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Seasonality in Micronesian Seaweed Population and their Biogeography as Affecting Wild Crop Potential*

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Introduction

Unlike the situation in our neighboring Asian countries to the west and the western coast of the United States, commercialization of seaweeds in Micronesia (Fig. 1) is presently nonexistent. Even if harvesting of wild crops was initiated on a commercial basis, the investors would soon find themselves in the unprofitable position of having to operate only during certain months of the year. The reason for this situation is primarily due to the unpredictable amount of wild crops available during the year. Although this situation is similar to other parts of the world (Michanek 1975), the limited coastal area and the distance between islands (i.e., the patchy distribution) makes harvesting a much more difficult problem in island systems. Thus, knowledge of the seasonal and distributional patterns of the indigenous marine flora is of utmost importance if wild crops are to be utilized.

Commercially Potential Seaweeds

Of the 188 genera and 621 species of marine benthic algae reported in the published literature from Micronesia (Tsuda and Wray, 1977), 10 species (Table 1) may have the potential as harvestable commercial products. At present, only two species, *Caulerpa racemosa* (Forssk.) J. Ag. and *Gracilaria edulis* (Gmelin) Silva, are harvested by the local people as a food source. These two species are primarily harvested on Guam.

As seen on Table 1, the 10 species fall within three categories - 1) food for human consumption, 2) food in finfish aquaculture, and 3) extraction of phycolloids, i.e., alginates, agar, and carrageenan.

The literature reviews on *Eucheuma* (Doty, 1970), gelidioids (Santelices, 1974), *Hypnea* (Mshigeni, 1974) and *Gracilaria* (Hoyle, 1975) represent an excellent start for these tropical-subtropical red algae.

Seasonality

The most critical factor which we have found that decreases the standing crop of algae is the high temperatures and exposure occurring during the periods when low tides occur during the daylight hours. This period occurs during May to August in Guam waters (Tsuda, 1974). Misra (1966) reported that high temperatures and exposure during certain times of year was the only cause in the change in standing crops of marine algae on the Indian coast. Thus, it is of utmost concern that 9 of the 10 species listed on Table 1 inhabit the reef flats or reef margins and are subject to these conditions.

The only alga which does not inhabit the reef flats is *Asparagopsis taxiformis* (Delile) Collins & Hervey. The gametophytic generation of this alga is found throughout the year on the submarine terraces in waters, 3 to 7 meters deep. Fertile gametophytes were found in February and March (J.O. Stojkovich, personal communication). Although *A. taxiformis* displays no seasonal pattern, its very presence in deeper water beyond the reef margin makes it inaccessible for easy harvesting.

Caulerpa racemosa var. *uvifera* (Turner)

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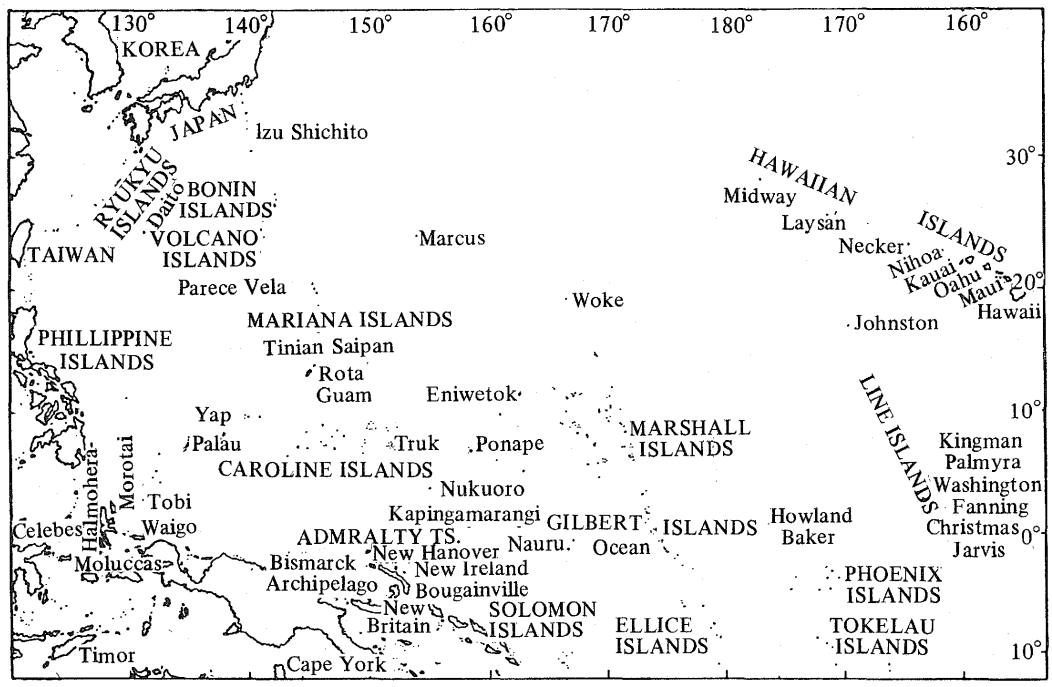

