PREPARATION OF THIS DOCUMENT

The parallel progress made in recent years both in our understanding of seaweeds, and in the growth of the seaweed industry, were addressed by Dr. J. MacLachlan, then Chairman of the International Seaweed Association, in his opening address to the Eleventh International Seaweed Symposium held in Qingdao, People's Republic of China, June 19-25, 1983. At this same symposium, discussions between FAO, the Academia Sinica and the International Seaweed Association, focussed on the requirement for training in applied seaweed activities. The need for a handbook or guide to practical phycology was also taken into account for the management both of wild seaweed resources and seaweed cultivation by man. From these discussions, it became clear that it is premature to look for such a handbook in the near future, given that although great strides have been made in understanding the biology and natural chemistry of seaweeds, relatively little has been written of global relevance on practical aspects of harvest and cultivation. The present set of case studies, by providing a detailed description of a range of such industries, aims at providing some of the basic elements from which such a broader and more relevant summary can be drawn. At the same time, these studies themselves can be of direct value to those working in the present seaweed industries.

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ABSTRACTS

Seven case studies are presented on commercial seaweed resources; five on wild crops, respectively Ascophyllum nodosum, Chondrus crispus, Gelidium, Laminaria longicruris and Macrocystis, are provided along with case studies of the farmed crops of Eucheuma and Laminaria japonica. Individually the cases range from descriptions of the wild crops and their management to the managed production of farmed crops including, in several examples, some information on economics and/or processing. These initial seven cases range from those emphaizing but one species from but one part of one country, to studies of a genus as it occurs commercially throughout the world.

Foreword

Seaweeds are of direct importance to man as a dietary supplement/food additive/source of industrial feedstock and as a base for synthesis of a wide range of chemical products. They are of indirectly importance as contributors to natural food chains and habitats supporting commercially important marine fish and shellfish. Except for a few areas of the world however; such as in the Asian region/their potential for contributing to coastal economies of developing countries has been largely unrealized to date and there is a general lack of information on how this resource may be used productively. As noted recently by Caddy and Fischer (1984): "Seaweeds pose the same questions to the resource manager with respect to national harvesting strategy as do commercially important marine animals on the one hand, and the optimal management of forest and pasture stands in the terrestrial context, on the other. The same important questions should be asked in relation to harvesting strategy, namely:

"(1) Where are the resources, of what kind, and how much? What are the possible alternative uses and markets for these kinds of resources?

> "(2) What is the rate and time of harvesting needed in order to maintain a sustainable optimal harvest of the wild resources?
>
> "(3) What are the appropriate levels of investment in manpower and equipment needed to achieve the above optimal harvesting rate in both wild and cultivated systems without wasting scarce economic resources?
>
> "(4) What, if any, are the indirect impacts of harvesting wild crops or farming on other resources in the ecosystem?"

Although an attempt at addressing the first of these considerations was made by Michanek (1975), and the second by Naylor (1976) and McHugh & Lanier (1983), we are clearly still at an early stage in beginning to realize the economic potential of this important grouping of organisms. The large scale culture of unicellular algae, and the culture and wild harvest of seaweeds or macrophytes are potentially an important addition to those other major spheres of human activity, namely agriculture, forestry and fisheries, which now provide most of our naturally renewable organic materials.

The utilization of marine algae is still in its infancy, and despite numerous articles scattered through the scientific literature there are few general accounts that provide the manager of coastal seaweed resources with practical information. There is a general lack of guidance on the management of wild seaweed resources; some of which are unexploited, some overexploited. Many are of ecological importance to fisheries and several form the basis for the rapidly growing field of seaweed farming.

Paradoxically, in comparison with mariculture of marine fish and shellfish, the technical problems of growing marine algae commercially are relatively simple, and are fairly well understood, as can be seen by the case studies included here. In contrast, the problems of market development for algal seaweed are generally more difficult than for the animal seafoods. This is because more sophisticated treatments are required for using the algae either directly as food, or extracting them to make a wide range of valuable chemicals available.

The chemical applications of seaweeds in particular support sophisticated, capital-intensive industries in developed countries as extraction and purification of a wide variety of products is now undertaken. Here, economic constraints both with respect to capital, equipment and labour intensive cultivation methods, and generally low unit prices paid for the product, are the main constraints, but are only touched on briefly here. A companion volume to the present series of case studies is now being planned, which will deal in more detail with special topics relevant to seaweed harvest and culture, such as approaches to management and assessment of seaweed resources, processing, legal aspects and economics.

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Introduction

This report applies the case study approach to seven of the more important and diverse world seaweed resources, to bring out some of the main factors affecting their rational production. Less emphasis is placed here on the ultimate uses of seaweeds, which range from their utilization in human food and animal foodstuffs, to their roles as food additives, in water purification systems, pharmaceuticals and as a source of biomass for power production among many other uses.

The editors are conscious of the fact that the seven case studies made available to us within the constraints of the present co-operative study do not cover all of the main types of seaweed resources of importance to man: for example, the production of seaweeds for direct human consumption especially in Japan and China is best represented here by the study on the Chinese Laminaria industry, but some of the economically most important resources are destined for other uses than directly as food. The problems faced on the production side are broadly similar in most cases however, and are likely to be addressed with some modification in one or other of the seven studies presented here.

As human populations increase and strive for better things in life, markets are created for more and more food and the luxury accoutrements of modern society. Among them are many products that require such hydrocolloidal materials as seaweeds produce. These materials are largely suspensoids which tend to keep finely divided particles or droplets separated and in suspension in liquids as in foods that are prepared by suspension in milk or water. As gels they may do the opposite; i.e., keep water suspended in solids, as in the preparation of ice-cream where the result is microcrystals in place of the sandy mouth feel of some ice-creams lacking them. They prevent the scorched taste characteristic of older forms of condensed or evaporated milk. They make many confections, foods and other modern substances possible such as cake icings that don't melt or become sticky at ambient temperatures.

The release of medicines by pills that burst only at the appropriate place as they pass through the intestinal tract are often the result of appropriate coatings of algal materials. Of algal origin are some of the world's most effective antihelminthics. Algal hydrocolloids provide the substratum for many horticultural abd biotechnological procedures such as coating seeds with pesticides and fertilizers and such as used in tissue culture, cytoplast fusion and other genetic mechanics. They produce substances that seem to be effective against some of today's most aggravating viral infections and much more.

Traditionally the seaweed of commerce has been produced from harvesting wild crops. As demands for seaweed have grown, their production by farming has proven attractive for its reliability in respect to quality and volume as well as lower costs. Thus we see the wild crops of Chondrus crispus and Laminaria longicruris, which have contributed so much to the history of seaweed use in the Western Hemisphere, being replaced by the farmed crops from other species in the Orient and Old World Tropics and by other wild crop species from the lower labour cost areas of the Southern Hemisphere. In the case of Eucheuma. shifting from wild cropping to farming has largely involved the same people in the same geographic areas and economic levels; so the change has been welcomed.

The reader will note that there is a wide range of sophistication in respect to the production of the different genera. Gelidium (and most all other agar sources but Gracilaria) is strictly still from wild crops with recognition of clear chemical differences in the agar from the different species involved, though there is little published knowledge of these differences. Our understanding and management of Ascophyllum and, even more so, Macrocystis. wild crops almost approach farming but without great concern in the literature for quality or yield of the hydrocollooid product. Yet the quality of the alginate from different genera and seasons is of primary concern to manufacturers.

Each of the seven seaweed chapters began with the same outline, but as the nature of the production of each is so very different, each chapter has come to have some unique features. However, the basic approach has been to provide the reader with the classical knowledge from science first, then the more experimentally developed specifics leading to crop management and, finally, utilization. The sequence is roughly that of the following ten numbered sections:

1 - Identity of the crop
2 - Distribution, ecology and metabolism
3 - Life history
4 - Population structure and mortality
5 - Productivity of the resource
6 - Method of harvesting and harvesting cycle
7 - Equipment used for harvesting of the resource
8 - Protection and management of the resource
9 - Utilization, processing and economics
10 - References

We hope that the provision of the available information in the above outline will tend to illuminate the gaps in the present information while providing that publicly available for these seven seaweeds. Thus the purposes include encouraging readers to fill the obvious gaps in the technology, to undertake research toward improving present practices and to write new case studies for others of the 25-odd seaweeds of importance in world commerce today.

Ascophyllum nodosum and its harvesting in Eastern Canada

1. IDENTITY
2. DISTRIBUTION
3. BIOMASS RECOVERY AND ECONOMICS
4. HARVESTING, BIOMASS RECOVERY AND ECONOMICS
5. ENVIRONMENTAL CONSIDERATIONS
6. ENVIRONMENTAL MANAGEMENT OF THE HARVEST
7. REFERENCES
8. APPENDIX: FISHING AND HARVESTING REGULATIONS

By: Ewan Todd
Coastal Research and Management Unit
Science Branch
Fisheries and Oceans Canada
St. Andrews, New Brunswick, Canada

ABSTRACT

Rockweed (*Ascophyllum nodosum*) is more than Atlantic Canada's resource, it dominates these inter-tidal zones to the point of its ecological health, in eastern Canada alone 50,000 T of wet *Ascophyllum* are considered harvestable. The harvesting of rockweed is a multi-million dollar industry in Atlantic Canada, and is a significant source of income for many coastal communities. Rockweed is also a valuable ecological resource providing habitat for many species, and is a source of nutrients for the inter-tidal and nearshore ecosystems. Rockweed is also used by many species of birds and mammals as a food source, and as a nesting material. Rockweed harvesting is a multi-million dollar industry in Atlantic Canada, and is a significant source of income for many coastal communities. Rockweed harvesting is also a valuable ecological resource providing habitat and nutrients to the inter-tidal and nearshore ecosystems. Rockweed is also used by many species of birds and mammals as a food source, and as a nesting material.

1. IDENTITY

1.1 Identification
1.2 Morphology
1.3 Morphological variations & reproductive structures
1.4 Life cycle and sexuality

1.1 Identification

Ascophyllum nodosum was originally placed in the genus *Fucus* by Carolus Linnaeus. It has numerous synonyms and has been treated various genus as follow:

Ascophyllum nodosum Fucus
Fucus nodosus Linnaeus, Sphaerelaria Fucus
Phyllacanthus nodosum Fucus
Scolophora nodosum Fucus
Ascophyllum nodosum f. mananense
Ascophyllum nodosum f. scorpioides

The complete accepted name and proposed by Le Jolis is 1901.

