MARINE PLANT MANAGEMENT AND OPPORTUNITIES IN BRITISH COLUMBIA

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Executive Summary

British Columbia's diversity and abundance of marine plants and in particular, kelp species, have long been viewed as an underutilized resource. This report details

- British Columbia's marine plant resources,
- current marine plant activities, management and issues in British Columbia,
- historical marine plant harvest in British Columbia,
- the international harvest and cultivation of marine plants,
- opportunities for expansion of the British Columbia marine plant industry.

The purpose of this report is to provide background information that may be used to update marine plant policy and give context to marine plant opportunities in British Columbia.

BRITISH COLUMBIA'S MARINE PLANT RESOURCE

British Columbia has approximately 600 species of marine plants, 20 of which are kelp species. Stock assessment efforts have concentrated on the kelp species *Macrocystis integrifolia* and *Nereocystis luetkeana* because of their relatively high commercial potential. The total standing stock of *Macrocystis* and *Nereocystis* is estimated to be in the neighbourhood of one million tonnes.

One study of *Salicornia virginica* resources of British Columbia has been completed. It estimated that there are approximately 10,000 metric tonnes (wet tonnes) of *Salicornia* in the province, most of this found in southern British Columbia.

MARINE PLANT MANAGEMENT

Different government bodies manage marine plants on the west and east coasts. The provincial Ministry of Agriculture, Food and Fisheries (MAFF) has jurisdiction over marine plant harvest on the west coast while the federal Department of Fisheries and Oceans, in conjunction with the provinces, control marine plant harvest on the east coast.

In British Columbia, both the Provincial Government and the Federal Government have a legal basis to manage marine plants in British Columbia. The Federal Government does not exercise its rights in regards to marine plants, rather there is an agreement that the Province will manage marine plants on the condition that licences are sent to the DFO for review. First Nations may also have rights regarding the management and harvest of marine plants in their traditional territories.

Marine plants are regulated under section 24(1) of the British Columbia Fisheries Act. The basic marine plant policy developed in British Columbia over two decades ago continues to be relevant today, although there are some current issues that are not adequately addressed in this policy.

Licensing policies include licence limitations, licence allocation, exclusive privilege. There is also 'right of first refusal' for the same area and quota given to harvesters unless there are conservation concerns. Marine plant aquaculture tenures and licences are issued to marine plant cultivators by BC Assets and Lands.

In Nova Scotia, the Federal Government manages most marine plant species independently. The Provincial Government employs a lease system to manage some species in conjunction with the Federal Government. Leases may be issued for up to 15 years for companies that have a proven record of sound management

Current marine plant management issues include concerns about harvesting impacts by the public, problems enforcing marine plant licences and length and untimely issuance of licences. There are also several issues regarding First Nations. The Supreme Court cases R. v. Gladstone and R. v. Delgamuukw may have important consequences for marine plant management.

HARVEST OF MARINE PLANTS

Internationally, the value and amount of production for marine plants as a whole have doubled over the last ten years. The top ten marine plant producing countries are mainly Asian and account for more than 90% of the world's harvest. The economic value of marine plants cultivated for food products was approximately US$4.5 billion in 1997, while the value of the industrial harvest was only US$603 million. The majority of the edible marine plant market is located in Asia.

First Nations of the Northwest coast made extensive use of marine plants. They were used in technology, medicine and traditions as well as eaten. Marine plants were, and still are, integral to the healthy lifestyle of Coastal First peoples, even though technologies and food habits have changed considerably.

British Columbia has a long history of attempts to capitalize on marine plant resources, in particular the kelp species *Macrocystis* and *Nereocystis*. The majority of failures were due to financial difficulties, although bad luck and administrative problems also played a role. The marine plant industry has never progressed beyond small-scale enterprises harvesting less than 100 tonnes a year.

Currently, the bulk of the marine plant harvest in British Columbia consists of *Macrocystis integrifolia* for the herring spawn on kelp (SOK) fishery. Other marine plants harvested commercially in BC include *Nereocystis luetkeana, Salicornia virginica, Laminaria, Alaria, Egregia, Zostera* and *Hedophyllum*. The number of licences for harvesting marine plants for purposes other than the SOK fishery increased slightly between 1992 and the present. In British Columbia, non-spawn on kelp marine plants are harvested for sea vegetables, sea urchin feed and horticultural products such as fertilizer, foliar spray or soil additives.

MARICULTURE OF MARINE PLANTS

Mariculture of marine plants is a very important sector of aquaculture world-wide with an annual value in the billions and employing hundreds of thousands of people. Eighty-one percent of the worldwide commercial harvest of marine plants is cultivated and was worth approximately US 5.9 billion in 1997.

Currently, four companies in Canada are cultivating marine plants commercially. Three of these companies farm red algae in land based aquaculture systems. The technology to culture several British Columbian marine plant species exists but only two companies are currently engaged in cultivation activities. The most successful marine plant culturing operation in British Columbia is cultivating *Gelidium* for the bacteriological agar market.

Marine Plant Opportunities in British Columbia

In the short term, the edible marine plant market in North America offers the greatest market opportunities for the marine plant resources of British Columbia. In the long term, the edible marine plant markets in Asia, particularly Japan, represent potential markets. Some other potential market opportunities include exploitation of the more than 600 marine plant species in BC to provide a new taste/food to sophisticated markets in Japan.

The industrial marine plant market holds far fewer opportunities for BC marine plants than the edible marine plant market. This is because of the relatively low prices for hydrocolloids (agar, algin and carrageenan) and the strong competition from marine plant producers in developing countries. The current mood/consciousness of the public, which does not support new resource development at the scale necessary to create a significant new industry also plays a role.

The development of British Columbia's marine plant resources should focus on species that target niche markets with high-value speciality products. For example bacteriological agar, abalone and urchin feed, fertilizers, animal food, health spas, cosmetics, medical uses, alternative energy source, packaging material and pollution control.

Conclusion

There is considerable potential for increasing British Columbia's marine plant industry although large scale harvesting is unlikely and perhaps not desirable, rather niche marketing, especially for edible products seems to be the most rewarding in terms financial gains.

The mariculture of marine plants may also present opportunities for British Columbia's coastal communities. A viable marine plant cultivation industry would require considerable effort in terms of supporting policy and investment from the private and public sectors.

Forward

British Columbia's marine environment supports an amazing array of marine plants. More than 600 species can be found along the coast, including twenty of species of kelp, representing one of the greatest diversity of kelps found anywhere in the world. Marine plants in British Columbia have long been recognised as a large but essentially under-utilised resource that could contribute significantly to the economy of coastal communities given appropriate demand and operational economics (Coon, 1983).

Marine plants play a vital role in coastal ecosystems by providing habitat for many marine species and contributing significantly to the oxygen and organic matter in the nearshore environment. Internationally, marine plants also form the basis of multibillion-dollar enterprises within the food, textile, pharmaceutical, cosmetic and biotechnological sectors. The goal of British Columbia's marine plant management strategy is to take advantage of the economic benefits of marine plants while not compromising the marine environment (Wheeler 1990, Coon 1983, Watson 1991).

The purpose of this report is to provide background information on the opportunities and challenges surrounding marine plant industry in British Columbia. Information on the marine plant industry worldwide with special reference to the East Coast of Canada is presented in order to give context to marine plant opportunities in British Columbia. Past and present marine plant opportunities and management in British Columbia are also discussed.

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1. Introduction

British Columbia's Fisheries Act defines marine plants as all benthic and detached brown, red and green algae, and other aquatic plants including marine flowering plants, and phytoplankton (Regulations, part 2). The term 'seaweed' is also used frequently in this report and is defined as marine benthic macroscopic algae from the divisions *Phaeophyta* (brown algae), *Rhodophyta* (red algae) and *Chlorophyta* (green algae). The large majority of species discussed fall within the seaweed category although two notable exceptions are *Salicornia virginica* (sea asparagus) and *Zostera marina* (eelgrass) which are marine flowering plants.

Seaweeds are divided into three groups according to their light absorption pigments and the characteristic colour (brown, red or green) these pigments impart. Although they are photosynthetic, seaweeds are not quite plants, as they lack roots and leaves. They generally have root-like attachment structures called holdfasts and leaf-like fronds that act like shoots. Stipes, which are analogous to stems, separate holdfasts and fronds (Figure 1). Simple unspecialized cells and complex life cycles further characterise seaweeds.

Brown seaweeds are the dominant group of seaweeds in temperate and polar regions where they grow at depths of up to 30 m (Watson 1991). Brown algae from the order Laminariales or kelp as they are more commonly known, stand out as both environmentally and economically important in British Columbia.

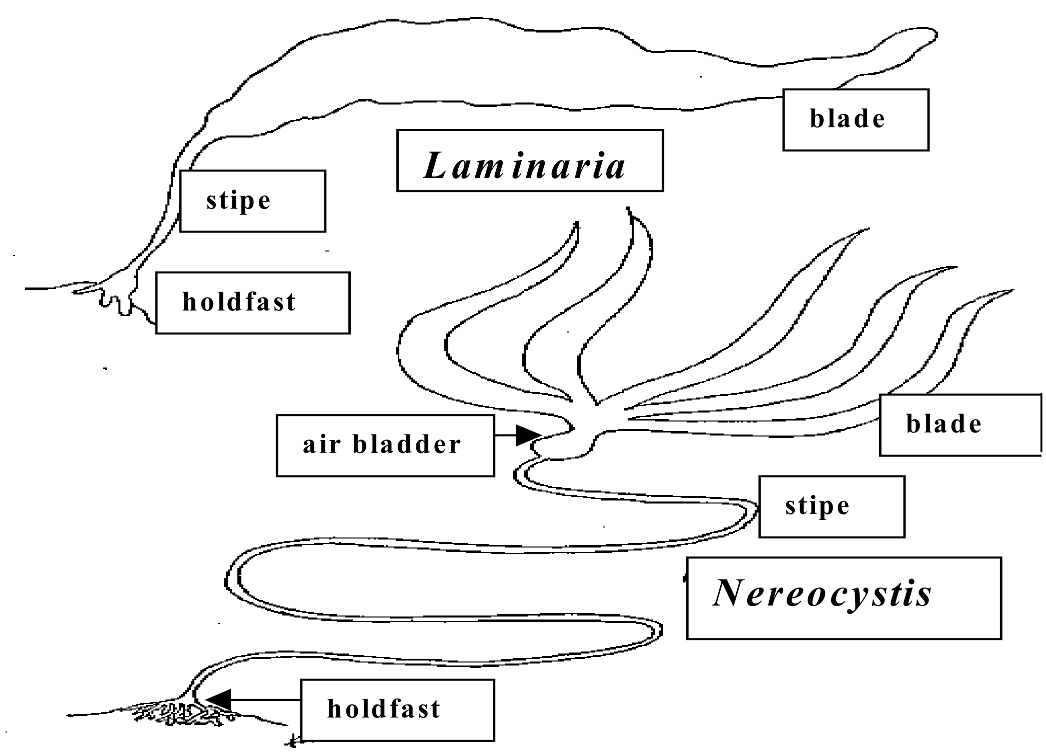


Figure 1. Basic morphology of the kelp species *Laminaria* and *Nereocystis.*

The cold, clean water and steady supply of nutrients of the Pacific Northwest coast supports the greatest diversity of kelp species in the world as well as one of the world's most productive ecosystems (Druehl 1999). The dominant kelp species in British Columbia are the large, canopy forming kelps *Macrocystis integrifolia* (giant kelp) and *Nereocystis luetkeana* (bull kelp) (Wheeler 1990).

Nereocystis is a fast growing annual kelp that can grow to 10 or 20 metres in a few months (Wheeler 1990). This species is more opportunistic and transitory in location than the perennial *Macrocystis*. While *Macrocystis* beds are more permanent than *Nereocystis* beds, they still show dramatic seasonal variation in standing crops (Coon and Roland 1980; Dale 1997). In the past, many entrepreneurs have viewed the vast beds of *Macrocystis* and *Nereocystis* found along the British Columbia coast as a potential resource for industry.

Red seaweeds, many of them delicate and fernlike, can be found at the greatest depths (up to 268 m); their red pigment enables them to absorb the blue and violet light present at those depths (Kozloff 1973). Well known species include red laver or nori (*Porphyra spp*), Irish moss (*Chondrus crispus)* and dulse (*Palmaria palmata*).

The majority of red and brown seaweeds are marine whereas the vast majority of green-coloured algae are freshwater and terrestrial. Green seaweeds are found nearest to the shore in shallow marine waters (Kozloff 1973). They often grow as threadlike filaments, irregular sheets, or branching fronds. *Ulva* and *Enteromorpha* are two common genera of green algae in British Columbia.

Coastal people have long used marine plants as food, animal fodder, medicine, fertilizer, material for tools and other items and a source of chemicals such as iodine and caustic soda. Seaweeds are still used in these capacities today, in fact, harvest of seaweeds for food is the most valuable commercial use of seaweeds. The market for nori, kombu and wakame, traditional edible Asian seaweed products is worth approximately US$ 4.5 billion.

Red and brown seaweeds are the primary source of a variety of polysaccharides of commercial value. Phycocolloids, as these polysaccharides are known, have the ability to give viscosity, gel strength and stability to aqueous mixtures, solutions and emulsions. The principal phycocolloids are the alginates (salts of alginic acid) from brown algae and the sulphated galactans, agars and carrageenans, from red algae (Tronchin 1998).

The gel-like properties and water holding abilities of alginates make them useful in products like beverages, dairy products and bakery goods and dry mixes that need to be returned to a liquid state, like pancake mix. Alginin's water-holding characteristics are also utilized by the paper and textile industries to make waterproof and flame retardant products (Tronchin 1998). Carrageenan has a wide variety of uses due to its ability to thicken and stabilize. It also provides texture and body, and prevents ingredients from separating. For example, it keeps the 'chocolate' in chocolate milk by holding the ingredients in suspension. Agar is used in similar ways but it is also used in the laboratory as a growth culture medium (Tronchin 1998).

