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Chondros crispus Stackhouse

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Comments

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Chondros crispus Stackhouse[1]

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[1]Also a Scientific Contribution from the New Hampshire Agricultural Experiment Station and Jackson Estuarine Laboratory Contribution Number 197.

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ABSTRACT

The Northwest Atlantic Chondrus fishery is the basis of a phycocolloid industry. Harvesting is centered in the Gulfs of Maine and St. Lawrence where the species is an ecological dominant. The extensive ecological-physiological data base is reviewed as is the biosystematics. Annual catch peaked in 1974 (approx. 50,000 t) and troughed in 1983 (approx. 18,000 t). Catch decline was due/in part, to a decrease in crop demand caused by international marketplace competition from other carra-geenophytes. Harvesting and handling techniques are described. Resource management structure is outlined, as are stock assessment and assessment science programs. The international aspect of resource utilization is discussed.

1. IDENTITY

1.1 The crop
1.2 Taxonomy

1.3 Nomenclature
1.4 Morphology and anatomy

1.1 The crop

The north Atlantic red alga Chondrus crispus Stackhouse **(Fig. 1)**, which is referred to as Chondrus, Irish moss, or "moss" in this text, is the basis of a western world multimillion dollar phycocolloid industry (Levring et al., 1969; MacFarlane, 1956; Michanek, 1983). However, its share of this industry has declined from ≥ 75% before 1975 to ≤ 20% at present, primarily due to the successful farming of Eucheuma spp. in the Philippines (Parker, 1976).

The steady increase in carrageenan demand in the 1960's led to a concern about future sources of raw material. The Canadian federal government, through the National Research Council's Atlantic Regional Laboratory (=NRC), began, in the late 1960's, to develop aquaculture techniques for Chondrus. The program was turned over to Marine Colloids Canada Ltd. in 1972 and to Genu Canada Ltd. (subsidiary of Copenhagen Pectin) a little later. NRC funded these ventures through various granting schemes (see Anderson et al. 1977). Genu stated in 1981 (Norve[1], personal comm. to J. Pringle) that it would likely not be cost effective in the near future, and dissolved their aquaculture program. Acadian Seaplants purchased Marine Colloids Canada Ltd. in ~ 1980 **(Table 1)** and continued their aquaculture development program, recently their facility was expanded, but they are not yet independent of government support (R. Foxall, personal comm. to J. Pringle)[2]. In the present account, the descriptions of productivity and harvesting will concentrate on the wild harvest and in particular the Irish moss fishery of eastern Canada, as 95% of the crop comes from this fishery.

[1]Mr. H. Norve, former manager of Genu Canada Ltd., Halifax, N.S.
[2]Dr. R. Foxall, Director, Atlantic Regional Laboratory, Oxford Street, Halifax, N.S.

1.2 Taxonomy

Chondrus crispus Stackhouse belongs to the division Rhodo-phyta, class Florideophyceae, order Gigartinales and family Gigartinaceae (Dixon and Irvine, 1977). Stackhouse (1797) established the generic name and C. crispus has become its type. As outlined by Taylor and Chen (1973), Chondrus is separated from other genera in the Gigartinaceae (i.e. Besa, Gigartina, Iridaea and Rhodoglossum, sensu Kylin, 1956) by having gonimoblasts diffusely extended among medullary filaments in the distal portions of female fronds, by producing totally immersed carpo-sporangia with no clear separation of vegetative tissues, by lacking any special external cystocarp opening, and by having bundles of cruciately divided tetrasporangia produced from branches of medullary filaments in the upper parts of the fronds.

Figure 1. Morphological variation of Chondrus crispus populations at an estuarine (Dover Point) and two open coastal sites (Rye Ledge and Jaffrey Point), in New Hampshire, U.S.A. (from Mathieson and Burns, 1975)

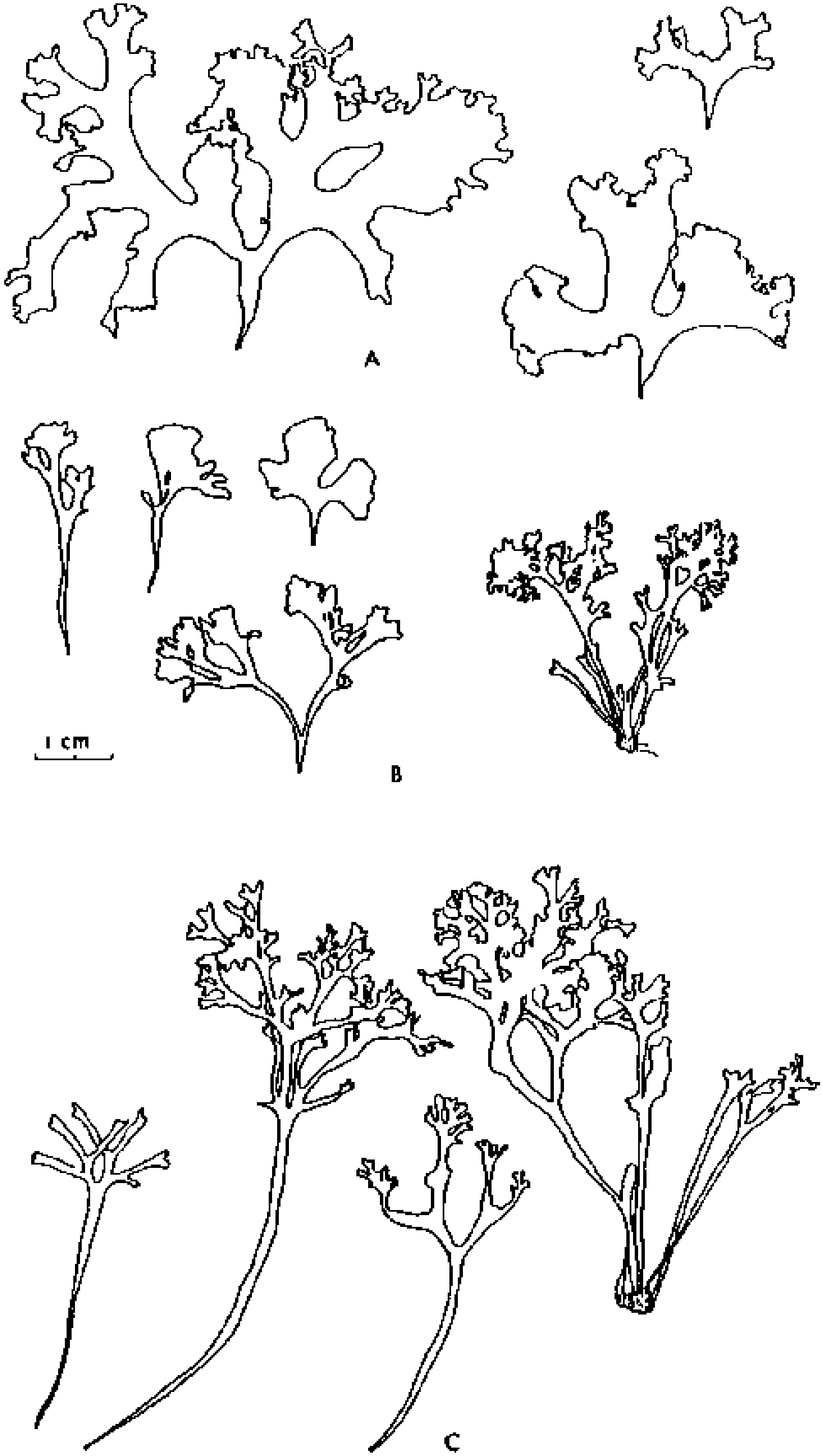


Table 1. Major companies directly buying Maritime Chondrus crispus between 1950 and present.

Companies	1950 1965	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85

Marine Colloids	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
Cunningham & Sons	X	X	X	X	X	X	X	X	X	X	X	X	X*								
Litex - P.E.I.Seaweeds Ltd.		X*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X**		
Genu Canada Ltd.		X*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
P.E.I. Marine																					
Plants Cooperative									*X	X	X	X	X	X	X	X					
Stauffer Chemicals														*X	X**						
Litex - N.S. Seaweeds Limited																X	X	X			
Acadian Seaplants																	X	X	X	X	X
Wendell Stewart[1]																*X	X	X	X	X	X

*Approximate date of first direct buying activity.
**Aproximate termination data of buying activity.
[1]Was a buyer for many years for commercial companies.

Additional species of Chondrus have been described from the Pacific Ocean (e.g. Chihara, 1970; Mikami, 1965) although their delimitation is uncertain (Guiry and Masuda, 1984; Taylor and Chen, loc. cit.).

1.3 Nomenclature

Taylor and Chen (1973) state that the earliest binomial applied to Chondrus was Fucus filiformis Hudson (1762), but this was never taken up and Okamura and Segawa (in Segawa, 1935) applied the combination Chondrus filiformis to a Pacific species. Fucus crispus Linnaeus (1767) is believed to refer to Irish moss, but it is a later homonym of Fucus crispus Hudson (loc. cit.), the first legitimate combination describing the plant currently known as Phyllophora crispus (Hudson) Dixon (1964). Stackhouse (1797) separated certain taxa from the wide-embracing genus Fucus L. and proposed Chondrus and included C. crispus as his first species among six. Thus, the name for Irish moss is continued as Chondrus crispus Stackhouse. See Taylor and Chen (loc. cit.) for a detailed listing of the synonyms.

MacFarlane (1968) and Madlener (1977) list common names for Chondrus crispus as Irish moss, others, such as carrageenan, carrageenan moss, jelly moss, sea moss, etc. Carrageenan refers to Carragheen, a town in Ireland where the plant is believed to have been first utilized (Vadas and Ring, 1969).

1.4 Morphology and anatomy

Dixon and Irvine (1977) give a detailed account of the plant's morphology and anatomy, which consists of a perennial discoid holdfast and erect fronds in tufts **(Fig. 1).** The upright fronds consist of compressed unbranched stipes, expanding gradually into fan-like blades, up to 220 mm long. The fronds are undulate in younger parts, membranous to cartilaginous, repeatedly (to 5 times) dichotomous, with rounded axils, 2-15 mm broad between dichotomies, occasionally proliferous from the margins, usually expanding but occasionally tapering towards rounded apices; dark reddish or purplish brown, bleaching to a greenish yellow, frequently iridescent at the tips. The multi-axial thallus consists of medullary filaments that are thick-walled, 7-16 μ m in diameter to 80 μ m in length; cortical cells are arranged radially, 4-8 x 3-4 μ m. The species is dioecious. Spermatangia are colorless, produced in white or pink superficial sori on terminal portions of young branches.

They are liberated through distinct pores in the thickened cuticle, 7.5-10 x 4-5 μ m. Cystocarps protruding strongly, usually as concavo-convex swellings about 2 mm in diameter, with a pore; carposporangia 20-30 x 14-25 μ m. Tetrasporangial sori only slightly protruding, oval to linear, 1-5 x 0.5-1.0 mm, numerous, particularly in the younger regions and often confluent. Tetrasporangia terminal or intercalary, immersed in the medulla, 17-40 x 11-30 μ m, cruciately divided.

2. DISTRIBUTION, ECOLOGY AND METABOLISM

2.1 Geographical extent
2.2 Local vertical and horizontal distribution
2.3 Effects of ecological determinants
2.4 Seasonality of growth
2.5 Nutrition and growth

2.1 Geographical extent

Chondrus crispus extends from Labrador to New Jersey, northern Russia to southern Spain and possibly Morocco and Cape Verde Isles, as well as in the western Baltic and Iceland (Dixon and Irvine, 1977).

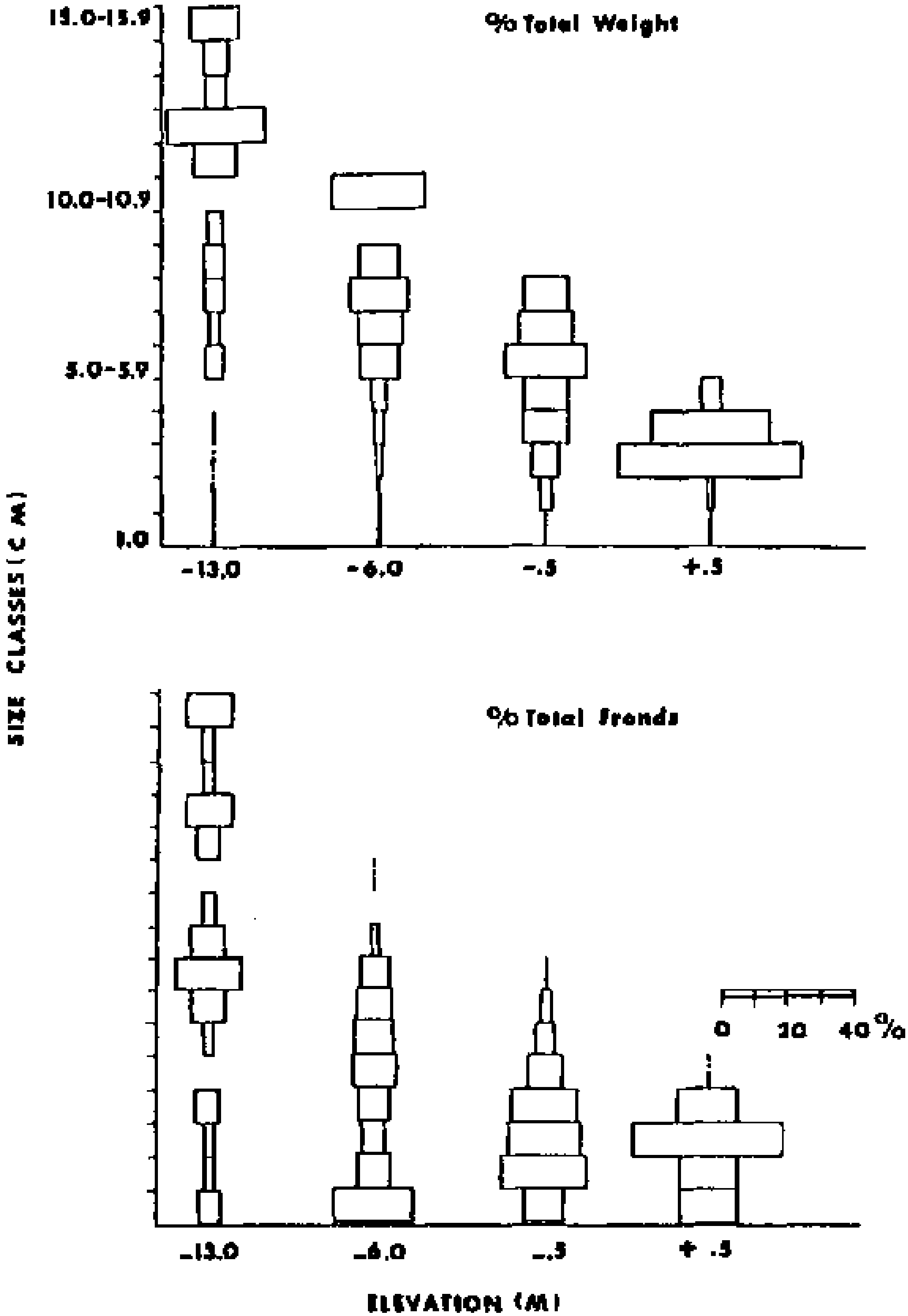
2.2 Local vertical and horizontal distribution

Irish moss extends from the littoral fringe (sensu Lewis, 1964) to -20m below mean low water, depending upon wave action, transparency and other local topographic conditions (cf. Bird et *al.,* 1983; Femino and Mathieson, 1980; Mathieson and Prince, 1973; Prince and Kingsbury, 1973b). Even so, it is usually most abundant near M.L.W. to the mid subtidal zone (Mathieson and Prince, loc. cit.), with varying densities and morphologies occurring throughout this gradient **(Fig. 2-4).**

2.3 Effects of ecological determinants

Chondrus crispus grows most abundantly on massive and stable outcrops (ledges) and boulders, with substantially reduced populations on smaller rocks and sand/or sediment-covered rocks (cf. Daly and Mathieson, 1977; Pringle and Semple, 1984). Occasionally, it will occur as detached populations (cf. Norton and Mathieson, 1983). Chondrus usually grows on shelving and horizontal surfaces, while adjacent vertical surfaces that are impacted by strong wave action, desiccation and freezing (Green, 1983; Lewis, 1964) are often dominated by Gigartina stellata (cf. Burns and Mathieson, 1972; Green, loc. cit.; Mathieson and Burns, 1975). Chondrus grows most abundantly on semi-exposed, open coastal sites; in addition, it is common in estuarine habitats, being particularly abundant where strong tidal currents occur (Conover, 1968; Kent and Buggeln, 1972; Mathieson and Hehre, 1986, Mathieson et al., 1983). The plant's extensive distribution in estuarine habitats (cf. Doty and Newhouse, 1954; MacFarlane, 1966; Munda, 1977, 1978) suggests a broad tolerance to temperature' salinity and light (cf. Mathieson and Burns, 1971; Mathieson and Prince, 1973). Even so, polluted harbor water and oil contamination can be harmful (cf. Boney, 1965; Grenanger, 1957; Marshall et al., 1949), while ice erosion in "northern" areas can be damaging, reducing the plant's reproductive potential and restricting it to crevices (cf. Bird et al., 1983; Hooper et al., 1980; Lilly, 1968). See Sections 4.3 and 4.4 concerning a variety of animals, bacteria, fungi and other plants that can adversely affect the survival and growth of Irish moss.

