih, 1990). Although income from small individual farms is less than those of corporate farms, profits are still high. With these changes and availability of livelihood, the standard of living and the peace and order situation have improved among the coastal populace especially the Muslims. Another important observation is the easing of migration of people from Tawi-Tawi to neighboring Asian countries such as Sabah.

CONCLUSIONS AND RECOMMENDATIONS

Seaweed farming has a great future in the Philippines where capital utilization is low, labor practices are less intensive and profits are high. With the world demand for algal phycocolloids, the existing seaweed farms have to be expanded and be competitive with other phycocolloid-producing countries. To this aim, more seaweeds with potential for mariculture should be explored. The biology and ecophysiology of potential species should be determined and the feasibility for its culture under appropriate conditions should be done. Researches on strain selection of cultivars that have broader tolerances to environmental conditions such as epiphytism and disease are needed. Production of strains which exhibit resistance to grazing, forms that withstand extremely strong water current, with high productivity, rapid growth and the ability to take up and store nutrients rapidly are among the research priorities. In addition, the technology on providing seed stock from spores and tissue culture of farmed species should be emphasized.

ACKNOWLEDGEMENTS

I thank Dr. W. Schramm for the discussion on the manuscript.

BIBLIOGRAPHY

ADNAN, H. and H. PORSE (1987)
Culture of *Eucheuma cottonii* and *Eucheuma spinosum* in Indonesia. In: M.A. Ragan and C.J. Bird (eds.) 12th Int. Seaw. Symp. Hydrobiologia 151/152: 355-358.

ALIH, E.M. (1990)
Economics of seaweed (*Eucheuma*) farming in Tawi-Tawi Islands in the Philippines. In: R. Hirano and I. Hanyu (eds). The Second Asian Fisheries Forum. Asian Fisheries Society, Manila, Phil. pp. 249-252.

ALIH, E.M. and M. TORING-ALIH (1985)
The *Eucheuma* industry in the Philippines and its future. NSTA Tech. J. 10 (2): 15 -18.

ANG, P.O. (1985)
Regenerations studies of *Sargassum siliquosum* J. Ag. and *S. paniculatum* J. Ag. (Phaeophyta, Sargassaceae). Bot. Mar. 28: 231-235.

BIRD, C.J. and J. McLACHLAN (1986)
The effect of salinity on distribution of species of *Gracilaria* Grev. (Rhodophyta, Gigartinales): an experimental assessment. Bot. Mar. 29: 231-238.

BRIAND, X. (1991)
Seaweed harvesting in Europe. In: M. Guiry and G. Blunden (eds). Seaweed Resources in Europe: Uses and Potential. John Wiley and Sons Ltd. pp. 260-308.

CHAPMAN, V.J. and D.J. CHAPMAN (1980)
Seaweeds and their Uses. Chapman and Hall Ltd. London. p. 334.

CHEN, H.-C. (1984)
Recent innovations in cultivation of edible molluscs in Taiwan with special reference to the small abalone *Haliotis diversicolor* and the hard clam *Meretrix lusoria*. Aquaculture. 39 (1-4): 11-27.

CHIANG, Y.-M. (1981)
Cultivation of *Gracilaria* (Rhodophycophyta, Gigartinales) in Taiwan. Proc. Int. Seaweed Symp. 10: 569-574.

CORDERO, P.A. (1989)
Notes on the sea vegetable algae from Palawan province. In: I. Umezaki (ed). Scientific Survey of Marine Algae and their Resources in the Philippine Island. pp. 102-104.

DAWES, C.J. (1987)
The biology of commercially important tropical marine algae. In: K.T. Bird and P.H. Benson (eds) Seaweed Cultivation for Renewable Resources. Developments in Aquaculture and Fisheries Science. Vol. 16. Elsevier, Amsterdam. pp. 155-188.

DeBOER, J.A. (1979)
Effects of nitrogen enrichment on growth rate and phycocolloid content in *Gracilaria foliifera* and *Neoagardhiella baileyi* (Florideophyceae). In: A. Jensen and J.R. Stein (eds.) Proc. 11th Int. Seaweed Symp. 9: 263-271.

DeBOER, J.A. (1981)
Nutrients. In: C.S. Lobban and W.J. Wynne (eds.). The Biology of Seaweeds. Blackwell Scientific Publications, Oxford 17: 356-362.

DeBUSK, T.A. and J.H. RYTHER (1984)
Effects of seawater exchange, pH and carbon supply on the growth of *Gracilaria tikvahiae* (Rhodophyceae) in large scale cultures. Bot. Mar. 27: 357-362.

