SEA GRANT PROJECT OFFICE

A PRELIMINARY FEASIBILITY STUDY OF IRISH MOSS HARVESTING SYSTEMS

By
James M. Patell

from
Subject 13.719 "Special Projects in Coastal Management"
Associate Professor J.W. Devanney III
Visiting Lecturer R.C. Blumberg

Massachusetts Institute of Technology

Cambridge, Massachusetts 02139

Report No. MITSG 72-14
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Administrative Statement

In the coastal zone, the engineer and the state authority could work productively together. To try to mix technical types with state employees working on problems of coastal zone and offshore resources management, Professor John W. Devanney, III, Department of Ocean Engineering, and Robert C. Blumberg, Massachusetts Department of Natural Resources and Visiting Lecturer, Department of Ocean Engineering, supervised an experimental education and research project during the spring term, 1972. During the academic course, interested students studied several specific coastal zone problems, overall resolution to which lay partly within the political sphere and process.

The written reports of the technical/political mixing attempt are this report on Irish Moss and the potential for harvesting it mechanically and a companion technical report (MITSG72-13), "Student Projects on Coastal Zone and Offshore Resources Management," with two papers--one on aspects of the power plant environmental problem, the other on some experiments in biological data gathering and analysis involving Woods Hole, Massachusetts sewer outfall. We consider these technical reports to be useful in themselves despite the less successful educational experiment that produced them.

The MIT Sea Grant Program, with the authors, has organized the printing and distribution of these project reports. Funds to do this came in part from a Henry L. and Grace Doherty Charitable Foundation, Inc. grant to MIT Sea Grant, as well as from the National Sea Grant Program, grant number 2-35150, and from the Massachusetts Institute of Technology.

Alfred A. H. Keil
Director

June 1972

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Contents

FORWARD

The following report, together with Report MITSG 72-13 constitute the output of the experimental program in Coastal Zone Management under the supervision of Dr. Robert Blumberg of the Massachusetts Department of Natural Resources and myself. Since this was an experimental program, some comments on the research and the educational effectiveness of the program are in order.

Statement by Professor Devanney

The output itself ranges from a solidly professional technical report on Irish Moss to an interesting and seminal but incomplete effort on power plant siting. The Irish Moss study is, I believe, a definitive investigation of this industry. The student involved became extremely interested in the area, aggressively interviewed industry sources, dived and raked for moss, and put together a coherent, comprehensive, and balanced survey which effectively addressed the question that the Department of Natural Resources was asking: what is the potential of mechanical harvesting? He also spent some time in the machine shops with several undergraduates, devising, building and testing the manual moss cutter.

The Woods Hole outfall study was essentially an experimental effort by three students with biolgocial backgrounds involving diver-operated sampling and hundreds of hours of species sorting and counting. These experiments undoubtedly were worthwhile and have added to our general fund of knowledge concerning marine sewage discharge.

However, the students felt uncomfortable with and shied away from the political and economic issues involved.

Both of the above efforts were characterized by little contact with the political bodies in control of the coastal zone after the initial introduction to the problem. So neither of these efforts was really successful in bridging the gap between the engineer/scientist and the political process.

The third effort, on Brayton Point power plant sitting, was more successful in this vein. The student involved was an unusually self-confident and aggressive person who arranged, mainly by himself, interviews with some forty key people involved in power plant siting in New England. In so doing, he probably obtained a unique set of insights into the attitudes of these people and the functioning of the siting process. However, the timing involved did not really give him time to think through his impressions, and thus his final report doesn't really hang together. It would have been better if we had been less ambitious and directed him to merely summarize the results of interviews. This student is now completely committed to coastal zone management problems and will probably continue the present line of inquiry through the doctoral level.

Two other efforts were undertaken under the auspices of the program. One was an aborted study of the process through which the Massachusetts Wetlands laws are being enforced and their effect on coastal zone management in which the student, whose background was solely engineering, was unable to ever get things sorted out and underway.

This person's introduction to the political process was a negative one and it is doubtful if he will ever leave the confines of engineering again.

During the January Independent Activities period a program in marine sewage treatment and discharge was offered. This program attracted some six students, three of whom produced an interim report on the physical properties of sewage plumes as a function of treatment severity. Research on this issue thus initiated is being continued by one student who intends to pursue it through the doctoral level.

Overall, in terms of the program's original goals, the intermeshing of technical types with the coastal zone political process, the program must be rated a failure. With the exception of the power plant study, the reaction was more like a ball hitting a hard surface and immediately bouncing back, bouncing in a different direction, perhaps, but essentially unchanged by the contact.

An important problem in this area was that the students were placed in the position of an expert searching for a problem in areas where no problem was perceived by the bureaucrats operating the political process. For example, with respect to Wetlands management, the bureaucrats perceived the problem as one of enforcing the present law as strongly as the courts allowed; the student was interested in the question of whether the present law was consistent with society's desires. An outsider, who essentially uninvited, come in an questions the established ground rules under which an organization has been operating, is not likely to find that organization very receptive for very long. Thanks to the strong intervention of Dr. Blumberg, we were usually able to smooth over such problems, but the students felt the tension between themselves and the people they thought they were trying to help and generally retreated to issues they could analyze independently of the political process.

The power plant siting example shows that this problem can be overcome if the student is sufficiently motivated. Better orientation prior to the actual meeting between student and public official would probably help. In any event, the program did not catch fire and we cannot recommend its continuation in its present form.

J. W. Devanney

Statement by Dr. Blumberg

My input to the program essentially was one of providing an entry into the arena in which resource decisions are made and to provide the students an "inside" look at this process. In this regard I dealt only with the studies involving Irish Moss, Brayton Point, the Woods Hole outfall and Massachusetts wetlands laws. Therefore, my comments will be confined to these projects.

I see the Irish Moss study as an unqualified success. The assessment of the mechanical harvesting potential was indeed a tremendous contribution to real problem presently being faced by the aquacultural community. By nature, the subject dealt with the scientific or technical in nature and although the student recognized the larger political problem, i.e. Massachusetts marine fisheries statutes stifle the development of Irish Moss and other types of aquaculture, his time constraints and inclinations led him away from this issue.

The Woods Hole outfall study also tended toward the scientific side of the spectrum. My discussions with the students highlighted several distinct economic and political issues involving treatment plant outfall siting and construction, and suggested several methods of approaching these issues. Again, however, the students felt that time constraints would not allow dealing with a wide variety of problems and opted for work most closely associated with their scientific backgrounds.

Study of Massachusetts wetlands laws was very disappointing. The student was extremely bright and perceptive and through three interviews which I arranged and participated in, he quickly identified all the political and economic issues that needed coverage. Further, his engineering background did not seem to be a hindrance in any way. Unfortunately, the student developed personal problems, lost interest in the project and failed to write a final paper despite several attempts to encourage him to continue. Not withstanding this failure, I felt the student was having no difficulty penetrating, understanding or dealing with the political processes and that his initial introduction to it was a positive one.

Finally, I felt the Brayton Point Power Plant study was quite successful. Although the final report has some deficiencies, I was able to assist the student to penetrate and analyze a very sensitive political issue presently being faced by the Department of Natural Resources. In this sense, the project met even the narrow goal of the program. Further, this was the only student who took full advantage of the services and guidance I provided. This, I felt, was due to the fact that he had an economic and political science background and was himself motivated to address these issues. I feel that his interest and commitment to further pursue coastal zone problems made the program successful in itself.

In summary, none of the projects produced any impact on the coastal zone political process and in terms of this specific goal, the program failed. In part, this might be due to the fact that the students with scientific backgrounds opted for work of a scientific or technical nature; in part, due to my reluctance to push the students toward the political and economic facets of their chosen projects and in part to a time limitation which did not permit them to address both.

Parenthetically, even if the students had utilized the relatively open access to the decision makers, the direct impact of such projects on essentially political decisions is questionable. However, all the projects did address real world resource problems. The Woods Hole outfall study and particularly the Irish Moss Project made significant scientific contributions. The Brayton Point Project did penetrate the political process and produced an individual commited, at least in the short term, to coastal zone management. In this larger sense the program made a significant contribution.

Dr. Robert C. Blumberg

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Mr. Paul Vantaglia, President, the Eastern Sea Moss Co.

This research was supported by the MIT Sea Grant Program Project, "Coastal Resource Management." It is one of a number of student projects carried out under the joint supervision of Mr. Robert Blumberg, Director of Mineral Resources, Massachusetts Department of Natural Resources, and Professor J. W. Devanney of the Department of Ocean Engineering at M.I.T. Construction of the experimental moss cutter was undertaken in the Engineering Projects Laboratory at M.I.T.

Introduction

As general enthusiasm continues to mount in the exploitation of the "untapped resources" of the sea, some interest has been expressed in increasing the use of marine algae, or seaweeds. Several popular oceanographic journals and books have dramatized (and in some cases severely over-dramatized) the potential food and drug production capabilities of seaweed. To date, U.S. use of marine algae has been confined to relatively few (less than 10) companies and local and state government marine agencies, although recently several small venture capital firms and one major U.S. chemical firm have attempted to enter the seaweed harvesting and processing field. This study was begun as a result of a meeting between the author and a group of Harvard Graduate School of Business students who were considering the formation of a harvesting company. It was further stimulated by the interest of the Massachusetts Department of Natural Resources in the potential of mechanized harvesting and resultant conservation problems.

The main purpose of this project is to determine the feasibility of developing and operating a mechanized Irish Moss (Chondrus crispus) harvesting system for use in the United States. The project necessarily included consideration of the ocean engineering aspects involved, study of the previous attempts to develop a suitable mechanized harvester, the market for the output, the available labor force, and the legal and conservation aspects. It is intended to carry the study to a point where the most feasible forms of harvester systems are delineated. However, extensive hardware construction and testing are beyond the scope and funding of this project.

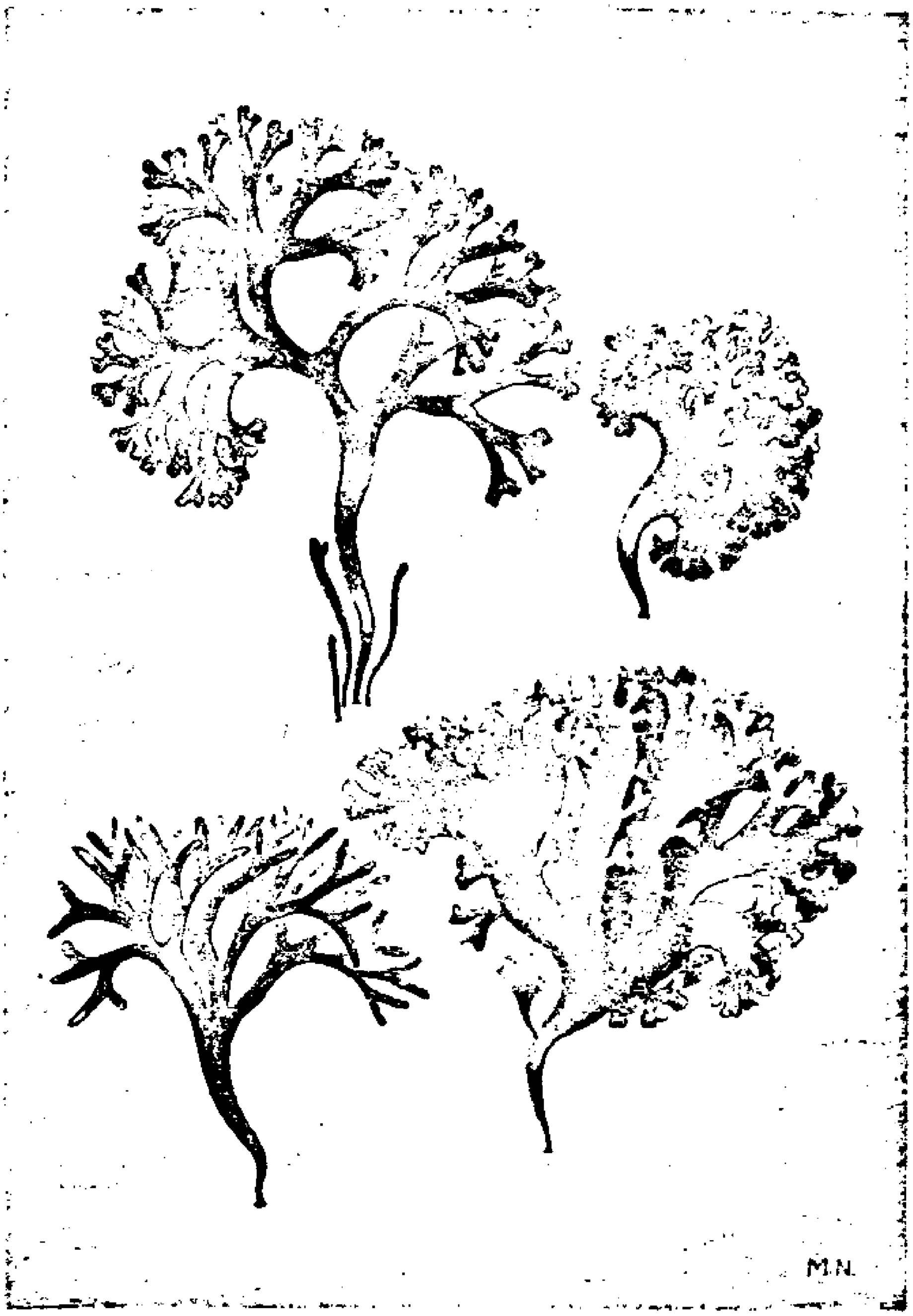
It is important to bear in mind that the various marine algae differ very widely in physical and chemical characteristics, as well as economic value. This project concentrates on one particular species of some economic importance in the U.S., and the conclusions and recommendations should in no way be extended to the U.S. seaweed industry in general. The algae and harvesting conditions on the east coast of the United States bear little resemblance to those on the west coast, and the engineering and economic problems of harvesting different species even in the same general region can be markedly different.