2. Marine Plant Resources of British Columbia

Stock assessments have been done for a number of species but efforts have been concentrated on the kelp species *Macrocystis integrifolia* and *Nereocystis luetkeana* because of their relatively high commercial potential. In fact, over 90% of surveyed BC seaweed resources consists of these two brown seaweed species (Ference Weicker &Co. 1995). Smaller kelps such as *Laminaria* and the red seaweeds have not received the same attention because they are much more difficult to survey and the potential commercial benefits don't justify the inventory costs.

2.1 Kelp Resources

A kelp inventory program for *Macrocystis integrifolia* and *Nereocystis luetkeana* was initiated in 1975. To date, twelve studies have surveyed a total of 958 km of coastline and more than 720,000 tonnes (wet tonnes) of kelp (Table 1). A 13th study on the kelp resources of Barkley Sound was begun in 1998 but has yet to be published. These studies represent most of the kelp beds that would support large scale harvests, however a very large portion of the kelp stocks on the coast are not in high density beds of commercially harvestable size (Wheeler 1990). Consequently, it would not be unreasonable to expect that the total standing stock of *Macrocystis* and *Nereocystis* to be in the neighbourhood of one million tonnes (Pilcher p.c). Approximately 94% of the standing stock in the beds suitable for large scale harvest consist of *Nereocystis* while *Macrocystis* forms only about 6% of these kelp beds (Watson 1991).

Table 1. Summary of bed area and total standing crop estimates for kelp beds in areas of British Columbia surveyed using the KIM-1 method

Inventory Area	*Year*	*Length of Inventoried Coastline (km)*	*Bed Area (ha)*	*Total Standing Crop (wet tonnes)*
Porcher, Goschen and Banks Islands and Estevan Group	1996	70	1,090	59,652
Hakai passage to Bardswell Group	1993	106	1,550	55,224
Port Hardy – Malcolm Island	1989	40	761	37,943
Juan de Fuca Strait	1988	118	511	50,148
Northwest Vancouver Island	1978	72	840	48,615
Estevan Group	1976	82	1,470	77,620
Dundas Group	1976	61	1,527	74,350
North Graham Island (QCI)	1976	162	2,375	77,410
Goscshen Island to Tree Nob Group	1976	122	1,741	113,575
North Vancouver Island	1976	68	885	38,020
Nootka Sound	1975, 1995	57	2,165	95,000
Totals		958	14,912	727,548

Foreman (1975) developed the Kelp Inventory Method (KIM-1) that has been used in all kelp inventories commissioned by the province with some slight modifications in more recent inventories. The basic technique uses infrared aerial photographs to determine bed area, density and species information. These data are combined with field determined information on bed structure, and mean plant weight to provide species specific biomass estimates for each kilometer-wide section of coastline that is covered in the inventory (Field 1996). Figure 4 shows the various locations of these studies.

The kelp inventory data, results and maps now form a component of the British Columbia Aquaculture System, a digital database of the Ministry of Agriculture, Food and Fisheries. This database includes the results of all British Columbia finfish and shellfish capability studies and marine plant inventories. Appendix 2 contains a listing of all kelp inventories, as well as all reports on the abundance and distribution of marine plants that are found in this database.

2.2 Salicornia Resources

Salicornia virginica L. is a saline tolerant perennial herb that is commonly found in intertidal salt marshes throughout the Atlantic and Pacific coasts of North America (Scagel 1971). It is often the dominant species in salt marsh ecosystems (Hutchinson and Smythe 1989).

There are approximately 10,000 metric tonnes (wet tonnes) of *Salicornia* in the province. This estimate originates in a 1988 report by Ian Hutchinson and Susan Smythe who were contracted by the Ministry of Agriculture to assess the impacts of harvesting *Salicornia* on the productivity of coastal salt marshes. They used a survey of the standing stock of *Salicornia* in Boundary Bay to derive abundance-standing stock regression equations which they applied to estimates of standing stock in thirty locations where *Salicornia* is known to be common.

Approximately 80% of the total standing stock is located in coastal wetlands around the Strait of Georgia and the eastern reaches of the Strait of Juan de Fuca, with at least 50% of the total in the Chemainus River estuary and Boundary Bay (Hutchinson and Smythe 1989). Figure 3, adapted from their report, shows the sites in British Columbia where *Salicornia* is known to be common, or rare or absent.

The primary conservation issues regarding the harvest of *Salicornia* are trampling of vegetation and compaction of the substrate by harvesters and removal of *Salicornia* shoots. It is possible that these activities could lower the *Salicornia* standing crop and impact the salt marsh community. Hutchinson and Smythe determined that rotational cropping (crop/fallow) on a two year cycle could minimize harvesting impacts on *Salicornia* populations. This harvesting method had far less deleterious effects on the standing crop of photosynthetic *Salicornia* shoots than two seasons of continual cropping (harvested twice yearly).

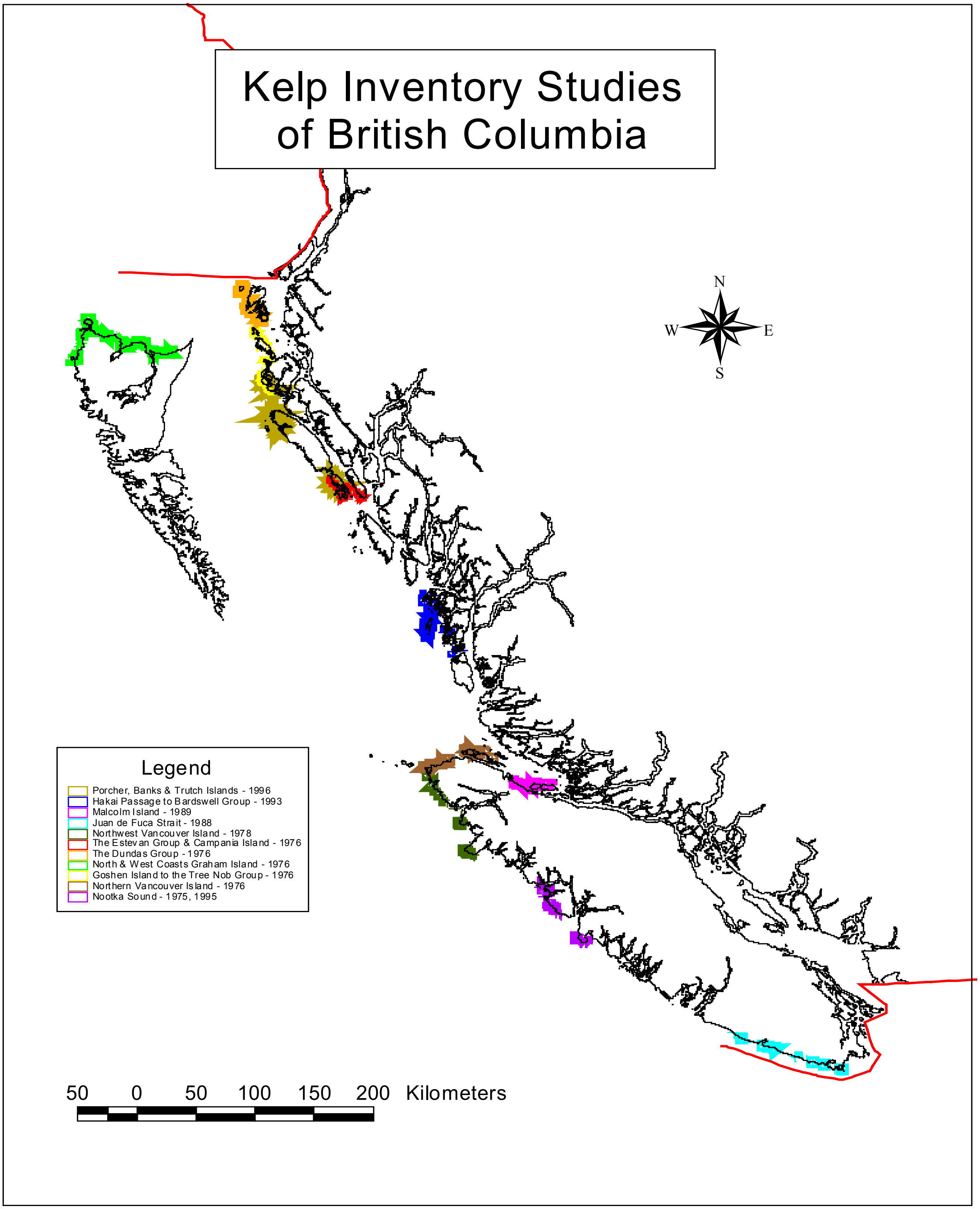
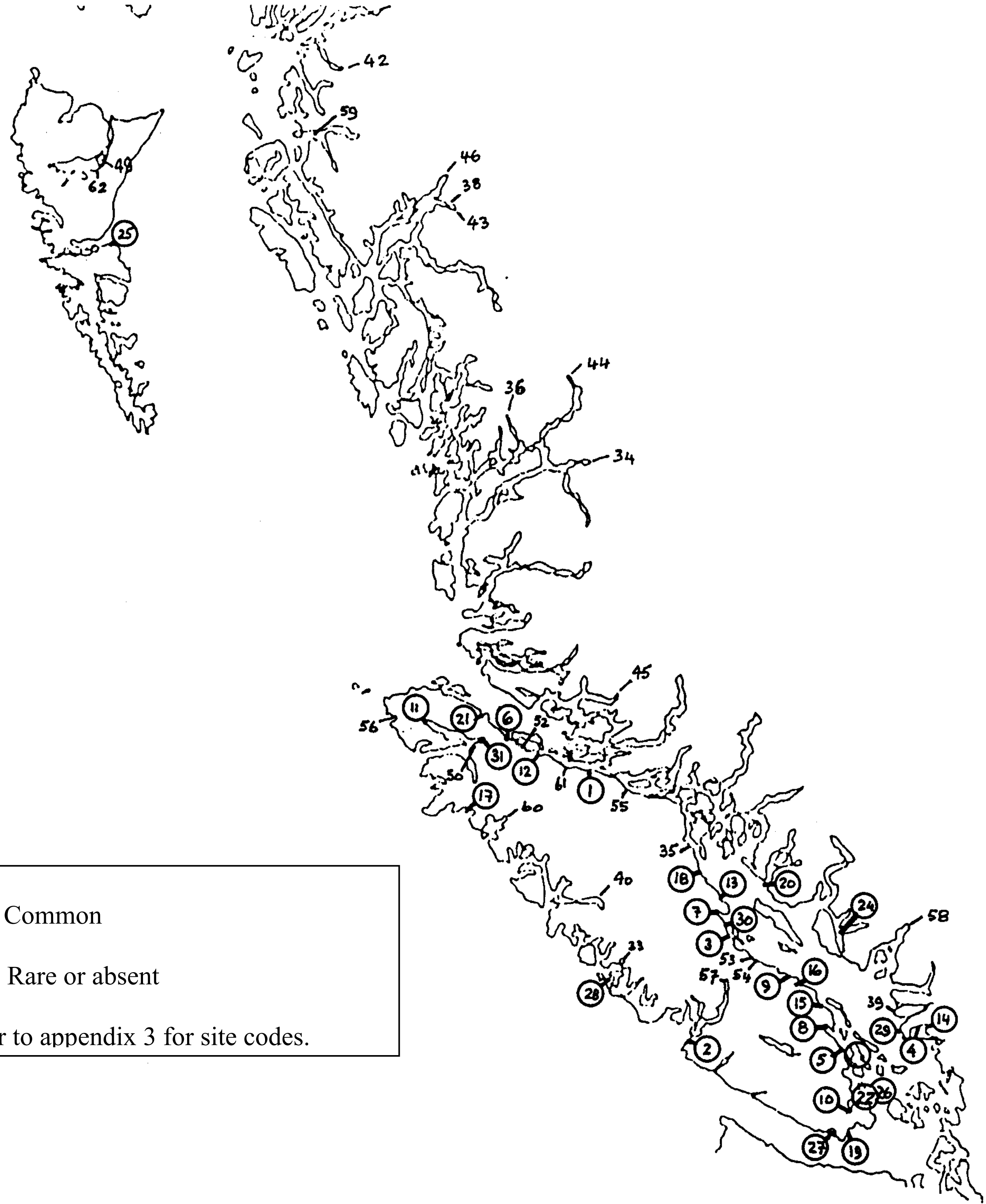


Figure 4. Map of Coastal British Columbia showing the locations of KIM-1 inventories undertaken between 1975 and 1996.



#	Common
#	Rare or absent

Refer to appendix 3 for site codes.

Figure 3. Sites in British Columbia where *Salicornia* is known to be common, or rare or absent, from published sources and questionnaire responses.

2.3 Other Marine Plant Resource Information

The distribution of most of the region's marine plant flora is relatively undocumented although there are some exceptions. Kelp species and the marine plants in and around Bamfield on the south-western coast of Vancouver Island are two such exceptions (Sloan 2000). Some good general guides to British Columbia's marine plants are Scagel (1971) which is for the entire coast and Hawkes et al. (1978) which provides a broad summary of northern British Columbia marine plants. Scagel also authored a 444 page synopsis on benthic marine algae of British Columbia, Northern Washington and Southeast Alaska.

Parks Canada has begun a series of reports providing baseline marine inventories of Haida Gwaii (Queen Charlotte Islands). The first report, completed in 2000 detailed the marine plant biodiversity of the area. This is the first comprehensive marine plant survey in a national park in North America (Sloan 2000).

3. Marine Plant Management

Different methods of marine plant management exist on the west and east coasts of Canada. In British Columbia, the provincial Ministry of Agriculture, Food and Fisheries (MAFF) controls marine plant harvest while in the East, the federal Department of Fisheries and Oceans (DFO) has jurisdiction over marine plants.