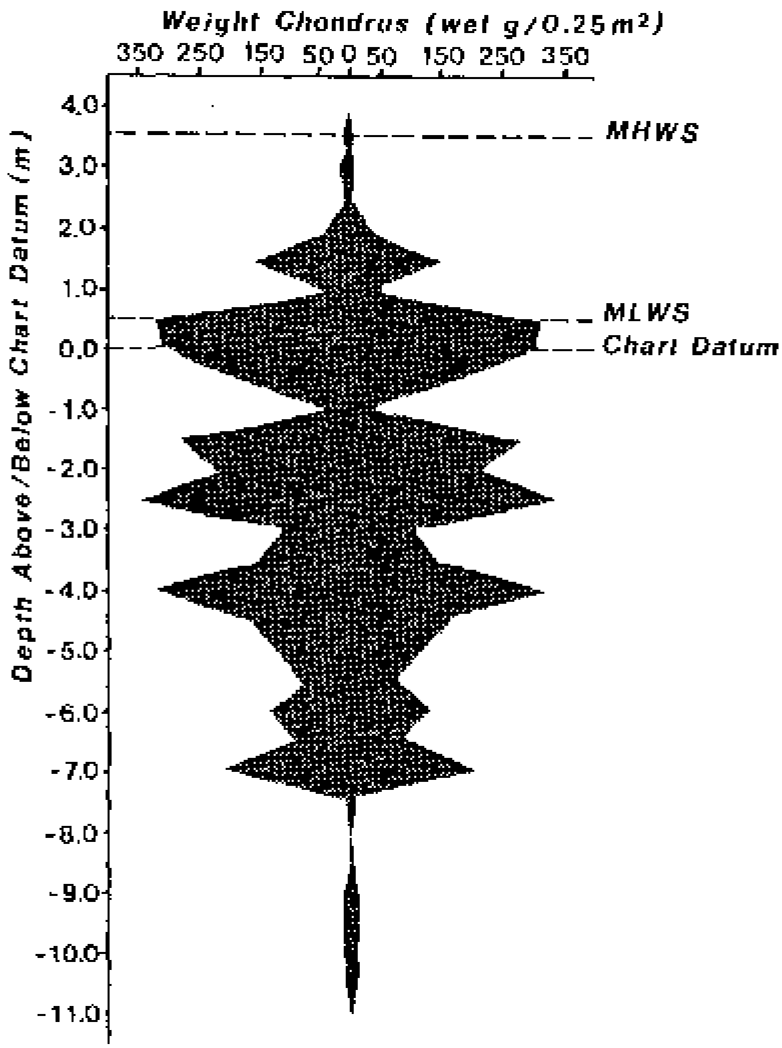
Figure 2. Size and weight distributions of Chondrus crispus fronds in the intertidal and subtidal zones at Jaffrey Point, Newcastle, New Hampshire, U.S.A. (from Mathieson and Burns, 1975).



2.4 Seasonality of growth

The seasonal growth of Chondrus crispus is maximal during late spring or summer and minimal during the winter (cf. Koop and Perez, 1979: Mathieson and Prince, 1973; Mathieson and Burns, 1975; Prince and Kingsbury, 1973a,b; Pybus, 1977). For example, Prince and Kingsbury (loc. cit.) found that growth was minimal during November-February; thereafter, it increased nearly linearly, reaching a maximum of approximately 0.37 mm/day in September or October. See Kanwisher (1966) and Taylor (1954, 1970) for further information on growth rates. Prince and Kingsbury (loc. cit.) suggest that the plant's growth patterns are coincident with temperature variations. However, Neish and Fox (1971) state that decreasing autumn growth rates are primarily due to declining solar radiation. Mathieson and Burns (1975) note that maximum nutrient levels (i.e. nitrate-N, nitrite-N and ortho-phosphate-P) are evident in early spring when growth is initiated, while lower levels occur during the summer and fall when maximum growth occurs. Hanic and Pringle (1978), Pringle (1979) and Taylor et al. (1975, 1981) emphasize that the holdfasts of Irish moss grow slowly. For example, Hanic and Pringle (loc. cit.) found that it took two years to produce a holdfast of 4-mm².

Figure 3. The distribution of Chondrus crispus standing crop at various depths above and below chart datum along the West Pubnico Peninsula, Nova Scotia, Canada, in Marine Plant Harvesting District 12 (i.e. MPHD 12), August, 1975.



2.5 Nutrition and growth

Recent aquaculture experiments with Irish moss have shown that adequate carbon is essential for normal growth and that photosynthetic uptake is proportional to HCO_3^- concentrations up to 2 m (Bidwell and McLachlan, 1985). The same authors found optimal growth with ammonium nitrate or ammonium phosphate, and that the addition of macronutrients other than N and P was not critical. Chondrus seems to grow equally well on NO^{-3} or NH^{+4}; in addition/it grows better on inorganic nitrogen than on urea (cf. Laycock et al., 1981; Neish and Fox, 1971; Neish and Shacklock, 1971; Prince, 1974). The dipeptide L-citrullinyl-L-argine accumulates to high concentrations when Chondrus is supplied with nitrate or ammonium at low temperatures; much of this reserve is readily mobilized for growth during periods of higher temperatures, increased irradiance and reduced nutrients (cf. Laycock and Craigie, 1977; Laycock, et al., 1981).

Figure 4. The vertical distribution of macrophyte taxa (in relation to chart datum) a single transect off the West Pubnico Peninsula, Nova Scotia, (MPHD 12), August, 1975.

3. LIFE HISTORY

3.1 Life cycle and reproduction

3.1 Life cycle and reproduction

Chondrus crispus has been shown to have a triphasic isomorphic life history in culture consisting of separate male and female gametophytes, carposporophytes parasitic on the female gametophyte and free-living tetrasporophytes (cf. Chen and McLachlan, 1972; Guiry, 1979). A cytological alternation of generations involving haploid gametophytic, diploid carposporophytic and diploid tetrasporophytic phases has also been documented (Hanic, 1973; Magne, 1964). Released carpospores and tetraspores develop identically in culture (e.g. Chen and McLachlan/loc. cit.; Prince and Kingsbury, 1973a; Ring, 1970; Taylor and Chen, 1973). Initially; they swell and then undergo a series of anticlinal and periclinal divisions, which result in a hemispherical cushion (i.e. holdfast initial) that initially produces a cylindrical frond primordia and ultimately a flattened dichotomous frond.

Reproductively mature fronds have been observed in culture after the growth of carpospores from 91 days-21 months and tetraspores from 114 days-21 months (cf. Chen and McLachlan, loc. cit.; Guiry, loc.cit.; Prince, 1971). Procarp-bearing plants produce carpospores only when male plants are in the same culture - e.g. Guiry (loc. cit.) records carpospore production 45 days after being mixed. If the density of spores is high or if inadequate spore contact occurs, an initial rhizoidal sequence may occur, which ultimately leads to formation of the holdfast initial. Juvenile gametophytic and sporophytic plants can also exhibit a high frequency of sporeling (i.e. holdfast) coalescence (Tveter and Mathieson, 1976; Tveter-Gallagher and Mathieson, 1980), which is associated with an accelerated production of frond primordia **(Fig. 5 and 6)** and an obvious ecological advantage (cf. Jones, 1956). See Section 4.1 regarding patterns of in situ longevity and reproductive maturity.

Field studies have documented different life history patterns (e.g. Craigie and Pringle, 1978; Mathieson, 1982; Mathieson and Prince, 1973; Section 4.2). **Figures 7 and 8** summarize the in situ life history patterns of Chondrus crispus populations in New England, employing a variety of procedures as suggested by Prince and Kingsbury (1973a) - i.e. seasonal spore discharge rates, percent viability of spores, the number of sori/frond segment and diverse habitat sampling. These studies and those of Taylor et al. (1975, 1981) demonstrate a reproductive strategy involving prolonged sporic as well as broad-scale vegetative reproduction (cf. Section 4.5), with the former consisting of unimodal carpo-sporic and bimodal tetrasporic maxima and the latter of extensive holdfast regeneration. The duration and phenology of sporic and sexual reproduction varies spatially (Mathieson, 1982; Tveter-Gallagher et al., 1980, **Fig. 7 and 8).** Tetrasporic plants have maximum discharge rates in May - June (36-48 x 10^3 spores/sorus) and a smaller maximum in December-January (29-31 x 10^3 spores/sorus). Tetraspore viability was lowest during February -April (68-74%); thereafter, it ranged from 82-92% **(Fig. 8).** Cystocarpic plants showed maximum discharge rates during summer (48 x 10^3 spores/sorus), a clinal decrease during fall-winter, and lowest discharge rates and number of reproductive sori during April (20 x 10^3 spores/sorus). Overall, cystocarpic plants exhibited their highest sustained viability (85-92%) during summer. In demographic studies of intertidal populations in the Canadian Maritime Provinces, Bhattacharya (1985) found that the carpospore and tetraspore discharge rates never fell below 106 spores/m²/month, while they were maximal during September (i.e. 8.7 x 10^9 carpospores and 10.4 x 10^9 tetraspores/m²/month). Overall, the annual release rates of carpospores was 4.7 times greater than that of tetraspores. In contrast to Bhattacharya, Mathieson (1982) employed subtidal plants and emphasized individual frond discharge rates; thus, the two studies are not directly comparable.

Figure 5. The relationship between sporeling area and the stature of upright fronds with Chondrus crispus; the plants were collected from the upper subtidal zone at Jaffrey Point, Newcastle, New Hampshire, U.S.A. (from Tveter and Mathieson, 1976 and Mathieson, 1982).

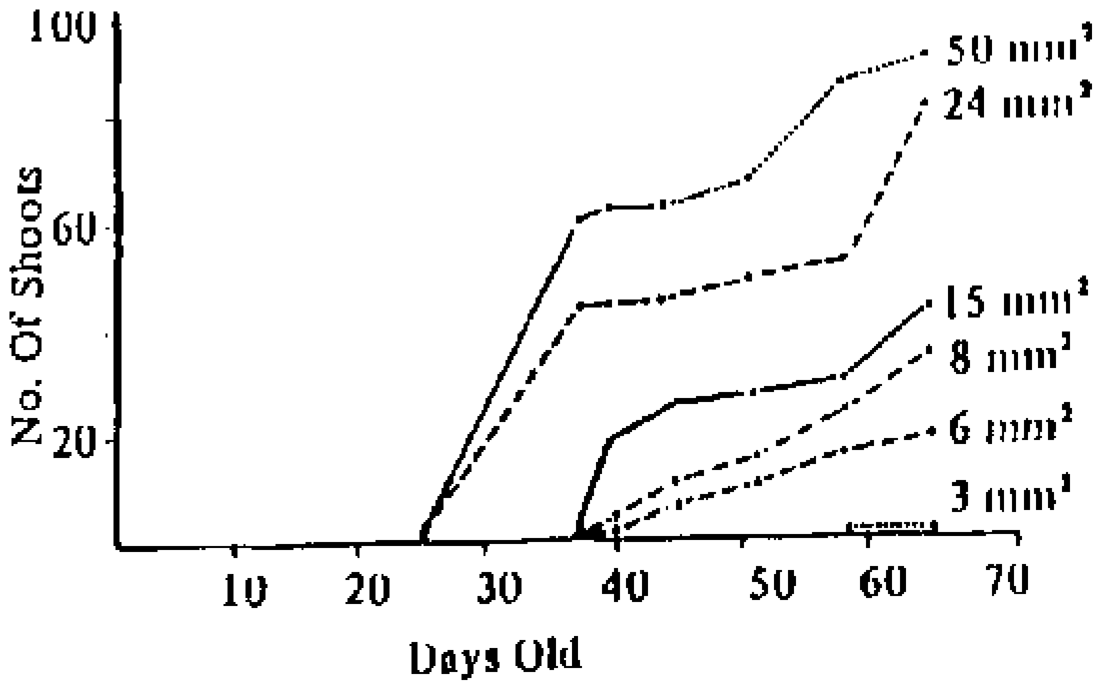


Figure 6. The relationship between sporeling area and number of upright fronds with Chondrus crispus; the plants were collected from the upper subtidal zone at Jaffrey Point, New Hampshire, U.S.A. (from Tveter and Mathieson, 1976 and Mathieson, 1982).

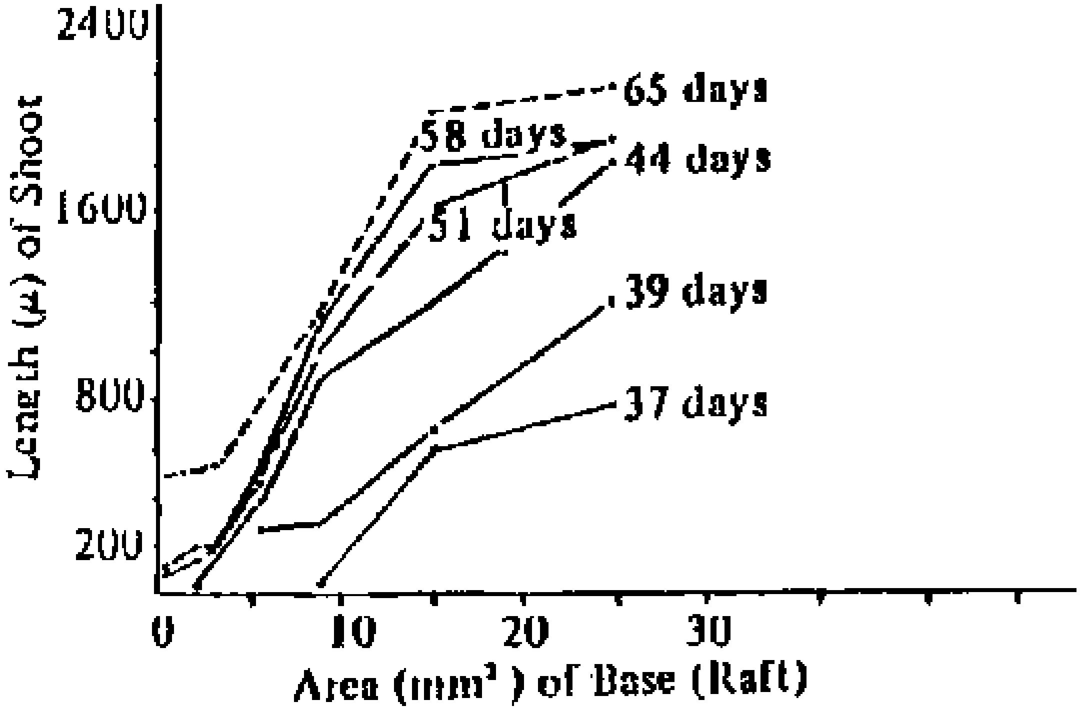


Figure 7. The reproductive phenologies of spermatangial, cystocarpic and tetrasporic plants of Chondrus crispus within the upper subtidal zone (-3m) at an open coastal site at Jaffrey Point, New Hampshire; as well as within the mid (+1.0m) and lower-intertidal zones at an estuarine site at Adams Point, New Hampshire; expressed as number (%) of each reproductive phase/sample (from Tveter-Gallagher, et al.; 1980).