1.2 Taxonomy

Ascophyllum nodosum is a member of the order Fucales. These are defined as growth form an apical root group. Ascophyllum comprehends very the seemingly endless genotypes are released and recombined in the gene pool. Ascophyllum is a member of the family Fucaceae, this family is characterized by the presence of air bladders, and the presence of a conceptacle with a pore. Rockweed is a dioecious species, meaning that it produces male and female gametes on different individuals. Ascophyllum is a member of the genus Ascophyllum, Ascophyllum nodosum is a linear ramifying plant with dichotomous primary branching and pinnated lateral branches. Ascophyllum nodosum is a member of the subgenus Euascophyllum, which is characterized by the presence of receptacles.

1.3 Morphology, anatomy & reproductive structures

Ascophyllum is an intertidal alga recognized due to its ability to float with the changing water surface. Vesicles are bladders support the thallus allowing the growing apices to be exposed to the air and light.

The vesicles form in the alternating branches in a distinct bilateral manner. Receptacles are found on the terminal branches, the receptacles are where the reproductive structures develop. Each conceptacle contains Oogonia, Antheridia and Paraphyses. The Oogonia and Antheridia are the reproductive cells produced for the mature sex thallus both antheridia and oogonia are released into the water column where fertilization occurs. The fertilized egg then develops into a young germling. Ascophyllum nodosum has a linear ramifying plant thallus with dichotomous primary branching and pinnated lateral branches. Ascophyllum nodosum is a member of the subgenus Euascophyllum, which is characterized by the presence of receptacles.

1.4 Life cycle and sexuality

Ascophyllum nodosum is a member of the order Fucales. These are defined as growth form an apical root group. Ascophyllum comprehends very the seemingly endless genotypes are released and recombined in the gene pool. Ascophyllum is a member of the family Fucaceae, this family is characterized by the presence of air bladders, and the presence of a conceptacle with a pore. Rockweed is a dioecious species, meaning that it produces male and female gametes on different individuals. Ascophyllum is a member of the genus Ascophyllum, Ascophyllum nodosum is a linear ramifying plant with dichotomous primary branching and pinnated lateral branches. Ascophyllum nodosum is a member of the subgenus Euascophyllum, which is characterized by the presence of receptacles.

Rockweeds are inhabitants in both the inter-tidal and sub-tidal zones. Rockweeds are found in sheltered to exposed inter-tidal zones. The inter-tidal zone is the intertidal zone between the tidal marks, the inter-tidal zone is the area between the high and low tide marks, the inter-tidal zone is the area between the high and low tide marks

Harvesting Ascophyllum with sickles or cutter rakes yields 2-3 wet tons per individual per tide (4-6 hours). Capital investment is dependent on the size and type of vessel used for harvest and transport. A 3.5-ton capacity power-assisted dory can carry Canadian $15 000 in 1975 dollars. Most operations use a larger boat or barge for wet harvest transport, and a smaller dory for harvesting. Wet "cut" if anchored over 15 years (Sharp and Nash, 1976). To complete drying of the raw material a transport vehicle and a drying field are added to the costs (**Table 6**). The return to the harvester was approximately Canadian $20 000 per year in 1975 dollars (Sharp and Nash, 1976). Harvesting costs are lower if the harvester does not own the boat, but the return to the owner is correspondingly lower. Unfortunately, (**Table 7**) Exclusive of drying operations, labor and capital cost were Canadian $15 000 harvester per year, trying skilled Canadian $5 47 capital.

Mechanical harvesting increases the productivity per individual but greatly increases capital costs. The Aquamarine harvester harvests 2 to 3 t h⁻¹ but costs Canadian $70 000 per unit. An average yield of 12.5 per ton per year and 120 operational days per year was used to calculate operating costs (**Table 8 and 9**). These estimates are probably low because they do not include any labor cost for (**Table 9**). Operations in southwestern Nova Scotia requiring a tide vessel and 120 I capacity barge repair Canadian $20 000 capital costs, amortizable over 15 years with daily operational costs (maintenance, fuel and labor) equal to the harvesting employs 20 to 34% of the total costs, depending on the harvesting method (Table 9). Operations in the Norwegian harvester capital cost is approximately Canadian $138 000 but daily production is 50 t per unit. The harvesting operation does not require a barge or large tow vessel assuming the harvester can dump its load into a truck. The harvester requires maintenance capital and operating costs per ton is 8 $ 50 per ton. Transport overland costs are approximately the same as a cost similar to the two vessel and barge system.

Persons hand harvesting Ascophyllum use this activity as a 6% to 20% supplement to their annual income. Alternative income sources during the summer months are ground fish, fishing or processing, hunting fishing for lobster and clamming. Harvesting Ascophyllum with rakes and sickles is a family operation involving the entire family. Women are reported to assist in sorting them on either alternating tides or using the low tide period for Chondrus and rising or falling tides for Ascophyllum. The remainder of the year fishermen either capition or dedicated on a lobster fishing operation. Lobster fishing is a full time occupation requiring 1 man per 10 m boat and 1 man per 5 m boat. Lobster fishing is a full time occupation requiring 1 man per 10 m boat and 1 man per 5 m boat. Lobster fishermen are reported to earn Canadian $ 20 000 per year in 1975 dollars (Sharp and Nash, 1976). Average employment in lobster fishing or utilization of the Canadian unemployment insurance program compares 50 to 120% of employment income for these individuals. Family income in southwestern Nova Scotia averages Canadian $20,000 to $22,000; the male contributes 55 to 65% of this income (Raymond 1985). Primary industry including fishing and harvesting employs 26 to 34% of the total income.

Table 6. Capital and operating costs associated with hand harvesting of rockweed in Year 1, assuming that all equipment except holding nets and the collecting seine are shared with other fishers. Half the boat time nets would be used for at least 50 days per year (or costs were proportionally extended amortization over 10 years). A mean daily harvest of 5.4 metric tons per day was assumed for a three-man harvest crew. (Sharp and Nash 1976).

Item	Cost	Amortization Period (Years)	Cost/Year	Cost/Day of use in at (Daily cost for Rockweed)	Cost/Day of use in at (Daily cost for Rockweed)	Cost/Day of use in at (Daily cost for Rockweed)
a) Harvesting boat and barge	20,000	10	2,000	5.00	10	2,000	200	32.50
b) Winch, mast and boom	4,500	10	450	1.50	10	450	100	8.00
c) Dory or skiff	1,000	10	100		10	100	100	2.00
d) Harvesting rake	2,000	5	400	2.00	10	400	200	8.00
e) Harvesting sickle	1,000	5	200		10	200	200	4.00
f) Collecting seine(100 x 2m)	600	5	120		20	120	50	4.80
g) Truck (4 ton)	14,000	8	2,800	6.00	10	1,400	200	28.00
h) Drying field(0.2 ha)	1,250	20	63		10	125	100	1.88
Dairy Cost								63.38
Overhead metric ton								11.12
Cost exclusive of drying								10.69

Table 7. Labour costs associated with hand harvesting of rockweed assuming a desired return to the fisherman of $4.00 per hour and a daily harvest rate of 8.4 wet metric tons per day (Sharp and Nash 1976).

Activity (See Figure 1)	Crew size	Man-Hours Day	Labour Cost at $4.00 Hr	Labour Cost per wet metric ton ($)
Travel	(1)	2	8.00	1.90
Harvest	(2)	2	16.00	60.00
Return to yard	(3)	2	16.00	3.80
Unload travel	(4)	3	3.00	12.00
Stop	(5)	3	1.50	6.00
Unload Truck	(6)	4	1.50	6.00
Unload Truck	(7)	4	4.00	16.00
Stack Rockweed				
Collect and pack	(10)	4	6.00	24.00
Wet and pack	(11)			
Trailer			32.50	130.00
exclusive of drying				10.69

*Costs associated with drying

Table 8. Labour costs associated with mechanical harvesting assuming a desired return to the fisherman of $4.00 per hour and a daily harvest of 12.5 metric tons. All figures are estimates based on experience with other crops (Sharp and Nash 1976).

Activity (See Figure 1)	Crew size	Man-Hours Day	Labour Cost at $4.00 Hr	Labour Cost per wet metric ton ($)
a) Harvest boat & staff	2	2.00	8.00	1.28
b) Shuttle boat, tender	(1)	1	4.00	0.64
c) Shield) harvester	(2)	2	10.000	8.00
Harvesting	(3)	2	1.200	1.20
Unload truck	6.500	10	650	5.00
Unload	1,300	10	300	1
Stack and bagging	10,000	10	1,000	10
d) Tub Truck	16,000	5	2,800	6.00
Drying ground(1 ha)	8,000	20	1,200	10
Dairy Cost				
Overhead metric ton				
Exclusive of drying				

*Costs associated with drying operations

Table 9. Capital and operating costs associated with mechanical harvesting in Year 1 using the Aquamarine HM462 harvester. A harvest rate of 12.5 wet metric tons per day and sharing of boat and truck costs with other fishers are assumed. Harvest rate is based on estimated rates achieved by Scotia Marine in Nova Scotia (Sharp and Nash 1976).

	Gross Amort. Rate	Depreciation Period (Years)	Cost/Hourly Op. Cost	Cost/Day of use in at (Daily cost 2)	Cost/Day of use in at (Daily cost 2)	Cost/Day of use in at (Daily cost 2)	at 12 Sm.t.(day)
a) Harvest boat & staff	20,000	10	2,000	5.00	10	2,000	160.00
b) Shuttle boat, tender	4,500	10	450	1.50	10	450	36.00
c) (Shield) harvester	70,000	7	10,000	8.00	10	7,000	192.00
Harvesting	2,000	2	1,200	1	20	500	14.00
Unload truck	6,500	10	650	5.00	10	650	54.00
Unload	1,300	10	300	1	10	300	25.00
Stack and bagging gear	10,000	10	1,000	10	10	1,000	16.67
d) Tub Truck	16,000	5	2,800	6.00	10	1,400	200	34.00
Drying ground(1 ha)	8,000	20	1,200		10	600		15.00
Dairy Cost								15.00
Overhead metric ton								11.12
Exclusive of drying								20.37

*Costs of drying

6. AQUACULTURE

Until recently the aquaculture of macrophytes, such as Ascophyllum, which dominate the intertidal algal biomass of many North Atlantic shores was not considered economically viable. The desire to control composition of phycoloid and products has justified applied research on culture techniques.