3.1 British Columbia

Both the Provincial Government and the Federal Government have a legal basis to manage marine plants in British Columbia. First Nations also have a claim to the marine plant resource. The Province has jurisdiction within coastal waters, which are defined as being between the "jaws of the land". On this basis, harvesting of marine plants is regulated under section 24 of the BC Fisheries Act (Twaddle p.c.). In addition, case law to date indicates that anything attached to the seabed belongs to the province (Coon p.c.).

The Federal Government has authority to manage marine plants under sections 44-47 of the Federal Fisheries Act but does not exercise this authority in British Columbia. There was an administrative agreement between the Province and the Federal Government in 1976 that gives the province the right to regulate marine plants on the condition that they refer licences to DFO for review (Coon p.c.).(note: location of the official record of this agreement is unknown).

In addition to section 44-47 of the Federal Fisheries Act, DFO may use section 35(1) of the federal legislation which states that 'no person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat'. Marine plant harvest could be construed in some situations to be a disruption of fish habitat and therefore in violation of the Federal Fisheries Act.

The regulations of s. 24 of BC's Fisheries Act provide for:

a. licence fees and reporting requirements for both harvesting and processing sectors
b. payment of royalties on harvested marine plants,
c. harvest licensing on the basis of species group,
d. definition of the harvesting area,
e. setting a harvest quota for the species group in the harvest area,
f. designation of approved harvest equipment,
g. designations of the manner in which harvesting may be carried out, and
h. closing areas when necessary for conservation purposes.

Licensing policies include licence limitations, licence allocation, exclusive privilege and tenure. Licence limitations are the prime means of affecting the MAFF's policy of scaling resource utilization to management capabilities (Wheeler 1990).

Licences are allocated to harvesters annually and on a first-come first-serve basis. In addition, the proponent must present evidence that the overall operation is economically feasible and the raw material requirement is low in absolute terms or compared to the estimated standing crop in the desired area, or both. Larger annual harvests are justified where a biological basis for management exists, as with kelp. (Coon 1983).

Exclusive harvesting privilege within a defined area is often part of a licence for several reasons. Exclusive privilege makes sense because marine plants are relatively static in space and therefore not 'hunted' like fish but 'cropped' like plants. Also exclusive privilege should promote sustainable use of a resource, since a licencee would suffer the results of any abuse to the resource. The herring spawn on kelp fishery is one exception to this policy because licence areas are typically quite large and relocation of the licence is common in this fishery (Coon 1983).

In addition to these licensing policies, harvesters are given the 'right of first refusal' for the same area and quota as held in previous years. This is subject to conservation needs and beneficial use qualifications. The main reason for giving 'right of first refusal' or tenure is to offer the harvester some guarantee to the resource. Tenures and licences are issued by BC Assets and Lands for marine plant cultivation.

The MAFF's management capabilities are well developed in relation to actual marine plant utilization. The provincial government's wish to see a viable marine plant industry arise led to the investment of millions of dollars in the 70s and 80s for research and an infrastructure responsible for management, policy development and the provision of liaison services (Wheeler 1990).

The MAFF's current marine plant policy is very similar to the policy that was in place over ten years ago (Coon p.c.). Although this policy remains relevant, the next two sections discuss some issues that should be considered in updating MAFF's marine plant policy.

3.1.1 Current Marine Plant Management Issues

A major issue that needs to be addressed in the development of an updated marine plant policy is whether the benefits of a large-scale wild marine plant industry would outweigh the management costs. One of the most difficult problems facing marine plant management in British Columbia is the perception that not enough is known about the effects of marine plant harvesting to ensure that it does not affect the coastal ecosystem adversely (Pilcher p.c).

In the early 90's, the MAFF commissioned a comprehensive review of the scientific information on the kelp forests of British Columbia. It was stated in this report that the "resource management and industrial development strategies described here will help calm the fears of concerned individuals with respect to the commercial utilization of kelp" (Wheeler 1990).

Providing evidence of sound resource management and industrial development strategies to concerned individuals today is perhaps a more difficult task than it was ten years ago. The lack of current stock assessments or even sometimes an initial assessment adds to the difficulty of this task. The MAFF has recently started doing presentations to educate concerned citizens (mainly First Nations) on current levels of harvest and how marine plants are managed in order to help alleviate this problem (Pilcher p.c).

Another issue of concern to many is enforcement of marine plant harvesting regulations (Pilcher p.c.). There are several obstacles to monitoring the harvest of marine plants. Non-commercial harvest is unregulated therefore it is very difficult for a fisheries officer to know that possession is for a commercial purpose, a requirement of prosecution. It is also difficult to check for adherence to licence specifications as time spent harvesting is minimal and may occur year-round. This makes encountering one of the very few harvesters an unlikely event. In addition, the current small-scale harvest does not justify the MAFF's input of substantial resources that would be needed to adequately monitor marine plant harvesting.

An issue raised by several marine plant harvesters was the length of licence and untimely manner in which it was issued. Business planning is impeded by the lack of long term assurance of seaweed resource availability and uncertainty regarding roles of natives and non-natives in managing the resource. One option for British Columbia is to offer licences for longer than a year. This would provide greater assurance of continued access to the resource, provided the terms of the permit are maintained. Nova Scotia, Oregon and California offer long-term licences (5-15 years) (See section 3.2 for a discussion of management in Nova Scotia).

3.1.2 First Nation Issues

Twenty years ago the provincial government began to heed First Nation's extreme displeasure over what they saw as a gradual but relentless erosion of their influence over, and right to access, marine resources which they traditionally utilized. It was apparent that if the marine plant industry was ever to realize its potential, First Nation's rights and privileges with respect to the resource would have to be clarified.

In the early 80s the Marine Resources Branch had the task of developing a fair and equitable formula for allocating access to marine plant resources. The Branch decided that "proper management" of kelp stocks included management of commercial harvest and was not limited to considerations of the resource base alone. Proper management must also be considered within the context of existing and constitutionally protected treaty and aboriginal rights that supersede provincial legislation (Coon 1983).

The province has worked towards greater First Nation's involvement in marine plant management. Today BC Fisheries has a policy of consultation with First Nations when a licence to be issued is within contested treaty areas. In addition, the two of the last three kelp inventories have been completed in conjunction with First Nations bands whose traditional territory included the area to be inventoried. The 1993 kelp inventory of the Central Coast from Hakai Passage to the Bardswell Group was done in conjunction with the Heiltsuk Band. The 1998 Barkley Sound Inventory was done with help from the Huu-ay-aht.

3.2 Eastern Provinces

Commercial harvest of marine plants on the East Coast of Canada is over half a century old. The most important commercial species for many years was *Chondrus crispus* (Irish moss) harvested for the hydrocolloid, carrageenan. Fifty percent of this harvest came from PEI until recently, when a cheaper source of raw material became available from the Philippines. Currently, the largest commercial industry in the Maritimes is the harvest of *Ascophyllum nodosom* (knotted wrack) in southern Nova Scotia by Acadian Seaplants Ltd. for the production of liquid fertilizer (Sharp p.c).

Early on in the history of commercial harvest in the Maritimes, awareness of overharvesting problems in Europe as well as advice from phycologists sparked provincial governments to enact the Sea Plants Harvesting Act (Sharp 1987). Important regulations included harvesting gear restrictions requiring the use of cutting implements to prevent holdfast loss and limited cutting to 12.7 cm above the substrate to allow regrowth (Sharp 1987).

In 1975, the responsibility to manage marine plants on the East Coast was transferred to the Federal government of Canada. As the Federal Government already had a set of marine plant regulations within the Fisheries Act of Canada, they simply incorporated the Sea Plants Harvesting Act into the Fisheries Act. The two major changes the federal government made were to establish fourteen Marine Plant Harvesting Districts and to make licences personal and annually renewable, with no provision for exclusive rights to the resource. In addition, provision was made for alteration of the harvesting season and setting of quotas (Sharp 1987).

Enforcement of regulations is the responsibility of the Department of Fisheries and Oceans. As it stands today, every commercial harvester of any marine plant in Quebec, New Brunswick, Newfoundland, Nova Scotia and PEI requires a DFO permit to harvest marine plants.

Jurisdiction over marine plants is not as clear cut as simply being DFO's responsibility. For example, Nova Scotia has legislation (Fisheries and Coastal Resources Act) which enables the province to manage all fucoids (rockweeds) and laminarians (kelps) but is explicit not to include *Chondrus crispus* (Irish moss), *Palmaria palmata* (dulse) or eelgrass. However, in practice, the only marine plant managed continuously in the wild through the Fisheries and Coastal Resources Act is the fucoid, *Ascophyllum nodosum* (Cameron, p. c.).

Nova Scotia allocates areas of the *solum* to a proponent for their exclusive use of the resource through a lease. Proponents are required to provide annual management plans that include harvesting and commercialization components. Lease applications must go through a public process before they can be approved. The lease may be granted for up to fifteen years without repeat of the public process (Cameron p.c.).

Only established companies with a proven record of sound management are considered for the maximum term of 15 years. Leases for less than five years are given to new applicants or any person or company that has not yet established itself in the seaweed market (Cameron p.c). This system guarantees an established company access to the resource while not tying up the resource in unsuccessful ventures. Another very important aspect of the lease system is to ensure that the resource user has a stake in proper stewardship of the resource.

In addition to obtaining a provincial lease of an area from the province, the proponent must secure a DFO licence to harvest marine plants or employ DFO licensed harvesters to reap their crop, similar to car registration and a driver's licence. Areas that are leased are referred to as 'exclusive licence areas' and are available only to harvesters associated with the leaseholder. Areas that can be harvested by anyone with a federal marine plant licence are known as 'open areas' (DFO 1998).

In New Brunswick, a joint federal-provincial memorandum of understanding co-ordinates management of the rockweed resource. A rockweed management committee reviews management plan and harvest reports on a quarterly basis (Cameron p.c, Sharp p.c.).

Experts on the east coast believe that the success of the seaweed industry is dependent on the region's ability to produce high value speciality products and not low priced commodity products (Cheney 1999, Hooper 1999)

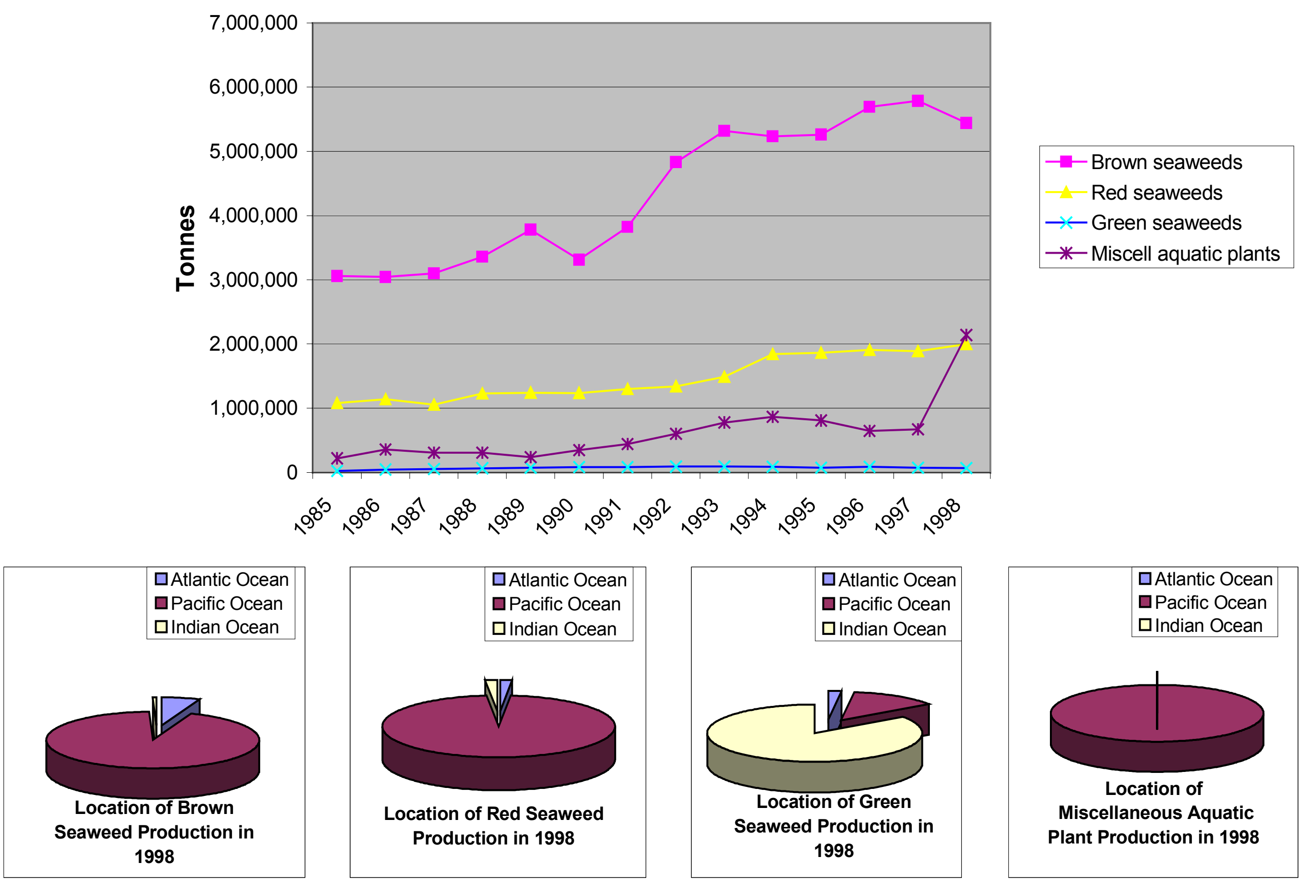
4. Harvest of Marine Plants

4.1 International Harvest

The worldwide commercial harvest of marine plants in 1998 was ~10.6 million metric tonnes (mt), 81 percent of this amount, or ~8.6 million mt, is cultivated, rather than harvested from wild populations (FAO 1999). The demand for brown and red seaweeds has grown steadily since 1985 while use of green seaweeds has remained stable (Figure 2). In fact the value and amount of production for seaweeds as a whole have doubled over the last ten years (Hanisak 1998).

