



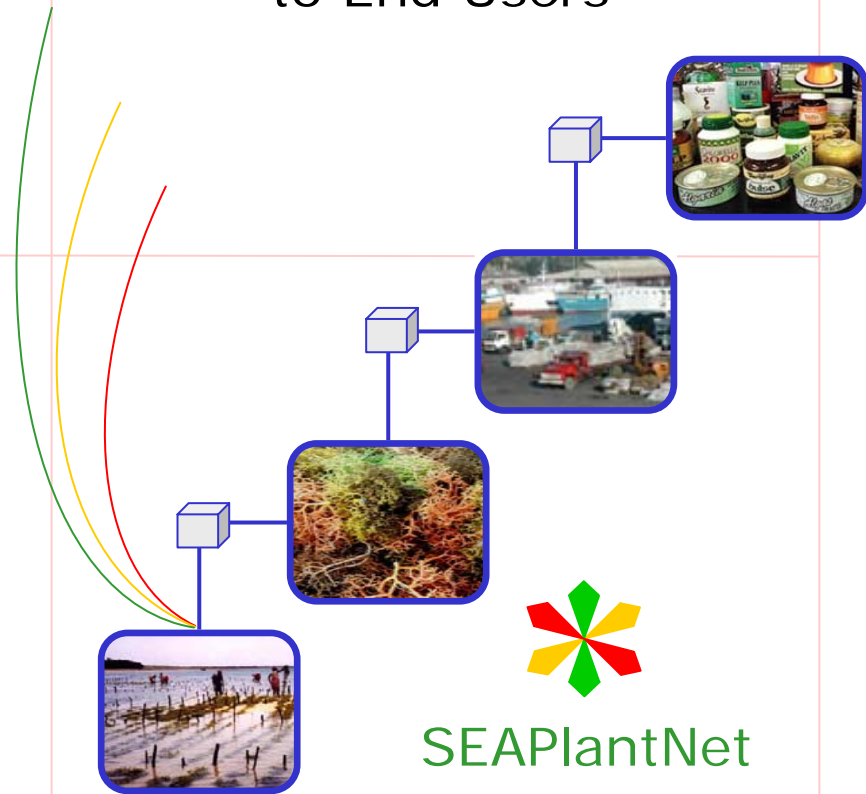
Eucheuma Seaplant Commerce

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6. SME Business Enabling Environment (Jakarta) – Working with governments, business associations and other stakeholders to improve competitive growth opportunities for SMEs in Indonesia.

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How Value Chains Link Farmers to End Users



The Eucheuma Seaplant Marketplace how Value Chains Link Farmers to End Users

SEAPlantNet **Technical Monograph No. 0105-5B**

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This monograph is fifth in a series that is intended for use by anyone interested in eucheuma seaplants in particular and seaplant value chains in general. It is also intended to be of use to people who are interested in the economic development of coastal communities in tropical regions.

Much of the material presented here originally appeared in "*The ABC of Eucheuma Seaplant Value Chains*" by Iain C. Neish (SuriaLink Monograph No. 1-0104 - ISBN 983 2893 03 8). That monograph is now out of print and with support from the IFC PENSA program it is being supplanted by the present series of monographs.

Iain C. Neish, December, 2005
 Makassar, Sulawesi Selatan, Indonesia



The development of commerce based on eucheuma seaplants is an outstanding instance of how widespread farming of a group of useful plants has evolved from very simple methods that have been refined mainly by farmers in the field. Farming of the eucheuma seaplants is a continuous process of screening and selection for fast-growing propagules.



Farmers tend to plant and harvest crops on a short cycle of 4-6 weeks. They replant cuttings from the most vigorously growing plants. Any reproductive plants are probably culled out because they would tend to be slow-growing and mottled in appearance.

The eucheuma seaplants discussed in the present monograph are defined as being members of the Tribe Eucheumatoideae within the Phylum Rhodophyta, Class Rhodophyceae, Subclass Florideophycidae, Order Gigartinales and Family Areschougiaceae. Commercially the most significant species are *Betaphycus gelatinum* ("gelatinae" of the trade), *Eucheuma denticulatum* ("spinosum" of the trade) and several species of the genus *Kappaphycus* ("cottonii" of the trade). The information base for these plants is expanding but has not yet achieved useful stability. Thus much of what is to be said about the biology of the eucheuma seaplants is practical conjecture, often extrapolated from knowledge of other seaplants. The present monograph is intended as a step in the direction of moving beyond this state of affairs.

The commercial significance of eucheuma seaplants is largely based on their role as raw material for production of the marine biopolymer known as carrageenan. *Betaphycus spp.*, *Eucheuma spp.* and *Kappaphycus spp.* produce carrageenans commercially known, respectively, as "beta", "iota" and "kappa". The development of commercial cultivation for *Kappaphycus* and *Eucheuma* since the mid-1970s has been the major source of expansion for the carrageenan industry and current combined production for these seaplants probably exceeds 150,000 dry tons per annum at commercial moisture standards of 30-40%. This translates to about 100 M USD worth of dried seaplants and over 30,000 tons of carrageenan with a value on the order of 250 M USD per annum.

In past years *spinosum* had generally been regarded as being more difficult to grow than *cottonii* so there has been much conjecture as to why the reverse seems true at some sites today. For example there have been suggestions that the commonly cultivated *cottonii* cultivars have been propagated for so many years (e.g. about 30 for "tambalang") that they are losing vigour while several new *spinosum* cultivars with various national origins been selected from wild stocks and have reached commercial scales of production.

Eucheuma seaplant farming has involved the widespread distribution of cultivars from source habitats to regions far away from their origins. For example *Kappaphycus* cultivars derived from a few plants originating in the Sulu Sea have been distributed to distant seas where they form the basis for commercially significant industries. There have been not yet been reports of proliferation of large wild populations arising from such stocks but the issue of eucheuma seaplants as "exotic" or "alien" species has been raised in some jurisdictions. This issue and concerns about general environmental impacts from seaplant farming are significant concerns to the industry and are addressed in the present monograph.



Natural stocks of eucheuma seaplants species occur naturally throughout the Indo-Pacific region from eastern Africa to Guam. They are found between about 20 degrees north and south of the equator – especially between the tenth parallels - in the Indo-Pacific. This zone is roughly defined by the winter isoclines of 21 and 24 degrees Celsius (Doty, 1987). The greatest abundance of eucheuma seaplants species seems to be in the algal reef areas of island archipelagos associated with Southeast Asia. They generally grow interspersed with corals and at first glance can often be mistaken for corals. There are also outlying species with relatively localized distributions. The photos below show wild *Kappaphycus spp.* growing in the Southern Sulu Sea (1977).



Three northern outliers are *Eucheuma uncinatum* in the Gulf of California, *E. isiforme* in the Caribbean and *E. amakusaensis* in southern Japan. There is also *E. deformans* from Lord Howe Island and *E. speciosum* (Sonder) J. Agardh in southwestern Australia as well as *E. platycladum* (Schmitz) and *E. odontophorum* (Boergesen) in Tanzania and Mauritius, respectively. Doty (pers. comm) suggested the possibility of biogeographic distribution changing in response to crustal changes in the earth. The species in Australia, aside from those at its most northward edge, are mostly unique and seem to have been developed with odd mixtures of genomes from species further north. In this regard one may list *Eucheuma deformans* and *E. speciosum*. Doty noted that there appear to be unlabeled specimens in herbaria that do not fit into the specific concepts ordinarily recognized among commercial species (Doty, 1988). *Eucheuma serra* is found nested well within the borders of the distribution of *E. denticulatum* and *Kappaphycus alvarezii* is within the distributional borders of *K. striatum*.

Human actions have had a major impact on the distribution and abundance of eucheuma seaplants. For example *Kappaphycus alvarezii* seems to have been narrowly restricted to the southernmost Sulu Archipelago, the Celebes Sea and Biak na Belau north of the equator until after 1974 when it became widely distributed by man. The occurrence of "cottonii" in Ponape before 1971 may be an introduction from further west during Japanese occupation of the area. *Kappaphycus striatum* has been taken to Japan recently (Mairh et. al., 1986) and *K. alvarezii* has been taken to India Mairh et al (1995).

***K. alvarezii* and *E. denticulatum* have both been taken to Hawaii where, although they not abundant, they are classified as "alien and invasive" algae.** From Hawaii they have been taken to eastern and western Kiribati, Tonga, Fiji and elsewhere (e.g., to the Society Islands and temperate North America). While *Eucheuma isiforme* were also brought to Hawaii along with *Hypnea musciformis* by some businessmen. From the Philippines both *K. alvarezii* and *E. denticulatum* strains have been taken to the Lombok Straits area of Indonesia and have since spread throughout Indonesia. *E. denticulatum* has also spread via Singapore to Djibouti. *K. alvarezii* of Philippine origin forms much of the basis for cottonii farming in Indonesia but the substantial spinosum production of Indonesia is based primarily on strains originating from Bali. Balinese plants have since spread to Sabah and the Philippines and seem to be widely cultivated in those countries now.

