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PROSPECTS FOR SEAWEED PRODUCTION IN DEVELOPING COUNTRIES

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1. THE SEAWEED INDUSTRY - AN OVERVIEW

The use of seaweed as food has been traced back to the fourth century in Japan and the sixth century in China. Today those two countries and the Republic of Korea are the largest consumers of seaweed as food and their requirements provide the basis of an industry that worldwide harvests 6 000 000 tonnes of wet seaweed per annum with a value of around US$ five billion.

Increasing demand over the last fifty years outstripped the ability to supply requirements from natural (wild) stocks. Research into the life cycles of these algae has led to the development of cultivation industries that now produce more than 90 percent of the market's demand.

China is the largest producer of edible seaweeds, about five million tonnes and the greater part of this is for kombu, produced from hundreds of hectares of *Laminaria japonica* that is grown on suspended ropes in the ocean. The Republic of Korea grows about 800 000 tonnes of three different species and about 50 percent of this is for wakame, produced from *Undaria pinnatifida* grown in a similar fashion to *Laminaria* in China. Japanese production is around 600 000 tonnes and 75 percent of this is for nori, produced from *Porphyra* species; this is a high value product, about US$ 16 000 per tonne, compared to kombu at US$ 2 800 per tonne and wakame at US$ 6 900.

Alginate, agar and carrageenan are thickening and gelling agents extracted from seaweeds and these three form the main basis of the industrial uses of seaweeds. Seaweeds as a source of these hydrocolloids dates back to 1658 when the gelling properties of agar, extracted with hot water from a red seaweed, were first discovered in Japan. Extracts of Irish Moss, another red seaweed, contain carrageenan and were popular as thickening agents in the nineteenth century but it was not until the 1930s that extracts of brown seaweeds, containing alginate, were produced commercially and sold as thickening and gelling agents. Industrial uses of seaweed extracts expanded rapidly after World War II but were sometimes limited by the availability of raw materials.

Today approximately 1 000 000 tonnes of wet seaweed are harvested and extracted to produce the above three hydrocolloids. 55 000 tonnes of hydrocolloids are produced with a total value of US$ 585 000 000.

Alginate production (US$ 213 million) is by extraction from brown seaweeds, all of which are harvested from the wild; cultivation of brown seaweeds is too expensive to provide raw material for industrial uses.

Agar production (US$ 132 million) is principally from two types of red seaweed, one of which has been cultivated since the 1960-70s, but on a much larger scale since 1990, and this has allowed the expansion of the agar industry.

Carrageenan production (US$ 240 million) was originally dependent on wild seaweeds, especially Irish Moss, a small alga growing in cold waters with a limited resource base. However since the early 1970s the industry has expanded rapidly because of the availability of other carrageenan-containing seaweeds that have been successfully cultivated in warm-water countries with low labour costs. Today most of the seaweed used for carrageenan production comes from cultivation although there is still a small demand for Irish Moss and some other wild species from South America.

In the 1960s, Norway pioneered the production of seaweed meal, made from a dried and powdered brown seaweed, used as an additive to animal feed. Drying is usually by oil-fired furnaces so costs are affected by crude oil prices. Approximately 50 000 tonnes of wet seaweed are harvested annually to yield 10 000 tonnes of seaweed meal, which is sold for US$ five million.

The total value of the industrial products from seaweeds is US$ 590 million.

The total value of all products from the seaweed industry is estimated at US$ 5.6 billion.

2. ABOUT SEAWEEDS

Seaweeds can be classified into three broad groups based on colour: brown, red and green. Botanists refer to these broad groups as Phaeophyceae, Rhodophyceae and Chlorophyceae respectively. Brown seaweeds are usually large and range from the giant kelp that is often 20 metres long, to thick, leather-like seaweeds from two-four metres long, to smaller species from 30-60 cm long. Red seaweeds are usually smaller, generally ranging from a few centimetres to about a metre in length; however red seaweeds are not always red, they are sometimes purple, even brownish red, but they are still classified by botanists as Rhodophyceae because of other characteristics. Green seaweeds are also small, a similar range in size to the red seaweeds.

Seaweeds are also called macroalgae. This distinguishes them from microalgae which are microscopic in size, often unicellular and are best known by the blue-green algae that sometimes bloom and contaminate rivers and streams.

Naturally growing seaweeds are sometimes referred to as wild seaweeds, in contrast to seaweeds that are cultivated or farmed.

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3.1 Seaweeds as food

Seaweeds have been used as a human food since ancient times, particularly in China, the Korean Peninsula and Japan. As people from these countries have migrated to other regions, they have taken this use of seaweed to their new countries so that dried and wet, salted seaweed products can now be found in most parts of the world. These seaweeds form the commercial side of the seaweed food industry.

Seaweed has also been eaten by the coastal populations of many countries, sometimes as part of a subsistence living, sometimes as a regular ingredient of salad-type preparations, the latter especially in Hawaii and the warmer countries of Southeast Asia such as Indonesia, Malaysia, Philippines and Thailand. These products are collected and sold on a local basis and their volume and value are not known.

The three most important seaweeds used as human food are species of *Porphyra* (common Japanese name, nori), *Laminaria* (kombu) and *Undaria* (wakame). In recent years, *Porphyra* has frequently appeared in the Japanese Fisheries Statistics as the third largest catch. All three algae were originally obtained from wild crops but today it is only possible to meet demand by large-scale cultivation methods. *Porphyra* is classed as a red seaweed, *Laminaria* and *Undaria* are brown seaweeds.

The *Porphyra* life cycle is complex and was only elucidated in the 1950s by a British phycologist. This led to the rapid expansion of the nori industry, at first in Japan, later in China and the Republic of Korea. Nori is sold in packets (about 30 g) of thin sheets, 10-12 cm square, usually uncooked or lightly baked and used to form the outer wrapping on sushi. Sometimes it is cooked and salted and eaten as a snack or sprinkled over rice or noodles. It has a high content of useful edible protein.

Annual production is estimated at 90 000 tonnes (dry), valued US$ 1 460 million.

Laminaria species were first cultivated in Japan but in the 1950s Chinese scientists were able to reduce the cropping time from two years to one year and Chinese production grew to exceed 1.5 million wet tonnes per annum. Most of this was dried and eaten as kombu in the coastal provinces, the surplus was used for alginate production. However the cost of cultivation is high and while this can be absorbed by the price obtained as food (about US$ 3 000 per tonnes (dry), it is not competitive in an open alginate market where the cost of raw material must be around US$ 500 tonnes (dry) so the current Chinese alginate industry needs to use wild crops, often imported. Kombu is used in a wide variety of dishes such as soups, as an ingredient of a Japanese hotpotch, to make pickles and as a tea.

Large-scale cultivation is carried out especially in Japan and China, to a smaller extent in the Republic of Korea, yielding a world output estimated at slightly more than 1 000 000 tonnes (dry) with a value of US$ 3 000 million.

Undaria is especially valued in the Republic of Korea where cultivation is on a larger scale than other countries. It is a thinner, more delicate seaweed than kombu. It is often prepared and marketed as a blanched and salted product, which is stored at -10 degrees Celsius before sale. In use, it is desalted by washing and used mostly in soups; in the Republic of Korea more wakame is used giving a much thicker soup than in Japan. Some processed wakame goods have been marketed as instant foods.

Total harvests of *Undaria*, most cultivated but some wild, is about 33 000 tonnes (dry) with a value of US$ 230 million.

In the past decade, some French research and development institutions have placed considerable effort into the development of edible seaweed products with a view to their introduction to the European diet and market.