A spray technique first developed by a University of Prince Edward Island for grow out of macrophytes has been further developed to grow Ascophyllum on draining surfaces (Rheault and Rufner, 1983). Spraying with unenriched seawater and pulse feeding of nutrients obtained 14.3 g m⁻² d⁻¹ Similar experiments with a multiple tier growing system and continuous addition of nutrients (Rheault, 1983) yielded 18.4 g m⁻² d⁻¹ Preliminary economic analysis indicates that the production of Ascophyllum at a cost of U.S. $1500 per dry ton (Rheault, 1983). Present costs of harvesting and delivering the factory product given Ascophyllum is approximately US $140 per dry ton (See Section 5.3).

7. PROTECTION AND MANAGEMENT OF THE RESOURCE

7.1 Regulations
7.2 Management

7.1 Regulations

Local physiologists recognized the problems of over harvesting Ascophyllum nodosum, as observed in Europe(were possible in the Maritime Province (C. MacFarlane, pers. comm.). Provincial governments enacted Sea Plants Harvesting Acts in response to the advice of seaweed experts. These regulations included harvesting gear restrictions requiring the use of cutting implements only to prevent harvesters from pulling plants out of the ground. Harvesters were also required to leave a specified amount of the plant.

The Sea Plants Act of Nova Scotia made provision for exclusive licenses for designated portions of the shoreline for up to 15 years. Licenses were granted to companies providing a monopoly for processing of the resource in return for commitments to provide employment and to develop the resource. The Act was repealed in 1975 because of the lack of compliance with the terms. In 1975 the Department of Fisheries and Oceans assumed responsibility for the management of Canada's seaweed resources. The Sea Plants Harvesting regulations for the Atlantic Coast Maritime Plants Regulations within the Fisheries Act. In 1985 the Atlantic Coast Marine Plant Regulations were incorporated in the Atlantic Fishery Regulations Part I (Appendix I). The regulations were not altered but provision was made for alteration of the harvesting season and setting of quotas. Part I (**Appendix I**).

There were two major changes in regulations from the Provincial Act. Marine Plant Harvesting Regulations (Nova Scotia) No 1-14 were established (**Fig. 1**) and licenses were personal and annually renewed. No exclusive privileges to the resource were provided and a fisherman's boat registration and general fisherman's license were required. Enforcement of regulations is the responsibility of the Department of Fisheries and Oceans. Operations Branch regional fisheries officers. All purchases of marine plants must be recorded on individual purchase slips for statistical reporting. Due to the difficulty of enforcing the regulations, harvesters are permitted to report total monthly landings by port to the Statistical Branch of Fisheries and Oceans Canada. In areas where less than 2 licenses are issued, the data is not made public.

As marine plants form a part of the fish habitat Section 31 of the Fisheries Acts of 1977 provides protection against disruption of the habitat. "No person shall carry on any work or undertaking that results in the harmful alteration/disruption or destruction of fish habitat".

7.2 Management

There are no additional restrictions/quotas/season or area of operations which require annual assessment of standing crop. The Research Branch of the Federal department of Fisheries has the mandate to maintain that biological information relevant to resource management.

Biologists are provided with species and regional representatives within the branch. Information relevant to management advice must pass thru a peer review process known as the Canadian Atlantic Fisheries Scientific Advisory Committee (CSAC) and thence as advice to upper level fisheries managers.

To communicate information to the industry/regional Marine Plant Advisory Committees were established including representatives of government, processors/buyers and harvesters. The biologist can present his advice to these committees and the committees can provide recommendations directly to the Minister of Fisheries via an area manager.

8. UTILIZATION

8.1 Chemical and nutritional content
8.2 Human food
8.3 Animal fodder
8.4 Fertilizer
8.5 Industrial products and processes

8.1 Chemical and nutritional content

The early industrial utilization of Ascophyllum nodosum required for practical purposes an analysis of its constituents. Baertsch (1970) recorded studies of a wide range of organic and inorganic substances in A. nodosum. Seasonal/geographical, and inter-thallus variations of water content, trace elements, alginates, and pigments were among the topics reviewed (**Table 10**). Since 1970, more detailed data on specific constituents were recorded and additional substances identified.

Pharmacological research continues to find potential in seaweeds. Fucoidan, as prepared from Ascophyllum, shows excellent metal binding abilities and binds lead most efficiently of the studied metal cations (Paderes-Mondoñedo et al. 1979). Ascophyllans are permitted to report total monthly landings by port to the Statistical Branch of Fisheries and Oceans Canada. In areas where less than 2 licenses are issued the data is not made public.

An antihypercholesterol activity of sterols in algae has led to studies of their content in Ascophyllum nodosum (Knights, 1970; Safe et al. 1974). Fucosterol comprises over 95% of the sterol content of Ascophyllum. Fucosterol has been found to be active against the cholesterol esterase of the pancreatic digestive system (Ikekawa et al. 1969). Fucosterol also accounts for over 90% of the sterols present in Fucus vesiculosus. Two other sterols of which sarcosterol was 6% (Safe et al. 1974). Hemostatic activity was found with solutions of powdered A. nodosum tested on human blood groups. No differences were found in hemagglutinic activity between thallus regions (Blunden et al. 1975).

Table 10. Average composition of Norwegian seaweed meal (Baardseth, 1970 from Jensen Nebb and Sverter 1966).

Component	Content	Component	Content
Moisture	12-15 %	Crude fibre	9 %
Ash	31-35 %	Crude protein	9-10 %
Alginic acid	20-26 %	Ether extract	2-4 %
Mannitol	2-4 %	Nitrogen free extr.	35 %
Laminarin	2- 3 %	N-free extractives	40-50 %
	2-3.5 %	Calcric value	0.36 (SPCHq)
	1 %	Phosphic acid	300-2000 mg/kg
Cl	3.1-4.4 %	Carotene	30-60 mg/kg
Na	3-4 %	Biotin	0.1-0.4 mg/kg
Mg	0.5-0.6 %	Folic acid	0.1-0.5 mg/kg
Fe	0.1 %	Folinic acid	0.1-0.5 mg/kg
	0.1-0.15 %	Choline	10-30 mg/kg
Cu	20-30 mg/kg	Niacin	15-25 mg/kg
CO	0-10 mg/kg	Tocopherole	150-300 mg/kg
Zn	150-1000 mg/kg	B12	0-004 mg/kg
Mn	30-80 mg/kg	Vit A	10 mg/kg
	250-1200 mg/kg		1.5- 3 mg/kg
Br	300-400 mg/kg	Vit D	0.3 mg/kg
Mo	0.3- 1 mg/kg	Biotin	15-50 mg/kg

1 SPU = Scandinavian feed units
Algnic acid 100-1000 mg/kg N-free extractives 500-2000 mg/kg

Vitamin content of Ascophyllum nodosum was extensively investigated by Baardseth (1970). However, several concurrent papers were not included in the synopsis. Tocopherol (Vitamin E) content and its variation with individual diurnal, and seasonal changes(were investigated after a rapid and sensitive analytical technique was developed (Jensen, 1969a). Total tocopherol was maximal in September and Febrary and lowest in April during the study period (1966). Proportions of tocopherols varied with immersion and extension periods. Optimally grown plants contained twice as much tocopherol than older portions of the plant (Jensen cpp. cit.). Choline is one of the B-complex vitamins which is included in commercial feeds. The choline content of A. nodosum was 0.9 to 3.2 mg/g dry weight over one year period. Highest choline content occurred in winter and spring. Shipping in June, July, and August (DeSilva and Jensen, 1973).

Anti-microbial compounds were detected in Ascophyllum nodosum as early as 1954 (Hecht and Walsh1954). Recent studies have found summer antimicrobial activity but none in spring or winter (Ramsey and Nash 1975). This could be further tested for post-harvest sampling in any study of chemical constituents.

Several recent studies of Ascophyllum nodosum chemical composition relate directly to an overall metabolic strategy within its geographical and zonal ranges. Amino acid composition was found to vary with tissue and season (Black, 1950). The amino acid composition was compared with lower satellites. This change was attributed directly to the increasing presence of algal mass and which is a key amino acid in the synthesis of protein (Black 1950).

Exposure and season were found to have the greatest combination with cationic value of Ascophyllum nodosum ferrates (Bricker-Provencher1976). Material cationic values vary in proof in the period of maximum growth. The ferrate complex is a complex of Ascophyllum nodosum and Fucus vesiculosus where A. nodosum dominated the complex.

Growth hormones were extensively investigated in higher plants and have only recently been examined in detail for algae. G.L.C. analysis of water soluble components from Ascophyllum nodosum found cytokinins were present in abscisic acid. These compounds were found in growth of lettuce hypocotyl sections. Auxin-like substances were also detected. Auxin-like substances were found in A. nodosum extracts using a bio-assay system (Kingman and Senn, 1971). A seasonal survey of gibberellin activity in three fucoids showed a maximum activity of extracts occurred in October for A. nodosum and a minimum of activity in January (Willingham et al. 1976).

Descriptions of alginate structure and its composition in a variety of algal species has been ongoing since 1970. The sequences of uronic acid, building blocks of alginate, were described for Laminaria digitata (Haug et al. 1967). Alginate from Ascophyllum nodosum was found to be composed of 30% mannuronic and 70% guluronic acid. Alternating sequences of both acids are given by Haug and Smidsrød (1967). Therefore, any differences in composition of alginates occurred in older portions of the plants (Jensen et al. 1969). Other polysaccharides were isolated from A. nodosum and their structure elucidated. Fucoidan was isolated and described as a sulphated glucuronomannofucan, existing as a building block of the complex macromolecule (Larsen et al 1970).

Concern for the effects of hydrocarbon spills in our coastal environment lead to an assessment of natural hydrocarbon background levels in various benthic algae (Youngblood et al. 1971). N-paraffasane predominates in Ascophyllum nodosum and other tested brown algae. Polyunsaturated hydrocarbons occur only in the reproductive leaves of A. nodosum.

8.2 Human food

Ascophyllum nodosum is not normally used directly as a foodstuff but may appear as a constituent of health food tablets. The polysaccharide algin extracted from Ascophyllum as algenic acid is used as a food additive in many products. Algenic acid is used in food as a stabilizer, a thickener, a gelling agent, a film former, a suspension agent and a protective colloid in food and other products. Ascophyllum nodosum algenic acid is composed of 60% mannuronic and 35% guluronic acid the ratio of these components can range between 1.40 and 1.95 (Cottrell and Kovacs, 1980). Common food uses for alginates include prepared pie fillings, instant mixes and sauces.

8.3 Animal fodder

Ascophyllum nodosum is used as a stock feed additive. It may make up to 5% of the diet for poultry, sheep, cattle, pigs and horses. The trace element and vitamin components of Ascophyllum meal are the active ingredients for growth of cattle, milk production, colon in eggs and improving wool color in sheep (Nedd and Jensen 1966). Canada has imported seaweed meal for use as a fodder supplement. Agricultural conditions near the sea have allowed farm animals access to storm tossed seaweed.