Although *K. alvarezii* strains of Philippine origin have been the basis of most cottonii farming throughout the world, there are also local strains that have been commercially grown in Indonesia, Tanzania and Malaysia. In recent years there has been a proliferation of strains in the Philippines, Malaysia and Indonesia. Differences in commercial value among strains has led to some market confusion but recent scientific studies are beginning to shed light on strain relationships as elucidated by studies of DNA and carrageenan characteristics (Aquilan et al, 2003; Zuccarello et al, in press).

Euचेuma seaplant cultivation has been tried in at least 29 countries as shown below.

Country	'000 km (%) of coast	Year started	Sources
China	15.3 (1.81)	1985	Wu <i>et. al.</i> (1988)
India	7.0 (0.83)	1989	Mairh <i>et. al.</i> (1995)
Indonesia	54.7 (6.48)	1975	Adnan & Porse (1987)
Madagascar	4.8 (0.57)	1998	Ask & Corrales (2002)
Malaysia	4.7 (0.55)	1977	Doty (1980)
Philippines	36.3 (4.30)	1971	Doty & Alvarez (1973)
Tanzania	1.4 (0.17)	1989	Lirasan & Twide (1993)
Totals			
Brazil	7.5 (0.89)	1995	de Paula <i>et. al.</i> (1998, 1999)
Cambodia	0.4 (<0.1)	2000	Pers. Obs. of author
Cuba	3.8 (0.44)	1991	Serpa-Madriral <i>et. al.</i> (1997)
Djibouti	0.3 (<0.1)	1973	Braud <i>et. al.</i> (1974, 1978)
Fiji	1.1 (0.13)	ca.1978	Prakash (1990)
French Antilles	0.1 (<0.1)	1978	Barbaroux <i>et. al.</i> (1984)
French Polynesia	2.5 (0.29)	ca.1985	Doty (1985a)
Guam	0.1 (<0.1)	ca.1985	Doty (1985a)
Honduras	0.8 (<0.1)	1978	Neish (pers.com.)
Japan	29.8 (29.75)	1983	Mairh <i>et. al.</i> (1986)
Kenya	0.5 (<0.1)	1996	M. Fazal, (pers. Comm.)
Kiribati	1.1 (0.13)	1977	Russel (1982)
Maldives	0.6 (<0.1)	1986	de Reviere (1989)
Micronesia	6.1 (0.72)	ca.1985	Doty (1985a)
Myanmar	1.9 (0.22)	2000	Pers. Obs. of author
Samoa	0.4 (<0.1)	ca.1978	Doty (1978a)
Solomon Islands	5.5 (0.65)	1987	Smith (1990)
Tonga	0.4 (<0.1)	1983	Fa'anunu (1990)
Tuvalu	0.1 (<0.1)	1977	Gentle (1990)
USA (Hawaii)	0.2 (<0.1)	1971	Doty (1985a,b)
Venezuela	2.8 (0.33)	1996	Rincones & Rubio (1999)
Vietnam	3.4 (0.40)	1993	Ohno <i>et. al.</i> (1995, 1996)

* Production figures from SuriaLink.com

** Legend: +++ = large; ++ = medium; +=small; - = none ? = in doubt

Estimates euचेuma seaplant production volumes for 2003 were estimated to be as follows:

Country	<i>Kappaphycus</i> mt/yr (%)	<i>Euचेuma</i> mt/yr (%)	Develop Status
China	800 (0.7)	nil	expand
India	200 (0.2)	nil	expand
Indonesia	48,000 (42.0)	8,000 (35.7)	expand
Madagascar	300 (0.3)	400 (1.8)	expand
Malaysia	4,000 (3.5)	trace	expand
Philippines	60,000 (52.5)	10,000 (44.6)	contract
Tanzania	1,000 (0.9)	4,000 (17.9)	static
Totals	114,300 (100)	22,400 (100)	
Brazil	small/variable	nil	static
Cambodia	small/variable	nil	expand
Cuba	small/variable	nil	static
Djibouti	nil	nil	ceased
Fiji	small/variable	nil	static
French Antilles	nil	nil	ceased
French Polynesia	nil	nil	ceased
Guam	nil	nil	ceased
Honduras	nil	nil	ceased
Japan	nil	nil	ceased
Kenya	small/variable	trace	static
Kiribati	small/variable	nil	static
Maldives	small/variable	nil	static
Micronesia	small/variable	nil	static
Myanmar	small/variable	nil	expand
Samoa	ceased	nil	ceased
Solomon Islands	small/variable	nil	expand
Tonga	small/variable	nil	static
Tuvalu	small/variable	nil	static
USA (Hawaii)	nil	nil	ceased
Venezuela	small/variable	nil	static
Vietnam	small/variable	nil	expand



Where *eucheuma* seaplants are transferred among sites the live material has generally been shipped in plastic bags or jute sacks wet enough to prevent desiccation. Sometimes transport has taken several days and a high proportion of the transported material has died. The author is aware of instances (e.g. in Tanzania and Bali) where surviving material amounting to only tens of grams led to commercial farming.

Today propagules are routinely shipped in multi-ton quantities from nursery areas to farm areas. This is usually done by loosely packing live plants in woven cloth that are kept shaded and are frequently wetted.



Several countries now produce significant amounts of commercially dry *eucheuma* seaplants (moisture content generally 30-45% and averaging about 38%). Accurate statistics are unavailable since secrecy and obfuscation are commercial devices still prevalent in the trade. However estimates can be made based on the apparent volumes of the commercial trade. Estimates presented here are drawn from SuriaLink trade contacts.

Commercial production of "cottonii of the trade" is currently on the order of 120,000 - perhaps more than 150,000 - dry tons per year at a commercial standard of 38% moisture-content.

The available figures indicate that about 99% of *cottonii* is commercially cultivated in four countries. Relative production volumes are approximately as shown on pages 7 & 8 with the Philippines at 70%, Indonesia at 24%, Malaysia (Sabah) at 4%, Tanzania at 1% and others (e.g. Fiji, Kiribati) at a total of 1%. Experimental farming or intermittent commercial activity has occurred in several countries including China, Japan, Ponape, the Solomon Islands, the USA (Hawaii), Belize, Maldives, Cuba, Venezuela Vietnam and India. In all of these countries cultivation has utilised *Kappaphycus* cultivars of Philippine origin. In some cases (e.g. the "Sumba strain" in Indonesia) indigenous populations have also given rise to commercially useful cultivars but it appears that a substantial percentage of the world crop is still descended from material that initially developed to commercial scale in the Philippines.

The demand for "spinosum" (illustrated below) is less than 1/4 the demand of "cottonii" so the world production of *Eucheuma spp.* seems to be on the order of 20-25,000 tons.



During early years of commercial production *spinosum* was more difficult to grow than *Kappaphycus* and it used to command a higher price. In recent years farmers have found *Eucheuma* to be the more easily grown and the *spinosum* market has had a persistent over supply.

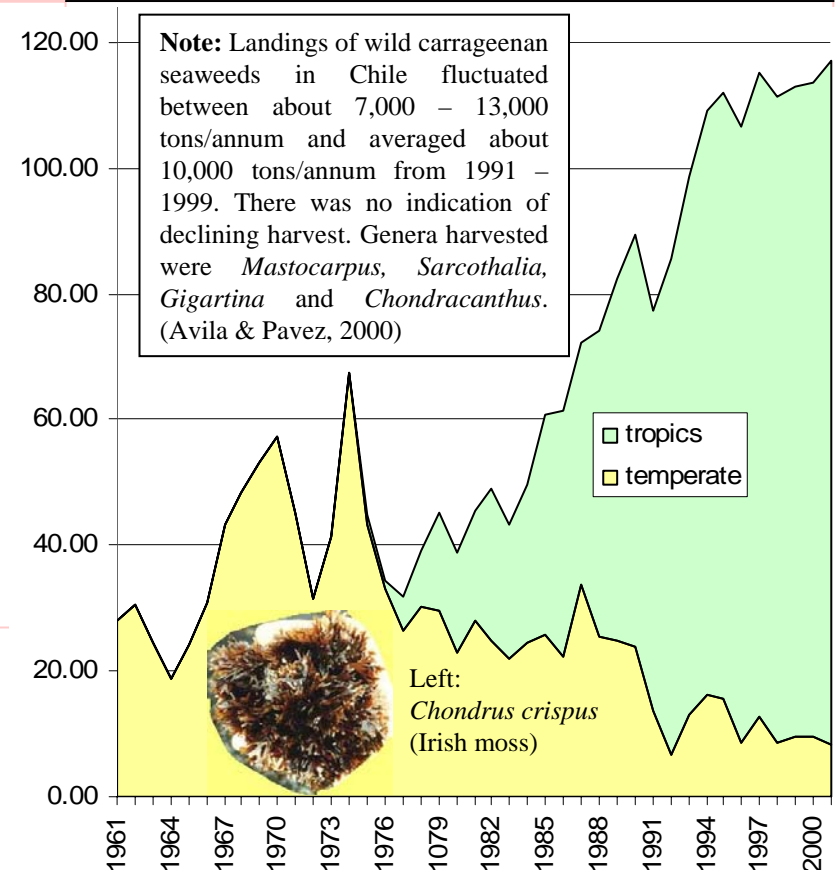
Betaphycus is a slow growing genus that has yet to make a serious market impact, although there have been serious efforts to find and propagate fast growing varieties (e.g. by the author).

