SURVEY AND SELECTION OF AGAROPHYTES AND CARRAGEENOPHYTES FOR CULTURE SEEDSTOCK

B.L. Bunting, J.G. Lindsay and R.G.Saunders

marine resources branch
Ministry of Environment
Province of British Columbia

SURVEY AND SELECTION

OF AGAROPHYTES AND CARRAGEENOPHYTES

FOR CULTURE SEEDSTOCK

by
B.L. Bunting, J.G. Lindsay and R.G. Saunders
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ABSTRACT

Several areas along the coast of British Columbia were sampled for potentially valuable colloid-bearing red seaweed during 1978. Twenty-one algal taxa were collected from 59 sites. Colloid analysis revealed the presence of at least 16 agarophyte and carrageenophyte taxa with gels of commercial interest. Experimental cultivation tested the amenability of these algae to air-agitated culture conditions and screened large numbers of plants for selection of superior individuals. Those algae with both an attractive colloid and a culture potential included Gracilaria "chorda" type, *Gymnogongrus leptophyllus*, and *Neoagardhiella baileyi*.

PREFACE

The development of a commercial cultivation technology for agar- and carrageenan-producing marine plants has been a major research objective of the Marine Resources Branch since 1976. Early efforts towards realization of this objective were, however, restricted by a low level of funding availability Largely unsuccessful attempts to develop procedures for growing the agarophyte *Gracilaria* in cheap, low or extensive technology systems did provide the conceptual stepping off point for the development of an intensive culture technology based on floating, semi-closed modules. The prototype Floating Algal Culture System (F.A.C.S.) was developed in 1977-78 and since that time has been undergoing modifications to make it a more efficient user of energy and producer of algal colloids. Initial experiments on *Gracilaria* production in F.A.C.S. indicated not only that this system had considerable commercial potential but also brought to light the problems which had to be overcome before this technology could be commercially applied. One of the major concerns expressed was that to truly evaluate the competitive position of F.A.C.S. technology we would have to isolate individual plants of one or more selected species which would grow much more rapidly than normal wild types, and subsequently develop clones from these individuals as culture seedstock.

The relatively massive, joint government/industry drive to develop commercially viable intensive, land-based culture technology for the carrageenophyte *Chondrus crispus* in the Canadian Atlantic Provinces, and the recent phenomenal success of the extensive cultivation practices for the carrageenophytes *Eucheuma striatum* and *E. spinosum* in the Phillipines, are predicated on the availability of superior seedstock material which has been isolated over a period of years. This should surprise no one, for we need only look at the farming of terrestrial plants to see our near total dependence on food plants which are the product of over 10,000 years of selection by agriculturists.

The information reported herein is the result of the first attempt to screen those local species thought to contain colloids presently of commercial importance, and to determine the colloid type, quality and quantity elaborated by each. Observations of sample populations in F.A.C.S. modules served to indicate the amenability of each taxon to air agitated culture conditions. Species which contained acceptable quantities of a commercially valuable colloid, which, by virtue of the interplay between their morphology and the air-driven agitation, were well circulated within F.A.C.S. modules, and which exhibited relatively rapid growth in culture were to be considered as candidates for more intensive selection and clone development procedures at a later date.

All opinions expressed in their report are those of the authors and do not necessarily reflect the view of the Marine Resources Branch. This study was conducted under contract for the Marine Resources Branch, Ministry of Environment.

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Project personnel included: field crew Zbigniew Pakula, Paul Ryan, and Barron Carswell; and culture crew Barb Bunting, Carol Swann and Shirley Smith. Thanks also go to Georgiana Mogensen for patient typing of the manuscript.

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INTRODUCTION

Agar and carrageenan are gel-forming colloids extracted from certain species of red seaweeds. Due to their varied and often unique gelling characteristics, these colloids have a wide range of commercial applications in the food processing, pharmaceutical, and manufacturing fields. Current world demand for agar and carrageenan is increasing steadily, placing a strain on the presently overharvested natural sources and increasing the importance of cultivation (Naylor, 1976). In addition, the phycocolloid market lacks a stable supply of high quality raw material (Bissell, 1972), emphasizing the need for selection and cultivation of commercially superior species.

Agar is a polysaccharide of variable chemistry derived from a number of algae, chiefly *Gelidium* and *Gracilaria.* Its thickening, stabilizing, and suspending properties give it many industrial applications and its high gel strength, low viscosity, and transparency make it almost uniquely valuable for microbiological work (Naylor, 1976). The estimated world production of agar is 6000 T per year, but has the potential for a three-fold expansion (Jensen, 1979; Woods Gordon, 1978). However, due to variable quality and inconsistent supply, the agar market is relatively unstable (Moss, 1977). Mass cultivation of agarophytes could alleviate this situation by providing dependable sources of high quality raw material and ensuring continued growth of the agar industry.

Carrageenan is also an algal polysaccharide with a variety of chemical configurations (e.g. lamda, kappa, and iota forms) and a range of colloidal properties. It shares a diversity of uses with agar but, due to its marked reactivity with milk protein, has the widest application in the dairy food industry (Naylor, 1976). Present world supplies of carrageenan are produced primarily from natural populations of *Mondrus and Gigartina* and cultivated populations of *Euchewna,* with Canada producing much of the first two and the Philippines most of the latter (Jensen, 1979). Total world production of carrageenan approaches 10,000 T per year (Jensen, 1979) but, unlike agar production, is relatively stable. This allows a continued expansion of applications and an annual industrial growth of between 2.5 and 5.0% (Woods Gordon, 1978). Cultivation could benefit the carrageenan industry by providing alternate sources, freedom from resource restrictions, and a means of enhancing colloid quality and quantity.

The feasibility of large-scale seaweed cultures has been demonstrated by the *Gracilaria* farms of Taiwan (Shang, 1976), the *Porphyra* (nori) farms of Japan (Okazaki, 1971), and the Eucheuma farms of the Philippines (Doty, 1979). Neish and Knutson (1979) report that the cultivation of *Chondrus crispus* on the east coast of this country is also approaching commercialization. Locally, interest has focused on developing cultivation technology; a prototype floating algal culture system for economically important seaweed has recently been designed and tested with the agarophyte *Gracilaria* in British Columbia (Lindsay and Saunders, 1979).

Isolating superior strains of algae is now of primary importance. As in the case of the highly successful Tambalang strain of *Eucheuma* in the Philippines, as well as the rapidly growing T4 strain of *Chondrus* in Nova Scotia, "the move toward commercial cultivation has depended upon selection of fast growing, perennial, vegetatively propagating strains originating from individual plants located during screening programs" (Neish and Knutson, 1979). The use of superior seedstock enhances the production of biomass and yield of colloid, increasing the economic viability of a culture operation.

The purpose of this preliminary study was to identify promising species and select superior strains of local agarophytes and carrageenophytes for culture seedstock. This was accomplished by collecting and sorting plants in the field, analysing their colloid content, and observing their behaviour and growth while under cultivation, with the objective of locating individuals which both performed better in culture and contained a colloid of commercial value.

MATERIALS AND METHODS

The selection process consisted of several phases, including:

1) surveying and collecting potentially valuable species;
2) drying samples for colloid analysis;
3) testing amenability to culture;
4) isolating superior individuals.

Plants were hand-harvested in the field, without their holdfasts, and efforts were made to pick only healthy and superficially non-reproductive plants. Reproductive material was avoided since necrosis often follows maturation of reproductive features and release of spores (Dixon, 1973). Prior to being placed in a culture apparatus, field collections were more thoroughly sorted in order to eliminate unhealthy, heavily fouled, or obviously fertile individuals. Small samples of each population were dried for colloid analysis by Dr. J.N.C. Whyte of the Department of Fisheries and Oceans in Vancouver or by Marine Colloids Division, F.M.C. Corporation, in Rockland, Maine.

The sorted plants, segregated by species, were then weighed and placed in one of three culture systems. Large collections (1.2 wet kg or more) were placed in a unit of the Floating Algal Culture System (F.A.C.S.) and small collections in tank or trough culture systems. These culture facilities were located in Bamfield Inlet (48°50.2'N, 125°8.3'W).

The Floating Algal Culture System (Lindsay and Saunders, 1979) consisted of cone-shaped polyethylene bags with a volume of 3600 1 and a surface area of 6.0 m2 (Fig. 1). These bags were suspended by styrofoam billets and housed in a floating log frame. An air-lift pump attached to the base of each bag provided aeration and agitation; fresh seawater was pumped from a depth of 10 m at a rate of approximately 75 1/min. Plants were retained in the F.A.C.S. for a minimum of two weeks, with wet weight determinations made weekly.

Figure 1. Photograph of the Floating Algal Culture System (F.A.C.S.) used as the primary screening apparatus.

At the conclusion of this initial screening period, individuals displaying reproductive features, epiphytism, bleaching, or necrosis were eliminated and the remaining plants were transferred to tank and trough culture systems.

Forty tanks, each with a volume of 18 1 and a surface area of $6.25x10^{-2}$ m^2, made up the second culture system (Fig. 2). Water pumped from a depth of 10 m and passed through a 25µ sand filter was supplied at the tank surface at a rate of 1.5 1/min; air was provided through the tank base. Plants were observed for periods ranging from a few days to several months. Periodically, weight determinations were made and reproductive, epiphytic, and necrotic material was removed. Throughout the screening process, superior individuals (those with rapid growth rates and a resistance to epiphytism) were isolated and transferred to the trough culture system in order to follow individual performance.

Figure 2. Photograph of the tank culture system used for the secondary screening of test collections.

The trough system, donated by Marine Colloids, was comprised of five troughs, each subdivided into 38 culture compartments with a volume of 3.0 1 and a surface area of $3.8x10^{-2}$ M^2 (Fig. 3). Each compartment received air from the base and fresh seawater at the surface. Seawater was pumped through a 25µ sand filter from a depth of 10 m and supplied at a rate of 0.15 1/min. Individuals or clumps of plants were monitored in the troughs as long as they remained healthy, non-fertile, relatively epiphyte-free, and continued to grow. As in the F.A.C.S. units and the tanks, inferior individuals were regularly discarded

Growth in all three culture systems was calculated using the formula

$$\mu = \frac{100 \ln (W_t/W_0)}{t}$$

Figure 3. Photograph of the trough culture system used for the tertiary screening of test collections.

where μ is the specific growth rate (percentage increase in fresh weight per day), W_0 is the initial wet weight, and W_t is the wet weight on day t; this equation assumes an exponential growth curve (DeBoer, et al, 1978). Specific growth rates of less than 1%/day were not considered in this report. Wet weights were determined using a drip-drying technique with a calculated error value of less than 1%.

RESULTS AND CONCLUSIONS

1. Survey and Collection

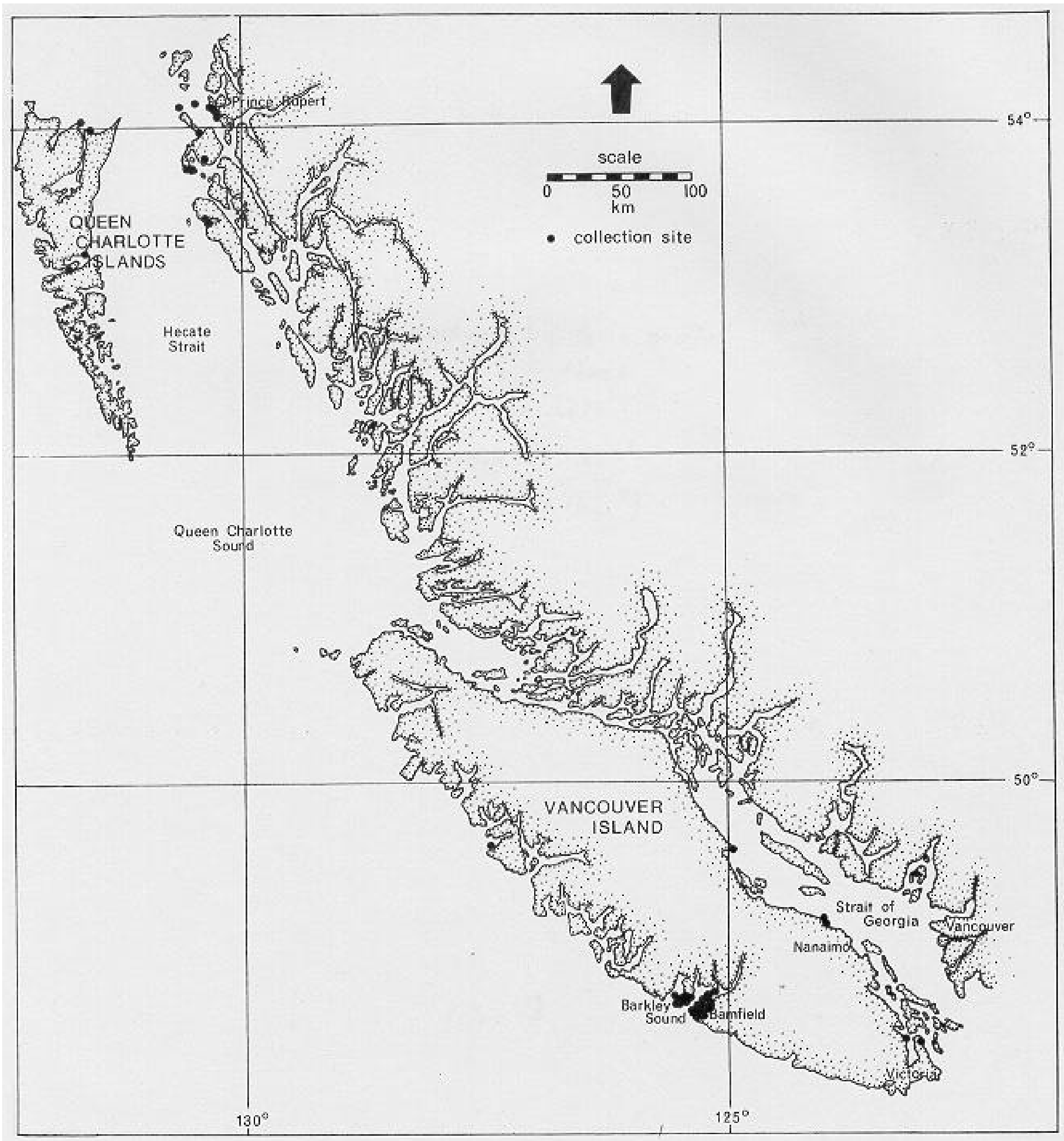
Areas sampled for potentially valuable red algae during 1978 included Barkley Sound, east coast Vancouver Island, no ' rth coast British Columbia and adjacent islands, and north and east coast Queen Charlotte Islands (Fig. 4 and 5). Over 100 sites were surveyed, but site numbers were assigned only those where collections were made.

A total of 21 varieties of algae representing 14 genera were collected from the intertidal and upper subtidal of 59 sites (Table 1 and Appendix I). The most commonly collected algae were *Gelidium, Gigartina, Gracilaria, Gymnogongrus, Neoagardhiella, and Rhodoglossum,* but none of the seaweeds collected were observed in commercially-harvestable quantities during the survey. The majority of species were known to contain agar or carrageenan; others were suspected sources and a few had never been analyzed. The following is a description of the algae collected.

a. *Ahnfeltia* (Gigartinales, Phyllophoraceae)

Ahnfeltia gigartinoides J. Agardh (Fig. 6) is a frequent to common, intertidal to subtidal alga, 10 30 cm tall and deep red to purplish-black in colour, with stiff, cylindrical, dichotomously-divided branches (Abbott and Hollenberg, 1976). Hoppe (1969) regards it as an agaroid raw material while Santos and Doty (1979, as *A. cocinna)* refer to its-colloid as a deviant iota carrageenan. *A. gigartinoides was* observed several times and collected at four sites during the 1978 survey.

Figure 4. Map of B.C. coast showing collection areas.



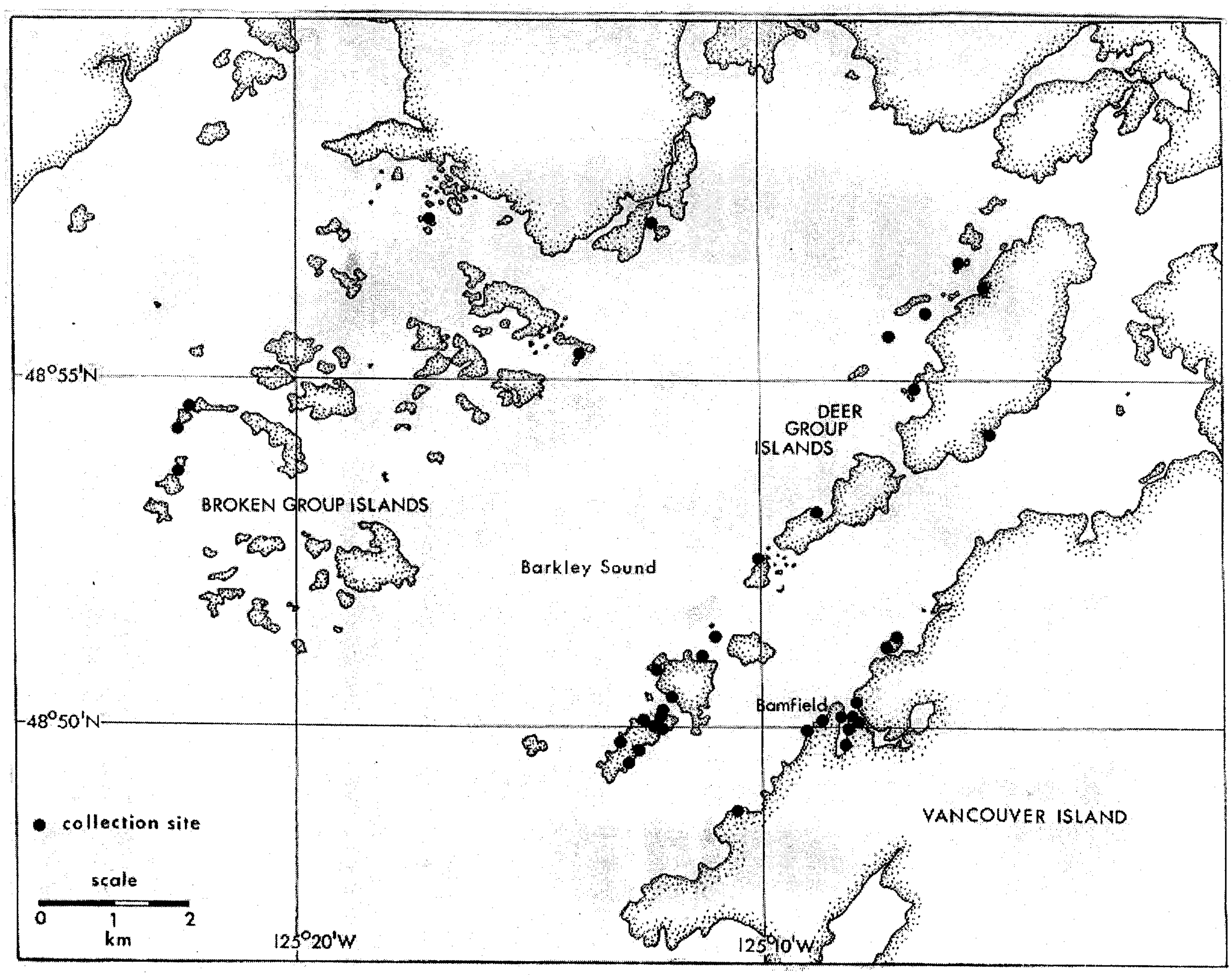


Figure 5. Map of Barkley Sound showing collection sites.

Table 1. List of species collected and frequency of collection.

Alga	No. of sites collected
Ahnfeltia gigartinoides	4
Ahnfeltia plicata	2
Caulacanthus ustulatus	2
Ceramium sp.	1
Endocladia muricata	3
Gelidium sp.	13
Gigartina agardhii	21
Gigartina stellata	21
Gracilaria "brown" type	2
Gracilaria "chorda" type	5
Gracilaria "verrucosa" type	19
Gymnogongrus leptophyllus	11
Gymnogongrus linearis	3
Gymnogongrus platyphyllus	7
Iridaea cordata	1
Iridaea cornucopiae	2
Laurencia spectabilis	1
Lomentaria hakodatensis	1
Neoagardhiella baileyi	11
Pseudogloiophloea confusa	3
Rhodoglossum affine	20

Anfeltia pzicata (Hudson) Fries (Fig. 7) is a wiry, slow-growing perennial (Fritsch, 1945), 5 - 14 cm tall and dark purple to black in colour, typically found in sand in the mid to low intertidal (Abbott and Hollenberg, 1976). It is widely distributed ' and in Russia *A. pzicata* is the primary source of raw material for agar production (Hoppe, 1969). This alga is relatively common in B.C. and was collected twice during the survey.

b. *Caulacanthus* (Gigartinales, Rhabdoniaceae)

Caulacanthus ustulatus (Mertens ex Turner) Kuetzing (Fig. 8) is a small, irregularly dichotomous, high intertidal species with short, spinose branches (Norris and Wynne, 1968) that tend to form secondary attachments to the substrate, other algae, and other branches, resulting in tangled clumps 1 - 3 cm high (Searles, 1968). *Caulacanthus* was observed both in Barkley Sound and the Strait of Georgia during 1978.

