An Annotated Bibliography on the current status and product development of *Caulerpa* in Fiji, Samoa and Tonga

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Preface

Sea grapes (*Caulerpa* species. Chlorophyta) are widely consumed in the Pacific as a delicacy, a salad and as an addition to many dishes. The traditional harvesting and consumption of sea grapes in the Pacific may well have had their origins among the South-East Asian peoples who migrated to and colonized the Pacific Islands 3-4,000 years ago (McHugh, 2003). Sea grapes are consumed throughout the region by Melanesian, Micronesian and Polynesian peoples.

The Fijian name most commonly used is nama (South 1993a-c), the Samoan name is limu fuafua and the Tongan name is tangau or limu fuafoa. In Fiji, Samoa and Tonga, with some local exceptions, Caulerpa racemosa (Forsskål) J. Agardh var. uvifera (Turner) J. Agardh (1873: 35), as illustrated in Meñez and Calumpong (1982: 9), is the most commonly harvested variety.

This annotated bibliography on *Caulerpa* was developed as part of the Scoping Study for PARDI 2010/002 prepared by South, G.R., et al., 2011. *Scoping study for Caulerpa (Sea Grapes)*. Suva: Institute of Marine Resources, School of Marine Studies, FSTE, USP. References are specific to *Caulerpa* in the Pacific, or are directly related to the project. Most of the references are annotated.

References

Agardh, J.G. (1873). Till algernes systematik. Nya bidrag. *Lunds Universitets Års-Skrift, Afdelningen for Mathematik och Naturvetenskap* 9(8): 1-71.

McHugh, D.J. (2003). *Seaweeds used as human food*, In: A Guide to the Seaweed Industry. FAO Fisheries Technical Paper 441: 73-90.

Meñez, E.G. & Calumpong, H.P. (1982). The genus *Caulerpa* from Central Visayas, Philippines. *Smithsonian Contributions to the Marine Sciences 17*

An Annotated Bibliography on the current status and product development of *Caulerpa* in Fiji, Samoa and Tonga

Abbott, I.A. & Williamson, E.H. 2nd Ed. (1974). *Limu: an ethnobotanical study of some edible Hawaiian seaweeds.* Lawai, Hawaii: Pacific Tropical Garden.

Sea grapes are consumed throughout the region by Melanesian, Micronesian and Polynesian peoples. It is not a preferred food item in Hawaii however, other edible seaweeds called limu are consumed. In the olden times, limu was the third component of a nutritionally balanced diet consisting of fish and poi. While limu primarily supplied variety and interest, they also added significant amounts of vitamins and other mineral elements to the diet. Not only are limu sold in supermarkets, but original Hawaiian methods of preparation are still used. Limu are served as vegetables in stews, poke, and salads; as condiments, adding zest to the meals; and are an important source of minerals, and vitamins, including vitamins A, C, B12, and riboflavin.

Agardh, J.G. (1873). Till algernes systematik. Nya bidrag. *Lunds Universitets Års-Skrift, Afdelningen for Mathematik och Naturvetenskap* 9(8): 1-71.

Original documenting of the *Caulerpa racemorsa* (Forsskal) J.Agardh, by its discoverer. The type species (lectotype) of the genus *Caulerpa* is *Caulerpa prolifera* (Forsskål) J.V.Lamouroux. This name is of an entity that is currently accepted taxonomically. Common names used in commerce, often for edible algae: sennarizuta (Japan); nama (Fiji); ar-arusip (Cagay) and latu (Cebu).

http://www.algaebase.org/SpeciesDetail.lasso?species_id=1221

Alarif, W.M., Abou-Elnaga, Z.S., Ayyad, S.E.N. & Al-Lihaibi, S.S. (2010). Insectidal metabolites from the green alga *Caulerpa racemosa. CLEAN: Soil, Air, Water 38* (5-6): 548-557.

The purpose of this study was to isolate and identify metabolites from the green alga *Caulerpa racemosa* and assay them against the medically important mosquito *Culex pipiens*. The chloroform/methanol extract of the green alga *C. racemosa* afforded a number of metabolites, as caulerpin (1), caulerpynyne (3), phytol (4), 10-keto-3,7,11-trimethyldodecanoic acid (5), a number of unsaturated compounds in addition to caulerpinic acid (2), the alkaline hydrolysis product of caulerpin. In summary, the larvicidal activity of *caulerpin* and *caulerpinic acid* were tested against *C. pipiens* mosquito (filarial victor) leading to the identification of novel effective mosquitocidal compounds.

Bold, H. C., & Wynne, M. J. (1978). *Introduction to the algae: Structure and reproduction*. (2nd Ed.). Englewood Cliffs, N.J: Prentice-Hall.

Comprehensive text that examines the morphology and physiology of algae. Provides an easy to read introductory chapter about the algae, followed by detailed sections on the Cyanophyta (blue-green 'algae', or, cyanobacteria), Prochlorophyta, Chlorophyta (green algae), Charophyta (stoneworts), Euglenophyta, Phaeophyta (brown algae), Chrysophyta, Pyrrhophyta (dinoflagellates), Rhodophyta (red algae) and Cryptophyta (cryptomonads).

Chamberlain, A. (1997). *Export potential of the edible seaweed Caulerpa racemosa from the Pacific*. Suva: The University of the South Pacific. Project 6607-6301-70766-00.