8.4 Fertilizer

The use of fresh Ascophyllum as a soil conditioner, source of trace elements and general growth stimulant began in the earliest settlements of Maritime Canada. European settlers brought this custom from centuries of use in Europe. Liquid seaweed extracts developed since 1950 and website powders are used as in foliar sprays. Extracts have proven chelating properties that improve the utilization of minerals by plants. The application of extracts to seeds increases germination and early growth (Britton and Nunes, 1984). Acum and glycerolate the activities are reported for seaweed extracts but the results are conflicting. Soluble powders as foliar sprays increased protein content of soybeans, smaller solids in tomatoes and yield of Southern pea (Anron, 1978).

A liquid extract of Nova Scotian Ascophyllum was produced in Yarmouth by Argosy Seaweeds Ltd., but commercial production did not follow.

8.5 Industrial products and processes

Sodium alginate is used as a part of a sizing solution for linen dowell. Alginate enhances penetration of adhesives, acts as a dye carrier in the reactive dyes. Its gelling properties are used in air conditioning systems and in the dyeing of wool. Alginate is used in the printing of cotton fabrics. Alginate is used in the manufacture of rayon, in paper, in ceramics, welding rods and cleaners. The industrial processing of Ascophyllum nodosum includes alginate. Alginate is also in addition to those shown in (**Fig. 16**) to prevent contraction of the final product.

Figure 16. Flow chart describing major steps in the manufacture of alginic acid (Cottrell and Kovacs, 1980).

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APPENDIX I EXCERPTS FROM: MARINE PLANTS/ATLANTIC FISHERY REGULATIONS

PART I GENERAL

Variation of Close Times and Quotas

4. A Regional Director-General may, by order, vary any close time or fishing quota fixed by these Regulations

5. Where, pursuant to Section 4, a Regional Director-General varies a close time or a fishing quota, he shall, by one or more of the following methods, give notice of the variation to the persons affected or likely to be affected by the variation:

SCHEDULE XXVI
(s.38,and 80)

MARINE PLANT HARVESTING DISTRICTS AND CLOSE TIMES*

Item	Column 1 Harvesting Districts	Column II. Period
1	District 1. Waters adjacent to the east shore of Prince Edward Island between West Point, Prince County and North Point, Prince County	November 1 to June 30
2	District 2. Waters adjacent to the north shore of Prince Edward Island between North Point, Prince County, and the

Chondrus crispus Stackhouse[1]

1. IDENTITY
2. DISTRIBUTION, ECOLOGY AND METABOLISM
3. LIFE HISTORY
4. PHYSIOLOGY, BIOCHEMISTRY AND GENETICS
5. PRODUCTIVITY OF THE RESOURCE
6. ECOLOGICAL IMPACT OF HARVESTING AND CULTIVATION
7. ASSESSMENT AND STATISTICAL ANALYSIS OF DATA
8. ACKNOWLEDGEMENTS AND ADDRESSES
9. REFERENCES
10. APPENDICES
11. APPENDIX 1. Some references to the seaweeds in Nova Scotia Atlantic Canada Archives

Nova Scotia Centre for the Non-Vascular Marine Plants Nova Scotia Marine Fishery Committee

Nova Scotia Department of Fisheries

Nova Scotia Centre for the Non-Vascular Marine Plants Nova Scotia Marine Fishery Committee

Nova Scotia Department of Fisheries

Nova Scotia Centre for the Non-Vascular Marine Plants Nova Scotia Marine Fishery Committee

Nova Scotia Department of Fisheries

Nova Scotia Research Foundation Corporation Nova Scotia Agricultural Experiment Station and Jackson Estuarine Laboratory Contribution Number 187

Jean D. Hughes
Curatorial Assistant and Nova Scotia Division
Nova Scotia Museum
Fisheries and Ocean Canada
Bedford Institute of Oceanography
Dartmouth, Nova Scotia

and

Arthur C. Mathieson
Professor of Botany and Plant Pathology and the
Jackson Estuarine Laboratory
University of New Hampshire
Durham, New Hampshire USA 03824

ABSTRACT

The Irish Moss species *Chondrus crispus* Stackhouse (Fig. 1), which is referred to as *Chondrus* from now on, "means" in the text, is a key species in western and northeastern Atlantic and provincial Canadian marine ecosystems. It is also a key species in the Canadian seaweed industry. Its life history is complex and its ecological and physiological responses to its environment are discussed.

The already increase in carrageenan demand in the 1960's led to a concern about future sources of raw material. The Canadian federal government, through the National Research Council's Atlantic Regional Laboratory, initiated a study of the species in 1970. The Nova Scotia Department of Fisheries established a marine plant section in 1972 and began a study of the species and its fishery. Cultivation of *Chondrus* was initiated in Canada in the mid-1970's. Nova Scotia's 1981 "Chondrus" cultivation survey found about 2 cultivation sites, 1 in Nova Scotia and 1 in New Brunswick, producing about 1 tonne of dry *Chondrus*. Nova Scotia's 1991 "Chondrus" cultivation survey found 12 cultivation sites, 11 in Nova Scotia and 1 in New Brunswick, producing about 12 tonnes of dry *Chondrus*. Nova Scotia's 1991 "Chondrus" cultivation survey also found that two sites were cultivated from sporophyte discharged gametes, a novelty that facility was expected but was not yet observed in the wild. Nova Scotia's 1991 "Chondrus" cultivation survey also found that two sites were cultivated from sporophyte discharged gametes, a novelty that facility was expected but was not yet observed in the wild.

Dr. Gordon Mitchell
Nova Scotia Marine Ecology Section
Department of Fisheries
Dr. P. Fredel Dennis, Marine Regional Laboratory, Oxford Street, Halifax, N.S.

1.1 Taxonomy

Chondrus crispus Stackhouse belongs to the division Rhodophyta, class Florideophyceae, order Gigartinales and family Gigartinaceae (Kraft and Vroman, 1981). Stackhouse (1797) established the genus *Chondrus* and described the species *C. crispus*. Stackhouse (1797) also described the genus *Mastocarpus* and the species *M. stellatus*. Stackhouse (1797) described the genus *Gigartina* and the species *G. mamillosa*. Stackhouse (1797) described the genus *Iridaea* and the species *I. edulis*. Stackhouse (1797) described the genus *Phyllophora* and the species *P. membranifolia*. Stackhouse (1797) described the genus *Ceramium* and the species *C. rubrum*. Stackhouse (1797) described the genus *Polyides* and the species *P. rotundus

5.7 Stocking stock and yield

Timber commercially dispersed their new seedlings from their nurseries beginning in 1960 based on distribution of commercial effort (through and through). Field season of home stand (May 20) underlies the stocking stock and yield. Stocking stock and yield. Stocking stock and yield.

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APPENDIX I: Terms of reference for the southwestern Nova Scotia Marine Plants Advisory Committee Committee

1. Purpose and Objective

The South West Nova Scotia Advisory Committee will serve as a forum for discussion and consultation among those sectors of the industry and provincial governments having an active interest in the fishery and the Federal Department of Fisheries and Oceans. The Committee shall provide advice and recommendations to the Department's Regional Director-General, through the prescribed reporting relationship, on all policies pertaining to conservation, utilization and enhancement of the marine plants resource.

2. Duties and Responsibilities

The Committee will be responsible for reviewing and offering comment, advice or recommendations on the following:

(a) The establishment of policies to enable implementation or better use of management measures, including examination of guidelines relating to such matters as seasons, closed areas, fishing methods and licensing for the local marine plant fishery;

(b) The establishment of regulations to ensure sufficient conservation and best utilization for its harvest, as well as methods to enable adequate enforcement for such regulations; and

(c) Review the necessity for development programs, including examination of environmental, biological, technical and economic considerations

3. Membership

Meeting on behalf of the Regional Director-General, the Department's Area Manager in the Southwestern Nova Scotia area will be the Chairman of that Committee. Representation will be drawn from all sectors dependent upon the marine plank resource. Membership shall normally be limited to a maximum of sixteen. The Committee will draw representation from among the following:

- Commercial fishermen/harvester
- Processors
- Provincial government
- Federal government

4. Technical Expertise

As required, the Committee may draw upon the expertise of the Department's biologists, engineers, economists or other scientific and professional advisors, and may request that these individuals attend meetings for specific purposes.

The production and use of Euchorne

1. IDENTITY
2. HABITAT
3. ECOLOGY, BIOLOGY AND PHENOLOGY
4. DISTRIBUTION, ECOLOGY AND HABITATS
5. PRODUCTION AND MANAGEMENT
6. PROTECTION AND MANAGEMENT OF THE RESOURCE
7. EQUIPMENT USED FOR HARVESTING AND CULTURE OF EUCHORNIA
8. ECONOMICS
9. MARKETS
10. REFERENCES

Bennett A. Holy
Department of Biology
Kansas State University
Manhattan, Kansas

ABSTRACT

Euchornia is a genus of Euchornia (Family Euchornia) in the Euchornia Family (Euchornia). Euchornia is a large genus of Euchornia, with many species being cultivated for their ornamental value. Euchornia is a genus of Euchornia (Family Euchornia) in the Euchornia Family (Euchornia).

communication) often the traditionally recognized village leader who gets the artisanal fishermen to collect seaweed, often a given or traditional amount. The village leader accumulates the seaweed and sells or barters it to the entrepreneur or trader, who will probably be but a representative of a traditional exporter. In a money-economy situation the village leader, the trader and the exporter may be considered second level interests. The third level interests, the processors, establish commercial relationships which are often agreements to buy a certain tonnage within certain time/quality limits "free and on board" a ship bound for the port nearest the processor's plant.

Table 9. Fish and Turtle Exclosure Fences and Trap Costs. The list of materials is for a square one acre farm ca 210 feet on a side in an area where the tides may rise as high as two meters. Values are in 1982 Malaysian dollars.