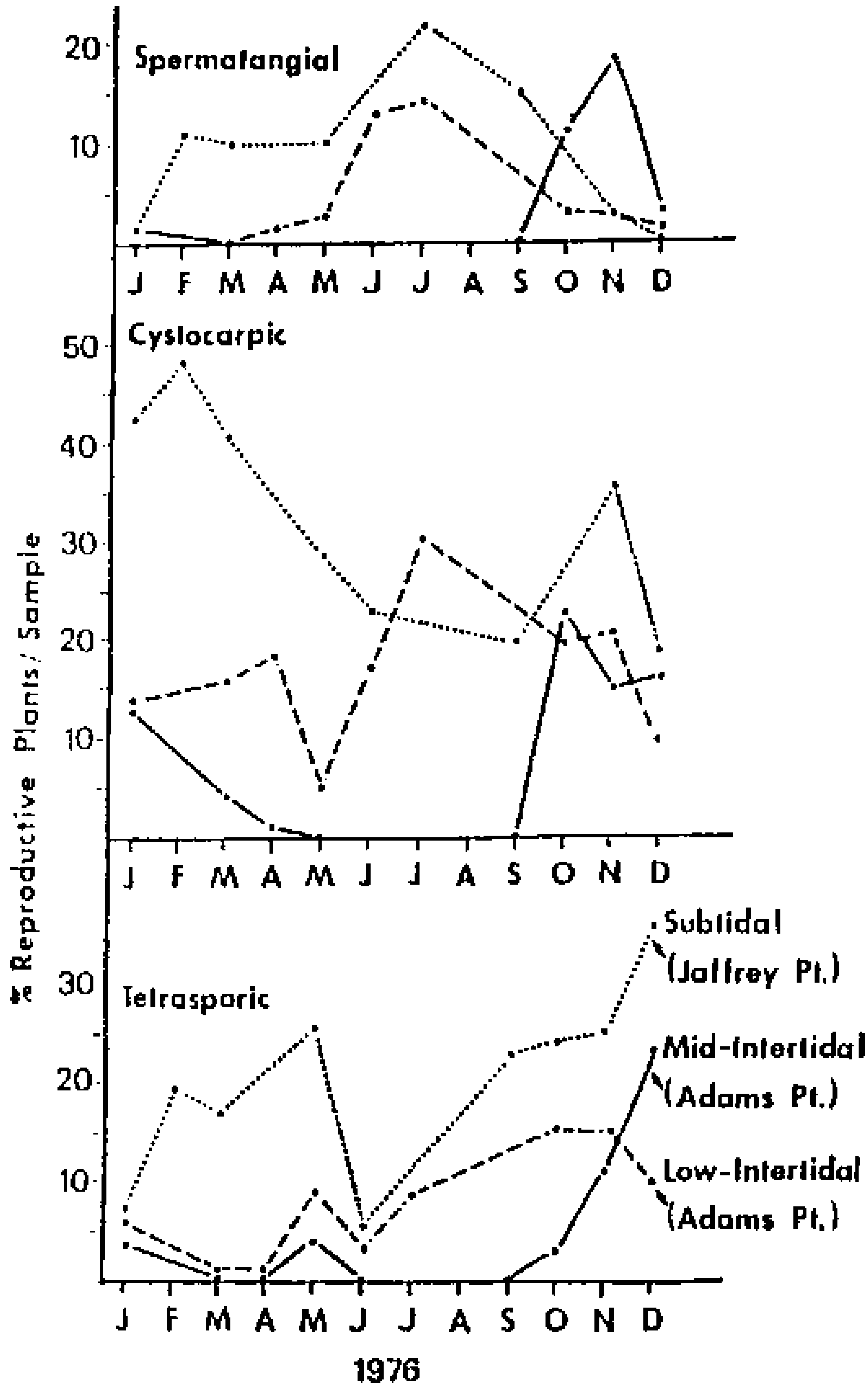
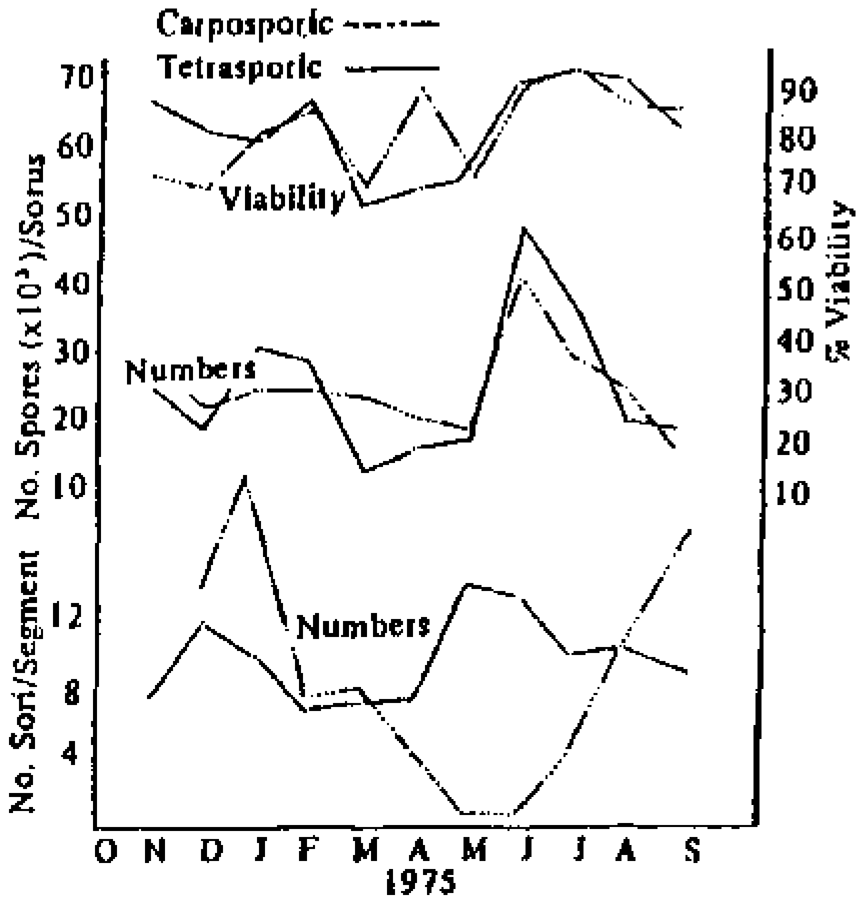


Figure 8. A summary of seasonal spore discharge, percent viability of spores and the number of sori/frond segment in Chondrus crispus; the plants were collected from the low intertidal zone at Jaffrey Point, Newcastle, New Hampshire, U.S.A. (from Mathieson, 1982b and Mathieson and Tveter, 1977).



4. POPULATION STRUCTURE AND MORTALITY

4.1 Age, weight or size composition
4.2 Sporophyte-gametophyte and sex composition
4.3 Mortality, morbidity
4.4 Grazing
4.5 Regeneration

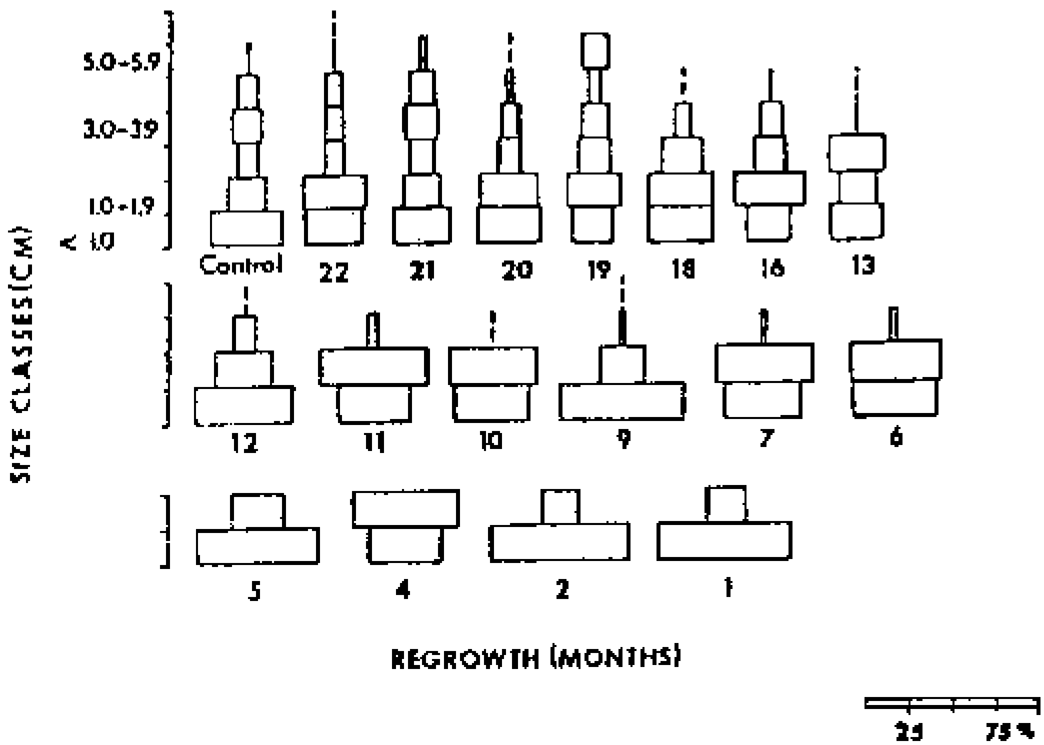
4.1 Age, weight or size composition

Fronds of Chondrus crispus can potentially grow 2-6 years while holdfasts have an even greater longevity (cf. Taylor and Chen, 1973; Taylor et al., 1975, 1981). Estimates of reproductive maturity for in situ plants range from 20 months to 5 years (MacFarlane, 1968; Mathieson and Burns, 1975; Rosenvinge, 1931). Shorter periods (13 months) have been recorded after regrowth from residual holdfasts (Mathieson and Burns, loc. cit.).

Taylor (1956, 1958/59, 1959, 1970, 1971, 1972, 1973) examined the composition and morphology (i.e., size and degree of branching) of fronds from Canadian locations ranging from the southern Gulf of St. Lawrence, to the Bay of Fundy, New Brunswick and Fife, Scotland. He divided fronds from these populations into arbitrary size-development classes (see Fig. 9), originally seven classes (Taylor, 1956), but later four (Taylor, 1959, 1970, 1971). As young fronds are formed throughout each growing season and older ones continuously lost, a large percentage (20-40%) occurs in Classes I-III, and a small percentage (3-10%) in Class IV (cf. Prince and Kingsbury, 1973b as well). Taylor and Chen (1973) noted a consistent percentage distribution pattern during different years and at various locations. The largest plants in Class III and those in Class IV were most vulnerable to storm removal. Mathieson and Burns (1975) observed the same patterns, particularly for low intertidal and shallow subtidal populations **(Fig. 2).** The size frequency distribution patterns also vary substantially depending upon the severity and time since harvesting **(Fig. 10).** After 16-18 months of regrowth on sequentially denuded quadrats, the size frequency distribution of various frond populations was basically at control levels, similar to those described by Taylor (1959, 1970, 1971).

Figure 9. Four arbitrary size development classes of Chondrus crispus fronds as outlined by Taylor (1959, 1970, 1971) - Taylor and Chen (1973).

Figure 10. Size frequency distribution of Chondrus crispus fronds on sequentially denuded quadrats at Rye Ledge, New Hampshire (from Mathieson and Burns, 1975).



Several investigators have described the density and/or standing crops of Chondrus crispus and/or Gigartina stellata (cf. Boney, 1965). Marshall et al. (1949) found that G. stellata made up 50-90% of the standing crop at several sites in England, Scotland and Wales. The standing crops of harvestable Gigartina, and smaller amounts of Chondrus, on Scottish shores varied from 1.4-146 tons and 0.5-60lbs./linear yard. Approximately 460 Chondrus fronds greater than 2.5 cm were found per m². Pybus (1977) found frond densities (as $\log_{10}$ (n+1)/dm²) for C. crispus and G. stellata in Galway Bay, Ireland, of 0.3-1.9 and 0.3-1.7, respectively. Monthly estimates of standing crop for Irish moss at three sites varied from 1.3-79.2 g dry weight/m², with the mean annual values for the three sites being approximately 14.6, 18.0 and 40.0g dry weight/m².

MacFarlane (1952) states that the average standing stock of Chondrus crispus in southwestern Nova Scotia varies from 1-2.5 lbs/ft^2 (i.e. 0.453-1.132 kg). In one 30 mile stretch of coastline in the same area, the average standing stock was approximately 1,361,000 kg/mile^2 (MacFarlane, 1968). In a study off Prince Edward Island, Taylor (1970, 1972) found approximately 11,000 fronds/m² for about 1000m in a shoreward direction. The mean dry weight of Irish moss on this same transect was 426 g/m², With a conversion factor of approximately five (Stoloff, 1949), this would correspond to a wet weight of 2.13 kg/m², On another of Taylor's transects off Prince Edward Island, he found approximately half this density. Pringle (1979) states that the mean standing crop off southwestern Nova Scotia is approximately 436 g dry weight/m², In reviewing the standing stocks of Chondrus in southwestern Nova Scotia and approaches to the Bay of Fundy/Michanek (1971, 1975) records wet weights of 5-12 kg/m², Gigartina stellata replaces C crispus within the Fundy area and its standing stock (i.e. wet weight) is approximately 5-15 kg/m².

Foster (1953, 1954, 1955b, 1956) records 0.6-7.5 kg wet weight/m² of Irish moss in Maine, with the most productive areas of Washington County (i.e. northern Maine) having 6.0-7.5 kg/m², In New Hampshire, Burns and Mathieson (1972) found 7-8 kg wet weight/m² of Gigartina stellata under ideal conditions of elevation and wave action. Similar studies of Chondrus crispus showed approximately 11-13 kg wet weight/m² (Mathieson and Burns, 1975) although both of these values were extremely variable depending upon elevation and local habitat characteristics. Prince and Kingsbury (1973b) state that the seasonal biomass of Irish moss at Plymouth, Massachusetts, varied from 5,035-12,768 fronds/m² (x = 7,409) and 739-1517 g dry weight/m² (x = 1084) at -3.0m versus 2,466-8,266 fronds/m² (x = 5,783) and 677-1,182 g dry weight/m² (x = 911) at -6.1m.

4.2 Sporophyte-gametophyte and sex composition

Although the life history of Chondrus crispus is triphasic in culture (see Section 3.1), several investigators have reported spatial differences in haploid and diploid dominance (Bhattacharya, 1985; Craigie and Pringle, 1978; Mathieson and Burns, 1975). While working in three subtidal sites in Prince Edward Island and one in Nova Scotia, Craigie and Pringle (loc. cit.) found that the number of tetrasporic plants varied from 22.2-31.2% at the former to 51.4% at the latter. In contrast, Bhattacharya (loc. cit.) found 6-10% of the intertidal populations at another Nova Scotian site to be tetrasporic. Mathieson and Burns (loc. cit.) found a greater number of tetrasporic than carposporic plants within the subtidal zone in New England **(Fig. 11);** pronounced spatial differences were noticed in the intertidal composition of tetrasporic plants depending upon the degree of exposure to water motion **(Fig. 12).**

4.3 Mortality, morbidity

Although Chondrus crispus is a perennial taxon, its fronds may be ephemeral or annual (cf. Hooper et al., 1980; Lilly, 1968; MacFarlane, 1968; Marshall et al., 1949) in fluctuating habitats. Shoots of different ages are present on a single discoid holdfast, and if left undamaged, it continues to produce shoot primordia for a number of years (MacFarlane, loc. cit.). Holdfasts damaged by storms, harvests, grazing, etc., may regenerate and give rise to new shoots (cf. Chen and McLachlan, 1972).

Ice scouring can result in ephemeral or annual frond populations, reduced plant stature and limited reproduction (cf. Section 2.3). Mathieson and Burns (1975) emphasize that winter storms cause pronounced fluctuations in the weight and size of Chondrus populations, particularly in exposed open coastal areas. Demographic studies by Bhattacharya (1985) on intertidal Irish moss demonstrated a strong relationship between size (maturation) and survivorship after storms.

Figure 11. Changes in reproductive capacity of Chondrus crispus with vertical position on the shore at Jaffrey Point, Newcastle; New Hampshire; U.S.A. (from Mathieson and Burns; 1975).

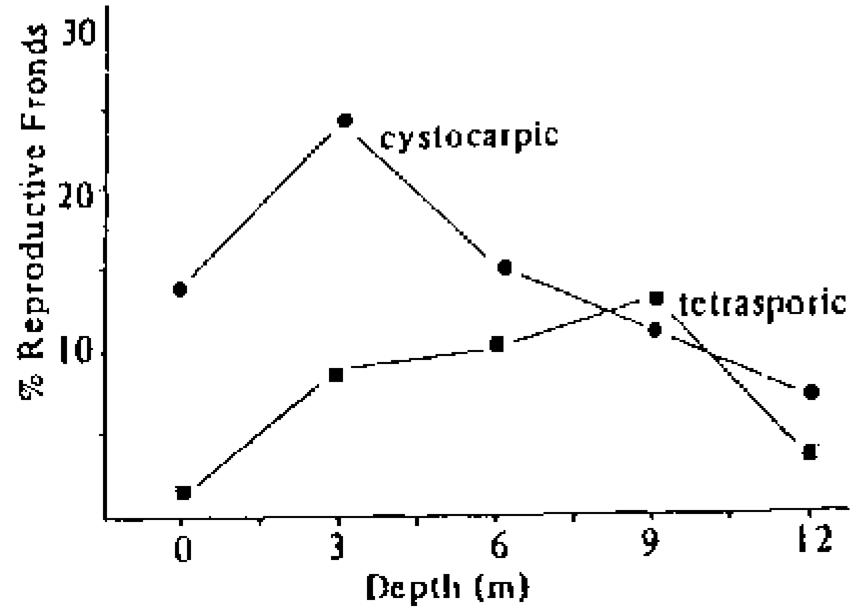
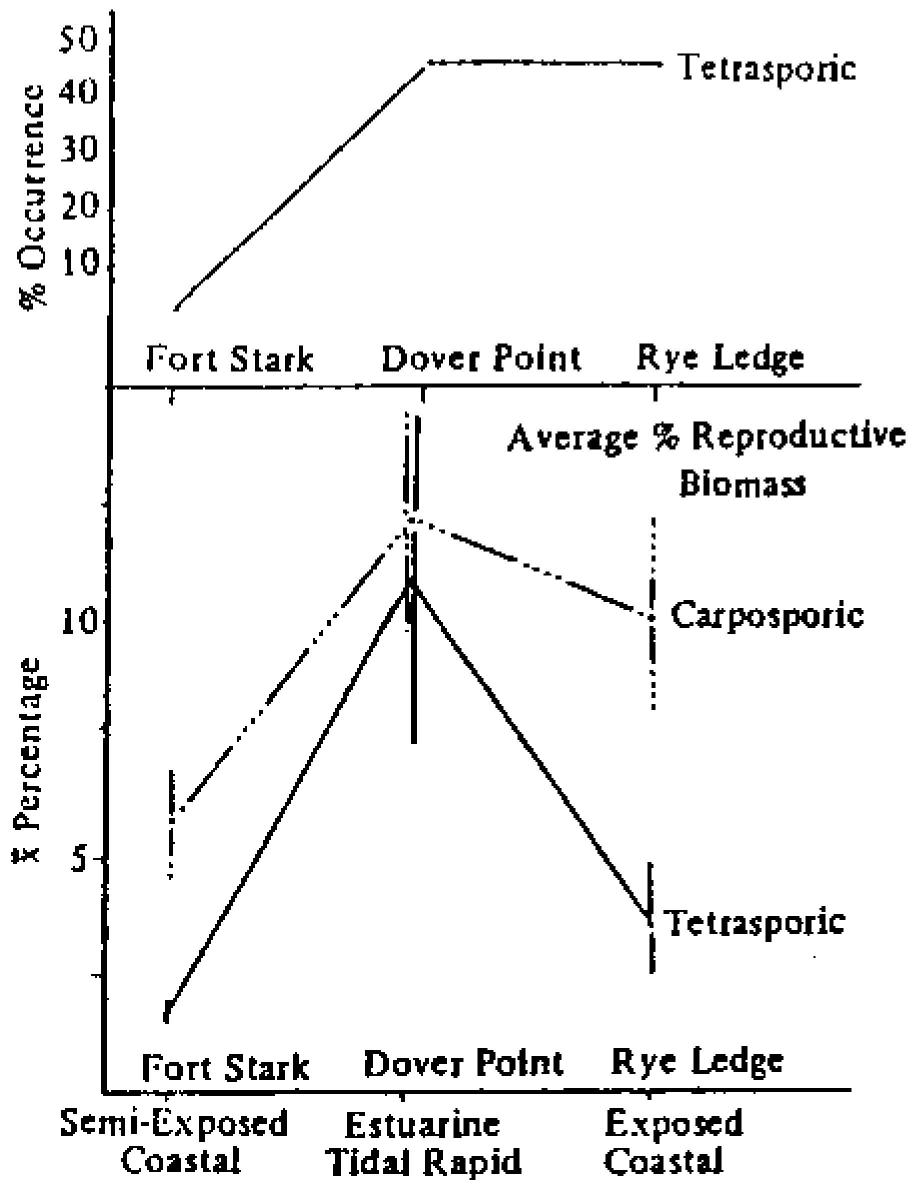


Figure 12. Horizontal variations of reproduction with Chondrus crispus populations in New Hampshire; U.S.A. (from Mathieson; 1982).