3.2 Seaweeds as sources of hydrocolloids

The cell walls of seaweeds contain long chain polysaccharides, which give flexibility to the algae and allow then to adapt to the variety of water movements in which they grow. For example, some brown seaweeds grow attached to rocks in very turbulent waters, requiring maximum flexibility to survive, and these contain a higher amount of these polysaccharides than brown seaweeds growing in calm waters. These polysaccharides are referred to as hydrocolloids because they will disperse in water to give a solution with colloidal properties. Polysaccharides from other sources such as land plants behave in a similar way so sometimes the term “phycocolloid” is used to distinguish the hydrocolloids that are derived from seaweed (from the term, phycology, the study of algae including seaweeds).

When hydrocolloids are dispersed in water they increase the viscosity and so find many uses as thickening agents. Under some conditions they will also form gels and this property is useful for other applications. Their colloidal properties can lead to other uses where their mode of action is less easily defined; for example the hydrocolloid from brown seaweeds is often added to ice cream where it inhibits the formation of ice crystals if the ice cream partly melts and is refrozen (on the way from the supermarket to home).

The hydrocolloids from seaweeds, of commercial importance, are alginate, agar and carrageenan.

The polysaccharide in brown seaweed is alginic acid, present as its sodium, potassium, magnesium and calcium salts (for the chemically minded, alginic acid is a carboxylic acid). Red seaweeds contain a variety of polysaccharides but the ones of commercial importance are agar and carrageenan; they are called sulfated polysaccharides because they contain negatively charged sulfate groups and in the seaweed are combined with a positively charged ion such as those found with alginic acid.

3.3 Brown seaweeds as sources of alginate

All brown seaweeds contain alginate, but there is a large variation in the quantity and quality of the alginate present. A commercial seaweed needs to contain around 20 percent alginate based on the dry weight of the seaweed. Quality of the alginate is based on the viscosity that it will produce as a one percent solution in water; high viscosity is regarded as high quality. Brown seaweeds that grow in cold waters usually produce a good quality alginate but those growing in temperate to tropical waters often yield low viscosity alginates.

The main commercial sources are species of *Ascophyllum* and *Laminaria* (Europe), *Lessonia* (South America), *Ecklonia* (South Africa), *Durvillaea* (Australia and Chile) and *Macrocystis* (California and Baja California). Species of *Sargassum* and *Turbinaria* are harvested from warmer waters but usually provide only low yields of lower quality alginate.

Alginates are used as thickening agents in food, pharmaceuticals and textile printing. Addition of a calcium salt to a solution of sodium alginate causes the formation of a gel and this property finds applications in the food and other industries. Calcium alginate can also be made in the form of fibres and these are used to manufacture surgical dressings.

All raw materials for alginate production are wild seaweeds with the exception of some used in China where the surplus of *Laminaria japonica*, cultivated for use as food, is used for alginate extraction. Approximately 85 000 tonnes, dry weight (tonnes, dry) are harvested to yield 23 000 tonnes of alginate with a value of US$ 211 million. There are nine known producers with probably 20 other smaller producers, many based in China. However two producers account for at least 60 percent of the total output. The historic growth rate of the industry has been three-four percent per annum over the last 20 years but with fluctuations down to zero in some years because of raw material shortages (El Niño) and competition from other hydrocolloids. Increasing use in the cosmetic, pharmaceutical and biotechnology industries may allow this growth rate to be maintained.

3.4 Red seaweeds as sources of agar

There are two main sources of seaweed for the world agar industry, species of *Gelidium* and *Gracilaria*. Species of *Gelidium* were the original source, historically from Japan, but shortages during World War II gave rise to a search for other raw materials. It was found that *Gracilaria* species were suitable if the seaweed was first treated with alkali. *Gelidium* gives the better quality agar (higher gel strength) but is only available from wild species; it is a small alga, grows slowly and attempts at cultivation have not proved to be commercially viable. *Gracilaria* species are larger algae and have been successfully cultivated so that it is now the major source (about 65 percent) of agar.

Gracilaria cultivation has been particularly successful in Chile but both wild and cultivated material is available in Argentina, South Africa, Japan, Indonesia, Philippines, China and India. *Gelidium* is always in high demand so that natural resources are collected wherever possible, the principal countries being Spain, Portugal, Morocco, Japan, Republic of Korea, China, Chile and South Africa. Other minor sources of raw material for agar production are species of *Pterocladia* (a small alga similar to *Gelidium,* harvested in the Azores and New Zealand) and *Gelidiella* (India, Egypt and Madagascar).

About 55 000 tonnes (dry) of seaweed are extracted annually to produce 7 500 tonnes of agar with a value of US$ 132 million. Chile, Spain and Japan produce 60 percent of the total agar output. There are 30 known producers and it is estimated there may be 20 other small producers. Development of new applications is slow and the estimated growth rate for the agar industry is one-two percent per annum, much the same as it has been for the last thirty years.

3.5 Red seaweeds as sources of carrageenan

Irish Moss (*Chondrus crispus*) was the original source of carrageenan and until the late 1960s expansion of the industry was limited by the availability of the wild sources of this alga which grows best in cold waters such as the coasts of Ireland and Nova Scotia. Cultivation of *Chondrus* in tanks has been found to be too expensive but since the 1970s other warm water species, *Kappaphycus alvarezii* (also called “cottonii”) and *Eucheuma denticulatum* (“spinosum”) have been very successfully cultivated so that they are now the main raw materials used for carrageenan production.

Cultivation of the latter two species started in the Philippines but has since spread to other warm water countries with low labour costs including Indonesia and United Republic of Tanzania (Zanzibar). The companies involved in carrageenan extraction are actively promoting cultivation in other areas such as India, Africa and the Pacific Islands. These two species now comprise about 85 percent of the raw materials used by the industry, *Chondrus* use is five percent (from Canada, France, Spain, Portugal and Republic of Korea), while species of *Gigartina*, from Chile, Morocco and Mexico account for the remaining 10 percent.

The total raw material consumption is about 150 000 tonnes (dry) of seaweed, yielding 28 000 tonnes of carrageenan with a value of US$ 270 million. There are 24 known producers of carrageenan with perhaps another 10 smaller producers. However three companies account for 65 percent of the total production. Producers are very active in promoting new uses and the growth in the last 15 years has been around eight percent per annum. The estimated growth in the next five years is around five percent per annum.

3.6 Other uses of seaweeds

Seaweeds have long been used as additives to soils, mainly in coastal areas where the wet or partly dried seaweed is easily transported to the area to be fertilised. The high fibre content of the seaweed acts as a soil conditioner and the mineral content as a fertiliser. The large brown seaweeds (species of *Laminaria* and *Ascophyllum* in Europe, *Sargassum* in warmer countries such as the Philippines) have found the greatest use but the advent of synthetic chemical fertilisers has reduced their market. In more recent times, liquid seaweed extracts have been marketed for use on more expensive crops such as vegetables and berry fruits; faster growth and better products are obtained and the results have been linked to the presence of auxin-type plant hormones in the extracts; about 500 wet tonnes of *Ecklonia* are used annually in South

Africa for such an extract but similar products from other brown seaweeds are also made in the United Kingdom and New Zealand.

The brown seaweed, *Ascophyllum nodosum*, grows abundantly in the colder waters of Ireland, Scotland, Norway and Nova Scotia. Some of it is used for alginate productions but an industry has also been established, based on its use as an additive to animal feed. The dried seaweed is ground to a fine powder and sold as seaweed meal. Artificial drying is used so the production costs fluctuate with the cost of crude oil and since the market can only bear a certain cost, the output has varied over the years. At present it is estimated to be about 1 000 tonnes (dry) per year with a value of US$ five million.

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4.1 Future directions for FAO - feedback from industry

In compiling this report, 30 people from 26 countries provided information about the seaweed industry and in some cases, mainly people from within the industry, they also offered more general comments and suggestions about the past and future role of FAO in the seaweed industry. Sometimes information was offered that might be helpful to FAO in making future decisions about the support of projects. The following is a summary of those comments etc. It should be remembered that those making the comments have little information about the detailed policies and procedures of FAO.