While seaweed consumption, especially for industrial uses is a global phenomenon, their location of harvest or cultivation is restricted to only a few regions of the world. The majority of commercial red, brown and miscellaneous seaweeds are harvested from the Pacific Ocean while the Indian ocean supplies approximately 80% of the world's green seaweed (Figure 4).

Figure 4. World utilization of marine plants



Source: FAO 2000a

As can be seen in table 2, only ten countries account for nearly all of the world's seaweed production. Canada harvested 12,489 tonnes of seaweed in 1998, which accounted for slightly more than 0.1% of the world-wide harvest (FAO 2000b). Most of the top seaweed-producing countries are in Asia, which reflects this area's long history of seaweed consumption and cultivation. Chile is one notable exception to Asian dominance. Its production of *Gracilaria* increased from 178,000 tonnes in 1989 to 265,881 in 1998 mainly through cultivation to make it the world's leading supplier of agar (Hanisak 1998).

Table 2. Top ten countries for marine plant production in 1998 (tonnes)

Country	*Total Production*	*Wild Harvest*	*Cultivated*	*Major Genera*
China	6,447,095	170,520	6,276,575	*Laminaria, Porphyra*
Korea	894,769	12,599	882,170	*Undaria, Porphyra, Laminaria*
Philippines	643,085	506	642,579	*Eucheuma*
Japan	640,566	116,892	523,674	*Porphyra, Laminaria, Undaria*
Chile	265,881	197,495	68,386	*Gracilaria*
Norway	179,762	179,762	-	*Ascophyllum, Laminaria*
Indonesia	133,890	16,680	117,210	*Gracilaria*
India	100,000	100,000	-	*Gelidiella, Gracilaria, Sargassum,*
France	67,094	67,032	62	*Laminaria, Fucus*
Russia	33,314	30,279	3,035	Brown Alga
Total	9,405,456	891,765	8,513,751	

Source: FAO 2000b

Norway and France have had a long history of wild seaweed harvest. However, the position of Europe is decreasing year after year even though the quality of European seaweed remains one of the highest in the world. The decline is attributed to the improved competitiveness of countries such as Chile, Korea, the Philippines, and Japan, and the relatively high price of European seaweed. As in North America, the future of seaweed industries in Europe will depend on high value-added products due to competition with developing countries in producing low value-added products. (Maritime Industry Forum 1999).

The greatest and most valuable use of seaweed by far is for direct human consumption. The worldwide economic value of seaweeds cultivated for food products was approximately US$4.5 billion in 1997 (Table 3). The majority of this market is located in Asia. For example Japan's primary aquaculture seaweed, nori, has an estimated value of $1.5 billion annually. By contrast, the edible seaweed market in the United States is valued at only about $30 million annually (Small 1999, Craigie 1999)

Table 3. Worldwide economic value of seaweeds cultivated for food products in 1997.

Product	*Value (10^6 US$)*	*Raw Material (mt)*	*Product*	
			(mt)	*(US $/mt)*
Kombu (Laminaria)	2,866	4,055,027	~1,014,000	2,826
Nori (Porphyra)	1,464	909,122	~91,000	16,088
Wakame (Undaria)	229	495,390	~33,000	6,939
Totals	4,555	5,459,539	~1,138,000	

Source: Hanisak (1998)

The value of seaweeds used for industrial purposes is worth approximately US$603 million worldwide, down from an estimated US$680 million in 1990 (Ference Weicker & Co. 1995) with carrageenan, alginate and agar products accounting for more than 95% of this value (Table 4). Agar is notable as receiving the highest price per tonne of any marine plant product; this is due to the very high value of agar used in laboratory work.

Table 4. Worldwide economic value of seaweeds cultivated for industrial use in 1997.

Product	Value (10^6 US$)	Raw Material (mt)	Product (mt)	Product (US $/mt)
Carrageenan	~240	400,000	~25,000	9,600
Alginate	~211	460,000	~23,000	9,174
Agar	~132	125,000	~7,500	17,600
Soil Additives	~10	550,000	~510,000	20
Fertilizers	~5	~10,000	~1,000	500
Seaweed Meal	~5	~50,000	~10,000	5,000
Totals	~603	1,595,000	~576,500	

Source: Hanisak (1998)

Emerging uses of seaweeds not yet significantly realized at the commercial scale include pigments, pharmaceuticals, bioconversion for alternative energy and bioremediation of wastewater. General Electric of the United States developed technology required to turn kelp into an alternative energy source (methane) during the OPEC oil crisis (Small 1999). The role of seaweeds in bioremediation is gradually becoming better understood, it seems they could act as biological nutrient scrubbers that remove wastes generated by human activities in coastal systems (Chopin and Yarish 1999a).

4.2 First Nations of the Northwest Coast

First Nations used, and to some extent continue to use marine plants for a wide array of purposes including food, materials and medicines, and in cultural traditions. Bull kelp (*Nereocystis luetkeana*), giant kelp (*Macrocystis integrifolia*), red laver (*Porphyra* spp), and eelgrass (*Zostera marina*) were the most extensively used species.

Dr. Nancy Turner, an ethnobotanist from the University of Victoria recently described the cultural importance of marine plants to coastal First Nations in a paper submitted to the 26th Annual International Association of Marine Science Information Specialists and Librarians Conference. Appendix 1 contains a copy of her paper.

4.3 Harvest of marine plants in British Columbia

4.3.1 Historical marine plant enterprises

British Columbia has a long history of attempts to capitalize commercially on marine plant resources, in particular the kelp species *Macrocystis* and *Nereocystis*. Unfortunately, very few of the attempts were successful. The first endeavour to harvest and process seaweed was by Canada Kelp Co. Ltd in 1949. They planned to produce soap, kelp meal, kelp meal tablets and alginates. However, they produced only a small amount of dried kelp from the kelp beds at Deer Island near the north end of Vancouver Island before financial problems forced closure (Lewis, 1985).

It was over 15 years before another attempt was made to start a marine plant industry in BC. In 1967 the entire BC coastline was allocated under 44 harvesting licences held by six companies (Coon, p.c; Lewis 1985). Two of the six companies never began any development activities and their licences were revoked two years later. The only company that had any commercial success was Sidney Seaweed Products. This was a small company that produced products for the home garden market (Wheeler 1990).

The largest company in terms of physical assets and development activity was North Pacific Marine Products, renamed Canada Kelp Co. Ltd. in 1969. This company had a three-phased development plan for an algin extraction operation near Masset in the Queen Charlotte Islands. They began construction of a drying facility before being forced into receivership by their major creditor, Dillingham Corporation. The drying plant was completed in 1970 by Dillingham but they were unwilling to invest extra capital to make the facility functional. The last attempt to bring the plant into production was by Kelpac Industries Ltd. They purchased the Masset plant and carried out a small-scale test run in 1972. Once again financial problems struck and Kelpac sold the equipment in 1975 (Lewis 1985).

Pacific Kelp Co., another company that was interested in algin extraction built a mobile pilot-scale extraction facility. However, $4 million in financing for a commercial scale alginate facility in the lower mainland area could not be secured due to the high risk associated with an untested marine plant venture. Once again a company was disbanded before commercial production could begin (Lewis, 1985).

The sixth company, Intertidal Industries, planned to produce kelp meal (product derived from ground kelp and used in livestock feed) on a large scale. They invested in a combined harvesting and processing barge and harvested 900 tonnes of kelp in their first year of operation. By their second year (1970) financial difficulties of their parent company, the low value of kelp meal and/or technical difficulties caused the company to sell its barge (Lewis 1985).

After approximately a ten-year lull in commercial seaweed activity another attempt at establishing a seaweed industry in BC was initiated by the provincial government. In 1981, the provincial Marine Resources Branch of the Ministry of Environment advertised for applications for kelp harvesting and processing licences. Out of the three proposals submitted, the province selected Enmar Resources Corporation as the most likely candidate to successfully develop the kelp meal industry (Coon p.c.).

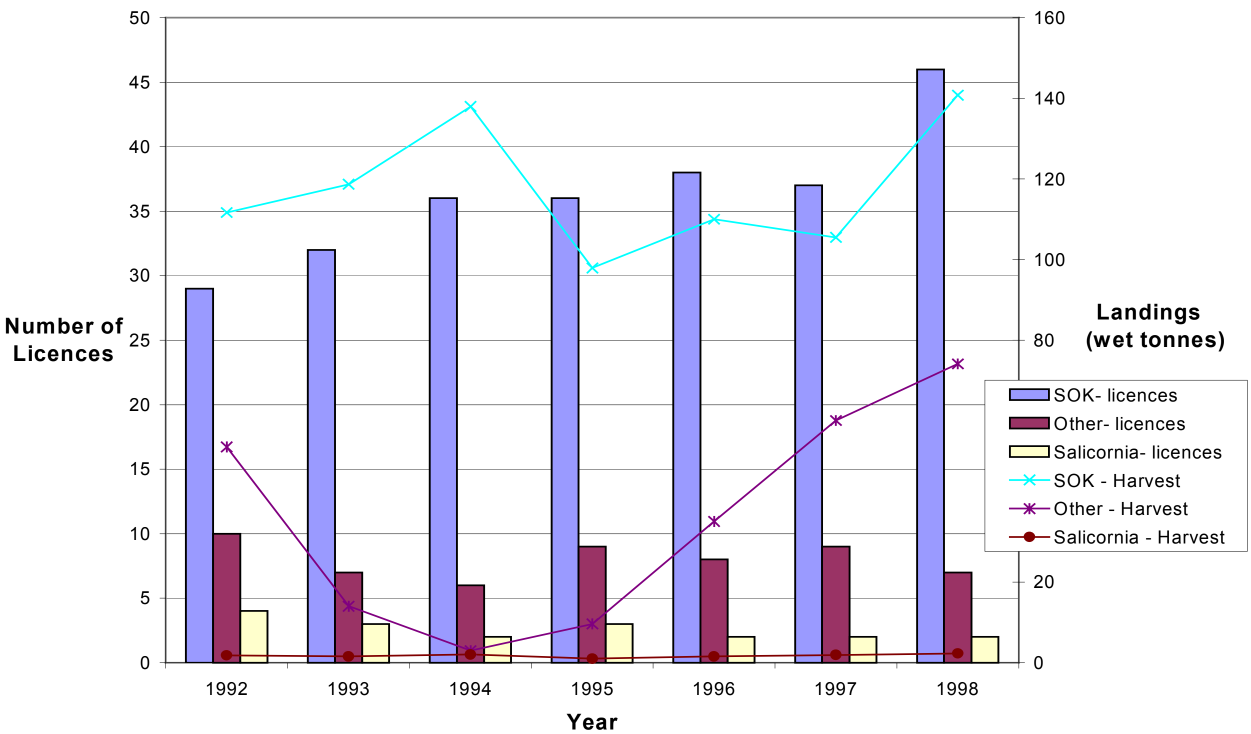
Enmar was awarded 5000 wet tonnes of *Nereocystis* and *Macrocystis* off the coast of Porcher Island, near Prince Rupert, for a five-year period. This venture failed due to uncertainties around marine plant jurisdiction rather than financial difficulties (See section 3.1 for a more complete description of jurisdictional issues). The provincial government approved the project while the federal government did not. The company was unwilling to risk capital unless there was mutual approval of this plant (Coon, p.c.).

The majority of the failures discussed above were due to financial difficulties, although bad luck and administrative problems also played a role. Marine plant industry since then has never progressed beyond small-scale enterprises harvesting less than 100 tonnes a year.

4.3.2 Current marine plant harvest

Canada currently provides approximately 0.13% of the world's seaweed production and most of this harvest comes from the East Coast rather than British Columbia (Small 1999). The bulk of the marine plant harvest in British Columbia consists of *Macrocystis integrifolia* for the herring spawn on kelp (SOK) fishery (Figure 4).

Figure 4. Summary of licence and landing information from 1992-1998



Source: Pilcher 2000

Note: Other=*Nereocystis*, Non-spawn-on-kelp *Macrocystis*, *Laminaria, Alaria, Egregia, Zostera* and *Hedophyllum*

In this fishery, kelp (mainly *Macrocystis*) fronds are harvested and placed in impoundments containing herring that will spawn on the kelp. The value of the product is largely attributed to the herring eggs. If the product is destined for market it is brined (Castledine p.c).

A SOK fisher must obtain a licence from the Department of Fisheries and Oceans (DFO) for the herring and a marine plant harvesting licence from the MAFF. First Nations hold most of the DFO SOK licences communally. The majority of marine plant harvesting licences issued in the province are for this fishery (Figure 4).

The landed value of the spawn on kelp fishery was $9.8 million dollars in 1999 down from $17.7 million dollars in 1997. The depreciation of the Japanese yen, inconsistent quality of the product and selective tastes of the spawn on kelp fishery's target market in Japan as well as possible over-supply of product are probable reasons for the decline in value of this fishery (Smith p.c; Castledine p.c).

Other marine plants harvested commercially in BC include *Nereocystis luetkeana, Salicornia virginica, Laminaria, Alaria, Egregia, Zostera* and *Hedophyllum*. Between 1992 and 1998 the number of companies or individuals licensed to harvest marine plants (excluding the spawn on kelp fishery) varied from six to ten (Figure 4). In 1999 this increased to 15, and in 2000 13 companies or individuals were licensed.