A variety of animals, bacteria, fungi and other plants can adversely affect the survival and growth of Irish moss (see Mathieson and Prince, 1973, for a synopsis). Thus, epiphytic algae can increase the potential of frond breakage, as well as decrease its growth, survivorship and reproductive output (D'Antonio, 1985; Prince, 1971; Pybus, 1977), while several fungi and bacteria can parasitize and badly infect the plant (e.g. Andrews, 1976; Cantacuzene, 1930; Chemin, 1927, 1931; Ring, 1970; Prince 1971).

4.4 Grazing

Most animals found on or amongst Chondrus crispus are small forms (e.g. amphipods, bryozoans, crustaceans gastropods, nematodes, etc.) or juvenile stages of larger organisms like urchins, mussels, crabs and sea stars (Lilly, 1968). Recent population explosions of the green urchin Strongylocentrotus droebachiensis have caused extensive damage, perhaps as a result of overfishing of one or more predators or pollution (Mann, 1977; Pringle et al., 1983; Sivertsen and Bjorge, 1980; Wharton and Mann, 1981). Similarly, Mytilus edulis can cause the plant's demise **(Fig. 13)** via altered sediment deposition patterns, reductions of light and while intense grazing by Littorina littorea of epiphytic species on Irish moss may cause similar effects (Lubchenco, 1978; Lubchenco and Menge, 1978; Menge, 1975). Haliotus and Acmea testudinalis browse on a variety of seaweeds, including Chondrus (MacFarlane, 1968).

Figure 13. Changes in biomass of Chondrus crispus and Mytilus edulis on a pier piling at an estuarine tidal rapid site at Dover Point, New Hampshire, U.S.A. (from Mathieson et al., 1983; Reynolds, 1971). space, etc. (Lilly, loc. cit.; MacFarlane, 1956, 1968; Reynolds, 1971),

4.5 Regeneration

Several workers (Foster, 1955a; MacFarlane, 1952; Marshall, et al., 1949; Mathieson and Burns, 1975; Taylor, 1959/60) have evaluated the regrowth of Chondrus after harvesting. Mathieson and Burns (loc. cit.), working in New Hampshire, found that carefully and moderately harvested plots (i.e. 1/3 and 2/3 of longest fronds removed) established during the summer (July) allowed regrowth to control levels of biomass after 5-6 months, while comparable winter plots took a year or more to reach control levels **(Fig. 14 and 15).** Totally harvested plots of summer took approximately one year for regrowth to control levels, while comparable winter plots took two years. Winter harvests had a drastic and long-range effect on regrowth. Foster (loc. cit.) evaluated regrowth of Chondrus in Maine after raking at monthly intervals (June-September, 1955). Regrowth was greatest in June and decreased in succeeding months. Marshall et al. (loc. cit.) found that harvesting in Great Britain during September had little or no effect on yields during the subsequent summer. Plots scraped totally in August began to colonize by January, and more than 460 plants exceeding 2.5 cm in length were counted in a metre square. They suggest that Chondrus is a more rapid colonizer than Gigartina stellata, even though the former is more sensitive to harvesting than the latter. The same authors showed that regeneration of harvested populations occurs from holdfasts, as well as from the surface and margin of cut or broken fronds.

Figure 14. Changes in biomass of Chondrus crispus within the low intertidal zone at Rye Ledge, New Hampshire, U.S.A., following harvesting in July, 1969 (from Mathieson and Burns, 1975).

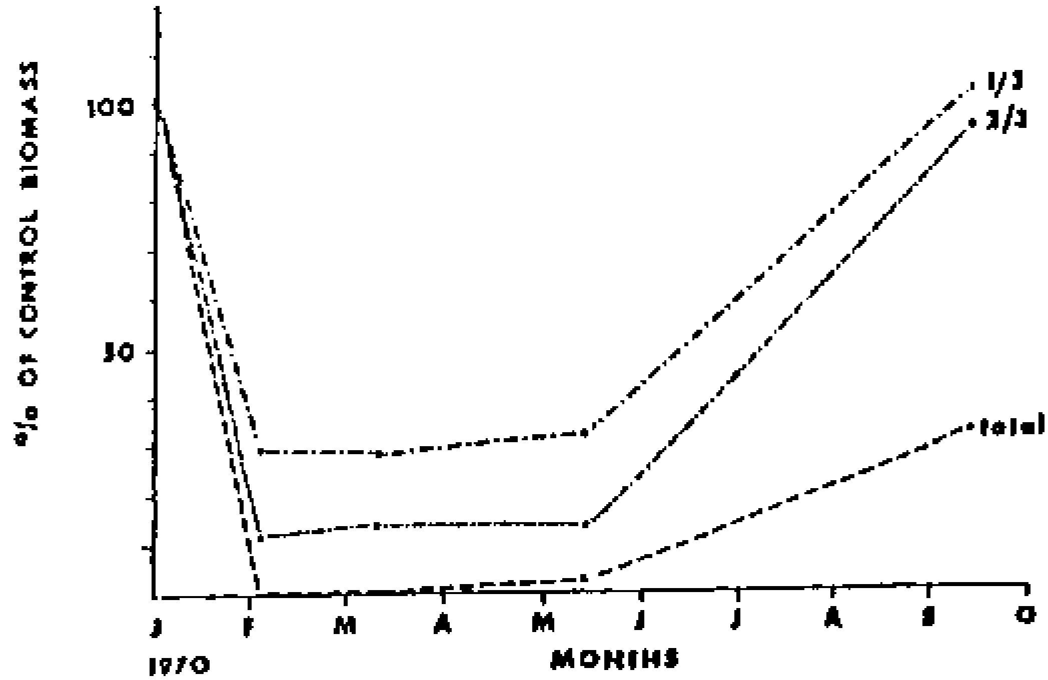
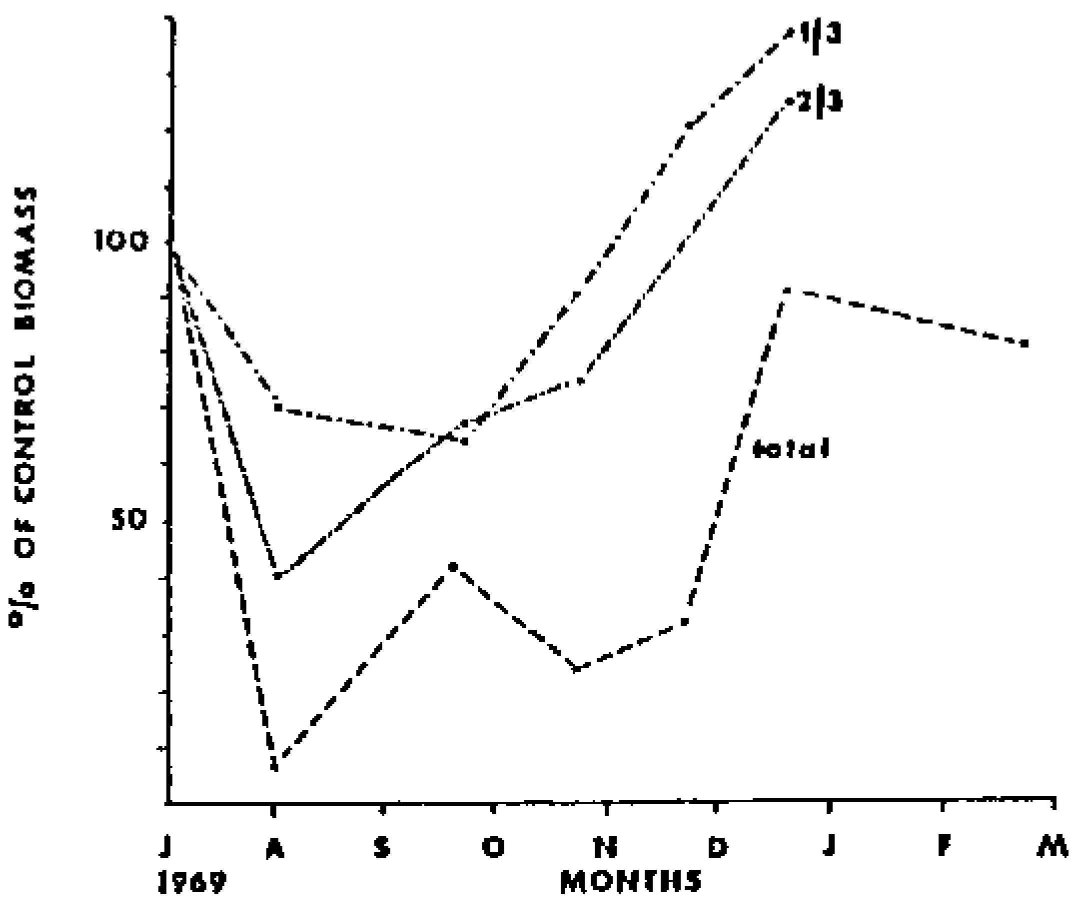


Figure 15. Changes in biomass of Chondrus crispus within the low intertidal zone at Rye Ledge, New Hampshire, U.S.A., following harvesting in January, 1970 (from Mathieson and Burns, 1975).



MacFarlane (1952) and Taylor (1959/60) recorded the effects of differential levels of harvesting on intertidal Chondrus in the Canadian Maritime provinces. MacFarlane (loc. cit.) found that plants cut with sheep shears, as closely as possible, returned to control levels after 18 months. In agreement with Mathieson and Burns (1975), she found that careful raking allowed control levels after six months. Taylor (loc. cit.) found that plucking the crop, in order to simulate intensive raking, reduced the harvestable population after 12 months to 24.5% of the previous year. Clipping the tops of fronds reduced the population after 12 months to 29% of the previous year. MacFarlane (1956) emphasized that severe holdfast injury can ruin a bed for several years. If raking is done properly, only the largest fronds will be removed leaving the short shoots for subsequent regrowth.

Mathieson and Burns (1975) summarized the effects of total harvesting (i.e. only residual holdfasts left) of intertidal quadrats for 20 consecutive months -i.e. starting in February, 1969, and ending in August, 1970 **(Fig. 16).** Plants were allowed to regrow until September, 1970, when the quadrats were simultaneously reharvested. Control levels of biomass and population structure (i.e. size distribution of fronds) were evident after 12-13 months of regrowth **(Fig. 10 and 16).** Younger plots showed differential levels of productivity and/or size.

Figure 16. Regrowth of sequentially denuded quadrats of Chondrus crispus within the low intertidal zone at Rye Ledge, New Hampshire/U.S.A. expressed as g fresh weight/cm² (dry weight = 10% of fresh) (from Mathieson and Burns 1975).

Mathieson and Burns (1975) evaluated the effects of differential levels (careful, moderate and total) and times of harvesting on the reproduction of Chondrus **(Fig. 17).** Carefully and moderately harvested plots of July were at or near control levels (80%) of reproduction after nine months of regrowth; similar December harvests were at 20% and 10%, respectively, of control levels after four months (April) and near control levels after a year. Totally harvested quadrats (both July and December) took over three years to reach control levels. Mathieson and Burns (loc. cit.) summarized the reproductive capacity of Chondrus on totally harvested quadrats established for 20 consecutive months (see previous description). Reproductive structures were found after 13 or more months. In addition, no intact frond less than 2 cm was reproductive. See Boney (1965) regarding further details on the effects of harvesting, including the percentage of holdfasts and juvenile fronds collected by various harvesting gear.

Figure 17. Seasonal changes in reproductive activity in Chondrus crispus populations within the low inter-tidal zone at Rye Ledge, New Hampshire, U.S.A., following harvesting at various levels (1/3, 2/3 and with residual holdfast) in July and January, 1970 (from Mathieson and Burns, 1975).

5. PRODUCTIVITY OF THE RESOURCE

5.1 Standing stock and yield
5.2 Physical and biological factors affecting yield
5.3 Genetic improvement of wild stocks
5.4 Contributions of sexual and vegetative reproduct ion and regeneration
5.5 Enhancement of wild stock environments

The annual landings of Irish moss within the Canadian Maritime Provinces, including a "mixture" of Furcellaria lumbricalis Lamouroux from Prince Edward Island (P.E.I.) since 1966 are summarized in Table 2. The latter material from P.E.I. in Marine Plant Harvesting District #4 (i.e. MPHD 4, cf. Fig. 19) consists of 50 percent "moss" and 50 percent Furcellaria harvested as "storm toss". It has been purchased by Prince Edward Island Seaweeds Co. Ltd., a subsidiary of the Danish Company Litex. since 1974 Furcellaria has constituted 13.0% of the P.E.I. harvest. Between 1948 and 1961 annual landings were similar for both Nova Scotia and P.E.I. Landings from Nova Scotia increased by 39% in 1962 and remained at these levels until 1979. Since 1981, landings have dropped to 1953-54 levels. Sharp and Roddick (1982) analyzed the 1978 to 1980 MPHD 12 fishery, which accounted for 75%-95% of the Nova Scotian annual harvest. The landings decreased 48% in this period due to the following reasons: bio-mass was down 25%; there were 28% fewer daylight low tides; weather conditions were poor; and Irish moss returns/kg were not competitive with other fisheries.

Landings from P.E.I. increased markedly in 1966, and nearly doubled again in 1967. Subsequently, they peaked in 1970 and 1974 (30/000 t) and then dropped to 15/000 t by 1982. The causes of the latter decrease were twofold. First, after 1974, demand decreased, coincident with the success of the Philippine Eucheuma spp. harvest (Parker, 1976). The direct result was a reduction in, or a closure of, buying efforts in marginally productive districts (e.g. MPHDs 5, 6, 7, and 9). Secondly, biomass in MPHD 1 appeared low. Pringle (1981) showed that the wild oscillations in landings **(Fig. 18)** were due to standing crop fluctuations and not effort and price/kg fluctuations. Biomass in 1978 on the Cape Gage bed was the lowest measured in the previous 11 years **(Fig. 20).**

Table 2. The landings of Irish moss (includes Furcellaria sp. in P.E.I. from 1966) per Canadian Maritimes province between 1948 and 1982.