4.1.1 Value of short-term contracts for surveys and experimental farming trials

These activities, often supported by FAO and similar funding sources, seldom lead to any sustainable commercial developments. There is no doubt that these short-term contracts provide valuable information to host countries, but too often reports remain on government department shelves and, without any follow-up or promotion, there is little prospect of these FAO inputs leading to any commercial development. There needs to be interest from industry/investors as well as governments before such work is undertaken so that there is a driving force towards commercial development after the FAO input is completed.

4.1.2 Long-term programmes

For FAO to have success in promoting seaweed in developing countries, it needs to consider supporting long-term programmes over three to five years, with less emphasis on short term contracts. It should also consider directing funding towards the commercial sector or consultants with private sector business experience, with less emphasis on local Government projects. The prospects of successful development could be enhanced by the following.

a. Funding programmes jointly with international processors and importers. International processors will generally want some protection of their investment from competitors, which can be achieved by the host country providing exclusivity to any initial production for a defined and limited period.

b. Providing a 'seed' capital fund for pioneer businesses in developing countries. This could be in the form of low interest loans or grants, which could be written off if the business meets certain criteria, such as exporting a certain amount of product after a three to five year development period.

c. Supporting, with funding, technical and management assistance, Non-Governmental Organizations (NGOs) such as local co-operatives and women's groups.

4.1.3 Regional workshops

Traditionally supported by FAO and similar bodies, regional workshops are very useful for the exchange of information between individuals and countries. However generally workshop participants come from government departments and institutions and the follow up for promotion of commercial development is often minimal. An example would be the workshop on the cultivation and biotechnology of marine algae held in Cumana, Venezuela in December 1996. The program included 20 speakers of whom 14 were from university/research organisations, three from government and the remaining three were from the single commercial organisation that participated. That company reports that it received negligible follow-up support from FAO and other United Nations (UN) agencies so the question remains as to what were the benefits of the workshop.

The more successful workshops are those that include a commercial partner as a co-sponsor who is willing to pursue and motivate the participants to further activity, as well as provide commercial assistance such as purchase contracts for outputs. An example is the regional workshop organised by FAO and Fiji Marine Colloids (FMC) in Fiji several years ago where the participants were seaweed farmers and local fisheries officers, with the company providing technical support and a guarantee to buy any product.

However regional or country workshops that involve government officials can be of indirect assistance to commercial development by providing officials with information about the industry, its requirements and benefits. Should commercial development later begin and permits, licences etc are required from government, well informed officials can expedite development rather than impede it as sometimes occurs at present. Uninformed officials, given a choice, often take an arbitrary and negative response, as much for their own protection as that of the country, and this occurs in both developed and developing countries.

4.1.4 Expatriate consultants

The view has been expressed that the inputs from expatriate consultants, and associated infrastructure and equipment, have been lost when the project design did not include training of native personnel to continue development when the project period for the externally-funded research came to an end. These comments were made about externally funded projects in general and not specifically about FAO.

4.1.5 Why some projects fail

For successful development of seaweed cultivation, there must be a demand for the algae and/or their products. The demand can only be classed as real when entrepreneurs are either willing to guarantee purchase of the seaweed or willing to invest money in the venture. The fact that a country spends US$ xx million per year on imports of seaweed products is not enough motivation, there may be better alternatives in the country for investment.

Is the income from seaweed cultivation comparable with the potential income from other sources? In countries where cultivation has been successful (Philippines, Indonesia and United Republic of Tanzania) seaweed cultivation provides a better income for the people involved than other activities. In some parts of Latin America, beach dwellers can get a better income from tourism and fishing shrimp and lobsters; in other parts, such as poor areas of north-east Brazil, seaweed cultivation could be a welcome source of income. Wide price fluctuations of seaweed for the hydrocolloid industry have occurred in the past but buyers are realising that supply can only be ensured by price stability and more buyers are now offering long term buying contracts.

Is a program in place to cope with sociocultural barriers that can arise in changing from a subsistence or fishing living to seaweed farming? For example, fisherman may prefer to be hired and receive a periodic payment for their labour and feel insecure in the change to being owners and managers of their own small farm. Subsistence livers may not wish to adapt to the regular, routine work required in seaweed farming.

Frequently experimental farming trials and wild crop surveys appear promising, but developing countries generally lack the experience in the commercialisation of seaweed production. The lack of sufficient entrepreneurs to invest, in what is initially a high risk development, is frequently a constraint in developing countries. In the absence of private sector funding, governments have frequently become involved in providing funding for development. However governments, whether in developing or developed countries, make poor business operators, generally to the detriment of developing a viable seaweed industry.

4.1.6 Successful projects

Analysis of the most successful and sustainable seaweed industries in developing countries over the last thirty years will show that most have been initiated by international buyers and processors, generally from developed countries. These developments have been market driven and, although supported by aid agencies and research institutions, the catalyst and driving forces have been the international commercial sector. Frequently these initially successful developments have led to the establishment of a viable commercial sector for exporting and processing within the developing country (e.g. Philippines, Indonesia, Chile, and United Republic of Tanzania).

With all new projects, initial surveys and feasibility studies should be done to ensure there is an interested market, that political, social and economic factors are favourable, that logistics and infrastructure are sufficient and that there is government support.

4.1.7 Cultivation for the phycocolloid industry

In recent years much effort have gone into developing large scale cultivation of *Gracilaria* for the agar industry and *K. alvarezii* plus *E. denticulatum* for carrageenan production. The costs of cultivation of brown seaweeds for alginate production are too high and such cultivation is only sustainable when the product is sold as human food.

Gracilaria production has been undertaken on a variety of scales, sometimes by former shrimp farmers using one or two former shrimp ponds, sometimes using large areas in protected bays on sandy bottoms. The buyers and agar extractors are often in the same country so transport to factories is relatively easy and both small and large-scale cultivation are viable.

On the other hand carrageenan extraction is mostly in large factories, usually remote from the seaweed source. For cultivation to be commercially viable, production levels in any area need to reach 1 000 tonnes, dry weight, per year (about four shipping containers per month) to cover operating costs and aim for at least 2 000 tonnes per year when fully established. The time frame for development should be about four years, to allow for setbacks from typhoons, El Niño, sickness etc and there should be a qualified project manager in charge with qualified field technicians (usually Filipinos because of the extensive experience in that country) who are in the villages doing training and making sure everyone is pointed in the right direction. Proper funding must be available, US$ two million is a reasonable estimate. Many projects that did not meet the above requirements have failed. At a beach price of US$ 200 per dry tonnes and an output of 2 000 tonnes, US$ 400 000 per year goes directly into the villages so the project money is recouped in the villages after five years.

4.1.8 Promoting the use of indigenous species - integrated aquaculture

The agar and carrageenan industries have fairly specific requirements for their algal raw materials and much emphasis has been placed on their cultivation and development.

However the conditions of some coastal communities might be improved by FAO encouraging the cultivation of local species of seaweed for use in local areas and markets, as food or fertilisers or even as seaweed meal for addition to animal fodder. Again there would be a need for a participant with a local commercial interest and FAO might also assist by the provision of seed money to assist the seaweed farmers. Such seaweed farming could be integrated with the traditional activities of fishing etc in the local communities.

4.1.9 Excellent ideas from Great Sea Vegetables

A reply received from Great Sea Vegetables has many excellent ideas for developing seaweed uses in third world countries, using a low-technology approach that is very appropriate and practical. Great Sea Vegetables is a company based in Maine, United States, run by a Mexican, David Myslabodski. Editing his reply could not do justice to the ideas that come from reading the letter. Therefore the entire reply is attached as Appendix A.