C. *Ceramium* (Ceramiales, Ceramiaceae)

Ceramium sp. Roth (Fig. 9) is a widespread, saxicolous or epiphytic red alga with distinct cortical banding and alternate to irregular branching (Abbott and Hollenberg, 1976). Although *Ceramium* by itself currently has little economic importance, it does contain an agar type colloid and is often mixed with other agarophytes for commercial applications (Hoppe, 1969). *Ceramium* is common in British Columbia but was collected in quantity only once during this survey (site 43).

Figure 6. Photograph of herbarium specimen of *Ahnfeltia gigartinoides*.

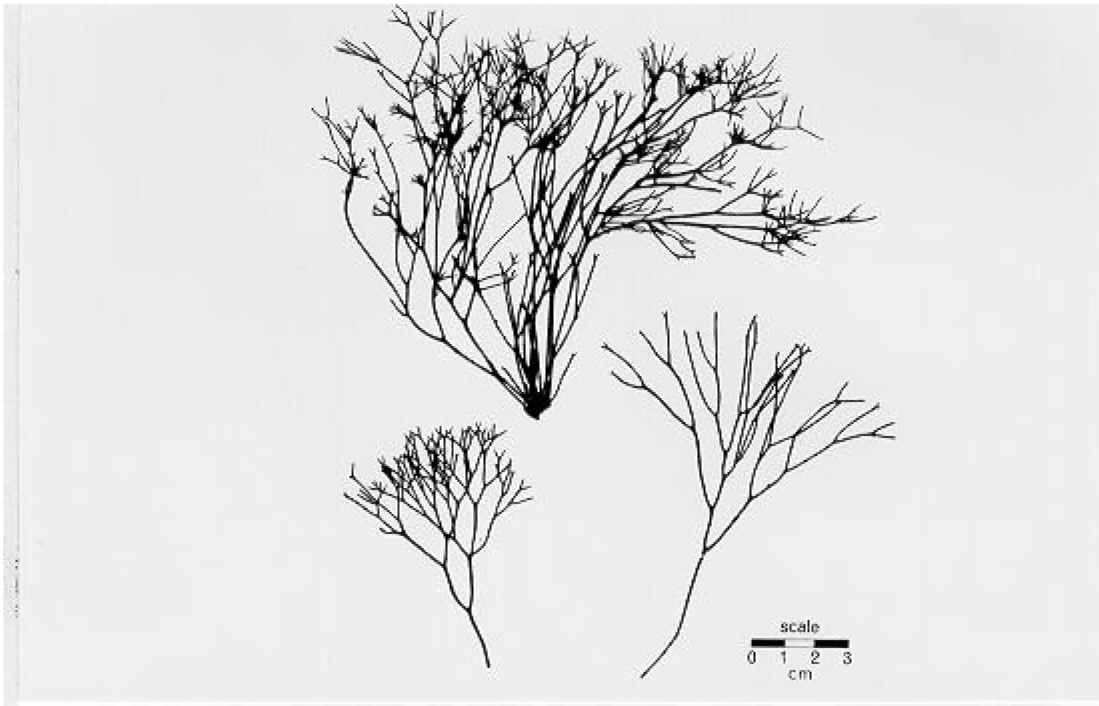


Figure 7. Photograph of herbarium specimen of *Ahnfeltia plicata*.

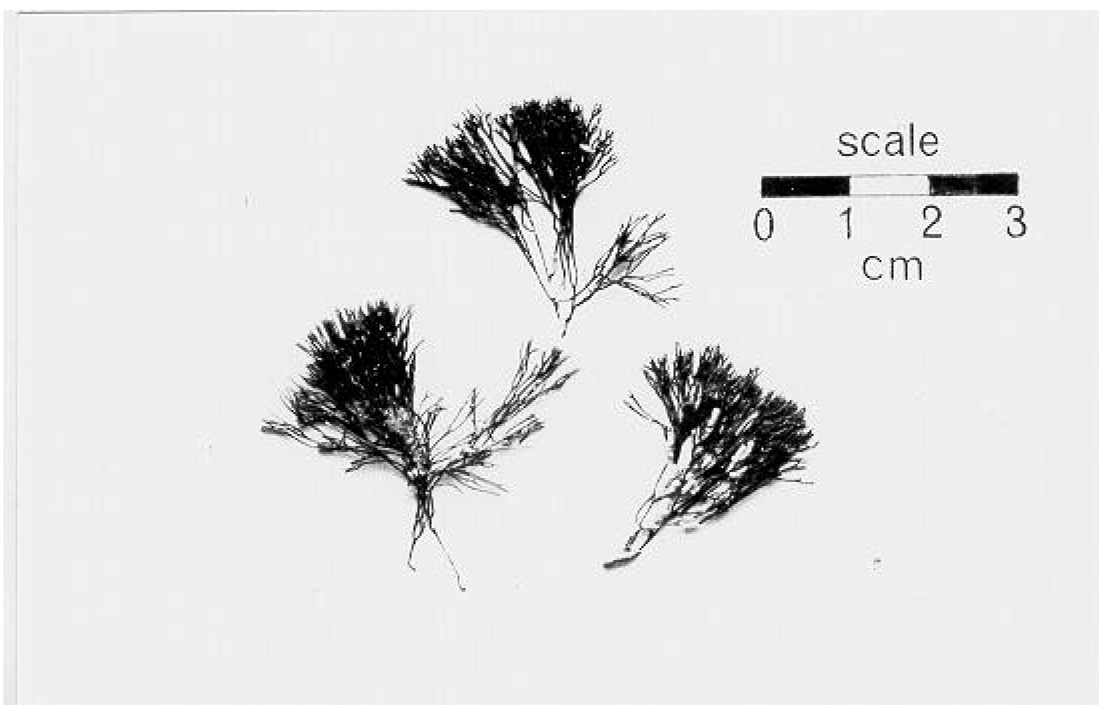


Figure 8. Photograph of herbarium specimen of *Caulacanthus ustulatus*.

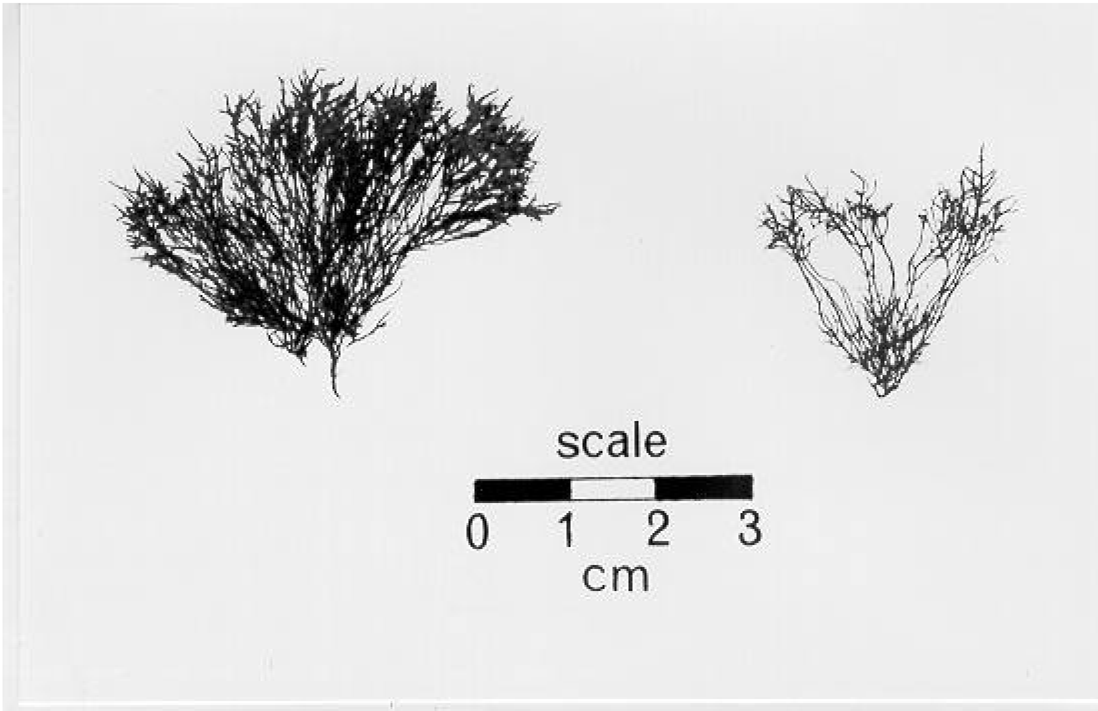
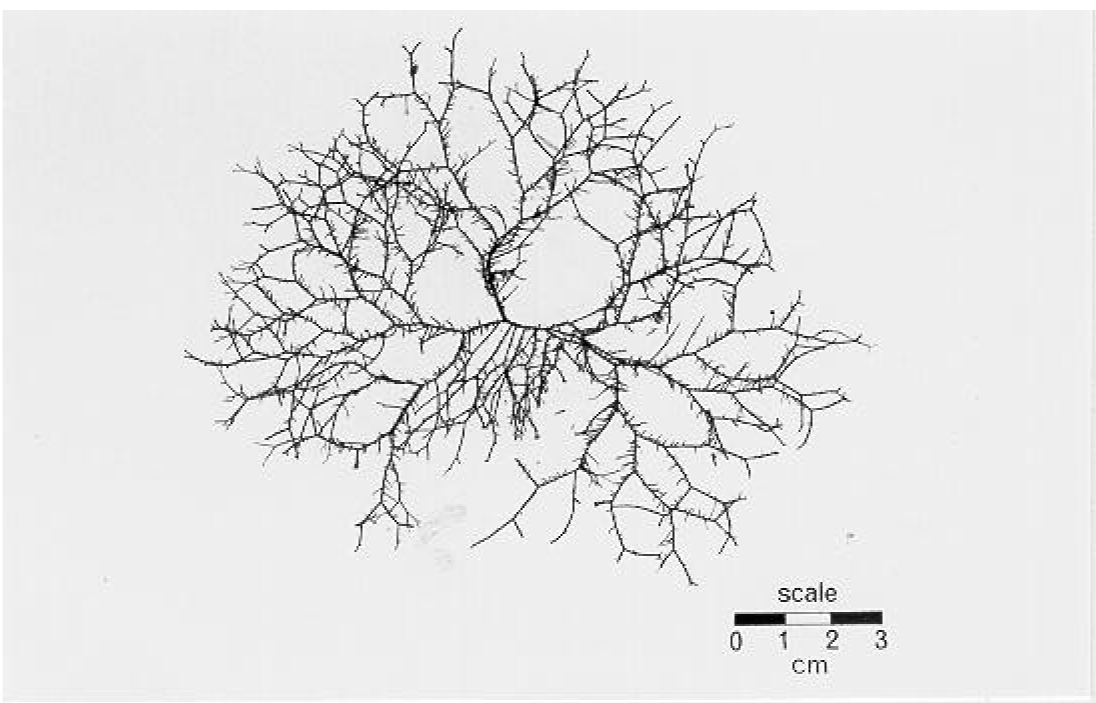


Figure 9. Photograph of herbarium specimen of *Ceramium* sp.



d. Endocladia (Cryptonemiales, Endocladiaceae)

Endocladia muricata (Postels and Ruprecht) J. Agardh (Fig. 10) is a small (4 - 8 cm tall), tufted, dark red to blackish alga covered in spines and found commonly on rocks in the upper intertidal (Scagel, 1967) and reported by various authors to contain agar, agaroid, or kappa carrageenan (Hoppe, 1969). It was frequently observed but collected at only two sites in 1978.

e. *Gelidium* (Nemaliales, Gelidiaceae)

Gelidium sp. is a stiff, cartilaginous, repeatedly pinnately branched plant found both intertidally and subtidally (Fritsch, 1945) and used by a number of countries including Japan, the U.S.A., South Africa, Chile, Spain, and Morocco as a commercial source of agar (Hoppe and Schmid, 1969). Of the five species of upright Gelidium reported in British Columbia, *G. robustum* (Gardner) Hollenberg and Abbott (Fig. 11) is the most common (Widdowson, 1974) and the only one observed in large quantities during this study.

f. *Gigartina* (Gigartinales, Gigartinaceae)

Two species of intertidal *Gigartina, G. agardhii* and *G. stellata,* were studied in 1978. *G. agardhii* is easily recognized in the field on the basis of gross morphology. Other species of intertidal Gigartina demonstrate greater morphological variability and are not as distinct (Abbott and Hollenberg, 1976); these require further taxonomic work and it seems probable that they should be synonymized with *G. stellata* (Widdowson, 1974). Due to this taxonomic confusion and for the purpose of this report, *G. papillata, G. latissima,* and other related morphologies were not differentiated from the species *G. stellata*.

Figure 10. Photograph of herbarium specimen of *Endocladia muricata*.

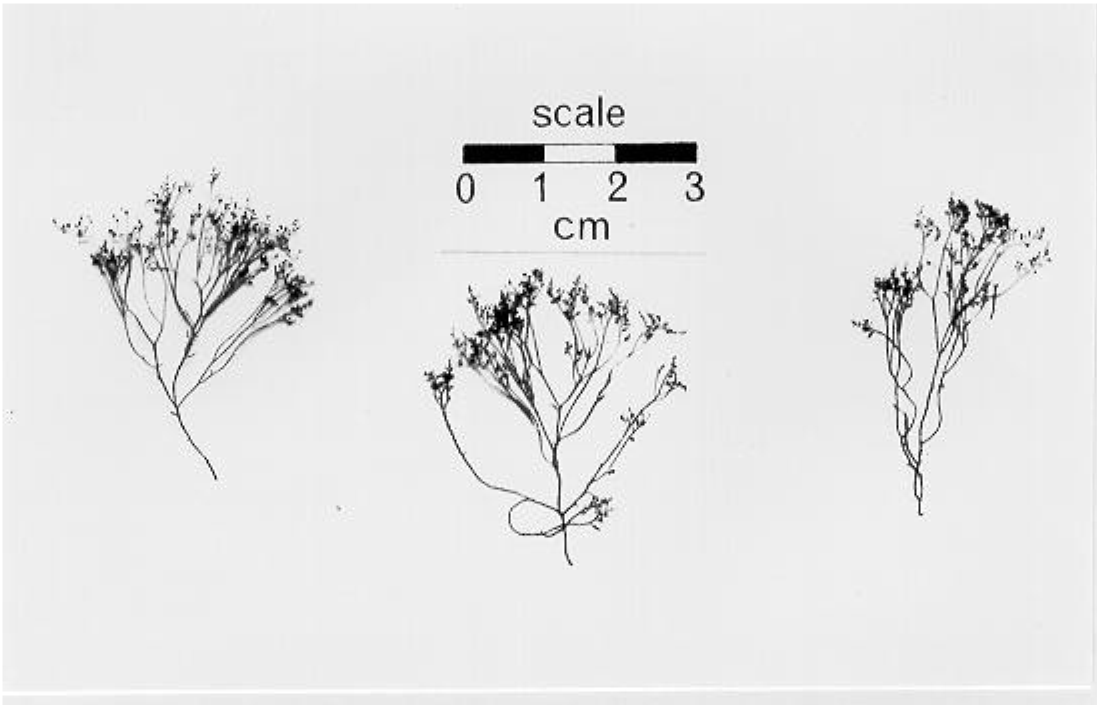
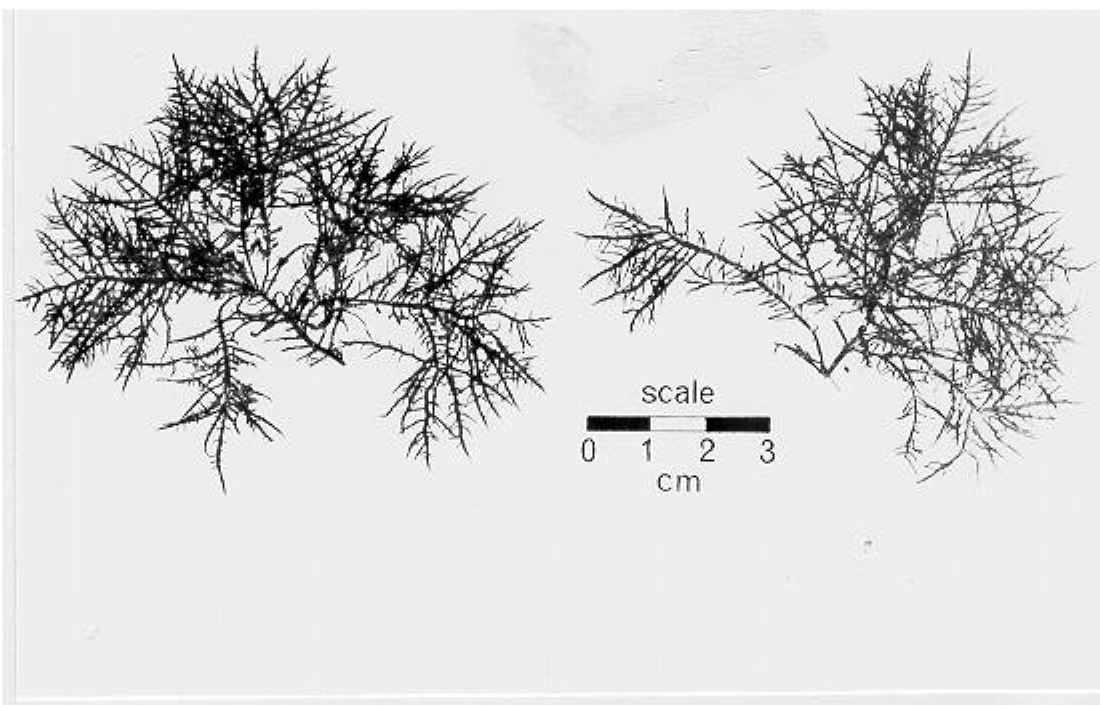


Figure 11. Photograph of herbarium specimen of *Gelidium robustum*.



Gigartina agardhii Setchell and Gardner (Fig. 12) is a dichotomously-branched, reddish-brown plant, 5 10 cm tall, with furrowed blades bearing occasional groups of papillae, and is found growing in small clumps on rocks in the high to mid intertidal (Abbott and Hollenberg, 1976). *G. stellata* (Stackhouse) Batters (Fig. 13) is a small (5 - 15 cm tall), tufted, dark purplish-brown plant with irregularly dichotomous, papillose branches (Taylor, 1957) often incurved at the edges and twisted (Fritsch, 1945). Like the Atlantic seaweed *Chondrus crispus* Stackhouse, *G. stellata is* one of the major sources of carrageenan (Hoppe and Schmid, 1969). Both species of *Gigartina* are locally common and abundant and were quite often found growing together during the survey.

g. *Gracilaria* (Gigartinales, Gracilariaceae)

Gracilaria is a variable, widespread alga used as a raw material for agar production in many countries, including Japan, the Philippines, South Africa, Australia, Chile, Argentina, and the U.S.A. (Naylor, 1976). It is also the subject of several recent studies in British Columbia concentrating o-1 its biology (Saunders and Lindsay, 1976), means of enhancing its growth using floating net's and impoundments (Lindsay and Saunders, 1977), and its experimental cultivation in the F.A.C.S. (Lindsay and Saunders, 1979). As a result, three types of G*racilaria* have been characterized in B.C. (Lindsay and Saunders, 1979).

Figure 12. Photograph of herbarium specimen of *Gigartina agardhii*.