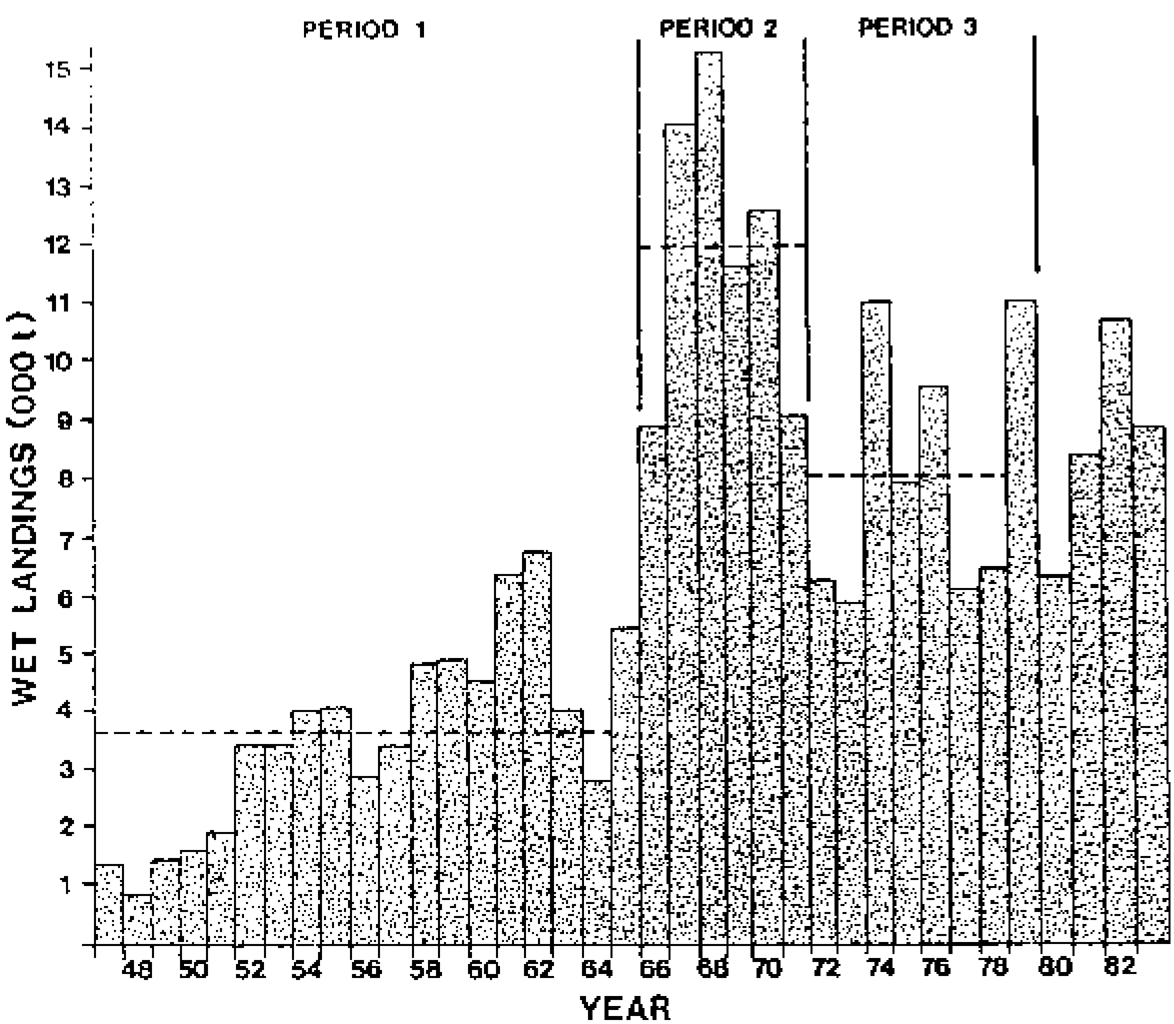
Year	Nova Scotia (MT)	New Brunswick (MT)	Prince Edward Is. (MT)	Total Maritimes (MT)	Percentage of total harvest from MPHD 1 and 12
1948	1,255.0	-	1,327.7	2,582.7	
1949	2,784.1	-	2.220.4	5,004.5	
1950	3,030.4	-	2,126.4	5,156.8	
1951	3,891.8	-	2,538.2	6,430.0	
1952	4,511.8	-	4,000.4	8,512.2	
1953	5,396.4	33.2	4,813.2	10,242.8	
1954	6,583.2	-	5,240.0	11,823.2	
1955	7,834.5	-	5,174.1	13,008.6	
1956	6,841.8	-	4,204.1	11,045.9	
1957	6,942.7	-	4,845.0	11,787.7	
1958	8,015.4	-	6,795.9	14,811.3	
1959	6,660.9	4.0	5,373.6	12,038.5	
1960	7,259.0	4.0	5,678.6	12,941.6	
1961	7,014.5	139.5	0,430.0	15,584.0	
1962	11,491.3	397.2	7,882.2	19,770.7	
1963	11,903.2	49.5	4,779.5	16,732.2	
1964	9,386.8	196.4	3,238.1	12,821.3	
1965	10,069.1	-	7,790.4	17,859.5	
1966	11,634.5	431.4	111,120.0	23,185.9	
1967	13,755.4	519.0	[1]21,784.5	36,058.9	
1968	14,613.2	565.4	[1]24,389.1	39,567.7	
1969	18,568.6	1,707.3	123,540.4	43,816.3	
1970	14,224.1	3,547.3	[1]30,237.2	48,008.6	
1971	12,017.7	1,496.8	[1]23,074.1	36,588.6	
1972	9,676.4	1,085.9	113,853.2	24,615.5	
1973	10,673.2	1,034.5	[1]22,328.6	34,036.3	
1974	15,378.2	4,696.4	[1]30,326.2	50,400.8	[2]56.8
1975	14,158.5	3,271.9	[1]18,958.3	36,388.7	[2]63.9
1976	10,653.5	565.5	[1]16,293.3	27,512.3	[2]83.1
1977	12,199,5	1,010.1	[1]12,000.1	25,209.7	[2]76.0
1978	13,155,5	985.6	[1]15,356.5	29,497.6	[2]68.9
1979	9,463,8	687.5	[1]17,840.1	27,991.4	[2]77.3

1980	7,036,3	1,091.1	[1]15,929.5	26,050.6	[2]62.8
1981	6,598,6	763.9	[1]14,707.3	22,069.8	[2]64.4
1982	5,207,5	661.7	[1]14,519.3	20,388.5	[2]65.9
1983	5,622,0	73.0	12,736.0	18,431.0	
1984	4,459,0	-	15,751.0	20,210.0	
1985	5,426,0	-	17,419.0	22,845.0	

[1]Includes "mixture" which constituted 13% of the harvest.

[2]The percentage of the total annual landings harvested in MPHD 1 and 12.

Figure 18. Annual Irish moss landings in MPHD 1 (Prince Edward Island, Canada) between 1947 and 1982. The broken horizontal lines represent the mean annual landing for each of three periods.



5.1 Standing stock and yield

Thirteen commercially important Irish moss beds have been identified in MPHD 1. Based on distribution of commercial effort (Pringle and Semple, 1984) seven of these beds **(Fig. 21)** yielded the bulk of the crop. In 1979 these seven beds were surveyed for their type of substratum, area, percent cover of Chondrus and other species (Pringle and Semple, 1983). The seven beds ranged in size from 16.3 ha (at Horses Head) to 104.4 ha (at Pleasant View), with their total area being 512 ha. The area of the remaining six beds would not exceed 100 ha; consequently, the total productive area in MPHD 1 is about 600 ha.

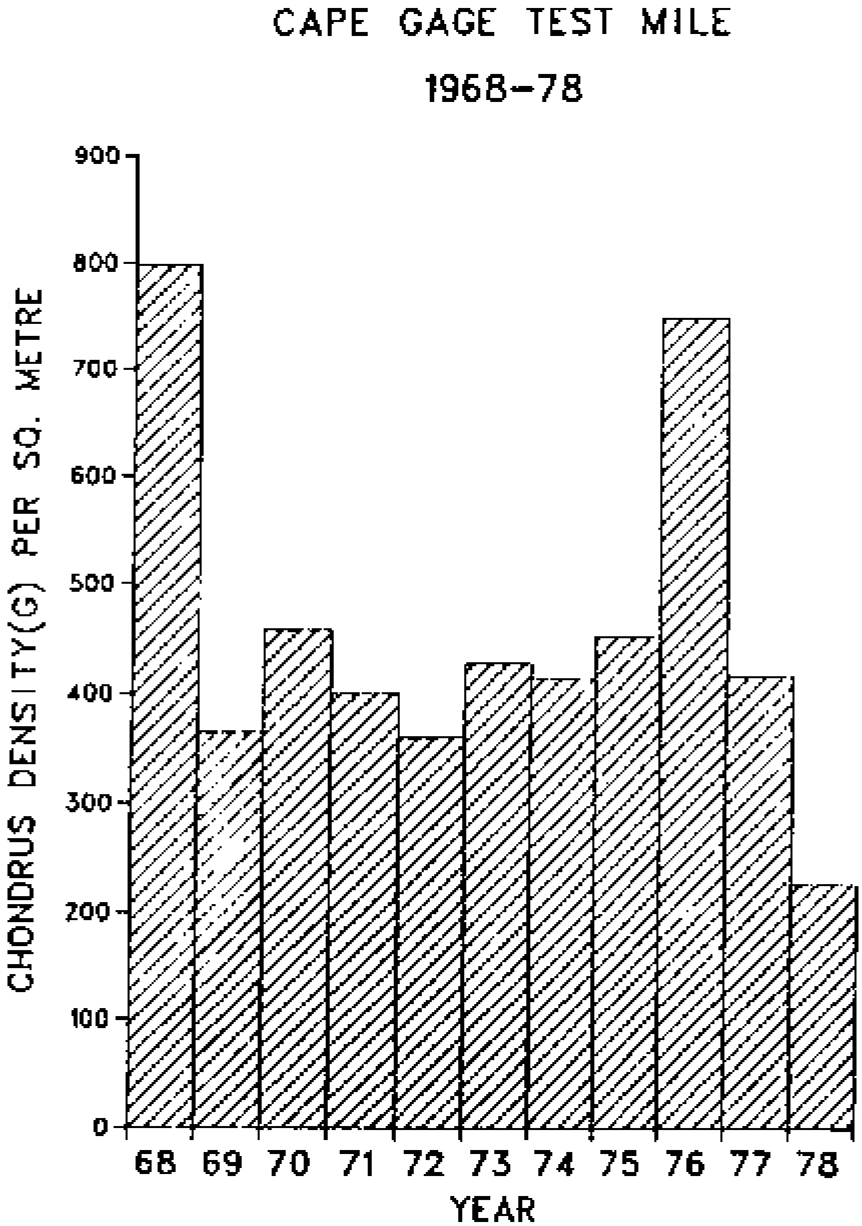
Figure 19. The designations of MPHDs 1-14 as per the Atlantic coast marine plant harvesting regulations. "Oceanic" Nova Scotia extends from the southeastern portion of MPHD 12 to the eastern portion of MPHD 10.

Annual landings for MPHD 1 are available from 1947 to the present **(Fig. 18).** The mean annual landing (wet wt.) between 1966 and 1971 was 12,000 t (Pringle, 1981); this value declined to 8,029 t between 1974 and 1982. The respective yields for the former and latter periods were 20 and 13.4 t/ha or 2.0 and 1.3 kg/m² respectively.

Preseason standing crop was measured on the Cape Gage Irish moss bed (cf. Pringle and Semple, 1983 for location) between 1968 and 1978, using a point transect technique (Johnstone and Herring, 1968). The mean annual standing crop fluctuated markedly through this period **(Fig. 20),** ranging from 0.23 kg/m² (1978) to 0.80 kg/m² (1968). The estimated standing crop for this 92 ha bed was 211.6 t in 1978 and 736 t in 1968.

A modified, random stratified, sampling technique (Pringle and Semple, unpublished) was employed in 1980 to assess preseason standing crop in MPHDs 1, 2, 6, 7, and 9 **(Fig. 19; Table 3).** The total macrophyte standing crop/m² (dry wt.) ranged between 24.5 g(MPHD 7) and 251.6 g (MPHD 9). Irish moss standing crop (dry wt.) ranged between 12.8 g/m² (MPHD 6 - by catch was 81.6%) and 199.5 g m^{-2} (MPHD 9). As summarized in **Table 3,** the catch per unit effort (i.e. CPUE) values for the dragrake "winchers" (cf. Section 7.0) employed in each district ranged from 141 to 470 kg/h (dry weight) in MPHD's 6 and 2, respectively.

Figure 20. The mean standing crop/m² of Chondrus crispus (i.e. all that could be removed by SCUBA divers) on the Cape Gage (Prince Edward Island) commercial Irish moss bed (MPHD 1) between 1968 and 1978.



Pringle and Semple (1980) used a point transect technique to assess Chondrus crispus biomass **(Fig. 3)** in the middle of MPHD 12. At the end of the harvest season in August, the mean standing crop throughout the range was 1.1 ± 0.9 kg m^{-2} (wet wt.). Haggerty and Hellenbrand (1976) employed a qualitative assessment technique. That is, a sled with a SCUBA diver was towed along the transects, while the percent cover was estimated and converted to biomass using fresh weight harvested from selected quadrats. An estimated 1,600 ha of commercial beds occurred in this area between the eulittoral and -4m. Chondrus wet weight/m² from 0 to -1.8 m, -1.8 m to -3.6 m and >-3.6 m was 1.5, 0.64 and 0.46 kg, respectively; a crude estimate of standing crop would be 13,920 t (i.e. 1,600 ha x 0.87 kg/m²). The mean annual handrake (see Section 7.0) landing for 1975/1976 was 12,405 t. Sharp and Roddick (unpublished data) demonstrated that the prime harvest area accessible to handrakes was above -1 m below chart datum. Thus, they concluded that only 800 ha is accessible to handrake harvesters in MPHD 12.

Figure 21. The location of the seven major commercial Irish moss beds in MPHD 1 (Prince Edward Island) between 1975 and 1981.

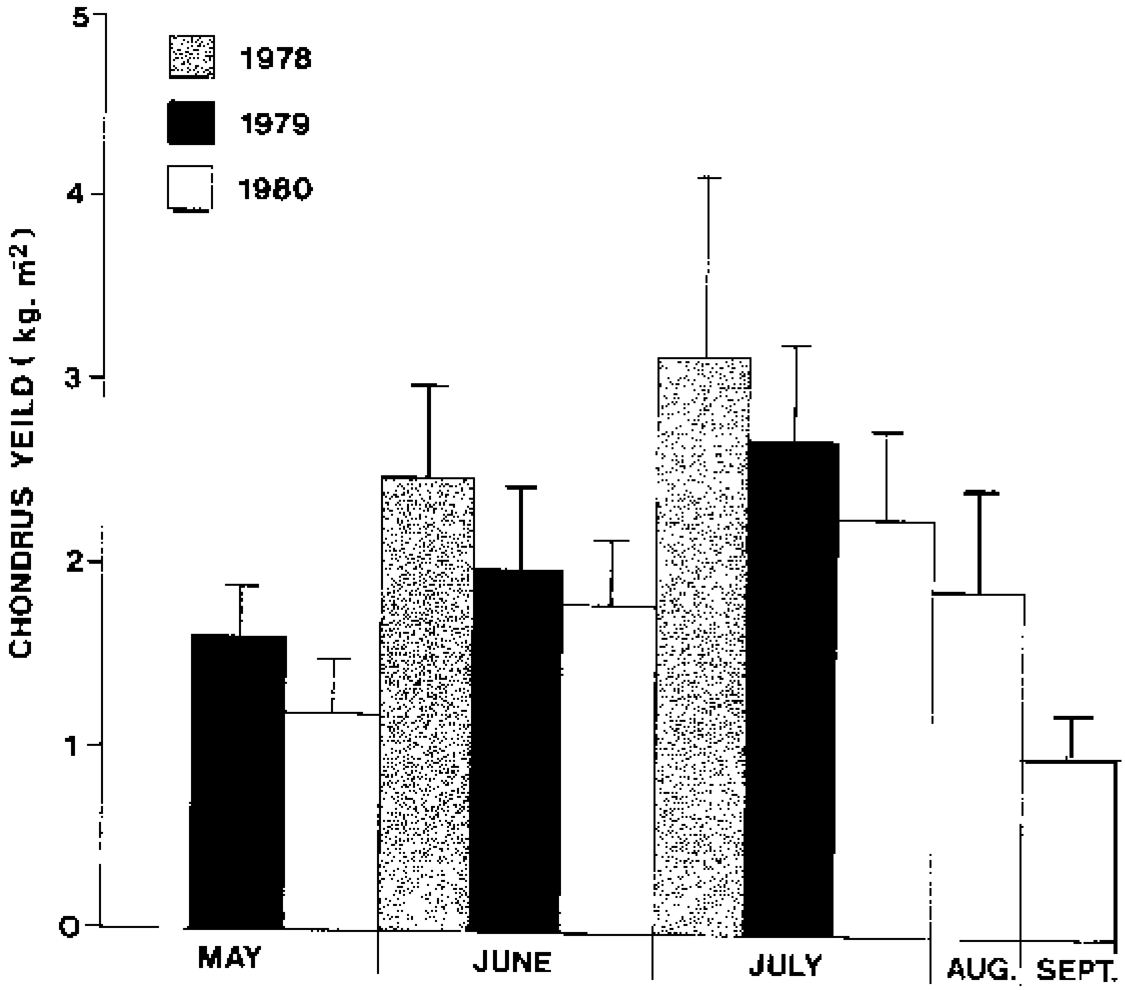
Table 3. Preseason CPUE and biomass of Chondrus and other taxa in commercial Irish moss beds in Marine Plant Harvesting Districts 1, 6 and 7

Biomass (g-1m² = dry wt.)

District	Bed	CPUE (kg h^{-1})	Chondrus	Other Species	Total Total	% Chondrus	% Other Species
6	Chelton Beach	141.9	35.4	7.8	43.2	81.9	18.1
	Redhead	249.7	12.8	56.7	69.5	18.4	81.6
7	Spruce Point North & south	213.8	24.3	0.2	24.5	99.2	0.8
1	Roseville South(Sullivan's)	280.4	-	-	-	-	-
	Pleasant View	306.5	38.4	3.0	41.4	92.8	7.2
2	Coop Dryer (Anglo)	470.7	101.2	7.2	109.6	92.3	7.7
	Sea Cow Pond North	454.0	96.1	4.6	100.7	95.4	4.1
9	Cape Jack	230.0	199.5	49.7	249.2	80.1	19.9
	Blue Rock	296.7	165.2	86.3	251.6	65.7	34.3

To assess annual yield/m² and to explain the above discrepancy/Sharp and Roddick (unpublished data) employed an experimental Irish moss bed (i.e. Lears Island that was closed to hand-raking after the 1977 season). Six successive biweekly harvests were made with a handrake having 5 mm tine spacings. Peak harvestable standing crop between May and September (1978-1980) occurred during early July **(Fig. 22).** The mean yield per harvest was 0.75 kg/m² or 4.5 kg/m² over the three month period. The mean yield per crop was 0.95 kg/m² when harvested monthly for four successive months (total yield was 3.8 kg/m²). There was a complete recovery of biomass with bi-monthly inclusive harvests between June and September.

Figure 22. Harvestable Chondrus crispus biomass/month between 1978 and 1980 on the "closed-to-raking" Lears Island/Nova Scotia, commercial Irish moss bed (MPHD 12).