4.1.10 Introduction of non-indigenous species

Most countries adopt a very cautious attitude to the introduction on exotic species of flora and fauna. In regard to seaweeds, accidental introductions have occurred, probably through discharge of ship ballast waters and this has led to a very negative attitude on the part of some government representatives to the introduction of any algae. At present the introduction of *Kappaphycus alvaresii*, now the main species used by the carrageenan industry, is the subject of much discussion. All evidence currently available indicates that the introduction of this species, for commercial cultivation, has not led to any deleterious effects on the natural biota of the countries involved. Yet many government officials are still reluctant to allow its introduction.

FAO could assume an important role here by arranging for an independent study of the impact of the introduction of both *K. alvarezii* and *Eucheuma denticulatum* (the second most important source of carrageenan) over the last 30 years in several countries and weigh that against the effect of NOT introducing them, since their non-introduction may have had a bigger impact on biodiversity. Those commercial interests asking for the introduction of these species argue that, if governments looked at the environmental benefits of the cultivation of these two species and a 30 year history of no major problems from commercial development, plus what villagers do to their coastal environment without seaweed farming (coral harvesting, dynamite and cyanide fishing, reef gleaning until nothing is left on the flats, high nutrient levels from villages and farming, deforestation of coastal hillsides for slash and burn farming causing silation and coral deaths), then governments would understand that seaweed farming actually protects biodiversity. However such arguments are often viewed with suspicion by government officials when they come from commercial interests. If a study by FAO reached similar conclusions and was available to governments, this would be of considerable assistance to the industry and would benefit the coastal communities for the reasons given above.

4.2 Future prospects in African countries

4.2.1 Kenya

Kenya does not have very good prospects for a seaweed industry. There is no significant biomass of seaweeds in the wild to sustain such an industry. None of the pilot studies carried out have given any promising results that would encourage investors to venture into seaweed farming.

4.2.2 Morocco

There is a well established industry based on the extraction of agar from wild *Gelidium* species. In cooperation with the Laboratoire d'Algologie de Kenitra, the Institut National Resource Halieutique and Institut français de recherche pour l'exploitation de la mer (IFREMER) France, a useful method has been developed to quantify seaweed resources. Steps are also being taken to identify suitable protected natural sites for seaweed cultivation, presumably with a view to cultivating *Gracilaria* to supplement the natural resources of *Gelidium*, for agar production.

4.2.3 Mozambique

Seaweed cultivation has started in the northern part of the country, with assistance from commercial sources, and is still in the development stage but is said to have good potential.

4.2.4 Namibia

Beach-cast *Gracilaria* is collected and cultivation is being developed by a local company but the current market is depressed. Wild *Laminaria* and *Ecklonia* (kelps) are harvested and dried; they was formerly exported for alginate extraction but are now used for abalone feed, wellness and health products and raw material for fish feed formulations. The President of Namibia has assisted the University of Namibia to develop a research infrastructure at Henties Bay and this will promote research on Namibia's seaweed resources.

4.2.5 Senegal

There is a company, Algasen that is active in promoting the collection of seaweed, which it buys from villagers for export. Two species are targeted, *Meristotheca senegalensis* which contains carrageenan but is exported to Japan for use as human food, and *Hypnea musciformis*, also containing carrageenan. From 1973 to 1981 another company, Senealgue, operated using *Hypnea*, probably just purchasing and exporting but the quality of the seaweed was too poor (too much sand etc mixed with it). Algasen hopes to overcome this problem. All seaweed collected is wild, there is no cultivation. Algasen plans to start collecting seaweed during the next season for *Hypnea*, which is in February. Their correspondence indicates some knowledge of the industry although it is difficult to estimate how good it really is. Great Sea Vegetables (see section 4.1.9) may be a useful source of information about activities there and about Algasen.

4.2.6 South Africa

Natural resources of seaweed are limited and no successful cultivation exists although research findings for *Gracilaria* exist but their extension to practical farming requires the interest of entrepreneurs willing to invest in farming. About 2 000 tonnes of brown seaweeds are collected from beaches, dried and exported for alginate extraction. A limited amount of fresh kelp (about 500 tonnes) is used to produce an extract that is used as a plant growth stimulant. Some fresh kelp is also collected for feeding abalone. *Gelidium* for agar extraction is collected in the Eastern Cape, about 200-300 tonnes (dry) annually, and exported. There are no hydrocolloid extraction industries in South Africa, the natural seaweed resources are too small, and no cultivation has been developed.

4.2.7 United Republic of Tanzania

Seaweed farming of carrageenan-containing seaweeds is well established in Zanzibar where commercial interests assisted the establishment and development of the industry.

4.3 Future prospects in Asian countries

4.3.1 Bangladesh

There is no regular seaweed-based industry. Some local collection of seaweed can occur for two-three months in the year. There is good growth of the edible red alga, *Catanella*, in the Sunbarbans mangrove forests, on the pneumatophores. There are said to be some favourable areas for small scale seaweed farming. If further contact is needed, it could be through the Chairman, Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka and the Director, Institute of Marine Science, Chittagong University, Chittagong.

4.3.2 China

China is probably the most advanced country in methods and development of seaweed cultivation. However there it is realised that the traditional ways of seaweed cultivation, developed in the 1950s to 1970s need to be improved, particularly in the following areas.

a. Only a few limited species of seaweeds have been successfully cultivated; their cultivation areas are very limited, both geographically and also in terms of total hectares.

b. Genetically improved strains for a few species have been bred but have not been used effectively for cultivation. Strains being used in the industry are actually confused.

c. Seedstock technology of cultivated seaweeds during their juvenile stage still has many problems. This affects the result of each cultivation year greatly and needs to be improved so that a more constant harvest size can be obtained from year to year.

d. Seaweed cultivation on a large scale is still not well developed, in that many cultivation techniques have not been properly managed because of lack of enough scientific knowledge of the processes.

Some of these problems are being addressed in research organisations in China.

A very interesting proposal from China is that seaweed farming should be used as a means of combating the problems that are arising from eutrophication of waters, especially as a result of marine aquaculture in Asia. Extensive mariculture of scallops and other shellfish produces large amounts of N, P and carbon dioxide; fish and shrimp release the same materials via excrement and respiration. Overfeeding of shrimp in ponds and fish in cages produces large amounts of nutrient-rich sediment in their surrounding environments. Autotrophic marine plants like seaweeds feed by absorbing N and P from the water, also carbon dioxide for their photosynthesis. Therefore cultivation of seaweed and marine animals complement each other ecologically. The large scale cultivation of *Laminaria japonica* in northern China has helped to balance the negative effect from scallop cultivation. China is looking for promising candidates for southern China and believes that species of *Gracilaria* and *Porphyra* may be suitable. Like *Laminaria* in the north, both species would be commercially useful, *Gracilaria* as a source of agar and as a feed for abalone, *Porphyra* as a human food.

FAO support for this kind of seaweed cultivation in China could have spin-offs to other countries where similar eutrophication problems exist.

4.3.3 India

Unfortunately no response was available from one of the principal algal research institutions in India, the Marine Algal Discipline at the Central Salt and Marine Research Institute, Bhavnagar.

4.3.4 Indonesia

The cultivation of carrageenan-containing seaweeds is well established, especially around Bali and Lombok. The industry was established by carrageenan processors and most of the seaweed produced is exported. Ironically the local carrageenan processors find it difficult to obtain raw material at a competitive price.

There is an active agar-extraction industry with factories varying between basic and very sophisticated facilities. The industry depends on locally grown *Gracilaria* species but suffers because of the low quality of the agar in this seaweed. Seed material is selected on a haphazard basis; the industry needs to have work done on finding and propagating better seed material, one that will grow fast enough but yield a better quality agar. There is a government fisheries research institute on South Sulawesi, where much of the *Gracilaria* is grown in ponds, with the staff capable of doing this, if it has the funding. The *Gracilaria* is grown in old shrimp ponds but farmers need capital to buy ponds, or to rent them. To assist potential farmers who cannot afford either, the most modern agar company has been experimenting with a local *Gracilaria* species that appears to grow well in open seashores or estuaries. However they do not have sufficient knowledge to develop this on a larger scale. This, and the development of better seed material, are areas where FAO could help.