A brief five-page final project document summarizing the objectives, budget, research methods, results and objectives achieved after culturing *C. racemosa* and studying the effect of different environmental variants on its growth. The research report that properly discusses its findings is titled '*Culture and shelf-life extension of Caulerpa racemosa.'*

Chamberlain, T. (1998). Culture and shelf-life extension of *Caulerpa racemosa*. *South Pacific Journal of Natural Science 16*: 11-19.

The edible seaweed *Caulerpa racemosa* has the potential to be exported on a sustainable basis to Japan and other overseas markets if the shelf-life can be extended. In Japanese restaurants it is consumed fresh as a side dish. Earlier attempts to air freight fresh C. racemosa to Japan have resulted in rejection of 100% of the produce. This study aimed to firstly culture C. racemosa and to study the effect of different environmental variants on its growth. It was found to prefer attachment to PVC tubes as opposed to sandy/clay substratum. Secondly the affect of chemical dips (Al, Ca and K) and temperature (5 degree C, 10 degree C and 25 degree C) on the quality of C. racemosa was examined. The quality of the product was then assessed by total plate counts and testing for the presence of coliforms. Little improvement in quality was achieved by chemical dips or temperature alteration, although the aluminium dip at temperatures <15 degree C resulted in the lowest bacterial loads.

Chamberlain, A. & Pickering, T. (1998). *Post-harvest handling of Caulerpa racemosa for artisanal and export fisheries in Fiji.* In: 'Fisheries and Marine Resources' Marine Studies Programme Technical Report 3: 90-102. Papers presented at Symposium 8, VIIIth Pacific Science Inter-Congress, the University of the South Pacific, Fiji, 13-19 July, 1997.

Caulerpa racemosa, an edible seaweed, has the potential to be farmed in Fiji and exported on a sustainable basis to Japan where it can be sold fresh to restaurants if the quality is good. Early attempts to air freight fresh *C. racemosa* to Japan have resulted in rejection of 100% of produce. This study aimed to examine current *C. racemosa* artisanal handling practices in Fiji and to trial various handling methods in

an attempt to improve the quality of the product exported to Japan. Existing artisanal and export practices were monitored, temperature/time profiles constructed and bacterial counts conducted. Various handling trials which examined the effects of packaging material, the ratios of seawater to seaweed, and the effect of healing time on the wound were then conducted. These trials simulated the temperature/time profiles of the export product. The quality of the product was then assessed by doing total plate counts (TPC), testing for the presence of coliforms and evaluation by a sensory panel comprising 5 Japanese and 5 Fijians. The results revealed that the current artisanal practices produced better quality product than any of the innovative handling trials. Some errors may have occurred due to bad temperature tracking of the incubator and rough weather damaging some of the seaweed samples. The current artisanal practice would be unacceptable for export because it results in rejection rates of greater than 50% of the produce.

Clifton, K.E. & Clifton, L.M. (1999). The phenology of sexual reproduction by green algae (Bryopsidales) on Caribbean coral reefs. *Journal of Phycology 35*: 24-34.

Recent field observations of highly organized, species- and sex-specific patterns of synchronous gamete release by tropical green algae (Bryopsidales) invite a variety of future studies into the ecology and life histories of an important component of tropical reef communities. This paper details sexual reproduction by 22 algal species within five common genera (*Caulerpa, Halimeda, Penicillus, Rhipocephalus,* and *Udotea*), including field observations on the spatial occurrence, timing, and color changes associated with fertility, data on gamete size and behavior, and descriptions of coincident changes in local species abundances. Ecologically ephemeral episodes of sexual reproduction involved macroscopic changes that reliably indicated developmental state and sexual identity. The time from onset of fertility to gamete release was 36 h (*Halimeda*), 48 h (*Caulerpa, Penicillus,* and *Rhipocephalus*), or 96 h (*Udotea*). All species produced flagellated, negatively buoyant, anisogamous gametes. Microgametes of all species were similar in size; however, considerable species-specific differences were seen in the size of macrogametes. In *Caulerpa, Halimeda,* and *Udotea flabellum (*Ellis and Solander) Lamouroux, the volumetric ratio of macrogametes to microgametes ranged from 2:1 to 45: 1, whereas more extreme levels of anisogamy (104: 1) were observed for *Penicillus* spp., *Rhipocephalus phoenix* (Ellis and Solander) Kuetzing, and other *Udotea* spp. The macrogametes of *Caulerpa* and *Halimeda* showed strong positive phototaxis. Although only a subset (generally about 5%) of the thalli representing each species released gametes on a given morning, most species underwent bouts of sexual reproduction on numerous occasions during the seasonal peak of reproductive activity (March–May). As might be expected for holocarpic species, dramatic declines in local algal abundance coincided with these periods. The density of sand-dwelling genera such as *Penicillus* fell by 80–90% during this 3-month period in 1997. Similar declines in the cover of sprawling species such as *Caulerpa racemosa* ((Forsskal) J. Agardh) exposed large (35–50 m2) sections of previously overgrown reef substrate.

http://bio.classes.ucsc.edu/bioe120/class%20readings%20pdf/clifton%20and%20clifton%201999.pdf

Coppejans, E. (1992). Marine Algae of Papua New Guinea (Madang Prov.): 2. A revised and completed list of *Caulerpa* (Chlorophyta – *Caulerpales*). *Blumea 36*: 383-410.