The Whitehead Island commercial Chondrus bed above -1 m² consists of 12/078 m². Its May biomass was 2.6 ± 1.6 kg/m². The cumulative yield from the harvestable zone of this bed on four test harvests was 2.8 kg/m² or 33,818 kg. However, this estimate did not include the crop removed by commercial harvesters which was estimated at 3.0 kg/m² (wet wt.).

5.2 Physical and biological factors affecting yield

Chondrus crispus, although ubiquitous through eastern Canada (Ffrench, 1971), is commercially harvested in only a few areas with >60% of the annual harvest coming from MPHDs 1 and 12 **(Fig. 19)**. Extensive sea urchin (Strongylocentrotus droebachiensis) grazing in southern and southeastern New foundland (Himmelman, 1980; Hooper, 1980) restricts Chondrus to the eulittoral. Small, sublittoral beds occur in isolated areas of western Newfoundland (Lilly, 1968). They were infrequently harvested in the early to mid 1970s. Standing crop, however, appeared insufficient to sustain a commercial buying/drying operation (Norve, personal comm. to J. Pringle).

Bell and MacFarlane (1933) divided the Nova Scotia biogeo-graphic province (see Watling, 1979) into the following districts based upon the distribution of benthic algal taxa: (1) coastal Bay of Fundy including the western portion of MPHD 12; (2) Nova Scotia's oceanic coast (MPHD 11 and the eastern portion of MPHD 12); and (3) coastal Gulf of St. Lawrence (MPHD 1-9). The flora within each region is uniform with respect to dominant forms and growth characteristics.

The oceanic climate varies between these three regions. For example, MPHD 12 occurs shoreward of an upwelling area (Garrett and Louck, 1976); hence, nutrients for kelp growth are not limiting throughout the year (Gagne et al., 1982), while light may be. Annual summer water temperatures peak at 12°C. By contrast, nutrients are limiting for 8 months of the year along oceanic Nova Scotia (Gagne et al., loc. cit.). Here, late summer surface water temperatures peak at 16°C. In the southern Gulf of St. Lawrence, waters are even warmer, averaging 17°C in summer with 23°C peak surface temperatures. Nutrient levels are ~ 3 times higher than those on the Scotian Shelf (Bugden et al., 1982).

The optimal light requirements for Chondrus crispus are lower than for many intertidal algae (Luning, 1981). Kanwisher (1966) noted a compensation point of only 25 ft. candles (6.3 μ e/cm²/sec.) or less than 1% of full sunshine. The plant's low compensation point is no doubt an important factor accounting for the high productivity of Chondrus in both the fog bound coast of MPHD 12 and the turbid waters of MPHD 1.

High production values are only important in establishing a low valued macrophyte (Chondrus equals $0.14/kg wet) as a commercially important species if biomass is large, and the physical environment, including weather, permits efficient harvesting. The tidal range in MPHD 12 is very large; in this district C. crispus has the widest vertical distribution, and it is the second most abundant macrophyte **(Fig. 4).** The rugged granitic substratum also provides a large surface area **(Fig. 23).** The tidal range in the southern Gulf of St. Lawrence is low, but the sandstone, nearshore ocean bottom slopes gently seaward. Consequently/although the center of a commercial bed can be 1 km from shore in MPHD 1, the mean depth of the beds is only 3.0 m below chart datum (Pringle and Semple, 1983). The prominent substratum in these beds is sandstone ledge (x 31%). Four other types of substratum were identified based upon their size (fines, cobble, rock, and boulders). A positive correlation was recorded between percentage of ledge and Irish moss cover in each bed (Pringle and Semple, 1983). The deposition of fines over a ledge or the movement of boulders and rock by water and ice reduces the standing crop.

Figure 23. A typical Irish moss handraker and hand powered (oars) boat from MPHD 12. Note the rugged granitic, glacial till of Lobster Bay, Nova Scotia (1976).

The maximum frond size varies significantly ($P \leq 0.05$) between Gulf districts (Pringle and Semple, unpublished data, in **Table** 4). Harvesting pressure and local environmental conditions may cause this variability with the mean frond dry wt. being much greater in MPHD 9 than in MPHD 1/6/and 7. Harvesting pressure is extremely high in District 1 (Pringle and Semple, 1984) and much lower in Districts 7 and 9. The beds are deeper in MPHD 9, which may be the cause of the larger fronds.

The single most important cause of frond and holdfast mortality in commercially important cropped beds is raking. Pringle (1979) showed that 5% and ~ 30% of the fronds in the harvests from MPHDs 12 and 1/respectively/were attached to holdfasts.

Table 4. Catch characteristics of preseason harvesting trials in districts 1, 2, 6, 7 and 9

Location	Mean Frond No./Sample Unit	Frond Mean Dry Wt. (9)	Percentage Chondrus	Percentage By Catch	% (by weight) of each Morphological Class in the Harvest					
					I	II	III	IV	V	VI
District 1 (Sullivan's)	1638.8±314.1	0.17	85.0	15.0	0.5	1.9	2.3	31.1	53.7	10.5
District 1 (Pleasant View)	1850.5± 87.9	0.19	79.2	20.8	0.5	1.8	2.4	17.8	68.9	8.6
District 2 (Anglo)	1259.7± 138.4	0.23	79.0	21.0	0.2	2.5	0.8	37.3	49.7	9.4
District 2 (Sea Cow Pond)	1333.3± 326.6	0.20	86.2	13.8	0.4	2.0	0.8	33.4	56.1	7.3
District 6 (Egmont	504.8± 150.9	0.15	15.0	85.0	2.2	3.4	1.5	1.6	79.8	11.5

Bay)										
District 6 (Chelton Beach)	3485.8± 611.9	0.08	61.1	38.9	1.3	7.3	9.8	18.3	54.5	8.8
District 7 (Pt. Sapin)	1556.3± 309.1	0.18	97.3	2.7	0.4	3.6	6.7	43.8	37.4	13.2
District 9 (Blue Rocks)	950.2± 59.0	0.35	93.5	6.5	0.1	0.2	0.1	0.5	92.3	6.8
District 9 (Caps Jack)	977.6± 86.5	0.29	86.3	13.7	0.1	0.3	0.2	1.3	90.1	8.1

Although dragrakes tend to select mature fronds, 35.8% in the harvest vs. 12.2% in the beds **(Tables 5 and 6),** immature fronds occur in the harvests (63.9% vs. 87.8% in the bed). Handrakes from MPHD 12, on the other hand, have 73.5% mature fronds in their crop (Pringle and Semple, 1978).

Table 5. The percentage of mature and immature Chondrus plants in both the commercial beds off Caps Cage, Prince Edward Island, and in commercial harvests from the same area during 1976.

Source or samples	Immature plants (I and II) (%)	Mature plants (III and IV) (X)
Scraped from the benthos	87.8	12.2
From the harvesters	63.9	35.8

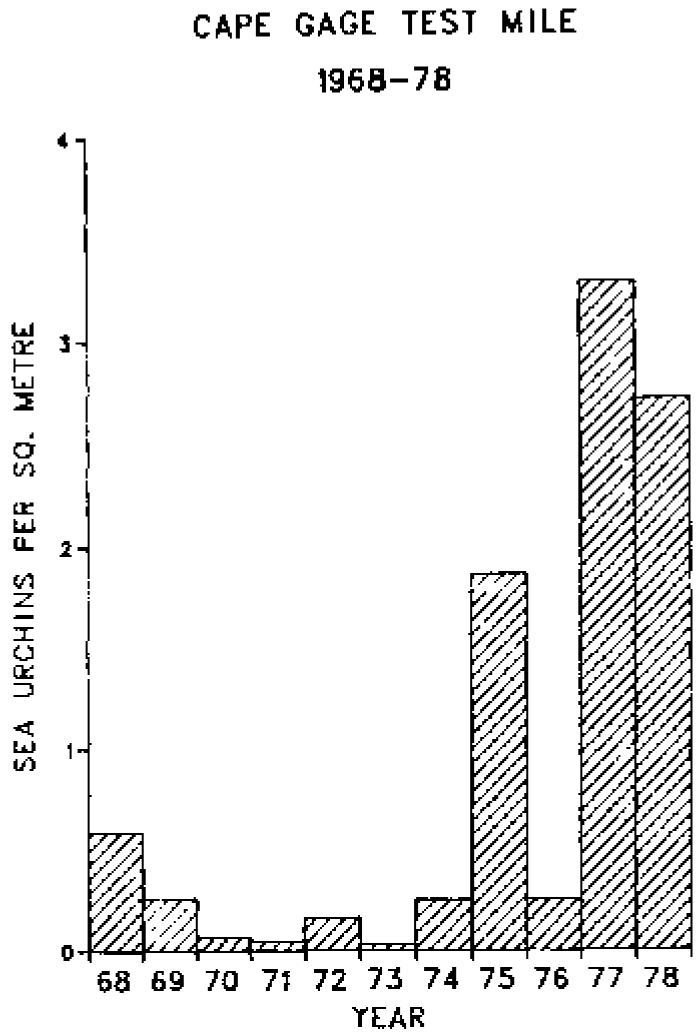
Table 6. The number and percentage of the commercial harvest that was mature, or immature, from the Miminegash, Prince Edward Island, area during June, July, and August, 1976.

Date of Harvest	Immature Chondrus		Mature Chondrus	
	Number of Plants	Percent of Harvest	Number of Plants	Percent of Harvest
June 7-9	728.3	68.0	342.7	32.0
June 14-17	469.4	61.4	294.5	38.6
July 16-21	784.3	67.6	376.5	32.4
August 18-19	594.2	57.7	435.5	42.3

The major herbivore in northwest Atlantic waters is the green sea urchin, Strongylocentrotus drobachiensis (cf. Pringle et al., 1980). It limits the abundance of sublittoral macrophytes throughout the Bay of Fundy and southern and eastern Newfoundland. Episodic overgrazing may occur along oceanic Nova Scotia (e.g. MPHD 11, see Miller, 198; Miller and Colodey, 1983). Urchins are rare in the commercially important beds of MPHD 12, but they are locally abundant in the southern Gulf of St. Lawrence. Sea urchins in the Cape Gaqe bed (MPHD 1) ranged in density from $<0.10/m^2$ (1973) to $3.0/m^2$ during 1977 and 1978 **(Fig. 24).** Sea urchins tend to graze unattached macrophytes (Mattison et al., 1977) unless starved, which may explain their frequent aggregation along the borders of dragraked beds (e.g. MPHD 1 and 2) where many unattached fronds occur. Evidence of extensive overgrazing has not been observed.

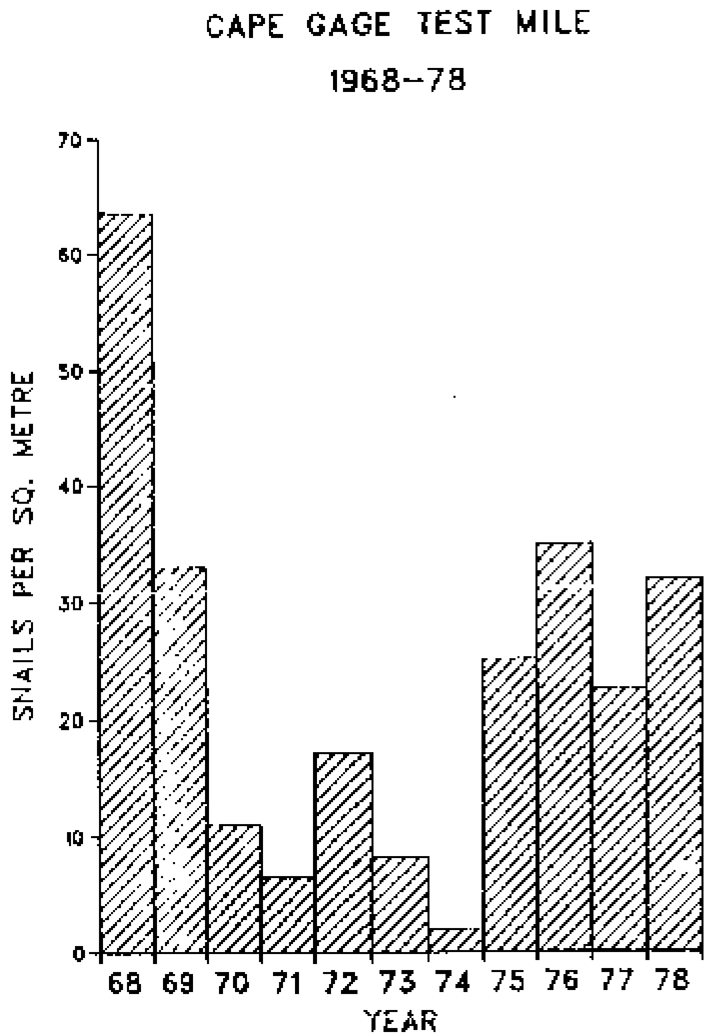
Littorina spp. may also occur abundantly in MPHDs 1 and 12, but extensive grazing has not been noted. The mean densities of snails in the former district can range from 3 to $>60/m^2$ **(Fig. 25).**

Figure 24. The mean sea urchin (Strongylocentrotus droebachiensis) density/m² on the Cape Gage, Prince Edward Island, commercial Irish moss bed (MPHD 1) between 1968 and 1978.



The holdfast of Irish moss adheres well to the substrata, increases in diameter annually (Taylor et al., 1981) and may bear up to 100 fronds of varying size classes (Pringle, unpub. data). With optimal harvesting (MacFarlane, 1968), larger fronds are selectively removed over immature fronds, and the plant's holdfast is left intact for vegetative regrowth. None of the other northwest Atlantic macrophytes occurring in the same zone has such an extensive vegetative recruitment system, and this may explain the competitive dominance of Chondrus crispus **(Table 3 and Fig. 4)** in commercially raked beds (Pringle, unpublished data). For example, many fishermen in various districts have observed that the size of beds increases following a few years of dragraking. That is, competitors are selectively removed from the margins, allowing C. crispus to dominate. Hanic and Pringle (1978) in a series of outplanting studies noted that Irish moss was the competitive dominant over Fucus spp. and Laminaria spp. on cement blocks placed at +5 cm. in MPHD 12 (also cf. Pringle and Semple, 1980).

Figure 25. The mean snail (Littorina spp.) density/m² on the Cape Gage, Prince Edward Island, commercial Irish moss bed (MPHD 1) between 1968 and 1978).



Grazer control in commercially important Irish moss beds has not been attempted. Prior to the massive declines of sea urchins due to disease (Miller and Colodey, 1983), quickliming was successfully attempted in localized habitats (Bernstein and Welsford, 1982). Large scale disease of locally occurring/wild Irish moss has not been recorded.

5.3 Genetic improvement of wild stocks

The potential exists for genetic manipulation within wild Irish moss stocks. The value of the resource, however, precludes this happening in the near future. Previous genetic studies carried out on economic seaweeds, with the exception of the Chinese breeding experiments with Laminaria japonica, have tended to be in concert with aquaculture ventures. Simple strain selection studies with Chondrus crispus have improved its growth rates, carrageenan concentrations, susceptibility to epiphytes, etc. (Chen et al., 1982; Chen and Taylor, 1980; Cheney and Mathieson, 1977, 1978, and 1979; Cheney et al., 1981). Wild stocks of Chondrus were assayed for genetic differences using starch gel electrophoresis (Cheney and Mathieson 1977). Differences were noted. As well, Cheney et al. (1981) showed that biomass productivity differed amongst strains grown under identical conditions. However, they warned growth differentials might be environmentally specific. Cheney (1984) has gone on, with some success, to explore macrophyte genetic engineering using protoplast fusion-somatic hydridization techniques.

5.4 Contributions of sexual and vegetative reproduct ion and regeneration

Plants of Chondrus crispus following 49 years of handraking in MPHD 12 still maintain a dense carpet **(Fig. 4),** whereas in MPHD 1 between 1.2-21.1% of the prime substrata (sandstone ledge) is devoid of plants (Pringle and Semple, 1984). They hypothesized that the major source of recruits in MPHD 1 was via vegetative growth of upright shoots from existing holdfasts. Spores repopulate barren areas (Bhatacharya, 1985; Pringle and Semple, 1980) caused by ice scouring, handrake holdfast removal, dragrake boulder rotation (Sharp and Roddick, 1980), grazing etc. but these barrens are a small portion of the bed.

The adherence of Chondrus crispus holdfasts to sandstone in the southern Gulf of St. Lawrence (i.e. MPHD 1) is more susceptible to interference (Pringle, 1979; Taylor et al., 1981) than that on the granite substratum of MPHD 12. The heavy harvesting intensity (Pringle and Semple, 1984) in MPHD 1 plus ice scouring, annually creates barrens, which can only be successfully recolonized by *C.* crispus sporelings. Pringle and Semple (unpublished data) and Hanic (unpublished data[3]) have shown that Chondrus recolonization by spores will occur on chisel-cleared, sandstone surfaces. However, recolonization of cement outplant blocks(Hanic and Pringle, 1978) was considerably slower in M'PHD 1 than in MPHD 12. Colonization of blocks occurred swiftly in MPHD 1 when there was an overhang of reproductively mature fronds (Pringle, unpublished data), while, elsewhere, C. crispus spore-lings were sparse. Similarly, clay pottery, control outplant units (Hanic and Pringle, 1978) were rarely colonized by in situ produced spores.

[3]Dr. L. Hanic, Professor of Biology, University of P.E.I., Charlottetown, P.E.I.