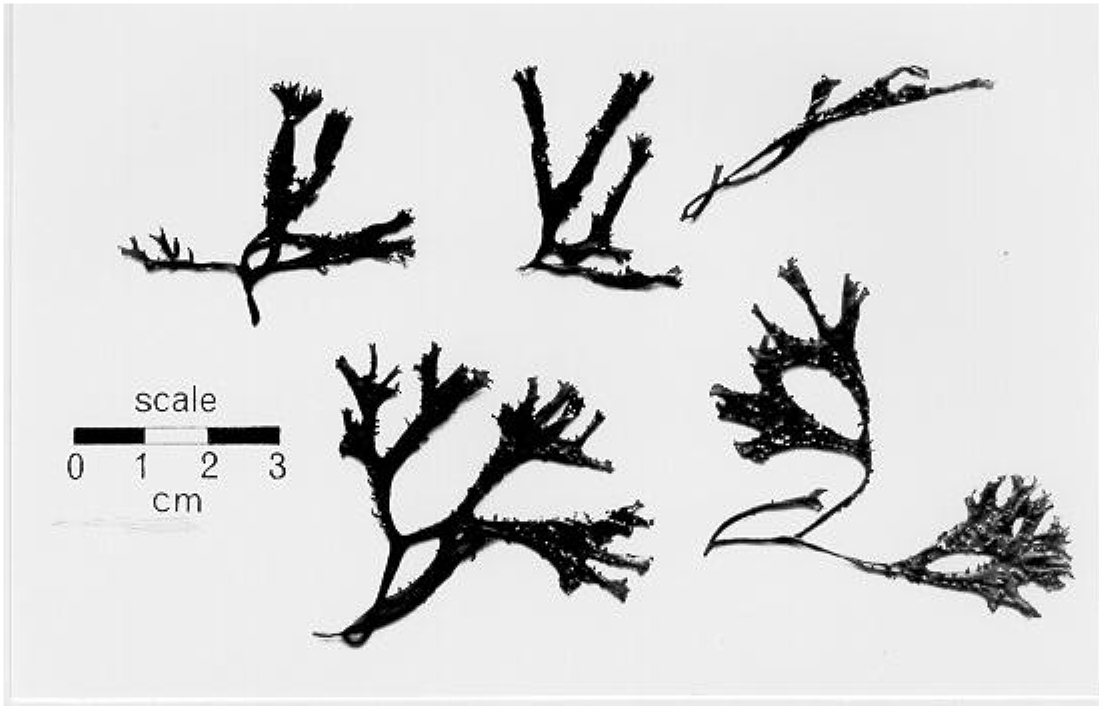
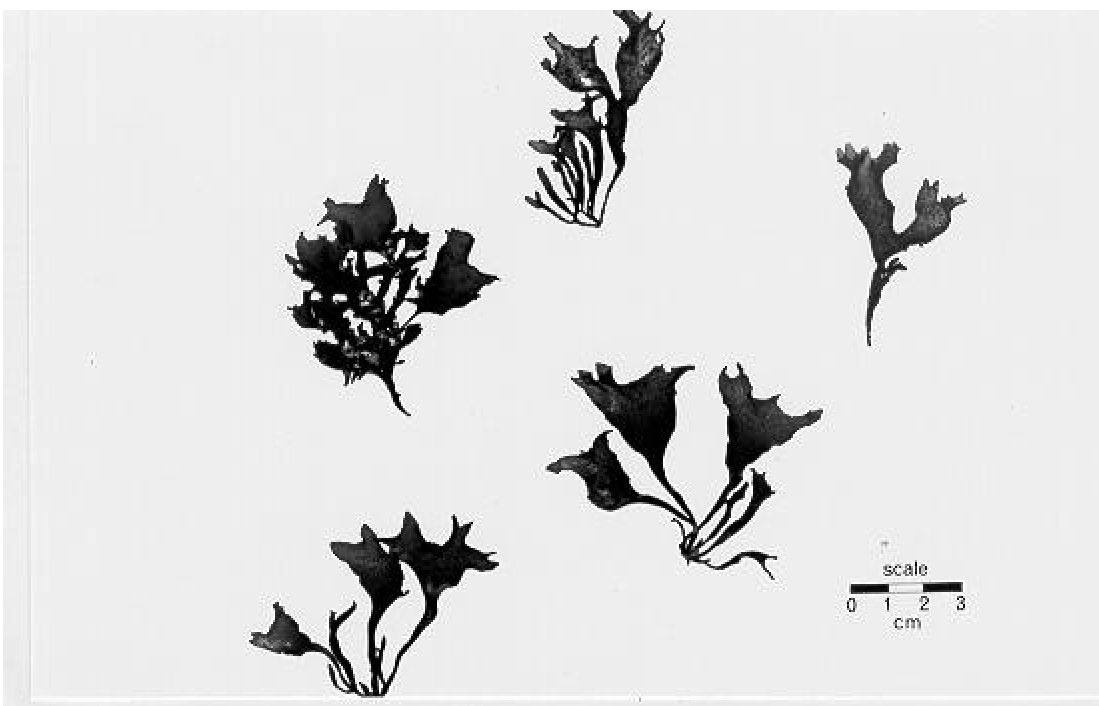


Figure 13. Photograph of herbarium specimen of *Gigartina stellata*.



Gracilaria "brown" type (Fig. 14) is irregularly branched, brown to yellow in colour, and found intertidally in unattached mats. To date, male structures for this type are unknown. *Gracilaria* "chorda" type (after Yamamoto, 1975) (Fig. 15) is more regularly branched, a light red in colour, and may be found either intertidally or subtidally, attached or unattached. The males of this type are characterized by having spermatia in indefinite sori in the cortex. *Gracilaria* "verrucosa" type (after Yamamoto, 1975) (Fig. 16) is a deep burgundy in colour, with irregular arborescent branching and is also found either intertidally or subtidally, attached or unattached. The male "verrucosa" type has spermatia in pot-shaped conceptacles in the cortex. *Gracilaria* "brown" type may prove to be a variant of this "verrucosa" type. All three types are common in B.C. and may be found in mixed populations. The "verrucosa" type was collected more frequently during the survey.

h. *Gymnogongrus* (Gigartinales, Phyllophoraceae)

Four species of *Gymnogongrus* have been recorded in British Columbia: *G. leptophyllus, G. lineari.9, G. norvegicus, and G. platyphyllus* (Widdowson, 19745 Newroth and Markham, 1971). *G. linearis* and *G.* platyphyllus are each morphologically distinct. However, collections made during 1978 'showed that differentiating *G. leptophyllus/G. norvegicus* using gross morphological features was often difficult, as there appeared to be a continuum of characteristics from one species to the other. As a result, G. *norvegicus* was not distinguished from *G. leptophyllus* in these samples; the occurrence

Figure 14. Photograph of herbarium specimen of *Gracilaria* "brown" type.

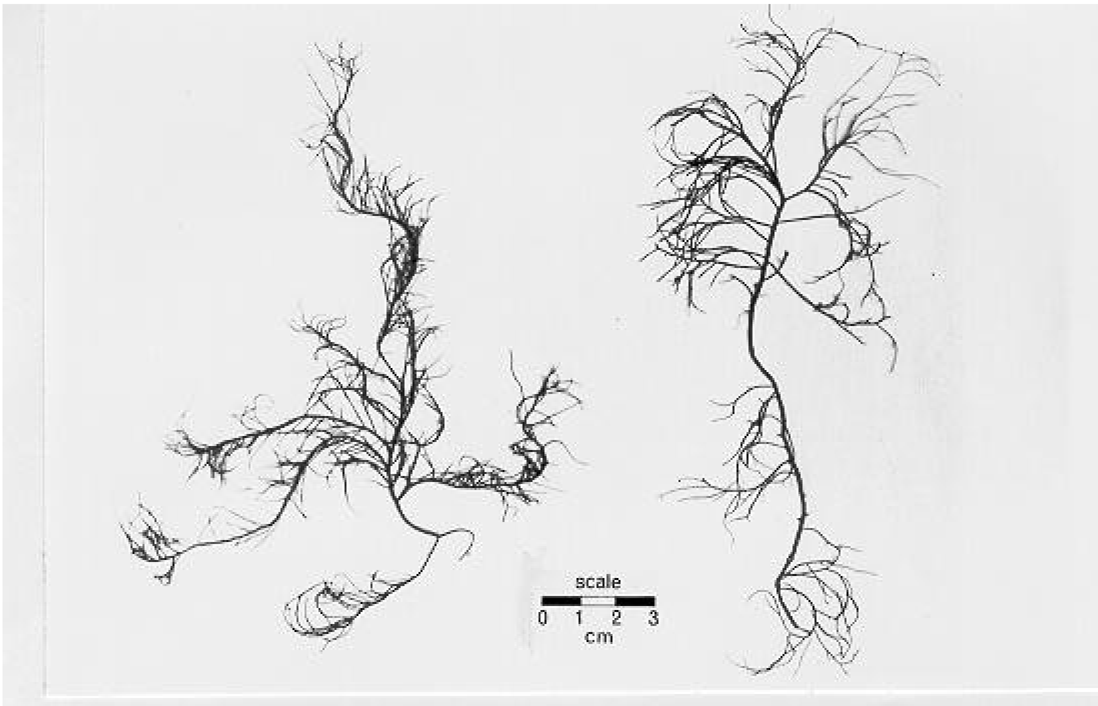
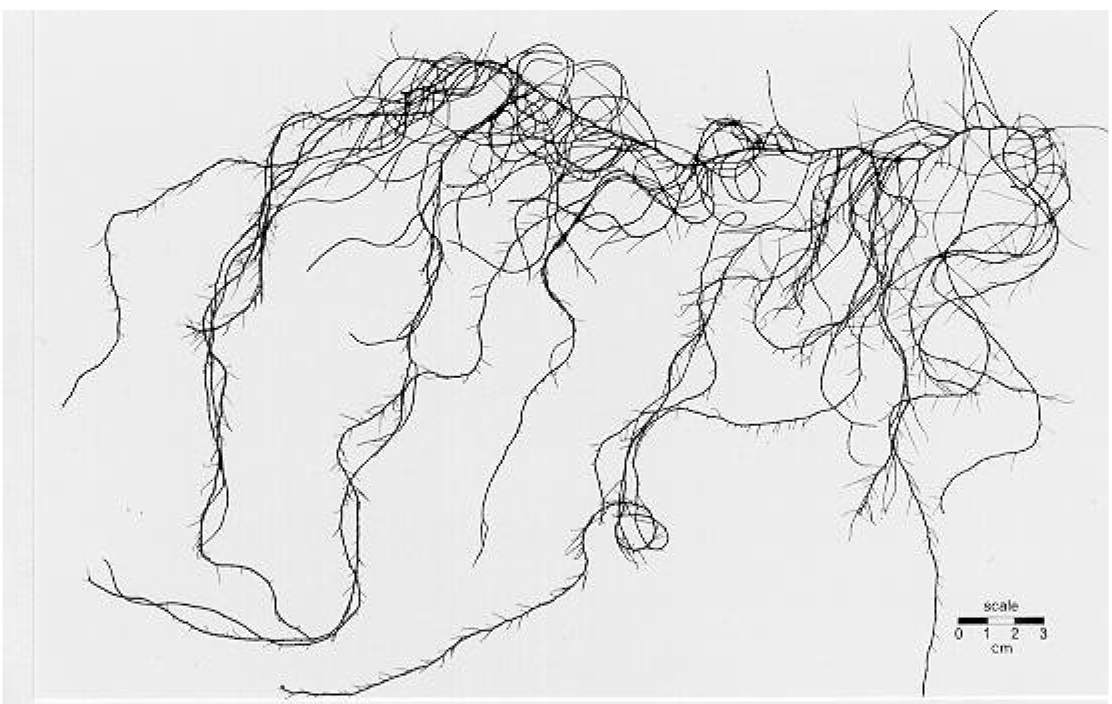


Figure 15. Photograph of herbarium specimen of *Gracilaria* "chorda" type.



of the former in this area needs confirmation (Widdowson, 1974) and the taxonomy of both needs further clarification (Newroth and Markham, 1971). In addition, other lists of algae for the western coast of North America include only *G. leptophyllus* and not *G. norvegtcus* (e.g. Phinney, 1977; Abbott and Hollenberg, 1976; Smith, 1969). Many species of *Gymnogongrus* are known to contain carrageenan, and in East Asia, are used as a phycocolloid raw material (Hoppe, 1969). Recent analysis of Hawaiian *Gymnogongrus* identified an iota type carrageenan (Santos and Doty, 1979).

Gymnogongrus leptophyllus (Gunner) J. Agardh (Fig. 17) is a reddish-purple, regularly dichotomous plant with a terete basal portion and flattened, forked branches (Taylor, 1957). Local collections frequently included individuals with proliferous short, lateral branches as well. *G. leptophyllus* was found in the mid to low intertidal of several sites. *G. linearis* (Turner) J. Agardh (Fig. 18) is a tan to deep purplish-brown, dichotomously branched plant that tends to grow in patches 10 - 18 cm tall on sand-swept rocks in the mid to low intertidal; its branches lie approximately in the same plane, with cylindrical stipe-like portions towards the base (Abbott and Hollenberg, 1976). *G. platyphyllus* Gardner (Fig. 19) is a dull red to reddish purple plant, up to 15 cm tall, having a cylindrical base but markedly flattened dichotomies, and found occasionally on rocks in the low intertidal or upper subtidal (Scagel, 1967). This alga was observed repeatedly but with one exception (site 33), was not abundant.

Figure 16. Photograph of herbarium specimen of *Gracilaria* "verrucosa" type.

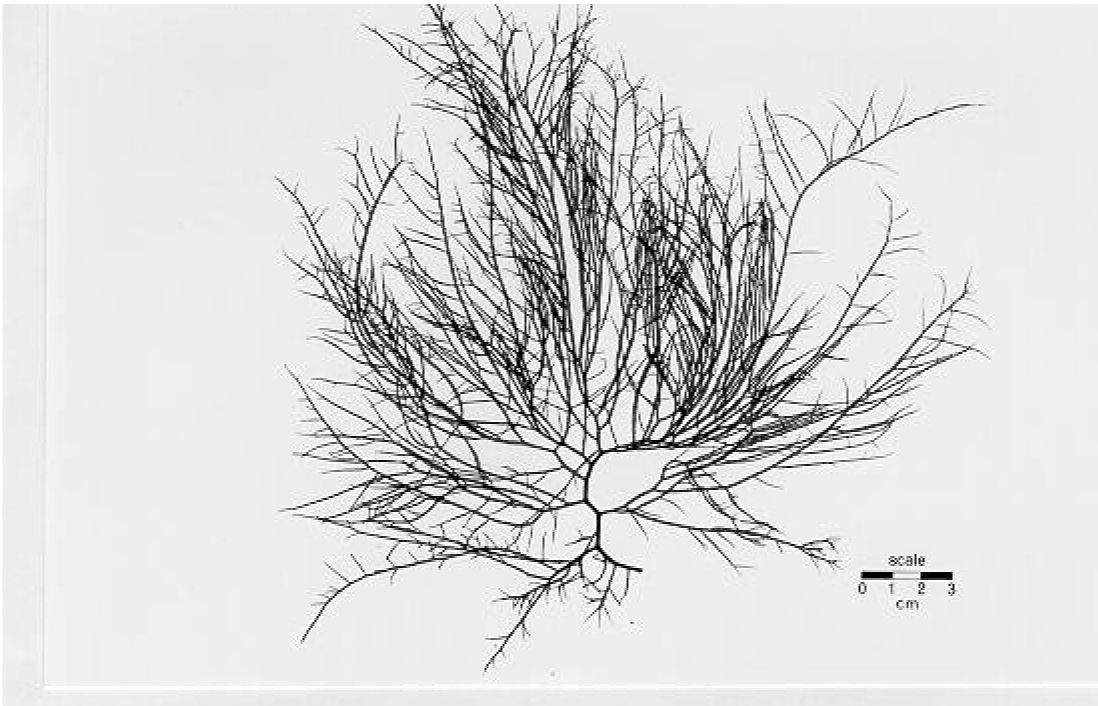


Figure 17. Photograph of herbarium specimen of *Gymnogongrus leptophyllus*.

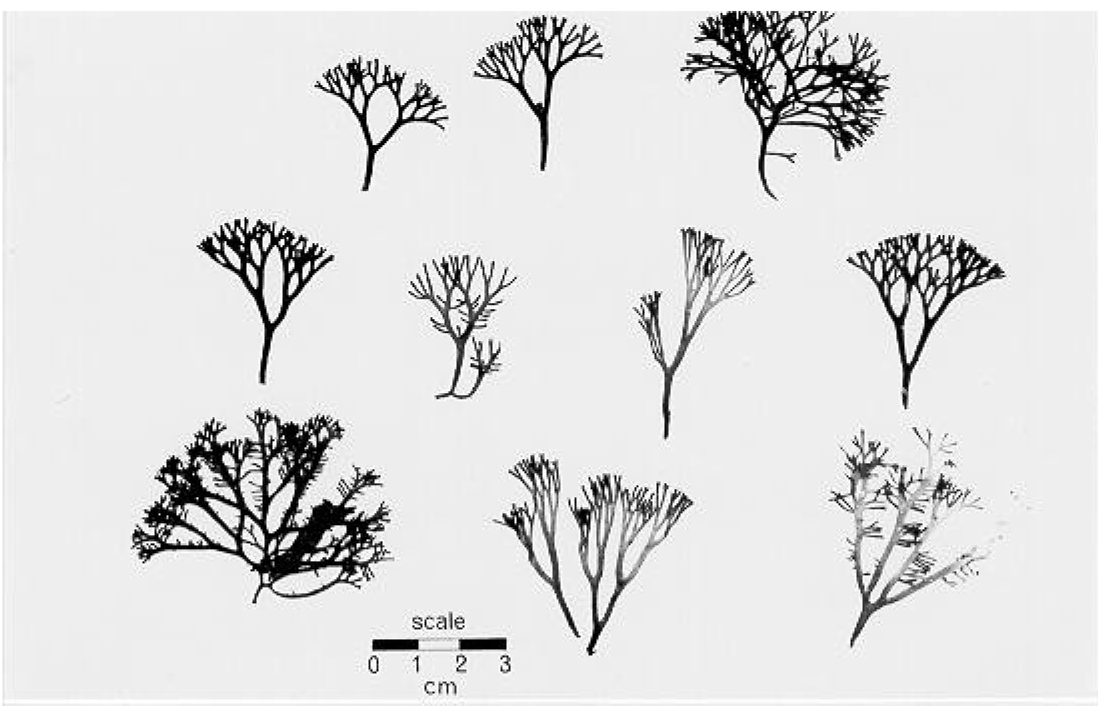


Figure 18. Photograph of herbarium specimen of *Gymnogongrus linearis*.

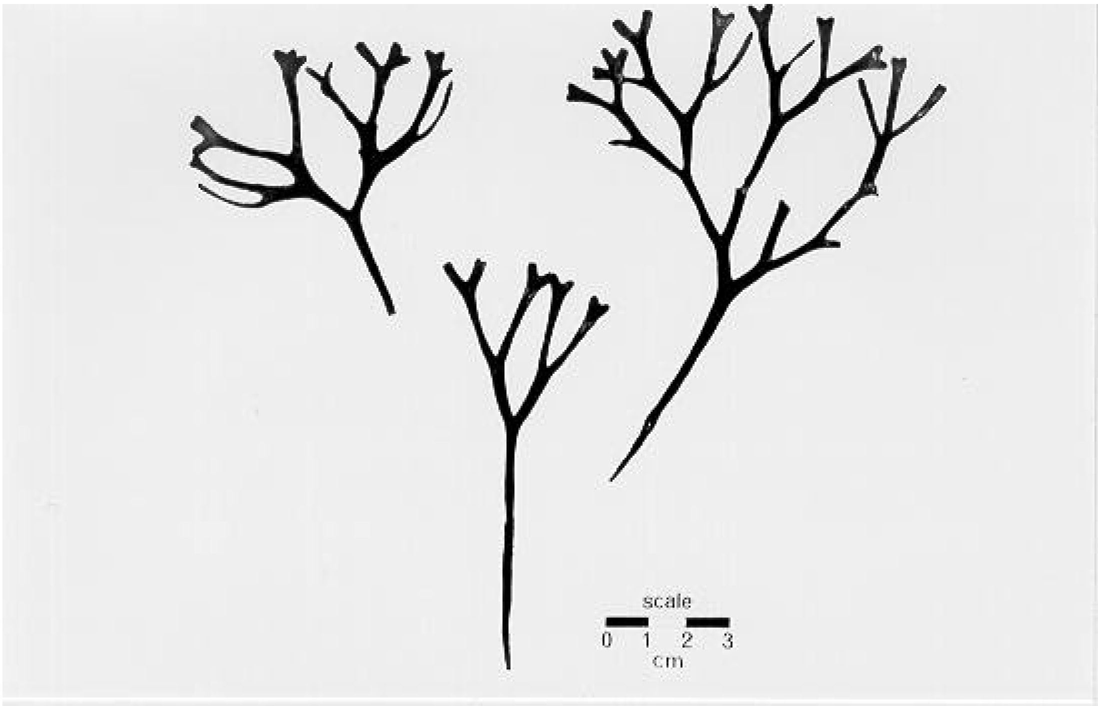
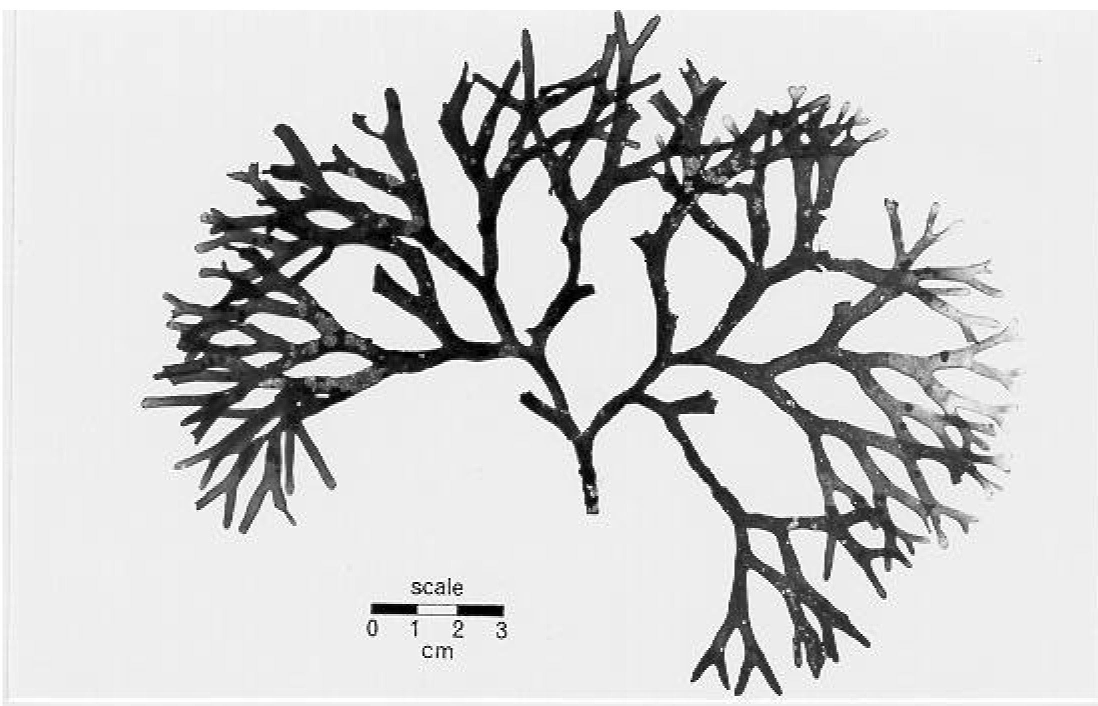