The study of marine macroalgae collected in N. Papua New Guinea in 1980, 1986, 1988 and 1990 resulted in 14 species (29 entities) of /*Caulerpa: C. biserrulata, C. cupressoides/ (5 ecads), /C. elongata/ (2 ecads), /C. filicoides var. andamanensis, C. lentillifera, C. manorensis, C. microphysa, C. opposita, C. racemosa/ (8 ecads), /C. serrulata/ (3 ecads), /C. sertularioides, C. taxifolia/ (2 ecads),/C. verticillata/, and /C. webbiana/ ecad /disticha/*. An identification key is added.

Coppejans, E. & Meinesz, A. (1988). Marine Algae of Papua New Guinea (Madang Prov.): 1. *Caulerpaceae* (Chlorophyta – *Caulerpales*). *Blumea 33*: 181-196.

In view of preparing a flora of the seaweeds of N. Papua New Guinea, material was collected by scuba-diving along the coast of Madang Province in June-August 1980 and July-August 1986. The *Caulerpales* are the first group to be studied. Thirteen taxa belonging to the genus /*Caulerpa/* are described and illustrated; ecological and biogeographical data are added. The list includes /*C. brachypus, C. elongata, C. filicoides/ var. /andamanensis, C. lentillifera/ var. /kilneri, C. manorensis, C. microphysa, C. opposita/ sp.nov., /C. racemosa/ var. /clavifera, C. racemosa/ var. /peltata, C. serrulata/ var. /serrulata, C. serrulata/ var. /pectinata, C. sertularioides*/, and /*C. verticillata/.*

Enomoto, S. & Ohba, H. 1987. Culture studies on *Caulerpa* (Caulerpales, Chlorophyceae). I. Reproduction and development of *C. racemossa* var. *laetevirens. The Japanese Journal of Phycology. 35: 167-177.*

Guiry, M.D. & Guiry, G.M. 2011. *AlgaeBase*. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org; Searched on 31 January 2011.

AlgaeBase is a database of information on algae that includes terrestrial, marine and freshwater organisms. At present, the data for the marine algae, particularly seaweeds, are the most complete. For convenience, we have included the sea-grasses even though they are flowering plants.

http://www.algaebase.org/

Higa, T. & Kuniyoshi, M. (2000). Toxins associated with medicinal and edible seaweeds. *Journal of Toxicology: Toxin Reviews 19* (2): 119-137.

Toxins associated with medicinal and edible seaweeds are reviewed with an emphasis on chemistry. The red alga *Digenea simplex* has been used for the treatment of roundworm disease for centuries. Its active principle is kainic acid (1). The related domoic acid (3) is a constituent of another red alga, *Chondria armata,* used for the same purpose. These compounds known as kainoids are potent neurotoxins and excitatory amino acids. Kainoids are important tools in

neurophysiological research. Domoic acids are also produced by diatoms and were responsible for the shellfish poisonings known as amnesic shellfish poisonings which occurred in Canada in 1987. *Caulerpin* (13) and *Caulerpicin* (15) have been described as toxic constituents of edible species of the green algal genus *Caulerpa*, but evidences in later studies indicate that they have no acute toxicity. *Caulerpin*, which has a structure related to auxin, promotes plant growth. *Caulerpenyne* (16), a toxic constituent of *Caulerpa taxifolia* and other inedible species, has been evaluated for its ecotoxicological effect in the Mediterranean where *C. taxifolia* bloomed explosively. Three different classes of compounds have been identified in the poisonings with species in the genus *Gracilaria*. They are prostaglandin E sub (2) (17) from *G. verrucosa* in Japan, aplysiatoxins and related compounds (19-23) from *G. coronopifolia* in Hawaii, and polycavernosides (26-30) from *G. tsudai* in Guam.

Horstmann, U. (1983). Cultivation of the green alga, *Caulerpa racemosa* in tropical waters and some aspects of its physiological ecology. ***Aquaculture 32*(3-4): 361-371.**

Caulerpa racemosa var. *occidentalis*, a benthic siphonaceous green alga, has its natural habitat in the sublittoral of tropical shallow water reef areas. In the Philippines, where *C. racemosa* is esteemed as a vegetable, it is cultivated in artificial ponds in the intertidal mangrove zone. The culturing of *C. racemosa* in ponds is described. In addition to a comparison of the ecological conditions in the natural habitat and the culture ponds, the responses of *C. racemosa* to the most important environmental factors have been studied. In contrast to the conditions in its natural habitat, *Caulerpa* in culture ponds is subjected to considerable changes of environmental factors such as salinity, temperature, light and pH. Experiments show that fluctuations of the parameters investigated in the culture ponds are usually within the physiological tolerance of *Caulerpa*. Under extreme conditions, however, detrimental effects may occur. The possibilities of controlling such factors are discussed.

Klein, J. & Verlaque, M. (2008). The Caulerpa racemosa invasion: a critical review. *Marine Pollution Bulletin 56*(2): 205-225.

Caulerpa racemosa var. cylindracea is a marine Chlorophyta introduced into the Mediterranean Sea from south-western Australia. Since 1990, it has been invading the Mediterranean Sea and the Canary Islands, raising ecological problems. Although this invasion event can be considered as one of the most serious in the history of species introduced into the Mediterranean Sea, C. racemosa has not triggered as much attention as the famous "killer alga"*Caulerpa* taxifolia. The aim of the present study was: (i) to summarize the current state of knowledge with regard to the distribution, the various biological and ecological characteristics of the introduced C. racemosa and its impact on the Mediterranean coastal environment; (ii) to discuss the various hypotheses regarding the explanation for its rapid and successful spread; (iii) to investigate the disparity in the treatment of C. racemosa and *Caulerpa* taxifolia invasions; and (iv) to outline future research needs.