5.5 Enhancement of wild stock environments

Few investigations have attempted the enhancement of wild Chondrus crispus production. Marshall et al. (1949) conducted weeding experiments on the British coast, but their techniques were not cost effective, although physically possible. Hand-raking at sheltered sites within MPHD 12 removed the "green thread weed" Chaetomorpha spp. from C. crispus, but again it was not cost effective(MacFarlane, 1968). MacFarlane (1952 and 1958) also found that raking reduced encrusting polyzoans on C. crispus.

Pringle (unpublished data) designed trial techniques to "reseed" barren areas in MPHD 1. To date, these techniques have not been employed.

6. METHOD OF HARVESTING AND HARVESTING CYCLE

6.1 Annual cycle of operations
6.2 Manpower productivity
6.3 Alternate employment

6.1 Annual cycle of operations

Individual inshore fishermen in eastern Canada tend to prosecute a number of fisheries. Of these, lobstering is usually the most important (Pringle et al., 1983). Thus, if and where possible, the auxiliary fisheries seasons are dictated by the seasonal occurrence of the lobster fishery which varies markedly between different Lobster Fishing Districts. For example, in MPHDs 1 and 2, the lobster fishing seasons are August 10 - October 10 and May 1 - June 30, respectively, while the corresponding opening dates for Irish moss harvesting are June 10 and July 1. The lobster fishing' season closes May 15 in MPHD 12, and the Irish moss season opens June 1. As a result of this schedule, bona fide fishermen begin mossing prior to the influx of students into the fishery in late June (Sharp and Roddick, 1982). Several other factors may influence the Irish moss harvesting seasons, including annual cycles of weather, tides, frond growth and reproduction, carrageenan concentration and epiphyte abundance (cf. MacFarlane, 1968).

Irish moss is harvested from small boats in MPHD 12 (see Section 7.0) 2 h on either side of low tide. The extreme tide range and fine summer weather permit this successful harvesting technique (40 years - Sharp and Roddick, 1982). In attempting to explain the marked (48%) decline in annual landings between 1978 and 1980, they note that the latter year's season had 28% fewer extreme low tides during daylight than the former year (cf. Sharp et al., In Press).

Frond growth rates increase in late spring, prior to season opening, in both MPHD 1 (Pringle, unpub. data) and 12 (Sharp and Pringle, unpub. data), but maximum growth does not occur until late summer/early fall - i.e. long after the harvestable biomass has been removed. Where exploitation rates are high, as in MPHD 1 (Pringle and Semple, 1984), this may have resulted in overharvesting (Pringle, unpub. data).

A study of the reproductive phenology of Chondrus crispus in MPHD 1 is currently underway. Initial data available from an experimental harvesting study **(Table 7)** shows that the percentage of carposporangium- and tetrasporangium-bearing fronds peaks in May and June, respectively, i.e., just prior to or during the start of the annual harvest. Nevertheless, decreased spore production may be the cause of persistent barrens within MPHD 1 (Pringle and Semple, 1984). Reproductive activity peaks in the Gulf of Maine during late fall/early winter following the harvest (cf. **Fig. 7 and 8**). Although this is a concern, it is presently felt that spore recruitment plays only a minor role in this area as compared to vegetative recruitment.

Table 7. Percentage carposporangial and tetrasporangial bearing fronds in the crop of experimental Irish moss dragraking in MPHD I (Prince Edward Island) in 1977 (n = 224.003).

Percent reproductive fronds		
Month	**Carposporangial bearing**	**Tetrasporangial bearing**
May	6.9	6.1
June	5.3	8.4
July	2.9	4.4
August	2.3	3.4

Within the southern Gulf of St. Lawrence (i.e. MPHD 1 and 2) the inshore fishing grounds are ice-bound from early December to about mid April. High winds in early spring and late fall blow across the exposed grounds. This tends to shorten the fishing seasons further. Another problem is partially silted harbors, which make entrance during storms dangerous. Prior to 1977 (regulation promulgation), the Irish moss season was initiated by harvesters usually in late April to early May. The season opening has since been moved back to June 11 and July 1 in MPHDs 1 and 2 respectively (Pringle, 1985), due to concerns regarding both recruitment and growth overharvesting.

A study of seasonal spore production in an experimental dragraking area (MPHD 1) is only now underway. A preliminary evaluation of the data for 1977 **(Table 7)** demonstrated the highest frequency of tetrasporangium-bearing fronds in June, while the percentage of fronds bearing carposporangia was maximal in May. If these data hold up, then there is a chance of recruitment overharvesting, particularly in MPHD 1. The holdfasts are attached to sandstone in this district. Thus, up to 30% of the harvested fronds are attached to holdfasts as opposed to <5% of the harvested fronds in MPHD 12 (Pringle, 1979). See Section 7.0 for further information regarding harvesting techniques, etc. Holdfast removal by dragrakes (particularly basket dragrakes, cf. Pringle et al., 1979), along with the coincidental occurrence of spore production and commercial harvesting may, in part, be responsible for the large percentage (14.5%) of barren substrata within MPHD 1's commercial beds. That is, 9.3% of the prime ledge substrata are barren within these beds (Pringle and Semple, 1983).

6.2 Manpower productivity

See Section 7.0.

6.3 Alternate employment

To attain a Canadian commercial fishing license for most fisheries one must be full-time or have ≥ 60% of his/her total annual income derived from the fishing industry. The above described license procedure is in effect for the dragrake fishery in the southern Gulf of St. Lawrence (MPHDs 1, 2, 6-9). Individuals gathering "storm toss" in MPHDs 3-5 require no license (cf. Section 7.0); those desirous of handraking need not be "full-time" fishermen. Other sources of income (many are students in MPHD 12) for "storm toss" harvesters are from farms, as farm laborers; fishermen, school teachers, etc., and governmental (welfare) assistance.

7. EQUIPMENT USED FOR HARVESTING AND CULTURE OF SEAWEED RESOURCES

7.1 For wild resources

7.1 For wild resources

Irish moss is either harvested by gathering unattached fronds or by cropping attached fronds with a drag- or hand-rake. The major, commercially important beds in the southern Gulf of St. Lawrence are located in MPHDs 1-4 **(Fig. 19),** along the western, northwestern and northeastern shores of P.E.I. The average daily wind speed for P.E.I. is high. Wave surge is frequently sufficient particularly in the spring and fall, to crop the larger fronds (Classes IV and V, see Prince 1971). The latter fronds are tossed (hence the term "storm tossed") along the shore in windrows **(Fig. 26).** Beginning as early as 1927 in St. George Bay, Nova Scotia or MPHD 9 **(Fig. 19),** harvesters gathered this crop (MacFarlane, 1968; Pringle, 1976).

Figure 26. "Storm toss" harvesters forking windrowed Irish moss into trucks along MPHD 1 (Prince Edward Island). Note horse and rider gathering unattached Irish moss with a horse scoop (1976).

The Gulf of St. Lawrence is ice bound from late December to mid April. Often ice will be driven onshore by winds where it gathers in piles up to 5 m thick. During ice breakup/these piles may be wind driven seaward, shoreward and/or laterally several times. Bottom ice scouring removes attached Irish moss crops (termed "spring moss") which may then be wind driven onshore. Harvesters are constantly checking the shore for "storm toss". Where the beach is accessible, searching is carried out on or in bicycles, horses, cars, trucks, tractors, etc. **(Fig. 27).** Elsewhere, the shore is surveyed from cliff tops.

Harvesters may enter the water wearing waterproof; chest length boots **(Fig. 28)** to gather the unattached "moss" concentrated in the surf; they will either pull a scoop with runners or dip the "moss" with a hand net **(Fig. 29).** Horses are also used to gather the unattached moss **(Fig. 30);** they are rigged with a "horse scoop" **(Pig. 26 and 27),** and the harvester either rides the horse into the water **(Fig. 26)** or sends the horse into the surf, guiding it from shore via long reins **(Fig. 30).**

The crop from this operation and the windrowed "storm toss" is forked into horse or tractor drawn wagons **(Fig. 29)** or truck beds **(Fig. 26).** It is then transported to a suitable location such as the harvester's yard or the border of an adjacent road **(Fig. 31 and 32)** for drying and the cleaning/removal of non-commercially acceptable material. The crop is then transported to a buying station.

Figure 27. "Storm toss" harvesters in MPHD 1 (Prince Edward Island) preparing to load horse scooped Irish moss into waiting vehicles (1976).

The land abutting the shores of the southern Gulf of St. Lawrence is frequently excellent farm land. The productive waters support a wide variety of fisheries with lobster as the mainstay of the inshore fishermen. The demand for Irish moss during World War II and the resultant economic value encouraged the gathering of "storm toss". Farmers with wagons, horses and tractors had an advantage over the fishermen in securing this moss. The fishermen in the late 1940s (A. Wedge, personal commun. to J. Pringle[4]) took the advantage from the farmers by going to sea and handraking from their fishing boats. The drag-rake in present use **(Fig. 33)** evolved from the handrake (Pringle et al., 1981). The dragrake weighs 25 kg, is 1 m wide and 0.9 m long; the 42 teeth, 12.5 mm x 12.5 mm x 20.0 cm, each spaced 6.5 mm apart, are secured to the bottom of a steel bar.

[4]Wedge, fisherman, Miminegash, Prince Co., P.E.I.

Dragrake boats are rigged for Irish moss harvesting in one of two ways, with the size of the vessel generally dictating the method **(Fig. 34).** Harvesters with smaller boats (7-10 m) use the "hauler" technique **(Fig. 35)** where up to 6 dragrakes are secured independently to the bulwark by rope (2.5 cm x 20 m). The boat is run in a circular direction when cropping. The dragrakes are returned to the boat via the lobster trap hauler **(Fig. 33)** which is a steel cone-shaped cap driven in a circular motion via the power takeoff of the vessel's engine. The skipper assists in the rake recovery operation.

Figure 28. "Storm toss" harvester equipped with rubber chest waders and modified "horse scoop" in MPHD 1 (Prince Edward Island). Harvester wades through the surf dragging scoop (1975).

"Winchers", vessels up to 14 m x 4.0 m are rigged with a centrally located iron spar (3.6 m x 10 cm); a pair of iron booms (5 cm x 8 m), secured at 45° angles to the deck amid ship **(Figs. 34 and 36)** and a pair of winches (12.5 cm diameter drum) forward of the boom base. Cable (9 mm x 60 m), attached to each drum, is strung through pulleys (10 cm in dia.) and attached to an iron tow bar.

Dragrakes are hooked in triplicate to the tow bar, but they are not attached laterally to each other. A set of dragrakes is used for both the starboard and port sides of the boat.

Figure 29. "Storm toss" harvesters gathering Irish moss from MPHD 1 (Prince Edward Island) waters with dip nets and loading it into a tractor drawn wagon just out of the picture (1975).

Figure 30. Horse and scoop entering surf to gather unattached Irish moss form MPHD 1 (Prince Edward Island) waters. Note long reins used by shore based harvester (1978).

Figure 31. "Storm toss" crop (Irish moss) drying along clay road verge in MPHD 1 (Prince Edward Island) Harvester is turning the crop with a lawn rake to permit faster drying (1979).

Figure 32. Children and mother "cleaning" (removing large, non-Irish moss, matter) "storm toss" harvest while it sundries in MPHD 1 (Prince Edward Island) during 1975.

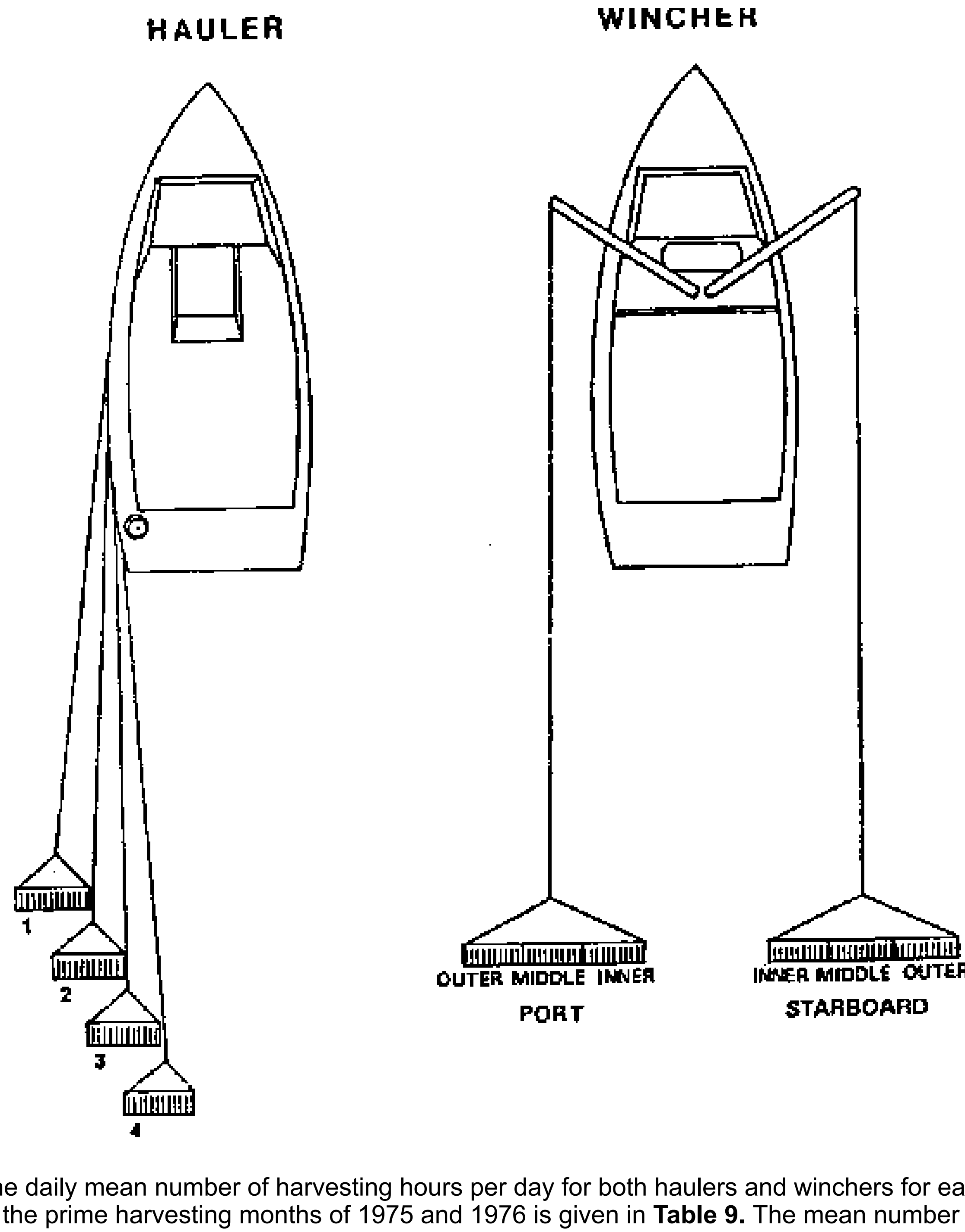
Figure 33. "Hauler" boat captain (at lobster trap hauler) winding dragrake rope around lobster trap hauler (powered by a power-takeoff from boat engine) while the deckhand cleans a single dragrake (1975).

The boat, while harvesting, moves continuously on a straight course; the skipper runs the winches and the boat. While one set of dragrakes is cropping, the deckhand removes the harvest from the opposite rakes **(Fig. 37).** The crop is loosened from the tines with a couple of blows to the dragrake by an iron bar **(Fig. 38).**

Prior to the introduction of the Atlantic Coast Maine Plant Harvesting Regulations (cf. Pringle, 1976, for details), harvesting was often begun in April following ice breakup.

Present regulations dictate a closed season from 11 October to 10 June in MPHD 1 and from 11 October to 30 June in MPHD 2. The number of haulers and winches operating in MPHD 1 and 2 in 1975 and 1976 is given in **Table 8.** The July increase in harvesters is due to the season opening in MPHD *2,* while the August decrease is due to diminished crops and the opening of the lobster fishing season.

Figure 34. Aerial schematic of both "hauler" and "wincher" Irish moss dragrakes typical of MPHD 1 (Prince Edward Island).



The daily mean number of harvesting hours per day for both haulers and winchers for each of the prime harvesting months of 1975 and 1976 is given in **Table 9.** The mean number of potential harvest days for June, July, and August during 1975-1982 was 13.4, 20.5, and 20.*3,* respectively. The mean length of time for each tow during 1975 and 1976 is given in **Table 10;** the two year (1975 and 1976) mean for harvester production for both haulers and winchers was 147.2 and 209.5 kg/h, respectively **(Table 11).** The mean area harvested by winchers and haulers was 7.2 and 6.2 ha/d, respectively (Pringle and Semple, 1984). Haulers and winchers cropped on average 1.1 and 1.72 metric tons/day respectively in 1975/1976 **(Table 11).** Mean annual production per harvester day (2 man-days per boat-day) in 1975/1976 for haulers and winchers was 0.55 and 0.86 t, respectively **(Table 12).**

Figure 35. A "hauler" (the steel booms for the winching technique are rigged as well as this boat was under charter for experimental raking studies) towing seven independently rigged dragrakes in the Pleasant View bed in MPHD 1 (Prince Edward Island) during 1977.

Figure 36. A typical "wincher" dragraking off MPHD 1 (Prince Edward Island). Note the midship attachment of the two steel booms. The winches are operated within the cabin by the skipper. Two cable blocks are visible at the distal end of each boom. The deckhand is resting on the Irish moss crop (1980).

Figure 37. Deckhand on a "wincher" cleaning crop from the port dragrake tines while the starboard dragrakes are cropping Irish moss. Three dragrakes are hooked in triplicate on both port and starboard (1975).