The main commercial use of eucheuma seaplants is as raw material for the production of red algal galactan (RAG) biopolymers known as carrageenan. The figure opposite presents a graphic history of the production of carrageenan-source seaplants from 1961 to 2002. This figure gives an overview of general trends that have taken place with respect to the commercial production of some major carrageenan seaweeds (carrageenophytes) during the past four decades. The producing countries taken into account are those that produce most of the carrageenophytes in their respective segments.

Top (green): Estimated production of the commercially cultivated "warm water" seaweeds *Kappaphycus spp.* In Malaysia (MY), Indonesia (RI) and the Philippines (RP) 1975-2002. (from SuriaLink.com & Seaweed Industry Association of the Philippines (SIAP)).

Bottom (yellow): Estimated production of commercially harvested wild "cold water" red seaweeds (mostly *Chondrus crispus*; some *Furcellaria fastigiata*) from France (FRA), Canada (CAN) and the U.S.A. 1961-2001. (from SuriaLink.com after FAO and Prince Edward Island Fisheries Dept. statistics).

The graph opposite is based on production of *Kappaphycus spp.* ("cottonii"). Comprehensive statistics are not available for all years and all locations but the numbers shown on the opposite page appear to reflect the following industry trends noted. The production of *Eucheuma spp.* ("spinosum") occurred more or less in parallel and production has generally run about 20% of *Kappaphycus* production. About 1/3 of *Eucheuma* production is from Tanzania (below).



***Chondrus*, *Furcellaria* and several other wild coldwater carrageenophytes tend to grow in "beds" that have high population density and are amenable to harvesting by rakes and drags.** Tropical seaplants seldom or never grow in this way. For example eucheuma seaplants tend to grow as individual plants or in small clumps interspersed with corals and other marine plants. Cultivation is therefore essential before eucheuma seaplants and many other types of tropical seaplant can be made available in commercial quantities. Cold water seaplants such as *Chondrus* can be cultivated but production costs are generally too high for economic production of carrageenan raw materials.

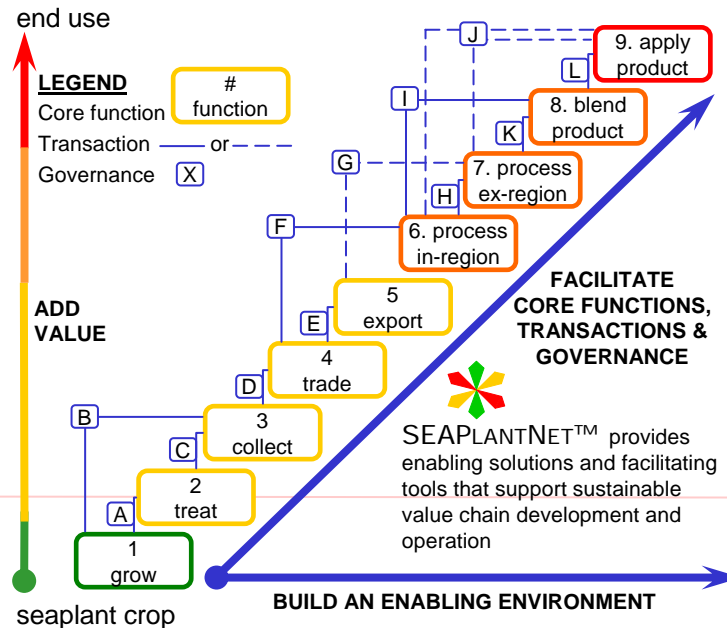
Technology for growing euचेमा सेपलंट्स व अडिंग वलू टू थेम हस बीन मोर ऑर लस इन थे पब्लिक डोमन सिन्स थे मीड-1970s बूट टेक्नॉलॉजी ट्रान्स्फर हस बीन पीसमेअल व क्वालिटी प्रॉब्लेम्स आर कॉमनप्लेस. Commercial euचेमा सेपलंट फार्मिंग बेकमे कॉमर्शियल्लि सिग्निफिकंट इन थे मीड-1970s व थिस लीड टू कॉमर्से इन अल्कली-मॉडिफाइड व्हाले प्लंट्स. थिस वरस रपिडली फॉलोव्डी बाय थे अडवेंट ऑफ "चिप्स" व इट रपिडली बेकमे ऑबिवस टू सेवरेल वलू-चेन पार्टिसपंट्स थॅट पाव्दरेड, ब्लेंडेड "प्रॉसेस्डेड एुचेमा सेव्हेड" (PES) वरस सुइटेबल फॉर वीडे रेंज ऑफ अडप्लिकेशन्स व वरस सिग्निफिकंटली चिपेअर थॅन क्लरिफाइड एक्स्ट्रॅक्ट्स इन सेम अडप्लिकेशन्स. पेटफूड स्टेबिलाइझेशन वरस थे फिर्स्ट मॅजोर अडप्लिकेशन फॉर PES बूट फूड-ग्रेड प्रॉडक्ट्स रपिडली फॉलोव्डी व थे प्रॉडक्शन ऑफ क्लरिफाइड कॅरॅजेनान एक्स्ट्रॅक्ट्स फ्रॉम PES रॉव मॅटेरियल इ अल्सो नोव् ए एस्टॅब्लिशेड टेक्नीक.

ड्यूरिंग ईअर्ली स्टेज्स ऑफ इंडस्ट्री डेव्हलपमेंट म्युच टेक्नॉलॉजी ट्रान्स्फर इन्वॉल्वेड इन्फॉर्मल ऑर ड्युबिअस मेकॅनिझम्स सुक अस "पिरॅटिंग" ऑफ स्टाफ्.. थेसे अड्रोअचेस टेन्डेड टू प्रॉव्डी येस्टर्डेय'स टेक्नॉलॉजी व फेइल टू अड्रेस टॉमॉरोव'स नेड्स. **इनिशियल सोर्सेस ऑफ क्नॉ-हॉव व टेक्नॉलॉजी ट्रान्स्फर इन्क्लूडेड:**

1. **The spread of "colagar" technology** to euचेमा सेपलंट्स.
2. **Internal development** by existing industry players व इन्टेन्शियल टेक्नॉलॉजी ट्रान्स्फर टू थेरि सप्लायर्स.
3. **Movement of technical staff** फ्रॉम एस्टॅब्लिशेड इंडस्ट्री प्लेयर्स टू अस्पिरिंग न्यू प्लेयर्स.
4. **Manufacturers व कन्सल्टंट्स सेलिंग प्रिवियस क्लिंट्स' टेक्नॉलॉजी** अलॉन्ग व्थ थेरि इक्विपमेंट व सेर्विसेस.

In तॉडेय'स वर्ल्ड डेव्हलपिंग टेक्नॉलॉजिसेस आर क्रेटिंग सेपलंट बिजनेस ऑपॉर्ट्युनिटीस अट अ असेलरेटिंग रेट. थे टूल्स ऑफ बायॉलॉजी व जेनेटिक्स कॉम्प्लेमेंट थे डेव्हलपमेंट ऑफ मॅटेरियल्स, बायोरिअक्टर्स व ऑथर टूल्स टू क्रेट ऑपॉर्ट्युनिटीस बूथ फॉर ससटेनिंग व फॉर डिस्रुप्टिव् सेपलंट टेक्नॉलॉजिसेस. थेरे इ अल्सो अ एन्विरॉन्मेंट ऑफ एन्बेल्डिंग टेक्नॉलॉजिसेस थॅट प्रॉव्डी टूल्स सुक अस इन्फॉर्मेशन टेक्नॉलॉजी; कॉम्युनिकेशन व ट्रान्स्पोर्ट सिस्टम्स; अलियन्स मॅनेजमेंट सिस्टम्स; व प्रॉसेस कंट्रॉल सिस्टम्स.

Value chains are series of value-adding functions that connect through governed transactions and result in the supply and sale of products.



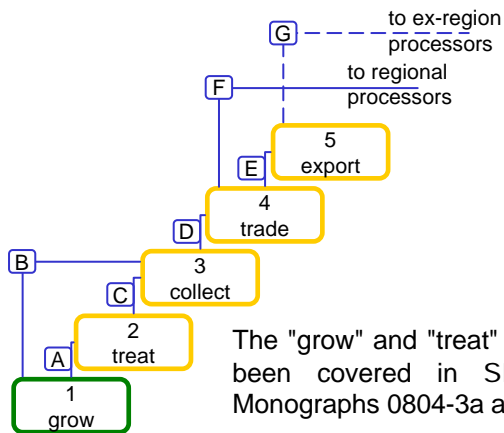
A generalized seaplant value chain structure is shown above. Some people find it useful to view value chains as "ladders" or "stairs" where each core function represents an upward step.

In order for sustainable value networks to operate an enabling environment must be built, maintained and improved. The enabling environment is a world of legal and hierarchical structures; trust networks; the physical environment; and the social environment. For most enterprises this means dealing with an array of stakeholders... including alliance network partners.