Figure 19. Photograph of herbarium specimen of *Gymnogongrus platyphyllus*.



i. *Iridaea* (Gigartinales, Gigartinaceae)

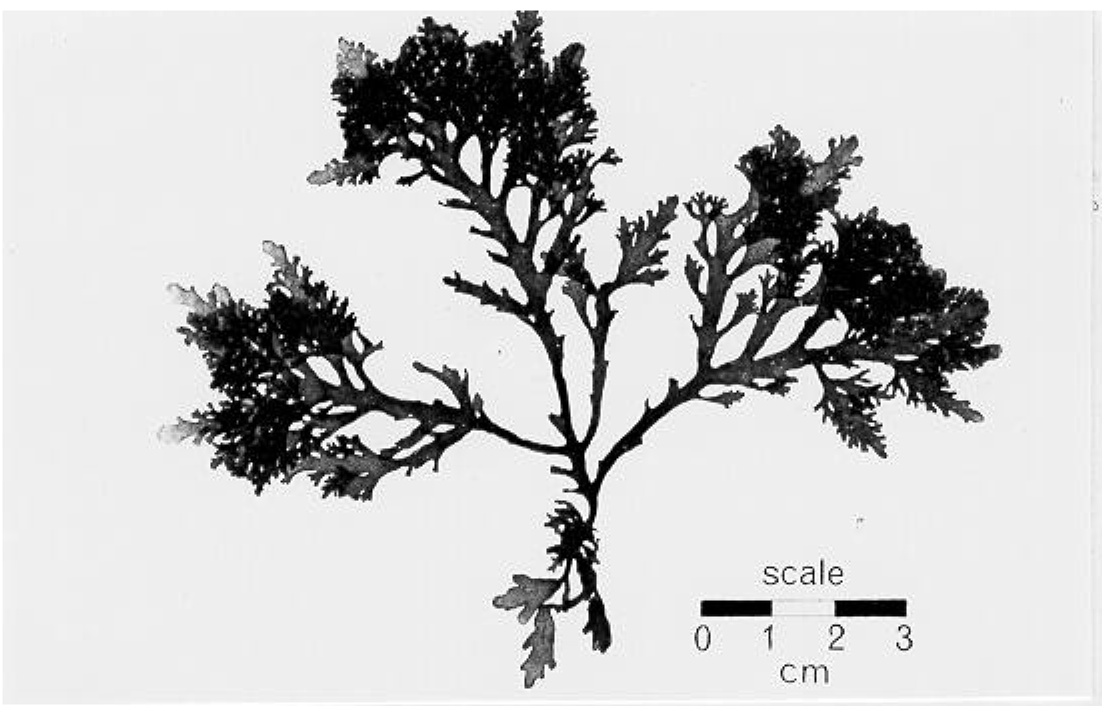
Iridaea cordata (Turner) Bory, (Fig. 20) is a cordate to broadly lanceolate, purple to blackish and often iridescent blade having an extremely variable morphology and found commonly in groups or bands in the intertidal or subtidal (Abbott and Hollenberg, 1976). Like the closely related genera Chondrus and *Gigartina, Iridaea cordata* is a commercial source of carrageenan (Chapman, 1950). *Iridaea cornucopiae* Postels and Ruprecht is a short (2 - 4 cm tall), often lobed blade with a short stipe flaring into a furrowed apophysis; it is usually found in clusters on rocks in the high to mid intertidal (Abbott and Hollenberg, 1976). Its colloid has several commercial applications in Japan (Hoppe, 1969). Both species of *Iridaea* are relatively common on the B.C. coast, although collected sporadically during this survey. *I. cordata* is the subject of several recent studies in this area (e.g. Mumford, 1977; Canadian Benthic Ltd., 1977; Waaland, 1977; Austin and Adams, 1975).

j. *Laurencia* (Ceramiales, Rhodomelaceae)

Laurencia spectabilis Postels and Ruprecht (Fig. 21) is a rose-red to purplish plant, up to 30 cm tall, with several erect, repeatedly-divided, compressed axes, symmetrical branches, and rounded apices: it may be frequent on rocks from the mid intertidal to the subtidal (Abbott and Hollenberg, 1976) but was collected in substantial amounts at only one location (site 35) in 1978. The extract of some types of Laurencia has been shown to produce a weak gel and it may also have antibiotic characteristics (Hoppe, 1969).

Figure 20. Photograph of herbarium specimen of *Iridaea cordata*.

Figure 21. Photograph of herbarium specimen of *Laurencia spectabilis*.



k. *Lomentaria* (Rhodymeniales, Champiaceae)

Lomentaria hakodatensis Yendo (Fig. 22) is a small (1 - 8 cm tall), purplish (but often bleached) intertidal perennial found usually as an epiphyte or growing in tufts on rocks; branches are generally hollow and tapered, irregularly but profusely divided, and like *Caulacanthus*, commonly form adhesion areas between adjacent branches and become arranged in a confused tangle (South, 1968). *Lomentaria* has only lately been reported in British Columbia and may be a non-endemic species of recent introduction to the Pacific Northwest (South, 1968). South (1968) found *Lomentaria* only in the Strait of Georgia whereas this survey located *Lomentaria* in Barkley Sound as well. In addition, tetrasporic *Lomentaria* was discovered growing epiphytically on Georgia Strait *Gracilaria* being cultured in the F.A.C.S. in the fall of 1978. The colloidal nature of this alga is not documented.

1. *Neoagardhiella* (Gigartinales, Solieriaceae)

Neoagardhiella baileyi (Harvey ex Kuetzing) Wynne and Taylor (Fig. 23) has an elongate, fleshy thallus (Fritsch, 1945) with irregular, sparse or dense, radial or distichous branching, and is found on rocks, mostly near sand, in the intertidal (Abbott and Hollenberg, *1976).* *Neoagardhiella* contains carrageenan and is used commercially in eastern North America (Hoppe, 1969). *Neoagardhiella* was observed and collected frequently during the survey.

Figure 22. Photograph of herbarium specimen of *Lomentaria hakodatensis*.

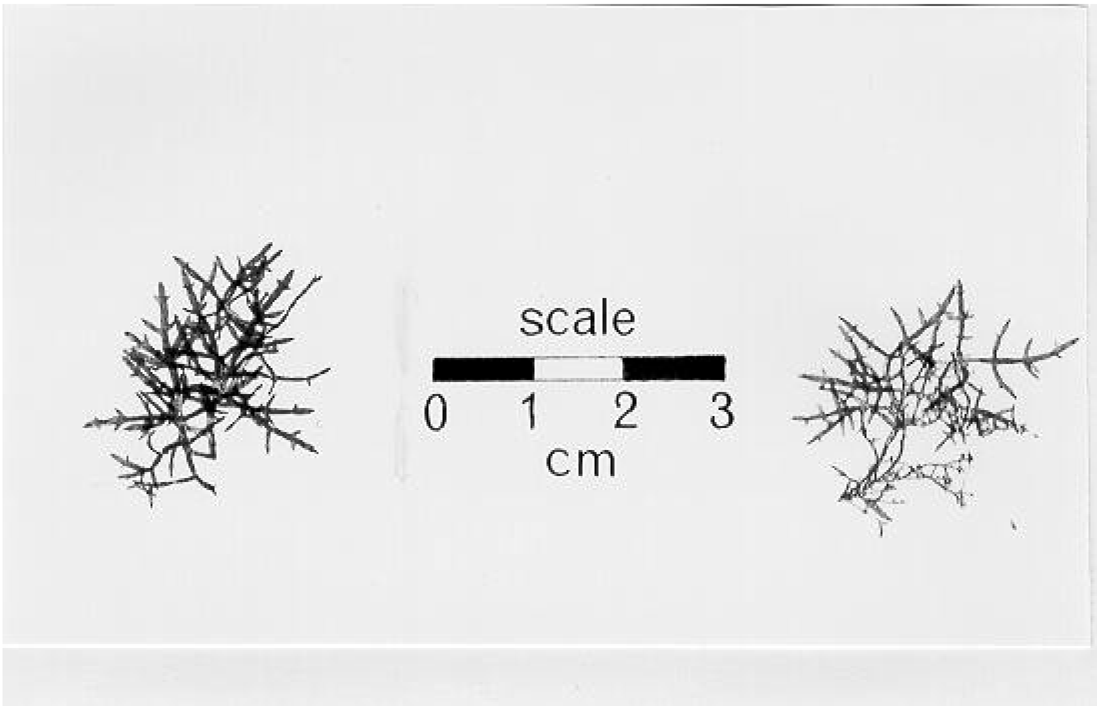
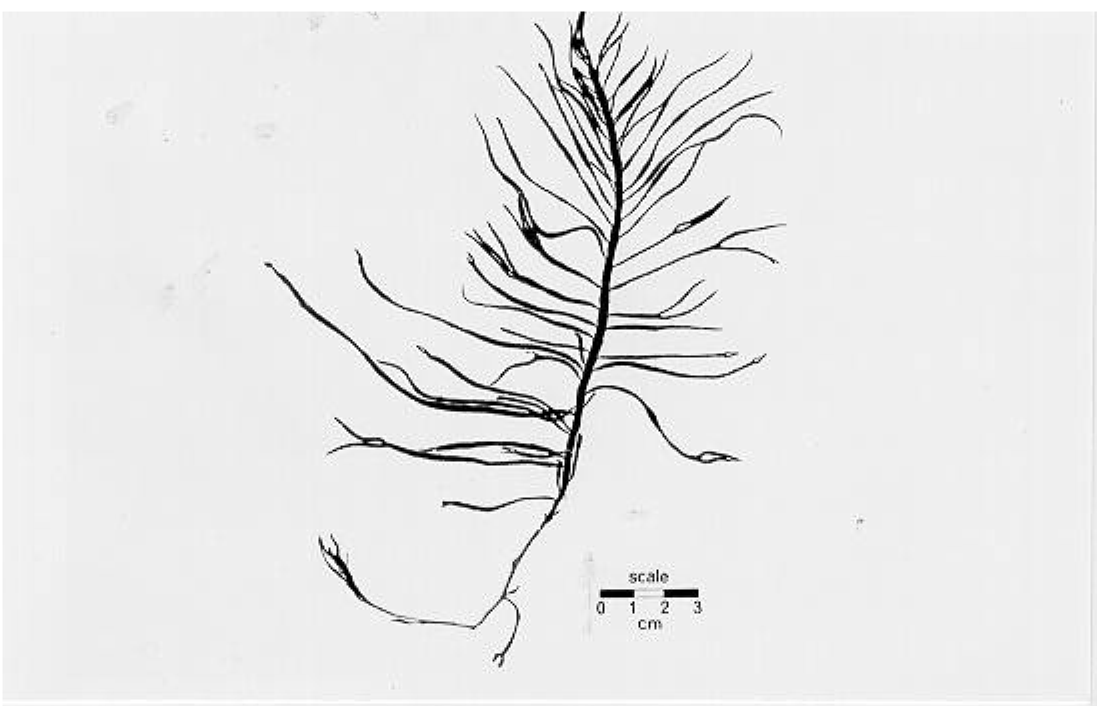


Figure 23. Photograph of herbarium specimen of *Neoagardhiella baileyi*.



m. *Pseudogloiophloea* (Nemaliales, Chaetangiaceae)

Pseudogloiophloea confusa (Setchell) Levring *in* Svedelius (Fig. 24) is an infrequent but widely distributed, saxicolous, mid intertidal to subtidal alga, 3 - 15 cm tall, dark red in colour, and regularly dichotomously branched with cylindrical branches and tapering apices (Abbott and Hollenberg 1976). It is not recorded whether *Pseudogloiophloea* contains a colloid of commercial potential. Abundant *P. confusa* was observed at three locations during 1978. However, it appeared to be very ephemeral in nature, growing rapidly in the spring and degenerating rapidly in the early fall. Plants collected during the spring and summer were remarkably epiphyte-free.

n. *Rhodoglossum* (Gigartinales, Gigartinaceae)

Rhodoglossum affine (Harvey) Kylin (Fig. 25) is a small (4 - 15 cm tall), greenish-olive to reddish-purple carrageenophyte with smooth, dichotomously branched blades, concave on one side, and occasional lateral proliferations; it is relatively abundant intertidally, usually in tufts or bands and often associated with Gigartina (Abbott and Hollenberg, 1976). Collections made during 1978 revealed a highly variable morphology in local intertidal populations as well as an abundance at the sites surveyed. The nature of the carrageenan of- *Rhodoglossum* is reportedly similar to that of Chondrus (Hoppe, 1969).

Figure 24. Photograph of herbarium specimen of *Pseudogloiophloea confusa*.

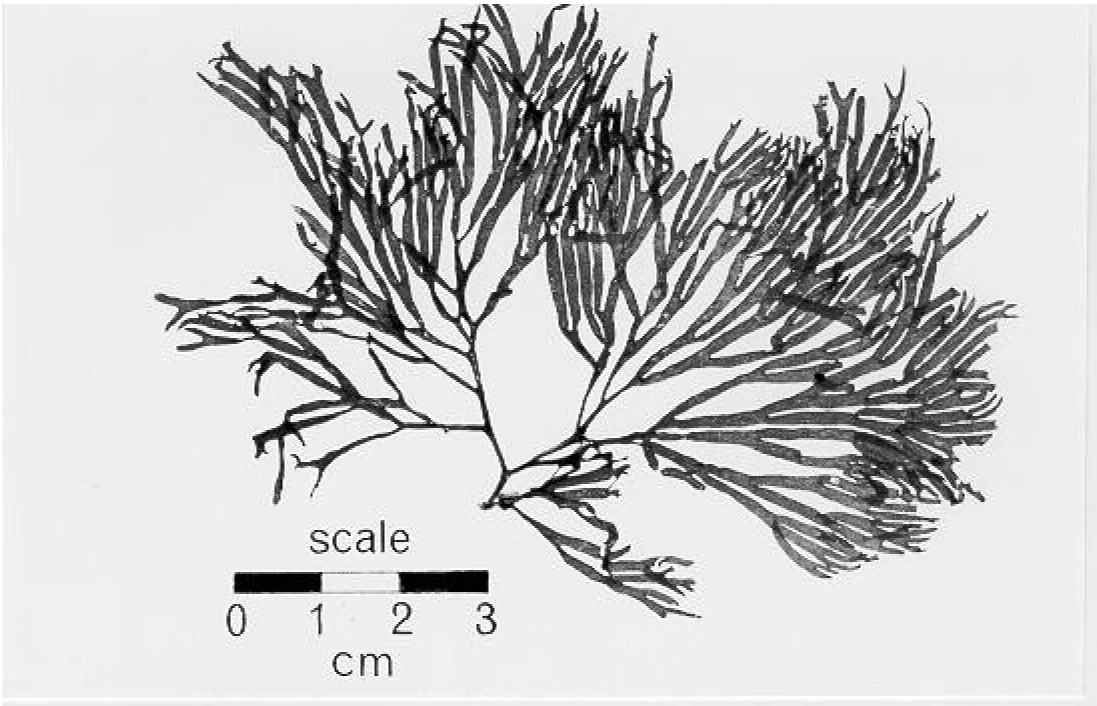
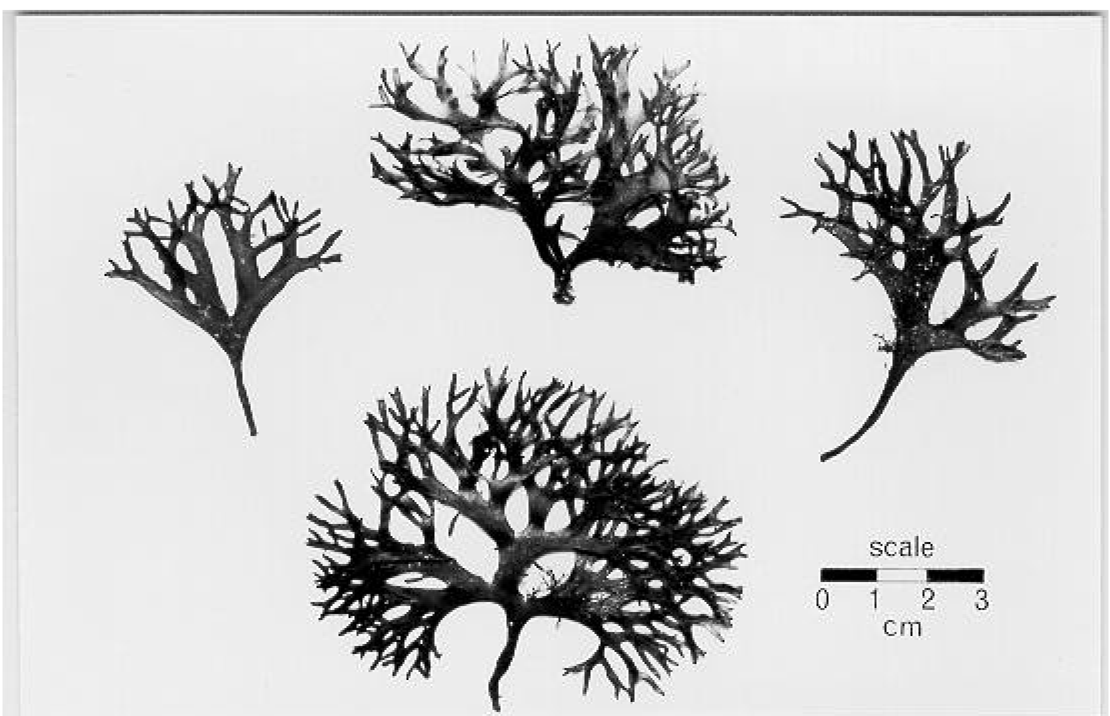


Figure 25. Photograph of herbarium specimen of *Rhodoglossum affine*.



2. Colloid Analysis

A total of 145 samples representing 20 types of algae and 41 different populations were sent for analysis during 1978 (Table 2 and Appendix II); 57% of these were shipped to Dr. J.N.C. Whyte in Vancouver and 43% to Marine Colloids in Rockland, Maine. Eighty-four samples came directly from field collections, the rest from populations in culture. Results have been obtained for 104 of these samples.

Those algae containing agar or agar-like colloids included *Caulacanthus, Endocladia, Gelidium, Gracilaria,* and Laurencia. *Caulacanthus* provided a high quality agar with a strong gel, and a good average yield (28.1% of clean dry weight). *Endocladia* gave a high yield (42%) of an agaroid polymer, probably with a porphyran type structure, but gel strength was relatively low. The agar extracted from *Gelidium* provided a relatively good average yield (23%) although gel strength varied considerably (68 - 378 g/cm^2). *Gracilaria* had a similar average yield (24%) and generally produced an acceptable gel, but variation between samples was large for both parameters. Of the three types of *Gracilaria, G.* "chorda" type produced the highest average yield (27%) and the "chorda" from Cherry Point (site 26) the highest gel strength (395 g/cm^2). *Laurencia* was found to have non-gelling, agaroid type polysaccharide.

Carrageenophytes analyzed included *Anfeltia, Gigartina, Gymnogongrus, Iridaea, Neoagardhiella,* and *Rhodoglossum*. *Anfeltia*, with an average yield of 23%, gave an iota type carrageenan with agar-like gel forming ability, but was difficult to extract. Both *Gigartina agardhii and G. stellata* yielded large percentages of kappa carrageenan (52 and 42% respectively). The gel from *G. agardhii* was less variable in yield and gel characteristics than that from *G. stellata*.