Biological Background

Chondrus crispus, or Irish Moss, is one of the red algae (Rhodophyceae). It is frequently found mixed with another red alga, Gigartina stellata, and when found growing together, both are harvested and processed as Irish Moss. However, Chondrus crispus is the chief carrageenan source. Chondrus is distributed in the North Atlantic from Newfoundland to New Jersey, and from Norway to the coast of North Africa. Some large Chondrus beds have also been located on the coast of Chile. Secondary supplies for both American and European industries come from Spain, Portugal, Indonesia, and the Philippines.

In the United States, the major suppliers of Irish Moss are located in Massachusetts (Scituate, Kingston) and in Maine (Portland, Rockland). In Canada, large beds of Chondrus are found on the coast of Nova Scotia (Yarmouth), in the Northumberland Strait, on the coast of Prince Edward Island, and on some other parts of the Atlantic coast.

Chondrus crispus is a relatively small seaweed, normally ranging from two to fifteen inches in height. Secured to the rocky substrata by holdfasts, the plants are thick and sturdy, with multiple branches near the tips giving them a crisp, tufted appearance somewhat resembling parsley. Chondrus is found growing from just above low water level down to a depth of twenty to thirty feet; those plants exposed to shallow water wave action tend to be shorter and more densely branched



Chondrus crispus — variation of form of frond X 1.0

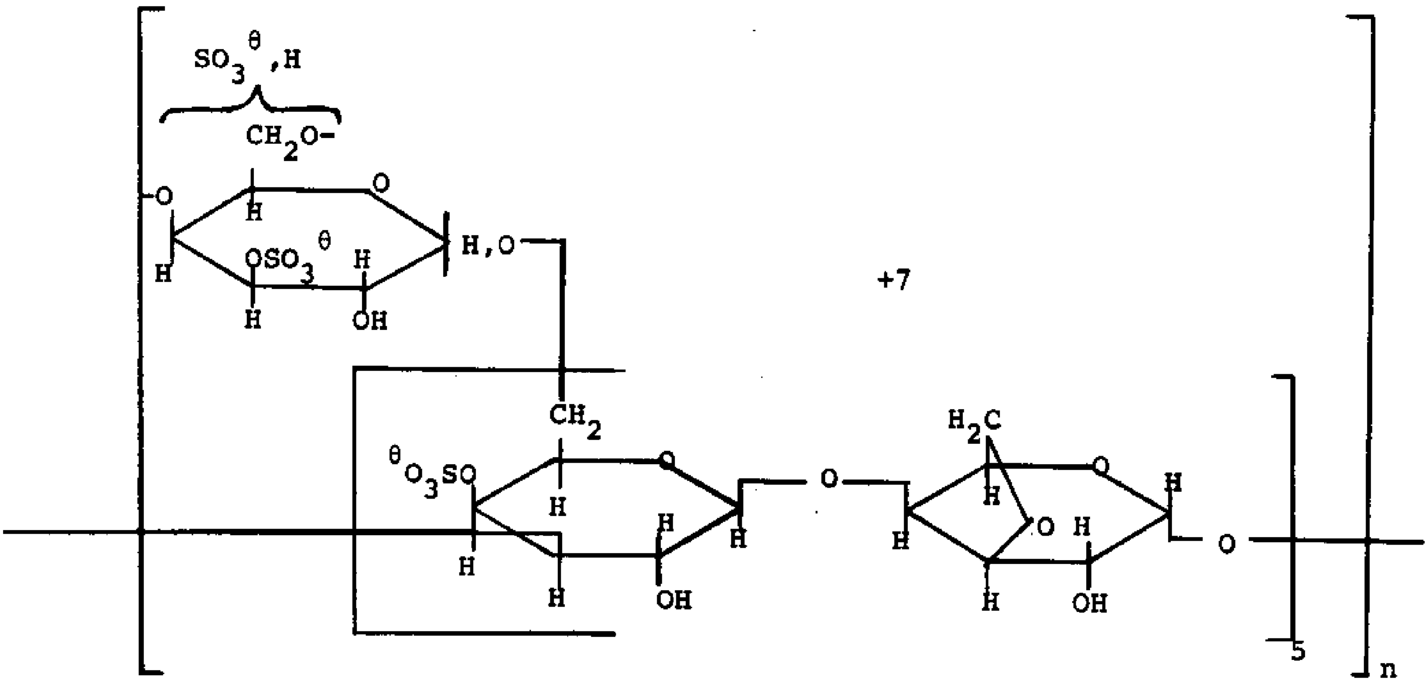
Figure 1

Figure 2

than those in deeper water. The color of the branches varies with season, water composition, and available sunlight, ranging from yellowish green to brown and reddish purple.

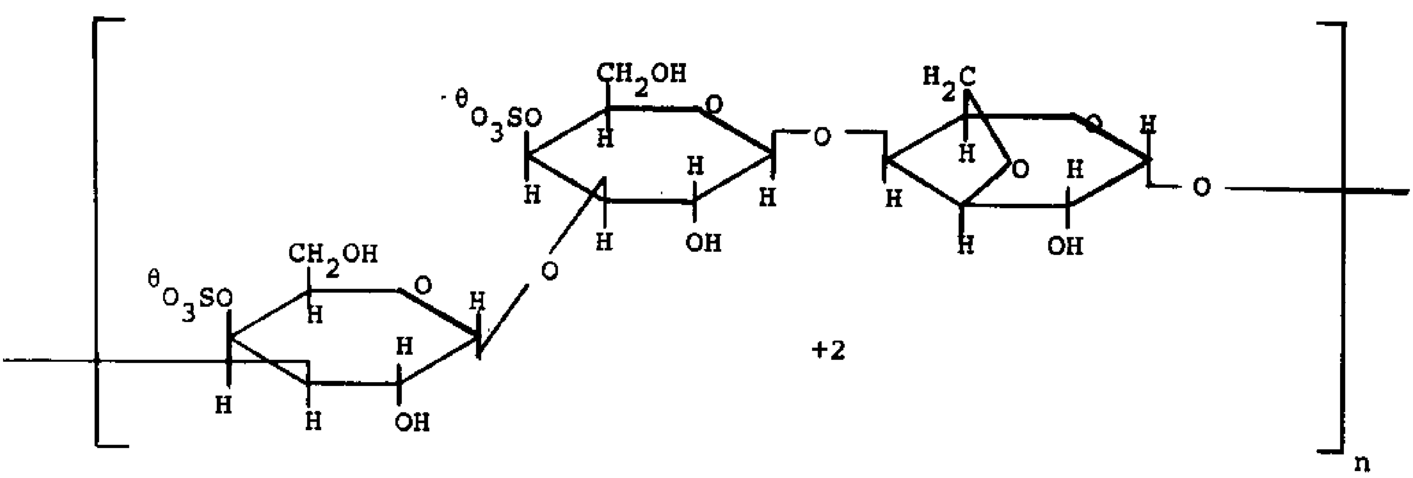
Irish Moss is economically valuable as a source of carrageenan, a hydrophilic sulfated polyanionic phycocolloid, which is obtained from the plant by water extraction. It is normally associated with metallic ions, such as sodium, potassium, or calcium. Three distinct types of carrageenan are highly sulfated linear polymers containing 20% to 40% ester sulfate. The predominantly kappa fraction is potassium sensitive and forms brittle gels. The iota type of carrageenan is calcium sensitive, and forms elastic gels. The lambda fraction is not normally cation sensitive and forms viscous, non-gelling solutions.

Carrageenan is used extensively in dairy products, as a stabilizer, gelling agent, 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). Carrageenan is also used as a gelling agent in such products as baby foods, dietetic foods, instant foods, and bakery and candy products. It is finding extensive use in the cosmetic industry, as a stabilizing and thickening agent for creams, lotions, toothpaste, etc. Use in industrial gels and in the textile industry is increasing.



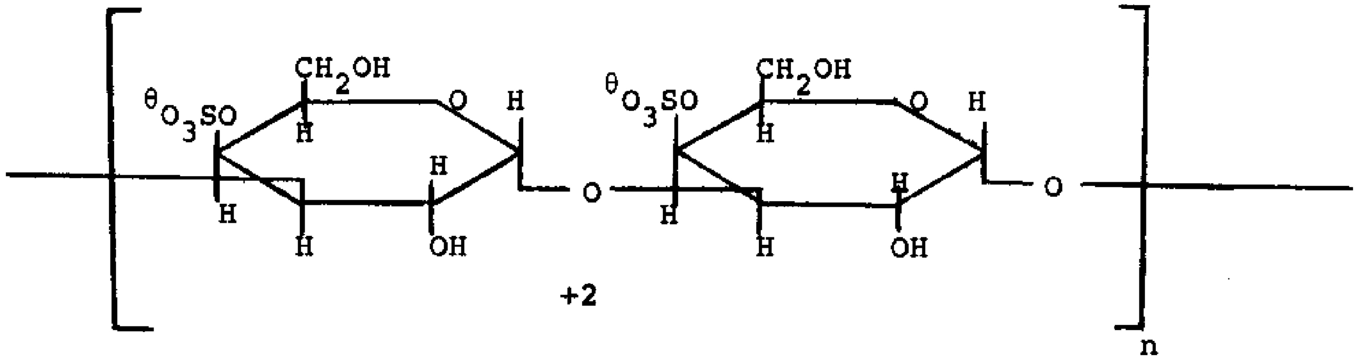
Kappa Carrageenan structure (chemical analysis)

Figure 3



Kappa Carrageenan structure (X-ray diffraction)

Figure 4



Lambda Carrageenan

Figure 5

Economic Background

It appears that, unless a significant breakthrough in harvesting methods is achieved, virtually all Irish Moss harvested in the U.S. for at least the next three to five years will be sold to Marine Colloids, Inc., based in Rockland, Maine. Until recently the Kraft Foods Division of National Dairy Products Corporation also operated a carrageenan processing plant in Maine, but this plant was sold to Stauffer Chemical Company in the summer of 1970, and since that time very little Irish Moss has been purchased from harvesters by this plant.