The operation of value chains within value networks is facilitated by tools that include information technology (IT); legal documents; communication and transport systems; metamediary websites; analytical services; and engineering design services.



Foundation links of eucheuma seaplant value chains (below) connect the "grow" function with post-harvest treatment (PHT) functions and the series of collecting, trading and export functions that get seaplant raw materials to processors.



The "grow" and "treat" functions have been covered in SEAPLANTNET™ Monographs 0804-3a and 0804-4a.

As crops leave the hands of farmers they go first to individuals or enterprises that undertake the "collect" function and (in some cases) other core functions. As value chains "mature" in particular geographic regions there is a tendency for complexity to develop. Some of the more frequently observed trends include the following:

1. **Successful farmers become collectors** and/or branch into trading and transportation functions.
2. **Enterprises that are successful in performing one function** (e.g. trading) tend to expand vertically downward (into collecting) and/or upward (into exporting and processing).
3. **There is a proliferation** of seaplant types and farming methods.
4. **"PHT trading games" proliferate** and the imposition of quality standards becomes difficult.
5. **Traders assume a significant role** in manipulating supply.
6. **Process plants proliferate** near seaplant sources.
7. **Opportunistic farmers** go in and out of farming depending on market conditions.

Eucheuma seaplant value chains are unusual with respect to the rapid rate at which expansion and contraction can occur in response to market forces. Lack of transparency in eucheuma seaplant markets can cause "false signals" that induce market oscillations and lead to value-chain "noise".

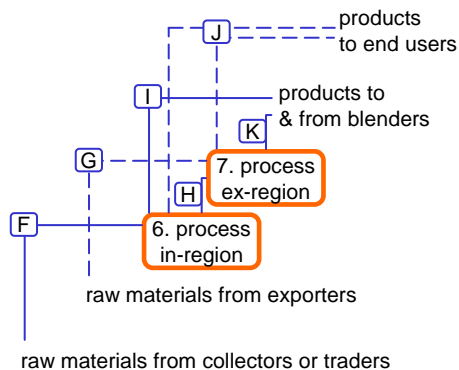
Collector Alex Yusof strikes a deal (right) using his "picul stick" on a beach near Zamboanga, R.P. He buys fresh cottonii from farms in front of the beach then salts it down (below, foreground), dries it and sells the dry, sacked material to Zamboanga traders. This collector is also a substantial farmer and he finances other farmers.



In some regions farmer groups (e.g. "kelompok petani" in Indonesia) collect rather than individuals or commercial enterprises. Successful farmers commonly expand into treatment, collection and trading functions.

Sad to say, some collectors are accused of playing "PHT trading games" and of lending money on unfair terms. As in many industries "the middleman" is accused of a multitude of sins but the fact is that the "collection" function is essential and trustworthy collectors are a crucial link in sustainable value chains.

Process functions of eucheuma seaplant value chains may occur either within or outside the same jurisdictional region as seaplant farms. Process facilities tend to cluster close to seaplant sources or close to markets.



During early stages in the development of eucheuma seaplant value chains virtually all finishing links occurred outside the tropical regions where farms are located. Until the late 1970s cold water carrageenophytes were dominant raw materials in the carrageenan industry, most processing was done in the USA, Europe or Japan and the market was dominated by three companies, namely Marine Colloids (now FMC), Copenhagen Pectin (a.k.a. GENU; now CP-Kelco) and Sanofi (now Degussa). These companies shared world markets essentially on a 4:2:1 ratio, and smaller producers played a role in small market niches.

The advent of eucheuma seaplant cultivation and consequent development of PES technology caused a shift in value chain dynamics that is still underway. The advent of massively expandable raw seaplant sources and technology for making PES caused a step-change in the industry and the increasing availability of enabling solutions is making it possible for small regional manufacturers to compete on an increasingly "level playing field" especially if they tie up with skillful blenders that have a strong position in their regional market niches.

There is a growing trend for eucheuma seaplants to enter international commerce as "chips" or "meal" rather than as dried eucheuma seaplants (DES). minimization of PHT trading games is one incentive for this trend and economics of production are another. The desire to avoid expensive effluent treatment in developed urban areas is a further incentive for using modified materials as raw material.

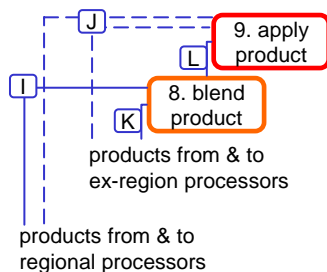
Supply proximity can give comparative economic advantage to local processors. Sources of comparative advantage include:

- 1. The PES process does not have significant economies of scale** and low-cost human resources can confer a substantial advantage.
- 2. Only about 20-25% of raw eucheuma seaplant composition tend to be realized as finished product** so transport cost savings result from processing near seaplant sources.
- 3. Processing close to seaplant sources also provides savings** in the form of quality retention; process control; inventory control; and minimization of processing steps.

There is an emerging trend for strategic alliance networks to develop among processors. Consequences of alliance network development include:

- 1. "Tolling" and barter arrangements** occur among processors in different jurisdictions.
- 2. SME are increasingly able** to realize competitive advantage based on local comparative advantages.
- 3. Alliance networks have increasing access** to enabling solutions formerly available only to large multinational firms.
- 4. Eucheuma seaplant value chains are steadily spreading** into emerging markets such as China, India, SEAsia and South America.
- 5. Entrepreneurial and innovative initiatives** are finding support that better enables them to achieve sustainable success (e.g. the IFC PENSA Program).

End links connect processing core-functions with the blending, distribution, marketing and sales functions that lead to the application of end products.



Most processors do some blending but specialized blending houses play a major role in eucheuma seaplant value-chains. For example, most carrageenan applications require that two or more types of gum be blended with salts, sugars and other products to create the mix that is used in end products.

Many kappa carrageenan applications require blends with synergistic glucomannans or galactomannans. These include carob (locust bean) gum, cassia and konjac gum. Some large, sophisticated customers such as petfood manufacturers prefer to purchase standardized blends of "pure PES" which they combine with other gums and ingredients at the point of final product manufacture but this is more the exception than the rule.

Marketing, sales and distribution functions are part and parcel of the blending function because most carrageenan is sold as a "specialty chemical" or "ingredient solution". The "magic" introduced at the level of processing and blending provides the competitive edge for biopolymer "solution providers".

The effective application of biopolymers is often more art than science so blending and applications skills are a valuable core-competency.

The front line of carrageenan marketing is often cooperative R&D among blenders and end-users. The R&D staff of leading solution providers have broad and deep knowledge that can be of substantial use to enterprises developing new products. In extreme cases the solution provider may do almost all of the product development work for a customer.

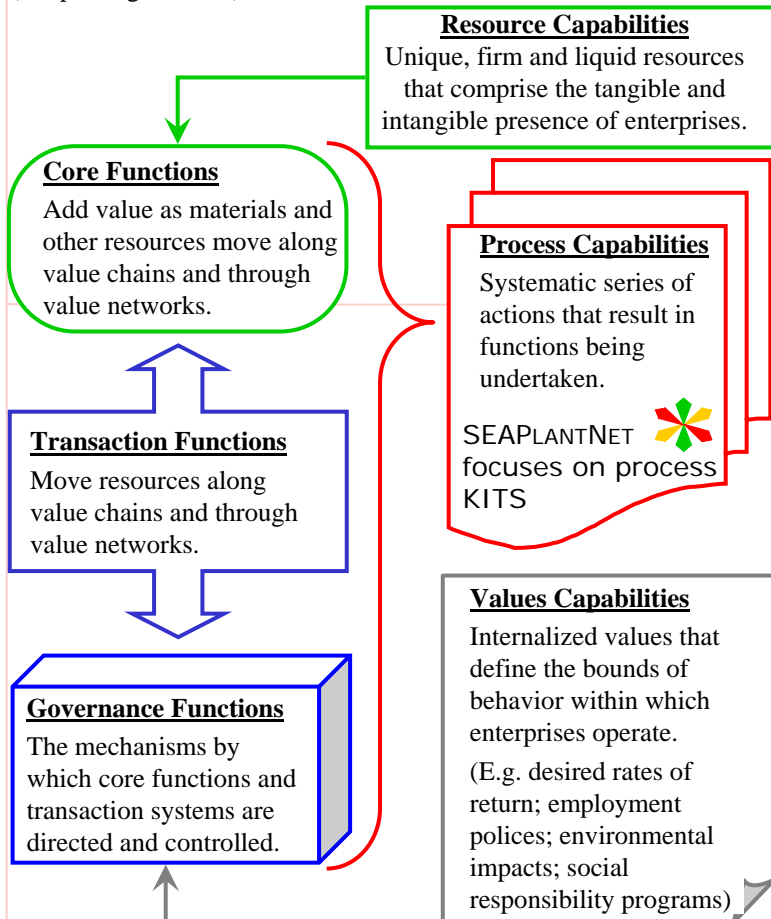
There is substantial inertia once suppliers are chosen and approved for particular products. The biopolymer component of a product is usually a small percentage of the product composition (e.g. about 0.5%) and may represent a small proportion of final-product cost but the biopolymer usually has a pronounced impact on product quality. This means that users are reluctant to switch suppliers or to tinker with the biopolymer mix once a product line has been established (see McHugh, 2003 pp. 48 & 71 for elaboration of this point). One product failure at the level of a full-scale plant run can be far more expensive than the slight saving to be achieved by buying a cheaper gum.