Item & Description	Number needed	Length needed	Weight needed	Amount in M$
A. For fencing:				
1) Mangrove posts	148	12 ft. long & 2 " diam.		44.40
2) Stranded fish net Twine: PE. 380/6 Mesh: 2 1/4" Width: 300 cm Length: 150 ft./roll	3 rolls	880.6 ft.		750.00
3) Border-line for stranded fish net, 150 ft test.			2 kilos	24.00
4) Wire for securing fish net to posts, 16 inches long	444 pcs.	592 ft.		20.00
5) For turtle net, 2.5 x 5 meters in standard net units	60 pcs.	946 ft. or 288.5m.	5 kilos	228.00
6) Mangrove posts for turtle net fencing	60 pcs.	12 ft. by 2" in diam.		20.00
7) Wire for securing turtle nets to posts, wire pieces 16" long.	174 pcs.	232 ft.		8.00
B. Two fish traps:				
1) Mangrove stakes, 3 meters long by 2 1/2 " in diam.	8 pcs.	10 ft.		2.40
2) Mangrove stakes, 2.5 meters by 2 1/2" in diam.	8 pcs.	9 ft.		2.40
3) Many mangrove stakes, 1 meter by 2 1/2" in diam.	8 pcs.	4 ft.		1.20
4) Stranded fish net: Twine: PE. 380/6 Mesh: 1 1/4" Depth: 300 cm		32 ft.		7.00
C. Total fencing & trap material costs				1,107.40[E]

[a]In 1985 this was **equivalent** to **about** U.S.$480.

8.1.2 Government roles

Two governmental groups are often the official bodies of concern: economic development authorities and the fisheries departments (often) of the agriculture department. They usually arise after-the-fact due to their lack of entrepreneurial and phycological capability as well as incentive, the need to heed the wishes of the politico/economic interests and their traditional fin/shellfish concerns.

The private sector has been the initiator (Doty 1973b; Adnan & Porse In Mss) and has been initially in control of the first two levels in almost all successful production areas: e.g., to the extent that there is production in Indonesia, Philippines, Taiwan and Tanzania. In Indonesia the Agency for the Assessment and Application of Technology and in Kiribati and Malaysia the fisheries departments have been very positively active in seeking to establish farming.

In the Philippines the national fisheries department research section played an unusually successful role by coordinating and contributing its facilities to the expatriate academic and processing interests of industry at the initial development level of both the wild crop harvesting and later the R & D leading to pre-eminence of the Philippines in both cottonii and spinosum farming.

There are no effective formal mechanisms for consultation between the levels of concern in the Eucheuma industry.

There are essentially no regulations effectively governing the harvesting/culture of Eucheuma. What arrangements exist for leasing or private ownership of nearshore or intertidal areas for this purpose have been ineffective or have been applied at the initiative of local fisheries officers and the private sector by what might be called field expediency. In southermmost Philippines, village councils have shouldered the responsibility for individual farmer concessions under the umbrella protection of master concessions from the government obtained by the processors. In some other places government participation in efforts to "facilitate" farmer leasing have been as much a barrier to success as an aid.

The concession plans in Indonesia and Malaysia; at least, were established so as to leave passageways for local boat traffic. On reef flats there is no conflict with fisheries useage or with ocean navigation. The farms result in enhanced fish crops, and fish traps and Eucheuma farms do not compete for the same space.

8.2 Regulation of seaweed

To date no specific legislation is known that affects Eucheuma farming. In Hawaii it has been effectively prevented in the past by the classification of all sub-tidal land as conservation, a designation that prevents its economic development. This situation in Hawaii is changing favorably through new legislation. In the Philippines legislative and executive bodies have considered legislation and various regulations, but these have not been effected. Regulations have been instituted to obtain advantages for individuals, but they are ineffective and largely ignored. Notably in one African country a monopoly has resulted in no development of farming and apparently no increase in export during the past 20 years. In two other countries government has entrusted development to innocent hands that despite goodwill have been unable to move to the economic export level. In some others nothing has happened. Only in those countries where there was no contrary legislation and the ultimate processing companies from abroad have sent in expatriate management has introduction led to farming and regular export.

9. UTILIZATION

9.1 Chemical and nutritional content
9.2 Human food
9.4 Animal Fodder
9.5 Manure
9.6 Industrial products and processes

9.1 Chemical and nutritional content

Industry's only concern for Eucheuma is its carrageenans. Carrageenan is a cell wall component which represents 40 to 75 percent of the seaweed's salt-free dry weight. In addition to carrageenan the cell walls of a Eucheuma contain a small amount of cellulose and minor amounts of other unspecified materials.

Eucheuma reaches the ultimate consumer as whole or particulated, dried material in one of several forms. Commonly the carrageenan may be extracted carrageenan (with or without chemical modification) or in the non-extracted modified form.

Basically carrageenans are d-galactopyranoses alternately paired by alpha 1-3 and beta 1-4 linkages. Their molecular weights may be as high as 400,000. They are typically sulfated though sulfate is lacking (Greer & Yaphe 1984) in beta carrageenan. Seven types are recognized and referred to by the greek letters, beta, gamma, kappa, lambda, iota, mu and nu. Infra-red absorption peaks are present for total sulfate and, respectively, that at any of the 2, 4 or 6 positions. In addition, the different carrageenans are distinguished by their solubilities in water at different temperatures (Greer & Yaphe 1984) and reactions to different salt solutions as well as the physico-chemical properties of their gels. At present there is considerable question as to their structure, e.g., whether they are purely one or another of the seven types listed above or whether there are blocks of one type in combination with blocks of other types. Relatively low sulfate content and 3-6 anhydro linkages are found to be related to high gel strengths. Milk reactivity and gel strength may be related to potassium and sulfate, respectively, at the 4-carbon positions. Various other radicals may be attached especially at 6-carbon positions.

The nutritional value of Eucheuma and its contained carrageenan are unknown. Its effect on humans is believed to be nil and, in foods containing it, the carrageenans are minor components by weight, though often indispensable for contributing a specific quality to the product.

9.2 Human food

Culinarily speaking, Eucheuma, the fresh or non-dried seaweed itself, adds delightful variety, novelty, and bulk to peoples' diets in various countries where it grows, e.g., as a fresh salad component or as pickles.

The extracted carrageenans provide stabilization and quality to the products in which they are combined. Today, many instant foods that come in powdered form for mixing with cold milk to make them cornestitde owe their speed and permanence of suspension to the carrageenan modification they contain. A desirable mouth feel is sometimes obtained by adding a carrageenan. Some major toothpastes contain it for its way of holding water in the product and, thus, extending shelf life. The successful suspension of chocolate in milk is perhaps best done with carrageenan. Most if not all evaporated milk nowadays contains carrageenan as the component that makes possible its pleasant flavor and thick, creamy quality.

Aside from "extracted carrageenan", there is the alkali-treated Eucheuma (sometimes spoken of as AMF or AMC, i.e., alkali modified flour or alkali modified carrageenan or semi-processed carrageenan). Making alkali-treated Eucheuma seems to consume most of the cottonii Eucheuma produced, for it is far less expensive than extracted carrageenan. It can usually substitute for extracted carrageenan where a little cloudiness from the small percentage of cellulose present does not interfere.

Both the alkali-modified Eucheuma products and the extracted carrageenans must compete with other hydrocolloids on the basis of amount required to do the job and cost per pound. An outstanding exception is their special effect in some milk products wherein carrageenan is often essential or nearly so. Carrageenans form synergistically desirable substances with other hydrocolloids and are chemically modifiable in many ways, giving them a wide variety of useful special qualities. Guiseley et al. (1980), Whistler & BeMiller (1973) and Glicksman (1969, 1982) provide four of the most useful treatises on applications of the different carrageenans and their modifications.

9.4 Animal Fodder

The carrageenans and Eucheuma are not normally used in animal fodder. However, the largest volume of alkali-treated Eucheuma is in pet foods where it is used as a powdered, granulated or hydrated gel component in the various formulations.

9.5 Manure

Eucheuma has essentially no use as a manure. Though its addition as an organic component in conditioning sandy soils is in some cases attractive, the cost is high. Some effort has been put forth to obtain use of the filter aid waste from the carrageenan extraction plants as a soil conditioner. Such waste filter aid is the major nonsoluble product from Eucheuma processing

9.6 Industrial products and processes

The carrageenans extracted from Eucheuma are modified by proprietary methods and even the relatively simple alkali-treatment process is hardly publicized. The assayed plant yields of extracted carrageenan may vary (Adnan & Porse In Mss) from 23 to 36 percent. A simple diagrammatic flow sheet is provided **(Figure 9)** though it is hardly applicable to any one actual alkali-modification plant.

The carrageenan extraction process itself is well known to be a hot water, high pH, process. The principal costs are in heat and separating the carrageenan from the extraction water. Three approaches are in use for water removal after centrifugation, filtering and sometimes vacuum removal of some water: a) spray drying on steam-heated drums as in the making of powdered milk; b) cold-water extraction of the seaweed (when Chondrus is the source) such that the lambda carrageenan is separated from the kappa, with the kappa being extracted and precipitated separately later; and c) precipitation with alcohol. Each process has its merits, and some large companies use more than one method to obtain different qualities in their final products. Moss & Doty (In Press) provide a flow sheet **(Figure 10)** for the latter plant type.

Aside from the raw seaweed material, the principal costs of carrageenan (Moss & Doty, In Press) are in inventory, warehousing, water, power, alcohol recovery (only in alcohol precipitation plants), filter aid (diatomite or expanded mica as a rule) and chemicals (largely calcium and potassium hydroxides).

Figure 9. The alkali-treatment process for cottonii. Depending upon end product specifications, live or dried cottonii with or without preliminary treatment is often treated first in a hot alkali solution containing about 8.5 percent potassium hydroxide and then rinsed in successive tanks of water. The seaweed may be handled in baskets by an overhead traveling crane. Following a final draining, the treated material may be dried whole, or chopped and dried. The lower part of the figure shows a succession of processing steps that may follow depending on control laboratory analysis and desired nature of the final product

Figure 10. The alcohol process for carrageenan extraction with addition of ancillary space requirements. (From Moss & Doty In Press.)

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The wild harvest and culture of Lamiraria longicauda in Eastern Canada

1. ABSTRACT
2. LIFE HISTORY, ECOLOGY AND METABOLISM
2.1 Life history
2.2 Ecology and metabolism
3. PRODUCTIVITY OF THE RESOURCE
3.1 Standing Stocks and Harvestable Yields
3.2 Physical and biotic factors affecting productivity, growth and mortality
4. POPULATION STRUCTURE AND MORTALITY
4.1 Gear, stock and size composition
4.2 Spatial and temporal size composition
5. Age, growth and size composition
6. POPULATION STRUCTURE AND MORTALITY
6.1 Gear, stock and size composition
6.2 Spatial and temporal size composition
7. Age, growth and size composition
8. ACKNOWLEDGEMENTS
9. REFERENCES
10. TABLES
11. FIGURES

D.A. Chapman
Department of Biology
University of Ottawa
Ottawa, Ontario, Canada
K1N 6N5

ABSTRACT

Lamiraria longicauda has increased as a source of algaeas through the 1990s. Heat stressed zone (HSZ) Stable State. Given that the species has been so productive for human consumption and is a great nuisance to divers in the HSZ, it would be worthwhile to consider how this species could be managed for both human consumption and ecosystem maintenance.

