THE SEAWEED RESOURCES OF THE CARIBBEAN

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MAIN ENVIRONMENTAL FACTORS

The Caribbean Sea (Fig. 1) is one of two major semi-enclosed basins within the wider Caribbean. It is fed by the North Equatorial Current, which is joined by the warm Guiana Current which flows from the Brazilian coast, passes between the Lesser Antilles and continues as the Caribbean Current. This current passes west of Cuba and enters the Gulf of Mexico as the Yucatán Current and leaves via the Florida Straights as the Florida Current which then becomes the main component of the Gulf Stream. Surface temperature averages 27°C and does not vary by more than 3°C. In the eastern Caribbean salinity varies seasonally, with maxima >36.5°C in February and March and minima <34.5°C in October and November that result from the increase in freshwater outflow from the Amazon and Orinoco Rivers of South America. While offshore conditions are well known, much less is known about water circulation and characteristics closer to the Caribbean Islands.

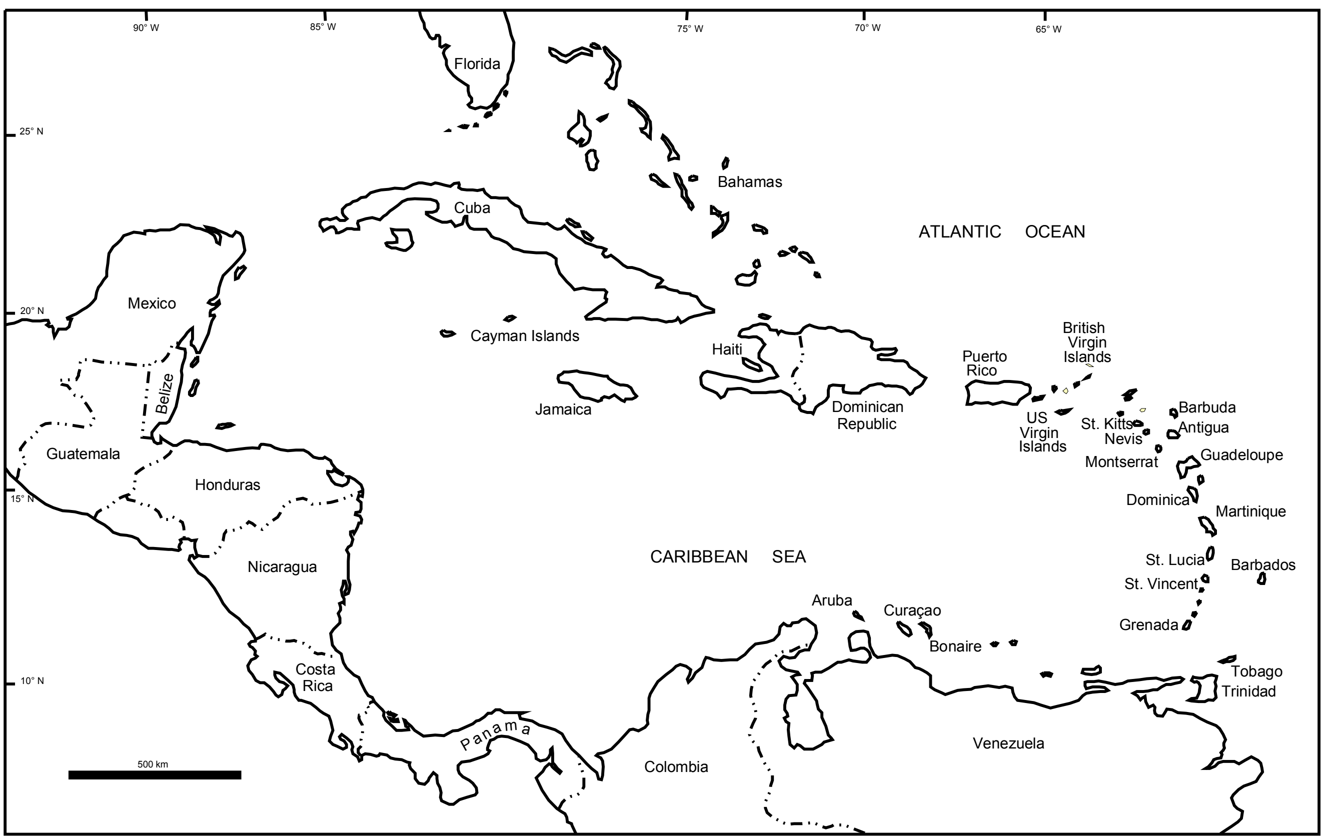

Figure 1. Map of the Caribbean Sea and associated islands.