The total marine plant harvest, excluding *Macrocystis* for spawn on kelp, varied from less than five tonnes to nearly eighty tonnes between 1992-1998 (Figure 4). Harvest of *Salicornia virginica* remained constant from 1992-1998 at approximately one tonne. Due to a lack of information on current market values for non-spawn on kelp marine plant products it not possible to estimate the value of these small-scale harvests.

In British Columbia, non-spawn on kelp marine plants are harvested for sea vegetables, sea urchin feed and horticultural products such as fertilizer, foliar spray or soil additives. In 2000, seven or eight companies harvested wild marine plants for the food market. These companies without exception are one or two person operations. Three or four of these companies produce a fresh seaweed product out of *Nereocystis*, mainly for the Asian food market in North America. *Nereocystis* is thought to be a blood-cleansing product by Koreans. New Korean mothers also traditionally eat it every week for a year after giving birth (Seykora p.c.)

The four remaining companies producing food products harvested *Salicornia virginica*. *Salicornia* is better known to gourmet cooks and seafood aficionados as 'sea asparagus'. The fleshy stems of this plant can simply be eaten raw or blanched and even pickled. At the present time virtually all of the commercial harvest of sea asparagus comes from southern British Columbia. From 1985 to present between 1-4 tonnes of *Salicornia* have been harvested annually, mainly from Boundary Bay and Vancouver Island.

The *Salicornia* harvest season is from mid May to early June or until the *Salicornia* becomes woody and bitter. One harvester is perfecting a blanch and freeze processing method to increase *Salicornia's* storage potential and expand his market area.

Four companies are using *Macrocystis* and/or *Nereocystis* to produce horticultural products. Kelp has long been used as a fertilizer, and many people are convinced of its value as a growth enhancer and pest deterrent. It has the advantage of being free of terrestrial weedy species and rich in micronutrients and phosphorus but low in nitrogen.

4.3.3 Harvest of kelp

Brown seaweeds are intensively harvested worldwide. Besides natural mortality, harvesting is the main disturbance in the structure and organization of kelp beds around the world (Vásquez 1999). The ecological impact of kelp harvesting depends on the frequency, intensity and percentage removed as well as the characteristics of the life history of the species harvested and its role in the marine community (Wheeler 1990) These factors have been considered in developing harvesting strategies for *Nereocystis* and *Macrocystis*. Due to their different biological characteristics, the harvesting strategies for these two species are quite different (see appendix 2 for a description of methods).

The goal for sustainable management of kelp resources in British Columbia is to ensure that kelp beds regenerate to their pre-harvest biomass within a year. Research in British Columbia and California has shown that this can be achieved by harvesting 20% of the available standing crop within individual kelp beds on an annual basis (Watson 1991, Wheeler 1990).

Harvest quotas are set annually, this ensures that the maximum harvestable tonnage will reflect that year's standing crop. As kelp plants are continually growing and losing material during the summer, the proposed harvest of 20% of the standing stock in fact represents only approximately 5-10% of the total seasonal production (Wheeler 1990).

There has been a great deal of research into kelp biology and effects of harvesting done in British Columbia. Most of it commissioned by the Marine Resources Branch in the late 70's and 80's. Examples include *The Ecology of Fishes in British Columbia Kelp Beds* (Leaman 1980)*; Implications of kelp harvesting: The fisheries impact study and kelp harvesting controls* (Black 1981)*; Harvesting impacts on Macrocystis integrifolia: a preliminary study* (Coon 1980).

In addition, much work has been completed on the importance of kelp beds to the marine environment (Mann 1982; Duggins et al. 1989; Lobban and Harrison 1997). In a recent LUCO (Land Use Co-ordination Office) report, kelp forests were designated a conservation VMEF (valued marine environment and features) which are habitats generally deemed to be of especially high ecological significance (Dale 1997).

A large portion of research on the effects of kelp harvesting show little in the way of negative effects on the near-shore environment (Coon 1982, Santelices and Ojeda 1984, Barilotti and Zertuch-Gonzale 1990, Sharp and Pringle 1990) although some studies have found that kelp harvest has significant impacts on the kelp forest communities (Druehl and Breen 1986, Vasquez and Santelices 1990, Schiel and Nelson 1990).

5. Mariculture of Marine Plants

5.1 International Mariculture

It is not generally appreciated in North America that seaweeds are a very important sector of aquaculture world-wide with an annual dollar value in the billions and employing hundreds of thousands of people (Hooper 1999). Globally, the production of seaweeds from aquaculture is over 8.5 million metric tonnes and represents about 25% of total annual world aquaculture production by volume (New, 1999).

In 1996, the production of the kelp species, *Laminaria japonica*, totalled over 4 million tonnes. In terms of volume, this production figure made it the most important species in aquaculture for that year. In fact, two of the top ten aquatic species produced through culture were plants (FAO 1999).

The cultivation of marine plants has lagged significantly behind the agriculture of land based species, but over the last decade, seaweed aquaculture has enjoyed an unprecedented rate of development. It now makes up a respectable 81% of the worldwide commercial harvest of seaweeds worth approximately US$ 5.9 billion in 1997(Chopin et al. 1998).

The trend towards marine plant culture reflects supply shortages of wild stocks as well as the general benefits of mariculture. Marine plant mariculture offers a greater opportunity to control product quality and rate of production while allowing the harvester exclusive and consistent access to the products on which his business depends. In addition, it is possible to improve commercial characteristics by cultivation. For example, the phycocolloid content of brown seaweeds may be increased through cultivation.

Table 5 shows the value of the top five cultivated seaweed species in the world; the top three species are used for human consumption. *Laminaria*, also known as kombu, is a highly regarded edible seaweed in many Asian countries, particularly Japan, China and Korea. Its popularity with a diversity of cultures has made this the most valuable seaweed species and nearly twice as economically valuable as *Porphrya* (nori) the next most valuable product.

Nori, used in sushi, is generally agreed upon as being the first marine plant ever cultivated (Craigie 1999). *Undaria*, (brown seaweed known as wakame) is used in Japanese miso soup and as a flavouring or vegetable. The red seaweed *Eucheuma* is cultivated on large scale for the production of carrageenan and *Gracilaria* is grown to produce agar.

Table 5. Top five cultivated seaweed genera in the world.

Product	*Value (10^6 US$)*	*Raw Material (mt)*
Laminaria	2,866	4,055,027
Porphyra	1,464	909,122
Undaria	229	495,390
Eucheuma	42	411,665
Gracilaria	31	71,533
Totals	4,632	5,972,737

Source: Hanisak (1998)

The culture of marine plants in many respects is similar to hydroponic culture of land plants. Seaweeds are almost exclusively photoautotrophic, that is they use light as an energy source to synthesize organic molecules. When essential nutrients are available, the two key limiting factors on growth are light and temperature (Craigie 1999). Like land farmers, seaweed farmers must also control weedy species, pests and pathogens to successfully raise their crops.

In many cases, knowledge of the life history is critical for cultivation and on-land cultivation of particular life history phases is often necessary for seeding. A considerable amount of effort has gone into the development of reliable methods for the cultivation of seed-stocks and their improvement.

In most of the western world, cultivation of seaweed has not advanced very far beyond the experimental stage. Currently, four companies in Canada are cultivating seaweeds commercially: Acadian Seaplants Ltd. and Ocean Produce International (OPI) on the East Coast and Marine Bioproducts International (MBI) and Canadian Kelp Resources on the West Coast. Three of these companies farm red seaweeds in land based aquaculture systems.

Acadian Seaplants Ltd. is cultivating a form of *Chondrus crispus* (Irish moss) that they have successfully marketed to the Japanese market as a sea vegetable. OPI has created a new product they call 'sea parsley' from a form of *Palmaria palmata*, the same family as the more familiar dulse. MBI has developed a process to cultivate *Gelidium* for production of very high quality bacteriological agar used in microbiological and biotechnological applications. Canadian Kelp Resources farms *Laminaria* for the sea vegetable market (see section 3.2 for more information on West Coast companies).

There is growing interest in incorporating the culture of marine plants into an integrated ecosystem approach to aquaculture (Neori and Shpigel 1999; Hanisak 1998, Chopin and Yarish 1999b). In this type of aquaculture the interactions within the aquaculture system mirror trophic interactions in nature. Such an approach would minimize coastal eutrophication problems by turning the wastes of one species into a resource for another species. Cultivation of seaweeds within this system would address the issue of inorganic wastes, mainly nitrogen and phosphorus while suspension feeding organisms would fill the role of organic waste users.

In pioneering work in the early 70s, The Israeli National Center for Mariculture demonstrated that integrating seaweed and phytoplankton culture into shellfish culture was an effective way to recycle nutrients. Since then several models of integrated aquaculture have been examined on an experimental scale. One model incorporating abalone, fish and seaweed has been tried on a pilot scale and is presently under accelerated commercialization (Neori and Shpigel 1999). PhycoGen, Inc. of Portland, Maine and associates from New England Universities are currently developing a program of integrated aquaculture involving salmon and *Porphyra yezoensis* and *P. purpurea* (Chopin and Yarish 1999b).

5.2 Mariculture in British Columbia

The technology to culture several British Columbian marine plant species exists but only two companies are currently engaged in cultivation activities. In the early eighties, the Marine Resources Branch funded studies to examine the possibility of culturing *Gracilaria* for the carrageenan market. Preliminary experiments suggested that a floating algal culture system would be viable on the West Coast (Lindsay and Saunders 1980) but no commercial activity ever resulted.

In the late 80s, nori was farmed for approximately 3 years before the effort collapsed due to factors that included damage to the cultivation system from winter storms, insufficient site selection efforts, lack of biological and farming experience, and an undercapitalised financial base (Levine 1999).

The technologies to cultivate the west coast species *Laminaria saccharina, Laminaria groenlandica, Nereocystis luetkeana*, and *Macrocystis integrifolia* were successfully developed in an effort to farm edible kelp species. Attempts to culture *Alaria marginata* were not successful due to severe grazing by a small crustacean (Druehl 1999).

Canadian Kelp Resources Ltd. is the only company in Canada that cultures brown algae, although there is interest in cultivating *Macrocystis* to provide a stable supply of high quality kelp for the spawn-on-kelp fishery. Considerable effort and expense is involved in securing *Macrocystis* of acceptable quality for this fishery. First Nations in particular have expressed interest in producing kelp for the spawn-on-kelp fishery (Castledine p.c.).

A successful marine plant culturing operation in British Columbia was started in 1992 by Dr. Ron Foreman, one of British Columbia's leading seaweed researchers. Dr. Foreman founded Marine BioProducts International while teaching at the University of British Columbia. He proved they could cultivate the red seaweed, *Gelidium*, in a controlled and sterile environment and turn it into a highly pure form of agar. This quality of agar is irreplaceable as a medium on which to culture fungi and bacteria for medical testing and research in microbiology.

Currently, around 85 per cent of the world's high quality agar comes from Spain, Portugal and Morocco. The agar produced in these countries is processed from seaweed harvested from the sea or beach. This makes the agar susceptible to contaminants, which frustrates testing (MBI 2000). In 1997, MBI signed a $14 million agreement to produce specialty agar products for Becton Dickinson, an agar supplier with worldwide distribution.

Chopin et al (1998) believe that "the success of seaweed aquaculture in North America will depend, in part, upon several key factors, including: (1) successful transfer and modification of Asian cultivation technologies (including mass culture of "seedstock"); (2) development of local indigenous species of marketable quality that will be fast growing; and (3) ability to grow high value seaweed in potentially eutrophic coastal waters."

In British Columbia, the cultivation of marine plants holds promise for several reasons. An environmentally conscious public would be unlikely to support harvesting on the scale necessary to initiate and maintain a large or even medium scale marine plant industry; whereas marine plant cultivation is environmentally benign and would likely receive less scrutiny and more support. Marine plant cultivation is also attractive because it gives the harvester assured access to the resource.

The challenges faced by marine plant cultivators in British Columbia include the labour intensiveness of seaweed cultivation and the lack of ready markets for its products. If seaweed-based cultivation is to develop in British Columbia, it should be based on a keen awareness of the seaweed market and on technology that reduces the labour requirements of cultivation.

6. Marine Plant Opportunities in British Columbia

In 1995, the Ministry of Employment and Investment in collaboration with the Ministry of Agriculture, Fisheries and Food commissioned Ference Weicker & Co. to examine the potential for a large-scale seaweed industry in British Columbia. The resulting document was the *British Columbia Seaweed Market Study* (1995). One of the key findings of this report was that "in the short term, the edible seaweed market in North America offers the greatest market opportunities for the seaweed resources of British Columbia". Table 6 outlines their conclusions in regards to market opportunities in British Columbia.

Table 6. Summary of Market opportunities in order of priority

Market	*Geographic Locations*	*Products*	*Species of Seaweeds used*	*Size of Market (millions)*	*Constraints*
1. Seaweed for human consumption	North America	Nori, Kombu, Wakame, and Hijiki	Porphyra, Laminaria groenlandica, *Nereocystis*, Hizikia	30.6	Cost competitiveness with imports
2. Seaweed for human consumption	Asia	Wakame, Hijiki, and other red seaweeds	Same as above	244.0	Import quotas, cost competitiveness
3. Bacteriological Agar	Global	Bacteriological Agar	Gelidium	2.8	Commercialization of cultivation technology
4. Agar	Global	Food grade agar	Gracilaria	217.2	Cultivation technologies, competitiveness with low-cost producers
5. Carrageenan	Global	Carrageenan	Iridaea, Gigartina	140.0	Competitiveness with low-cost producers
6. Algin	Global	Alginate	*Macrocystis*	320.0	Competitiveness with low-cost producers

Source: **Ference Weicker & Co. 1995**

6.1 Edible Seaweed Market

In 1995, the North American market for edible seaweed products was estimated to be $30.6 million dollars. More than half of this market (64%) consisted of nori while wakame and kombu accounted for nearly all the remaining market. Nearly all the edible seaweed products consumed in North America are imported from Japan, China, Korea and Taiwan. Over 75% of these products are used in Asian restaurants while the remaining edible seaweed products are found primarily in Asian retail stores (Ference Weicker & Co. 1995).