4.3.5 Malaysia

Malaysia provides an example of the need for commercial interests before too much money is invested by FAO and other agencies. Max Doty, in cooperation with the local Fisheries Department, successfully ran a Bay of Bengal Program (BOBP) pilot study on the cultivation of *Gracilaria* near Penang in the 1980s but the government redirected the funds available into shrimp farming so there was no follow up to that work. Market studies for agar have been made by the University of Malaysia and more recently interest has been revived by the Fisheries Department and the Universiti Sains Malaysia, for both cultivation and improved methods of agar extraction. Yet no commercial activity has resulted. The reasons given are, in summary, that there are easier and better ways of making money in Malaysia that investing in seaweed cultivation and extraction.

4.3.6 Sri Lanka

There is very little activity in seaweed although it is reported that there are diverse algal beds on in-shore and off-shore areas of the sea all around the coastline. Recently the government has decided to establish a Higher Education Institute in the southern part of the country and this will assist in the development of the marine industry in Sri Lanka.

4.3.7 Thailand

Wild *Gracilaria* is collected in the southern part of Thailand, around Pattani. It also grows in Songkhla Lagoon where it is collected from the mesh of the fish cages in which sea bass are grown. It is purchased, about 400 tonnes dry per year, for an agar factory located near Bangkok. However the agar market is very difficult because of the low price of imported material.

4.3.8 Viet Nam

Earlier work, supported by FAO, investigated the cultivation of a *Gracilaria* species that produces the best growth rate and agar in China. Recently this work has been expanded to four other species of *Gracilaria* that yield a higher quality agar than the Chinese variety and trials are also being run with *Kappaphycus alvarezii* in the seawaters of central and southern Viet Nam. The work is being done by the Nha Trang

Institute of Material Science.

However there are problems in the processing technology for the agar and the products are not good enough even for the local market. Attempts at processing *Sargassum*, said to be the largest natural resource in Viet Nam, have also encountered problems.

4.4 Future prospects in Latin American countries

4.4.1 Argentina

Four useful suggestions were received regarding Argentina. The first is to develop *Gracilaria* culture from spores. Argentinean *Gracilaria* plants are not very long and are not easy to culture by vegetative methods (as can be done in Chile using the larger *Gracilaria chilensis*). Introduction of foreign species is prohibited so native species must be used. On the positive side, the native *Gracilaria gracilis* yields a good quality agar. There is already an agar producer in Argentina, established for many years; agar production is limited by raw material so the producer may be interested in a cooperative programme to develop cultivation from spores.

The second suggestion is the preparation of human food from *Porphyra columbina* (nori), *Monostroma undulatum* (green nori) and *Undaria pinnatifida* (wakame). There is a small internal market for *Porphyra* but the suggestion is that the market could be increased and the other two species promoted as well. The present and potential markets would need to be assessed and a potential processor identified before any further development was funded.

The third suggestion is to produce commercial quality carrageenan using *Gigartina skottsbergii* and *Sarcothalia crispata* from Santa Cruz province. Harvesting these subtidal species by scuba is difficult and expensive. In Chile some culture of these species has been developed. People have gathered beach-washed material and sold it to the agar factory that also produces carrageenan; the social benefit of this harvest is very low. The potential market for these carrageenophytes, both within Argentina and for export, would need to be assessed before cultivation studies were funded.

The last suggestion is that the large seaweed beds in the south of Argentina should be properly surveyed to determine the quantities and types of natural commercial seaweed. Earlier estimates are available but were not necessarily derived using reliable survey methods.

4.4.2 Brazil

The opinion has been expressed that some previous FAO projects in Latin America have failed because of the failure to find entrepreneurs to invest money to bring the projects to commercial fruition. However currently a project is being considered by FAO to farm seaweeds by low income, coastal populations in north-east Brazil; the product will be purchased by an existing agar producer whose expansion has been impeded by an insufficient supply of native raw material.

The draft of this project [TCP/BRA/0065(A)] is an excellent example of how a project should be planned and executed. It fulfils the suggestions made by the industry to FAO as outlined earlier in this report (section 4.1). For example, a demand for the products is assured by the participation of a commercial enterprise that will purchase the seaweed; the income from seaweed cultivation is better than any other sources available to these communities; provision has been made to monitor the social and cultural changes that arise as the project progresses (section 4.1.5 of this report). Support for local co-operatives and women's groups is provided (4.1.2). The project will initially be market driven because of the presence of an agar factory and plans for future markets and expansion will be made after the market study is complete (4.1.6). The report of the Formulation Mission has shown that political, social and economic factors are favourable, that logistics and infrastructure are sufficient and that there is support from the various government bodies involved (4.1.6). A donor sponsored project proposal will be discussed for the follow up and expansion of the activities started by this Technical Cooperation Programme (TCP) project, in-country personnel will be trained during the project, so these factors overcome the criticism noted in 4.1.4 of this report. Finally, the purpose is to integrate seaweed cultivation with the normal activities of these coastal people (4.1.8). If the TCP draft proposal becomes available as a public document, pages 2-11 should be attached to this report as Appendix B, as an illustration of how a project should be designed and executed.

4.4.3 Colombia

During the last 15 years there have been a number of studies by university investigators related to the ecology and biology of potential commercial algae. These studies have provided basic information of algal distribution, seaweed biomass, chemistry of phycocolloids and potential uses of species for algal derived products. However there do not appear to be any large natural beds of commercial seaweeds except perhaps for natural beds of *Grateloupia* (containing carrageenan) on the Caribbean coast. There are beds of agarophytes in the San Andres Islands but the algal biomass has not been estimated, nor have there been any surveys of seasonal abundance. While Colombia has two large seashores, there is a great diversity of algae rather than concentrations of a few particular algae, such as those found in Chile. It is said that there has been a recent increase in the demand for carrageenan and agar in Colombia.

Market studies and an assessment of commercial interest in investment for seaweed cultivation would be needed before any other funds were committed to development of a seaweed-based industry.

4.4.4 Cuba

Information about Cuba was derived from sources outside the country. Cuba has successfully cultivated *Eucheuma/Kappaphycus*. Cuba however does not have the money to expand the cultivation to a point that they could export it, nor to produce enough for their own carrageenan production. Therefore the need is for outside companies interested in joint ventures. With the embargo in place, there are few options remaining.

Cuba did extensive research and development on the production of alginate from *Sargassum* species, abundant along its coast. There was exchange of information with the FAO-funded group in La Paz but again there are no funds available for an extraction plant. Joint ventures with outside companies are unlikely because most alginate manufacturers regard *Sargassum* as a poor source of alginate.

4.4.5 Ecuador

There is said to be an interest in cultivating carrageenan-containing seaweeds but no response was available from people with seaweed interests in Guayaquil. An opinion from Mexico is that there may be large seaweed beds in Ecuador but no surveys have been undertaken to confirm this. The same source says that *Gracilaria* has been cultivated in shrimp ponds to mitigate the effect of "Taura Syndrome" in shrimp culture; at least one producer was successful and was able to find a market for the *Gracilaria*.

4.4.6 Mexico

Mexico is unique among Latin American countries in that it has temperate, subtropical and tropical sea conditions. No other country in the region has such marine environmental diversity. The present methods used for the cultivation of *Kappaphycus alvarezii* and similar carrageenan-containing seaweeds originated 30 years ago in the southern Philippines and although these techniques require very little capital investment, their labour input is very high, their profitability is low and can only be attractive in relatively poor areas where no other profitable commercial activities are available. In many areas of Latin America, including Mexico, more productive cultivation techniques are needed. There is a lack of progress in this area because the work is too applied for many academics and most agencies that fund scientific research do not support development projects. This is scope for FAO intervention here.