FLORA OF THE MAIN SEAWEED SPECIES OF THE CARIBBEAN

The last major flora of the eastern tropical and subtropical coasts of the Americas (except for Cuba) was published by Taylor (1960) and included a comprehensive coverage of the history of marine algal taxonomy of the region. Twenty-five years later, Wynne (1986) published a checklist of the marine benthic algae of the tropical and subtropical western Atlantic which, incorporated the many revisions since Taylor's work.

The Caribbean contains 81% of the benthic marine algae of the tropical and subtropical western Atlantic region (Diaz-Piferrer 1969, for which the most complete checklist contains 1058 species, including 150 Phaeophyceae, 253 Chlorophyceae and 655 Rhodophyceae, Wynne 1986). However, the flora of most Caribbean islands or island groups rarely exceeds 300, which may simply reflect insufficient study.

In a review of algal diversity, Norton *et al.* (1996) noted that the figure of around 300 species recorded for a number of Caribbean islands was high compared with most Pacific islands. McLachlan and Bird (1984) suggested that the western Atlantic has a distinct *Gracilaria* flora, in which the abundance of species is correlated with temperature, the largest number of species (approximately 20) being found between 30°N and 30°S.

Influence of the freshwater intrusion from the Amazon and Orinoco Rivers carried into the Lesser Antilles by the Guiana Current may be expected to exert an influence on algal distribution, but this has not been studied in any detail with regard to distribution of macroalgae.

ECONOMIC SEAWEEDS OF THE CARIBBEAN

The region has received much attention from phycologists, but the majority of studies have been taxonomic. The first attempt to document seaweed use in the Caribbean was made by Richardson (1958), who compiled data from questionnaires. The results indicated a number of examples of local small-scale use as crop fertilizers and human food.

Studies by Díaz-Piferrer and colleagues were the first to begin to assess the actual and potential seaweed resources in the region, including Puerto Rico (Díaz-Piferer and Caballer de Perez 1964), Cuba (Díaz-Piferrer 1961) and Venezuela (Díaz-Piferrer 1967). Despite a general lack of resource assessments available for the region at the time, Díaz-Piferrer (1969) noted 20 species, in six genera of Chlorophyta, which were useful for nutritional flours, 20 species, in seven genera of Phaeophyta, which were useful as sources of alginates and about 28 species in 12 genera of Rhodophyta which were useful as sources of agar or carrageenan. He noted that uncontrolled exploitation would "exterminate many valuable species in a relatively short time", and recommended both the regulation of wild harvests and the development of methods for cultivating economic species.

The global review of algal resources by Michanek (1975) included some examples of agarophytes and carrageenophytes having been harvested as raw material for industrial processing, such as the export of *Gracilaria cornea* to the USA for agar extraction. These exports have since ceased.

Species of *Gracilaria* have received the most attention in assessments of commercial potential in the region. Taxonomy of many species remains problematic. Norris (1985) provided a key to species with economic potential. Ortiz Sotomayor and Almodóvar (1982) listed four out of 15 *Gracilaria* species found in Puerto Rico as having potential for commercial exploitation.

Yield and quality of agar extracts have been determined for many of the Caribbean *Gracilaria* spp. Most have extracts of poor gelling ability but a few are of commercial quality. Lahaye *et al*. (1988) reported that the properties of alkali-treated extracts from *G. mammillaris* from St. Lucia indicated a high quality agarose which was suitable for industrial and biotechnological applications. A study of five species from Barbados showed that only *G. cornea* (as *G. debilis*) was able to form a firm gel without treatment with alkali and was comparable to the weaker gels required by the food industry (Duckworth *et al.* 1971). Similar gel strengths were reported for this species in Venezuela (Rincones 1990). Alkali-treated extracts from *Gracilariopsis* sp. from Venezuela showed gel strengths around 1000g.cm^{-2} (Racca *et al.* 1993), probably the highest for a Caribbean gracilarioid. A programme to evaluate agars from Venezuelan species is currently underway (Murano *et al*. 1996).