Table 2. Summary of properties of extracts of 20 types of red algae analyzed during 1978. Data from Whyte and Hosford (1979) except where indicated. Appendix II details these results.

Alga	no. of samples analyzed	colloid type	average yield (% clean dry wt.)	range of yield (% clean dry wt.)	average gel strength† (g/cm²)	range of gel strength (g/cm²)
Ahnfeltia gigartinoides	2	carrageenan	24.0	23.0-24.9		
Ahnfeltia plicata	3	carrageenan	22.9	17.6-26.6		
Caulacanthus ustulatus	3	agar	28.1*	24.7-30.7	220.0(n=2)	213.0-227.0
Ceramium sp.	1	not identified	9.8			
Endocladia muricata	1	agaroid	42.1		4.3(n=1)	
Gelidium sp.	4	agar	22.8	12.3-28.0	153.2(n=4)	68.0-377.6
Gigartina agardhii	16	carrageenan	51.6*	44.4-54.6		
Gigartina stellata	4	carrageenan	41.5	29.4-49.1		0.0-348.0
Gracilaria "brown" type	10	agar	23.0	10.1-40.2	79.1(n=10)	
Gracilaria "chorda" type	10	agar	26.6	15.6-37.8	72.8(n=10)	0.0-395.0
Gracilaria "verrucosa" type	9	agar	22.7	14.6-29.8	127.0(n=8)	0.0-361.7
Gymnogongrus leptophyllus	4	carrageenan	47.0*	36.1-64.0		
Gymnogongrus linearis	2	carrageenan	38.4	36.3-40.5		
Gymnogongrus platyphyllus	2	carrageenan	28.9	25.6-32.2		
Iridaea cordata	1	carrageenan	40.0		0.0(n=1)	
Laurencia spectabilis	2	agaroid	18.2	15.0-21.3		
Lomentaria hakodatensis	1	not identified	15.9Ω			
Neoagardhiella baileyi	13	carrageenan	25.8*	19.8-29.4	0.0(n=1)	
Pseudogloiophloea confusa	2	not identified	13.0	9.8-16.2		
Rhodoglossum affine	14	carrageenan	52.6*	43.4-57.6		

† Whyte and Hosford (1979), measured as the force required to rupture a 1% aqueous solution, measured on an Instron Model 1122.

* Pooled data from Whyte and Hosford (1979) and Marine Colloids Division, F.M.C. Corp., personal communications.

Ω Marine Colloids Division, F.M.C. Corp., personal communications.

Gymnogongrus also had good yields of predominantly kappa carrageenan, especially the species *G. leptophyllus* (47%) and *G. linearis* (38%). The gel derived from *G. leptophyllus* was stiff and dry, somewhere between kappa and iota types in nature. Iridaea provided a high percentage (40%) of lambda carrageenan while *Neoagardhiella* provided mostly iota type. The yield from *Neoagardhiella* was low (26%), possibly due to its high water content (I.C. Neish, personal communication), but the gel was highly elastic in nature. The colloid extracted from *Rhodoglossum* proved to be similar to that from Chondrus, with an excellent average yield (53%) of a 50:50 kappa:lambda carrageenan, and a relatively high viscosity.

The colloids extracted from *Ceramium, Lomentaria,* and *Pseudogloiophloea* have yet to be elaborated, but produced poor gels and do not appear to be commercially valuable at this time.

Based on economic attractiveness, several of the species analyzed provide colloids of potential interest. *Caulacanthus*, *Gelidium* and *Gracilaria* are potential sources of agar. The *Caulacanthus* agar in particular has interesting properties (I.C. Neish, personal communication) and outperformed in yield and quality the other agarophytes analyzed (Whyte and Hosford, 1979). Carrageenan producers of interest include *Iridaea*, *Gigartina, Gymnogongrus, Neoagardhiella*, and *Rhodoglossum.* Tetrasporic *Iridaea* is the best source of lambda carrageenan among the genera analyzed (Whyte and Hosford, 1979) and has excellent properties for applications requiring high viscosities (I.C. Neish, personal communication). *Gigartina agardhii,* followed by *Gymnogongrus leptophyllus*, provide attractive yields of kappa carrageenan; the *Gymnogongrus* in particular has an unusual, interesting colloid (I.C. Neish, personal communication). *Neoagardhiella* produces the most iota type carrageenan, with an exceptionally elastic gel and a yield approximately two-thirds that of the commercial producer *Eucheuma spinosum*; it could be commercially valuable, especially if its yields could be enhanced (I.C. Neish, personal communication).

The quality and application of a colloid are determined by its yield and the characteristics of its gel, especially gel strength and viscosity. Yield figures are often confused by variations in water content (I.C. Neish, personal communication); nevertheless, most of the species analyze-d provide yields comparable to those from commercial producers. Moss (1977) reports average values of 32 - 38% for commercial carrageenophytes and 17 - 25% for commercial agarophytes.

Variation in yield and type of colloid, however, is poorly understood. Both varied with species, geographical source, and season in the samples analyzed, but background data was insufficient to suggest causes. Fluctuations are known to be related to a variety of factors, including environmental conditions, reproductive state, and extraction technique. For example, carrageenan yields have been shown to vary with nutrient concentration in *Neoagardhiella* (DeBoer and Ryther, 1977) and carrageenan types with reproductive state in *Chondrus* (McCandless et al., 1973) and Iridaea (McCandless et al.,1975). McCandless (1975) demonstrated that most sporophytic carrageenophytes yield lambda carrageenan and most gametophytic carrageenophytes yield kappa carrageenan. Samples analyzed for the present study were not intentionally segregated into reproductive states, which may help to explain results such as the 50:50 lambda:kappa split in *Rhodoglossum* (which has isomorphic sporophytic and gametophytic Dhases) or the predominantly kappa fraction from *Gigartina and Gymnogongrus* (which can have a heteromorphic life cycle with only a crustose sporophytic stage).

This phenomenon is less consistent in agarophytes, although some variation with sexual phase has been suggested with local *Gracilaria* (Whyte and Englar, 1979b). Yield of agar from B.C. *Gracilaria* also fluctuates with type (Whyte and Englar, 1979a) and season (Lindsay and Saunders, 1979), although the ultimate role of environmental factors is emphasized (Whyte and Englar, 1979a). The gelation characteristics of a single population of *Gracilaria* "brown" type (site 42) changed from brittle, hard, and stiff to soft, elastic, and non-rigid with a change in season (Whyte and Englar, 1979a), demonstrating how highly influential the environment can be. In *Gracilaria* "chorda" type, there may be an inverse relation between yield and gel strength (J.N.C. Whyte, personal communication).

The effect of extraction technique on yield was demonstrated in this study with the enhancement of *Caulacanthus* agar by alkaline pretreatment (Whyte and Hosford, 1979), a technique that is used industrially in Japan (Tagawa and Kojima, 1972).

In general, however, sources of variability in algal colloids have not been thoroughly examined and must be more clearly understood before we can hope to realize the full commercial potential of any of these algae in a culture system.

3. <u>Screening and Selection</u>

Twenty varieties of algae were tested in culture during this study, including 28 trials in the F.A.C.S., 78 trials in the tanks, and 146 trials in the troughs (Table 3 and Appendices III - V). The populations studied in the F.A.C.S. came directly from field collections; all but four of these yielded plants for further screening in the tank and trough culture systems. Approximately half of the algae cultured in the tanks were initially screened in the F.A.C.S.; the rest came directly from field collections. Seventeen of these trials yielded superior plants for screening in the trough system. One of the tank cultures *(Gymnogongrus leptophyllus)* was still being monitored as of August 31, 1979. Of the 146 individuals or clumps of individuals examined in the troughs, the majority (64%) were selected from tank cultures and the rest from field collections (22%) or the F.A.C.S. (14%). Twenty trough cultures (all *Gymnogongrus leptophyllus)* were still in operation on August 31, 1979.

Specific growth rate measurements were biased by a number of factors. There may have been an acclimatization period for algae placed in culture and this could have been longer than the actual period of cultivation employed in this preliminary screening study. Increases in weight also included weight due to epiphytes; on the other hand, loss of plant material through the outflow or to other sources, such as necrosis, could not be quantified. The observed response of certain algae to culture conditions may have been due to previous or uncontrollable natural factors, or by handling, and in fact unrelated to the culture system itself. In addition, many factors such as plant density, plant health, and environmental conditions influence plant growth; since these were not uniform from one trial to the next, comparison of growth rates should be made cautiously. Growth rates recorded in this study were, with a few exceptions, relatively low. However, it must be emphasized

Table 3. List of algae cultured, number of trials and maximum growth rate of each in the three culture systems, and appraisal of the amenability of each to air-agitated cultivation.

Alga	F.A.C.S. number of trials	F.A.C.S. max. growth rate* (%/day)	TANKS number of trials	TANKS max. growth rate (%/day)	TROUGHS number of trials	TROUGHS max. growth rate (%/day)	General amenability to air-agitated culture	Major problems experienced in culture
Ahnfeltia gigartinoides	1	1.2	0		4		fair	slow growth, poor circulation
Ahnfeltia plicata	1	1.0	1	1.2	5		fair	slow growth
Caulacanthus ustulatus	1		2	1.8	3		fair	fragmentation, fouling
Endocladia muricata	0		0		1		undetermined	fragmentation, fouling
Gelidium sp.	1	5.4†	0		8	1.0	poor	fouling, slow growth
Gigartina agardhii	2		12	2.4	11	2.0	poor	slow growth
Gigartina etellata	2		3		6	1.4	poor	slow growth, poor circulation
Gracilaria "brown" type	3	3.2	5	2.3	18	5.5	good	Fouling
Gracilaria "chorda" type	3	3.0	15	2.4	9	3.1	very good	
Gracilaria "verrucosa" type	1		3		0		good	
Gymnogongrus leptophyllus	1	1.5	4	2.0	26	4.4	good	slow growth
Gymnogongrus linearis	1		4		5		poor	slow growth, poor circulation
Gymnogongrus platyphyllus	1		7		0		fair	Slow growth, Fertility
Iridaea cordata	0		0		1		undetermined	fertility, necrosis$^{\Omega}$
Iridaea cornucopiae	0		0		4		Undetermined	fertility, necrosis$^{\Omega}$
Laurencia spectabilis	1		1		1		poor	necrosis$^{\Psi}$, slow growth
Lomentaria hakodatensis	1		3		1	1.2	good	fragmentation, fouling
Neoagardhiella baileyi	4	1.5	9	1.7	23	4.2	very good	
Pseudogloiophloea confusa	1	2.2	2		1		good	necrosis$^{\Omega}$
Rhodoglossum affine	3	1.4	7	2.3	19		fair	necrosis$^{\Omega}$, fouling

* Growth rates of less than 1%/day were not considered in this analysis.
† Heavily fouled plants.
Ω Necrosis corresponding to natural decline of plants in the fall.
Ψ Necrosis apparently related to sorting and handling procedures and accompanying period of exposure to air.

that growth rates of most marine algae are minimal in the fall and winter months, when much of this study took place. Nevertheless, growth data did serve to indicate relative potentials and to identify individuals with superior growth under the culture conditions provided.

a. *Ahnfeltia*

Only one sample of *Ahnfeltia gigartinoides was* tested in the F.A.C.S. during 1978. Growth was slow (1.2%/day) although all the plants visibly increased pigmentation and lost some of their wiry texture within two weeks in culture. In addition, due to the high specific gravity of the species, agitation in the F.A.C.S. unit was inadequate to maintain the plants in suspension, a problem that may be remedied by increasing agitation. Individuals selected from the population in the F.A.C.S. unit were maintained in the trough system for nearly three months; growth, however, was negligible and all thalli eventually became totally epiphytized by diatoms and bryozoans. Again, the time of year of culture (early fall) is emphasized.

Ahnfeltia plicata behaved similar to *A. gigartinoides* in the F.A.C.S. In the tank system, *A. plicata* maintained a slow but consistent rate of growth (1.2%/day) for nearly five months, but eventually became overgrown with fouling organisms such as diatoms, *Ulva*, and, towards the end of the study, *Alaria*. Growth in the troughs was also slow and like *A. gigartinoides,* all plants were slowly but inevitably fouled. In summary, both species of Ahnfeltia demonstrated only fair potential for floating culture, limited primarily by slow growth.

b. *Caulacanthus*

Caulacanthus ustulatus initially performed well in the F.A.C.S. Circulation of the plants was good and bleached specimens became more darkly pigmented within two weeks. However, clumps of plants tended to break up due to the constant agitation; smaller portions were then able to block or escape through the outflow screen. Reducing the agitation may alleviate these problems. Caulacanthus also demonstrated a susceptibility to diatom fouling, and growth was relatively slow (<1.0%/day). Performance in the tank and trough systems was likewise poor; growth was also slow (maximum 1.8%/day in the tanks) and epiphytism was more of a problem. The overall potential of Caulacanthus for floating culture is restricted by these problems.

c. *Endocladia*

Due to the small volume of samples collected, *Endocladia muricata* was only tested in the troughs in 1978. Endocladia experienced problems in culture similar to those of Caulacanthus; clumps of thalli tended to act as a trap for diatoms and fragments of thalli often blocked or escaped the outflow, making accurate growth rate determinations impossible. *Endocladia* was maintained in the troughs for four months during the fall and winter, but all specimens eventually succumbed to necrosis. Its culture potential is doubtful considering these obstacles.

d. *Gelidium*

One sample of *Gelidium robustum* was tested in the F.A.C.S. in 1978. Circulation was fair provided additional aeration was supplied. However, colonial diatoms completely overgrew the thalli within two weeks, distorting growth rate measurements with diatom biomass and making further screening of this population impossible. The time of year and source of this particular population may have influenced this massive diatom infestation. In the trough system, *Gelidium* also displayed a marked susceptibility to epiphytism, especially diatoms and green algae. Growth in the form of new tissue was not observed in these plants. In conclusion, *Gelidium* appears to be too slow growing and too easily epiphytized to have potential for cultivation.

e. *Gigartina*

Gigartina agardhii remained visibly healthy and relatively epiphyte-free while in the F.A.C.S. although circulation was achieved only by supplying extra agitation and growth over a two-week period was negligible. Growth of *G. agardhii* in the tanks was also poor (average of 1.4%/day) although one trial grew especially well (2.4%/day) in the fall. Most plants eventually reached reproductive maturity in the tanks as well and slowly were overgrown with diatoms. Performance of *G. agardhii* in the trough system was similar. Although growing apices were evident, fertility and epiphytism were again problems, the amenability of *G. agardhii* to culture is thus questionable.

Like *G. agardhii, G. stellata* performed poorly in culture. Marginal necrosis was observed on some of the thalli after two weeks in the F.A.C.S., and growth (<1.0%/day) and the ability of this plant to remain in suspension were poor. In the tank and trough cultures, *G. stellata* grew slowly (maximum 1.49/day in the troughs); thalli were rapidly fouled by diatoms, became reproductive or fragmented and degenerated. As a result, the culture potential of *G. stellata.* is also doubtful.

f. *Gracilaria*

The behaviour of *Gracilaria* in culture has already been examined (Lindsay and Saunders, 1979): the F.A.C.S. was designed with algae like *Gracilaria* in mind. As a result, Gracilaria generally performs well, circulating easily and displaying good growth rates. New growth is evident in the form of small, spike-like branches and plants which are bleached when introduced darken within a short period of time. Fragmentation is often observed as a natural means of vegetative propagation in *Gracilaria.*

Gracilaria "brown" type displayed good summer growth in the F.A.C.S. (maximum 3.2%/day), although some populations were easily fouled by diatoms. In tank cultures, growth was also relatively good (maximum 2.3%/day); again, diatom fouling was a problem. Growth in the tanks declined simultaneously with a decrease in plant pigmentation. The maximum recorded growth rate in the troughs during the fall was 5.5%/day by an individual plant, although most other thalli had good growth rates as well (average 3.1%/day). Individuals displayed a loss of pigmentation after two or three months in the troughs and slowly became fouled by diatoms and Ulva, but overall growth was good. Possibly the intertidal nature of *G.* "brown" type affected its performance under constant submergence.

Gracilaria "chorda" type tended to braid or curl in culture, and displayed a maximum fall growth rate of 3.0%/day in the F.A.C.S. Some fragmentation occurred, but many new branchless were observed. Some diatom fouling took place, but G. "chorda" type did not appear to beas susceptible to epiphytes as *G.* "brown" type, and overall performance was very good in both the F.A.C.S. and tank cultures. Growth in the troughs was similar although bleaching, fragmentation, and epiphytism by diatoms and filamentous algae were observed more often in this culture system.

Gracilaria "verrucosa" type from the Queen Charlotte Islands demonstrated a slow but consistent fall and winter growth in the F.A.C.S. Tank cultures, however, tended to become reproductive and heavily epiphytized. The trough compartments proved to be too small for successful cultivation of the "verrucosa" type morphology.

Gracilaria in general, and "chorda" type in particular, demonstrates an excellent potential for cultivation.

g. *Gymnogongrus*

Gymnogongrus leptophyllus circulated well within the F.A.C.S. once additional aeration was provided and showed a low (1.5%/day) but consistent rate of growth. In the tank system, growth was slightly higher (maximum 2.0%/day) and the plants continued to grow into the winter months. Plant pigmentation was good and epiphytism only minor at this time of year. The performance of *G. leptophyllus* in the troughs was likewise good. Most trials demonstrated consistently good growth in the fall and winter with new tissue evident at the apices; a maximum winter rate of 4.4%/day was recorded. A variety of morphologies emerged in the trough cultures, from short and bushy forms to elongate and flattened forms. Some diatom fouling occurred but was not a major problem on the plants exhibiting continued growth. The culture potential of *G. leptophyllus* is promising if fast growing individuals can be isolated.

G. linearis grew slower and did not circulate as well in the F.A.C.S. as compared to *G. leptophyllus;* growth after three weeks was negligible and epiphytes soon covered the thalli. However, pigmentation visibly increased in the growing tips in only two weeks in the F.A.C.S. *G. linearis* also exhibited negligible growth in the tanks, and experienced problems with bleaching, epiphytism, and circulation. It was obviously not well suited to the tank design. In the troughs, performance was similarly poor; overall, *G. linearis* does not appear to be amenable to airagitated culture systems. *Gymnogongrus platyphyllus* circulated well but grew slowly (<1.0%/day) in both the F.A.C.S. and the tanks. Most plants were eventually discarded due to necrosis, ediphytism, or fertility. Trough culture of *G. platyphyllus* was not attempted in the study. This alga appears to have some potential for the F.A.C.S. culture, especially if screening can isolate rapidly-growing, vegetative individuals.

h. *Iridaea*

Due to small size of collections, both Iridaea *cordata* and *I. cornucopias* were tested only in the trough system during 1978. The thalli of both species degenerated following the appearance of reproductive structures. Growth was generally poor at the time these species were examined (fall and winter); however, new blades appeared from the old holdfast of one individual. Iridaea is the subject of much recent interest in the state of Washington (e.g. Mumford, 1977; Waaland, 1977; Waaland, 1976) where *I. cordata* spores are currently being seeded, both artificially and naturally, on nets and subsequently outplanted in Puget Sound (Mumford, 1979). The culture potential of these species warrants further examination.

i. *Laurencia*

Laurencia spectabilis circulated well in the F.A.C.S. but appeared to suffer from the handling and sorting and accompanying period of exposure to air. As a result, necrosis was evident in portions of most thalli after only 24 hours in culture; consequently, growth could not be measured accurately. In the tank and trough systems, *Laurencia* remained unhealthy and rapidly became overgrown by diatoms; overall growth was negligible. Laurencia does not appear to be amenable to cultivation due to its intolerance of present handling and sorting procedures.

j. *Lomentaria*

Lomentaria hakodatensis remained healthy and circulated well in the F.A.C.S. but, like Caulacanthus, experienced problems with excessive fragmentation. Due to the loss of fragments through the outflow, it was impossible to determine the growth rate for this alga. However, new tissue was observed on the plants within two weeks in culture. Lomentaria also experienced problems in the tanks and troughs, especially with diatom infestations of clumped thalli. However, with modifications to culture design, *Lomentaria* may prove to be amenable to cultivation.

k. *Neoagardhiella*

Neoagardhiella baileyi performed very well in the F.A.C.S., with a fair but consistent growth rate (maximum 1.5%/day); new growth appeared in the form of tiny spike-like branchless. Plants circulated well and maintained an even, dark red pigmentation. Epiphytism was usually restricted to older portions of the thalli. Growth in the tanks was similar, with evidence of new tissue, although necrosis and loss of pigmentation were observed in isolated cases. Growth in the troughs through the fall and winter was generally slow (maximum 2.0%/day) but accelerated in the early spring to a high of 4.2%/day by July, 1979. Epiphytism was more of a problem in the troughs, with diatoms and green algae often proliferating on the older tissue. In general, the potential of *Neoagardhiella* for culture is very good.

l. *Pseudogloiophloea*

Pseudogloiophloea confusa demonstrated a good potential for growth in the F.A.C.S., circulating well and displaying a relatively good growth rate (2.2%/day). However, an eventual deterioration of plant tissue, as evidenced by necrosis and a general decline in firmness, was observed in all culture facilities in the late summer, but was found to correspond with the natural condition of P. *confusa* in the field. As a result, *Poeudogloiophloea has* only limited culture potential.

m. *Rhodoglossum*

Suspension of *R. affine* in the F.A.C.S. was achieved only through additional agitation. Growth was slow (maximum 1.4%/day) but growing tips remained robust; the only major problem encountered was fouling of the older tissue. *Rhodoglosswn* cultured in the tanks during the summer displayed a relatively good growth rate (maximum 2.4%/day) but was susceptible to diatom and bryozoan fouling. During the late fall, apices tended to degenerate and deflate, resulting in necrosis and fragmentation. This loss of vigour during the fall was also observed in the trough cultures of *Rhodoglosswn;* growth at this point was negligible. However, *Rhodoglossum* does appear to have some culture potential if this apparently seasonal phenomenon can be controlled or eliminated.