In the international markets for raw seaweed and commercial carrageenan, Marine Colloids, Inc., has two maine competitors, Copenhagen Pectin Factory Ltd., (Lille Skensved, Denmark) and Pierrefitte Auby Corporation (Neuilly, France). The Auby Corporation does not, at this time, purchase any raw moss from North American sources. However, Copenhagen Pectin maintains a subsidiary, Genu Products Canada Ltd., which competes strongly with Marine Colloids,Inc. for Canadian supplies of raw Irish Moss. At the time of this writing, Genu Products was not purchasing any American supplies of moss. Therefore, essentially all harvested American Irish Moss is sold to Marine Colloids,Inc. At present, Irish Moss constitutes about 50% of the total amount of various seaweed species bought by Marine Colloids, and as will be shown later, American sources account for only between 5% and 10% of the Irish Moss purchased by Marine Colloids,Inc.

Marine Colloids, Inc., purchases Chondrus crispus in both wet and dry form. The company owns and operates the only mechanical drying plant in Maine, located on Orr's Island. At this facility, the moss is bought directly from the boats of the moss rakers, at the dock of the drying plant. Although this plant has supplied roughly half of the annual dry moss collected from American waters, it was not in operation for the 1971 summer season, and at the time of this report, no notice has been given as to whether the Orr's Island drying station will reopen.

The only other mechanized drying station in the United States is operated by the Eastern Sea Moss Co. of Kingston, Massachusetts. This firm operates 60-70 dories on a lease arrangement during the summer months, and operates 8-10 overhead lift trucks which transport the weed from beach collection sites, scattered from Kingston to Rhode Island, to the Kingston drying plant.

A smaller Irish Moss operation which employs open air drying on the beach is conducted by a broker based in Scituate, Massachusetts. Beach drying is slow and cumbersome, and may somewhat degrade the quality of the dried moss, as well as limiting the size of the operation.

Unless Stauffer Chemical Co. greatly increases its demand for raw Irish Moss, or a foreign buyer enters the American market, the question of an equilibrium price for Irish Moss is settled by the price offered by Marine Colloids, Inc. Fully processed carrageenan sells for a price of $1.25 to $2.00

per dry pound, depending on fractional content and desired gelling qualities. The processing costs of obtaining the carrageenan from the dried raw moss are not immediately available, and are dependent on many factors, including the quality of the raw moss, moisture content when shipped and stored, time in storage, desired fractional content, etc.

Prior to 1967, most wet moss was being purchased at 1-1/2 cents/lb.(wet). In that year, due to increased demand and, to a lesser extent, some organization on the part of the Maine harvesters, the price was increased to 3 cents/lb.(wet). Since it requires 4 to 5 pounds of wet moss to yield one pound of dry moss, the inclusion of operating costs in drying and handling established a price of 20 cents/lb.(dry) for dried, baled Irish Moss.

The price levels of 3 cents/lb.(wet) and 20 cents/lb.(dry) were maintained through 1970, and in these four years demand equalled or exceeded the supply of raw moss. However, in 1970, due to a mild spring and exceedingly good harvesting weather in the summer, the supply of raw moss exceeded immediate demand, and a sizeable stockpile of dried, baled moss was established. Prior to the 1971 season, it was disclosed that the Orr's Island drying station would not be operating, and the Eastern Sea Moss Co. was notified that the official price for dried, baled moss was 18-1/2 cents/lb.(dry). A price of 2-1/2 cents/lb.(wet) was suggested for wet moss, although Eastern Sea Moss Co. paid 2-3/4 cents/lb.(wet) throughout the 1971 summer season.

Considerable uncertainty also exists concerning the amount of Irish Moss which could potentially be harvested from American waters. The Food and Agricultural Organization of the United Nations lists the following nominal landings of Irish Moss. (Figures are in lbs., presumed uniformly wet.)

TABLE 1

LANDINGS OF IRISH MOSS

	United States	Canada	Price per lb. (wet)
1964	4,400,000	28,200,000	1.7 ¢
1965	4,620,000	39,240,000	1.7
1966	4,180,000	51,140,000	1.8
1967	5,060,000	79,340,000	1.75
1968	7,280,000	87,060,000	3.0
1969	5,060,000	96,760,000	3.0
1970	4,000,000	105,800,000	3.0

Source: Yearbook of Fishery Statistics, Food and Agricultural Organization of the United Nations, vols. 28 and 29. (landing figures)

A Current Appraisal of the Irish Moss Industry, R. A. ffrench, Department of Fisheries and Forestry, Ottawa, Canada, 1970. (price figures)

Marine Colloids, Inc., estimated that in 1970, of its total world supply of approximately 10,000,000 lbs. of dried Chondrus crispus, (roughly equivalent to 45,000,000 lbs.[wet]) approximately 1,000,000 lbs. (dry) (equivalent to 4,500,000 lbs.[wet]) were supplied by U.S. brokers. Of this 1,000,000 lbs.(dry), approximately 600,000 lbs.(dry) were harvested in Maine, and 400,000 lbs.(dry) were harvested in Massachusetts.

Preliminary reports appear to indicate that the 1971 crop was quite poor in comparison to the 1970 crop. In August 1971, the Eastern Sea Moss Co. estimated that its total harvest for the year would be around 700,000 lbs.(wet), whereas its harvest for 1970 was around 1,500,000 lbs.(wet).

Estimates of the actual available Chondrus crop vary considerably, both in the amount of vegetation actually present on the bottom, and in the fraction of this amount that could be recovered by harvesters. In talking with members of the Raw Materials Procurement Division of Marine Colloids, Inc., an estimate of 5,000,000 to 8,000,000 wet pounds of Chondrus was reached for the harvestable Maine crop. An equal, or slightly smaller, estimate would be applicable for Massachusetts.[1]

Discussions with the Maine Department of Sea and Shore Fisheries yielded an estimate of 7,000,000 to 12,000,000 lbs. (wet) for the potential annual harvest from Maine waters. Members of the Eastern Sea Moss Co. estimated the Massachusetts coast potential at 3,000,000 to 4,000,000 lbs.(wet) in a good year. (Both estimates are based on current harvesting systems.)

Of course, the actual amount of Irish Moss that can be harvested from these waters is a function of the depth

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[1]The New England Marine Resources Information of May 1969 states that "[unnamed] scientists at Marine Colloids say that between 30 and 50 million pounds of dry moss [135 to 225 million wet pounds] can be harvested on the Maine Coast." It appears now that this report was primarily responsible for the enthusiasm expressed by the Harvard students in setting up a harvesting firm.

capabilities of the harvesting system. Nevertheless, although the estimates of available moss vary widely, it does appear that the annual harvest from both the Maine and Massachusetts coastlines, which now averages a combined total of approximately 5,000,000 lbs. wet, could be increased by at least a factor of two, and perhaps by more than a factor of three. At a market price of 3 cents/lb.(wet), a 10,000,000 lb.crop represents potential revenue to harvesters of $300,000.

It is clear that the United States' supplies of available Chondrus cannot approach the available Chondrus of Canadian sources. A further discouraging consideration lies in the fact that the Canadian Chondrus is generally found on more level, accessible bottom terrain that the American Chondrus. However, it must also be borne in mind that the American and Canadian strains of Chondrus differ somewhat in carrageenan content and quality, and for certain products the American strain is considered superior. Also, at present, the Canadian imports of raw moss to Marine Colloids, Inc. are subject to a 7% tariff.

One final consideration in operating any Irish Moss harvesting endeavor, which is essentially economic in nature, is the available labor force. In Massachusetts, the Eastern Sea Moss Co. depends almost entirely upon high school and college students who work during their summer vacations, and to a smaller extent during the pre-vacation weekends. This presently limits the harvesting activity to the period from 15 May to 01 September.

In Maine, students comprise only about 35% to 40% of the moss rakers. Most of the local workers, especially lobstermen, consider mossing a sometimes-profitable, part-time job, and even during the summer do not usually attempt to make a living solely from moss-raking. Prior to its closing in 1971, the Orr's Island drying plant bought wet moss from 01 May to 01 September, which effectively dictated the mossing season.

Therefore, the following general economic conditions must be considered:

1) There is a biological potential of harvesting at least 7,000,000 lbs.(wet) of Chondrus crispus, and depending on depth and weather capabilities of the harvesting system, perhaps as much as 20,000,000 lbs.(wet), from American waters.

2) If an American harvester maintains the harvested annual crop at around 7,000,000 lbs.(wet), he would be facing an essentially elastic demand market for the raw (wet or dry) moss, due to the relatively small portion of demand satisfied by American sources. At this level, it appears fairly secure that Marine Colloids, Inc. would buy all the dry Chondrus produced. It is apparent that the price level would be set by total world harvest conditions of the previous year.

3) If an American harvester boosted the harvested annual crop above 10,000,000 lbs.(wet), he would

probably begin to have an effect on the market price offered by Marine Colloids Inc. At this level, some negotiation with Copenhagen Pectin Factory Ltd. would be advisable.

4) In Maine, the Orr's Island drying plant may or may not be operating in the future. However, the possibility of buying or leasing the plant from Marine Colloids Inc. does exist. In Massachusetts, a moss harvester would need either to establish another drying station to compete with Eastern Sea Moss Co., or contract to supply raw wet moss to Eastern Sea Moss. Data on construction of drying facilities, or purchasing the one other existing (but non-operating) plant in Massachusetts are included in Appendix 3.

5) The 1971 market prices of 2-1/2 cents/lb.(wet) and 18-1/2 cents/lb.(dry) are down from the price levels of 3 cents/lb.(wet) and 20 cents/lb.(dry) which obtained from 1968 through 1970. The 1971 crop appears to have been poor, and the chances of the price rising to the 1970 level are fair.

Definition of the System

In order to include the widest possible number of alternatives, we will define the subjective human purpose of an Irish Moss harvesting system to be:

The location, collection, and delivery of wet Chondrus crispus, collected in U.S. coastal waters, and delivered to a standard drying station, by that method which maximizes profit to the harvester, while providing a stable, long range crop.

Several restrictions must now be placed on the scope of this report. Regarding the location of the harvestable crop, we will assume that a potential harvester will obtain the surveys available from the Maine Department of Sea and Shore Fisheries. As in the case of most fisheries, the location of the crop is probably best obtained from local experts, and from members of state fishery departments. Of course, the operator will probably wish to conduct some exploration and survey work of his own, but these should not include more than the use of a small boat and perhaps a SCUBA diver using underwater photography techniques. We are dealing with an immobile resource found in depths of less than thirty feet of water, and usually in only ten to fifteen feet. Therefore the location of Irish Moss beds has become available to all local lobstermen and should be easily obtained.

Similarly, the purchase and operation of new or used drying facilities will be summarized in the form of cost data for currently available equipment. If a prospective harvester chooses to construct a new dryer, rather than purchase, lease, or supply one of the three currently existing dryers in the U.S., cost data is included in more detail in Appendix 3.

The major portion of the following material will therefore deal with the problem of delineating the most feasible form of a harvesting system which collects Irish Moss from known beds, and delivers it to a known drying station. Conclusions are drawn from:

1) general engineering considerations,
2) previous designs for manual and mechanical harvesting systems,
3) an experimental hand-operated harvester constructed and tested for this report.

In the selection of a suitable working craft, emphasis will be placed on modifying currently available boats.

Constraints on the System

1. Economic Constraints

The most severe constraint on an Irish Moss harvesting system is the low unit price of the harvested moss. At a level of around 7,000,000 lbs.(wet) annual harvest, a system must be economically feasible at a market price of 2-1/2 cents/ lb.(wet), or at least at the possible future price of 3 cents/ lb.(wet). At higher levels of production, uncertainty in price level and possible purchasers becomes an important factor which would require further study and inquiries.

At the present time, there is ample mechanical drying capacity to handle an annual harvest of 7,000,000 lbs.(wet), although only one of the three sites is currently operating. Constructions of new facilities does not seem to offer any possibility of reduced drying costs, thereby forcing the system to operate economically at a price of 2-1/2 cents/lb.(wet).

The available labor force must be utilized, or new labor imported or bid away from other jobs. Any system utilizing available labor may have to provide for training procedures. Provision must be made for compensating the non-student labor force for the fact that, even under ideal conditions, the labor force will be employed for a maximum of six months yearly.