In Cuba, a number of agarophytes were identified as having commercial potential (Sosa 1983). In particular, *Bryothamnion triquetrum* has been evaluated as a potential source of industrial agar. The extract yield and quality were reported to be suitable for biomedical applications (Areces 1990).

The carrageenophytes of the Caribbean, viz. *Eucheuma isiforme* and *Hypnea musciformis* have received some attention. *E. isiforme* is the only Caribbean species in the genus, and produces iota carrageenan. The species is been harvested commercially in Belize, where approximately 800kg (air-dry weight) are exported annually from the USA for use in health-food applications. The species was also harvested commercially in Antigua and Barbuda until the 1980's for traditional food applications in the region, but this has discontinued as a result of severe over-harvesting. Chemical composition and cultivation of *E. isiforme* have been extensively studied in Florida (Dawes 1987, Dawes and Koch 1988).

The economic potential of *Hypnea musciformis* has been investigated in Cuba (Estévez *et al.* 1985) and Venezuela (Muñoz *et al.* 1986). At one time the species was exported from Haiti to Denmark for carrageenan extraction (Renoux-Meunier 1978), but there is apparently no commercial use of the species in the region at present.

Despite the richness of the Caribbean seaweed flora, and the proximity to industrial processing facilities in North America and Europe, there has been little economic development of the region's seaweed resources. The most widespread use at present is the harvest of a limited number of red algae for the preparation of traditional drinks and puddings (Smith 1992). This traditional use is found primarily in the English-speaking islands, but also in a few Central American locations, including Honduras and Panama (Espinoza-Avalos 1994) where the habit was no doubt introduced by West Indian migrants. In most islands these algal species, and the drinks, are known as 'seamoss', but as Irish moss in Jamaica and simply as seaweed in Belize. The most important of these are *Gracilaria cornea*, *G. crassissima*, *G. domingensis*, an unidentified terete species with 'verrucosa-type' spermatangia, and *Eucheuma isiforme*. Clean, dry and bleached seamoss species fetch high prices, commonly retailing for around US$8 per kg.

Far less attention has been paid to brown algal resources, although species of *Sargassum* were evaluated as sources of alginic acid in Puerto Rico (Aponte de Otaola *et al.* 1983). The potential of both *Sargassum* and *Turbinaria* species is being investigated in Cuba (Areces 1995).

It seems that natural stocks of seaweeds of economic importance in the Caribbean are unable to support industrial exploitation. At present, even harvesting for traditional use within the region has led to a decline in stocks everywhere that they exploited. Further development must therefore be based on mariculture.

CULTIVATION OF SEAWEEDS IN THE CARIBBEAN

While the development of mariculture in the Caribbean has been slow in general, there have been a number of initiatives aimed at producing seaweeds for both the extraction industries and traditional uses.

Experimental cultivation of Caribbean seaweeds, as sources of phycocolloids, began in the 1970's. Using seed material from St. Martin, Barbaroux *et al.* (1984) attempted to cultivate *Eucheuma* spp. in Guadeloupe and Martinique. They concluded that economic returns would have been too low and that production would not have been competitive with Asian sources of carrageenophytes.

Pilot-scale farming of Caribbean agarophytes for possible industrial applications began a decade ago, in Venezuela, first with *G. cornea* (Rincones 1990) and subsequently with *Gracilariopsis* sp. (Rincones *et al.* 1992). The first cultivation method was based on large floating bamboo rafts. Seed plants were inserted into the lay of ropes, which were then strung across the rafts, in shallow in-shore areas. Problems of siltation, epiphytism and herbivory led to the development of a floating rope system that was established in deeper water further off-shore (Racca *et al.*

1993). Biomass yield, agar yield and agar quality are higher and siltation and epiphytism are both reduced, using the rope system with this species (initially reported as *G. lemaneiformis*, but later identified as *G. tenuifrons*, Dawes 1995). The productivity of this system was reported to be 50mt dry weight.ha^{-2}.y^{-1}.