In order to capitalize on the North American seaweed market, the BC seaweed industry would have to overcome several obstacles. In the case of nori, limited wild stocks of *Porphyra* in BC and the poor quality sheets they produce are major stumbling blocks. In order to take advantage of the nori market, it would be necessary to establish cultivation and processing facilities for nori, something that has already been attempted in Washington State and British Columbia (Ference Weicker & Co. 1995).

In Washington State, attempts to cultivate nori were unsuccessful. The failure was not due to market size, economic viability of the participants, nor the biological aspects of cultivation, but solely on the inability of nori farmers to obtain aquaculture lease permits. Political pressure by riparian land owners and commercial fishermen was too much for the fledgling industry to overcome (Yarish et al. 1999.) Reasons for failure in BC included damage to the cultivation system from winter storms, insufficient site selection efforts, lack of biological and farming experience, and an undercapitalized financial base (Levine 1999).

Despite the obstacles, cultivation of *Porphyra* is seen as being one of the greatest potentials for generating a viable seaweed culture industry in Canada and the United States (Table 6). Despite earlier failure, researchers have once again begun to examine the possibilities of domesticating indigenous species of *Porphyra* and modifying Chinese and Japanese cultivation technologies to local coastal environments (Yarish et al 1999).

The obstacles are not as daunting for the production of wakame and kombu. BC kelp species such as *Laminaria* are well suited for the production of kombu, while *Nereocystis* is almost identical to the traditional wakame. Marketing these alternative species is the primary challenge if a significant share of the North American imports of seaweeds from Asia is to be replaced.

In the long term, edible seaweed markets in Asia, particularly Japan, represent potential markets for B.C. seaweed products. Some other potential market opportunities include exploitation of the more than 600 seaweed species in BC to provide a new taste/food to sophisticated markets in Japan. In addition, British Columbia's marine environment may remain much less polluted than elsewhere, providing an advantage in marketing seaweed and seaweed products intended for human consumption. (Small 1999, Ference Weicker & Co.)

6.2 Industrial Seaweed Market

The industrial seaweed market holds far fewer opportunities for BC seaweeds than the edible seaweed market. This is because of the relatively low prices for hydrocolloids (agar, algin and carrageenan) and the strong competition from seaweed producers in developing countries. The majority of seaweeds used for hydrocolloid production are harvested from countries such as China, Chile and the Philippines.

British Columbia is unlikely to develop a large, or even medium scale hydrocolloid industry although the majority of BC seaweed consists of brown species that could be used in the manufacture of algin. In 1992, Michael Coon, the provincial government's primary seaweed researcher believed that kelp resources would remain undeveloped due to British Columbia's high labour costs and the remoteness of major harvestable stocks. Another concern was the possible impacts on fishery resources.

One of the greatest obstacles to the development of a large-scale kelp harvesting industry is the current mood/consciousness of the public, which does not support new resource development at the scale necessary to create a significant new industry. For example, the California or Norwegian kelp industries would likely receive much greater scrutiny and be much less likely to receive authorization to harvest at current scales if they were to be initiated today instead of 50 years ago (Coon p.c).

Seaweed cultivation could provide an alternative to wild harvest that would help overcome some of these obstacles, although there are some impediments to marine plant cultivation in British Columbia.

6.3 Niche Markets

A conclusion of the Ference Weicker & Co. report was that any development of BC's seaweed resources should focus on species that target niche markets with high-value speciality products. This same conclusion was reached by Michael Coon earlier and continues to be the finding of current analysis (Craigie, Staples and Archibald 1999).

There are several potential niche markets that seaweed harvesters in British Columbia could exploit. Bacteriological agar, abalone and urchin feed, fertilizers, animal food, health spas, cosmetics, medical uses, alternative energy source, packaging material and pollution control are the niche markets discussed in the Seaweed Market Study. The discussion below concentrates on markets that are currently being exploited to some extent in BC.

Currently the most lucrative seaweed market in British Columbia is the bacteriological agar market. Five hundred grams of microbiological agar sells for $220.00 while noble agar sells for as high as 192.50/250g (MBI 2000). However, Marine Bioproducts International Ltd. is now successfully exploiting this small niche and would provide considerable competition for any new companies (see section 5.2 for a more complete description of this company).

The potential to market seaweed for abalone, sea urchin and sea cucumber feed was mentioned very briefly in the 1995 Seaweed Market Study. There are currently two licensed abalone farms and five sea urchin farms in British Columbia (Deegan, p.c.). At present, these operations are experimental in nature. The feed used in these operations is mainly manufactured but fresh kelp is being used experimentally in at least two (Wheeler 2000). There are three licences to harvest kelp for sea urchin feed, all with quotas under five tonnes.

Algae used as food in cultivation of invertebrates have to be fresh; hence they must be harvested. The amount of algae needed to sustain an aquaculture center varies with the species being raised and the stage of the individuals (recruit, juvenile, adult). *Haliotis* species consume between 15 and 30 percent of its body weight per day, and the estimated volume of brown algae needed to feed an abalone culture center with an average of 500,000 units, is 600 metric tonnes/year of fresh algae. A similar center growing red sea urchins requires 1,000 metric tonnes/year (Vásquez, 1999). If fresh kelp feed trials are successful there could be a modest opportunity to provide kelp for sea urchin cultivation facilities.

A similar possible niche market is kelp based fish food. Kelp and fish offal are the main ingredients in a new method of manufacturing fish food developed in Japan. This production system is being tested in Japan and considered for the Prince Rupert area (Druehl 1999).

Another small niche market that is already being exploited to some degree in British Columbia is the seaweed-based fertilizers and foliar market. These items are popular with organic farmers and as organic farming expands so could the market for seaweed based horticultural products. These goods have been manufactured in North America since the 1950s, but the number of available products has grown significantly in the past decade (Mitham 2000).

In 1989, five manufacturers sold seaweed garden products in Canada, the number has since doubled. Likewise, a glance on the Internet shows a range of products available on-line. According to Patrick Bennett, vice president of sales, of the largest manufacturer of seaweed fertilizer, Acadian Seaplants of Dartmouth, Nova Scotia, the world market for soluble seaweed products has increased by as much as 25% since 1994 (Mitham 2000).

Innovation also seems to be a key element of success in the seaweed industry. In a survey of marine plant harvesters done for this report, all felt that demand for their product was increasing and many were interested in expanding their operations in terms of tonnage harvested and to include other species.

6.4 Description of recent requests for marine plant licences

- A recent request for funding for a kelp farming industry including a spore culturing greenhouse facility was made from a group on the North Coast. The project is reportedly stalled due to problems obtaining permits from BC Assets and Lands (B-Cal) for use of the land for the farm.
- A group from Vancouver have proposed an alginic acid extraction plant in Port Hardy. They plan to cultivate and wild harvest kelp and have cited Norway as an example of a successful alginate industry. They have also requested one million dollars in government funding.
- There is significant interest in increasing tonnage and species harvested among current licensed marine plant harvesters.

7. Conclusion

Although there is significant economic opportunity associated with British Columbia's marine plant resources, they have remained virtually untouched while many other fishery resources have been heavily exploited. British Columbia's development of a seaweed industry lags far behind that of other countries for several reasons. High production costs due to labour expenses as well as a climate that makes year round production impossible have limited the competitiveness of British Columbian enterprizes as compared to many traditional seaweed producing countries in Asia. An absence of a ready market for seaweed products has also contributed to the lack of development of British Columbia's marine plant resource.

The majority of marine plants harvested worldwide are cultivated rather than wild harvested. Marine plant cultivation holds promise in British Columbia, in particular for the cultivation of edible marine plant products. Cultivation also has the advantage of being completely in line with British Columbia's marine plant management strategy, which is to provide access to marine plant resources while not compromising the marine environment.

British Columbia's marine plant policy has remained virtually unchanged for the last decade. The major issue that should be addressed in the development of an updated policy is whether the benefits of a large-scale wild marine plant industry would outweigh the management costs to government.

Increasing the value of British Columbia's seaweed industry does not seem to rely on large-scale industry but rather on niche marketing and the development of high value kelp products such as food products, specialized horticultural products, pharmaceuticals and chemicals that utilize lower harvest volumes. If there is a will to develop new seaweed products and exploit niche markets in British Columbia, then it is likely that the seaweed industry will expand in the future.

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Appendices

1. First Nations and marine plants

INTRODUCTION

The First Peoples of the Northwest Coast are characterized by a number of features in common, such as high dependence on salmon and reliance for much of their material economy on western red-cedar. One of the major features, in many cases subsuming and underlying all the others is their maritime economy and lifestyle. These people spend a large portion of their lives on or near the ocean and, as well as salmon, they subsist in large measure on fish, sea mammals, shellfish and marine plants. The time required to procure and process these foods and to construct the canoes and implements required to obtain them, was, and to some extent, still is, a major part of peoples' lifeways.

Today, marine resources are still important for First Peoples and continue to define them as a culture (Suttles 1990). In this paper I focus on the cultural importance of marine plants to coastal First Peoples. This includes the use of these plants for food, material purposes, medicine and healing and in other cultural traditions. Northwest Coast peoples comprise several different language families and subdivisions, and their cultures also differ from one people to another. In all, on the British Columbia Coast alone, there are at least 16 languages spoken by NW Coast peoples, in four different language families, one of which – Haida – is a linguistic isolate, with no known linguistic relatives anywhere in the world. Thus, the names and uses of these plants vary considerably from one people to another, and this paper represents only a general overview to demonstrate the broad spectrum of uses and relationships people have had, and continue to have with plants in the marine environment.

It is interesting to note that, although there are many names for various marine plants there is, in many cases, no all-inclusive term for "seaweeds" or marine plants. Rather, such a category is inferred by context of conversation and inclusion of various species together in discussions and discourse. In Haida (Skidegate dialect), for example, there are names for bull kelp (*Nereocystis luetkeana* –lhqyaama), giant kelp (*Macrocystis integrifolia* – ngaal), rockweed (*Fucus* spp. – t'al), red laver (*Porphyra abbottae* – sGyuu), sea lettuce (*Ulva lactuca* – Gandll sGiinawaay), and many other species, but no collective word for these algae (Turner 1995).

IMPORTANT MARINE PLANTS FOR COASTAL FIRST PEOPLES

<u>*Edible Seaweeds and Marine Plants*</u>

In many parts of the world, such as Japan and Polynesia, marine algae are a predominant source of food (Abbott 1992; Abbott and Williamson 1974; Madlener 1977). In fact, there are hardly any macroscopic marine algae anywhere that could be considered poisonous, although some are difficult to digest (Turner and Szczawinski 1991). On the Northwest Coast, one major species was gathered and eaten in quantity: red laver (*Porphyra abbottae*) (named after the famous algologist and ethnobotanist Dr. Isabella Abbott). Other species of *Porphyra* were also harvested to some extent (Turner 1995). This plant, simply called "edible seaweed", is still harvested and eaten in quantity by the Heiltsuk, Tsimshian and Haida people as well as the Tlingit of Alaska (Jacobs and Jacobs 1987; Turner 1995; Compton 1993). Sometimes it is used as a famine food (Turner and Davis 1993).

At Hartley Bay, a Coast Tsimshian community for example, people go to their seaweed camp for the entire month of May to gather and dry their seaweed and harvest other marine resources like crabs and halibut. The seaweed is harvested when young and, ideally, dried on the sun-baked rocks along the shoreline. If the weather is rainy, drying the seaweed is difficult; there are many cultural sanctions and taboos associated with the weather. For example, for the Haida, there are certain flowers, the “rain flowers” which children are cautioned not to pick because to do so would bring rain and people would not be able to dry their seaweed. Red columbine (*Aquilegia formosa*) and blue harebell (*Campanula rotundifolia*) are two of these flowers, known as “red rain flowers” and “blue rain flowers” respectively (Turner 1995). Today, if the weather is rainy, people can freeze their seaweed, then take it out and dry it later when the weather improves.

Once dried, the seaweed is stored away to be eaten as snacks or cooked in soups and stews. A favourite dish is salmon egg and seaweed soup, often served at feasts and potlatches. Another is pieces of dried seaweed dipped in oulachon grease, fat rendered from a small, oily fish and used as a condiment. A more modern dish many people enjoy is seaweed cooked with creamed corn. The laver seaweed, a relative of Japanese nori, is highly nutritious, being especially rich in all the necessary essential vitamins and minerals (Kuhnlein 1980; Medical Services Branch 1985; Kuhnlein and Turner 1991). Dried seaweed is an important trade item, and peoples of the interior – the Dakelh or Carrier, and Gitksan for example – use it to treat goiter, a disease of iodine deficiency (Turner 1973; Turner 1995; Turner and Loewen 1998). Some people also cooked fresh bull kelp fronds and other kinds of kelp in their stews and soups, as is also done in Japanese cuisine.

The Straits Salish and Ditidaht peoples of southern Vancouver Island apparently did not use the edible seaweed traditionally, but in the early part of the 20th Century, these people used to collect and dry the seaweed and sell it by the gunnysackful to the Chinese people in the Victoria area (Williams 1979; Elsie Claxton, pers. comm. 1997; Turner et al. 1983). They called it “Sluckus” or lheq’es, a term derived from its Kwak’wala name, lhaq’astan or its variants.