Fig. 1. Map of western Pacific showing the island groups of Micronesia.

W.V. Bosse is primarily harvested by the Filipino population on Guam and is eaten raw or pickled. Peterson (1972) studied this variety over a year's period on Guam and found this alga appearing on the reef flats in October and reaching its maximum abundance on the outer reef flats during December and May. During the low Spring tides which occur during the daylight hours in June, the standing crop of this alga slowly diminishes. By September, the majority of the mature thalli are gone, except for those thalli inhabiting the depressions on the outer reef flat.

The most common species of *Sargassum* on Guam is *S. cristaefolium* which occurs on the reef margin. This brown alga attains its maximum abundance during the months of April to June (Tsuda, 1972). During the remaining months, *S. cristaefolium* is either dying (July to September), absent (October to December), or actively growing (January to March). The complete absence of this alga during October to December is unusual, but two other brown algae, *Hydroclathrus clathratus* (Bory) Howe and *Colpomenia sinuosa* (Roth) Derbes & Solier, also disappear from the reef flat. The seasonality of the Guam species differs from the Hawaiian species (De Wreede, 1976) where maximum standing crop occurred during November to April when the seawater temperature was lowest between 22° and 25°C.

Gracilaria edulis (Gmelin) Silva, on the other hand, seems to appear on the outer reef flats on the southwestern coast of Guam in early November. The alga reaches its maximum abundance by mid-January, and gradually declines by late April (S. Hedlund, personal communication). This alga, however, can still be found in limited amount during the summer in the deeper depressions of the reef flat.

Enteromorpha clathrata (Roth) J. Ag., which inhabits the intertidal zone near shore on the western coast of Guam, presents a different seasonal pattern. First, this alga is always submerged at least twice a day, and thus, desiccation is not critical. FitzGerald (1978) found that the abundance of the alga in Tumon Bay (Guam) during any one month varied in relation to the intensity of wave action, abundance of juvenile rabbitfish (*Siganus*) schooling onto the reef flat, and the enrichment of near-shore waters from freshwater springs and storm-drains. The abun-

Table 1. Listing of 10 marine algal species with commercial potential in Micronesia.

Species	Habitat
FOOD FOR HUMANS	
Caulerpa racemosa var. *uvifera* (Turner) W.V. Bosse	Outer Reef Flat
Gracilaria edulis (Gmelin) Silva	Outer Reef Flat
Asparagopsis taxiformis (Delile) Collins & Hervey	Submarine Terrace
FOOD IN FISH MARICULTURE	
Enteromorpha clathrata (Roth) J. Ag.	Intertidal (Shore)
ALGINATES	
Sargassum cristaefolium C. Ag.	Reef Margin
AGAR	
Gracilaria arcuata Zanard.	Inner Reef Margin
Gracilaria edulis (Gmelin) Silva	Outer Reef Margin
Gelidiella acerosa (Forssk.) Feldmann & Hamel	Reef Margin
CARRAGEENAN	
Hypnea pannosa J. Ag.	Outer Reef Flat
Eucheuma cottonii Weber van Bosse	Inner Reef Flat
Eucheuma striatum Schm.	Inner Reef Flat

dance of this alga can vary from year to year (Kami and Ikehara, 1976) and depends on the amount of juvenile rabbitfish, *Siganus argenteus* (Quoy & Gaimard) and *S. spinus* (Linnaeus), schooling onto the reef flats during April, May, June and October (Tsuda and Bryan, 1973). The several-fold increase in nitrates and phosphates (Marsh, 1977) near shore is also a factor in the patchy distribution of this alga along the shoreline.

The seasonal pattern of *Hypnea pannosa* J. Ag. on the outer reef flat has not been investigated on Guam or on any of the other Micronesian islands. This alga which grows in clumps is usually found in association with live *Acropora* (staghorn coral) which grows in water not exposed during low tides. However, this alga can be found growing on rubble bottom. Isaac and Hewitt (1953) claim this genus to be abundant throughout the year in tropical regions.