2. Environmental Constraints

Several factors must be considered under the generic term of environmental constraints:

a) Bottom topography. - The extreme ruggedness of the underwater terrain where Irish Moss is found in U.S. waters is the worst environmental obstacle to the development of a successful harvesting system. The moss grows most abundantly on rocky ledges and boulders, expecially in areas of turbulent water activity. Very little moss seems to be found growing on open flat stretches of rock on the U.S. coasts, although much of the Canadian Chondrus is gathered from quite flat bottom surfaces. Any successful system will be forced to operate at a variety of attitudes, since the moss will attach to vertical and inverted rock surfaces. The unit must be able to fit into small holes (about 3 ft. diameter), and must be able to withstand fairly rough treatment, with frequent and severe banging against the rock surfaces.

b) Weather conditions. - At present, in both Maine and Massachusetts, the Irish Moss harvesting season extends from 15 May to 01 or 15 September, due to drying plant practices in Maine (which could be altered), and availability of a student labor force in Massachusetts. Members of the Maine Department of Sea and Shore Fisheries estimate that careful planning and scouting could lengthen the useful season to the period 15 April to 15 October.

Assuming that the harvesting system will be utilized for this full six month period, the operator must be willing to operate on any day of the week. In Maine, estimates taken from moss raking experience indicate that in April and May, and in September and October, an average of three or four days a week will be suitable for raking, due to wind and tide conditions in the harvesting areas. Due to the depth and location of the mossing areas (described below), it does not appear that any system configuration will be able to improve this situation.

In the months of June, July, and August, an average of 5 days per week should (optimistically) be suitable for work in both Maine and Massachusetts. Most production estimates for the Eastern Sea Moss Co. summer operations are based on a "5 tides a week" work load.

Some use can be made of a small labor force on "down days" in work other than processing and maintenance, since storm action will deposit moss on the beaches. This beach moss, which is mixed with other seaweeds, is presently collected and sold for a lower price than raked Chondrus.

c) Water conditions. - The raking of Irish Moss is now a low-tide operation, since the moss grows from water level to depths of 30 feet. Ideally, a harvesting system would not be constrained to operate at low tide, in order to utilize all favorable wind and weather periods. However, most systems designed to operate in such very shallow water are quite depth sensitive, and some tidal constraint may be imposed. It should be borne in mind that when the tide is running, or at flood condition, visibility may be reduced, current and turbulence action is increased, and water temperature may be reduced.

Since the harvesting work is being conducted in shallow water, from within a few hundred yards of a shoreline right up onto the exposed rocks, wave action becomes extremely important, and is the chief reason for the high number of "washed-out" harvesting days. Any surface craft that may be used will be operated in shallow, rocky water where the probability of damage caused by wave action is high. Also, in these shallow waters, the effects of wave action are operative from the surface to the bottom, making underwater movement and manipulation difficult.

As mentioned above, underwater visibility, availability and intensity of sunlight and cloud cover may restrict moss location and collection. Since Chondrus thrives in areas of high water turbulence, visibility will often be poor.

The low water temperature poses another obstacle to any system which employs divers. Water temperatures on the Maine and Massachusetts coastlines seldom rise above 55° F during July and August, and are usually below 45° F during the months of April, May, and September. A diver whose thermal protection consists solely of a wet suit(s) can be expected to maintain a steady work pace for no more than 90 minutes at a shift under these conditions. Underwater work at this temperature is extremely fatiguing, as well as uncomfortable.

In summary, the environmental conditions are discouraging indeed. The roughness of the bottom terrain demands a small, highly mobile and agile harvesting unit. The wave action and shallow depth make operation of a surface unit very weather dependent. And finally, low water temperature will limit usable diver time to about one and one-half hours a shift, with probably no more than two shifts per man per day.

3. Biological Constraints

The biological constraints on any harvesting system are the limits on both the type and amount of harvesting that will allow a "maximum sustainable yield". In the case of Irish Moss, the question becomes one of setting the allowable damage that may be done to the plant during the harvesting process.

There exists an unresolved controversy on the merits of mechanical cutting of the plant versus the raking method.

Proponents of a "raking only" philosophy claim that in raking, only the mature fronds of the plant are removed. The younger fronds are not reached, and most importantly, the holdfast (the flattened appendage which attaches the Chondrus plant to a rock surface) is not damaged or dislodged. Frequent reference is made to the "well-known fact" that thoroughly raked moss beds grow thicker and faster than unraked beds. (See the regrowth study cited below.) The author's limited experience in hand raking did not entirely substantiate the claim that no holdfasts were dislodged.

The opponents of mechanical cutters claim that a uniform height cutter removes all the younger fronds as well, thereby removing the reproductive spore structures. Furthermore, it is contended that cutting assists in the development of mytilus edulis, and to excessive grazing by gastropods. There appears to be at least one documented case of a New England Irish Moss bed which was harvested by an experimental cutter (1965) and which was abandoned the following year due to extensive development of mytilus edulis.

Proponents of mechanical cutters also have a well-documented experimental case from Maine where a mechanically harvested bed showed regrowth superior to any nearby raked bed. Furthermore, they claim that uniform cutting leads to uniform regrowth and therefore, on the average, a fuller, richer crop that can be harvested on a more regular basis. The final stroke of the pro-cutting argument is provided by reference to the mariculture experiments described on page

50 in which plants which have been removed from their holdfasts have shown extensive regrowth potential.

Extensive biological study of Chondrus crispus now being conducted by Prof. Arthur Mathiason of the University of New Hampshire should shed considerable light on the problem of cutting damage. Given the available information, Marine Colloids, Inc. has taken the view that a mechanical cutter which does not damage the holdfast is biologically acceptable, and the author agrees with this attitude.

The second biological consideration, the number of times a bed may be harvested per season, is generally agreed to be three times per season. This figure is now usually attainable in the four and one-half month effective season. Since an operator of an efficient harvesting system would attempt to extend the season towards the biological and environmental limit of six months, three harvests per season is a relatively conservative figure. The results of a regrowth study conducted by Walter S. Foster for the Maine Department of Sea and Shore Fisheries are summarized on the graph below. Each line corresponds to an average regrowth rate of a plot which is raked clean once in the beginning of the month noted, and allowed to regrow.

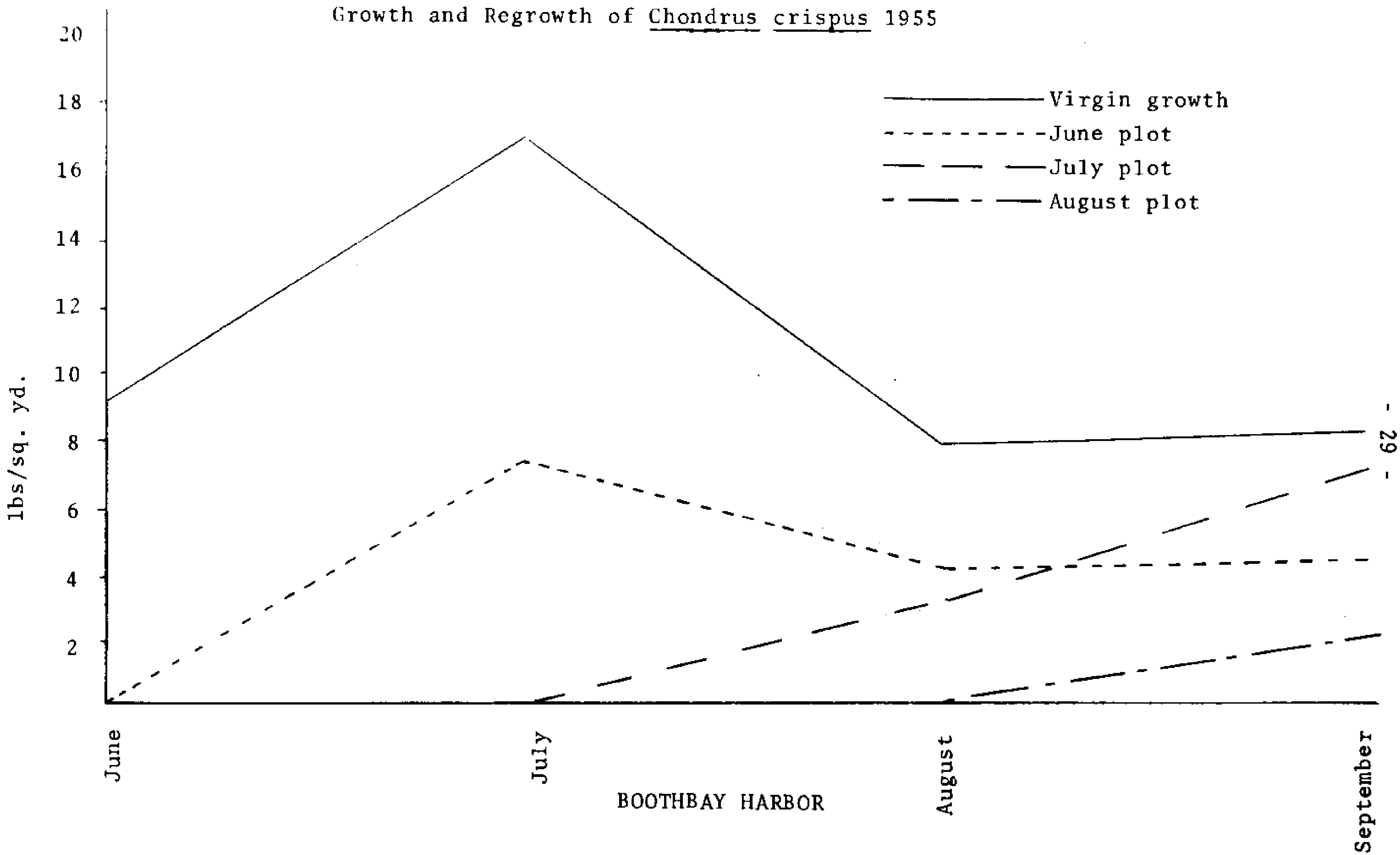
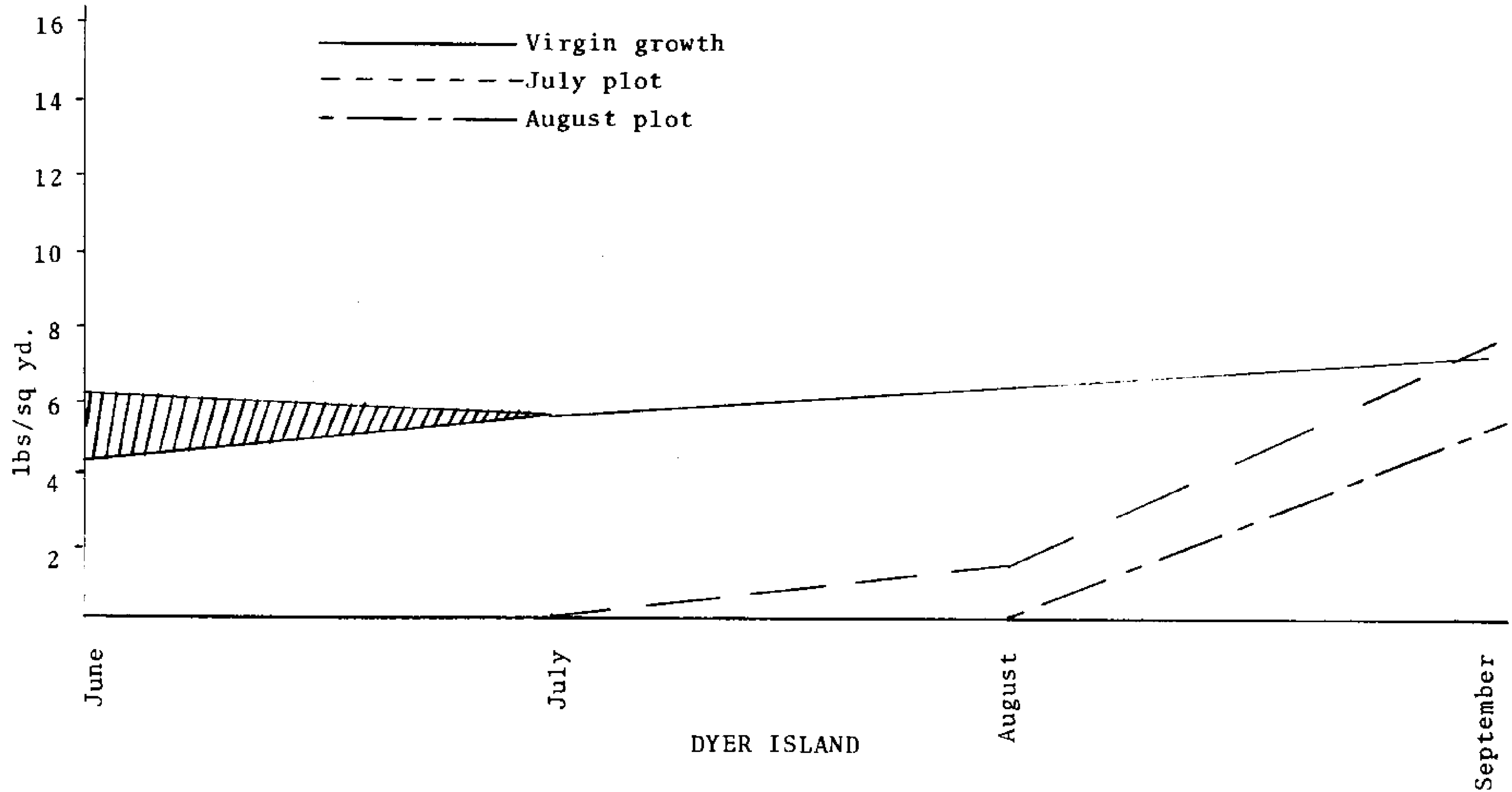