To date all seaweed industry in Mexico has been confined to Baja California; *Macrocystis* for sale to alginate producers in the United States and *Gelidium* for local agar extraction. *Gracilaria*, for agar production, is reported in the Pacific and Gulf of California but surveys are needed to quantify the amounts available.

More exhaustive surveys could also be made for the native carrageenan-containing seaweeds but if there is insufficient for commercial production, their cultivation could be tried in regions of the Yucatan peninsular. However a production of at least 200 dry tonnes per year would be required and to develop farms for that quantity would takes several hundred thousand dollars and a four year plan so there would need to be a commercial input if a pilot cultivation proved successful. The better approach would be a combination of private sector and aid money for any pilot project, thus having some private sector support from the outset. This is a possibility in Mexico. However the main native species are not in the very restricted list of algae that the United States Food and Drugs Administration (USFDA) allows for use as carrageenan raw materials so this limits the market for any output. This has led to work being done on the culture of *Chondrus crispus*, approved by the FDA, and initial studies have shown promising results.

Academia and the private sector in Latin America have tended to look at the phycocolloid industry as *the seaweed industry.* Although this is not necessarily bad, it has meant that other options have been neglected. Mexico has suggested other options for itself and other Latin American countries. These are: the cultivation of edible species, using seaweeds as a biofilter (as previously noted under China and Ecuador), using seaweeds as fodder for abalone and sea urchins.

Cultivation of edible species such as *Undaria, Laminaria* and *Porphyra* would provide a much more attractive financial outcome than any cultivation of seaweeds for phycocolloids. Mexico has waters suitable for such cultivation; local species of *Porphyra* are known but *Undaria* and *Laminaria* would need to be introduced. There is a long history of consumption of native seaweeds by some coastal communities in Mexico, also in Belize, Honduras and Panama. Usually they are agar- or carrageenan-containing species that are dispersed in boiling water, different spices are added and the drink is usually served cold. Puddings and porridges are also prepared by increasing the amount of algal material during the boiling. However the uses of the species proposed above, *Undaria* etc, would be quite different, to be consumed more in the Japanese/Chinese way. There has been at least one formal request to introduce some of these species in Mexico (and similar cases in Chile and Argentina).

Seaweeds as a biofilter was noted above in the discussion of China (4.3.2). The cultivation of *Gracilaria* in shrimp ponds was noted for Ecuador (4.4.5). The idea of integrating seaweeds in aquaculture, to reduce the impact of waste water and to generate added value from sale of the seaweed, has gained momentum. In Chile *Gracilaria* has been tested with salmon and flounder, in the United States *Porphyra* has been cultivated with fish while in Israel *Ulva* (a green seaweed often called sea lettuce) has been cultured with abalone. Mexico has done some evaluation of the capacity of *Gracilaria* as a biofilter in shrimp cultivation.

Seaweeds as fodder for abalone or sea urchin culture is being investigated using local species of *Porphyra* and *Gracilaria*. Abalone farms depend on natural seaweed beds for feed but these have proved to be unreliable because of their variable nutritional quality and loss of availability through El Niño. Artificial feeds can produce undesirable flavours as well as sanitation problems. Integrated seaweed cultivation can act as both a feed and a biofilter, improving the water quality. However a fully developed abalone farm may demand up to 15 wet tonnes per day so the chosen seaweeds must be readily cultivated and have good nutritional qualities.

4.4.7 Peru

There is at least one company that has been involved in the export of seaweeds for several years. *Gigartina chamissoi* (or *Gigartina chondrocantus*) is used by the carrageenan industry and is also used in Japan as part of a seaweed salad. Currently 200 tonnes per year are exported, the potential could be 500 tonnes but this amount is not usually available from natural sources. The demand is relatively low and cultivation, if possible, would only be justified if Japan increased their purchases.

Gracilariopsis was exported in the past to agar producers but the agar quality is low (low gel strength) and, with the increased cultivation of high quality *Gracilaria* in Chile, it is becoming increasingly difficult to find markets for this seaweed.

Lessonia nigrescens and *L. trabeculata* are available from natural beds in the south of Peru but the biomass is affected by strong El Niños. In normal years about 3 000 tonnes are exported. *Macrocystis pyrifera* is also widely available but is exported only in small quantities. These three species are brown seaweeds and not easily cultivated.

Taxonomists find *Gelidium, Ahnfeltia* and *Durvillaea* species but the readily accessible quantities are not commercially viable.

4.4.8 Venezuela

One company is very active in promoting the cultivation and use of seaweeds. It is involved in the cultivation of native species of *Gracilariopsis*, an agar producing seaweed, and the non-indigenous *Kappaphycus alvarezii*, containing carrageenan. The same company is also developing food products and fertilisers from local seaweeds. Iron bioavailability of some species, mainly *Gracilariopsis* due to their high iron content, is being examined with a view to adding it to foods to supplement nutritional aspects of the Venezuelan diet.

The introduction of *Kappaphycus alvarezii* from the Philippines is being monitored for any impact on local flora and fauna; it has an excellent growth rate, a good quality carrageenan and a market has been found for it.

Large financial resources are needed to train people and install farms and a joint venture between the company and an NGO has been awarded funds from the Venezuelan government and a multilateral financial institution for these purposes.

The company believes that FAO should help to educate public administration officers in the benefits of seaweed cultivation (the obstacles they sometimes raise can act as deterrents to investment in seaweed aquaculture), and convince donors of the need for financial resources in soft terms to assist seaweed farmers.

4.4.9 West Indies

In the West Indies, farming of *Gracilaria* commenced several years ago. The product is consumed locally, usually in the form of a drink made by extracting the “sea moss” with hot water. More recently *Eucheuma* has replaced *Gracilaria* as the main crop but extracts of the replacement do not behave in the same way when milk is added, so some re-education of the processors and users has been necessary. The development of cultivation and processing has been organised and supervised by the Caribbean Natural Resources Institute (CANARI) based in St Lucia. There is cultivation in St Lucia, Barbados and Jamaica. In Guadeloupe, scientists from IFREMER, France, were successful with some pilot cultivation in 1980-83 but there was a lack of interest by the local population so this work was never expanded to a larger scale.

4.5 Future prospects in the Pacific Islands

There are some Pacific Island countries that have shown an interest in seaweed cultivation. They may have discussed it, or sent representatives to regional workshops, or actually tried some experimental farming. However no real progress to any commercial scale has resulted in the Cook Islands, New Caledonia, Palau, Samoa, Solomon Islands and Tuvalu.

There is activity in four countries: Fiji, Kiribati, Tonga and Vanuatu.

Until the recent coup, Fiji was shipping regular commercial quantities of dried *Kappaphycus alvarezii* and will probably continue to do so when the country returns to stability. Kiribati has been producing *K alvarezii* for several years around Tarawa and other islands in the Gilbert Islands and selling it under long term contract to a carrageenan producer. Similar cultivation is under development at Christmas Island in the Line Islands, with assistance from the New Zealand government. There is also some activity in Vanuatu, probably sponsored by a commercial carrageenan producer. Tonga has previously tried to cultivate *K. alvarezii* but schools of siganids ate the young plants and no method could be devised to overcome this problem. However recently Tonga has successfully exported an edible seaweed, a species of *Cladosiphon*, to Japan and is considering cultivation with the assistance of the Japanese, who cultivate the same species in southern Japan. This market has been developed through the activities of the FAO regional project based in Fiji.