The seasonality of *Gelidiella acerosa* (Forssk.) Feldmann & Hamel and *Gracilaria arcuata* Zanard. is unknown. *Gelidiella acerosa* attains its most luxuriant growth on the elevated reef margin in the presence of wave action. I assume its seasonal pattern is similar to *Sargassum cristaefolium*. *Gracilaria arcuata* attains its most luxuriant growth near shore and usually near the mouths of rivers. Some of the specimens, which are clumped, were up to a meter in diameter.

Eucheuma cottonii Weber van Bosse is rare on Guam. Only about six specimens have been collected on Guam. The occurrence has been noted by Doty (1970) as being present most frequently within a narrow range surrounding the level of the lowest yearly tides. Likewise, the seasonal pattern of *Eucheuma striatum* Schm. which occurs in Palau is still unknown. However, since this alga occurs in the seagrass beds, I suspect that this alga will diminish in standing crop during periods of low Spring tides which occur during the daylight hours.

Phytogeography

In general, the Micronesian flora taken as a whole attenuates in number from west to east, i.e, from the Palau Islands to the Marshall and Gilbert Islands. Yamada (1926) refers to the Micronesian flora as simply a branch of flora in the Malayan Archipelago. Trono (1968) found that 60 percent of the green algae reported from the Caroline Islands are similar to those in the Philippines. The most striking example of this eastern attenuation is the distribution of seagrasses in Micronesia (Tsuda et al., 1977) where nine species are known from Palau and only one species from the Marshalls and Gilberts.

Four of the 10 algal species which we are discussing are pantropic. *Caulerpa racemosa, Enteromorpha clathrata, Asparagopsis taxiformis,* and *Hypnea pannosa* can be found also in the subtropical zone.

Although *Ulva,* a close relative to *Enteromorpha,* is present in Asian countries, the alga was not listed among the 10 species because of its scareness in the Micronesian region. The only published records (Tsuda, 1968) of this genus are from Peleliu (Palau) and Tarawa (Gilberts) which represent the western fringe of Micronesia. Recently, this genus has been found in the deep waters of Guam (136-201 m), intertidal zone on Saipan, and associated with seagrass beds in Yap.

A unique distributional pattern which is

becoming more obvious is the restriction of certain genera to high islands and their exclusion from atolls. Doty (1954) was the first to notice this phenomenon in *Sargassum*. Although numerous additional floristic studies were undertaken since then, recent records (Tsuda, 1976) have shown *Sargassum* to occur only on two atolls, Kayangel Atoll (Palau Islands) and Ulithi Atoll (Yap Outer Islands).

Gracilaria and *Eucheuma* also seem to be restricted to high islands. The only record of *Gracilaria* on a low island is its presence on Fanning Atoll (Tsuda et al., 1973). *Eucheuma* has never been found on any low islands. Experiments have been conducted by M.S. Doty which indicate that *Eucheuma* can grow on the reefs of Fanning Atoll (D. Russell, personal communication).

Future Trends

The seasonal patterns alone make wild crop harvest undesirable since the standing crop of any one species on an island is low. Even when one considers all 10 potentially commercial algae, most of the species are present in abundance during the same time of year, thus, negating the possibility of simply rotating the harvest of a particular species.

The solution to this problem which is the main focal point of this symposium is cultivation, whether it be in the field or in holding tanks. The alga which seems to possess the best potential in the Mariana Islands is *Gracilaria edulis*. We have only been able to test the marketability of this species on a limited scale because Guam and Saipan simply do not have a surplus of this alga growing abundantly on the reefs throughout the year. The alga can be sold for 50 cents per wet pound as fresh vegetable. Since the wet to dry weight ratio is about 7:1, this price is far superior (10 times) than the 5 cents per wet pound farmers could get if they harvested and sold this alga for its agar content. A conservative estimate of the amount of *Gracilaria* which can be sold to the retail stores and hotels is about 500 pounds per week or 13 tons per year. We have yet to test all of the retail stores and hotels on Guam and Saipan. Both islands cater to Japanese tourists who are accustomed to eating fresh seaweeds.

Preliminary growth rate studies of sprigs of *Gracilaria* (about 8-10 cm long) attached to polyethylene mesh frames submerged in seawater tanks indicate that the alga can grow 17 mm/day or obtain a doubling rate within six days. These values are only for small sprigs.