Growth and Regrowth of Chondrus crispus 1955
Virgin growth
June plot
July plot
August plot
lbs/sq. yd.
20
18
16
14
12
10
8
6
4
2
June
July
August
September
BOOTHBAY HARBOR

Figure 6

Growth and Regrowth of Chondrus crispus 1955



DYER ISLAND

Figure 7

Growth and Regrowth of Chondrus crispus 1955

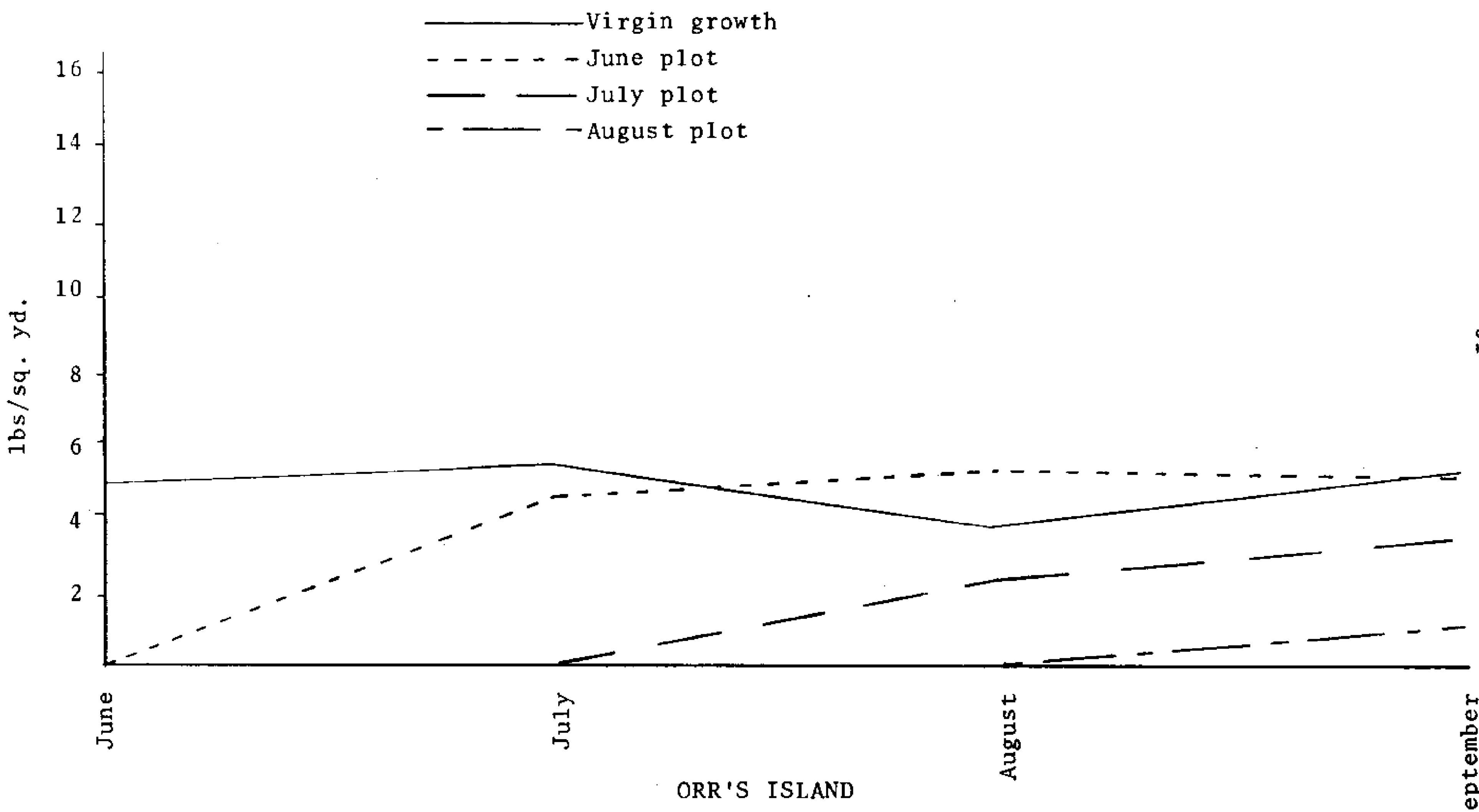
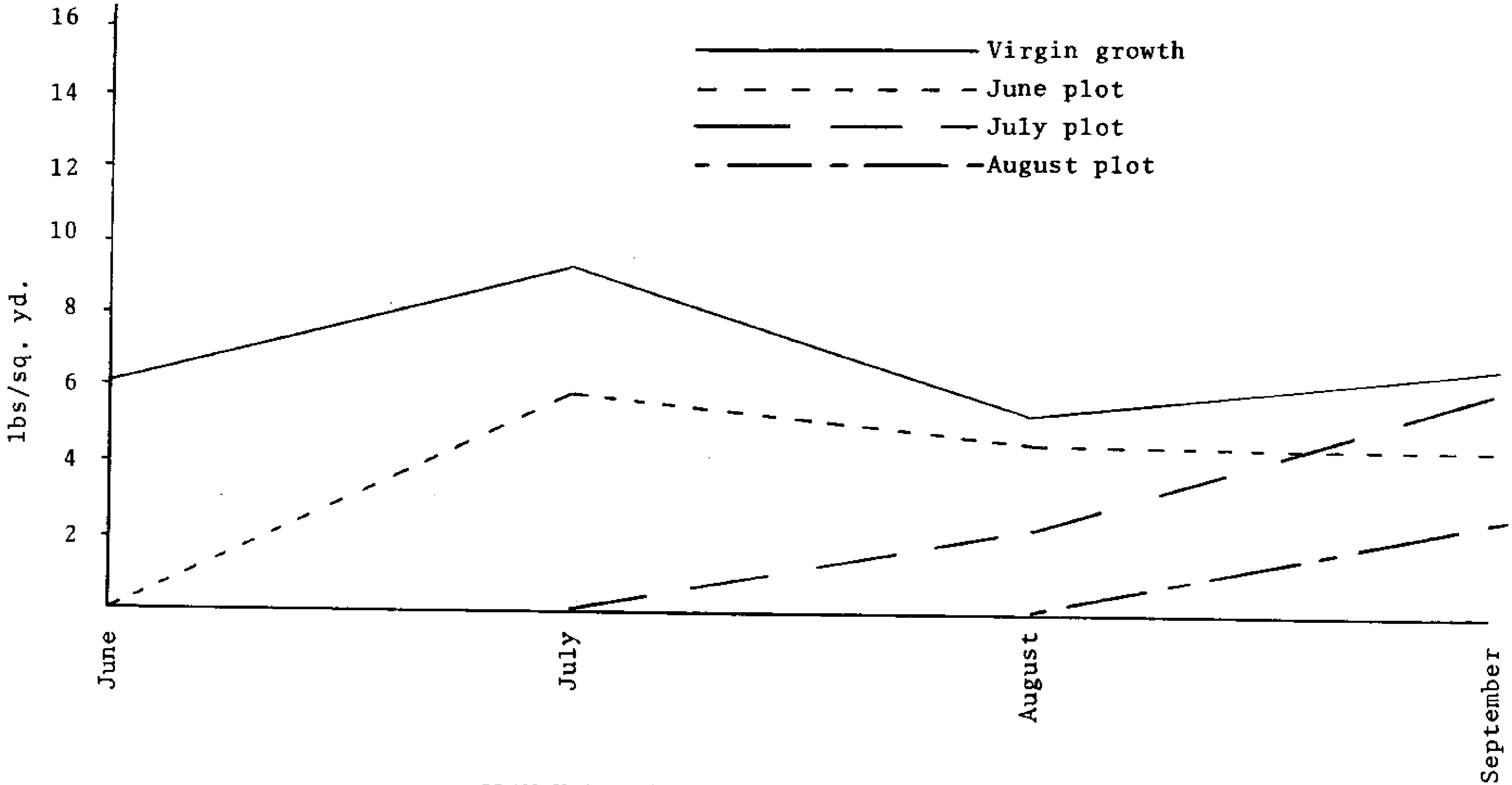


Figure 8



GROWTH PLOTS OF THE THREE AREAS AVERAGED

Figure 9

4. Legal Constraints

At present, neither Maine nor Massachusetts prohibit use of a mechanical harvester which has been duly licensed. The Canadian provinces do prohibit mechanical cutting, although a mechanical cutter is being developed by Canadian Fisheries Service on Prince Edward Island. Therefore the legal situation in the U.S. presents essentially no restrictions on the development of an Irish Moss harvesting system. However, if it appears that a system does significantly damage the regrowth potential of the Chondrus, it should be expected that the Department of Sea and Shore Fisheries or Department of Natural Resources would ban the harvester. The results of seaweed legislation in coastal states and provinces are presented in Appendix 2.

Previous System Development

1. Hand Raking of Irish Moss

The only method by which Irish Moss is now commercially harvested is hand raking. The rake is constructed of tempered steel, with closely spaced triangular times about six inches in length. The rake head is usually about 18 inches in width, and is fastened to the handle at an angle of about 45° so that the face will lie flat on the bottom when the rake is extended forward. The handle, usually wood or aluminum, varies from ten to twelve feet in length.

Most mossers use a fishermen's dory or punt, usually about 14 feet in length with a 5-1/2 foot maximum beam. Stationary bulkheads are usually placed about three feet aft of the bow and three feet forward of the stern to contain the moss. The Eastern Sea Moss Co. equips its dories with net bags attached to steel rod stringers, which are slung just under the gunwale on each side, extending the full length of the moss-containing section. These rods and net bags facilitate unloading directly into the overhead lift trucks.

In raking the moss, the mosser braces himself against the forward bulkhead and rakes over the rocks and ledges, depositing each rakefull of moss behind himself in the dory. The boat is not anchored, and the mosser pulls himself back up to windward over the moss ledge with each stroke of the rake. Mossers seldom try to rake moss lying in more than eight feet of water, and therefore work only at low tide, usually for a period of about four hours.

Most mossers watch for dark patches on the bottom, rake a few times, and then drift to a new spot.[3] Generally, only the highest points of a moss-bearing ledge are worked, and much more moss could be harvested at depths of ten feet or less. The most successful mossers will get out of their dories and rake standing in the water, lifting the moss into the boat. This method encourages a much more thorough raking, but it can be used only in very shallow water. Relatively few mossers appear to make use of this more productive method.

Most mossers will rake an average of about 1000 lbs.(wet) of Chondrus per work shift. More proficient individuals can harvest 1500 to 1800 lbs.(wet) using the same boats and equipment. One individual, a Maine school teacher of prodigious size and strength, has been known to rake 3000 lbs.(wet) on a tide.