Lal A., Vuki V. (2010). The historical development of seaweed farming, including roles of men and women, and prospects for its future development in Fiji. *SPC Women In Fisheries Information Bulletin 21*: 11-16.

Over 200 seaweed species occur naturally in Fijian waters (Chapman 1977). Three seaweed species were particularly important in traditional subsistence fisheries; these were recorded by Ohno and Critchley (1993) as *Caulerpa* spp. (Nama), *Gracilaria* spp. (Lumi cevata) and *Codium* spp. (Sagati). However, most of these species are not cultivated in Fiji. This article presents an overview and assesses the historical developmental of seaweed farming in Fiji since 1976. Particular reference is given to *Kappaphycus alvarezii* (still referred to in the industry as *Eucheuma cottonii* species), as it has dominated the Fiji seaweed industry. Statistics were limited in some areas, especially after 1988; nevertheless, through interviews, surveys and literature review, information on the seaweed industry in Fiji was gathered and assessed. Seaweed farming was initially introduced to Fiji in 1976 from the Philippines, and was re-introduced in 1984. The first commercial production began in 1986. In this report, we provide historical details on areas of where farming took place, numbers of farms, marketing, farming methods, production, exports, prices and assistance provided. We also provide an overview of the current status of Fiji's *Kappaphycus* industry and the relative roles of men and women in rural seaweed farming.

http://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/WIF/21/WIF21_11_Lal.pdf

McHugh, D.J. (2003). *Seaweeds used as human food*, In: A Guide to the Seaweed Industry. FAO Fisheries Technical Paper 441: 73-90.

For several centuries there has been a traditional use of seaweeds as food in China, Japan and the Republic of Korea. As people from these countries have migrated around the world, this custom has moved with them, so that today there are many more countries where the consumption of seaweed is not unusual. Coastal dwellers in tropical climates such as Indonesia and Malaysia have also eaten fresh seaweeds, especially as salad components. In recent years there has been a strong movement in France to introduce seaweed into the European cuisine, with some success, although it is still regarded as an exotic component of the menu. It has gained more acceptance in regions like California and Hawaii, where communities of Japanese are larger and the taste for seaweeds spreads out into the surrounding population through finding them on restaurant menus and supermarket shelves. On the east coast of United States of America and Canada, some companies have begun cultivating seaweeds onshore, in tanks, specifically for human consumption, and their markets are growing, both in those two countries and with exports to Japan. Ireland and Northern Ireland are showing a renewed interest in seaweeds that were once a traditional part of the diet. Already on the market in many countries around the world are cooking books incorporating recipes using "sea vegetables". With the current trend for consumers to embrace organically grown foods and "natural" foods from clean environments, seaweeds should receive an increasing acceptance.

ftp://ftp.fao.org/docrep/fao/006/y4765e/y4765e05.pdf

Meñez, E.G. & Calumpong, H.P. (1982). The genus *Caulerpa* from Central Visayas, Philippines. *Smithsonian Contributions to the Marine Sciences 17*

This taxonomic study of *Caulerpa* shows 20 taxa occurring in Central Visayas, Philipines, including *Caulerpa reyesii*, new species. Of these, three are newly reported from the Philippines and seven taxa are new records from Central Visayas.

http://www.sil.si.edu/eresources/silpurl.cfm?purl=8474560

Nuber, N., Gornick, O., Lauc, G., Bauer, N., Juljevik, A., Papes, D. & Zodos, V. 2007. Genetic evidence for the identity of *Caulerpa racemosa* (Forsskål) J. Agardh (Caulerpales, Chlorophyta) in the Adriatic Sea. *European Journal of Phyclology* 42:113-120.

Novaczek I. (2001). *A guide to the common edible and medical sea plants of the Pacific Islands.* Noumea, New Caledonia: Secretariat of the Pacific Community.

In this guide seaweeds are referred to as sea plants, or, when they are edible, as sea vegetables. Sea plants are used by humans for food, medicine, body care products, animal feed, and fertilizer for agriculture. There are more than 500 sea plants in the Pacific Islands, and perhaps over 100 of these are recognized, either locally or in Asia, as being edible. There are three main groups of sea vegetables: red, green and brown. The following guide describes twenty-six genera of edible sea plants, and provides advice on where and when to collect them. Some of these genera contain more than one edible species, and each species varies in appearance and preferred habitat. Descriptions are given as well as how they can be prepared as food and the known medicinal uses of each plant. Almost all of the sea plants featured in this guide can be assumed to occur throughout the region; however, suitable habitat is a critical factor. This training guide also provides advice on safe and sustainable harvesting, preservation methods, ideas for small business products based on sea plants and a guide for developing community workshops.

http://www.spc.int/DigitalLibrary/Doc/FAME/Manuals/Novaczek_01_MedicinalSeaPlants.pdf

Novaczek I. (2001). *Sea plants*. Noumea, New Caledonia: Secretariat of the Pacific Community. Community Fisheries Training Pacific Series 3.