5. SUMMARY

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5.1 FAO involvement in the seaweed industries - suggestions

See section 4.1 for details.

a. Spend less on short term contracts.

b. Be prepared to enter into long term contracts, up to three-five years, preferably in collaboration with industry.

c. Have commercial co-sponsors for regional workshops.

d. Ensure the markets for seaweed products are real, as defined.

e. Determine whether investment in the proposed seaweed activities is at least equal to other investment opportunities.

f. Assess the effect of cultural barriers that may arise from the introduction of seaweed cultivation or related activities and plan accordingly.

g. For seaweed cultivation, before the project begins, estimate the scale of operation that will be necessary for commercial viability.

h. Promote the use of indigenous species for local uses and integrate seaweed utilisation with the other activities of the coastal people.

i. A low technology approach may achieve more in the beginning, expanding activities and methods as markets demand.

j. Study the long term effects of the introduction of non-indigenous species for commercial cultivation.

5.2 Prospects in developing countries

5.2.1 African countries

In East Africa the cultivation of *Eucheuma denticulatum* and *Kappaphycus alvaresii* for carrageenan extraction are established in Zanzibar; however there is currently an overproduction of the main crop, *E. denticulatum* and sales are difficult. Cultivation of these two carrageenophytes is under development in Mozambique with commercial backing; the company involved believes there is also potential in Kenya and Somalia. However none of the pilot studies by government organisations in Kenya have been promising. In Namibia commercial interests are assisting the cultivation of *Gracilaria* for agar extraction; a new use for kelps is being developed, as an additive to salt so that the iodine content of the salt is increased using an additive that does not separate from the salt during transportation.

Senegal appears to be the only African country where FAO input could be of benefit at present. There is one company that is actively trying to revive interest in harvesting wild *Hypnes musciformis* and a cooperative program between the company and either the Senegal government or FAO for the training of coastal people in the collection and post harvest treatment of seaweed would be beneficial to the coastal communities. This might later be extended to attempts to cultivate *Hypnea*, if the commercial demand is there for more product.

The ideas from Great Sea Vegetables, already active in West Africa, could also be tried in Senegal if the company is not already working there.

5.2.2 Asian countries

Of the countries considered, China, Indonesia and Viet Nam offer the best prospects for positive results from any input from FAO.

Proposals from **China** for the complementary cultivation of seaweed and marine animals, to overcome problems of eutrophication of waters, are worth pursuing and the benefits would be applicable to other countries involved in the aquaculture of fish, shrimp and shellfish. China has the proven scientific and practical expertise to pursue such work.

Indonesia needs more, and better quality, *Gracilaria* for its agar industry. The present seedstock is chosen at random and of mediocre to poor quality; there is one government research organisation in Ujung Pandung capable of searching for seedstock that yields a higher quality agar. One of the largest agar extraction companies, certainly the one with the most sophisticated equipment, is very interested in obtaining better raw material and could be willing to join in a cooperative venture with FAO, along the lines suggested in section 4.1.2 of this report.

In **Viet Nam** there have been studies on the cultivation of *Kappaphycus* and *Gracilaria*, some of the work on *Gracilaria* was funded by FAO. The results are not clear, nor is the driving force behind the studies. There appears to be a demand for both seaweeds but this would need to be confirmed by a market survey before any other FAO commitment was made. The market study would need to identify exactly which companies would be buying the seaweeds, probably international processors for the carrageenan-containing *Kappaphycus* but Vietnamese agar processors would be preferable for *Gracilaria*; however such general statements are unacceptable, more specific details should be obtained.

5.2.3 Latin American countries

Colombia and Ecuador offer possibilities, especially Colombia with its two different coasts. However there is no interest from any commercial organisations at this time so it is doubtful that any FAO money should be spent there. Cuba has developed methods for cultivating seaweeds and also has some knowledge about extraction procedures but lacks the necessary capital or foreign investment needed to establish any industry. Wild seaweeds are collected and exported from Peru and one company, with several years experience in the business, believes there is further scope for harvesting the wild seaweeds and that any cultivation would be premature at this time.

Argentina, Brazil, Mexico and Venezuela offer the best prospects for development of seaweed-based industries.

Argentina has one large producer of agar that can no longer find sufficient wild resources of *Gracilaria*; the same company produces carrageenan from imported seaweed. That company might be interested in a cooperative project with FAO for the cultivation of Argentinean *Gracilaria*; however the cost of such cultivated seaweed would need to be compared with competitive raw material available from Chile.

Sea conditions are probably suitable for the cultivation of edible seaweeds such as nori, green nori and wakame. There is a small market within Argentina; the present and potential markets would need to be assessed before any development was funded.

Two carrageenan-containing seaweeds are candidates for possible cultivation, *Gigartina skottsbergii* and *Sarcothalia crispata.* The potential market, within Argentina and for export, would need to be carefully assessed before cultivation studies were funded.

Brazil: a very well structured project is currently being considered by FAO to farm seaweeds by low income, coastal populations in the north-east of the country.

In **Mexico** the problem appears to be finding investors willing to become involved in the seaweed industry. Better surveys of wild stocks are needed, as are more productive cultivation techniques. However there is little point in FAO or other aid money being spent on these projects unless there are investors willing to use the results. A combination of aid and investor money for development projects would be more likely to lead to a commercial outcome, with the investor utilising the results.

The cultivation of edible seaweeds has been suggested and this could be more profitable than cultivation for hydrocolloids. A market study of the potential for edible seaweeds is needed to encourage investors to become involved.

Abalone grow well when fed on seaweeds if a consistent nutritional quality can be guaranteed. This could be achieved by combining seaweed and abalone cultivation (wild seaweeds vary in their nutritional quality). A cooperative venture between FAO and abalone farmers could be of benefit to Mexico and other areas where abalone cultivation is successful.

Venezuela has one company that has been very active in encouraging seaweed cultivation and the use of native seaweeds for food and fertilisers. It guarantees the purchase of all harvested seaweed. It looks to FAO for support in convincing donors to make financial resources available to seaweed farmers in soft terms, and to develop social programmes that support the technological ones. It believes technical cooperation with developing countries must rely more and more on NGOs. The industry would benefit from any FAO programmes that gave technical assistance to public administration officers so they can realise the benefits of seaweed aquaculture and cooperate in its implementation.

5.2.4 Pacific Island countries

Tonga may need further FAO support if it decides to attempt cultivation of edible seaweeds for export to Japan.

5.3 Countries where market studies might be useful

For each country listed below, see section 5.2 for a brief summary and further details in sections 4.2 to 4.5, under the country name.

Argentina
Colombia
Mexico
Viet Nam

5.4 Countries needing assistance for seaweed cultivation or related activities

For each country listed below, see section 5.2 for a brief summary and further details in sections 4.2 to 4.5, under the country name.

Senegal
China
Indonesia
Viet Nam
Argentina
Brazil
Mexico
Venezuela

5.5 Developing countries as raw material suppliers

Developing countries are well placed to be suppliers of raw material for either the hydrocolloid industry or edible seaweeds. Seaweed cultivation is usually very labour intensive so low labour costs are necessary to make it viable. Capital outlays can depend on the scale of operation but are usually small, although still beyond the affordability of some coastal people so that often seaweed buyers will provide initial finance to the growers.

Cultivation by vegetative reproduction requires the least capital; for example, to cultivate *Kappaphycus* the requirements are polypropylene lines stretched between stakes that are driven into the sea floor, a means of attaching the small pieces of seaweed to the lines, some kind of racks to dry the seaweed so that it is off the ground, away from contamination by sand etc; sometimes netting is placed around the perimeter of the area to capture any seaweed pieces that break off from the growing algae. *Gracilaria* is also grown vegetatively, sometimes on lines, sometimes by inserting pieces into a sandy sea bottom and holding them there by various means.

Cultivation via the sexual reproduction cycle requires a larger capital outlay and is best suited to edible seaweeds such as nori, kombu and wakame, where the additional expense can be recouped from the higher selling price of the final product.