The physical inefficiency of the rake as a moss harvesting tool is immediately obvious. In an experiment conducted by Marine Colloids, Inc., an area of bottom with 100% Irish Moss coverage was selected, and a one square yard sampling frame was placed on the bottom. The area was then raked with a standard mosser's rake until only a trace of Irish Moss could be brought up on the tines. (Note that this is a much more thorough raking than the area would receive under normal conditions.) The balance of the moss remaining within the frame

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[3]Many mossers will carry a bottle of fish oil to be used to form a slick on the water beside the dory, so that the moss may be seen on the rocks below.

was then hand picked. The weight of moss harvested with the rake, divided by the weight of moss harvested with the rake plus the weight of the hand picked moss then yields a nominal rake efficiency:

$$\text{Rake Efficiency} = \frac{\text{wt. of raked moss}}{\text{wt. of total moss collected}}$$

$$= 0.675 = 67.5\%$$

This figure represents the ideal mechanical efficiency of the tool, when it is raked over an area until no more moss can be raised. However, no mosser will expend this much time and effort for the diminishing returns of a raked-over area. A man using a hand rake from a drifting boat raking areas of dense moss as he spots them harvests only a fraction of the moss available to a raker. The inefficiency of the tool only aggravates a mosser's disinclination to thorough raking.

Having raked his fill for the day, the mosser now must unload the moss. In Massachusetts, the Eastern Sea Moss Co. operates over-head lift trucks, which drive down to the shore where the dories are beached, and load the net bags directly into the truck, weighing them in the process. In an area where the harvesting operation is spread over a considerable extent of shoreline, this method is most efficient.

In Maine, most of the mossers would unload directly at the dock of the drying station, pitching the moss into baskets with forks. The Maine Department of Sea and Shore Fisheries has made several recommendations for improvement of this method, including construction of an all-tide unloading dock and the installation of conveyer belts. Unfortunately, the Orr's Island drying plant was closed before any action was taken on these suggestions.

In summary, three main conclusions can be drawn:

1) The raking tool is inefficient, and perhaps a more effective, surface-operated tool can be designed.

2) If a more efficient tool can be developed, there may be need for a boat with more capacity and ease of handling. However, in trying to find a small craft suitable for this operation, one must realize that the usefulness of a small boat is much more a function of the operator's skill than of the boat's design. The local labor force (who possess the only accurate information on moss location) is now experienced in handling these dories, and may be reluctant to change.

3) The overhead lift trucks utilized by Eastern Sea Moss Co. are an efficient unloading system, although somewhat expensive.

2. The Marine Colloids, Inc. Mechanical Harvester

Marine Colloids, Inc. has invested a substantial amount of money and effort in the development of a mechanized Irish Moss harvester. They have succeeded in developing a sophisticated, diver-operated unit, which is soundly designed and does a very good job of collecting Irish Moss. However, they have also reached the conclusion that such a sophisticated unit is economically infeasible at a market price for Chondrus of 3 cents/lb.(wet).

The basic design work for the harvester was conducted by Batelle Memorial Institute. This unit has been operated experimentally by Marine Colloids, Inc., and subsequently redesigned and refined to its present configuration.

Without attempting to reproduce the unit in complete detail,[4] it consists basically of:

1) A rotary cutting head, powered by a 3 horsepower hydraulic motor. The head is approximately 12 inches wide, and the cutting blade, similar to that of a rotary lawn mower, is about 9 inches long.

2) Directly above and behind the cutting surface is a fiberglass faired scoop, into which the cut moss is drawn. The scoop feeds the moss into a flexible hose of about 4 inches inner diameter.

3) The scoop and hose constitute the edductor unit, which lifts the moss to the surface. A water pump delivers high pressure water at a flow rate of about 100 gal./min. into the edductor line at the surface end, inducing the lifting suction and flow.

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[4]The harvester now operated by Marine Colloids, Inc. has not been patented, but any drawings, blueprints, or specifications should be considered the property of Marine Colloids, Inc. and are not suitable for inclusion in this report.

4) The power plant for the unit is a gasoline engine rated at about 40 H.P., which drives the edductor water pump, the hydraulic pump, and an air compressor for the diver's hookah breathing unit.

The entire cutting head occupies about one cubic foot, and has a handle which enables the diver to push or pull it through the water. There are four lines to the surface; the edductor hose, two hydraulic lines, and the diver's air hose, all of which are about 30 feet in length.

The most important fact to bear in mind concerning this harvester is that it has been tested and refined until it works well. Combined with the freedom of movement of a diver, it can conform to any bottom terrain. It cuts at a speed which taxes the diver's ability to keep the edductor full; the diver spends no time waiting for the harvester to digest the moss.

The table below lists the results of a series of tests conducted with this harvester in the summer of 1970.

TABLE 2

Date	Hours Harvested	Pounds Harvested	Rate lbs. (wet)/hour
5/29/70	1.3	1210	932
6/ 4/70	2.5	1705	682
6/ 9/70	2.5	2055	804
6/10/70	1.8	1740	967
6/12/70	1.0	935	935
6/29/70	0.25	340	1360
7/ 8/70	2.75	2115	768
7/12/70	2.5	1820	728
7/14/70	4.0	3240	810
7/23/70	4.0	2195	548
7/24/70	4.0	2000	500
	26.6	19355	

This test period yielded a number of significant results. First, it established a fair estimate of the average cutting rate of the harvester at approximately 730 lbs.(wet)/hr. Two opposing considerations must be addended to this nominal rate. Further modification and diver experience might raise the average rate somewhat. However, in normal use, the harvester would actually be in operation for six hours per day, and the longest test period was four hours. On two out of three of the long four hour test days, the average cutting rate was significantly below the 730 lbs.(wet)/hr. rate. Consideration must also be given to the fact that many moss areas are below the size which will support a rate of 730 lbs.(wet)/hr. for a period of six hours, necessitating movement of the entire system.

During the test period, the surface vessel for the power unit and moss collection operator consisted of an open (anchored) raft, about 12 ft. x 4 ft. in size. The raft proved unmanageable in medium swells, during which many moss rakers were able to work relatively unimpeded with their dories. While this difficulty might be overcome by careful design, the shallow water depth transmitted surface disturbances to the divers, and underwater work around even the leeward side of moss-bearing ledges became hazardous and impractical. A comparison of the number of days when the harvester was prepared to work and could not handle the weather conditions to the number of days in which mossers were able to rake showed 27 hand raking harvest days to 12 mechanical harvest days.

A careful examination of time records showed that, discounting diver changeover time which could be eliminated, 57% of the dockside to dockside trip time was spent harvesting. In normal operation, in which the total harvesting time would hopefully be six hours (in the test period, an average of 2.45 hours per day were spent actually harvesting), total dockside to dockside time would average 9 to 10 hours, plus unloading time.

A great number of alternative operating, and leasing plans, together with various diver incentive pay schedules have been formulated to attempt to make such a harvester economically viable. One can dazzle the reader with schemes involving number of work days, base salaries and poundage pay rates, together with the present value analysis of initial capital and operating expenses. However, the basic economic situation is as follows:

Three relatively industrious hand rakers can harvest (using the present rakes and boats) about 4000 lbs.(wet) in a four hour work shift, plus unloading time. Three operators of the mechanical harvester, at least two of whom are trained divers, can harvest about 4500 to 5000 lbs.(wet) in an eight hour work shift, plus unloading time. Furthermore, the mossers should be able to harvest on at least 30% to 40% more days, due to the inability of a diver to work efficiently, if at all, in shallow water during periods of moderate swell.

The key to the problem with the Marine Colloids, Inc. harvester is the use of divers, rather than a low harvesting rate. Conceivably, the harvesting rate could be increased to 1000 lbs.(wet)/hr. or more, but again we face the inability of a single diver to physically transport the cutting head through 1000 lbs. of Chondrus per hour at a sustained rate for two 60 or 90 minute work shifts per day. Furthermore, as the harvesting increases, the amount of time spent changing the positions of the surface unit also increases.

Capital costs for the entire unit, including harvester head, hose assembly, edductor, hydraulic power unit, water system, hookah system, diving equipment, tools, and power supply are estimated at $3000. This excludes purchase or construction of a special surface craft. Operating costs, including diver training, diver insurance, wages and gasoline vary widely in response to the various management schemes employed.

The most effective summary to the previous discussion of the Marine Colloids Harvester lies in the fact that, although the harvester works quite well mechanically, it is sitting in a closet in Rockland, Maine. A market price of even 3¢/lb. (wet) cannot support a system which depends on SCUBA divers. Divers require rest periods between dives, high pay and insurance rates, and good weather conditions, none of which can be obtained in the present Irish Moss resource situation.

3. Resources Development Corporation Harvester

The Resources Development Corporation of Bath, Maine, developed an air-lift harvester for the collection of drift moss. Rather than actually cutting moss, this device was developed to pump out large holes where moss, which has already been severed from the holdfast, is deposited by current action. Such holes have been known to contain 5,000 to 50,000 lbs.(wet) of fair quality Chondrus.

The system consisted of:

1) A Worthington gasoline-engine driven, two-stage compressor with a capacity of 40 cubic feet of air per minute at 175 p.s.i.

2) A 70 foot 1/4 inch rubber air line attached to an 8 inch "Flexaust" flexible pipe.

3) A wire-mesh sorting table.

4) The entire unit was mounted on a 33 foot lobster boat.

A driver using a hookah rig moved the hose around on the bottom collecting the moss. The pressurized air is fed into the mouth of the hose, and the air bubbles accelerate through the hose to the surface. The entire water column is thus accelerated, and the entrained water and moss are spewed onto the sorting table.

At the present time, this project has also been abandoned. In the preliminary tests, harvesting rates of up to 2000 lbs.(wet)/hour were attained. Lobsters which were swept up with the moss were essentially unharmed, and since the moss has all previously detached, no harm was done to the moss beds. Again, however, economic considerations overwhelmed the mechanical efficiency. In addition to a team of divers working shifts with the harvesting head, a crew of four or five was necessary to man the pumping vessel. Members of the Maine Department of Sea and Shore Fisheries who helped in the tests felt that the vessel was poorly suited to the task, both physically and economically. It also appeared that the operators were too unfamiliar with the locations of productive moss holes to fully utilize the potential of the system.

Again, in summary, the most important fact is that the project was economically infeasible, although the harvester itself performed adequately. And again, the major economic obstacles were the high labor cost of divers and crew in relation to the low unit price for Irish Moss. However, the Maine Department of Sea and Shore Fisheries has not dismissed this concept. They stated that an operator who was thoroughly familiar with the area, and who used a more workable surface vessel, could operate a viable harvesting operation. Extensive survey work would be necessary, as well as daily scouting runs to program the pumper's movements. The drift moss potential harvest from Maine waters could probably support two or three such pumping rigs on a full-time basis for the six-month season.

4. Marine Plants Experimental Station - Miminegash Harbor

In a design project that was initiated in 1969, the Marine Plants Experimental Station on Prince Edward Island has been developing a mechanical harvester. Based on presently available information, the following conclusions can be drawn:

1) The harvester has been developed for the relatively flat bottom conditions characteristic of the P.E.I. moss beds.

2) The harvester requires at least one and perhaps two divers in the water at all times. Their divers report the same fatigue problems as the Marine Colloids, Inc. experiences.

3) No hardware or operating costs are available.

4) Harvesting rates of 500 to 1500 lbs.(wet)/hour seem possible.

This harvester also appears to be mechanically sound, and has been tested. Whether or not it can operate economically at the current unit price for Irish Moss is another question. However, this design reinforces the conclusion that an efficient design requires diver support.

5. Sea-Harvest

It appears that another mechanical harvester has been developed by Sea-Harvest, Inc., 17 Battery Place, New York, New York. When we contacted Sea-Harvest, it was explained that they were in the process of filing for patents on the harvester, and therefore were reluctant to discuss its operation. Various reports were received as to whether or not the harvester was diver-operated.