This book provides a short course on the common edible and medicinal sea plants of the South Pacific and their uses. The aim is to increase the knowledge of the various uses for sea plants and to assist people in identifying the many edible and medicinal sea plants in the region. Recipes are presented as examples of how to cook with sea plants. Most of the recipes can be altered to suit local tastes and available resources. This book is also designed to provide information on how healthy and nutritious sea vegetables are, to promote its use in communities where fresh vegetables are difficult to obtain, to enable readers to develop workshops on sea plants in their own communities and to use sea plants for agricultural aids and for economic purposes.

http://www.spc.int/DigitalLibrary/Doc/FAME/Manuals/Novaczek_01_SeaPlants.pdf

Panayotidis, P. & Žuljevic, A. 2001. Sexual reproduction of the invasive green alga *Caulerpa racemosa* var *occidentails* in the Mediterranean Sea. *Oceanolgica Acta 24: 199-203.*

Pickering, T. (2006). Advances in seaweed aquaculture among Pacific Island Countries. *Journal of Applied Phycology 18*(3-5): 227-234.

Recent developments in the seaweed aquaculture industries of Pacific islands are reviewed from the perspective of technical, production, geographic, marketing, species-diversification, socio-economic and institutional-support advances. Successful commercial aquaculture of seaweeds in the Pacific island region is presently based on two species, Kappaphycus alvarezii in Kiribati, Fiji and Solomon Islands, and Cladosiphon sp. in Tonga. It is possible that other candidate species could be considered for aquaculture for food (e.g. *Caulerpa* racemosa or Meristotheca procumbens) or extraction of agar (Gracilaria), although further research on the technical feasibility of aquaculture methods to produce sufficient tonnage, and particularly on their marketing, is needed. While the Pacific island region may be environmentally ideal for seaweed aquaculture, the limitations of distance from main centres and distance from markets, vulnerability to world price fluctuations, and socio-economic issues, make it unlikely that the Pacific Island region will ever rival the scale of Asian seaweed production. Regional seaweed farming can nevertheless make a useful contribution to supplement other sources of income, and can be an important economic boost for isolated outer islands where few alternative income-generating opportunities exist.

Pickering T. & Mario S. (1999). *Survey of commercial seaweeds in South-East Viti Levu (Fiji Islands): a preliminary study on farming potential of seaweed species present in Fiji.* Suva, Fiji: FAO South Pacific Aquaculture Development Project Phase II.

The findings are presented of a survey of commercial seaweeds in Fiji conducted in the framework of the FAO South Pacific Aquaculture Development Project. The survey aimed to determine the distribution, abundance and seasonality of economic seaweeds in Southeast Viti Levu and also determine whether there would be any demand for them as sources of phycocolloids. The most common economic seaweeds found in Suva Harbour and Tailevu were *Gracilaria maramae, G.edulis, Hypnea pannosa* and *Caulerpa racemosa*. The survey showed that the species of seaweed so far evaluated for commercialization in Fiji fall into 2 categories: those which can be cultivated but presently have no export markets (Gracilaria, Hypnea) and those which have ready markets but cannot easily be cultivated/transported (Meristotheca, *Caulerpa*).

Price, I.R. (2011) A taxonomic revision of the marine green algal genera *Caulerpa* and *Caulerpella* (Chlorophyta, Caulerpaceae) in northern (tropical and subtropical) Australia. *Australian Systematic Botany* 24: 137-213

A detailed taxonomic revision of the siphonous marine green algal genus C*aulerpa* J.V.Lamour. in northern (tropical and subtropical) Australia, covering mainland shores, continental islands, coral reefs and offshore territories, is presented. Sixteen

species and 10 varieties of *Caulerpa* are described and illustrated. One variety, *C. cupressoides* var. *urvilleana* (Mont.) I.R.Price is a new combination. A lectotype is proposed for *C. racemosa* (Forssk.) J.Agardh var. *macrodisca* (Decne) Weber Bosse. One species of Caulerpaceae long included in *Caulerpa*, but more recently placed in a separate genus, *Caulerpella*, as *C. ambigua* (Okamura) Prud'homme & Lokhorst, is also treated for completeness. The present publication will complement Womersley's (1984) account of southern Australian taxa of *Caulerpa*.

Ruitton, S., Javel, F., Culioli, J.-M., Meinesz, A., Pergent, G. & Verlaque, V. (2005). First assessment of the *Caulerpa racemosa* (Caulerpales, Chlorophyta) invasion along the French Mediterranean coast. *Marine Pollution Bulletin 50*(10): 1061-1068.

The introduced green alga *Caulerpa racemosa* var. *cylindracea* has been rapidly spreading in the Mediterranean Sea since 1990. It was first observed in France in 1997 (Marseilles). In early 2004, the stretch of the French Mediterranean coastline and the surface area affected by the invasion were estimated at about 83 km and 4014 ha, respectively. The depth range of colonized areas was usually 10–35 m depth. Shallow (0–10 m) and deep (down to 40 m) dense meadows were rarely observed. In contrast to the dead matte of *Posidonia oceanica*, which constituted the most widely colonized substratum, dense *P. oceanica* meadows and fine sand with large ripple-marks were not invaded. Few rocky areas were colonized and coarse sand bottoms were usually colonized below 20 m depth. All the colonized areas were exposed to human activities and more than 40% were fishing areas. Mild climate, suitable substrata, presence of vectors of dispersal and absence of efficient biological control make the French Mediterranean coast particularly vulnerable to the further spread of the alga.

Santos, G.A. & Doty, M.S. (1971). Constituents of the green alga Caulerpa lamourouxii. *Lloydia 34*(1): 88-90.

Caulerpin, ***caulerpicin***, palmitic acid, Beta-sitosterol and a triterpene were isolated quantitatively from C. lamourouxii. The triterpene (C sub(30)H sub(50)O), melting point 280 degrees, was identified as taraxerol from its infrared and mass spectra and by comparative TLC and mix-melting point determination with an authentic sample.