Giant kelp (*Macrocystis integrifolia*) was another seaweed prominent in coastal peoples’ diets, but in this case, the large, bumpy fronds served as a surface for repositing of herring eggs. Early in the year all along the coast, starting in the south, herring by the millions congregate in quiet bays and inlets to spawn. People were very careful of the herring populations and treated them with great respect, never yelling or banging when the herring were in the water nearby. Giant kelp and other types of kelp such as *Laminaria* and *Egregia*, eelgrass (*Zostera marina*) and seagrasses (*Phyllospadix* spp.), and bundles of western hemlock boughs (*Tsuga heterophylla*) or other conifer boughs anchored out in the water, were used to gather this precious food. Then the fronds or branches were hung up and dried and the eggs used all winter. The eggs on the seaweed were eaten together with the seaweed itself. For seagrasses, they were pulled off with the teeth, making a distinctive sound, Hesh-hesh-hesh, after which the West Coast people of Hesquiaht are named (Turner and Efrat 1982).

Eelgrass, mentioned previously, is also a vegetable in its own right, not only a repository for herring eggs. It is a flowering vascular plant, not a marine alga. People used to relish the young leaf bases and rhizomes. The plants were harvested in quiet bays by canoe, using a long pole with crossed sticks fixed at the end. The pole was thrust down into a dense eelgrass meadow on the ocean floor, twisted to entangle the leaves and then pulled up, leaves, rhizomes and all. The eelgrass was bundled up in a specific way, and the bundles eaten raw after being dipped in oil or oulachen grease. The Seri Indians of Baja California gathered and ate the seeds of eelgrass (Felger and Moser 1985).

As well as being used for herring spawn collection Seagrasses, which are relatives of eelgrass only with longer, narrower, tougher leaves, were used for basketry and other types of weaving. Eelgrass leaves were also used. The leaves bleach almost white in the sun and make excellent decorative overlay in baskets (Turner 1998). Eelgrass, seagrass, and various types of marine algae were also utilized in the storage and preparation of food. They were laid over salmon and other fish to keep them cool. They were also used in pit-cooking, being layered over red hot rocks at the bottom of the pit, and over the food in the pit, both protecting the food being cooked from contamination with sand and providing flavour and steam-generating moisture in the pit. Clams are said to be delicious cooked in a steaming pit surrounded by seaweed.

Today, some people make pickled bull kelp, using a similar method of boiling and steeping in vinegar and spices that are used to make other kinds of sweet pickles. The Northwest Coast laver also lends itself to making sushi and other types of dishes that have been made popular through Japanese cuisine. At least one company, in Barkley Sound on Vancouver Island's West Coast, is producing top-quality dried kelps of various types that can be purchased at health food and other specialty stories and used in various dishes. There are several cookbooks that focus on edible marine plants (Madlener 1977; McConnaughey 1985).

Marine Plants in Technology

Without doubt, the most valued marine plant material in traditional Northwest Coast technology is bull kelp (*Nereocystis luetkeana*). This long-stiped alga was, and is used for many purposes, such as anchor lines, and especially fishing lines. To make the very best line, the stipes were cut by specially trained divers from places where they grow very long and strong. The stipes were then specially cured, by alternately soaking in fresh and salt water, drying and rubbing them along the entire length with dogfish oil until the tissue was completely saturated with oil. This process could take up to a year, according to Ditidaht cultural specialist John Thomas (Turner et al. 1983). Then, before it was actually used, it was soaked in water again. Sections of the line were joined together using fisherman's knots, so that lines long enough for deepsea fish like halibut could be made (Stewart 1977). Hooks of split and bent tree knot sections, or dense yew wood (Taxus brevifolia), were attached to the line. Kelp fishing line can be dried and stored for several years. Sometimes it was used as a trade item; apparently it was taken through trade to be used in some interior lakes inland from the central coast. Bull kelp was also used to make fishing nets, ropes, anchor lines and harpoon lines (U'mista Cultural Centre et al. 1998)
Another role for bull kelp is the use of the hollow bulbs and adjoining stalks in the process of steaming wood for bending and shaping. Kelp fronds and other

seaweeds like rockweed were used by the Kwakwaka'wakw as a source of steam in making bentwood cedar boxes (U'mista Cultural Society et al. 1998). In the manufacture of fishhooks for halibut and other large fish, the dense knotwood of trees extracted from rotten logs in the forest was cut into lengths and shaped, then two or three inserted into a hollow kelp bulb with a little water and sealed in with a plug of wood or moss. The entire bulb was then buried in the hot sand beside a fire on the beach and left overnight. The knot lengths, heated and steamed by this treatment, became flexible. They were bent into the correct shape using a mold, then allowed to cool and dry. Fixed with a barb and bait and tied onto a leader of stinging nettle (*Urtica dioica*), this contrivance became a perfect blending of the forest and the sea to be used for the benefit of the saltwater people. Yewwood (*Taxus brevifolia*) bowstaves were treated in the same way, being placed inside a hollow length of bull kelp then steamed to make them soft and flexible so they could be formed to the right shape. Kelp bulbs and hollow stipes were also cured and used to store seal oil, oulachen grease and even molasses (Turner 1998; U'mista Cultural Centre 1998).

Children up and down the coast played many different games with seaweeds. Dried stipes of the short, tough-stemmed kelps like *Lessoniopsis littoralis* became sticks in a favourite beach-hockey game played by Nuu-Chah-Nulth children. The "puck" was a ball carved from the dense holdfast of the kelp. Children also like to play with the small inflated bladders of giant kelp and rockweed, or sea wrack (Fucus spp.), which will pop if stepped on or thrown into a fire. The water-filled sacs of *Halosaccion* become squirt-guns for children (the Haida name means "nipple"), and kelp bulbs are also used for a variety of games and toys, including as set targets in spear-throwing contests (Turner and Efrat 1982; Turner et al. 1983; Turner 1998).

The hollow stipes of kelp could also be used as hoses, for adding water into steaming pits, for example. In fact, the Nuxalk name for bull kelp is also, today, applied to garden hose (Turner 1973). One rather unusual application of kelp was by the Koskimo (Gusgimukw) from Quatsino, to bind the heads of their infants, giving their heads an elongated shape, which was said to be a sign of importance (U'mista Cultural Centre et al. 1998).

<u>Medicine and Tradition</u>

Marine algae were also used in healing and health care. For example, the gelatinous material at the centre of fresh rockweed receptacles was used as a burn medicine, like aloe vera, and was applied to sores and swellings (Elsie Claxton, pers. comm. 1996). It was also applied to the eyes to remove foreign objects and soothe stinging or burning eyes. It was rubbed on the limbs for strengthening them or to alleviate muscle aches and pains or even paralysis of the legs (U'mista Cultural Society et al. 1998).

Red laver itself is rightfully considered a health food, and is taken, with oulachen grease, as a strengthener and energy booster. Giant kelp and bull kelp were used in steambathing. A patient, with aching muscles or some undefined illness, would lie on a bed of seaweed lain over red hot rocks, then a blanket or mat was placed overtop, and the patient would rest in a sort of medicated sauna. Bull Kelp was used as a container not only for edible products, but also in the making of a skin salve by Nuu-Chah-Nulth people, in which the main ingredients were cottonwood buds (*Populus balsamifera* ssp. *trichocarpa*) and the hard fat from around the stomach of a deer.

The cottonwood buds were heated with the fat until the sweet aromatic resins had dissolved into the fat; this warm solution was then poured into a kelp bulb to solidify. After it had hardened, the kelp could be peeled off, leaving a bulb-shaped block of salve, which was used for skin sores, burns, sunburn and other purposes (Turner 1998).

Sea Palm (*Postelsia palmaeformis*) is a good example of a marine plant valued for its strength and resilience. Among some Nuu-Chah-Nulth peoples of the past, a newborn baby destined by birth and inheritance to be a whale hunter, would have his spine rubbed with the charcoal made from burning this alga; this was said to make the child strong and as tough as the sea palm, which has to withstand pounding surf hour after hour, day after day.

In Northwest Coast traditions and narratives, marine plants feature prominently. In the Haida tradition, a double-headed kelp indicated the entrance to house of a supernatural chief under the ocean, and anyone who could follow it down to the ocean bottom and meet the supernatural people there was destined to gain power, prestige and good luck when they returned to their own village.

Kelp was used in a very interesting way in the dramas that were enacted in the big houses of the Kwakwaka'wakw and other coastal peoples as part of the Winter Ceremonials. A long, hollow kelp stipe was buried under the dirt in the floor of the big house, from the outside of the wall leading right to the hearth in the centre. A person standing outside the house could chant or yell into the kelp tube, and it would sound uncannily like someone, or someone's spirit, was calling from the middle of the burning fire. This was just one of many theatrical effects people used to bring their ceremonies and dances to life, and to give them dramatic impact.

DISCUSSION AND CONCLUSIONS

Marine plants were, and still are, integral to the healthy lifestyle of Coastal First peoples, even though technologies and food habits have changed considerably. It is important to stress, as well, that marine plants are part of, and have helped to create, the coastal habitat that is so productive for all life. Bull kelp, giant kelp and eelgrass, for example, have been identified as "keystone" marine species, which, by their very existence and dominance in the coast environment, have tremendous influence over the biodiversity, structure and function of the "kelp forest" and "eelgrass meadow" ecosystems along the coastline. Many of the other resources which people rely on, from sea urchins, or "sea eggs", to crabs, rockfish, herring, and even salmon, are sought from the vicinity of these ecosystems. It's no wonder that they are so significant in peoples' lives.

For fishing in the ocean, a common practice was to actually cut a swathe through an offshore kelp bed to create a channel through which the sockeye and other salmon could swim more easily. This was the point at which people would stand in their canoes to spear the fish (Stewart 1977). Direction of tides and predictions of weather were also provided by "reading" the seaweed beds. Seaweeds washed up on shore were sometimes browsed by deer, which must be attracted to the salty flavour. Coastal hunters would watch for deer and bear wandering amongst the seaweeds along the beach. Brant and other types of waterfowl seek eelgrass rhizomes as a food source, and are sought after by hunters along the shoreline. Algae are also used as ecological indicators, their presence or condition reflecting the passing of the seasons or other events important to coastal peoples. For example, in one Nuu-Chah-Nulth community, it is said that *Enteromorpha* at the mouth of salmon creeks has to be washed out of the creek by late-summer rains before the salmon will start coming up to spawn.

Many Aboriginal elders have expressed concern that the marine environment has deteriorated considerably over the past few decades, that eelgrass beds are being damaged by log booms and dredging, and that marine waters are increasingly polluted (Scientific Panel for Sustainable Forest Practices in Clayoquot Sound 1995; Wyllie-Echeverria et al. 1995; Daisy Sewid-Smith and Chief Adam Dick, pers. comm. 1998). These losses are related to general environmental deterioration, from forestry activities, overfishing, introduced species, and urbanization, and their impact on First Nations' lifeways are profound. Elders talk about this situation with sadness and deep regret; they feel the loss very personally, as well as for the lands and waters and other lifeforms who share and are part of the environment and its resources. Certainly, they feel, if these marine plants and their environments disappear, so will an entire way of life and culture, and all of us will be poorer for it. In fact, our well-being and survival will be at risk.

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2. Harvesting methods for *Macrocystis* and *Nereocystis*

(Adapted from Wheeler 1990)

Harvesting methods for *Macrocystis* and *Nereocystis* are based on research on how harvesting affects the recruitment, growth, survivorship and mortality of the harvested species. The objective of an optimal harvesting strategy for both of these species is sustained regrowth of 100% to pre-harvest levels by the following year.

Harvesting methods for *Macrocystis*

Research into a harvesting strategy for *Macrocystis* by the Province of British Columbia between 1979 and 1981 led to a greater understanding of the optimal parameters for cutting height above bottom, season of cut, and number of cuttings. There is a direct relationship between the height of fronds after harvest and biomass recovery over time for *Macrocystis*. Frequency and season of harvest modify this relationship.

Findings of 1979-1981 study

Once a year harvest

- Plots cut a 4.5 m above the seabed returned 100%.
- Plots cut a 3.0 m might do better in years with lower spring light conditions, perhaps due to increased light reaching younger fronds.
- Data suggested complex relationship between light and growth of frond remnants and initials.

Twice a year harvest

- Plots cut in May and August at 4.5 m returned greater than 100% yield of the May harvest within the same growing season, while those cut at 3.0 m and 1.5 m never returned 100% of the original yield.
- Plots cut in June and September showed that delaying the initial cut is detrimental, perhaps due to the light regime. In delayed harvests, plots cut at 3.0 m often did surpassed 4.5 m yields.

Three times a year harvest

- Plots cut in May, July and September at 4.5 m returned only 90-100% of the yield. 3.0 m and 1.5m cuts did not achieve over 50% recovery.

Harvesting methods for *Nereocystis*

A harvesting strategy for *Nereocystis* must take into account its strongly annual life history and the fact that it reproductive zoospores are associated with the surface canopy. At some times of the year, the entire standing crop of *Nereocystis* dissapears and canopy regeneration is wholly dependent on new recruits. Harvesting of *Nereocystis* tends to remove most of the plant including its reproductive capacity, therefore it is important to ensure that harvesting does not occur before most of the reproductive spores are produced and released (July and August). Or, harvesting must leave sufficient plants in the forest to insure adequate recruitment the following year. In a study carried out between 1978 and 1980 no differences were found between plant biomass in either the control or harvest plots. Thus, no significant harvesting effect could be detected on recruitment and regrowth of beds in subsequent years. The author of the study suggested that 100 m strips could be clear cut without a high risk to the resource.