Design Recommendations and Conclusions

As stated in the introduction, the purpose of this project was the determination of the feasibility of developing and operating a mechanized Irish Moss harvesting system for use in the United States. Although it is unpleasant to be forced to settle for negative results, we must, in all honesty, report that such an undertaking does not appear economically justified at this time. Development of the harvester itself is feasible; in fact, at least two harvesters are operated at this time, one of which would probably be available for leasing. It is the operation of the entire system at the current market price for Irish Moss which is prohibitive.

The Marine Colloids, Inc. harvester has been constructed, tested, and refined in a thorough manner. Estimates of total project cost to date range to $100,000. This project has been shelved due to economic infeasibility of operation. The Miminegash harvester is in advanced development stages. Although it is designed for Canadian bottom topography, which is much more regular than that of the U.S., it still requires diver-operators as well as surface craft support. An economic evaluation of this system has not as yet been presented.

When one considers the environmental constraints on the system presented earlier, the development of a high-volume mechanical harvester which does not require a diver-operator appears infeasible. The economic constraints, on the other hand, clearly preclude the use of a skilled diver. In our opinion, it will take outstandingly brilliant design, with its attendant time and money, to circumvent the necessity for the diver-operator. Therefore, we recomment that the design work not be undertaken until such time as a significantly higher unit price for Chondrus is assured.

However, two smaller projects may be justified. The first is described in the section on the Resources Development Corporation Harvester, which collected drift moss. The Maine Department of Sea and Shore Fisheries feel that one operator, thoroughly experienced and familiar with the area, could operate successfully.

The second possibility is the design, manufacture, and sale of an improved hand-operated harvester for use by the current labor force - essentially a more efficient rake. Some interest was expressed at Marine Colloids for incorporating their harvesting head on a handle or boom for surface operation, although no actual design work had been initiated. The other alternative is a strictly manually-powered harvester. A first iteration of such a harvester was built and tested, and the results are presented in Appendix 2. Both Marine Colloids and the Maine Department of Sea and Shore Fisheries felt that there would be a market for such an improved hand rake if it could be priced in the \$20.00 to \$30.00 range.

Summary of Design Constraints

I. Economic

1. must be feasible at 2-1/2¢ - 3¢ per lb. (wet)
2. currently available labor force technically unskilled, although good at small boat handling

II. Environmental

1. must operate at all attitudes
2. must fit into small, rocky areas
3. must withstand rough treatment around rock ledges
4. must operate 15 April to 15 October
5. must operate from depth of 0 to 30 feet
6. must withstand shallow water wave action
7. must operate in poor visibility conditions
8. must operate at water temperature of 45° F to 60° F
9. must operate in areas of tidal flow
10. must cover wide areas of moss bed
11. must be able to hover over bed until harvesting completed

III. Biological

1. Holdfast must not be damaged
2. Allow for three harvests per bed per season, spaced 5 to 7 weeks

The Potential for Aquaculture

Experiments carried out in 1970 and 1971 by Dr. A. C. Neish and associates at the Atlantic Regional Laboratory, Halifax, Nova Scotia, have indicated that the potential may exist for the commercial aquaculture of Chondrus crispus. These experiments are still in laboratory scale, and no commercial scale economic analysis has been performed.

The first series of experiments, conducted from February to December of 1970, attempted to grow detached plants of Chondrus crispus (i.e. plants lacking holdfasts) in greenhouse tanks supplied with flowing seawater. The following is a very condensed version of the results:

1) Growth of detached plants was possible in the flowing seawater tanks.

2) Growth was observed over the range of 5°-15° C and was most rapid at the warmest temperature.

3) The longest photoperiod tested produced the fastest growth rate, although nitrogen had to be artificially supplied to prevent bleaching.

4) Growth was exponential; doubling times as low as 2 - 3 weeks were obtained.

5) Aeration caused only a slight (if any) increase in growth rate, and, as it encouraged the development of epiphytes, aeration was of doubtful benefit.

6) It does seem possible to isolate and propagate superior strains.

Professor Neish did, however, add the following caveat concerning commercial aquaculture:

> The results reported above show that it is possible to cultivate detached Irish Moss plants (similar to those obtained by commercial harvesting methods) but there is not enough information to decide whether or not this could be profitable on a commercial scale. The purpose of these initial experiments was to see if an increase of weight of detached plants could be obtained, and in this we have been successful since an increase of 1000-fold in one year was realized with a selected strain, which at the time of writing (April, 1971) is still growing well...
> As Irish Moss of good quality is only worth about three cents per pound (fresh weight) it is not promising as a greenhouse crop, not is it likely that any system employing supplementary artificial illumination would be profitable. However it is possible that artificially-contained (i.e. impounded) Irish Moss might be propagated advantageously.

The following year, two more experiments were conducted, one on "Greenhouse Experiments on the Propagation of Strain T-4 of Irish Moss," and a second on "Cultivation of Irish Moss (Strain T-4) in the Sea." The first experiment tested the growth rates possible on a selected superior strain of Irish Moss. The results are best summarized by the following extract:

> The mass culture of Irish Moss in tanks on a large scale, with little labor, appears to be feasible but there is not enough data for calculation of the costs as the amount of mixing and flushing required, the optimum depth of the tank, and the minimum concentration of nutrients required have not been established.

The experiment concerning the growth of Irish Moss in boxes moored in the open sea appeared to show favorable results. However, loss of samples due to storm action, and the relatively short duration of the experiment precludes any generalization to a commercial scale operation.

Appendix 1

Initial Development of an Improved Manual Harvester

Several members of the Marine Colloids Engineering Staff indicated interest in the development of a manual cutting and collecting tool. Such a tool would be based on the separation of the harvesting process into two distinct processes; the cutting of the moss from the bed, and the lifting of the cut moss into the surface vessel. The manual harvester should improve the efficiency of the cutting and collecting process, while leaving the lifting process to the strength of the mosser.

A patent search through various hand farming tools yielded one useful design; the Pendulum Cultivating Tool, Patent # 2,943,690, by Donald G. Towt, 1957. This tool is currently being marketed under the trade name of Hula-Ho. Using this principle as a point of departure, first iteration design was generated. In this first design, we attempted to:

1) Keep construction cost under $20.00.
2) Keep the cutting edge out where it could easily be resharpened with a hand file.
3) Keep the blade up off the rocks and holdfasts.
4) Keep the cutting and collecting head light.

The cutter frame is constructed of 1/4" x 1" flat aluminum stock. The blade is 1/32" x 2" oil-hardening ground die steel. Construction was completed using only a band saw, drill press, and belt sander, although the initial edge on the blade was milled. A small torch was used to facilitate some of the bending work. The collecting basket is normal wire mesh hardware cloth. The frame was mounted on a 12 foot section of 1" by .083" wall aluminum tube.

The manual harvester was subjected to normal moss raking use, and the following criticisms and modifications were noted:

1) After about one hour of use, the blade had lost most of its cutting edge. Repairs with a file were awkward.

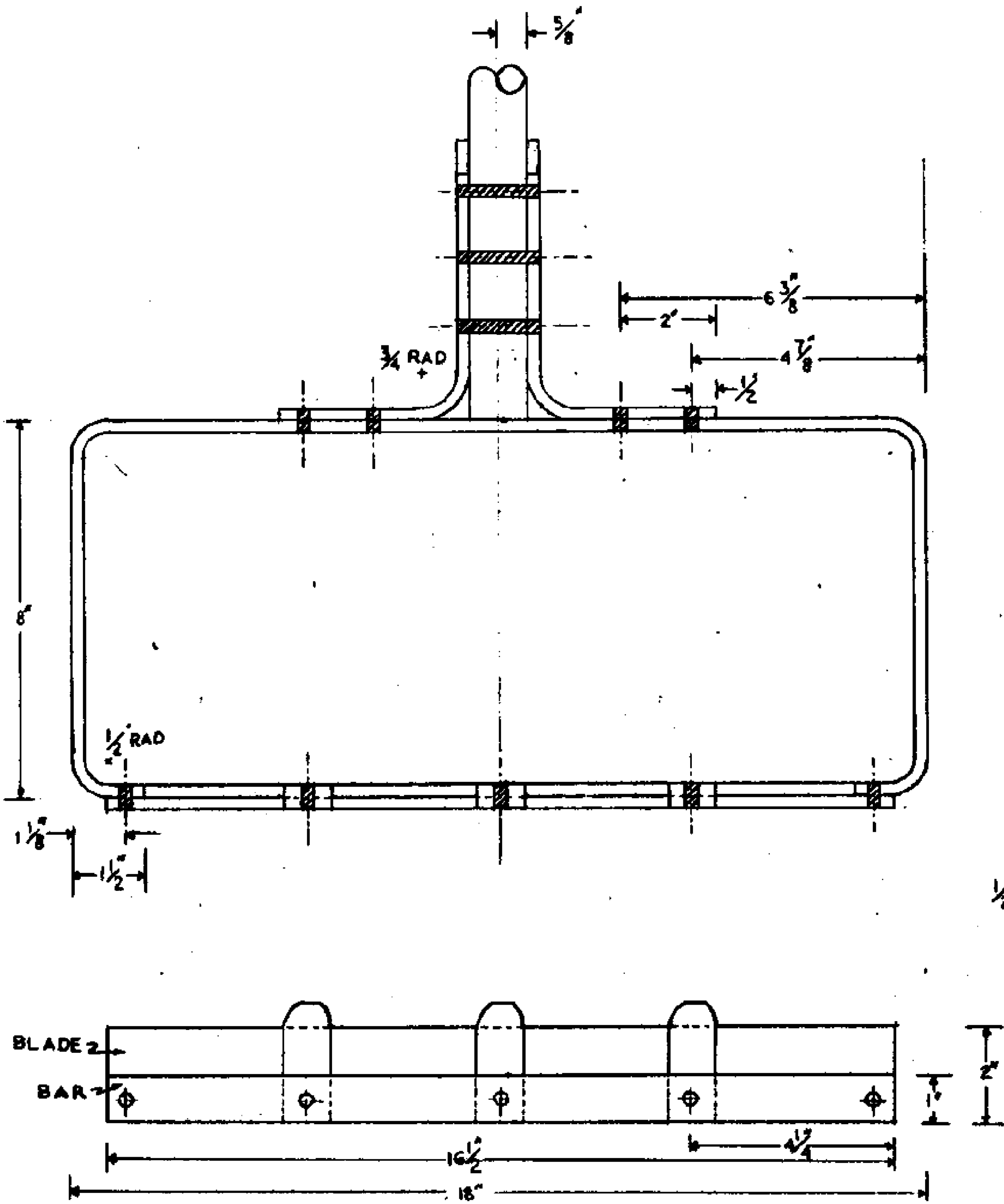
2) The use of a stationary cutting blade could probably be improved by adding a vibratory or shearing motion to the blade.