Following an assessment of the potential use of seaweed resources in Cuba (Suarez 1984), a programme was developed to investigate the mariculture of *Gracilaria domingensis* and *Bryothamnion triquetrum.* Trials with *G. domingensis* were discontinued due to severe herbivory and low extract quality. Areces and Raúl Soberats (1992) evaluated various methods of vegetative propagation and found that the use of mesh bags reduced loss of material through fragmentation, but epiphytism adversely affected growth (Areces and Martínez-Iglesias 1993). In 1991, *Kappaphycus striatum* and *K. alvarezii* were introduced to Cuba from the Philippines. Cultivation trials were conducted to determine the appropriate environmental conditions for cultivation (Areces and Céspedes 1992) and the species were shown to have adapted successfully to Caribbean conditions.

The development of cultivation of the species used for food in the Caribbean began in St. Lucia in 1981 (Smith *et al.* 1984, Smith 1990). The approach taken was to develop low-cost, labour-intensive, methods that could be transferred to people in coastal communities. Various species of *Gracilaria* were grown successfully, but farmers chose to cultivate only the fastest-growing species, despite its relatively poor agar quality (Smith 1992). This is the unidentified "verrucosoid" species referred to above and known as "GT" (*Gracilaria* terete). All cultivation of this species, in St. Lucia and other islands to which it has been transferred, is based on vegetative propagation. Fronds are inserted in the lay of polypropylene rope. Farmers have tested various planting methods, including tying lines between mangrove stakes and suspension across floating bamboo rafts (Smith 1986). At present the most widely-used method involves lines of 10 - 15m anchored at each end and buoyed by a series of plastic bottles. This method has proved to more resilient to wave action than the raft system. With either system, the doubling time of this species ranges from 12 - 20 days.

A programme was recently completed in St. Lucia to identify a species suitable for the seamoss market that would be less susceptible to the seasonal appearance of epiphytes that either reduced the quality of the GT crop in many areas, or made cultivation impossible. Preliminary results with *Eucheuma isiforme* from Belize have shown that, under cultivation conditions, plants remain completely free of silt and epiphytes, and maintain a doubling time of 10 - 12 days (Smith unpublished data). Accordingly, commercial farmers in St. Lucia have begun to establish the species within their *Gracilaria* farms. Most recently, a seaweed cultivation programme has been started in Belize, based on native *E. isiforme*.

SEAWEED PROCESSING AND INDUSTRY IN THE CARIBBEAN

At present there is no facility for the industrial extraction of phycocolloids in the Caribbean. All processing is for the production of traditional concentrates and beverages. There is apparently no documentation of the history of this tradition but it dates back at least to the first half of the 19th Century. The commerce has developed informally and there are no accurate records of the quantities involved. However, the dried, bleached seaweeds fetch high prices and the harvest and processing is locally important to many coastal communities.

Until the 1980's, seamoss was marketed almost exclusively in a dried, bleached form. It was sold locally or exported to the more populous islands in the region where wild stocks had been depleted through over-harvesting. Over the past 15 years, processing facilities have been established on many islands and a wide variety of packaged and bottled seamoss products are now available. However, the supply of commercial species from wild stocks has declined over the same period and has limited the output from the smaller processing facilities that exist in many islands. The region's largest processor, in Jamaica, now relies entirely on imported carrageenophytes from the Philippines to meet the demand. Given the shortage of raw material for processed products in the region there is evidently potential for expansion of mariculture to meet the demand.

The development of cultivation for the extract industry will be limited to those areas of depressed economy with a very low income, such as the north-east of Venezuela, as described by Racca *et al*. (1993). It is unlikely that production for the phycocolloid industries would ever be viable in the countries where seaweeds are already used for food.

References

Aponte de Otaola, N.E., M. Diaz-Piferrer and H.D. Graham. 1983. Seasonal variations and anatomical distribution of alginic acid in *Sargassum* spp. found along the coasts of Puerto Rico. J. Agric. U.P.R. 47(4):464-475.