3. Reports in the British Columbia Aquaculture System

Vancouver Island

Reference	Location	Species Surveyed
Scagel, R.F. 1947. An investigation on marine plants near Hardy Bay, B.C. Provincial Department of Fisheries, Victoria, B.C. Report No.1. 70p.	Northeast end of Vancouver Island, just west of Malcolm Island	*Nereocystis* and *Macrocystis*
Austin, A. and Adams, R. 1972. Algal Vegetative Maps. Figure 2- Southeast coast of Denman Island, Figure 3- Northern coast of Denman Island, Figure 4 Willemar Bluff to Little River. Internal publication of the Department of Biology, University of Victoria. 4p.	South end of Denman Island to Elma Bay on the east coast of Van. Is.	Iridaea cordata. Prioritis lyalli, Plocamium coccineum, Cryptosiphonia woodii, Iridaea heterocarpa, Sargassum muticum, Laminariaceae-Alaria spp. Desmarestia spp. Porphyra spp. Ulotricales, Fucus distichus, Gigartina stallata, *Nereocystis* luetkeana, Rhodomela larix, Zostera
Austin, A. and Adams, R. 1972. Algal Vegetative Maps. Figure A1- Elna Bay to Shelter Point, Figure A2- Shelter Point to Campbell River, Figure A3- Hernando Island. Internal publication of the Department of Biology, University of Victoria. 4p.	Miracle Beach north to Campbell River, and the south end of Quadra Island, and Marina, Hernando, Savary and Harwood Islands	Iridaea cordata. Prioritis lyalli, Plocamium coccineum, Cryptosiphonia woodii, Iridaea heterocarpa, Sargassum muticum, Laminariaceae-Alaria spp. Desmarestia spp. Porphyra spp. Ulotricales,
Humphreys, R.D and Haegele, C.W. 1976. An evaluation of herring spawn survey techniques used in British Columbia waters. Environment Canada, Fisheries and Marine Service, Research and Development Directorate. Technical Report No. 613. 142p.	Barkley Sound (Macoah Pass, Mayne Bay, and Hand Island)	All marine plants
Haegele, C.W. and Hamey, M. J. 1976. Shoreline vegetation maps of Nanoose and Ganges herring management units. Fisheries Research Board of Canada Manuscript Report Series No. 1408. 43p.	Ganges and Long Harbours and Departure Bay	All marine plants
Haegele, C.W. and Humphreys, R.D. 1976. Surveys of vegetation in herring spawning localities in the vicinity of Nanoose Bay, B.C. Fisheries Research Board of Canada Manuscript Report Series No. 1412. 37p.	Nanoose Bay, Wallis Point, and Icarus Point	All marine plants
Coon, M.L., Field, E.J., Canadian Benthic Ltd. 1976. Nootka Sound kelp inventory, 1975. British Columbia Marine Resources Branch, Fisheries Management Report No. 2. 26p.	Nootka Sound	*Nereocystis* and *Macrocystis*
Leaman, B.M. 1976. The ecology of fishes in British Columbia kelp beds, Barkley Sound *Nereocystis* beds. Marine Resources Branch, British Columbia Department of Recreation and Tourism. 108p.	North coast of Diana Island in the Deer Group Islands	*Nereocystis*
Haegele, C.W. 1977. Vegetation Survey of herring spawning localities in Ganges Harbour, B.C. Fisheries and Marine Service Manuscript Report No. 1433. 17p.	Ganges Harbour and vicinity	All marine plants
Haegele, C.W. 1978. Shoreline vegetation on herring spawning grounds between Deep Bay and Dorcas Point, Strait of Georgia, B.C. Fisheries Research Board of Canada Manuscript Report Series No. 1485. 49p.	Deep Bay to Northwest Point, Georgia Strait	All marine plants
Haegele, C.W. and Hamey, M.J. 1979. Shoreline vegetation on herring spawning grounds in Stuart Channel, Strait of Georgia, B.C. Fisheries Research Board of Canada Manuscript Report Series No. 1534. 29p.	Stuart Channel, Georgia Strait	All marine plants

Haegele, C.W. and Hamey, M.J. 1980. Shoreline vegetation on herring spawning grounds in Barkley Sound in 1978 compared with similar assessments for 1974 and 1975. Fisheries Research Board of Canada Manuscript Report Series No. 1549. 37p.	Barkley Sound	All marine plants
Haegele, C.W. and Hamey, M. J. 1981. Shoreline vegetation maps on herring spawning grounds for Comox, Denman Island and Hornby Island. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1617. 41p.	Comox, Denman Island and Hornby Island	All marine plants
Coon, L.M., Roland, W., Field, E.J., Clark, E.A.C., Clayton, W.E.L. 1981. Kelp Inventory, 1976. North Coast Vancouver Island, Hope Nigei and Balaklava Islands. British Columbia Marine Resources Branch, Fisheries Management Report No. 20. 19p.	North Coast, Hope Nigei and Balaklava Islands.	*Nereocystis* and *Macrocystis*
Coon, L.M., Roland, W., Sutherland, I.R., Hall, R.A. 1982. Kelp Inventory, 1978. Northwest coast of Vancouver Island. British Columbia Marine Resources Branch, Fisheries Management Report No. 28. 16p.	Northwest coast, Brooks Peninsula to Cape Scott	*Nereocystis* and *Macrocystis*
Foreman, R.E., Cabot, E., Oates, B. 1982. Studies on *Nereocystis* luetkeana I: Annual and seasonal dynamics of the floating kelp beds off the Northwest coast of Malcolm Island. A report to the B.C. Marine Resources Branch, Ministry of Environment, Draft No.3. 54p.	Northwest coast of Malcolm Island	*Nereocystis* and *Macrocystis*
Haegele, C.W. and Hamey, M.J. 1987. Shoreline vegetation on herring spawning grounds in the upper west coast of Vancouver Island. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1921 43p.	Upper west coast, Quatsino Sound and Forward, Holberg, Klaskino and Klaskish inlets	All marine plants
Sutherland, I.R. 1989. Kelp inventory, 1988. Juan de Fuca Strait. B.C. Ministry of Agriculture and Fisheries, Aquaculture and Commercial Fisheries Branch, Fisheries Development Report No. 35. 18p.	Canadian Shore of Juan de Fuca Strait	*Nereocystis* and *Macrocystis*
Sutherland, I.R. 1990. Kelp inventory, 1989. The Vancouver Island and Malcolm Island shores of Queen Charlotte Strait, including a summary of historical inventory. B.C. Ministry of Agriculture and Fisheries, Aquaculture and Commercial Fisheries Branch, Fisheries Development Report No. 36. 41p.	Northern shore of Vancouver Island from Thomas Point to the Cluxewe River and west and north shores of Malcolm Island	*Nereocystis* and *Macrocystis*
Sutherland, I.R. 1996. Kelp inventory, 1995. Nootka Sound. B.C. Ministry of Agriculture and Fisheries, Aquaculture and Commercial Fisheries Branch, Fisheries Development Report No. 36. 41p.	Southwest shore of Nootka Island, west and south shores of Hesquiat Peninsula	*Nereocystis* and *Macrocystis*

Central Coast

Reference	Location	Species Surveyed
North Pacific Marine Products Ltd. 1968. 1967 summer survey of the marine plant resource lying within an eighteen mile radius of Masset, located on the northern coastline of the Queen Charlotte Islands. North Pacific Marine Products Ltd. Report. 52p.	North coast of Graham Island.	*Nereocystis* and *Macrocystis*
Jenkins, B.W. and Britt, I. 1972. Seaweed Inventory of two Queen Charlotte Inlets. A report for the Department of the Environment, Fisheries Service, 1090 West Pender Street, Vancouver, BC. 8p.	Skidegate and Cumshewa Inlets	*Nereocystis*, *Macrocystis* integrifolia, *Macrocystis* pyrifera, Laminaria
Blakely, B.B. and Chalmers, W.T. 1973. Final Report, Masset kelp inventory. Report submitted to Fisheries Operations, Department of the Environment, Vancouver, B.C. 77p.	Masset to Tow Hill	*Nereocystis* and *Macrocystis*
Coon, L.M. 1974. M.V.Roset Cruise, East coast of the Queen Charlotte Islands, June 21-27, 1974. Unpublished report. 6p.	Gray Bay to Skedans Bay on Moresby Island.	*Nereocystis*, *Macrocystis*, Cymathere triplicata, Eelgrass
Coon, L.M., Roland, W., Field, E.J., Clayton, W.E.L. 1979. Kelp Inventory, 1976. Part 3. North and west coasts Graham Island (Queen Charlotte Islands). British Columbia Marine Resources Branch, Fisheries Development Report No. 13. 41p.	Fredrick Island to Cape Knox to Klashwun Point, Klashwun Point to Masset Harbour, and Entry Point to Yakan Point.	*Nereocystis* and *Macrocystis*
Haegele, C.W. and Hamey, M.J. 1980. Shoreline vegetation on herring grounds in Laredo Sound, British Columbia. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1580. 23p.	Laredo Sound	All marine plants
Haegele, C.W. and Hamey, M.J. 1980. Shoreline vegetation on herring grounds in Thompson Bay, British Columbia. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1579. 21p.	Thompson Bay	All marine plants
Haegele, C.W. and Hamey, M.J. 1981. Shoreline vegetation on herring spawning grounds for Cumshewa Inlet, Queen Charlotte Islands. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1619 25p.	Cumshewa Inlet	All marine plants
Field, E.J. 1996. Kelp Inventory, 1993. Areas of the British Columbia Coast from Hakai Passage to the Bardswell Group. B.C. Ministry of Agriculture and Fisheries, Aquaculture and Commercial Fisheries Branch, Fisheries Development Report No. 37. 23p.	Central Coast from Hakai Passage to the Bardswell Group	*Nereocystis* and *Macrocystis*
Jacqueline Booth and Associates and Clover Point Cartographics Ltd. 1997. The Johnstone Strait and Central Coast Biological and Human Use Data Dictionary. Report prepared for the Land Use Co-ordination Office.	Johnstone Strait	*Nereocystis* and *Macrocystis*

North Coast

Reference	Location	Species Surveyed
Field, E.J., Coon, L.M., Clayton, W.E.L., Clark, E.A.C. 1977. Kelp Inventory, 1976. Part 1. The Estevan Group and Campania Island.. British Columbia Marine Resources Branch, Fisheries Development Report No. 9. 19p.		*Nereocystis* and *Macrocystis*
Field, E.J. and Clark, E.A.C. 1978. Kelp Inventory, 1976. Part 2. The Dundas Group. British Columbia Marine Resources Branch, Fisheries Development Report No. 11. 22p.	Port Simpson and Big Bay in Chatham Sound	*Nereocystis* and *Macrocystis*
Coon, L.M., Roland, W.G., Field, E.J., Clayton, W.E.L., Jenson, V. 1980. Kelp Inventory, 1976. Part 4. Goschen Island to the Tree Nob Group. British Columbia Marine Resources Branch, Fisheries Development Report No. 19. 19p.	Coasts of Campania Island and the Estevan Group	*Nereocystis* and *Macrocystis*
Haegele, C.W. and Hamey, M.J. 1982. Shoreline vegetation on herring grounds in Kitkatla Channel, British Columbia. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1664. 29p.	Kitkatla Channel	All marine plants
Haegele, C.W. and Hamey, M.J. 1982. Shoreline vegetation on herring grounds in Chatham Sound, British Columbia. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1660. 27p.	Goschen and Porcher Islands, Prescott and Stephans Islands and the Tree Nob Group	All marine plants
IEC Collaborative Marine Research and Development, Ltd. 1998. Kelp Inventory 1996. Porcher Island, Goschen Island, Banks Island and the Estevan Group. B.C. Ministry of Agriculture and Fisheries, Aquaculture and Commercial Fisheries Branch, Fisheries Development Report No. 39. 27p.	Porcher Island, Goschen Island, Banks Island and the Estevan Group.	*Nereocystis* and *Macrocystis*

Entire Coast

Reference	Location	Species Surveyed
British Columbia Research Council. 1947. A report on the location of marine plants of economic importance in British Columbia coastal waters. Technical Bulletin Number 4, British Columbia Research Council, University of British Columbia, Vancouver, BC.	BC Coast	*Nereocystis* and *Macrocystis*
Druehl, L.D. 1978. The Distribution of *Macrocystis* integrifolia in British Columbia as related to environmental parameters. Canadian Journal of Botany. Vol. 56, No. 1. 11p.	BC coast with detailed look at Barkley Sound	*Macrocystis* integrifolia
Hutchinson, I. and Smythe, S.R. 1989. Impact of Commercial Harvesting of Sea-Asparagus (*Salicornia virginica* L.) on the Productivity of Coastal Salt Marshes in BC. Contract Report no. 900086, Min. of Agriculture, Province of British Columbia.	BC Coast	*Salicornia virginica* L.

4. Site codes for figure 4.

Common		Rare or Absent	
Map Reference	Estuary	Map Reference	Estuary
1	Adam-Eve	32	Bay of Plenty
2	Bamfield Inlet	33	Bedwell
3	Baynes Sd.	34	Bella Coola
4	Boundary Bay	35	Campbell
5	Chemanius	36	Cascade Inlet
6	Cluxewe	37	Chief Matthew Bay
7	Courtney	38	Dala
8	Cowichan	39	Fraser
9	Englishman	40	Gold
10	Goldstream	41	Kaouk
11	Goodspeed	42	Khutzeymateen
12	Kokish	43	Kildala
13	Little	44	Kimsquit
14	Mud Bay	45	Kingcome
15	Naniamo	46	Kitimat
16	Nanoose	47	Klaskish
17	Ououkinish	48	Kuinamass
18	Oyster	49	Kumdis
19	Pedder Bay	50	Marble
20	Powell River	51	Moycha
21	Quatse	52	Nimpkish
22	Saanichton Bay	53	Qualicum (big)
23	Saltspring Is.	54	Qualicum (little)
24	Sechelt Inlet	55	Salmon
25	Sheldon's Lagoon	56	San Josef
26	Sidney Is.	57	Somass
27	Sooke Harbour	58	Squamish
28	Tofino Inlet	59	Skeena
29	Tsawwassen	60	Tahsish
30	Union Bay	61	Tsitika
31	Waukwaas	62	Yakoun