DEVEAU, L.E. and J.R. CASTLE (1976)
The industrial development of farmed marine algae: The case-history of *Eucheuma* in the Philippines and USA. In: T.V.R. Pillay and W.A. Dill (eds) Advances in Aquaculture. FAO Techn. Conf. on Aquaculture, Kyoto, Japan. pp. 410-415.

DOTY, M.S. (1971)
Physical factors in the production of tropical benthic marine algae. In: J. D. Costlow (ed) Fertility of the Sea. Vol. 1. Gordon and Breach Science Publishers. pp. 1-25.

DOTY, M. (1973)
Farming the red seaweed *Eucheuma* for carrageenans. Micronesica 9: 59-73.

DOTY, M.S (1979a)
Status of Marine Agronomy, with special reference to the tropics. Proc. 9th International Seaweed Symposium. pp. 35-58.

DOTY, M.S. (1979b)
Realizing a nation's seaweed potential. In: B. Santelices (ed) Actas Primer Symposium Sobre Algas Marinas Chilenas. Subsecretarria de Pesca Min. de Econ., fomento Y Reconstr. Santiago, Chile. pp. 133-153.

DOTY, M. (1983)
Coral reef diversified farming. In C.K. Tseng (ed.) Joint China-US Phycology Symp. Science Press, Beijing: 437-478.

DOTY, M. (1986)
Biotechnological and economic approaches to industrial development based on marine algae in Indonesia. In: Workshop on Marine algae Biotechnology Summary Report, Jakarta, Indonesia, Dec. 11-13, 1985. U.S. National Academy Press, Washington, D.C.

DOTY, M.S. and V.B. ALVAREZ (1975)
Status, problems, advances and economics of *Eucheuma* farms. Mar. Technol. Soc. J. 9(4): 30-35.

DY, D. (1984)
Nutrient flux across the sediment-water interface and the role of marine sediments in the nutrient budget of a *Eucheuma* farm. M.S. Thesis. University of San Carlos, Cebu City, Philippines.

EDDING, M., J. MACHIAVELLO and H. BLACK (1987)
Culture of *Gracilaria* sp. in outdoor tanks: productivity. In: M.A. Ragan and C.J. Bird (eds). 12th International Seaweed Symposium. Dr. W. Junk Publishers, Dordrecht. pp. 369-373.

FRALICK, R.A., J.E. HUGUENIN and B.E. LAPOINTE (1981)
The growth of commercially useful seaweeds in a nutrient-enriched multipurpose aquaculture system. In: G.E. Fogg and W.E. Jones (eds.) Proc. Int. Seaweed Symp. 8: 692-698.

FRIEDLANDER, M. and N. ZELIKOVITCH (1984)
Growth rates, phycocolloid yield and quality of the red seaweeds *Gracilaria* sp., *Pterocladia capillacea*, *Hypnea musciformis* and *Hypnea cornuta* in field studies in Israel. Aquaculture 40: 57-66.

GERARD, V.A. (1982)
In situ rates of nitrate uptake by giant kelp, *Macrocystis pyrifera* (L.) C. Agardh: Tissue differences, environmental effects, and predictions of nitrogen-limited growth. J. Exp. Mar. Biol. Ecol. 62: 211-224.

GUALBERTO, E. (1984)
The effects of artificial fertilizers on the growth rate of *Eucheuma cottonii* under special consideration of water movement and application techniques. M.S. Thesis, University of San Carlos, Cebu City, Philippines.

HANISAK, M. (1981)
Methane production from the red seaweed *Gracilaria tikvahiae*. Proc. Int. Seaweed Symp. 10: 681-686.

HANISAK, M.D. (1987)
Cultivation of *Gracilaria* and other macroalgae in Florida for energy production. In: K.T. Bird and P.H. Benson (eds), Seaweed Cultivation for Renewable Resources. Developments in Aquaculture and Fisheries Science. Vol. 16. Elsevier, Amsterdam. pp. 191-218.

HANSEN, J.E., J.E. PACKARD and W.T. DOYLE (1981)
Mariculture of red seaweeds. California Sea Grant College Program, La Jolla, USA. 52 p.

HORSTMANN, U. (1983)
Cultivation of the green alga, *Caulerpa racemosa* in tropical waters and some aspects of its physiological ecology. Aquaculture 32: 361-371.

HOYLE, M.D. (1978)
Agar studies in two *Gracilaria* (*G. bursapatoris* (Gmelin) Silva and *G. coronopifolia* J. Ag.) from Hawaii. II. Seasonal aspects. Bot. Mar. 21: 347-352.