Silva, P.C., Meñez, E.G. & Moe, R.L. (1987). Catalog of the benthic marine algae of the Philippines. *Smithsonian Contributions to Marine Science 27*

All published records of benthic marine algae from the Philippines are assembled in a catalog with the taxa arranged according to an assumed phylogenetic scheme to the rank of family. The taxonomic framework takes into consideration recently published opinions. Each taxonomic synonym is accompanied by a citation of the author who first proposed the synonymy. Additional taxonomic and nomenclatural notes are provided where deemed useful. Type localities are indicated for all accepted names and taxonomic synonyms.Cyanophyceae (blue-green algae) comprise 19 genera with 61 species. They are arranged according to the Geitlerian system, accompanied by reconciliation with the Drouetian system. Their nomenclature is based on a 1753 Linnaean starting point rather than the later

starting points specified by the International Code of Botanical Nomenclature.Rhodophyceae (red algae) comprise 130 genera with 506 specific or infraspecific taxa, of which 35 have Philippine type localities.Phaeophyceae (brown algae) comprise 23 genera with 154 species or infraspecific taxa, of which 27 have Philippine type localities.Chlorophyceae (green algae) comprise 37 genera with 251 species or infraspecific taxa, of which 20 have Philippine type localities.Portieria Zanardini 1851 is adopted in place of Chondrococcus Kützing 1847, Eupogodon Kützing 1845 in place of Dasyopsis (Montagne) Montagne 1847, and Hincksia J.E. Gray 1864 in place of Giffordia Batters 1893. In addition, new binomials are proposed in Gelidium, Halymenia, Callophyllis, Sporolithon, Gracilaria, Ceramium, Polysiphonia, and Hormophysa.The catalog is preceded by a brief history of Philippine phycology.

http://www.sil.si.edu/eresources/silpurl.cfm?purl=15631747

South, G.R. (1993a). *Seaweeds,* In: Wright, A. & Hill, L. (eds.). Nearshore Marine Resources of the South Pacific: information for fisheries development and management. Suva: University of the South Pacific, Institute of Pacific Studies, pp. 683-710.

The seaweeds in the Pacific islands region are not widely understood and their potential as a resource has been scarcely developed. Tropical seaweeds have long been utilized by humans as food, medicines, and ceremonial objects and for ornaments. There is a significant potential for subsistence seaweed gatherers to cultivate edible seaweed species in the South Pacific. The author provides an overview of the seaweed resources of this region. The characteristics, distribution, diversity, and life history of seaweeds are discussed. Aquaculture of seaweeds has been practiced in some Pacific island countries. The author discusses the farming of Eucheuma species, the farming technology and practices, and the evolution of carrageenan industry in the context of economic importance to the countries.(DBO)

http://www.spc.int/DigitalLibrary/Doc/FAME/Reports/South_93_seaweeds.pdf

South, G.R. (1993b). Edible seaweeds of Fiji: an ethnobotanical study. *Botanica Marina 36*(4): 335-349.

Seven taxa of seaweeds feature in the diet of native Fijians: ***Caulerpa*** racemosa, ***Caulerpa*** racemosa var. occidentalis, Codium bulbopilum, Hypnea pannosa, Gracilaria sp., Solieria robusta, and Acanthophora spicifera, with the preferred species being ***Caulerpa*** and Hypnea. A survey of the taxonomy and nomenclature of the edible species is provided, together with the Fijian names for the species, a description of harvesting, marketing and the socio-economic role of seaweeds in Fijian society. The harvesting, sale and consumption of edible seaweeds is almost exclusively an activity of women and girls from the native Fijian (Melanesian) population, and is organized through family and village groups in a cooperative manner. Seaweeds are regarded as a delicacy by the Fijians, who consume them using a variety of recipes, which are described. The volume and value of the crop is summarized for the period 1981-1991; up to 36 metric tonnes of seaweeds, valued at

FJ$50 000 (US$32 000) per annum are sold in Fijian Municipal Markets and other outlets.

South, G.R. (1993c). Edible seaweeds – an important source of food and income to indigenous Fijians. *NAGA: the ICLARM Quarterly 16(2-3)*: 4-6.

The increasing harvest of 7 edible seaweeds in Fiji and their importance to the economy of indigenous Fijians are discussed. Traditional methods in the collection, preparation and consumption of seaweeds by the indigenous Fijians are also presented.

South, G.R. and A.D.R. N'Yeurt. (1993). Contribution to a catalogue of benthic marine algae of Fiji. 2. *Caulerpa* and *Caulerpella* (Bryopsidales, Chlorophyta). *Micronesica 26*(2): 109-138.

South, G.R. & Pickering, T. (2006). *The seaweed resources of the Pacific Islands.* In: Critchley, A.T., Ohno, M. & Largo, D.B. Wokingham, UK: World Seaweed Resources [DVD Rom]

This interactive multimedia DVD-ROM of which the 'Seaweed resources of the Pacific islands' is a part of, was compiled over a three year period and incorporates the expertise of almost 150 authorities from all over the world. The extensive information is organized in to a number of categories covering cultivation, farming, utilization, worldwide resources, socio-economics, recent developments in ecology, and applied phycology. The subjects are covered in detail and include vivid examples ranging from food and cosmetics to medicine, with examples from major production centers worldwide, including practical aspects of modern farming. The information is enriched by numerous high quality pictures and exclusive video footage. Extensive web reference links are provided to help locate additional information.