Expertise has dispersed in recent years. When eucheuma seaplant cultivation became commercially successful in the mid 1970s the carrageenan industry was dominated by relatively few companies based in the E.U., Japan and the U.S.A. Since then the following trends have taken place:

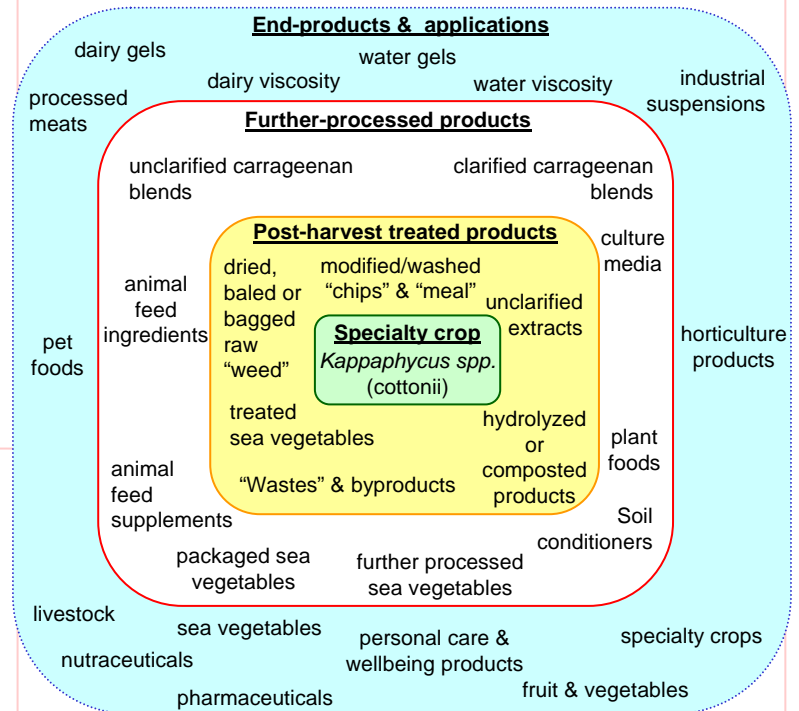
- 1. Several innovative SME** that initially developed carrageenan value chains were absorbed into large companies.
- 2. Operating priorities of these large companies caused outward migration** of staff with an innovative orientation.
- 3. Several SME were founded** as the availability of eucheuma seaplant and expertise fueled industry growth.
- 4. "Globalization"** based on the availability of cheaper and better communication and information technology is enabling industry players to innovate with renewed vigour.

Value chains are the building blocks of value networks. They are built around series of connected core functions, transaction functions and governance functions. This functional framework operates within an environment of enterprise capabilities that includes resources, processes and values. Each type of capability has an impact on all types of function but resource capabilities are most strongly associated with core functions and value capabilities are most strongly associated with governance functions. Process capabilities strongly impact all types of function.

(see paradigm below)



Value networks are clusters of value chains that are based on a common foundation link. In the case of seaplant networks the foundation link is a specialty crop based on particular genera or species of marine algae.



The paradigm above depicts the sort of value network that can be formed of *Kappaphycus spp. (cottonii)* value chains (After Christensen, 1997 pp. 36-44).

Individual enterprises may participate in one or several of the value chains in a network such as this and synergies among value chains may significantly impact process economics. For example the by-products and wastes from alkaline carrageenan production may form a basis for agricultural products of high value and result in "wastes" becoming a profit center rather than a cost item.



Eucheuma seaplant value chains course through several geographic routes on their way from farm to end use. The dynamics of value chain operation are intertwined with the exigencies of operating foundation, processing, finishing and enabling links within the variety of transaction governance systems imposed as value chains move through jurisdictions.

The bulk of eucheuma seaplant production is currently concentrated in Southeast Asia. The Philippines and Indonesia account for as much as 95% of world production (est. 120+ K mt) and "BIMP-EAGA" (Brunei, Indonesia, Malaysia, Philippines - East ASEAN Growth Area) is the core region for production. The EAGA also includes Sabah, Malaysia which produces eucheuma seaplants and is also an entrepôt. Minor amounts are also farmed seasonally in Cambodia, Vietnam and South China.

Major hubs and feeder hubs (see map on page 10) are:

- 1. Cebu City, RP & Manila, R.P.** - Sites of several process plants. Receive from Zamboanga, nearby farm areas and Indonesia.
- 2. Jakarta, R.I.** - Site of at least three PES plants; fed by Makassar, Surabaya and some R.I. feeder hubs.
- 3. Makassar, R.I.** - Site of 3 PES factories; entrepôt for Sulawesi feeder hubs; feed Jakarta & Surabaya or export.
- 4. Singapore & Hong Kong** - Major shipping, trading and marketing centres. Not sites of process plants or farms.
- 5. Surabaya** - Madura is a major hub/farm area at Surabaya's doorstep. Surabaya is also fed by Bali, Kupang, Kendari, Manado and Makassar.
- 6. Tawau, MY** - Serves 2 Sabah PES plants and Semporna production/feeder hub site; entrepôt for EAGA.
- 7. Zamboanga, R.P.** - original hub of the eucheuma seaplants industry; site of several PES plants; fed by Southern RP hubs such as Bongao, Jolo and Sitangkai.

Zamboanga City is a major hub in the Philippines. Tens of thousands of DES tons move from the Southern Philippines across this jetty every year (photo below shows seaplants in white sacks; copra in dark sacks; Jan, 2004).



Zamboanga City, Philippines and Surabaya, East Java, Indonesia are the places to go if you want to see how most eucheuma seaplants get from farm to market. Surabaya is a busy port that has been a link in supply chains for an awesome array of tropical products for several centuries. Zamboanga is in a region with socioeconomic issues and is not huge like Surabaya so seaplant commerce has a relatively high profile there. Zamboanga is home to several PES processing plants and there are seaplant farms very close to the city.

Farms to the west (right) are located near recreational beaches. Zamboanga is the most convenient and enjoyable place in the world to see all facets of eucheuma seaplants farming - provided that "peace and order" problems are not a concern.



Euचेमा seaplant value chains involve geographic movement of seaplants and seaplant products from production areas through several feeder hubs and major hubs.

Current euचेमा seaplants production is concentrated in Southeast Asia. The Philippines and Indonesia account for as much as 95% of world production (est. 150+ K mt) and "BIMP-EAGA" (Brunei, Indonesia, Malaysia, Philippines - East ASEAN Growth Area) is the core region for production.

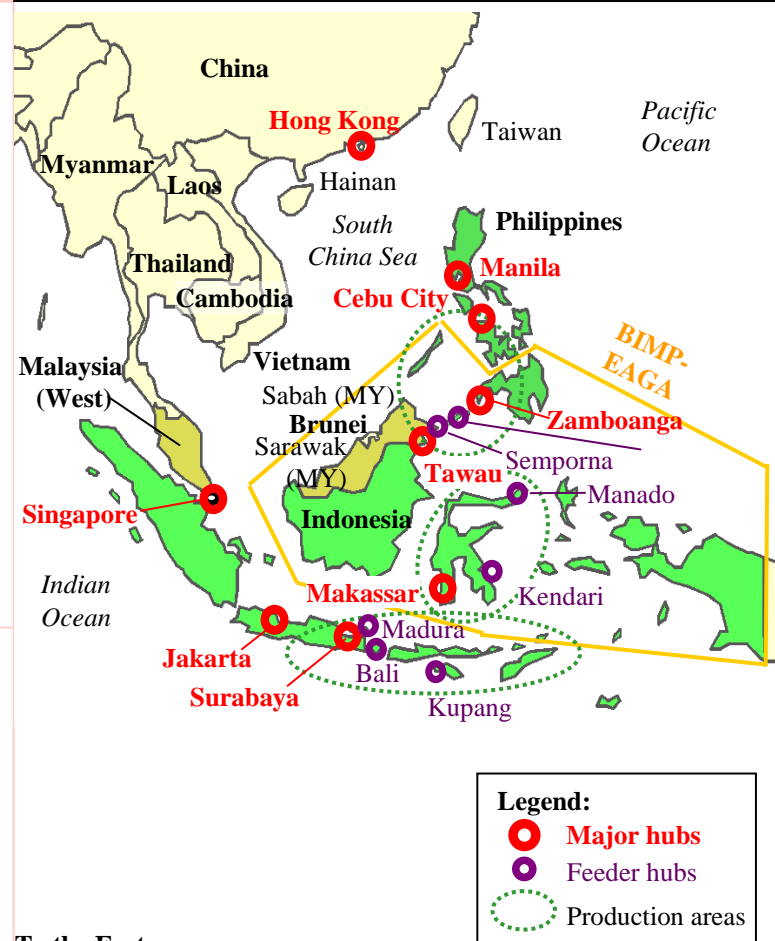
The EAGA also includes Sabah Malaysia which produces euचेमा seaplants and is also an entrepôt. Minor amounts are also farmed seasonally in Cambodia, Vietnam and South China.