HURTADO-PONCE, A.Q. (1990)
Vertical rope cultivation of *Gracilaria* (Rhodophyta) using vegetative fragments. Bot. Mar. 33: 477-481.

JENSEN, A. (1979)
Industrial utilization of seaweeds in the past, present and future. In: A. Jensen and J.R. Stein (eds.) Proc. Int. Seaweed Symp. 9: 17-34.

KINNE, O. (1984)
Realism in Aquaculture - the view of an ecologist. Biologiya Morya. 6: 3-11.

LAPOINTE, B.E. (1981)
The effects of light and nitrogen on growth, pigment content and biochemical composition of *Gracilaria foliifera* v. *anqustissima* (Gigartinales, Rhodophyta). J. Phycol. 17: 90-95.

LAPOINTE, B.E. and J.H. RYTHER (1978)
Some aspects of the growth and yield of *Gracilaria tikvahiae* in culture. Aquaculture. 15: 185-193.

LAPOINTE, B.E. and J.H. RYTHER (1979)
The effects of nitrogen and seawater flow rate on the growth and biochemical composition of *Gracilaria foliifera* var. *anqustissima* in mass outdoor culture. Bot. Mar. 22: 529-537.

LARGO, D.B., P.T. BACOLOD, M.A. CUSI, C. OROSCO and M. OHNO (1989)
Growth rate of *Gracilaria verrucosa* and *G. salicornia* in an intertidal and semi-enclosed pond system in the Visayas, Philippines. In: I. Umezaki (ed) Scientific Survey of Marine Algae and their Resources in the Philippine Islands.

LARGO, D.B., P.T. BACOLOD, M.A. CUSI and P. COBRADO (1991)
Stock assessment of the agarophyte genus *Gracilaria* (Gracilariales, Rhodophyta) in Central Visayas and their cultivation potential. Phil. Scientist. 28: 5-26.

LIM, R. (1982)
Farming the Ocean (The Genu Story). R.P. Garcia Publishing.

LIM, J.R. and H. PORSE (1981)
Breakthrough in the commercial culture of *Eucheuma spinosum* in northern Bohol, Philippines. In: T. Levring (ed.) Proc. Int. Seaweed Symp. 10: 601-606.

LLANA, E.G. (1990)
Commercial potential of other seaweed species. Pisces 18(1): 5-9.
LOBBAN, C.S. and M.J. WYNNE (1981)
The Biology of Seaweeds. Blackwell Scientific Publications. Oxford. 786 p.
McLACHLAN, J. and C.J. BIRD (1986)
Gracilaria (Gigartinales, Rhodophyta) and productivity. Aquat. Bot. 26(1-2): 27-49.
MALIG, J.B. (1990)
Identified new possible seaweed farming areas and their viability. Pisces 18(1): 4.
MATHIESON, A. (1985)
Seaweed Aquaculture. Marine Fisheries Review. 37(1): 2-14.
McHUGH, D.J. (1984)
Marine phycoculture and its impact on the seaweed colloid industry. In: C.J. Bird and M.A. Ragan (eds.) Proc. 11th Int. Seaweed Symp. Hydrobiologia 116/117: 351-354.
McHUGH, D.G. and B.V. LANIER (1983)
The World Seaweed Industry and Trade: Developing Asian producers and prospects for greater participation. ADB/FAO INFOFISH Market Studies. Vol 6. 30 p.
McLACHLAN, J. and BIRD, C.J. (1986)
Gracilaria (Gigartinales, Rhodophyta) and productivity. Aquat. Bot. 26(1-2): 27-49.
OROSCO, C.A. (1984)
Growth rate, chlorophyll a and phycoerythrin level of *Eucheuma cottonii* as a function of nitrogen source and concentration. M.S. Thesis, University of San Carlos, Cebu City, Philippines.
OROSCO, C.A. and H. YAMAMOTO (1989)
Standing stocks of some *Gracilaria* species in Palawan Island, the Philippines. In: I. Umezaki (ed) Scientific Survey of Marine Algae and their Resources in the Philippine Islands. pp. 87-94.
PARKER, H.S. (1974)
The culture of the red algal genus *Eucheuma* in the Philippines. Aquaculture 3: 425-439.
PIZARRO, A. and H. BARRALES (1986)
Field assessment of two methods for planting the agar-containing seaweed, *Gracilaria*, in northern Chile. Aquaculture. 59: 31-43.
RAJU, P.V. and P.C. THOMAS (1971)
Experimental field cultivation on *Gracilaria edulis* (Gmelin). Silva. Bot. Mar. 14: 71-75.
REN, G.-Z., J.-C. WANG and M.-Q. CHEN (1984)
Cultivation of *Gracilaria* by means of low rafts. Hydrobiologia 116/117: 72-76.
RICOHERMOSO, M.A. (1990)
Seaweed Industry in the Philippines. Dating-Bayan Agro-Industrial Corp., Cebu. 8 p.
ROSALES-APAO, P. (1991)
Nutrient requirement of selected tropical seaweeds potential for mariculture. Doctoral Dissertation, Kiel University, Kiel, Germany.
RYTHER, J.H. and W.M. DUNSTAN (1971)
Nitrogen, phosphorus and eutrophication in the coastal marine environment. Science 171: 1008-1013.
RYTHER, J.H., J.A. DeBOER and B.E. LAPOINTE (1979)
Cultivation of seaweed for hydrocolloids, waste treatment and biomass for energy conversion. Proc. Int. Seaweed Symp 9: 1-16.
SANTELICES, B. and M.S. DOTY (1989)
A review of *Gracilaria* farming. Aquaculture. 78: 95-133.
SANTELICES, B. and J. LOPEHANDIA (1981)
Chilean seaweed resources: a quantitative review of potential and present utilization. In: T. Levring (ed.) Proc. Int. Seaweed Symp. 10: 725-730.
SANTELICES, B. and R. UGARTE (1987)
Production of Chilean *Gracilaria*: problems and perspectives. In: M.A. Ragan and C.J. Bird (eds.) Proc. 12th Int. Seaweed Symp. Hydrobiologia 151/152. 295-299.
SANTOS, G. and M. DOTY (1983)
Agar from some Hawaiian red algae. Aquat. Bot. 16: 385-389.
SHANG, Y.C. (1976)
Economic aspects of *Gracilaria* culture in Taiwan. Aquaculture 8: 1-7.
SMITH, A.H., K. NICHOLS, and J. McLACHLAN (1984)
Cultivation of seamoss *Gracilaria* in St. Lucia, West Indies. Hydrobiologia, 116/117: 249-251.