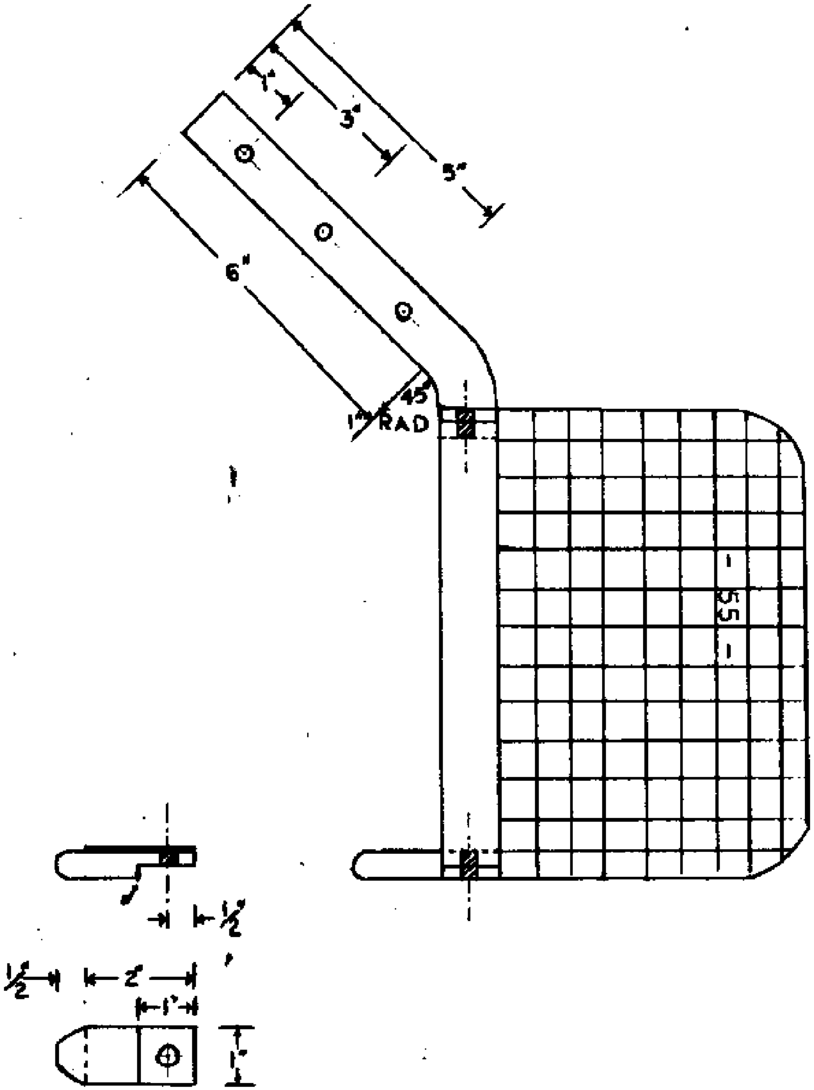
3) Corrosion of the blade should be prevented.

4) A serrated blade should be tested.

5) Use of wooden or plastic skids would probably be better than the aluminum guard teeth.

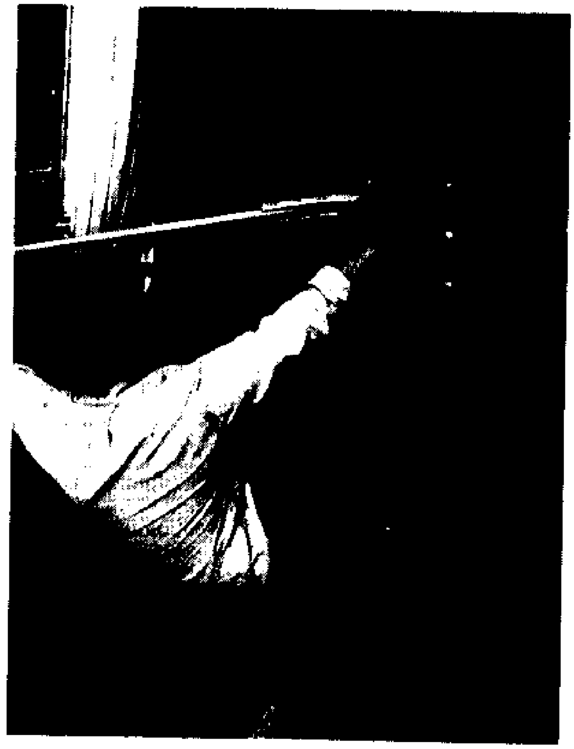
6) The aluminum tube handle should be capped.





MOSS HARVESTER

FRAME AND BLADE



Appendix 2

Survey of Seaweed Harvesting Legislation

State U.S.	Information Requested	Information Received	Any Regulations	License Required
Maine	x	x	yes	yes
New Hampshire	x	x	yes	no
Massachusetts	x	x	yes	no
Rhode Island	x		-	-
Connecticut	x	x	no	no
New York	x	x	no	no
New Jersey	x	x	no	no
Delaware	x		-	-
Maryland	x		-	-
Virginia	x	x	no	no
North Carolina	x	x	no	no
South Carolina	x	x	no	no
Georgia	x	x	no	no
Florida	x	x	no	no
California	x	x	yes	yes
Oregon	x	x	yes	yes
Washington	x	x	no	no
Alaska	x		-	-
Canada				
Newfoundland	x	x	no	no
Quebec	x	x	no	no
New Brunswick	x	x	yes	yes
Prince Edward Island	x		-	-
Nova Scotia	x	x	yes	no

Summary of Regulations - Maine

1. License required.
2. A certificate to conduct research on Irish Moss in situ is required.

Summary of Regulations - New Hampshire

1. No seaweed may be harvested or collected at night.
2. No seaweed may be collected from a salt marsh or flat without leave of the owner.
3. No seaweed may be harvested or collected for sale outside the state.
4. Seaweed shall not be uprooted. Seaweed may be cut with a knife if the roots are not injured.
5. No person shall take away growing rockweed or sea moss in excess of three bushels in one day.

Summary of Regulations - Massachusetts

1. No person shall take by mechanical means Irish Moss or kelp, marine plants of the species Chondrus crispus, except with the written approval of the director and in accordance with such rules and regulations relative thereto as he may adopt. (Handraking permitted without license.)

Summary of Regulations - New Brunswick

1. When harvesting Irish Moss, no person shall use a knife, blade, or other cutting device by which the Irish Moss plant may be cut or scraped.

2. No person shall cut or scrape an Irish Moss plant so close to the holdfast as to endanger or destroy the plant.
3. License required.

Summary of Regulations - Nova Scotia

1. When harvesting Irish Moss, no person shall use a knife, blade or other cutting device by which the Irish Moss plant may be cut or scraped.
2. No person shall cut or scrape an Irish Moss plant so close to the holdfast as to endanger or destroy the plant.
3. Seasons established for certain harvesting areas.

Summary of Regulations - California and Oregon

These regulations deal with kelp harvesting and are not applicable to this study.

References

General Seaweed:

1. , Yearbook of Fishery Statistics, Food and Agricultural Organization of the United Nations, Vol. 28, 1969.

2. , Alginates, Alginate Industries Ltd., London, England, 1969.

3. , Marine Science Affairs, Selecting Priority Programs, Annual Report of the President to the Congress on Marine Resources and Engineering Development, April, 1970.

4. , Public Policy in the Seafood Industry, Progress Report, Department of Agricultural Economics, Oregon State University, 1970.

5. Boney, A.D., A Biology of Marine Algae, Hutchinson Educational Press, London, 1966.

6. Firth, F.E., The Encyclopedia of Marine Resources, Van Nostrand Reinhold Company, New York, New York, 1969.

7. Frey, H.W., California's Living Marine Resources and Their Utilization, State of California Department of Fish and Game, 1971.

8. DeVirville, A.D.D., and Feldman, J., Proceedings of the Fourth International Seaweed Symposium - Biarritz, Sept. 1961, MacMillan Co., New York, 1964.

9. Levring, T., et al., Marine Algae - A Survey of Research and Utilization, Cram, DeGruyter and Co., Hamburg, Germany, 1969.

10. Marx, W., The Frail Ocean, Ballantine Booke, New York, 1967.

11. Mathieson, A., The Promise of Seaweed, Oceanology International, Jan./Feb. 1969.

12. Neushul, M., et al., Studies of Seaweed Resource Management, Department of Biological Sciences, University of California, Santa Barbara, California, 1970.

13. Ricketts, E., and Calvin, J., Between Pacific Tides, Stanford University Press, Stanford, California, 1968.

14. Williams, R., Florida Seaweeds and Their Commercial Use, Marine Laboratory, University of Miami, 1950.

15. Youngken, H.W., Marine Pharmacognosy, Sea Grant Annual Report, 1970-71, Department of Pharmacognosy, University of Rhode Island, 1971.

16. Zajic, J.E., Properties and Products of Algae, Plenum Press, New York, 1970.

Irish Moss

17. , Annual Report 1970-71, Marine Plants Experimental Station, Miminegash, Prince Edward Island, Fisheries Service, Department of the Environment, Ottawa, Canada, 1971.

18. , Irish Moss, A Major Factor in Maine's Economy, New England Marine Resources Information 1, May 1969, Pell Marine Science Library, Narragansett, Rhode Island, 1969.

19. , Compressor Vacuum Harvests Irish Sea Moss, Under Sea Technology, February, 1969.

20. Dow, R.L., The Maine Sea Moss Industry, Bulletin of the Department of Sea and Shore Fisheries, Augusta, Maine, 1948.

21. ffrench, R.A., A Current Appraisal of the Irish Moss Industry, Department of Fisheries and Forestry, Ottawa, Canada, 1971.

22. Foster, W.S., Sea Moss (Chondrus crispus) Survey Washington County, General Bulletin 3, Department of Sea and Shore Fisheries, Augusta, Maine, 1953.

23. Foster, W.S., Sea Moss (Chondrus crispus) Survey West Point to Pemaquid Neck, General Bulletin 4, Department of Sea and Shore Fisheries, Augusta, Maine, 1954.

24. Foster, W.S., Sea Moss (Chondrus crispus) Survey Pemaquid Point to Owls Head, General Bulletin 5, Department of Sea and Shore Fisheries,Augusta Maine, 1955.

25. Foster, W.S., Growth Studies of Maine Sea Moss (Chondrus crispus), Department of Sea and Shore Fisheries, Augusta, Maine, 1955.

26. Foster, W.S., Sea Moss (Chondrus crispus) Survey Islesboro, Long Island, Maine, General Bulletin 6, Department of Sea and Shore Fisheries, Augusta, Maine, 1956.

27. Kingsbury, J., Seaweeds of Cape Cod and the Islands, The Chatham Press Inc., Chatham, Mass., 1969.

28. Neish, A.C., and Fox, C.H., Greenhouse Experiments on the Vegetative Propagation of Chondrus crispus (Irish Moss), Technical Report 12, Atlantic Regional Laboratory, National Research Council of Canada, Halifax, Nova Scotia, 1970.

29. Neish, A.C., and Shacklock, P.F., Greenhouse Experiments (1971) on the Propagation of Strain T-4 of Irish Moss, Technical Report 14, Atlantic Regional Laboratory, National Research Council of Canada, Halifax, Nova Scotia, 1971.

30. Neish, A.C. et al., Experiments (1971) on the Cultivation of Irish Moss (Strain T-4) in the Sea, Technical Report 15, Atlantic Regional Laboratory, National Research Council of Canada, Halifax, Nova Scotia, 1971.

31. Nicholson, J.D., Further Development of a Mechanical Harvester, Marine Plants Experimental Station, Industrial Development Branch, Mininegash, Prince Edward Island, Fisheries Service, Department of the Environment, Ottawa, Canada, 1971.

32. Ricker, F.W., and Spencer, F.R., Chondrus crispus Survey, Memorandum, State of Maine Department of Sea and Shore Fisheries, Augusta, Maine, 1967.

33. Rigney, J.A., Chemical Investigations of Chondrus crispus, Progress Report, 1970, Fisheries Service, Department of Fisheries and Forestry, Ottawa, Canada, 1971.

Kelp

34. , Search in the Aquasphere - the Story of Kelco, Kelco Co., San Diego, California, 1968.

35. Durrant, N.W., The West Coast's Seaweed Industry, Commercial Fisheries Review, May, 1967.

36. North, W.J., and Hubbs, C.L., Utilization of Kelp Bed Resources in Southern California, Department of Fish and Game, Fish Bulletin 139, State of California, 1968.

37. North, W.J., Kelp Habitat Improvement Project, Annual Report, 1970, California Institute of Technology, 1970.

38. Scholes, W.A., Harvesting Seaweed off Australia, Ocean Industry, March, 1969.

39. Scofield, W.L., History of Kelp Harvesting in California, California Fish and Game, July, 1959.

40. Waldron, K.D., A Survey of the Bull Kelp Resources of the Oregon Coast in 1954, Research Briefs, Vol. 6, No. 2, Fish Commission of Oregon, Dec., 1955.

Legal Regulations

41. , Laws and Regulations, Maine Sea and Shore Fisheries, Revised to Oct.1, 1969.

42. , Fish and Game Laws, The State of New Hampshire, 1970-71.

43. , Marine Fisheries Laws, South Carolina Wildlife Resources Department, Nov., 1969.

44. , An Act Respecting Irish Moss, Province of New Brunswick, 1969.

45. , A Regulation Under the Irish Moss Act, New Brunswick Regulation 69-27, Province of New Brunswick, 1969.