Figure 38. A "wincher" deckhand beating the dragrakes with a steel bar to loosen the tightly bound Irish moss harvest from the tines. Note the single chain bridle linking all three dragrakes to a single towbar. The equipment over the stern is the banned (1977) "basket dragrakes" and a hay fork for moving the crop within, and from the boat (1975).

Table 8. The number of both haulers and winchers observed harvesting the Irish moss beds in MPHD 1 and 2 (Prince Edward Island) in 1975 and 1976

Year	June	July	August
1975	119.8	211.2	63.0
1974	125.3	154.0	39.3

Accurate measures of the harvesting efficiency of dragrakes have not been made. Subjective estimates by SCUBA divers were 10-15% removal of harvestably mature fronds. Probably another 5% is removed but not tine bound; the latter probably forms a portion of the free-floating crop once gathered by basket dragrakes (Pringle et al., 1979 and **Fig. 38).** The free-floating crop is now either swept seaward by currents and lost to the annual yield or swept shoreward by waves and harvested as "storm toss".

About 75% of the Irish moss boats are multipurpose, inshore fishery vessels used in the lobster, herring and groundfish fisheries. Such multipurpose boats tend to be larger and better equipped electronically than those only employed for "mossing". Consequently, the range of boat costs is substantial, varying from about $5,000-25,000 (Canadian). Low interest government loans and grants were available in the past to construct inshore fishing vessels, but this program is no longer available. Boat and gear insurance is offered by the Department of Fisheries and Oceans, but frequently the fishermen fail to purchase it. Harvesters having worked 10 full weeks in areas where the unemployment is ≥ 20% are able to collect unemployment insurance for 40 weeks. Through the 1970s, dragrake gear including winches and dragrakes were available from the buying companies, but this subsidization is no longer available. Dragrakes cost about $60.00 apiece (Canadian) and last about one season. The approximate annual (1985) cost estimates **(Table 13)** for gasoline, engine oil, boat paint, and miscellaneous items necessary to run an Irish moss "wincher" in MPHD 1 was $6,610 (Canadian). This does not include annual amortization of boat construction.

Irish moss harvesting in MPHD 12 **(Fig. 19)** is an important supplementary income for bona fide inshore fishermen, area non-fishermen, and area students. Harvesting technology has not developed beyond the use of the original handrake (MacParlane, 1966; Pringle, 1979) from "moss boats" **(Fig. 39).** These crafts are 4-5 m in length. They are generally powered by outboard motors **(Fig. 40),** but some are rowed as well **(Fig. 23).**

Table 9. Mean daily number of hours harvesting for Irish moss harvesters (haulers and winchers) In MPHD 1 (Prince Edward Island) in 1975 and 1976.

Daily Mean Number of Harvesting Hours

	1975				1976				
	June	July	August	Season Mean	June	July	August	Season Mean	Two year Mean
Haulers	6.9	6.4	7.4	6.9	9.1		7.9	8.5	7.5
Winchers	8.0	5.2	9.6	8.1	10.3	7.9	-	9.1	8.2
Mean	7.5	5.8	8.5	7.3	9.7	7.9	7.9	8.8	7.9

Table 10. Mean length of tow (minutes) for Irish moss harvesters in MPHD 7 (New Brunawick) during 1975 and 1976. Harvesters employed both basket-dragrakee and dragrakes.

Mean length of tow (min)								
	Basket-dragrakes				Dragrakes			
	June	July	August	Seasonal Mean	June	July	August	Seasonal Mean
1975	9.9	8.9	11.3	10.0	2.7	2.8	-	2.8
1976	6.2	8.6	-	7.4	2.0	4.4	-	3.2
Two year mean	8.1	8.8	11.3	8.7	2.4	3.6	-	3.0

Table 11. Mean seasonal hourly production of Irish moss harvesters (haulers and winchers) in MPHD 1 (Prince Edward Island) in 1975 and 1976.

Production h^{-1} of harvest (kg)									
	June	July	August	Season mean	June	July	August	Season mean	Two year mean
Haulers	258.3	159.2	82.2	166.6	125.5	-	110.9	118.2	147.2
Winchers	215.3	126.6	173.9	171.9	398.7	133.2	-	265.9	209.5
	236.8	142.9	128.1	169.3	262.1	133.2	110.9	192. 1	169.0

Table 12. Harvester production for both haulers and winchers in MPHD 1.

1	2	3	4	5	6	7
Harvesting method	Mean daily area harvested (ha da^{-1})	Mean harvesting day (h da^{-1})	Mean hourly production (kg h^{-1})	Mean area (ha) harvested h^{-1}	Mean daily boat prod. (t da^{-1})	Prod. per harvester day (t)
Hauler	[1]6.2	[1]7.5	[2]147.2	[3]0.82	[4]1.1	[5]0.55
Wincher	[1]7.2	[1]8.2	[2]209.5	[3]0.88	[4]1.72	[5]0.86

[1]From Pringle and Semple (1984)
[2]From Table 11
[3]Column 2/Column 3
[4]Column 3 x Column 4
[5]Column 6 x 0.5

Table 13. The approximate annual coat of items required to run an Irish moss "wincher" in MPHD 1 (Prince Edward Island) In 1985 ("hauler" costs Mould be slightly less).

Description or Item	Individual cost ($Cdn)	Number yr^{-1}	Total cost ($Cdn)
Dragrakes	60.0	8	480.00
Dragrake teeth	0.15	600	90.00
Cable blocks	50.00	8	400.00

Cable	2.00 m-1	300 m	600.00
Gasoline or	50.00 da-1	60 da	3,000.00
Diesel	30.00 da-1	60 da	(1,800.00)
Engine Oil	1.50 da-1	60 da	90.00
Boat upkeep (paint, etc.)			*1,000.00
Miscellaneous			60.00
Boat hauling		60 da	*50.00
Food (2 harvesters)	14.00 da-1		840.00
Total			**6,610.00

*These costs are amortized over 3 fisheries for winchers.
**Calculated for gasoline.

Figure 39. A schematic sketch of a MPHD 12 (Nova Scotia) handraker cropping attached Irish moss fronds. The plants always cover the substratum much more thickly than shown here (sketch by G. Jeffrey).

Figure 40. A typical outboard motor powered Irish moss boat in MPHD 12 (Nova Scotia) during 1976.

The granitic substratum off southwestern Nova Scotia is glacial till, hence, the bottom is rugged **(Fig. 23).** There are 61 distinct commercial Irish moss beds between Cape Sable Island, Shelburne Co., and Pinkney's Point, Yarmouth Co., (Pringle and Semple, 1980). Commercial beds occur between +1 and -5m (chart datum). Due to a 5m mean tidal amplitude, handraking is restricted to 2 h on either side of low tide.

The harvester places "mossoil" (fish oil) on the water, creating a slick that reduces wave chop and improves visibility. The rake has a 6 m wooden handle; head dimensions are listed in **Table** 14. The harvester wears both rubber boots and pants when standing in the aft cropping the moss with a raking, then pulling motion **(Figures 23 and 40).** The rake is cleaned in the boat and then returned immediately to the water. The moss is generally sold wet at dockside, although, as with dragrakers in the Gulf of St. Lawrence, a few sell "sundried moss".

With the introduction of outboard motors, about 10% of the harvest (Sharp and Roddick, 1980) is cropped with dragrakes **(Fig. 41).** Thus, both the depth and the harvesting hours have been extended (i.e. not restricted to low tides). However, the rugged bottom restricts the use of this technique.

The total cost of boat and motor are $2,000 (Canadian); they last about six years. Handrakes cost approximately $50 (Canadian); the head and handle are replaced two and three times/season, respectively. Unemployment insurance is available to these harvesters as well.

Figure 41. A typical dragrake towed behind outboard motor powered Irish moss boats (cf. Figure 40) in MPHD 12 in Nova Scotia (a = tines; b = runner and c = tow bar).

Table 14. Handrake dimensions in MPHD 12 (Nova Scotia) during the 1975 harvesting season.

Rake dimensions										
Area studied	Number measured	Head length (cm)		Tine width (mm)		Tine spacing (mm)		Tine length (cm)	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean
Westport	66	22.9-44.4	36.3±4.1	3.18-6.36	4.45±1.06	3.18-12.70	6.80±2.9	6.2-12.5	9.8±1.9

Pubnico	114	22.2-45.7	33.8±4.3	3.18-7.70	4.80±0.36	3.18-12.70	6.28±2.2	6.2-16.3	10.8±1.5
Cape Sable	26	30.5-33.1	33.3±2.5	4.76		3.18-4.76	3.18-4.76	8.6-12.5	10.3±1.3

8. PROTECTION AND MANAGEMENT OF THE RESOURCE

8.1 Management of seaweed resources

8.1 Management of seaweed resources

The British North American Act of 1867 ceded all Canadian, renewable marine resources from, and including, the intertidal zone and below, to the federal government. The resource is considered common property, belonging to the Canadian public; resource leases are not permitted. Harvesters are given the right to harvest on behalf of the Canadian people, but the resource does not belong to them. To prevent a "tragedy of the commons" (sensu Hardin, 1968) the resource is managed; all aspects from resource development through assessment science to resource allocation being under one government agency (see Pringle, 1986), Fisheries Management of the Department of Fisheries and Oceans (DFO). The Minister of Fisheries (elected representative) is the resource manager, but certain responsibilities are relegated to the Directors General (DG) of each of the seven fisheries regions.

The two most important commercial marine plant regions are the Gulf (Gulf of St. Lawrence) and Scotia-Fundy area **(Fig. 18).** Resources are managed via the techno-centric model of Larkin (1977) where harvest rates by species, area, season, gear type, etc., are controlled by the State. The DG receives input from biologists (Fisheries Research Branch), economists (Economics Branch) and industry via a marine plant advisory committee (see **Appendix I** for committee mandates). Members of this committee consist of elected representatives of the harvesters, buyers/processors, provincial government personnel, a DFO biologist, an economist and regulation enforcement personnel. Biological advice is presented to the committee and the DG, only after it has been vetted by the Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC), which is made up of Atlantic Canadian DFO fisheries scientists. Generally, resource management plans are modified annually in large part by this advisory committee.

Canadian fisheries (marine plants are "fish" under the Canadian Fisheries Act) are managed under the concept of optimum sustained yield (OSY). Regulations (see Pringle, 1976, for the Canadian Atlantic Coast Marine Plant Regulations) are enforced by fisheries officers and judicial courts. Marine plants specifically are managed by controlling both the annual number of harvesting days (seasons) and effort within marine plant harvesting districts **(Fig. 19).** Harvesting gear type is also controlled based on impact to the target species (Pringle, 1979; Sharp and Roddick, 1980) and other commercially important species in the community (Scarratt, 1972; Pringle and Jones, 1980; Pringle and Sharp, 1980).

Due to fears of both overharvesting in MPHD 1 and 2 **(Fig. 19),** a freeze was placed on the issuance of new licenses in 1978. To reduce the adverse impact of dragraking, the most deleterious implement, the basket dragrake **(Fig. 38)** was banned in 1977 (Pringle, 1985; Pringle et al., 1979). Further, dragraking **(Fig. 36)** which was thought to be deleterious to the commercially important alga Furcellaria (Scarrat, 1972), was prohibited in MPHD 4 until its impact could be assessed. A minimum handrake tine spacing of 7.0 mm was introduced in MPHD 12 in 1979 based on a study by Pringle and Semple (1978). There is evidence from this district that annual yield would be enhanced by varying each season's opening date in order to better correspond with seasonal growth (Sharp and Roddick, 1982) and tide regime (Sharp, unpublished data). Regional DGs have only recently attained the ability to vary seasonal opening dates on short notice; this harvesting strategy will now be permitted.

9. UTILIZATION

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

9.1 Chemical and nutritional content

Much of the ash in Chondrus crispus (i.e. 17.6 - 21.8%) is represented by the calcium salt of a non-dialyzable sulfate, which is linked to the colloidal polysaccharide, carrageenan (Buggeln and Craigie, 1973). Even so, a wide variety of other minor ash constituents are also evident (e.g. calcium, sodium cobalt, etc.). The plant's major carbohydrates are carrageenan, cellulose and mannitol, with the former being the most important economically (cf. section 9.5). Upon extraction in boiling water, Irish moss is found to be composed of 70 - 79% by weight gelatinous carrageenan substance, plus 15% minerals and 7% proteins (Chapman, 1970). Carrageenan is a hydrophilic, sulfated polyanionic phycocolloid that is a structural component of the cell walls; it is composed of two polymers, D-galactose and 3,6 anhydro-galactose (Anderson and Rees, 1966; Patell, 1972). The percent Nitrogen in the plant varies from 1.3 - 4.6%, depending upon the season and site of collection (cf. Buggeln and Craigie, loc. cit.). Young and Smith (1958) record 20 amino acids, some of which (e.g. gigartine) may have a role as N-storage compounds (Laycock and Craigie, 1977; Laycock et al., 1981). Buggeln and Craigie (loc. cit.) also summarize the variety of lipids, sterols, vitamins and pigments. The vitamin and pigment contents within the plant seem fairly typical of other red algae, except for the relatively high riboflavin content (25 μ g/g dry weight).

9.2 Human foods

Chondrus crispus is only palatable when cooked; even then, it still contains a high proportion of indigestible carbohydrates (Chapman, 1970). In New England and western Europe, fresh or hydrated Irish moss is boiled, and the gel sweetened and flavored with sugar, salt, vanilla, honey, nutmeg, lemon or orange powder to taste; it is then used as a gelatin dessert called blanchmange or used to make aspic dishes and jellies. Boehmer (1982), Chapman (loc. cit.) and Stephenson (1968) note its usefulness in a variety of other recipes, such as in vegetable stews, in soups, and sauces.

9.3 Animal fodder

Irish moss has at various times been used as a "favorite food" for farm animals; as well as for the curing of "wasting disease" in calves, the reduction of gastric ulcers in guinea pigs, as a dietary supplement for dairy cows and pigs providing beneficial effects on their pregnancies, etc. (Boney, 1965; Stephenson, 1968). Even so, there are some accounts of negative effects of carrageenan extracts on experimental animals, including toxicity and suppression of antibody response in mammals (cf. Bird, 1972; Brewer et al., 1974; Thompson and Home, 1976; Yaphe, 1973).

9.4 Manure

Irish moss has been used by maritime farmers in Europe to create soils where little exists and to enrich soils for increased yields (Boney, 1965; MacFarlane, 1968; Stephenson, 1968). It is either added straight from the beach, partly composted or mixed with various barnyard manures; in contrast to the latter manures, it releases nitrogen and phosporus more slowly, has more trace elements (cf. section 9.1) and growth substances and contains no weed seeds or soil micro-organisms (Scagel, 1961).

9.5 Industrial products and processes

Carrageenan from Irish moss is used extensively in dairy products as a stabilizer, gelling and viscosity control agent. A milk protein-carrageenan interaction is employed in products such as ice cream to stabilize the product and in chocolate milk to provide body and suspend the cocoa. It is also used as a gelling agent in baby, dietetic and instant foods, in bakery and candy products, plus in the cosmetic industry as a stabilizing and thickening agent f*or* creams, lotions, toothpastes, etc.

Michanek (1983) notes that the advantage of carrageenan relative to other emulsifiers and stabilizers in foods is that it is possible to manufacture "tailor-made" products, to control texture, mouth-feel, and stability in gels, liquids, pastes and suspensions. That is, different types of carrageenans (kappa and lambda plus, from other seaweeds, iota) can be mixed and blended for diverse uses.

The commercial Irish moss harvest from the northwest Atlantic and, in particular eastern Canada, is purchased by one of a number of buying companies/extractors **(Table 1)** that have been in the region for a varying number of years. The first commercial export of Irish moss was harvested in George Bay, Nova Scotia, in 1927. It was sun-dried by the harvesters and then shipped by them to France (Pringle, 1976). The first P.E.I. Irish moss was purchased and shipped in 1944. Since then the bulk of the crop has been purchased by Canadian subsidiaries of foreign based extractors such as Marine Colloids of the U.S.A. and Litex and Copenhagen Pectin, both of Denmark.

The harvesters in P.E.I. formed a cooperative in the early 1970s and developed mechanical drying capacity, but, without an extraction facility, they were dependent on the foreign extractors. Their market dried up in the late 1970s (cf. Anderson et al. 1977 for details).

Until 1975 Canada produced up to 75% of the western world's raw material source for carrageenan. Even so, no initiative was taken to build an extraction facility, and government agencies did little to encourage local extraction. The provincial government of P.E.I, sought advice from the American based Arthur D. Little consulting firm (Anon., 1971) regarding the potentials of building an extraction plant; they advised caution as the major extractors dominated the markets. This, despite a lack of, or very little, raw material in the countries of extraction. Since then other countries with little or no raw material such as Spain, Japan and New Zealand have developed carrageenan extraction facilities!

Chile is determined not to make the same mistake. The harvests of carrageenophytes (Iridaea and Gigartina spp.) in this country increased by 53% between 1979 and 1983 (Lopehandia, personal comm. to J. Pringle[5]). The bulk of this crop is exported. Recently, the Chileans took the initiative and constructed a carrageenan extraction facility which should permit a marked increase in the value-added to their carrageenophyte harvest.

[5]Mr. Lopehandia, Biologist, National Fisheries Service, Santiago, Chile

By contrast, the value-added for the Canadian harvest is low. Irish moss when purchased wet, is put through a shaker to rid the crop of sand, stone, etc. It is then dried in an oil-fired drum drier, baled and transported to the foreign-based extraction facilities.

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

1. Purpose and Objective

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

2. Duties and Responsibilities

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

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

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

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

3. Membership

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

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

4. Technical Expertise

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