TECHNOPACK-CV-CIRRD (1991)
Central Visayas seaweed farming technoguide *Caulerpa Lentillifera*. J. Agardh. Central Visayas Technology Packaging for Countryside Development and Central Visayas Consortium for Integrated Regional Research and Development. 27 p.

TSENG, C. (1981a)
Commercial cultivation. In: C.S. Lobban and M.J. Wynne (eds.) The Biology of Seaweeds. Blackwell Scientific Publications. Oxford. pp. 680-725.

TSENG, C. (1981b)
Marine phycoculture in China. In: T. Levring (ed.) Proc. Int. Seaweed Symp. 10: 123-152.

TRONO, G.C. JR. (1980)
Field culture of *Gracilaria* and other species. In: G.C. Trono and E.T. Ganzon-Fortes (eds) Report on the training course on *Gracilaria* algae, 1-30 April 1980. South China Sea Fisheries Development and Coordinating Programme (of the UN) SCS/Gen/8/29, pp. 51-56.

TRONO, G.C. Jr. and R. AZANZA-CORRALES (1981)
The seasonal variation in the biomass and reproductive states of *Gracilaria* in Manila Bay. Proc. Int. Seaweed Symp. 10: 743-748.

TRONO, G.C., Jr. R. AZANZA-CORRALES and D. MANUEL (1983)
The genus *Gracilaria* (Gigartinales, Rhodophyta) in the Philippines. Kalikasan, Philipp. J. Biol. 12: 15-41.

TRONO, G.C., Jr. and E. GANZON-FORTES (1988)
Philippine Seaweeds. Technology and Livelihood Resource Center. National Bookstore, Inc. 330 p.

TRONO, G.C., Jr. and E.T. GANZON-FORTES (1989)
Eucheuma Farming. SICEN, Univ. of the Philippines, Philippines. 57 p.

TRONO, G.C. Jr. and M. OHNO (1989)
Seasonality in the biomass production of the *Eucheuma* strains in Northern Bohol, Philippines. In: I. Umezaki (ed) Scientific Survey of Marine Algae and their Resources in the Philippines Islands. pp. 71-80.

UYENCO, F., L.S. SANIEL and G.S. JACINTO (1981)
The "ice-ice" problem in seaweed farming. Proc. 10th Seaweed Symposium: 625-630.

VELOSO, A.R.V. (1990)
Seaweeds. Philippine Environment 289-293.

VELOSO, A.R.V. (1990)
Eucheuma farming in the Philippines. Dating-Bayan Agro- Industrial Corporation, Cebu. 12 p.