South, G.R. & Skelton, P.A. (2003). Revisions and additions to *Caulerpa* (Chlorophyceae, Caulerpaceae) from the Fiji Islands, South Pacific. *Australian Systematic Botany 16*(4): 539-548.

Twenty-three taxa of *Caulerpa* Lamouroux are listed from the Fiji Islands, including *Caulerpa* reniformis sp. nov. and four taxa newly recorded [*Caulerpa* biserrulata Sonder, *Caulerpa* nummularia Harvey ex J.Agardh, *Caulerpa* racemosa var. lamourouxii (Turner) Weber-van Bosse and *Caulerpa* webbiana f. disticha Vickers]. A further four taxa are listed as Species inquirendae [C. crassifolia (C.Agardh) J.Agardh, C. juniperoides J.Agardh. C. mexicana var. pluriseriata W.R.Taylor and C. remotifolia Sonder]. A revised key to the species of *Caulerpa* from the Fiji Islands is presented. Verification of records is based on the personal collections of the authors and specimens housed in the Phycological Herbarium, South Pacific Regional Herbarium (SUVA-A), the University of British Columbia (UBC), the Bernice P. Bishop Museum (BISH) and the University of California at Berkeley (UC).

South, G.R. & Skelton, P.A. (2003). Catalogue of the marine benthic macroalgae of the Fiji Islands, South Pacific. *Australian Systematic Botany 16*(6): 699-758.

A catalogue of the marine benthic macroalgae of Fiji is provided. All records are fully referenced, and type localities and local distributions (accompanied by listings of voucher specimens) are provided. Taxonomic notes are also included where appropriate. Records from SUVA-A, UC and BISH examined by the authors, together with updates from recent publications, form the substance of the report. A total of 448 taxa are included, comprising 136 Chlorophyta, 46 Phaeophyta and 266 Rhodophyta. This represents an increase of 116 new records since 1996, of which 39 are newly reported by the authors, and the remainder are recently published records from the Suva Lagoon (29) and the Great Astrolabe Reef and Lagoon (48). Also included are a total of 36 nomenclatural changes made since 1996, a compilation of 33 uncertain records, and a list of 34 species with type localities in Fiji, Samoa and Tonga. Apart from the far more extensive region of Micronesia, the flora of Fiji is the richest in the south and central Pacific Islands.

Tanduyan, S.N., Gonzaga, R.B. & Benzig, V.D. (2006). *Off-bottom culture of Caulerpa lentillifera Ag. (Chlorophyta) in three different water levels in three different sites using different culture media in the marine waters of San Francisco, Cebu, Philippines.* Laguna, Phillipines: APCAB College.

Caulerpa lentillifera has been traditionally reared in the bottoms of the fishponds. It was reared in Mactan Island, Cebu, Philippines in ponds, and is considered one of the export commodities because of its high demand. The conversion of mangroves into ponds has been banned in the Philippines, leaving interested farmers with no place for planting. Thus this research on the off-bottom culture of this alga was conducted in order to study its growth in an open and natural body of waters cultured of three different water levels and different culture sites. The Randomized Block Design (RCBD) was used, with four culture media as treatment, treatment 1 was the use of plastic screen cages; Treatment 2, tabular plastic screens; Treatment 3 nylon screen cages and Treatment 4, tubular nylon screens. The culture media were placed in a bamboo raft, where which was divided into three layers representing the layers of the sea which are the surface, midlayer and bottom, the rafts were placed in different sites: the muddy, rocky and sandy bottom. Sampling was done every 15 days for 3 months, taking the wet weight of the plant as a factor. Results show that with respect to the efficiency of each culture medium based on the water level, it was found that on the surface level, the *Caulerpa letillifera* placed in a plastic screen cage had the highest growth rate in site 1 (muddy site), and tubular nylon screen nets ranked first in site 2 (rocky) and 3 (sandy). For the bottom layer of the marine area, the tubular plastic screen had the highest growth rate of all the culture media used, dominating all sites from site 1 to site 3. Analysis of Variance (ANOVA) revealed that there is no significant difference in the growth rate of *Caulerpa lentillifera* placed in plastic screen cages, tubular plastic screens, nylon screen cages and tubular nylon screen nets, with the different water levels in the three culture sites.

Tonga Ministry of Fisheries & SPC. (2010). *Tonga Aquaculture Commodity Development Plan: 2010-2014.* Noumea, New Caledonia: Secretariat of the Pacific Community.

The Aquaculture Management and Development Plan is a five-year "road map" for the future of aquaculture in Tonga. The plan is a tool that will assist government and local entrepreneurs as well as foreign investors on what type of aquaculture development they should pursue. Marine resources have always been a source of livelihood for the people of Tonga. In terms of export, agriculture has often been the bigger contributor. Fisheries, however, is becoming the "new frontier" in Tonga for export revenue, and aquaculture is seen as a way forward in terms of enhancing the economic contribution through employment, trade and skills development, and ensures food security for its people. Aquaculture is not new in Tonga, although it is new to most Tongans. Before this plan came into reality, the main aim of aquaculture in Tonga for over 20 years was to restock the reefs and assist the aquarium trade through culturing and rearing of giant clams. Now, the experiences and results of trials have encouraged the government and the Fisheries Department to move Tonga's aquaculture capacity into commercialization. The plan has outlined how licenses shall be allocated, categorized and managed and also provides avenues for communities to utilize their adjacent waters for aquaculture purposes. The current status of seaweed as a commodity: Wild stocks of the seaweed mozuku (*Cladosiphon* sp.) are exported to Japan depending on seasonal demand. On occasion, some spores are cultured to supplement the wild harvest and about 300–500 tonnes are farmed.