Several problems were repeatedly encountered during the experimental cultivation of the previous algae. Fouling by diatoms and other algae (e.g. *Ulva, Ectocarpus)* was a widespread problem, especially in the spring and early summer. Epiphytes frequently exhibited growth rates higher than those of the cultured species, so often completely covered the cultivated plants. Some algae were more susceptible to epiphytism than others (particularly those with tiny branchless such as *Endocladia* and *Caulacanthus*) and slow growing algae often experienced additional problems with invertebrate foulers such as bryozoans and tube-forming polychaetes.

Many of the algae tested became reproductive while in culture (e.g. *Gigartina, Gracilaria, Iridaea);* this generally resulted in a decline in growth rate as well as necrosis of the fertile areas. Species capable of vegetative propagation, such as the fragmentation of *Gracilaria,* or continued growth during and after the production of reproductive structures will more readily lend themselves to large scale cultivation where constant production is an asset to economic viability.

Several algae experienced problems with the physical design of the culture facilities used in this study. Most types could be maintained in suspension by adjusting the degree of agitation, but some (e.g. *Ahnfeltia gigartinoides, Gymnogongrus linearis)* were not suited to this type of cultivation due to their. High specific gravity and thallus morphology. Smaller algae or those that fragmented easily (e.g. *Caulacanthus, Lomentaria)* often escaped through or blocked the outflow; modifications in outflow design may alleviate this problem. While most species maintained or increased their pigmentation in the F.A.C.S., many became bleached in the tanks and troughs, presumably due to the increased illumination in the tank and trough culture systems as compared to the F.A.C.S.

The following algae performed particularly well in this study: *Gracilaria* "chorda" type, *Gymnogongrus leptophyllus, and Neoagardhiella baileyi.* All showed an amenability to air-agitated culture and, through screening, indicated individuals or varieties with superior qualities. Others (e.g. *Gigartina, Rhodoglossum)* could be maintained for long periods of time at a low but consistent rate of growth, but will only be feasible for culture when particularly fast growing strains are found.

SUMMARY AND DISCUSSION

In this investigation, several areas along the British Columbia coast were sampled for colloid-bearing red seaweeds and a variety of potentially valuable species were located. Many were widely distributed, but no populations were found in commercially harvestable abundance. In addition, much of the coastline surveyed was remote, accessible only by boat. These features emphasize the need for cultivation of selected types of commercially important algae.

Colloid analysis of the collected algae identified several colloids of potential economic value. *Caulacanthus*, *Gelidium*, and *Gracilaria* produced attractive agars, with *Caulacanthus* and *Gelidium* yielding firm gels, characteristic of bacteriological agar, and *Gracilaria* yielding softer gels, characteristic of industrial grades.

Iridaea, Gigartina, Gymnogongrus, Neoagardhiella, and *Rhodoglossum* provided carrageenans of commercial interest. Iridaea produced a good yield of lambda type carrageenan, which forms viscous, non-gelling solutions. Kappa carrageenan forms brittle gels and was extracted in commercially attractive amounts from *Gigartina and Gymnogongrus.* *Neoagardhiella* yielded mostly iota carrageenan, which has special value in the preparation of dietary foods, and *Rhodoglossum* yielded a highly viscous kappa/lambda mixture.

Screening and selection isolated several types of algae with an amenability to air-agitated culture. However, only a few have commercial potential when the results of the colloid analysis are taken into consideration.

Gracilaria, the subject of several recent investigations (e.g. Lindsay and Saunders, 1977; Lindsay and Saunders, 1979), has the most optimistic future for cultivation of an agarophyte. Preliminary seedstock selection has already identified superior strains, such as the "chorda" type from Cherry Point (Lindsay and Saunders, 1979). Most importantly, however, *Gracilaria* is able to thrive under culture conditions. Once the causes of variability in the quality and quantity of agar produced by *Gracilaria* are fully understood, the potential for commercial cultivation of this alga will be markedly improved.

While *Caulacanthus* and *Gelidium* produce higher quality agars and greater yields, their cultivation potential is much lower than that of *Gracilaria.* Changes in technology will have to occur before Caulacanthus can be successfully farmed as its morphology does not suit current mass cultivation schemes. *Gelidium* has an extremely low growth rate relative to that of *Gracilaria,* so the economic feasibility of its production is quite doubtful unless a fast-growing strain is isolated.

Of the carrageenophytes with colloids of commercial interest, *Gymnogongrus leptophyllus and Neoagardhiella baileyi* show the greatest culture potential. *Neoagardhiella* is most amenable to the F.A.C.S.; considering its yields of predominantly iota carrageenan and the early culture successes of American researchers (e.g. DeBoer and Ryther, 1977), it may be a candidate for large-scale commercial cultivation. *Gymnogongrus leptophyllus* has such attractive yields of kappa carrageenan that its future is also encouraging.

Due to the high price and market demand for agar and the lack of stable natural supplies, any agarophyte with a commercially acceptable colloid and a potential for mass cultivation will have immediate market value. In the case of carrageenan producers, however, competition from established sources is a major factor. For example, the carrageenans from *Gymnogongrus and Neoagardhiella* should have immediate market acceptance, but those from *Gigartina*, *Iridaea, and Rhodoglossum* would have to compete with established *Chondrus* producers (Whyte and Hosford, 1979), wild stocks of other attractively priced Gigartinales (I.C. Neish, personal communication), and cultured Eucheuma from the Philippines.

In summary, three seaweeds with high potential for commercial cultivation were identified in this study: *Gracilaria* "chorda" type, *Gymnogongrus leptophyllus, and Neoagardhiella baileyi* (Table 4). However, the preliminary nature of this investigation is emphasized. Further sceening may isolate superior strains of those algae which demonstrated an overall low culture potential but which contain an attractive colloid (e.g. *Gelidium)* and further selection may locate other valuable species which were not dealt with in this study(e.g. *Dilsea and Grateloupia,* two local genera that Hoppe (1969) reports contain polysaccharides).

The demand for agar and carrageenan shows no sign of abatement. Although phycocolloids compete with other natural and synthetic gums, they still offer uniqueness and diversity, so are not likely to be replaced (Naylor, 1976). With increasing demand and widening uses, supply is now a problem; traditional wild sources of raw material are overexploited and new ones are often inaccessible or uneconomical to harvest. In addition, wild stocks are usually variable in quality and often unreliable in yield. Consequently, interest in mass cultivation has recently intensified, encouraged by the prosperity of seaweed farming in other areas of the world. The success of the *Eucheuma cottonii* farming for kappa-carrageenan (Doty, 1979) demonstrates the stabilizing effect that cultivation can have on colloid markets.

The development of seaweed farming technologies in British Columbia began only recently. The future is promising, but before large-scale commercialization can be attempted, several areas require further investigation. Selecting superior strains of algae with commercially valuable colloids is of prime importance, but our basic biological knowledge of these seaweeds must also be expanded.

Table 4. Summary of colloid analysis and culture potential of the algae collected.

Alga	Colloid Type	Commercial Value of Colloid	Amenability to air-agitated culture (F.A.C.S.)
Ahnfeltia gigartinoides	carrageenan	good	fair
Ahnfeltia plicata	carrageenan	good	fair
Caulacanthus ustulatus	agar	very good	fair
Ceramium sp.	?	poor	not tested
Endocladia muricata	agaroid	good	not tested
Gelidium sp.	agar	good	poor
Gigartina agardhii	carrageenan	very good	poor
Gigartina stellata	carrageenan	very good	poor
Gracilaria "brown" type	agar	good	good
Gracilaria "chorda" type	agar	good	very good
Gracilaria "verrucosa" type	agar	good	good
Gymnogongrus leptophyllus	carrageenan	very good	good
Gymnogongrus linearis	carrageenan	good	poor
Gymnogongrus platyphyllus	carrageenan	good	fair
Iridaea cordata	carrageenan	very good	not tested
Iridaea cornucopiae	not tested	not tested	not tested
Laurencia spectabilis	agaroid	poor	poor
Lomentaria hakodatensis	?	poor	good
Neoagardhiella baileyi	carrageenan	very good	very good
Pseudogloiophloea confusa	?	poor	good
Rhodoglossum affine	carrageenan	very good	good

As Naylor (1976) states, "...a full knowledge of the plant's biology ... is a fundamental prerequisite to successful seaweed cultivation". The chemical nature of most phycocolloids and the sources of variation in colloid content are not fully understood either. Yield and quality are known to vary with many factors including species, site, season, and processing, but casual relationships must be comprehended before control or manipulation of phycocolloids can be achieved. There is also a gap in information on the genetics and reproduction of colloid-bearing seaweeds; such information is necessary in order to form an empirical basis for the selection, maintenance, and manipulation of seedstocks.

Although cultivation technology has progressed rapidly in recent years, mass culture has its own technical and biological problems which remain to be solved. Technically, a large-scale culture facility must be flexible in order to accommodate market fluctuations as well as manipulative in order to optimize growth and colloid production. More specifically, the relationship of nutrition, plant density, and growth to colloid production needs further clarification. Biologically, the major problem encountered in mass monoculture is fouling by unwanted organisms and this is an area demanding immediate attention. In addition, the economic feasibility of mass cultivation has to be evaluated. Cheap and efficient large-scale culture systems have to be designed and tested and potential sites for a culture operation need to be identified.

Finally, there are administrative problems confronting commercial seaweed cultivation As Doty (1977) comments, "...the physical environment and the biological characteristics of algae may not be the severe barriers to economic seaweed production that the bureaucratic and socio-political ones are.....Seaweed research should be uncoupled from year-to-year project funding, from traditional thinking, and from its all too frequent submersion in other programs."

Nevertheless, the future of mass seaweed cultivation in British Columbia is optimistic and, considering recent advances, the potential of a phycocolloid industry should soon be realized.

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APPENDIX I

Site description and collection data for 59 sites along the coast of B.C. sampled for selection of culture seedstock during 1978.

Site Number	Location and Dates	Latitude and Longitude	Site Description	Species Collected
1.	Bamfield Inlet, west side 24/5/78, 19/7/78	48° 50.2'N 125° 08.3'W	rocky; semi-sheltered intertidal	*Gelidium* sp., *Gracilaria* "verrucosa" type
2.	Grappler Inlet, north shore 24/5/78	48° 50.3'N 125° 07.9'W	rocky; moderately exposed intertidal	*Gelidium* sp., *Gigartina stellata*, *Gymogongrus leptophyllus*, *Neoagardhiella baileyi*
3.	Wiseman's Bay 24/5/78, 14/9/78	48° 49.9'N 125° 08.1'W	rocky, gravel and sand; sheltered intertidal	*Gigartina stellata*, *Gracilaria* "brown" type
4.	Bamfield Marine Station 8/6/78	48° 50.1'N 125° 08.1'W	rocky; semi-sheltered intertidal	*Gelidium* sp., *Gigartina agardhii*, *Gigartina stellata*, *Gymnogongrus platyphyllus*, *Rhodoglossum affine*
5.	Grappler Inlet, south shore 8/6/78	48° 50.2'N 125° 07.9'W	rocky; semi-sheltered intertidal	*Gigartina agardhii*, *Gigartina stellata*, *Iridaea cordata*
6.	Mills Peninsula, west shore 8/6/78, 19/7/78	48° 50.2'N 125° 08.5'W	rocky; moderately exposed intertidal	*Ahnfeltia gigartinoides*, *Gigartina agardhii*, *Rhodoglossum affine*
7.	Dixon Island, north shore 9/6/78	48° 51.2'N 125° 06.9'W	bedrock and boulder; moderately exposed intertidal	*Gigartina agardhii*, *Gigartina stellata*, *Gymnogongrus platyphyllus*, *Rhodoglossum affine*

8.	Haines Island, south shore 20/6/78, 22/7/78	48° 49.8'N 125° 11.7'W	rocky; moderately exposed intertidal	*Gigartina agardhii*, *Gigartina stellata*, *Rhodoglossum affine*
9.	Small islet north of Haines Island 20/6/78, 24/7/78	48° 50.3'N 125° 12.1'W	rocky sheltered intertidal	*Gigartina agardhii*, *Gigartina stellata*, *Rhodoglossum affine*
10.	Diana Island, Kirby Point 20/6/78	48° 50.8'N 125° 12.1'W	surge channel; exposed intertidal	*Rhodoglossum affine*
11.	Geer Islets 21/6/78	48° 55.5'N 125° 06.5'W	rocky; semi- sheltered intertidal	*Gelidium* sp., *Gigartina agardhii*, *Gigartina stellata*, *Gymnogongrus leptophyllus* *Rhodoglossum affine*
12.	Meade Islets 21/6/78, 19/7/78, 21/7/78, 12/9/78, 29/11/78	48° 55.5'N 125° 07.2'W	boulder beach; semi-sheltered intertidal	*Ahnfeltia gigartinoides*, *Caulacanthus ustulatus*, *Endocladia muricata*, *Gigartina stellata*, *Gymnogongrus leptophyllus*, *Lomentaria hakodatansis*
13.	Dixon Island, southwest shore 22/6/78	48° 51.1'N 125° 07.3'W	bedrock and boulder; semi-exposed intertidal	*Gelidium* sp., *Gymnogongrus leptophyllus* *Gymnogongrus platyphyllus*, *Rhodoglossum affine*

14.	Diana Island, southwest shore 23/6/78	48° 50.3'N 125° 11.7'W	boulder and sand beach; sheltered intertidal	*Gigartina stellata*, *Gracilaria* "verrucosa" type, *Gymnogongrus leptophyllus*, *Gymnogongrus platyphyllus*, *Rhodoglossum affine*
15.	Sanford Island, northwest shore 6/7/78	48° 52.3'N 125° 09.9'W	surge channel and rocky beach; moderately exposed intertidal	*Gigartina agardhii*, *Gigartina stellata*, *Gymnogongrus leptophyllus*, *Rhodoglossum affine*
16.	Fleming Island, northwest shore 6/7/78, 21/7/78	48° 53.0'N 125° 08.8'W	bedrock and boulder; sheltered intertidal	*Gymnogongrus platyphyllus*, *Rhodoglossum affine*
17.	Brady's Beach 19/7/78	48° 49.7'N 125° 09.0'W	sand; moderately exposed intertidal	*Ahnfeltia gigartinoides*, *Ahnfeltia plicata*, *Gracilaria* "chorda" type, *Gymnogongrus linearis*
18.	Haines Island, north shore 20/7/78	48° 50.2'N 125° 12.1'W	bedrock and boulder; moderately exposed intertidal	*Gigartina stellata*, *Rhodoglossum affine*
19.	Tzartus Island, Sproat Bay 21/7/78, 11/9/78	48° 54.4'N 125° 04.6'W	mud and silt; sheltered subtidal	*Gracilaria* "verrucosa" types, *Neoagardhiella baileyi*
20.	Diana Island, north shore 26/7/78	48° 50.9'N 125° 11.2'W	bedrock, boulder and sand; sheltered intertidal, subtidal	*Rhodoglossum affine*
21.	Islets south of Ohiat Island 2617/78, 15/8/78	48° 51.2'N 125° 11.9'W	intertidal bedrock and subtidal sand; moderately exposed	*Gigartina agardhii*, *Neoagardhiella baileyi*, *Pseudogloiophloea confusa*

22.	Channel between Fry and Tzartus Islands 27/7178	48° 54.8'N 125° 06.7'W	intertidal bedrock, subtidal shell and gravel; moderately exposed	*Gelidium* sp., *Gymnogongrus leptophyllus*, *Pseudogloiophloea confusa*
23.	Tzartus Island Holford Bay 27/7/78	480 56.3'N 125 05.0'W	boulder, bedrock, and sand-gravel; semi-sheltered subtidal	*Gelidium* sp., *Gracilaria* "verrucosa" type
24.	Stud Islets 27/7/78	48° 56.5'N 125° 05.6'W	sand, gravel, boulder and bedrock; sheltered intertidal and subtidal	*Gelidium* sp., *Gracilaria* "verrucosa" type, *Gymnogongrus leptophyllus*, *Pseudogloiophloea ccnfusa*
25.	Robert's Bay 1/8/78	48° 39.2'N 123° 24.0'W	mud and silt; sheltered intertidal	*Gracilaria* "brown" type
26.	Cherry Point 1/8/78, 4/12/78	48° 42.5'N 123° 32.8'W	sand; moderately exposed intertidal and subtidal	*Gracilaria* "chorda" type *Gracilaria* "verrucosa" type
27.	Comox Bar, Willimar Bluff 2/8/78	49° 40.2'N 124° 53.2'W	sand, pebble and boulder; exposed subtidal	*Gracilaria* "verrucosa" type, *Neoagardhiella baileyi'*
28.	Nuttal Bay 3/8/78, 7/12/78	49° 18.5'N 124° 11.1,W	boulder, bedrock, sand and silt; sheltered, subtidal	*Gracilaria* "chorda" type, *Gracilaria* "verrucosa" type, *Neoagardhiella baileyi*
29.	Alma Russel Islands 9/8/78	48° 57.1'N 125° 12.0'W	sand and silt; sheltered subtidal	*Gracilaria* "verrucosa" type *Neoagardhiella baileyi'*

30.	Pinkerton Islands 10/8/78	48° 57.1'N 125° 17.0'W	shell sand and gravel; sheltered intertidal and subtidal	*Gracilaria* "verrucosa" type
31.	Channel between Reeks and Turner Islands 10/8/78	48° 55.3'N 125° 13.8'W	intertidal bedrock and boulder, subtidal shell sand and gravel; Moderately exposed	*Gelidium* sp., *Gracilaria* "chorda" type, *Gymnogongrus leptophyllus*, *Rhodoglossum affine*
32.	Edward King Island, north shore 17/8/78	48° 50.0'N 125° 12.4'W	sand, moderately exposed intertidal and subtidal	*Ahnfeltia gigartinoides*, *Gigartina agardhii*, *Gigartina stellata*, *Gracilaria* "verrucosa" type, *Rhodoglossum affine*
33.	Channel between Edward King and Haines Islands 19/8/78	48° 49.8'N 125° 12.1'W	bedrock and boulder; moderately exposed intertidal	*Gigartina agardhii*, *Gigartina stellata*, *Gymnogongrus platyphy llus*
34.	Chaftnel between Clark and Owens Islands 22/8/78	48° 53.6N 125° 22.5'W	intertidal bedrock, subtidal sand; moderately exposed	*Gelidium* sp., *Neoagardhiella baileyi*, *Rhodoglossum affine*
35.	Channel between Lovett and Puffin Islands 23/8/78	48° 54.2'N 125° 22.4'W	bedrock; exposed subtidal	*Laurencia spectabilis*
36.	Islets west of Tricket Island 23/8/78	48° 54.5'N 125° 21.9'W	bedrock, boulder and sand; sheltered intertidal and subtidal	*Gelidium* sp., *Gracilaria* "verrucosa" type, *Gymnogongrus leptophyllus*, *Rhodoglossum affine*

37.	Bay east of Execution Rock 6/9/78	48° 48.8'N 125° 10.5'W	bedrock, boulder and sand-pebble; moderately exposed intertidal and subtidal	*Ahnfeltia plicata*, *Gigartina agardhii*, *Gymnogongrus linearia*, *Rhodoglossum affine*
38.	Edward King Island, east shore 7/9/78	48° 49.7'N 125° 12.6'W	bedrock, boulder, and sand; moderately exposed intertidal and subtidal	*Gigartina agardhii*, *Gymnogongrus platyphyllus*, *Rhodoglossum affine*
39.	Edward King Island, west shore 14/9/78	48° 49.8'N 125° 13.0'W	bedrock and boulder; exposed subtidal	*Gymnogongrus leptophyllus*
40.	Edward King Island, east shore 14/9/78	48° 49.5'N 125° 12.8'W	bedrock and sand; moderately exposed intertidal and subtidal	*Gigartina agardhii*, *Gigartina stellata*
41.	Northwest Bay 29/12/78	49° 17.9'N 124° 11.8'W	bedrock and sand; sheltered intertidal	*Gelidium* sp.
42.	Bamfield Inlet 12/12/78	48° 48.9'N 125° 09.1,W	mud and silt; sheltered intertidal	*Caulacanthus ustulatus*
43.	Fitz Island 1/6/78	49° 46.0'N 126° 55.7'W	rocky; moderately exposed intertidal and subtidal	*Ceramium* sp.
44.	Skidegate Channel 9/9/78	53° 08.9'N 132° 15.4'W	shell sand and cobble; sheltered subtidal with heavy tidal action	*Gracilaria* "verrucosa" type, *Neoagardhiella baileyi*