Areces, A.J. 1990. Mariculture of agarophytes in Cuba: present status, trends and perspectives. In: E.C. de Oliveira and N. Kautsky (Eds), Cultivation of seaweeds in Latin America. University of São Paulo, Brazil. pp. 105-109.

Areces, A.J. 1995. Recent advances on applied phycology in Cuba. Applied Phycology Forum 11(3):14-15.

Areces, A.J. and N. Céspedes. 1992. Potencialidad productiva de algunas caragenófitas del Indopacífico en aguas del Caribe. Bolitin de la red de acuicultura 6(2):13-16.

Areces, A.J. and J.C. Martínez-Iglesias. 1993. Dinámica, estacionalidad, y efectos de la epifauna colonizadora sobre el cultivo de la agarófita *Bryothamnion triquetrum* (Gmelin) Howe. Avicennia 10:43-59.

Areces, A.J. and L. Raúl Soberats. 1992. Optimization del cultivo *in situ* de *Bryothamnion triquetrum* (Gmelin) Howe, mediant evalución de diversos sistemas de sujeción. Ciencias Marina 18(2):65-76.

Barbaroux, O., R. Pérez and J.-P. Dreno. 1964. L'algue rouge *Eucheuma spinosum*: posibilités d'exploitation et de culture aux Antilles. Sci. Pêche 348:2-9.

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. Elsevier Science Publishers, Amsterdam, Netherlands. pp. 155-190.

Dawes, C.J. and E.W. Koch. 1988. Physiological acclimation of the Caribbean seaweeds *Eucheuma isiforme* and *Solieria filiformis* (Rhodophyta, Gigartinales) in culture. Caribbean Journal of Science 24(3-4): 89-94.

Dawes, C.P. 1995. Suspended cultivation of *Gracilaria* in the sea. Journal of Applied Phycology 7:303-313.

Díaz-Piferrer, M. 1961. Taxonomía, ecología y valor nutrimental de algas marinas cubanas:III. Algas productoras de agar. Inst. Cubano de Invest. Tecnol., ser. Estud. Trav. De Invest. No 17:1-84.

Diaz-Piferrer, M. 1967. Los recursos marinos de Venezuela. Algas de importancia económica. El Farol 29(222):18-22.

Díaz-Piferrer, M. 1969. Distribution of the marine benthic flora of the Caribbean Sea. Carib. J. Sci. 9(3-4):151-178.

Díaz-Piferrer, M. and Caballer de Perez. 1964. Taxonomía, ecología y valor nutrimental de algas marinas de Puerto Rico. Admin. Fomento Económico. Hato Rey, Puerto Rico. 145p.

Duckworth, M., K.C. Hong and W. Yaphe. 1971. The agar polysaccharides of *Gracilaria* species. Carbohydrate research 18:1-9.

Espinoza-Avalos, J. 1994. Seaweed as food in the Caribbean. Applied Phycology Forum 11(3):13.

Estévez, M.L., E. Oliván de la P. and L. Velásquez R. 1985. Estudio químico de algas marinas Cubanas. Revista Cubana de Química 1(1):87-93.

Lahaye, M., J.F. Revol, C. Rochas, J. McLachlan and W. Yaphe. 1988. The chemical structure of *Gracilaria* *crassissima* (P. *et* H. Crouan in Schramm *et* Mazé)P. *et* H. Crouan in Schramm *et* Mazé and *G. tikvahiae* McLachlan (Gigartinales, Rhodophyta) cell-wall polysaccharides. Botanica Marina 31:491-501.

Littler, D.S., M.M. Littler, K.E. Bucher and J.N. Norris. 1989. Marine plants of the Caribbean, a field guide from Florida to Brazil. Smithsonian Institution Press, , Washington, D.C. 272 pp.

McLachlan, J. and C.J. Bird. 1984. Geographical and experimental assessment of the distribution of *Gracilaria* species (Rhodophyta: Gigartinales) in relation to temperature. Helgoländer Meeresuntersuchungen 38:319-334.

Michanek, G. 1975. Seaweed resources of the ocean. FAO Fisheries Technical Paper No. 138. 127p.