1. LIFE HISTORY

1.1 Life history and reproduction

The species Ascophyllum nodosum is a source of algaeas through the 1990s. Heat stressed zone (HSZ) Stable State. Given that the species has been so productive for human consumption and is a great nuisance to divers in the HSZ, it would be worthwhile to consider how this species could be managed for both human consumption and ecosystem maintenance.

1.2 Ecology and Biology

The morphological and anatomical terms for the sporophytes of Lamiraria longicauda are shown in Figure 1. The species has a very short stipe (< 5 cm) blades up to 1 m in length have been recruited from beds depth of the southeastern shore of Newfoundland (Chapman 1975). Lamiraria longicauda is a perennial species with a life span of up to 5.5 years (Chapman 1975; Sjøtun, 1993).

Figure 1. Morphological Terms used for Lamiraria longicauda (modified after Sjøtun, 1993, 1995).

The proportion of Lamiraria longicauda is based the numbers of the plants as described by Polykin (1968). The species has been the index of abundance for the previous analysis. The only aspect of Lamiraria longicauda that has been studied in detail is its life history (Sjøtun, 1993, 1995). Lamiraria longicauda is a perennial species with a life span of up to 5.5 years (Chapman 1975; Sjøtun, 1993). The blades are shed every year (Sjøtun, 1993). The species has been the index of abundance for the previous analysis. The only aspect of Lamiraria longicauda that has been studied in detail is its life history (Sjøtun, 1993, 1995).

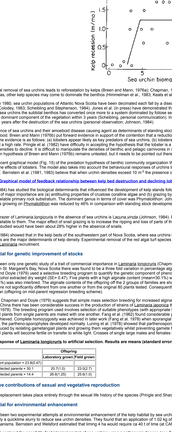
2. DISTRIBUTION, ECOLOGY AND METABOLISM

2.1 Geographical range

Since Wilkins (1969) gave the biogeographical range of Lamiraria longicauda as the Northwest Atlantic and some records in the Northwest Pacific, the species has been recorded in the Northwest Atlantic (Sjøtun, 1993; Chapman, 1975; 1979; 1979; 1979; 1980; 1979; Lindstrøm, 1979; 1980; Sjøtun et al., 1995). In spite of this, the species is deemed as a sequoiaide while is the most western characterized species sequoiaide of western Canada (Chapman 1975; Sjøtun, 1993; Sjøtun et al., 1995). Lamiraria longicauda is a perennial species with a life span of up to 5.5 years (Chapman 1975; Sjøtun, 1993). The species has been the index of abundance for the previous analysis. The only aspect of Lamiraria longicauda that has been studied in detail is its life history (Sjøtun, 1993,

The relationship between the kelp biomass and sea urchin biomass was examined by Breen and Mann (1976a). The destruction of kelp appeared to be a threshold event (**Fig. 14**). Above a biomass of about 2 kg/ m² sea urchins were able to effect kelp bed recession. Below this threshold kelp bed recession did not occur. However, once kelp had been removed, reforestation was prevented at urchin densities of only 1/4 m².

Figure 14. Relationship between the rate at which a kelp bed receded and the biomass of sea urchins. Curve fitted by eye (after Breen and Mann, 1976).



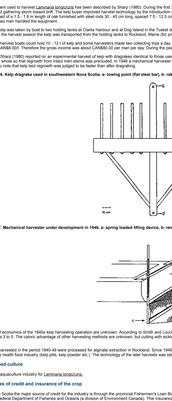
Experimental removal of sea urchins leads to reforestation by kelps (Breen and Mann, 1976a); Chapman, 1981). When Laminaria longicruris is rare in areas adjacent to experimental sea urchin barrens, it does not grow into areas from which sea urchins have been removed (Chapman et al., 1983; Keats et al., 1984).

Beginning in 1980, sea urchin populations of Atlantic Nova Scotia have been decimated each fall by a disease that has led to the loss of >99% of their biomass over nearly 1000 km of coastline (Scheibling and Hennigar, 1980; Scheibling, Lauzon and Donnalley, 1986; Scheibling and Stephenson, 1984; Scheibling, Hennigar and Lauzon, 1986). Subsequently, in the absence of sea urchins the subtidal benthos has converted once more to a system dominated by folose seaweeds (Johnson, 1984). As sites exposed to strong wave action Laminaria longicruris became the dominant component of the vegetation within 3 years (Scheibling, personal communication). In sheltered sites the benthos remains dominated by diminutive species of fleshy seaweeds more than 4 years after the destruction of the sea urchins (personal observation: Johnson, 1984).

The importance of sea urchins and their amoebiod disease causing agent as determinants of standing stocks of kelps is self evident. The reasons for the expansion of urchin populations are less clear. Scheibling (1980) and Lauzon (1984) have shown that the disease causing agent is density dependent and that epizootics occur only at relatively high sea urchin densities. The evidence is as follows: (a) biomass appears to be greater in areas of sea urchins, (b) biomass has declined in abundance and (c) sea urchins have increased in number and developed kelp beds at a high rate. Pringle et al. (1982) have difficulty in accepting the hypothesis that the biomass is a keystone predator of the kelp bed ecosystem and that overfishing of lobsters has caused the observed increase in sea urchin biomass. Although lobsters do prey on sea urchins, they do not appear to be the principal predator of the sea urchin at lower lobster levels. In this respect the predation hypothesis of Breen and Mann (1976b) remains untested, but it needs to be pointed out that there is no evidence in support of its rejection.

In a more recent graphical model (Fig. 15) of the predation hypothesis of benthic community organization Wharton and Mann (1981) have incorporated the effects of fishtoh (plaice, wolfish etc.) along with the effects of lobsters. The model also takes into account the behavioural responses of urchins to the presence of predators. The model predicts that destruction of the sea urchin population occurs at ¼ kg m². Bernstein et al. (1981, 1983) believe that when urchin densities exceed 10 m² the presence of lobsters leads to the formation of aggregations which can overgraze kelp beds.

Figure 15. Diagrammatic representation of the predation relationship between kelp bed predators and declining lobster stocks in the northeast Atlantic (after Wharton and Mann, 1981).



Johnson (1984) has studied the biological determinants that influenced the development of kelp stands following the disappearance of sea urchin populations in St. Margaret's Bay. The interaction of algal recruitment and growth was an attributing proportion of urchin survival against algal grazing by the gastropod Lacuna vincta. As of 2 sites in St. Margaret's Bay invasion coulmes covered >50% of available primary rock substratum. The dominant genus in terms of cover was Phyllophoridin. Johnson (1984) was able to demonstrate experimentally that the standing stock development of Laminaria longicruris was reduced by 66% in comparison with standing stock development in the absence of L. vincta. The enclosing effect was not species specific, all seaweeds were equally affected.

The major grazer of Laminaria longicruris in the absence of sea urchins is Lacuna vincta (Johnson, 1984). Between February and September of 1980 the snails consumed only 0.05% of the biode by the bed but in the absence of sea urchins they consumed 30% of the standing crop and loss of plants. Kelp bed recession (Johnson (1984) estimated that the standing biomass of L. longicruris in the bed had decreased by 50% in the absence of snails.

Chapman (1984) showed that in the kelp beds of the southwestern part of Nova Scotia, where sea urchins have never been recorded in high densities, interactions with perennial turf-forming red algal species are the most important factor in determining the rate of recruitment and growth of the red alga turf species (mostly Chondrus crispus, Phyllophora brodiaei and Ceramium rubrum) led to a ten fold increase in Laminaria recruitment.

3.3 Potential for genetic improvement of stocks

There has been only one genetic study of a trait of commercial importance in Laminaria longicruris (Chapman and Dunk, 1979). Within a sample of 80 sporophyte plants collected from a single population in St. Margaret's Bay, Nova Scotia there was found to be a three fold variation in percentage dessication of dry weight. Algae is a structural cell wall polysaccharide of commercial value. Chapman and Dunk (1979) used a selective breeding program to quantify the genetic component of phenotypic variance in alginate content. The mean alginate content of the 80 plants tested was 29.8% dry weight with a range of 19.5% to 58.5% dry weight. The heritability of alginate content was 0.42 ± 0.08 (S.E.) and the genetic correlation between alginate content and blade length (Table 6 of Chapman and Dunk) was 0.64 ± 0.14 (S.E.). The alginate contents of the offspring after 2 groups of families are shown in **Table 7**. After 6 months growth in the sea the alginate content of the two groups of offspring were not significantly different from one another or from the original 80 plants tested. Consequently the realized heritability values are very low. This result was confirmed in a separate breeding pair (offspring-on-parent regression breeding scheme).

The work of Chapman and Dunk (1979) suggests that simple mass selection breeding for increased alginate content is unlikely to work. It should be pointed out, however, that in the People's Republic of China, Laminaria japonica has been selected for increased iodine content (Chapman and Chapman, 1980; Chapman et al., 1980; Chapman et al., 1981; Fang et al., 1979). The breeding program used involves selection of suitable phenotypes (with appropriate temperature tolerance, growth rates, etc.) followed by clonexe interesting in which the gametangial plants from single parents are mated with one another. Fang et al. (1982) found considerable phenotypic variability within inbred lines indicating that a high degree of homozygosity had not been achieved after inbreeding for 3 generations. Fang et al. (1982) also found that the gametophyte generation of Laminaria japonica is haploid and not diploid as in Laminaria longicruris. Surprisingly, the partenogenic sporophyte developed normally. Luning et al. (1978) showed that partenogenetic sp. L. longicruris were extremely stunted. However complete homozygosis lines can be produced by isolating gametangial plants and growing them vegetatively without preventing gamete formation through the use of red light (Luning and Dring, 1979). Large filamentous gametangial plants of Laminaria form fertile or transfer to white light. Crosses of single large males and female lines in this way will lead to the production of hundreds of genetically identical offspring.

Table 7. Response of Laminaria longicruris to artificial selection. Results are means (standard errors) for % alginate of alcohol extracted dry weight.

	Offspring	
	Offspring parent [Female parent]	
Mean of parent population ± (S.E.)	29.8 (0.4)	
Mean of 2 selected parents ± (S.E.)	25.7(1.0)	23.9(2.7)
Mean of 2 selected parents ± (S.E.)	25.8(1.25)	25.6(1.5)

3.4 Relative contributions of sexual and vegetative reproduction

Population replacement takes place entirely through the sexual life history of the species (Pringle and Sharp, 1980; Chapman, 1984).