Efforts to cultivate euचेमा seaplants have taken place in the Caribbean Sea (e.g. Cuba, Florida U.S.A. and Belize) but the socioeconomic and regulatory climates have apparently inhibited development of commercial production.

Indo-Pacific areas where euचेमा seaplants farming occurs (and may develop further) are listed below and at the bottom of the opposite page:.

To the West...

- 1. Tanzania** produces significant quantities of spinosum and minor amounts of cottonii. Dar es Salaam is the hub.
- 2. India** produces cottonii in Tamilnadu and other states. Foreshore usage issues currently inhibit industry growth.
- 3. The Maldives** has had commercial production but future prospects are unknown.
- 4. Madagascar** has produced euचेमा seaplants but socioeconomic issues apparently inhibit industry growth.



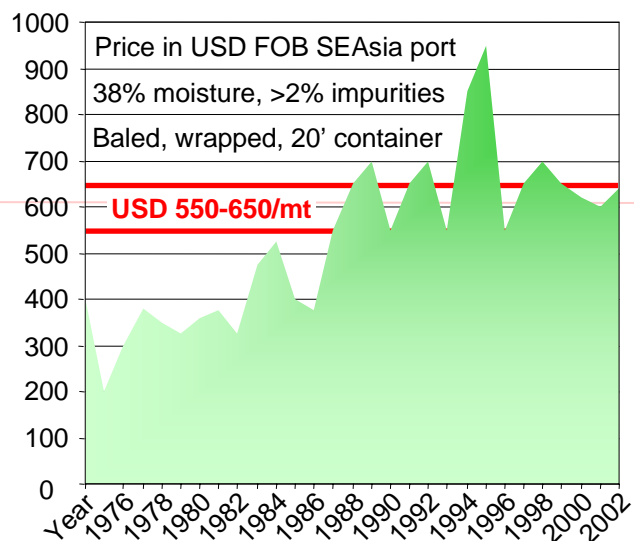
To the East...

- 1. Pacific Oceania** has produced significant quantities of cottonii. Solomon Is., Fiji, Ponape and Kiribati all have potential but high freight costs are an issue.
- 2. Baja California, Mexico and Australia** have had test plots but commercial production has not resulted.
- 3. Hawaii, U.S.A.** was the site of vigorously growing test plots but euचेमा seaplants are rated as "alien and invasive species" so farming is out of the question.

Market prices for eucheuma seaplants are unregulated and tend to follow the law of supply and demand. Some key features of the market are as follows:

- 1. USD are generally used** in international transactions.
- 2. Trust/commitment relationships** are prominent.
- 3. Supply can be rapidly expanded or contracted** due to the short crop cycles and low incremental cost of farm expansion that typify eucheuma seaplants agronomy.

The graph below shows trends in cottonii prices in USD/mt from 1975 until 2003 (Data from SIAP and SuriaLink sources)



Since eucheuma seaplants became items of commerce the "world price" in USD (unadjusted) has had several ups and downs but it has tended to level off in recent years. Since Indonesia became a major producer by 1988 a "base price" of about USD 550/mt seems to have become established. Except for an anomalous "peak" around 95 prices have averaged around 600 +/- 50 USD/mt.

A high percentage of the FOB price of raw, dried seaplants goes to the farmers. Generally the "farm gate" price of eucheuma seaplants is on the order of 70-80% of the FOB export price of export-ready raw seaplants. Thus an FOB price of 600 USD/mt equates to a farm gate price of about 0.42-0.48 USD/kg.

Prices fluctuate within each year. There are generally seasonal factors that influence supply and there is a certain amount of the "wheeling and dealing" typical of any open trading situation. For larger market players it is standard practice to move prices in order to influence supply so there is a tendency for the market to oscillate between being a "buyer's" and a "seller's" market.

Lack of market transparency is a major factor that can cause value chain disconnects to occur. Seaplant commerce does not yet enjoy tools and facilities such as accurate, generally available crop and market reports or technical information. The present monograph and the literature cited herein are responses to that need. Some features of eucheuma seaplants "market opacity" are:

- 1. Intentional manipulation of information** is a strategy that some market players utilize to gain trading advantage.
- 2. Poor decision-critical information** effects all industry players from the largest to the smallest.
- 3. Precipitous inventory adjustment**, "over buying" for erroneously perceived markets and poor handling of "safety stocks" can cause large market players to induce "boom and bust" cycles.

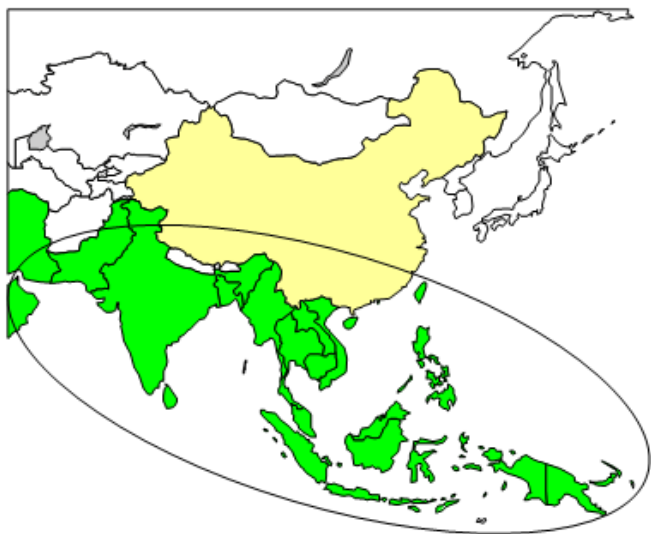
"Seasonality" factors, variable year-to-year weather patterns and natural disasters also influence supply.

"*Force majeure*" is often cited as a reason why supplies do not materialize according to contract and sometimes this is true. As more transparency develops actual *force majeure* can be addressed and false *force majeure* will be exposed.

About 80% of the world's tropical seacoast coast is in East Asia. As shown on page 4, the tropical eucheuma seaplant genera *Kappaphycus* and *Eucheuma* have become the main source of carrageenan during the past two decades:

The ASEAN countries have almost 60% of this and have several comparative advantages for seaplant production including:

1. Most tropical seacoast
2. Great human resources... half of humanity lives there
3. Cultures that value botanical products
4. Strongly developing regional markets



It is important to note that as *Chondrus*, *Furcellaria* and several other wild coldwater carrageenophytes tend to grow in "beds" that have high population density and are amenable to harvesting by rakes and drags. Tropical seaplants seldom or never grow in this manner. For example eucheuma seaplants tend to grow as individual plants or in small clumps interspersed with corals and other marine plants. **Cultivation is therefore essential before eucheuma seaplants and many other types of tropical seaplant can be made available in commercial quantities.**

Based on the material presented in pages 3-5 one can perceive the following carrageenan raw material industry trends:

- 1. The *Chondrus* harvest has shown a steady decline** since reaching peak levels on the order of 40-60,000 tons per annum in the decade from 1967-1977. Harvests have leveled off at about 6-10,000 tons per annum.
- 2. Declining effort and declining resources** may both be implicated as causes in harvest declines. Industry sources suggest that populations of *Chondrus* have diminished in size and/or that the distribution of harvestable beds has become reduced.
- 3. There has been a tendency for *Chondrus* and *Furcellaria* to grow in mixed populations** in areas such as Prince Edward Island in Canada. This reduces crop value as plants must be separated to facilitate extraction.
- 4. Average *Chondrus* and *Furcellaria* production held steady** at about 25,000 tons per annum during the period 1977 - 1991 before declining to present levels around 1992.
- 5. Cultivation of cold water carrageenophytes** has been technically successful but is economically attractive only for high-value crops such as specialty foods.
- 6. By 1977 commercial cultivation of eucheuma seaplants became firmly established** and growth of the carrageenan industry was driven by the availability of cultivated tropical carrageenophytes.
- 7. Development of "Processed Eucheuma Seaweeds"** (PES - E407a) was a major development precipitated by the availability of cultivated eucheuma seaplants. PES is cost-effective and opened new carrageenan markets.
- 8. Development of cultivation in tropical Asia is driving a trend** for carrageenan process capacity to migrate from Europe and North America to Asia.



eucheuma seaplants are eaten as sea vegetables but their main commercial value is due to the carrageenan that is a structural component in their cell walls.

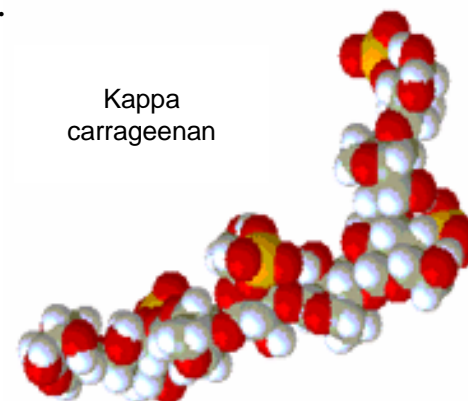
Carrageenan is synthesised in the Golgi apparatus. Enzymatic processes defined by the plants' genetic codes effect its structure (e.g. pattern of sulfation). Synthesised carrageenan is exported via cisternae to the cell wall and excreted to the matrix.