Both methods of reproduction are labour intensive although Japan has mechanised some important stages in the production of nori from *Porphyra*, necessary because of the higher labour costs in that country.

5.6 Developing countries - prospects for processing industries

Developing countries should avoid becoming involved in processing seaweeds for hydrocolloid extraction unless it is in cooperation with international processors. The capital outlay is large, several million dollars, but the provision of capital does not ensure success. The chemistry for hydrocolloid extraction is simple but the technology and engineering aspects are complex, with detailed information being difficult to obtain unless it is a cooperative venture with an experienced producer. These comments apply especially to alginate and carrageenan extraction, agar is a little simpler but even here the best product at the most economical cost is obtained using equipment with a high capital cost. Developing countries can produce agar using low technology methods but the product would need to be consumed in the home country, it is unlikely to be competitive in the international market.

Another deterrent to developing countries becoming involved in hydrocolloid production is the difficulty in selling the products on the international market. Agar sales are split between a large number of producers and it is not too difficult to break into the market for food grade agar. The alginate and carrageenan industries are in the hands of a very limited number of producers who have strong control of the markets and can afford to supply specialised customer support for their sales. Customers are often reluctant to change suppliers because of the variability that can occur between brands, since the final properties of these natural products depend on both the source of the raw material and the nature of the extraction and refining processes. While some developing countries have developed extraction methods and sales to suit their own internal market, they often find it difficult to compete in the long term when international processors move into their market.

For edible seaweeds, developing countries are best suited to process seaweeds for their own local markets which are often for coastal people who have consumed seaweeds over a long period of time. The cost of producing large quantities of edible seaweeds for export is high and the risk is also high because of the difficulty of breaking into the larger Asian markets.

Appendix A

Personal communication from
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Wild seaplant resources should be exploited based on carefully executed management plans to ensure that one achieves full sustainable capacity and, if the conditions exist, farming will always be a good option to improve the total catch.

I am claiming that every single seaplant, that can be harvested and/or farmed in enough quantities, will be useful in more than one way. It should be possible to encourage people to use local resources. Today there is enough knowledge to enable us to make a quick guess about uses of local resources.

Projects could be started on a pilot scale, obtaining enough raw materials to be evaluated and taking care to slowly increase the harvest to ensure a sustainable yield. This can be done with local communities of fishermen that are already connected to the sea. Based on preliminary data, it will not take long before one has a good idea of how to proceed in order to develop a market for these seaplant products. At a very early stage it will be determined if the project will harvest/farm cash crops to be sold in the international market or produce food, fertilizers, etc. to be consumed in the local markets. My guess is that some of the projects will be a combination of both.

One does not require lots of capital or knowledge to start a project to harvest wild seaplants and manufacture human food, animal feed and agricultural products. Again, the local conditions will dictate the scale and the final aim of the project. What is frustrating is that most of these small projects waste valuable resources in discovering the wheel one more time! This is where FAO should have a critical role.

I envision regional hubs where the necessary human and financial resources are located. These hubs will serve as repositories of the necessary knowledge so a single place can serve many local communities. Obviously, there has to be a very strong connection between the hub people and the small communities. In my experience, one has to be working in the field with the local people to really understand the way they think and this tends to build long lasting and trusting personal relations that increase the chance of having a successful enterprise.

I must also recognize that in some instances, small coastal communities will not be the adequate channel to exploit the seaplant resources. In cases where large entities are necessary it will be a matter of the local conditions dictating who will manage the enterprise - a private company, a government company or a hybrid entity. My only concern would be that such entities are somehow connected to the sea, understand how fragile this environment is, and are willing to have patience and reap the benefits in the long run and ensure sustainable exploitation of the resources.

I have seen first hand enough over-exploitation of the seas [cod, shrimp, sea urchins, etc.] and the last thing I want is to start overharvesting seaplants. I must also add that until now, all the seaplant harvesters I have been involved with run their businesses in a responsible way.

So what would be my hands-on approach?

One can start in places where there is enough natural accumulation of storm-cast seaplants or easily accessible material that can be harvested on foot during low tide. A quick pilot survey will guide us regarding what to collect and how to collect.

Even if the material is a bag of mixed species, this is useful material for producing compost and possible kelp meal to be used as animal feed or fertilizers. There are some easy bush-tech ways of cleaning the stuff from sand and other junk. All that is really needed is people to collect the stuff and some basic ways of getting it dried as soon as possible so it does not rot. If warranted, one can also go the high tech way, or at least the grand scale way, and end up producing large quantities of kelp meal.

The next step would be to select seaplants to be consumed directly by humans as sea vegetables or as "sea farina" (this is food grade seaplant meal, mesh size depending on final application, fine for baking, coarser for use as salt substitute or condiment). Like in the good old days of Irish carragheen. This can also be done at various scales from a small family business all the way to Chinese style *Laminaria* harvesting-farming.

I am aware that the moment one starts talking about food grade materials one has to deal with the local regulatory agencies to ensure the safety of the sea vegetables. I do not see this as a big headache. Again, there is a long list of seaplants used as food in all sort of places around the world and this information should be used as a reference.

This is also an opportunity for FAO in trying to establish [together with WHO?] a set of health standard for seaplants. I am not aware of many countries that have a good consistent regulation in these matters but I do have some references if you are interested.

Can you imagine the health benefits for children and pregnant women in third world countries if we could add just three percent sea-farina to the tortillas, pitas and breads of the world? This would be a wonderful way of helping improve the health of general populations.

I would insist on the concept of the sea-farina because not everybody will jump at the opportunity of having a plate of *Sargassum* for lunch or having Dulse as a snack. Take into consideration that properly dried seavegetables or sea-farina are stable for months [if not years]. They do not need to be frozen or refrigerated and the sea farina is very compact and easy to transport.

I have information about the use of seavegetables as food and their nutritional benefits. I managed to surprise myself by being able to buy 28 different seavegetables cooking books. This tells you that there is much more to seavegetables than eating sushi! I have recipes from China, Japan, Republic of Korea, Ireland, Wales, Brittany, France, Chile, Mexico, Far East Russia ...

If one wants to get a little fancier, it is possible to pickle, salt, roast or even can seavegetables!

The consumption of kelp-meal for agricultural and feed use has increased in the last couple of years. Much of it has to do with people buying more natural [organic, bio-] products. This is not a fad. This trend is here to stay. The debate about genetically modified food ingredients will only create more demand for sea farina/kelp meal products.

Some places might choose to grow cash crops either to be exported or used locally as raw materials in the manufacture of gums [food, industrial or otherwise]. I also see a role for FAO in this endeavour. Not all the carrageenan has to come from *Eucheuma* and not all the agar must be extracted from *Gracilaria* or *Gelidium* seaplants. In India alginate is extracted from *Turbinaria* and *Sargassum*. *Ahnfeltia* is used for agar in Russia and *Phyllophora* was used for carrageenan in Ukraine.

I think that it is only in the United States that there is an unreasoned list telling you what can be used as a source of carrageenans. Alginate and agar raw materials are quite open. If there is enough raw material to make a decent extract why not use it? If there is not enough material, try to grow more of your local stuff instead of bringing exotic species!

If people want to use local types they must be very careful on the protocols used to evaluate the raw materials. I have seen many, many papers talking about potential sources of agar and am still waiting to see a new industry being built on them. It is sad to read papers where it is clear that the gum was degraded during extraction or papers claiming a good source without having done a material balance on the raw material to enable a correct calculation of the real yields.

FAO can be the catalyst to establish R&D hubs where the necessary process-chemistry expertise exists. Let the farmers farm, the harvesters harvest and give the engineers a chance to do the process development.

I see there is a very good chance of developing seaplant resources to be used as raw material for many different products.