3.5 Potential for environmental enhancement

There have been two experimental attempts at environmental enhancement of the kelp habitat by sea urchin removal (Bernstein and Welsford, 1982; Miller, 1983). Bernstein and Welsford used a diver to apply a lime slurry to reduce sea urchin densities. They found that an application of 1 kg of lime/ m² resulted in a 75% reduction in urchin densities. There were no apparent ill effects on other organisms. Bernstein and Welsford estimated that bring 4 ha would require ca 40 t of lime (at CAN$600) and 60 man days of work.

Miller (1983) explored the possibility for biological control of sea urchins using a gastropod predator (species of Fusitriton). Miller (1983) found that 580 sea urchins exposed to the disease (and presumably infected) were transplanted into a natural population of urchins. A control group of uninfected animals were transplanted to another site. By October, 1983, diseased animals were found at the first site. The disease was not evident at the control site. There is therefore a potential for biological control of sea urchins by introducing the virulent pathogen that occurs naturally in Nova Scotia.

6. METHOD OF HARVESTING AND HARVESTING CYCLE

6.1 Annual cycle of operations
6.2 Manpower productivity
6.3 Alternate employment

6.1 Annual cycle of operations

Laminaria longicruris was harvested in southwestern Nova Scotia between 1940 and 1949 (Sharp, 1980). Harvesting since 1949 has been sporadic and without any consistent annual cycle of operations. During the 1940s the main harvest began in the early summer and continued for many months into the early winter. At Clarks Harbour the operational period was 6 months/year through the first half of the decade according to a frontmanager in the period 1940-40 (Sharp, 1980).

The annual cycle of harvesting operations was related to biological and environmental conditions in only one respect. During the early part of the 1940s a significant portion of the harvest came from Crescent Beach. The volume of the beach cast increases during the stormy winter months and is related to the tide rate of larger plants. This portion of the harvest was clearly related to environmental conditions.

6.2 Manpower productivity

The only data available are for the Clarks Harbour operation during the 1940s. According to Sharp (1980) 20 - 30 boats with a 2 man crew worked on the harvest operations around Clarks Harbour. Harvesting was done by hand using a long handled rake. The harvest was transported to the shore in 1.75 lb. The manpower requirements to maintain the operation were therefore 0.04 - 0.05 man/ha. The raw material for transport requirements is unknown.

In an experimental harvest using a dragrake method (see Section 7.1 below) Pringle and Sharp (1985) demonstrated an economic CPUE (catch/unit effort) rate of 2 t/ 1h⁻¹.

6.3 Alternate employment

During the 1940's kelp harvesting was done from lobster fishing boats. The lobster fishing season in southwestern Nova Scotia extends through the winter months and provides alternate seasonal employment for the fishermen. After 1949 the Irish Moss (Chondrus crispus) harvesting industry developed into a major alternate form of employment. The dominant seaweed industry in eastern Canada is now based on Irish Moss.

7. EQUIPMENT USED FOR HARVESTING OF SEAWEED RESOURCES

7.1 The weir resource
7.2 Dragrake harvester
7.3 Sources of credit and insurance of the crop

7.1 The wild resource

The equipment used to harvest Laminaria longicruris has been described by Sharp (1980). During the first 3 years of commercial harvesting plants were cut with sickles or scythes at low tide, using gardens and gathering stoon based (off the beach). The kelp buyer imposed harvest technology by the introduction of a large dragrake (**Fig. 16**) with which deeper water populations could be accessed. The rake consisted of a 3.6 - 1.8 m length of pale furnished with steel tods 30 - 45 cm long, spaced 7.5 - 12.5 cm apart as tines. This equipment was dragged behind a wooden lobster boat (9.2 - 12.3 m in length). Two men handled the equipment.

Harvested kelp was taken by boat to two holding tanks at Clarks Harbour and dog dated in the Island Islands. The holding tanks had dimensions of 4.6 x 4.6 x 1.2 m and could hold 40 - 60 t of kelp. During the harvest season the kelp was transported from the holding tanks to Rockland, Maine (for processing) twice a week in a 25 m boat.

Each of the harvest boats could hold 10 - 12 t of kelp and some harvesters made two collecting trips a day. The harvesting rate was therefore about 10 t per man per day. The price paid by the buyer ranged at CAN$8.00/t. Therefore the gross income was about CAN$80.00 per man per day. During the early years of harvesting 5-600 t of kelp were cut each year in southwestern Nova Scotia.

Pringle and Sharp (1980) reported on an experimental harvest of kelp with dragrakes identical to those used in the 1940s. Kelp stipes and gar ten of the harvest was Laminaria longicruris. The plants were cut at a depth of 3 m using a dragrake. The harvesting rate was 1 t/h. The harvest operation was discontinued (Pringle, 1979). There were numerous problems with this mowing device, but it is interesting to note that kelp bed regrowth was judged to be faster than after dragrakes.

Figure 16. Kelp dragrake used in southwestern Nova Scotia. a- towing point (flat steel bar), b- rake tines (mild steel rod), c- main beam (hardwood), d- trip point (steel flange, 1950).

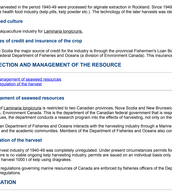
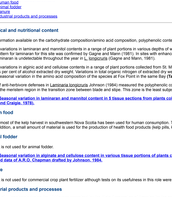


Figure 17. Mechanical harvester under development in 1948. a- spring loaded lifting device, b- removable net bag, c- mower blade chain driven from main engine (after Sharp, 1980).



The detailed economics of the 1940s kelp harvesting operation are unknown. According to Smith and Lucas (1949) the calorie advantage (caloric output (in calories)/caloric input (in calories)) of dragraking is 3 to 5. The caloric advantage of other harvesting methods are unknown, but cutting with sickles and scythes and collecting stoon based (off are assumed to have high caloric advantages.

The plants harvested in the period 1940-49 were processed for alginate extraction in Rockland. Since 1949 there have been only minor harvests of 20 - 300 t per year and the product has been used mostly in the health food industry (kelp pills, kelp powder etc.). The technology of the later harvests was identical to that of the 1940s with similar calories per unit effort.

7.2 Seaweed culture

There is no aquaculture industry for Laminaria longicruris.

7.3 Sources of credit and insurance of the crop

Within Nova Scotia the major source of credit for the industry is through the provincial Fisherman's Loan Board. Insurance for boats only is provided by an insurance program operated by the Canadian Federal Department of Fisheries and Oceans (a division of Environment Canada). This insurance program is to be discontinued in 1986.

8. PROTECTION AND MANAGEMENT OF THE RESOURCE

8.1 Management of seaweed resources
8.2 Regulation of the harvest

8.1 Management of seaweed resources

Harvesting of Laminaria longicruris is restricted to two Canadian provinces, Nova Scotia and New Brunswick. The seaweed resource is managed in both provinces by the Department of Fisheries and Oceans. Management of the resource is based on the concept of maximum sustainable yield. Management measures include: (a) restricted harvesting seasons, (b) restrictions on harvest gear and techniques, the requirement for a research program into the effects of harvesting, and only on the seaweed resource, but also on associated fisheries (Pringle and Sharp, 1985).

The Canadian Department of Fisheries and Oceans interacts with the harvesting industry through a Marine Plants Advisory Committee. This committee has representatives from the industry, government and the academic institutions. Members of the Department of Fisheries and Oceans also consult directly with the fishermen at local meetings arranged within the fishing communities.

8.2 Regulation of the harvest

The kelp harvest industry of 1940-49 was completely unregulated. Under present circumstances permits for harvesting are issued through the Canadian Department of Fisheries and Oceans. Because there is no stable kelp harvesting industry permits are issued on an individual basis only. In 1979 the government issued an experimental permit for one kelp bed. There was no evidence of kelp using dragrake.

All fisheries regulations governing marine resources of Canada are enforced by fisheries officers of the Department of Fisheries and Oceans. The officers may confiscate catches and equipment that contravene regulations.

9. UTILIZATION

9.1 Chemical and nutritional content
9.2 Human food
9.3 Animal fodder
9.4 Manure
9.5 Industrial products and processes

9.1 Chemical and nutritional content

There is information available on the carbohydrate composition/cond composition, polysaccharide content and total organic nitrogen content of the species.

The annual variations in laminarian and mannitol contents in a range of plant portions in various depths of water in St. Margaret's Bay are shown in **Fig. 18** (from Chapman and Craigie, 1978). The laminarian content of the blade was lowest in the winter and highest in the summer. The enhanced seasonal nitrate availability the laminarian content is produced. At Cambeltown in the Bay of Fundy laminarian is undetectable throughout the year (L. longicruris Craigie and Mann, 1981).

The annual variations in alginic acid and cellulose contents in a range of plant portions collected from St. Margaret's Bay are shown in **Fig. 19** (from unpublished data of A.R.O. Chapman). The data are given as % of extracted dry weight. Variations in total organic nitrogen of extracted dry weight for the same site are given in **Fig. 20** (from Chapman and Craigie, 1977). Fronds (1978) measured seasonal variation in the amino acid composition of the species at Fox Point in the same Bay (**Table 8**).

In a study of air-freshness deterioration in Laminaria longicruris Johnson (1984) measured the variation of various tissue portions (**Fig. 21**). The highest concentration of polyphenols occurred in the meristem region in the transition zone between blade and stipe. This zone is the least subject to grazing by Lacuna vincta.

Figure 18. Seasonal variation in laminaran and mannitol content in 5 tissue sections from plants collected at 5 and 10 m depth in Nova Scotia. Means for 5 plants are given (from Chapman and Craigie, 1978).

9.2 Human food

Since 1949 most of the kelp harvest in southwestern Nova Scotia has been used for human consumption. The largest recent harvest (1979) of about 300 t was sold as kombu for consumption in Korea. In addition, a small amount of material is used for the production of health food products (kelp pills, kelp powder).

9.3 Animal fodder

The harvest is not used for animal fodder.

Figure 19. Seasonal variation in alginate and cellulose content in various tissue portions of plants collected from St. Margaret's Bay, Nova Scotia. Means for 5 plants are given. (from unpublished data of A.R.O. Chapman drafted by Johnson, 1984.

9.4 Manure

The harvest is not used for commercial crop plant fertilizer although tests on its usefulness in this rate were done during the late 1970s (P Brick, personal communication).