Genes determine the presence of the biosynthetic enzymes involved in carrageenan synthesis but the actual process is not a template mechanism that makes perfect copies as with proteins under DNA or RNA control. *Kappaphycus* will always produce kappa carrageenan but environmental parameters have effects on molecular structure. The plants have a natural growth, maturation and senility cycle that influences carrageenan composition. Azanza-Corrales & Saa (1990) have shown that there is seasonal variation in the gel quality in *K. alvarezii*. The gel from *K. alvarezii* improves in strength with the diameter of the thalli (i.e. with age) but it appears that both haploid and diploid plants have similar carrageenans. This is in contrast to *Chondrus* and various other Gigartinales.

There is ongoing experimentation into ways of getting more and better gels from *K. alvarezii* and *E. denticulatum* in the face of opposing interests of farmers and extractors. Farmers seek methods that involve less work or provide more weight (be it water, sand or seaweed) for they sell by weight, not by yield or quality. On the other hand extractors want fewer tons of less-expensive seaweed with higher yields and more valuable gel per ton. This can lead to some "to-and-fro" in agronomy practices. For example during early farm development pruning of growing tips was practiced but this led to a preponderance of low gel strength young material being marketed and such methods are now discouraged.

Seaweed buyers generally encourage harvesting methods that yield predominantly older plants in order to obtain higher gel strength or higher viscosity gels.

Carrageenans are complex polysaccharides considered to be molecular hybrids of several basic units (G4S-DA, G0S-DA, G4S-DA2S, etc.).



Kappa carrageenan comprises alternating units of 3-linked D galactosyl (G unit) and 4-linked D galactosyl (D unit). The G unit is mostly sulfated at carbon 4 (G4S). The D units are often sulfated at carbon 6 (D6S). The D units may also be converted to 3,6 anhydro galactosyl sugar (DA). Variations to these basic units include a G unit that is unsulfated (G) and a D unit sulfated at carbon 2 (DA2S). The D6S sugar is considered as the biological precursor of the DA sugar. This conversion can also be achieved by chemical methods (e.g. alkaline modification). Carrageenan molecules are flexible and provide fibre components and/or a matrix in which skeletal fibres are embedded. In function it may be analogous to more rigid glucans such as cellulose, mannans and xylans that occur in other seaplants and land plants.

It is standard practice in the carrageenan industry for seaplant crops to be treated under harsh alkaline conditions in order to maximise gel strength and/or other rheological characteristics of the carrageenan biopolymer. Un-modified carrageenan will give a weak gel but the alkali-modified product has a gel strength several times as strong. This is due to the fact that modification effects the chemical conversion cited above and also "opens up" the molecule to expose ester sulfate groups to the surrounding medium.

Carrageenans are characteristically sulfated with the exception of "beta" which lacks sulfation and therefore strains the definition of "carrageenan" (Santos, 1989). Greer and Yaphe (1984) considered beta-carrageenan to be a precursor of gamma-, mu- and kappa-carrageenan but it appears in high concentration with some kappa-carrageenan in *B. gelatinum* and *B. speciosum*.

Kappa carrageenan from *K. procrusteanum* and *K. cottonii* lack infrared absorption at Wave Number 805 (Doty & Santos, 1978) and this differentiates their carrageenan from the kappa-carrageenan of *K. alvarezii* (Santos, 1989). Aguilan et al (2003) have recently shown that such is also the case with the "Sacol" strain of *Kappaphycus* and this, along with DNA evidence, may lead to re-classification of the Sacol variety. The lack of a peak at the 805 position is interpreted as being due to a complete lack of sulfate in the 2-positions of the galactose units.

Today farmed material is thought to be predominantly *K. alvarezii* so when one says "cottonii" the reference is usually to varieties of that species. Strictly speaking, though, the commercial term "cottonii" may include any or all species of the section Cottoniformia. Carrageenan from the more slowly growing *K. striatum* and *E. inermis* Schmitz do show infrared absorption at Wave Number 805, which means that at least some of the galactose moieties are sulfated at their 2-positions.

Some species such as *E. odontophorum* and *E. platycladum* are reported to contain both iota and kappa carrageenans. (Mshigeni & Sems, 1977; Santos, 1989). Thus far such species have not attracted significant commercial interest.

Since cottonii is mostly prized for gel strength farming so that the average age of the harvest is older is advised. The generally accepted practice in most commercial farming areas is to harvest the crop about 6-8 weeks after planting.

Iota-carrageenan is produced by all species in *Eucheuma* section *Eucheuma* which contains *E. denticulatum* and in section *Anaxiferae* which contains *E. arnoldii* and *E. amakusaensis*. The iota-carrageenans from the species *E. uncinatum* and *E. isiforme* are deviant types and less commercially useful than those from *E. denticulatum* (Lawson et al., 1973; Penman & Rees, 1973; Dawes, 1979). Another factor bearing on commercial value is that *E. isiforme* is not known to be present in quantities sufficient to supply commercial needs and it tends to occur in regions where aquaculture is not encouraged.

Laboratory gel-yields can be higher than those obtained in commercial extractions. Most extractors must be content with yields of as low as 25 percent. In some cases laboratory yields from cottonii have run to more than twice this amount. Yield may be lower with age in cottonii thalli but the strength of the gels made using carrageenan extracted from older *Kappaphycus* thalli appears to be greater.

Gel strength may even be high in branches displaying the symptom of malaise called ice-ice (below) so in harvesting or buying such bleached segments of thalli should not be discarded if the interest is gel strength. However, it was shown that low carrageenan yields may be due to the state of crops during harvest (Trono and Lluisma 1992). In slow growing and "sickly" crops (with ice-ice) the amount of pure carrageenan yield may be 25 to 40% less than those from healthy crops (Trono 1993).



Over the years a variety of trade names has been used for the various forms of modified "gel-mode" products of eucheuma seaweeds.

The term "SRC" (semi-refined carrageenan) came into general use in the marketplace around 1978 and this is still commonly used in the trade. The term "SPC" (Semi-Processed Cottonii) was briefly current but this term met resistance from petfood producers due to connotations of the Society for the Prevention of Cruelty. Other trade names have included AMF (alkali modified flour), alkali-treated cottonii (ATC), Philippine Natural Grade Carrageenan (PNG carrageenan), alternatively Processed Carrageenan (APC), treated seaweeds, treated cottonii chips (TCC), alkalized seaweeds, bleached cottonii and a variety of other names.

The term "Processed Eucheuma Seaweed" (PES) was adopted when European Union regulatory authorities added this product to their list of approved food additives in December, 1996 by Directive 96/83/EC. INS and E numbers designate food grade-PES as "407a". INS and E number "407" applies to carrageenan extract.

Since the European Union and the Codex Alimentarius Commission both use Processed Eucheuma Seaweed as an accepted name the present monograph has adopted it as well.

For further information go to:

1. http://www.food.gov.uk/multimedia/pdfs/elist_numbers.pdf
2. <ftp://ftp.fao.org/codex/standard/volume1a/en/CXxot04e.pdf>
3. <http://www.fst.rdg.ac.uk/foodlaw/additive.htm>

Precedents that moved things along...

One of the earliest forms of carrageenan production was a nineteenth century process in which Irish moss was powdered to produce "sea-moss farine" which was distributed for the making of blancmange (a milk pudding). This sort of product can still be found in some health-food outlets.

PES arose partly from the application of Japanese "colagar" technology (McHugh, 2003) to making un-milled PES in the Philippines as a raw material for carrageenan manufacture in the mid-1970s. By then some of the larger carrageenan extractors and users had already worked out basic methods for making PES. With the Japanese product as a precedent PES rapidly became a commercially significant product by the early 1980s. The stimulus for wide-scale PES production came was the development of commercial cottonii farming in the Philippines. The process was catalyzed by a perceived need for "low-energy" biopolymers. The development of PES, initially to supply needs of the petfood industry, accelerated a shift in the fundamental nature of the carrageenan business. Before cottonii farming reached commercial proportions in the Philippines the carrageenan industry depended on natural harvests from all over the world. This created problems that made PES development impractical:

- 1. Natural phenomena, harvest pressure and trading factors** caused the quantity, price and mixture of available seaweed species to vary unpredictably from year to year.
- 2. By the early 1970s most major stocks were being harvested at (or beyond) sustained yield limits.**
- 3. The prevalence of raked and beach-cast raw material** caused deliveries to contain large quantities of extraneous algae, sand, dirt, rocks and epiphytes.

Of course, Philippine seaweed farming was not the sole factor precipitating PES development. There were at least four other factors that coincided with farm development and contributed to the creation of a market for PES. These were:

- 1. The existence of traders willing and able** to purchase seaweeds on speculation.
- 2. The existence of agarophyte and *Furcellaria* producers** who were facing a raw material shortage and had plants and/or technology adaptable to processing cottonii.
- 3. The precipitous rise of petroleum prices** subsequent to 1973 and a subsequent need for "low-energy" biopolymers.
- 4. The development of gum technology expertise** by major carrageenan users and their conviction that carrageenan or agar extracts were more refined than necessary.