Muñoz, O., H. Palma and G. Guevara. 1986. Agar content of two species of Rhodophyte algae, *Gracilaria domingensis* Sonder and *Hypnea musciformis* (Wulfen) Lamouroux from the Margarita Island coast, Venezuela. Conv. Nac. Asivac. 36:188.

Murano, E., R. Toffanin, C. Pedersini, A. Carabot-Cuervo, G. Blunden and R. Rizzo. 1996. Structure and properties of agar from two unexploited agarophytes from Venezuela. Hydrobiologia 326/327:497-500.

Norris, J.N. 1985. *Gracilaria* and *Polycavernosa* from the Caribbean and Florida: key and list of the species of economic potential. In: I.A. Abbott and J.N. Norris (Eds.), Taxonomy of Economic Seaweeds. Report no. T-CSGCP-011, California Sea Grant College Program, La Jolla. pp. 101-113.

Norton, T.A., M. Melkonian and R.A. Anderson. 1996. Algal biodiversity. Phycologia 35(4):308-326.

Ortiz-Sotomayor, A. And L.R. Almodóvar. 1982. El género *Gracilaria* (Gigartinales: Rhodophycophyta) y su posible potencial como agarófita a escala industrial. Carib. J. Sci. 18(1-4):49-57.

Racca, E., R. Hurtado, C. Dawes, C. Balladares and J. Rubio. 1993. Desarrollo de cultivo de Gracilarias en la Peninsula de Araya (Venezuela). In: J.A. `Zertuche González (Ed.) Situación actual de la industria de macroalgas productoras de ficocoloides en América Latina y el Caribe. Proyecto AQUILA II, Documento de Camp No.13. FAO, Rome, Italy. pp. 33-38.

Renoux-Meunier, A. 1978. Inventaire des algues marine des côtes d'Haïti. Rapport preliminaire de la mission effectuée pour le FAO. Project HAI/78/004: 16p.

Richardson, W.D. 1958. Preliminary investigations on the utilization of marine algae in the Caribbean. Abstr. Int. Seaweed Symp. 3:49-50.

Rincones, R.E. 1990. Experimental cultivation of an agarophyte alga: *Gracilaria cornea* in the northwest coast of Venezuela. In: E.C. de Oliveira and N. Kautsky, (Eds), Cultivation of seaweeds in Latin America. University of São Paulo, Brazil. pp. 65-67.

Rincones, R.E., J.N. Rubio and E.C. Racca. 1992. *Gracilaria* pilot farming in Venezuela. In: K.E. Mshigeni, J. Bolton, A. Critchley and G. Kiangi (Eds), Sustainable seaweed resource development in sub-Saharan Africa. University of Namibia, Windhoek. pp. 309-318.

Smith, A.H. 1986. A guide to seamoss cultivation in the West Indies. Caribbean Conservation Association, Barbados. 20p.

Smith, A.H. 1990. Commercial cultivation of *Gracilaria* spp. used for food in the West Indies. In: E.C. de Oliveira and N. Kautsky (Eds.), Cultivation of Seaweeds in Latin America. University of São Paulo, Brazil. pp. 75-78.

Smith, A.H. 1992. Seaweed cultivation in the West Indies. In: K. Mshigeni, J. Bolton, A. Critchley and G. Kiangi

(Eds.), Sustainable Seaweed Resource Development in Sub-Saharan Africa. University of Namibia, Windhoek. pp. 337-351.

Smith, A.H., K. Nichols and J. McLachlan. 1984. Cultivation of seamoss(*Gracilaria*) in St. Lucia, West Indies. Hydrobiologia 116/117:249-251.

Sosa, E.M. 1983. Posibilidades de utilización industrial de los agarófitas de Cuba. Rep. Inv., Inst. Bot., Acad. Cien. Cuba 4:1-25.

Suarez, A. 1984. Análisis de las perspectivas de la utilización del macrofitobenthos de la plataforma de Cuba. Arch. Min. Ind. Pesq.: 5p.

Taylor, W.R. 1960. Marine algae of the eastern tropical and subtropical coasts of the Americas. University of Michigan Press, Ann Arbor.

Wynne, M.J. 1986. A checklist of benthic marine algae of the tropical and subtropical western Atlantic. Canadian Journal of Botany 64(10):2239-2281.

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