45.	Rooney Bay 10/9/78	53° 15.9'N 131° 59.0'W	shell sand with scattered boulders; exposed subtidal	*Gracilaria* "verrucosa" type, *Gelidium* sp.
46.	McIntyre Bay 10/9/78	54° 03.0'N 132° 10.3'W	sand and boulder; exposed subtidal	*Gracilaria* "verrucosa" type
47.	Graham Island, Wiah Point 14/9/78	54° 07.1'N 132° 18.6'W	bedrock and boulder; exposed intertidal and subtidal	*Endocladia muricata*, *Gigartina agardhii*, *Gymnogongrus linearis*
48.	Spike Island, southwest shore 15/9/78	54° 14.9'N 130° 21.8'W	bedrock and boulder; moderately sheltered subtidal	*Gigartina stellata*
49.	Lima Point 15/9/78	54° 14.9'N 130° 22.6'W	bedrock; moderately exposed intertidal	*Gigartina agardhii*, *Gigartina stellata*
50.	Chassepot Rocks 15/9/78	54° 14.0'N 130° 23.8'W	bedrock; exposed intertidal	*Gigartina agardhii*, *Gigartina stellata*
51.	Lucy Island 1519/78	54° 17.7'N 130° 37.2'W	bedrock and boulder; exposed intertidal and subtidal	*Endocladia muricata*, *Gigartina agardhii*, *Gigartina stellata*, *Iridaea cornucopiae*
52.	Kinahan Island, west shore 17/9/78	54° 12.21N 130° 24,8'W	bedrock and boulder, exposed subtidal	*Gigartina agardhii*
53.	Tree Nob Group 18/9/78	54° 14.5'N 130° 51.8'W	bedrock, moderately exposed intertidal	*Gigartina agardhii*, *Gigartina stellata*, *Iridaea cornucopiae*

54.	Refuge Bay 19/9/78	54° 03.3'N 130° 32.4'W	bedrock, sheltered intertidal	*Gigartina agardhii*, *Gigartina stellata*
55.	Porcher Narrows 22/9/78	53° 53.2'N 130° 28.5'W	sand and bedrock; sheltered subtidal with heavy tidal action	*Neoagardhiella baileyi*
56.	Bay on northwest tip of Porcher Peninsula 22/9/78	53° 51.0'N 130° 36.6'W	sand and shell sand; sheltered subtidal	*Gracilaria* "chorda" type, *Gracilaria* "verrucosa" type
57.	Channel between Porcher Peninsula and Absolum Island 19/9/78	53° 51.5'N 130° 36.5'W	shell sand and cobble semi-sheltered subtidal	*Gracilaria* "verrucosa" type, *Neoagardhiella baileyi*, *Rhodoglossum affine*
58.	Channel north of Kirkendale Island 25/9/78	53° 30.6'N 130° 25.4'W	intertidal boulders extending to subtidal mud and sand; sheltered	*Gracilaria* "verrucosa" type
59.	Channel between Kirkendale and Shadford Islands 25/9/78	53° 29.0'N 130° 25.1'W	shell sand; sheltered subtidal	Gracilaria "verrucosa" type, *Neoagardhiella baizeyi*

APPENDIX II

Collection data, culture history, colloid type, and colloidal properties of 145 samples of 20 types of algae analyzed during 1978.

Alga	Sample Number	Source and Date Dried	Site Number and Date Collected	Analyzed by	Colloid Type	Average yield (% clean dry wt.)	Viscosity	Gel Strength	Comments
Ahnfeltia gigartinoides	1	field,7/4/78	#17,7/4/78	M.C.					not analyzed
	77	F.A.C.S.,17/8/78	#6&12,19/7/78	M.C.					not analyzed
	78	F.A.C.S.,17/8/78	#6&12,19/7/78	Whyte	carrageenan	24.9			iota form
	79	field,17/8/78	#32,17/8/78	M.C.					not analyzed
	80	field,17/8/78	#32,17/8/78	Whyte	carrageenan	23.0			iota form
Ahnfeltia plicata	104	field,6/9/78	#37,6/9/78	Whyte	carrageenan	24.5			iota form
	105	field,6/9/78	#37,6/9/78	M.C.					not analyzed
	130	F.A.C.S.,25/9/78	#37,6/9/78	Whyte	carrageenan	26.6			Iota form
	131	F.A.C.S.,25/9/78	#37,6/9/78	M.C.					not analyzed
	161	tanks,27/10/78	#37,6/9/78	Whyte	carrageenan	17.6			iota form
Caulacanthus ustulatus	114	field,12/9/78	#12,12/9/78	Whyte	agar	28.8	168.0*	227.0†	
	141	F.A.C.S.,29/9/78	#12,12/9/78	M.C.	agar	24.7		1336.0Ψ	
	142	F.A.C.S.,29/9/78	#12,12/9/78	Whyte	agar	30.7	34.0*	213.0†	
Ceramium sp.	145	field,25/9/78	#58,25/9/78	Whyte	not identified	9.8			
Endocladia muricata	4	field,1/6/78	#43,1/6/78	Whyte	agaroid	42.1		4.3†	
Gelidium sp.	3	field,24/5/78	#1&2,24/5/78	Whyte	agar	12.3		377.6†	
	18	field,21/6/78	#11,21/6/78	M.C.					not analyzed
	38	field,27/7/78	#24,27/7/78	Whyte	agar	27.4		46.3†	
	40	field,27/7/78	#22,27/7/78	M.C.					not analyzed
	71	field,10/8/78	#29,10/8/78	Whyte	agar	23.6		68.0†	
	72	field,10/8/78	#29,10/8/78	M.C.					not analyzed
	81	field,22/8/78	#34,22/8/78	Whyte	agar	28.0		121.0†	
	82	field,22/8/78	#34,22/8/78	M.C.					not analyzed
Gigartina agardhii	14	field,20/6/78	#8,20/6/78	M.C.	carrageenan	50.8	66.0Ω	40.0Ψ	pool of 8 samples
	33	field,26/7/78	#21,26/7/78	Whyte	carrageenan	53.6			80.6% k, 19.4% l
	34	field,26/7/78	#21,26/7/78	M.C.	carrageenan				pooled
	62	F.A.C.S.,8/8/78	#8,22/7/78	Whyte	carrageenan	44.4			
	63	F.A.C.S.,8/8/78	#8,22/7/78	M.C.	carrageenan				pooled
	106	field,6/9/78	#37,6/9/78	Whyte	carrageenan	54.6			
	110	F.A.C.S.,1/9/78	#33,19/8/78	Whyte	carrageenan	52.6			
	111	F.A.C.S.,1/9/78	#33,19/8/78	M.C.	carrageenan				pooled
	118	field,16/9/78	#78,16/9/78	M.C.	carrageenan				pooled
	123	field,14/9/78	#75,14/9/78	Whyte	carrageenan	52.9			
	156	tanks,24/10/78	#33,19/8/78	Whyte	carrageenan	50.3			
	157	tanko,24/10/78	#74,14/9/78	Whyte	carrageenan	51.9			
	158	tanks,24/10/78	#74,14/9/78	M.C.	carrageenan				pooled
	159	tanko,20/10/78	#33,19/8/78	Whyte	carrageenan	52.9			
	162	tanks,21/10/78	#33,19/8/78	M.C.	carrageenan				pooled
	166	tanks,27/10/78	10/78	M.C.	carrageenan				pooled
Gracilaria stellata	12	field,20/6/78	#8,20/6/78	M.C.					not analyzed
	13	field,20/6/78	#8,20/6/78	Whyte	carrageenan	48.2			60.8% k, 39.2% l
	59	F.A.C.S.,8/8/78	#18,20/7/78	Whyte	carrageenan	39.2			
	60	F.A.C.S.,8/8/78	#18,20/7/78	M.C.					not analyzed
	108	F.A.C.S.,2/9/78	#33,19/8/78	Whyte	carrageenan	29.4			
	109	F.A.C.S.,2/9/78	#33,19/8/78	M.C.					not analyzed
	120	field,16/9/78	#51,16/9/78	M.C.					not analyzed
	121	field,15/9/78	#48,15/9/78	M.C.					not analyzed

	164	tanks,27/10/78	#33,19/8/78	Whyte	carrageenan	49.1			
Gracilaria "brown" type	9	F.A.C.S.,13/8/77	#3,13/7/77	Whyte	agar	40.2		none†	
	10	field,8/8/77	#3,8/8/77	Whyte	agar	10.1		none†	
	25	field,19/7/78	#1,19/7/78	Whyte	agar	23.1		88.0†	
	27	field,19/7/78	#1,19/7/78	M.C.					not analyzed
	61	F.A.C.S.,8/8/78	#3,19/7/78	Whyte	agar	23.9		21.5†	
	116	field,14/9/78	#3,14/9/78	M.C.					
	117	field,14/9/78	#3,14/9/78	Whyte	agar	25.0		4.0†	not analyzed
	124	tanks,19/9/78	#3,19/7/78	M.C.					
	125	tanks,19/9/78	#3,19/7/78	Whyte	agar	26.8		135.0†	not analyzed
	138	F.A.C.S.,26/9/78	#25,1/8/78	M.C.					not analyzed
	139	F.A.C.S.,26/9/78	#25,1/8/78	Whyte	agar	13.6		23.0†	
	148	F.A.C.S.,19/10/78	#25,1/8/78	Whyte	agar	13.4		52.0†	
	150	F.A.C.S.,19/10/78	#3,14/9/78	Whyte	agar	28.8		348.0†	
	152	tanks,20/10/78	#1&3,19/7/78	Whyte	agar	24.9		119.0†	
Gracilaria "chorda" type ·	5	field,8/5/78	#26,8/5/78	Whyte	agar	15.6		0.0†	
	6	field,19/9/77	#26,19/9/77	Whyte	agar	20.7		395.0†	
	7	field,18/7/77	#17,18/7/77	Whyte	agar	32.7		0.0†	
	8	field,26/9/77	#17,26/9/77	Whyte	agar	16.6		0.0†	
	20	field,23/6/78	#14,23/6/78	Whyte	agar	31.8		59.3†	
	48	field,3/8/78	#28,3/8/78	Whyte	agar	37.8		50.5†	
	49	field,1/8/78	#26,1/8/78	M.C.					not analyzed
	51	field,1/8/78	#26,1/8/78	Whyte	agar	31.6		9.2†	
	64	F.A.C.S.,8/8/78	#19,21/7/78	M.C.					not analyzed
	65	F.A.C.S.,8/8/78	#19,21/7/78	Whyte	agar	25.8		99.0†	
	73	field,10/8/78	#31,10/8/78	M.C.					not analyzed
	74	field,10/8/78	#31,10/8/78	Whyte	agar	23.9		58.3†	
	136	F.A.C.S.,26/9/78	#19,11/9/78	Whyte	agar	29.6		57.0†	
	137	F.A.C.S.,26/9/78	#19,11/9/78	M.C.					not analyzed
	144	field,22/9/78	#57,22/9/78	M.C.					
Gracilaria "verrucosa" type	36	field,27/7/78	#24,27/7/78	M.C.					not analyzed
	37	field,27/7/78	#24,27/7/78	Whyte	agar	17.5		57.0†	not analyzed
	46	field,3/8/78	#28,3/8/78	Whyte	agar	29.3		0.0†	
	47	field,3/8/78	#28,3/8/78	Whyte	agar	14.6		106.7†	
	50	field,1/8/78	#26,1/8/7R	Whyte	agar	20.1		39.0†	
	52	field,2/8/78	#27,2/8/78	Whyte	agar	22.6		119.7†	
	53	field,2/8/78	#27,2/8/78	M.C.					not analyzed
	54	field,3/8/78	#28,3/8/78	Whyte	agar	25.4		361.7†	
	55	field,3/8/78	#28,3/8/78	M.C.	agar	18.6		1008.0Ψ	
	66	field,10/8/78	#30,10/8/78	Whyte	agar	26.1		60.0†	
	141	field,29/9/78	#59,29/9/78	Whyte	agar	29.8		272.0†	
Gymnogongrus leptophyllus	16	field.21/6/78	#11,21/6/78	M.C.					not analyzed
	17	field,21/6/78	#11,21/6/78	Whyte	carrageenan	48.4			84.4% k, 13.6% l
	28	field,21/7/78	#12,21/7/78	Whyte	carrageenan	39.4			89.9% k. 10.1% l
	39	field,27/7/78	#24,27/7/78	M.C.					not analyzed
	43	tanks,3/8/78	#12,21/7/78	M.C.					not analyzed
	44	tanks,3/8/78	#12,21/7/78	Whyte					not analysed
	85	field,23/8/78	#36,23/8/78	Whyte	carrageenan	36.1			
	115	field,14/9/78	#39,14/9/78	M.C.					not analyzed
	160	tanks,25/10/78	#36,23/8/78	M.C.	carrageenan	64.0	34.0Ω	340.0Ψ	kappa-like
Gymnogongrus linearis	2	field,7/4/78	#17,7/4/78	M.C.					not analyzed
	26	field,19/7/78	#17,19/7/78	Whyte	carrageenan	36.3			

	75	F.A.C.S.,17/8/78	#17,19/7/78	M.C.					not analyzed
	76	F.A.C.S.,17/8/78	#17,19/7/78	Whyte	carrageenan	40.5			
Gymnogongrus platyphyllus	19	field,22/6/78	#13,22/6/78	M.C.					not analyzed
	98	F.A.C.S.,1/9/78	#33,18/8/78	Whyte	carrageenan	25.6			
	99	F.A.C.S.,1/9/78	#33,18/8/78	M.C.					not analyzed
	165	tanks,27/10/78	#33,18-19/8/78	Whyte	carrageenan	32.2			
Iridaea cordata		field,31/6/76	#27,31/6/76	Whyte	carrageenan	40.0	3650.0*		96.0%ι, 4.0% κ
Laurencia spectabilis	86	field,23/8/78	#35,23/8/78	Whyte	agaroid	21.3			
	87	field,23/8/78	#35,23/8/78	M.C.					not analyzed
	112	F.A.C.S.,11/9/78	#35,23/8/78	M.C.					not analyzed
	113	F.A.C.S.,11/9/78	#35,23/8/78	Whyte	agaroid	15.0		0.0†	
Lomentaria hakodatensis	15	field,21/6/78	#12,21/6/78	M.C.	unidentified	15.9		0.0$^\psi$	
Neoagardhiella bailezyi	29	field,24/7/78	#9&14,24/7/78	M.C.	carrageenan	36.2	39.0$^\Omega$	290.0$^\psi$	pool of 5 samples
	31	field,26/7/78	#21,26/7/78	M.C.	carrageenan				pooled
	56	field,2/8/78	#27,2/8/78	Whyte	carrageenan	19.8			iota form
	67	field,9/8/78	#29,9/8/78	Whyte	carrageenan	29.4			iota form
	68	field,9/8/78	#29,9/8/78	M.C.	carrageenan				pooled
	83	field,23/8/78	#34,23/8/78	M.C.	carrageenan				pooled
	84	field,23/8/78	#34,23/8/78	Whyte	carrageenan	27.2			
	126	F.A.C.S.,19/9/78	#34,22/8/78	Whyte	carrageenan	25.3			
Neoagardhiella baileyi	127	F.A.C.S.,19/9/78	#34,22/8/79	M.C.	carrageenan				pnoled
	128	F.A.C.S.,22/9/78	#29,9-10/8/78	M.C.					not analyzed
	129	F.A.C.S.,22/9/78	#29,9-10/8/78	Whyte	carrageenan	21.2			iota form
	134	F.A.C.S.,25/9/78	#19,11/9/78	Whyte	carrageenan	25.1			iota form
	135	F.A.C.S.,25/9/78	#19,11/9/78	M.C.					not analyzed
	151	tanks,20/10/78	#34,22/8/78	Whyte	carrageenan	23.5			iota form
	163	tanks,27/10/78	#19,11/9/78	Whyte	carrageenan	24.5			iota form
Pseudogloiophloea confusa	41	field,27/7/78	#22,27/7/78	Whyte	unidentified	9.8			poor gel
	42	field,27/7/78	#22,27/7/78	M.C.					not analyzed
	92	F.A.C.S.,30/8/78	#21,15/8/78	M.C.					not analyzed
	93	F.A.C.S.,30/8/78	#21,15/8/78	Whyte	unidentified	16.2		0.0†	poor polymer
Rhodoglossum affine	11	field,20/6/78	#8,20/6/78	Whyte	carrageenan	56.1			57.3% ι, 42.7% κ
	21	field,7/7/78	#16,7/7/78	M.C.	carrageenan	61.7	267.0$^\Omega$	50.0$^\psi$	pool of 6 samples
	32	field,26/7/78	#20,26/7/78	M.C.	carrageenan				pooled
	35	field,26/7/78	#20,26/7/78	Whyte	carrageenan	43.4			50.5% ι, 49.5% κ
	57	F.A.C.S.,8/8/78	#8&18,20/7/78	Whyte	carrageenan	57.6			
	58	F.A.C.S.,8/8/78	#8&18,20/7/78	M.C.	carrageenan				pooled
	69	field,10/8/78	#31,10/8/78	Whyte	carrageenan	55.4			
	70	field,10/8/78	#31,10/8/78	M.C.	carrageenan				pooled
	88	field,22/8/78	#34,22/8/78	M.C.	carrageenan				pooled
	89	field,22/8/78	#34,22/8/78	Whyte	carrageenan	52.3			
	96	F.A.C.S.,1/9/78	#33,18/8/78	M.C.	carrageenan				pooled
	97	F.A.C.S.,1/9/78	#33,18/8/78	Whyte	carrageenan	53.4			
	107	field,7/9/78	#38,7/9/78	Whyte	carrageenan	47.7			
	132	F.A.C.S.,25/9/78	#9,7/9/78	Whyte	carrageenan	45.4			
	133	F.A.C.S.,25/9/78	#9,7/9/78	M.C.					not analyzed

* Viscosity measured in centipoise, using a 1% solution at 65°C (Whyte and Hosford. 1979).

† Gel strength measured in g/cm^2, defined as **the** force required to rupture a 1% aqueous solution of polysaccharide using an Instron Model 1122 (Whyte and Hosford, 1979).

ψ Gel strength measured in g breakforce, using a 0.91 cm^2 plunger and 2.0% gel (Marine Colloids, personal communication).

Ω Viscosity measured in Milli Pascal seconds, using a 1.5% solution at 75°C (Marine Colloids, Personal communication).

APPENDIX III

Collection data, culture history, and fate of 28 trials of 17 types of algae in the F.A.C.S. during 1978.

Alga	Site Number and Date Collected	Period in F.A.C.S.	Stocking Density (kg/m^2)	Average Growth Rate* (%/day)	Fate
Ahnfeltia gigartinoides	#6&12,19/7/78	19/7/78-17/8/78	0.4	1.2	troughs
Ahnfeltia plicata	#37,6/9/78	8/9/78-25/9/78	0.3	1.0	tanks & troughs
Caulacanthus ustulatus	#12,12/9/78	13/9/78-29/9/78	0.9	<1.0	discarded
Gelidium robustum	#4,19/7/78	19/7/78-8/8/78	0.2	5.4†	discarded
Gigartina agardhii	#8,22/7/78	24/7/78-8/8/78	0.6	<1.0	tanks
	#33,19/8/78	19/8/78-1/9/78	1.3	<1.0	tanks
Gigartina stellata	#18,20/7/78	20/7/78-8/8/78	1.0	<1.0	tanks
	#33,19/8/78	19/8/78-2/9/78	0.5	<1.0	tanks
Gracilaria "brown" type	#1&3,19/7/78	19/7/78-8/8/78	1.5	3.2	tanks
	#25,1/8/78	11/8/78-19/10/78	0.9	2.2†	discarded
	#3,14/9/78	15/9/78-8/12/78	3.0	<1.0	returned to site
Gracilaria "chorda" type	#19,21/7/78	24/7/78-8/8/78	0.4	2.6	tanks
	#19,11/9/78	12/9/78-26/9/78	0.2	3.0	tanks
	#56,22/9/78	3/10/78-1/2/79	0.5	1.2	other studies
Gracilaria "verrucosa" type	#44-46,9&10/9/78	3/10/78-11/1/79	1.0	<1.0	other studies
Gymnogongrus leptophyllus	#39,14/9/78	15/9/78-29/9/78	0.2	1.5	tanks
Gymnogongrus linearis	#17,19/7/78	19/7/78-17/8/78	0.2	<1.0	troughs
Gymnogongrus platyphyllus	#33,18&19/8/78	19/8/78-1/10/78	0.6	<1.0	tanks
Laurencia spectabilis	#35,23/8/78	28/8/78-11/9/78	0.5	<1.0	tanks
Lomentaria hakodatensis	#12,28/11/78	29/11/78-11/1/79	0.4	<1.0	tanks
Neoagardhiella baileyi	#19,21/7/78	21/7/78-9/8/78	1.1	1.2	tanks
	#29,9&10/8/78	11/8/78-22/9/78	2.4	1.5	troughs
	#34,22/8/78	28/8/76-19/9/78	3.3	1.0	tmks
	#19,11/9/78	12/9/78-26/9/78	1.5	<1.0	tanks
Pseudogloiophloea confusa	#21,15/8/78	16/8/78-30/8/78	1.3	2.2	tanks
Rhodoglossum affine	#8&18,20/7/78	20/7/78-8/8/78	1.2	<1.0	tanks
	#33,18/8/78	19/8/78-1/9/78	0.7	<1.0	tanks
	#9,37&38,7/9/78	8/9/78-25/9/78	0.4	1.4	tanks

* based on weekly weighings

† heavil fouled

APPENDIX IV

Collection data, culture history, and fate of 78 trials of 15 types of algae in the tank culture system during 1978-79.