PES is generally cheaper to make than carrageenan extract but applications for PES are limited; especially by the presence of fiber, color and odor.

PES characteristics minimize use in applications that require:

1. clear, smooth gels and sols.
2. uncolored gels or sols.
3. no "seaweed" odor or flavor.
4. high cold-solubility or cold viscosity.

PES limitations can be somewhat offset by procedures such as the following:

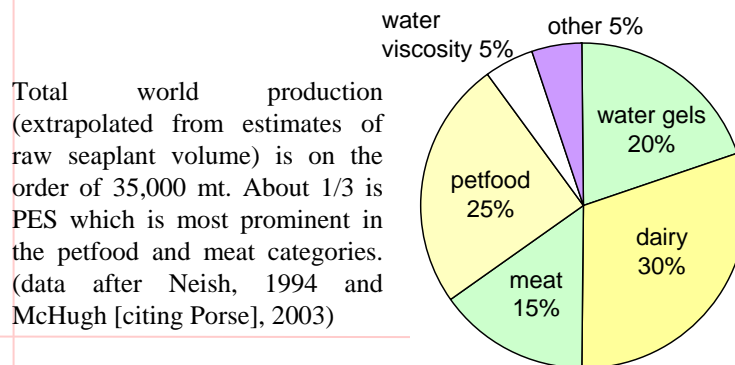
1. If low residual alkali is required (e.g.: to limit pH drift) a well-neutralized form of PES must be used.
2. If low AIM is required in a final blend PES content must be kept low (e.g.: 8-15% to keep AIM below 1-2%).

PES has been effectively and economically used in the following applications as a:

1. constituent of petfood stabilizers.
2. constituent of brine systems used for "meat pumping"
3. component of dairy stabilizers.
4. gum source in meat stabilizer and wort-floccher.
5. gelling agent for jelly desserts.
6. component of air freshener products.

Carrageenan is commercially identified by a confusing array of names and this is confounded by the fact that carrageenans are classified chemically both by the traditional "Greek" system and by the "Trondheim" system. The more recent "Trondheim" system is gaining favour. The systems are compared and contrasted by Myslabodsky (in prep).

Actual volumes of carrageenan sold in blended end-products are not accurately known but eucheuma seaplants comprize at least 70% of the total raw material base. Estimates are complicated by the fact that volumes are company confidential and carrageenans are generally applied as components of blends in which any given type of carrageenan may comprize a small percentage of the total blend. **The carrageenan market is segmented by application approximately as shown below.:**



Examples of segment applications	
Segment	Application
water gel	dessert gels, toothpaste, meat processing, air fresheners, glazes, formed foods, food canning
water viscosity	anti-icer, toothpaste, desserts, cosmetics, toppings, sauces, dressings, piping jelly
dairy gels	flans, puddings, custards, pies
dairy viscosity	beverages, ice cream, infant formula, shakes, dressings.
petfood	mostly gelled, canned petfood.
meat	mainly used for "pumping" ham and poultry.
other	cold soluble water and milk applications, salt suspensions, industrial suspensions.



Carrageenan is generally marketed as a component of "specialty" or "performance" chemical blends or as an "ingredient solution"; it is sold into markets where it generally has a "derived demand".

This means that it is generally retailed to the general public as a component in products that people buy without necessarily knowing that carrageenan is in them unless they read the label. Even reading the label sometimes does not tell the story since carrageenan and PES have several commercial designations.

Some commercial designations of carrageenan/PES:

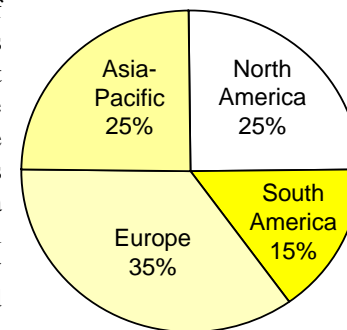
1. E407 for carrageenan and E407a for PES.
2. SRC, PNG and several other trade names for PES.
3. "Approved stabilizer" or "gelling agent"
4. Hydrocolloid or vegetable gum.
5. Red algal galactan.
6. Marine, plant or vegetable biopolymer.
7. Seaweed, seaplant or algal extract.

Pricing is all over the map - from as low as 3 USD/kg for low-grade PES to more than ten times that amount for specialty blends with exacting performance criteria.

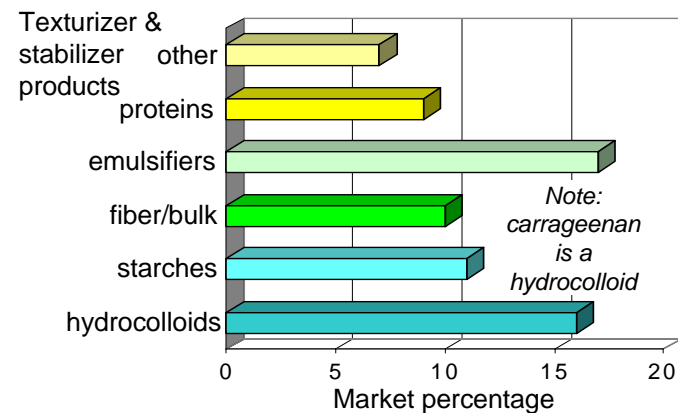
Some industry players suggest that PES and some carrageenans are "commodities", not "performance" or "specialty" chemicals. It is true that the required level of technical sales and service support for some such products is now very low; especially in the case of PES for the petfood industry where users have a high degree of sophistication and routinely play suppliers off against each other. Nevertheless, the "performance" of PES and carrageenan is important in virtually all applications and blending for uniform quality still requires close quality control. Thus it seems that the "performance" label can still be legitimately applied even to products that are "commoditized".

Process capacity has proliferated in recent years and developing markets such as China are poorly quantified.

The approximate segmentation of global carrageenan markets is shown at right. There are signs that European markets are fairly stable but Asian markets (e.g. China) are rising. There are no solid statistics so these estimates are based on a consensus of personal communications from industry players rather than on published sources.



Carrageenan market growth is conventionally projected at about 5-7 %/annum (McHugh, 2003) but it must compete with a wide range of competing texturizers and stabilizers. Estimated relative sales volumes among various texturizing and stabilizing products. Carrageenan, a marine biopolymer, is one among many types of hydrocolloid (a.k.a. vegetable gum). (Data compiled from consensus of customer responses during author's marketing and sales discussions. Neish, 1994.)



There has been scant development of eucheuma seaplant value chains other than those leading to carrageenan. Indeed, there has been little recent development of new carrageenan markets since the step-change to petfood and meat processing markets 20-25 years ago. Nowhere has this been more noticeable than in recent spinosum markets where prices have been extremely weak (below 200 USD/mt on some spot-markets during 2003).

This situation is a surprize to industry old-timers because spinosum was traditionally a high-priced raw material (well over 1,000 USD/mt around 1990) and commercial cultivation was difficult to bring about (personal experience of the author and his colleagues). Until about the late 1990s spinosum was generally regarded as being "harder to grow" than cottonii. For some reason many farmers now consider spinosum to be much easier to grow than cottonii and in several areas such as Tanzania spinosum seems to thrive where cottonii does not grow well - or not at all (Fazal, pers. comm.).

With a steady supply at reasonably prices eucheuma seaplant products may be able to penetrate several large-volume markets where eucheuma seaplant extracts are known to be effective but have previously been too expensive relative to other stabilizers.

With stable, low prices spinosum may be able to penetrate previously closed markets. It can serve as a component in liquid plant foods or biostimulants (photo opposite) and iota PES (semi-refined spinosum) has the capacity to thicken slurries and solutions in some interesting ways. For example:

- 1. It makes thixotropic (mechanically reversible) gels** that can be used in products such as paints, coal slurries, the manufacture of ceramics and several other industrial applications.
- 2. It can stabilize high-salt solutions** such as oil completion fluids and other brines.

Eucheuma seaplants have traditional markets as sea vegetables and further development may be feasible.

Cottonii (known as "guso") is traditionally eaten fresh in the Philippines in salads ("kinilaw" or "kilawin") and several hundred tons per month of dried, sun-bleached "spinosum putih" is sold from Indonesia to China where it is used as a garnish and as a component of several dishes.

Spinosum in various forms has also been consumed in Japan from time to time. Applications such as this can be expanded and eucheuma seaplants also have a potential place in "nutraceuticals" for human and domestic animal consumption and as animal-feed binders or nutritional components.

Carrageenans also have roles in agricultural, silvicultural and horticultural culture media. Agar has a long-standing role as a gelation and thickening agent in microbiological and plant growth media and carrageenan can be used as well in many applications. For example PES gels and slurries are used by some orchid growers and in plant nurseries in Asia.

The product shown right is used as a foliar spray for agricultural applications. Products such as this act as sources of trace elements and as organic biostimulants for plant growth. eucheuma seaplants are useful raw materials for such products and can be processed singly or in combination with other seaplants; notably brown algae such as *Sargassum spp.* In the past eucheuma seaplants were too expensive for such applications but spinosum can now be produced at prices that make its use feasible.