Literature Cited

De Wreede, R.E. 1976. The phenology of three species of *Sargassum* (Sargassaceae, Phaeophyta) in Hawaii. Phycologia 15(2): 175-183.

Doty, M.S. 1954. Distribution of the algal genera *Rhipilia* and *Sargassum* in the central Pacific. Pacif. Sci. 8(3): 367-368.

———. 1970. The red algal genus *Eucheuma* in the Philippines. Univ. Hawaii, Hawaii Botanical Sci. Pap. No. 18. xiv + 358 pp.

FitzGerald, W.J., Jr. 1978. Environmental parameters influencing the growth of *Enteromorpha clathrata* (Roth) J. Ag. in the intertidal zone on Guam. Botanica Marina 21: 207-220.

Hoyle, M.D. 1975. The literature pertinent to the red algal genus *Gracilaria* in Hawaii. Univ. Hawaii, U.S. Sea Grant Program, Marine Agronomy, Tech. Rept. No. 3. 339 pp.

Isaac, W.E., and F. Hewitt. 1953. The morphology, geographical distribution and ecology of *Hypnea spicifera* (Suhr) Harv. J.S. Afr. Bot. 19: 73-83.

Kami, H.T., and I.I. Ikehara. 1976. Notes on the annual juvenile siganid harvest in Guam. Micronesica (12)2: 323-325.

Marsh, J.A., Jr. 1977. Terrestrial inputs of nitrogen and phosphorus on fringing reefs on Guam. Proc. Third Internat. Symp. Coral Reefs (Miami) 1: 331-336.

Michanek, G. 1975. Seaweed resources of the ocean. FAO Fisheries Tech. Pap. No. 138. 127 pp.

Misra, J.N. 1966. Phaeophyceae in India. Indian Council of Agri. Res., New Delhi. 203 pp.

Mshigeni, K.E. 1974. An extended review of the literature on *Hypnea*, a red algal genus. Univ. Hawaii, U.S. Sea Grant Program,

Marine Agronomy, Tech. Rept. No. 2. 221 pp.

Peterson, R.D. 1972. Effects of light intensity on the morphology and productivity of *Caulerpa racemosa* (Forsskal) J. Agardh. Micronesica 8(1-2): 63-86.

Santelices, B. 1974. Gelidioid algae, a brief resume of the pertinent literature. Univ. Hawaii, U.S. Sea Grant Program, Marine Agronomy, Tech. Rept. No. 1. 111 pp.

Trono, G.C., Jr. 1968. The marine benthic algae of the Caroline Islands, I. Introduction, Chlorophyta and Cyanophyta. Micronesica 4(2): 137-206.

Tsuda, R.T. 1968. Distribution of *Ulva* (Chlorophyta) on Pacific Islands. Micronesica 4(2): 365-368.

————. 1972. Morphological, zonational, and seasonal studies on two species of *Sargassum* on the reefs of Guam. Proc. Seventh Internat. Seaweed Symp. (Sapporo). Univ. Tokyo Press. 40-44.

————. 1974. Seasonal aspects of the Guam Phaeophyta (brown algae). Proc. Second Internat. Symp. Coral Reefs (Australia) 1: 43-47.

————. 1976. Occurrence of the genus *Sargassum* (Phaeophyta) on two Pacific atolls. Micronesica 12(2): 279-283.

Tsuda, R.T., and P.G. Bryan. 1973. Food preference on juvenile *Siganus rostratus* and *S. spinus* in Guam. Copeia (3): 604-606.

Tsuda, R.T., and F.O. Wray. 1977. Bibliography of marine benthic algae in Micronesia. Micronesica 13(1): 85-120.

Tsuda, R.T., F.R. Fosberg and M.-H. Sachet. 1977. Distribution of seagrasses in Micronesia. Micronesica 13(2): 191-198.

Tsuda, R.T., D.J. Russell, and M.S. Doty. 1973. Checklist of the marine benthic algae from Fanning Atoll, Line Islands. p. 61-67. *In* K.E. Chave and E.A. Kay (Eds.), Fanning Island Expedition, July and August, 1972. Hawaii Inst. Geophysics, Tech. Rept. HIG-73-13.

Yamada, Y. 1926. The phyto-geographical relation between the Chlorophyceae of the Marianas, Carolines and Marshall Islands and those of the Malay Archipelago, Australia and Japan. Proc. Third Pan-Pacific Sci. Congress (Tokyo) 1: 964-966.