Alga	Site Number and Date Collected	Source	Period in Tanks	Maximum Growth Rate* (%/day)	Period of Maximum Growth Rate	Fate
Ahnfeltia plicata	#37,6/9/78	F.A.C.S.	25/9/78-19/2/79	1.2	27/10/78-6/11/78	discarded
Caulacanthus ustulatus	#13,7/7/78	field	18/7/78-25/7/78			discarded
	#19,21/7/78	field	21/7/78-18/9/78	1.8	25/7/78-3/8/78	discarded
Gigartina agardhii	#8,22/7/78	field	24/7/78-3/8/78			discarded
	#8,22/7/78	F.A.C.S.	8/8/78-24/10/78			discarded
	#33,19/8/78	F.A.C.S.	1/9/78-24/10/78			discarded
	#33,19/8/78	F.A.C.S.	1/9/78-11/12/78			discarded
	#33,19/8/78	F.A.C.S.	1/9/78-11/12/78			discarded
	#33,19/8/78	F.A.C.S.	1/9/78-12/12/78	2.4	27/10/78-6/11/78	troughs
	#40,14/9/78	field	20/9/78-11/12/78	2.1	3/11/78-21/11/78	discarded
	#51,16/9/78	field	21/9/78-11/12/78	1.3	6/11/78-22/11/78	discarded
	#47,14/9/78	field	21/9/78-24/1/79			discarded
	#47,14/9178	field	21/9/78-24/1/79	1.1	24/10/78-6/11/78	discarded
	#47,14/9/79	field	21/9/78-24/1/79	1.2	24/10/78-6/11/78	discarded
	#47,14/9/78	field	21/9/78-24/1/79	1.4	22/11/78-11/12/78	discarded
Gigartina stellata	#18,20/7/78	field	20/7/78-25/7/78			discarded
	#18,20/7/78	F.A.C.S.	8/8/78-21/8/78			troughs
	#33,19/8/78	F.A.C.S.	2/9/78-27/10/78			discarded
Gracilaria "brown" type	#1&3,19/7/78	F.A.C.S.	8/8/78-11/12/78			discarded
	#1&3,19/7/78	F.A.C.S.	8/8/78-11/12/78			discarded
	#1&3,19/7/78	F.A.C.S.	8/8/78-11/12/78	2.3	19/9/78-18/10/78	troughs
	#1&3,19/7/78	F.A.C.S.	8/8/78-11/12/78	2.2	6/11/78-21/11/78	discarded
	#1,24/5/78	F.A.C.S.	23/8/78-15/9/78			discarded
Gracilaria "chorda" type	#19,21/7/78	field	24/7/78-3/8/78			discarded
	#9,24/7/78	field	25/7/78-3/8/78			discarded
	#9,24/7/78	field	25/7/78-3/8/78			discarded
	#9,24/7/78	field	25/7/78-3/8/78			discarded
	#19,21/7/78	F.A.C.S.	8/8/78-20/9/78			troughs
Gracilaria "chorda" type (cont.)	#44/9/9/78	field	18/9/78-11/12/78	2.4	6/11/78-21/11/78	discarded
	#44/9/9/78	field	18/9/78-11/12/78	1.7	6/11/78-21/11/78	discarded
	#19,11/9/78	F.A.C.S.	26/9/78-24/1/79	1.6	6/11/78-21/11/78	discarded
	#19,11/9/78	F.A.C.S.	26/9/78-24/1/79	2.0	27/10/78-6/11/78	discarded
	#19,11/9/78	F.A.C.S.	26/9/78-24/1/79	2.4	27/10/78-6/11/78	discarded
	#19,11/9/78	F.A.C.S.	26/9/78-24/1/79	2.4	27/10/78-6/11/78	discarded
	#19,11/9/78	F.A.C.S.	26/9/78-24/1/79	2.0	27/10/78-6/11/78	discarded
	#19,11/9/78	F.A.C.S.	26/9/78-24/1/79	2.1	27/10/78-6/11/78	discarded
	#26,fall/77	F.A.C.S.	22/1/79- 7/3/79			discarded
	#26,4/12/78	F.A.C.S.	22/1/79-7/3/79			discarded
Gracilaria "verrucosa"type	#28,3/8/78	field	4/8/78-16/8/78			discarded

	#56,22/9/78	F.A.C.S.	19/1/79-7/3/79			discarded
	#28,7/12/78	F.A.C.S.	19/1/79-7/3/79			discarded
Gymnogongrus leptophyllus	#13,7/6/78	field	18/7/78-3/8/78			discarded
	#11,21/7/78	field	21/7/78-15/8/78			troughs
	#36,23/8/78	field	28/8/78- †	2.0	27/10/78-6/11/78	troughs
	#39,14/9/78	F.A.C.S.	29/9/78-25/10/78			troughs
Gymnogongrus linearis	#17,19/7/78	field	19/7/78-15/8/78			discarded
	#17,19/7/78	field	19/7/78-15/8/78			discarded
	#17,19/7/78	field	19/7/78-15/8/78			discarded
	#37,6/9/78	field	6/9/78-15/9/78			troughs
Gymnogongrus platyphyllus	#13,7/7/78	field	8/7/78-15/8/78			discarded
	#13,14/7/78	field	25/7/78-15/8/78			discarded
	#13,14/7/78	field	25/7/78-16/8/78			discarded
	#13,14/7/78	field	25/7/78-16/8/78			discarded
	#13,14/7/78	field	25/7/78-16/8/78			discarded
	#33,18-19/8/78	F.A.C.S.	1/9/78-20/2/79			discarded
	#33,18-19/8/78	F.A.C.S.	1/9/78-12/4/79			discarded
Laurencia spectabilis	#35,23/8/78	F.A.C.S.	11/9/78-15/9/78			troughs
Lomentaria hakodatensis	#12,28/11/78	field	29/11/78-24/1/79			discarded
	#12,28/11/78	F.A.C.S.	19/1/79-7/3/79			discarded
	#12,28/11/78	F.A.C.S.	19/1/79-7/3/79			discarded
Neoagardhiella baileyi	#19,21/7/78	F.A.C.S.	16/8/78-18/9/78			troughs
Neoagardhiella baizeyi	#32,17/8/78	field	18/8/78-15/9/78			troughs
(cont.)	#32,17/8/78	field	19/8/78-15/9/78			troughs
	#34,22/8/78	F.A.C.S.	19/9/78-3/11/78			discarded
	#19,11/9/78	F.A.C.S.	26/9/78-6/11/78			discarded
	#19,11/9/78	F.A.C.S.	26/9/78-6/11/78	1.7	26/9/78-18/10/78	discarded
	#28,3/8/78	F.A.C.S.	19/1/78-7/3/79			discarded
	#28,3/8/78	F.A.C.S.	19/1/78-7/3/79			discarded
	#28,3/8/78	F.A.C.S.	19/1/78-7/3/79			discarded
Pseudogloiophloea confusa	#21,15/8/78	F.A.C.S.	30/8/78-15/9/78			discarded
	#38,7/9/78	field	7/9/78-15/9/78			troughs
Rhodoglossum affine	#13,7/7/78	field	18/7/78-8/8/78			discarded
	#8,22/7/78	field	24/7/78-16/8/78			troughs
	#8,22/7/78	field	24/7/78-18/9/78	2.3	3/8/78-16/8/78	troughs
	#8,16,13,20-22/7/78	F.A.C.S.	8/8/78-27/11/78	1.8	27/10/78-6/11/78	discarded
	#33,18/8/78	F.A.C.S.	1/9/78-15/9/78			troughs
	#8,20/9/78	field	22/9/78-20/10/78			troughs
	#9,37&38,7/9/78	F.A.C.S.	25/9/78-27/11/78	2.0	27/10/78-6/11/78	discarded

* Growth rates of less than 1% per day were not considered in this report.
† Still being monitored as of August 31, 1979.

APPENDIX V

Collection data and culture history of 146 trials of 17 types of algae in the trough culture system during 1978-79.

Alga	Site Number and Date Collected	Source	Period in Troughs	Maximum Growth Rate* (%/day)	Period of Maximum Growth Rate
Ahnfeltia gigartinoides	#6&12,19/7/78	F.A.C.S.	18/8/78-4/10/78		
	#6&12,19/7/78	F.A.C.S.	18/8/78-4/10/78		
	#6&12,19/7/78	F.A.C.S.	18/8/78-4/10/78		
	#6&12,19/7/78	F.A.C.S.	18/8/78-3/11/78		
Ahnfeltia plicata	#37,6/9/78	F.A.C.S.	25/9/78-3/10/78		
	#37,6/9/78	tanks	27/10/78-12/12/78		
	#37,6/9/78	tanks	27/10/78-12/12/78		
	#37,6/9/78	tanks	31/10/78-28/11/78		
	#37,6/9/78	tanks	31/10/78-28/11/78		
Caulacanthus ustulatus	#12,12/9/78	field	18/9/78-2/11/78		
	#42,4/12/78	field	11/12/78-19/2/79		
	#42,12/12/78	field	13/12178-7/3/79		
Endocladia muricata	#53,18/9/78	field	2/10/78-20/2/79		
Gelidium sp.	#45,10/9/78	field	18/9/78-3/10/78		
	#45,10/9/78	field	18/9/78-3/10/78		
	#45,10/9/78	field	18/9/78-3/10/78		
	#45,10/9/78	field	18/9/78-3/10/78		
	#45,10/9/78	field	18/9/78-3/10/78		
	#45,10/9/78	field	18/9/78-3/10/78		
	#12,28/11/78	field	13/12/78-20/2/79	1.0	13/12/78-26/1/79
	#41,29/11/78	field	13/12/78-20/2/79		
Gigartina agardhii	#48,14/9/78	field	18/9/78-3/10/78		
	#48,14/9/78	field	18/9/78-3/10/78		
	#48,14/9/78	field	18/9/75-3/10/76		
	#48,14/9/78	field	18/9/78-3/10/78		
	#48,14/9/78	field	18/9/78-3/10/78		
	#48,14/9/78	field	18/9/78-3/10/78		
	#48,14/9/78	field	18/9/78-3/10/78		
Gigartina agardhii	#48,14/9/78	field	18/9/78-3/10/78		
(cont.)	#48,14/9/78	field	18/9/78-2/11/78	2.0	20/10/78-2/11/78

	#33,19/8/78	tanks	11/12/78-26/1/79		
	#33,19/8/78	tanks	12/12/78-19/2/79		
Gigartina stellata	#18,20/7/78	tanks	21/9/78-2/10/78		
	#18,20/7/78	tanks	21/9/78-2/10/78		
	#18,20/7/78	tanks	21/9/78-2/10/78		
	#18,20/7/78	tanks	21/9/78-2/10/78		
	#56,22/9/78	field	2/10/78-2/11/78		
	#52,17/9/78	field	2/10/78-13/12/78	1.4	20/10/78-3/11/78
Gracilaria "brown" type	#1,19/7/73	F.A.C.S.	23/8/78-3/10/78	2.6	23/8/78-18/9/78
	#1&3,19/7/78	tanks	19/9/78-3/10/78		
	#1&3,19/7/79	tanks	19/9/78-3/10/78		
	#1&3,19/7/75	tanks	19/9/78-2/11/78		
	#1&3,19/7/78	tanks	19/9/78-14/11/78		
	#1&3,19/7/78	tanks	19/9/78-12/12/78	1.7	2/11/78-13/11/78
	#1&3,19/7/78	tanks	19/9/78-12/12/78	2.1	19/9/78-20/10/78
	#1&3,19/7/78	tanks	19/9/78-13/12/78	2.4	19/9/78-20/10/78
	#1&3,19/7/78	tanks	19/9/78-13/12/78	1.9	14/11/78-29/11/78
	#1&3,19/7/78	tanks	19/9/78-13/12/78		
	#1&3,19/7/78	tanks	19/9/78-11/12/79	2.7	19/9/78-20/10/78
	#1&3,19/7/78	tanks	19/9/78-13/12/78	3.9	19/9/78-20/10/78
	#29,9-10/8/78	tanks	22/9/78-13/10/78	4.2	22/9/78-20/10/78
	#1&3,19/7/79	tanks	20/10/79-12/12/78	3.5	20/10/78-31/10/78
	#1&3,19/7/79	tanks	20/10/79-12/12/78	2.5	20/10/78-31/10/78
	#1&3,19/7/79	tanks	20/10/79-12/12/78	2.6	20/10/78-31/10/78
	#1&3,19/7/79	tanks	20/10/79-12/12/78	4.6	20/10/78-31/10/78
	#1&3,19/7/79	tanks	20/10/79-12/12/78	5.5	20/10/78-31/10/78
Gracilaria "chorda" type	#26,fall/77	F.A.C.S.	15/9/78-2/10/78		
	#26,fall/77	F.A.C.S.	15/9/78-2/10/78		
	#26,fall/77	F.A.C.S.	15/9/78-2/10/78		
	#26,fall/77	F.A.C.S.	15/9/78-2/10/78		
	#26,fall/77	F.A.C.S.	15/9/78-2/10/78		
Gracilaria "chorda" type (cont.)	#19,21/7/78	tanks	21/9/78-2/10/78		
	#19,21/7/78	tanks	21/9/78-2/10/78		
	#19,21/7/78	tanks	21/9/78-2/10/78		
			3/10/78-25/1/79	3.1	29/11/78-12/12/78

Gymnogongrus leptophyllus	#11,21/7/78	tanks	15/8/78-21/8/78		
	#39,14/9/78	field	18/9/78-3/10/78		
	#39,14/9/78	field	18/9/78-3/10/78		
	#39,14/9/78	field	18/9/78-3/10/78		
	#56,22/9/78	field	2/10/78-13/12/78		
	#39,14/9/78	tanks	25/10/78- †	4.2	28/11/78-12/12/78
	#39,14/9/78	tanks	25/10/78- †	2.4	25/1/79-19/2/79
	#39,14/9/78	tanks	25/10/78- †	2.7	11/4/79-16/5/79
	#39,14/9/78	tanks	25/10/78- †	4.4	25/1/79-19/2/79
	#39,14/9/78	tanks	28/11/78- †	3.6	25/1/79-19/2/79
	#36,23/8/78	tanks	3/12/78-13/3/79	2.9	26/1/79-20/2/79
	#36,23/8/78	tanks	13/12/78- †	3.9	26/1/79-19/2/79
	#36,23/8/78	tanks	13/12/78- †	3.2	26/1/79-20/2/79
	#36,23/8/78	tanks	13/12/78- †	3.1	12/3/79-6/4/79
	#36,23/8/78	tanks	13/12/78- †	3.0	12/3/79-6/4/79
	#36,23/8/78	tanks	13/12/78- †	2.7	12/3/79-6/4/79
	#36,23/8/78	tanks	13/12/78- †	2.9	13/3/79-6/4/79
	#36,23/8/78	tanks	13/12/78- †	2.6	26/1/79-20/2/79
	#36,23/8/78	tanks	13/12/78- †	2.3	26/1/79-20/2/79
	#36,23/8/78	tanks	13/12/78- †	2.9	26/1/79-20/2/79
	#36,23/8/78	tanks	13/12/78- †	2.6	26/1/79-20/2/79
	#36,23/8/78	tanks	13/12/78- †	3.1	26/1/79-20/2/79
	#36,23/8/78	tanks	13/12/78- †	2.3	26/1/79-20/2/79
	#36,23/8/78	tanks	20/2/79- †	3.4	11/4/79-14/5/79
	#36,23/8/78	tanks	20/2/79- †	3.2	11/4/79-14/5/79
	#36,23/8/78	tanks	20/2/79- †	3.5	11/4/79-16/5/79
Gymnogongrus linearis	#17,19/7/78	F.A.C.S.	17/8/78-13/12/78		
	#37,6/9/78	tanks	15/9/78-2/10/78		
	#37,6/9/78	tanks	15/9/78-2/10/78		
Gymnogongrus linearis	#37,6/9/78	tanks	15/9/78-2/10/78		
(cont.)	#37,6/9/78	tanks	15/9/78-2/10/78		
Iridaea cordata	#12,28/11/78	field	13/12/78-20/2/79		
Iridaea cornucopiae	#51,16/9/78	field	18/9/78-3/10/78		
	#51,16/9/78	field	18/9/78-29/11/78		

	#56,22/9/78	field	2/10/78-26/1/79		
	#56,22/9/78	field	2/10/78-26/1/79		
Laurencia spectabilis	#35,23/8/78	tanks	15/9/78-2/10/78		
Lomentaria hakodatensis	#28,3/8/78	F.A.C.S.	24/10/78-28/11/78	1.2	31/10/78-7/11/78
Neoagardhiella baileyi	#32,17/8/78	tanks	15/9/78-2/10/78		
	#32,17/8/78	tanks	15/9/78-2/10/78		
	#32,17/8/78	tanks	15/9/78-2/10/78		
	#32,17/8/78	tanks	15/9/78-2/10/78		
	#32,17/8/78	tanks	15/9/78-2/10/78		
	#32,17/8/78	tanks	15/9/78-2/10/78		
	#32,17/8/78	tanks	15/9/78-2/10/78		
	#32,17/8/78	tanks	15/9/78-2/10/78		
	#32,17/8/78	tanks	15/9/78-2/10/78		
	#32,17/8/78	tanks	15/9/78-2/10/78		
	#19,21/7/78	tanks	18/9/78-3/10/78		
	#19,21/7/78	tanks	18/9/78-3/10/78		
	#19,21/7/78	tanks	18/9/78-3/10/78		
	#19,21/7/78	tanks	18/9/78-3/10/78		
	#19,21/7/78	tanks	18/9/78-3/10/78		
	#19,21/7/78	tanks	18/9/78-3/10/78		
	#29,9-10/8/78	F.A.C.S.	22/9/78-4/10/78		
	#29,9-10/8/78	F.A.C.S.	22/9/78-4/10/78		
	#29,9-10/8/78	F.A.C.S.	22/9/78-4/10/78		
	#29,9-10/8/78	F.A.C.S.	22/9/78-4/10/78		
	#29,9-10/8/78	F.A.C.S.	22/9/78-4/10/78		
		F.A.C.S.	29/11/78-26/1/79	2.0	29/11/78-12/12/78
	#28,3/8/78	F.A.C.S.	26/1/79-5/7/79	4.2	6/4/79-17/5/79
Pseudogloiophloea confusa	#38,7/9/78	tanks	15/9/78-2/10/78		
Rhodoglossum affine	#8,22/7/78	tanks	16/8/78-3/11/78		
(cont.)	#33,18/8/78	tanks	15/9/78-2/10/78		
	#33,18/8/78	tanks	15/9/78-2/10/78		
	#33,18/8/78	tanks	15/9/78-2/10/78		
	#33,18/8/78	tanks	15/9/78-2/10/78		
	#33,18/8/78	tanks	15/9/78-2/10/78		
	#33,18/8/78	tanks	15/9/78-2/10/78		

#33,18/8/78	tanks	15/9/78-2/10/78
#33,18/8/78	tanks	15/9/78-2/10/78
#33,18/8/78	tanks	15/9/78-2/10/78
#33,18/8/78	tanks	15/9/78-2/10/78
#33,18/8/78	tanks	15/9/78-2/10/78
#33,18/8/78	tanks	15/9/78-2/10/78
#33,18/8/78	tanks	15/9/78-2/10/78
#33,18/8/78	tanks	15/9/73-2/10/78
#33,18/8/78	tanks	15/9/78-2/10/78
#8,22/7/78	tanks	18/9/78-3/10/78
		4/10/78-13/12/78
#8,20/9/78	tanks	20/10/78-7/11/78

* Growth rates of less than 1% per day were not considered in this report.

† Still being monitored as of August 31, 1979.