9.5 Industrial products and processes

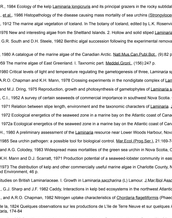
The harvest of L. longicruris during the 1940s was organized by the Atlgin Corporation of America for the production of alginate (a cell wall carbohydrate). Alginate is used in a wide variety of industrial products. The major use is as a thickener in food products (ice cream, salad dressing, etc.). In the textile industry it is used as a sizing agent. In addition, the product is used in the dental and pharmaceutical industries and in the production of coatings for high speed paper.

Figure 20. Seasonal variations in total organic nitrogen content of 3 blade tissue portions in plants collected from St. Margaret's Bay. Means are from 5 plants (after Chapman and Craigie, 1977).

Table 8. Amino acid composition of Laminaria longicruris from St. Margaret's Bay, Nova Scotia. Values are means for 3 plants expressed as per cent by weight of total amino acid composition (after Fronds, 1978).

Amino acid	April 1977	June 1977	August 1977	October 1977	December 1977	February 1978
ASP	10.67	12.08	12.39	12.44	11.01	11.05
THR	4.44	4.38	3.86	4.05	4.08	4.06
SER	3.05	2.46	2.40	2.65	2.65	2.74
GLU	24.86	25.23	27.69	32.17	27.16	25.51
PRO	4.29	4.08	3.86	3.77	3.86	3.86
GLY	5.25	4.69	5.06	4.80	4.69	4.69
ALA	10.54	9.45	7.26	9.61	13.48	16.15
VAL	2.82	2.55	1.42	4.11	3.81	4.58
MET	0.84	0.68	1.19	0.76	0.93	0.69
ILE	1.84	1.69	1.53	1.84	1.84	1.84
LEU	3.06	2.91	3.20	3.28	3.21	3.21
TYR	1.72	2.17	2.86	2.12	3.19	2.76
PHE	2.71	2.77	3.68	3.47	3.47	3.47
LYS	5.69	5.08	5.21	4.51	4.03	4.81
HIS	0.12	0.11	0.16	0.26	0.14	0.14
ARG	5.37	6.15	5.94	4.74	5.33	5.07

Figure 21. Polyphenolic content of various plant portions (after Johnson, 1984).



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The wild harvest and culture of the economically important species of Gelidium in Chile

1. IDENTITY
2. DISTRIBUTION, ECOLOGY AND METHODS OF
3. DISTRIBUTION, ECOLOGY AND METHODS OF
4. FUTURE DEVELOPMENT AND MATTERS OF
5. LIFE HISTORY
6. PRODUCTIVITY OF THE RESOURCE
7. PRODUCTION, MARKETING, PROCESSING AND CULTURE OF RESOURCES
8. PRACTICES AND MANAGEMENT OF THE CULTURE
9. ACKNOWLEDGEMENTS
10. REFERENCES

Bernabe Santelices
Departamento de Ecología
Pontificia Universidad Católica de Chile
Casilla 114-D, Santiago, Chile

ABSTRACT

Gelidium corallinum (= *G. rhigosum* and *G. pulchellum*) is the most important species of *Gelidium* (Gelidiales, Rhodophyta) in Chile (29 to 41° S latitude) and the most important species for agar in the world. Its distribution is from the intertidal to 20 m depth, in exposed to sheltered coastal areas, on rocks and on other seaweeds. Its life history is typically isomorphic with a dominant gametophyte and a short-lived tetrasporophyte. Its reproductive phenology is characterized by a long period of gametogenesis, followed by a short period of tetrasporogenesis. Its growth is slow, with a maximum of 1 mm per month. Its productivity is low, with a maximum of 1 g dry weight per 100 g of fronds per month. Its carbon budget is characterized by photosynthetic carbon fixation, translocation and respiration. Its ecological role is that of a pioneer, with its spores being the most important propagules. Its ecological interactions are those of a competitive species, with its spores being the most important propagules. Its ecological interactions are those of a competitive species, with its spores being the most important propagules. Its ecological interactions are those of a competitive species

Laminaria masticatione in China

1. IDENTITY
2. TAXONOMY
3. MORPHOLOGY, PHYSIOLOGY
4. GENETIC IMPROVEMENT AND BREEDING OF MOLSTEINS
5. WORKING PROCEDURE OF MOLSTEIN PRODUCTION
6. MARICULTURE PRACTICE
7. REFERENCES

Q. A. Tseng
Institute of Oceanology
Academia Sinica
Tsingtao, China

ABSTRACT

Laminaria is a genus of Chinese choice through it has been a well-known food commodity in the Chinese culture. Laminaria masticatione is the only species cultured in China from Korea and then, known in Japan (qualified Cheng 1958, 1963) as its 1947 Laminaria was accidentally introduced to Dalian (Dairen), Liaoning Province, in the North Tsingtao line. From that until 1950, wild and semi-wild Laminaria growing in natural rocky beds were harvested by the local people. Since the beginning of the 1950 decade, the Laminaria industry developed very rapidly. Laminaria masticatione has been cultivated in the coastal provinces from Liaoning to Fujian and Taiwan and in the offshore islands since the 1960 decade. Laminaria masticatione is a cold-water species. Its optimal growth temperature is around 10°C. Its optimal growth temperature is around 10°C. Its optimal growth temperature is around 10°C

Biology of the Macrocystis incarnis in North America

1. ABSTRACT
2. TAXONOMY, ECOLOGY, ANATOMY AND LIFE
3. LIFE HISTORY
4. DISTRIBUTION, ECOLOGY AND METABOLISM
5. PRODUCTIVITY OF THE RESOURCE
6. MANAGEMENT OF MACROCYSTIS RESOURCE
7. ECONOMIC ASPECTS OF MACROCYSTIS
8. MARICULTURE AND PROCESSING THE RESOURCE
9. REFERENCES

Wayne J. Wolf
Wolf Resource Consultants
Pasadena, California
Pasadena California 91107-2305

ABSTRACT

This report on the biology of Macrocystis incarnis (=M. pyrifera) in North America covers its taxonomy, life history, ecology, productivity, and economic aspects. It is intended as a reference for those who are managing the resource, those who are considering its management, those who are considering its harvesting, those who are considering its cultivation, those who are considering its processing, those who are considering its use, and those who are just plain curious about the resource. Keywords: Macrocystis, Kelp, Seaweed, Ecology, Biology, Management, Economics, Mariculture, Processing, Uses.

2. ABSTRACT

2.1 Nomenclature

The genus Macrocystis (Macro = large; Kystis = bladder) is presently recognized as containing three species: M. pyrifera, limited to the year-whipped or southern blades; M. integrifolia (named for the entire blades); and M. incarnis (named for the flesh-colored blades). Although the genus is well known, the taxonomy of the species is still in dispute. Although the genus is well known, the taxonomy of the species is still in dispute. Although the genus is well known, the taxonomy of the species is still in dispute.

product of this kind. Dried powdered kelp (probably M. pyrifera) was formerly marketed by Philip R. Park, Inc. A fraction of the product entered specialty items in health food stores (P. Neushul in Neushul and Harger, 1985).

9.3 Animal fodder and feed additives

Dried kelp (probably Macrocystis pyrifera) was formerly produced by Philip R. Park Inc. and Kelp Organic Products Co. of Los Angeles. Most of the material was incorporated into animal feeds. Neither of these concerns exist at this time (P. Neushul, 1.c.). The value of this Macrocystis as fodder might be enhanced by fertilizing shortly before harvesting to increase nitrogen and phosphorus contents of the tissues via (cf. Mateus et al., 1976) its amino acid composition.

9.4 Manure and fertilizer

No present usage of Macrocystis as a manure exists in California. A large and successful effort was mounted during the first World War to secure kelp as a source of potash for manufacture of fertilizer and explosives (Cameron, 1915; Scofield, 1959; P. Neushul, 1.c.). Presently, all Macrocystis harvested in California and Baja California is processed for alginate production and the resource is fully utilized. An economic study of the feasibility of using Macrocystis for methane production proposed dispersal of sludge remaining from digestion of the kelp, into their kelp farm as a fertilizer (Ralph M. Parsons, 1983).

9.5 Industrial products and processes

As noted above, alginates are the only products currently manufactured from harvested Macrocystis in California. Various compounds of the complex polysaccharides, alginic acid, serve as stabilizers, thickeners, emulsifiers, water-holders, and film-forming or suspending agents. Most of the usages are in foods, pharmaceuticals, beverages, dairy products, and in the manufacture of latex, textiles, as well as paper and cardboard, plus other applications (Kelco, 1961; P. Neushul, 1.c.). Two methods for alginate manufacture are the Le Gloahec-Herter and Green's cold processes, both described with flow charts by Chapman (1970). Salts are first leached from cut or slurried kelp in weak acid. The alginate is then solubilized or induced to form a gel by soaking the kelp in a solution of sodium carbonate or other weak alkali. Reduction of pH by dilution with water or addition of acid causes precipitation and the recovered material can be sold as crude alginate or refined further by repeated solubilization and precipitation (Tseng, 1945).

In the past, a number of other industrial products have been derived from Macrocystis in California, particularly during the period of intense utilization during World War I. These included potash and acetone for explosives manufacturing (potash was also employed in manufacture of matches), iodine, and char (P. Neushul, 1.c.). The early kelp industry was unable to compete with German sources of potash which once more became available to American industry after termination of the war in 1919. The California kelp industry collapsed for about a decade until interests in alginate production and the uses of kelp in animal feeds revived harvesting activities in 1927-28.

A possible future usage of Macrocystis is as alternative sources of energy in the form of gaseous or liquid fuels. The feasibility of liquid fuel production has already been demonstrated on a commercial scale by production of acetone in World War I by Hercules Powder Company (P. Neushul, 1.c.). Extensive investigations of the potential for methane production from kelp were recently completed (Tompkins and Bryce, 1984). This study, the Marine Biomass Program, also yielded considerable information relating to Macrocystis biology, and many of the resulting publications were cited above. We also referred to two of the economic analyses that were performed (Integrated Sciences, Inc., 1976; Ralph M. Parsons, 1983). Macrocystis tissue proved to be an excellent substrate for methane production by bacterial digestion processes. Yields of 4.5 SCF/lbVS (0.28 liters of combustible gas per gram of volatile solids) were reported by Chenoweth et al. (1978). Maximal methane yields were recovered from those kelp samples highest in mannitol.

In closing, we should mention that the Macrocystis forests in nature provide an extensive habitat for fishes and shellfish utilized by humans (North and Hubbs, 1968; Leighton, 1971). As such, Macrocystis and other large kelps are an important sustaining element in recreational and commercial fisheries, both of which are well-established activities in California.

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