Trono, G.C. Jr. (1986). *Seaweed culture in the Asia-Pacific region.* FAO/ Regional Office for Asia and the Pacific 1987/8. 41p.

Trono, G.C. Jr. (1987). Studies on the pond culture of Caulerpa. *Phillipine Journal of Science Monograph 17*: 83-98.

Trono, G.C. Jr. (1988). Manual on seaweed culture. 2. Pond culture of *Caulerpa* and 3. Pond culture of *Gracilaria*. ASEAN/UNDP/DF/FAO *Regional Small-Scale Coastal Fisheries Development Project, Manila, Philippines.* ASEAN/SF/88/Manual No. 3. Rome: FAO.

Several species and varieties of *Caulerpa* may be utilized as food in the form of fresh vegetables. These are mainly produced through gathering of natural stocks. Only *C. lentillifera* is commercially cultivated in ponds in the Philippines. The culture of this species started in the early 1950s in 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 in 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 present cultivation utilizes the traditional brackishwater ponds. However, results of recent studies (Trono, 1987) have shown that water management is a primary factor in the productivity of *Caulerpa*, the culture of which would require a flowthrough system to facilitate water exchange. Thus, some modification of the traditional pond such as the introduction of water control gates, have to be made. Unlike pond culture

of fish where water exchange is relatively infrequent (e.g., once a week or a fortnight) pond culture of *Caulerpa* requires more frequent water exchange in order to maintain the necessary level of nutrients required 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.

http://www.fao.org/docrep/field/003/ac417e/ac417e00.htm

Trono, G.C. Jr. (1989). The pond culture of *Caulerpa* and its use as food. *Applied Phycol. Forum., 6*(3): 1-3.

Several species of *Caulerpa* are presently utilized as a fresh salad vegetable. Except for *C*. *lentillifera,* which is cultured, production comes mainly from gathering natural stocks. *C*. *lentillifera* is preferred because of its delicate light taste and soft succulent texture. It is also a fast-growing species. Its cultivation started in the early 1950s in the island of Mactan (Cebu Province) when it was accidentally introduced with other seaweeds into fish ponds as food for the milkfish. At first *Caulerpa* was a secondary crop to fish and shrimp, but marginal *,* productivity made farmers shift to it as a major crop. The high demand in local markets in Metro Cebu and Manila was a major factor contributing to the success of its commercial production. At present more than 400 ha of ponds produce this seaweed on Mactan.

Trono, G.C. Jr (1990) A review of the production technologies of tropical species of economic seaweeds. *FAO Technical Resource Papers.*

The world-wide increasing demand for seaweeds and seaweed products as items of food alginate has been the main factor which has encouraged the development of production 0.3 technologies of economic species of seaweeds. This paper is a brief review of the current production technologies for four tropical seaweed genera, namely, Eucheuma, Kappaphycus, Gracilaria and Caulerpa. The related production problems and needs are also described.

Yip, M. & Madl, P. (2005). Semiosis aspects of ecosystems of the invasive *Caulerpa taxifolia*

Presentation describing the properties of the Mediterranean invasive species *Caulerpa taxifolia.* Introduced by accident into the waters off Monaco, the *C.taxifolia* aquarium strain is extremely invasive and smothers other algal species, seagrasses and sessile invertebrate communities. It does this by either out-competing them for food and light or due to the toxic effects of its caulerpenyne compounds. Its large monospecific meadows have vastly reduced native species diversity and fish habitat. Effects on humans are mostly related to the reduction of catches for commercial fishermen due to the elimination of fish habitat by *C.taxifolia*, although the entangling of nets and boat propellers with this weed also affect efficiency. Fish which are able to eat *C.taxifolia*, such as the Mediterranena bream (*Sarpa salpa*), accumulate toxins

in their flesh that make them unsuitable for human consumption. *C.taxifolia* outcompetes the seagrasses *Posidonia oceanica* and *Cymodocea nodosa* in Mediterranean ecosystems.

http://www.sbg.ac.at/ipk/avstudio/pierofun/protocol/caulerpa.pdf

Žuljevi, A, Antoli, B, Vedran, N, Despalatovi, M & Cvitkovi, I. (2012) Absence of successful sexual reproduction of *Caulerpa racemosa* var. *cylindracea* in the Adriatic Sea. *Phycologia* 51 (3): 283-286.

Gamete formation and release in *Caulerpa racemosa* var. *cylindracea* from the Croatian part of the Adriatic Sea was followed in the field and laboratory conditions. During the ten years of research only female gametes were observed. Gamete formation occurred when seawater temperatures were above 20C. Gametes had a distinct eyespot and were 9.3 ± 0.6 µm (mean ± SD, n = 140) long and 3.3 ± µm (mean ± SD, n = 35) wide. *In situ* gamete release started 12 – 18 min before sunrise. In *Caulerpa*, a typically monoecious genus, the production of only one gamete phase in the same thallus is a rare exception. Our observation also differs with previous research of *C. racemosa* var. *cylindracea* reproduction in Greece where both gametes are found. [NOTE: see the references in this paper for more information on the occurrence of *C. racemosa* as an invasive species in the Mediterranean].