GRI-81/0096

MARINE BIOMASS:

NEW YORK STATE SITE AND SPECIES STUDY. COMPOSITIONAL ANALYSIS AND SYSTEMS STUDIES

FINAL REPORT

MARCH–DECEMBER 1981

Gas Research Institute
8600 West Bryn Mawr Avenue
Chicago, Illinois 60631

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FINAL REPORT FOR 1981

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16. Abstract (Limit: 200 words)

The primary objective of the Marine Biomass Programs is to provide an optimized, integrated process for producing methane from seaweeds cultivated in the open ocean and to do so at a price which is competitive with that of methane from other sources. The New York State Site and Species Study represents the first evaluation of a site outside of Southern California.

In this phase of the contract, comparative compositional analyses were performed on 11 seaweed species indigenous to New York waters, and these data were then used to rank these species based on their composition. In the process of performing this work, a new HPLC based method for quantitating sugars and sugar alcohols in macro-algal specimens was developed and some non-specificity problems with some of the standard macroalgal analytical procedures were identified. Also, an on-line computer data base to store the compositional data was implemented.

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RESEARCH SUMMARY

<u>TITLE</u> Marine Biomass: New York State Site and Species Study. Compositional Analysis and Systems Studies.

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<u>CONTRACTOR</u> General Electric Company

<u>PRINCIPAL INVESTIGATOR</u> Ralph W. Makinen

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<u>MAJOR ACHIEVEMENTS</u>

Comparative compositional analyses were performed on 11 seaweeds indigenous to New York State waters. Relative rankings, based on composition, were developed to determine the suitability of each species in a biomass to methane system.

A new HPLC (High Performance Liquid Chromatography) method for quantitating sugars and sugar alcohols in macroalgae was developed. This is significant in that the new technique affords an unambiguous quantitation of mannitol and eliminates the interference problems caused by other compounds such as algin and fucoidan. The technique greatly improves upon previously "standard" seaweed analytical techniques which have inherent non-specificity problems.

A preliminary (zero order) systems analysis was initiated with the aid of computer codes originally developed for West Coast kelp (<u>Macrocystis</u>). This preliminary study identified the artificial substrate if one is needed for cultivation, as the driving cost element of the methane from seaweed concept. The study also pointed out the sensitivity of the gas costs to seasonal variations in plant growth (yield). This reinforced the need for multi-crop concepts that would present the most consistent supply of biomass throughout most of the year in order to maximize the significant capital investment in growth, harvesting and processing facilities.

Conceptual farm design work identified the plant specific gravity as one of the major drivers in the cost of the farm substrate.

Based on growth and compositional data, *Laminaria*, *Gracilaria* and *Agardhiella* have been identified as the primary species that will be emphasized in future phases of this work.

RECOMMENDATIONS

Detailed chemical analyses should be obtained on controlled growth and raft cultured macroalgae in order to obtain enough data for statistical correlations between growth conditions and composition.

Gasification studies should be performed on the prime candidate species in order to determine the actual sustainable yields attainable in steady state digestors.

Since the New York State system will probably require two sequentially grown species in order to assure year round operation, the effect of changing the feedstock of steady state digestors should be evaluated.

The potentially negative effects of "lignin", and of sulfur, on methane production should be quantitated.

Since specific gravity may be one of the major drivers in the system economics, the plant specific gravity should be determined as a function of growth and harvesting conditions.

The effect of multiple sequential crops (e.g. warm and cold weather) with a possible non-harvestable gap during the changeover period should be evaluated from an overall systems viewpoint. This evaluation should include information on maintaining feedstock for the digestors during this period. It should also address the question of how to effect a crop changeover on a large oceanic farm.

DESCRIPTION OF WORK COMPLETED

Sixty macroalgal specimens were received from the Marine Sciences Laboratory, State University of New York, Stony Brook, N.Y. These were analyzed for major constituents known to be present. These compositional data, plus data from an additional 22 specimens analyzed in 1980, and all data obtained for *Macrocystis pyrifera* on the Marine Biomass Program, were compiled and incorporated into an on-line computer database. Relative ranking factors were developed for each major plant constituent. These factors were based on expected digestibility (rate and extent), on the results of the systems analysis task, and on theoretical grounds such as expected decreases in methane yields in the presence of high sulfur. These relative ranking factors were summed over all constituents of all species, and the relative, composition-based, suitability of each species as a candidate crop for a biomass to methane system was obtained.

Non-specificity problems were observed in the analytical procedures for some macroalgal constituents. Since mannitol has an important effect on methane yields, an HPLC based system was developed which will specifically separate and quantitate each sugar and sugar alcohol present. This system is not subject to interferences from algin, fucoidan, or other seaweed constituents.

A ten liter digester was constructed and fed a mixture of New York State seaweeds. After the initial startup period, its methane output exceeded 5 SCF/pound of volatile solids (5 SCF/lb VS) for 9 out of 12 weeks, and it seemed to be settling down to approximately 5.5 SCF/pound volatile solids.

A joint meeting with MSL personnel was held, and the species selected to receive future detailed attention were reduced to *Laminaria*, *Gracilaria*, Agardhiella and possibly *Codium* and *Fucus*.

GRI COMMENT

General Electric has participated in the New York State Site and Species Study Program since its inception in December 1979 when this program was a task in the Methane from Marine Biomass Program in which General Electric served as a prime contractor. Subsequently, this program was directly contracted by GRI and the New York State Energy Development Authority. General Electric has performed the work on gasification analysis and supported systems work where needed.

This final report represents General Electric's work in which the chemical compositions of potential seaweed biomass candidates were determined, and the program was focused on three selected species. In addition, General Electric identified a number of factors which should be addressed in any systems analysis of the multicrop concept.

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1.0 PROGRAM OBJECTIVE

The primary objective of the Marine Biomass Programs is to provide an optimized, integrated process for producing substitute natural gas (methane) from seaweeds cultivated in the open ocean, and to do so at a price which is competitive with that of methane from other sources. The New York State Site and Species study represents the first evaluation of sites outside Southern California. The objectives for this phase of the program are to evaluate macroalgal species indigenous to New York State waters, and to develop screening procedures to select the best candidate species for further detailed analyses.

2.0 SUMMARY OF PREVIOUS WORK

The Marine Biomass Program is a fully integrated study to determine the feasibility of economically producing substitute natural gas (SNG) from seaweeds cultivated on oceanic farms. The overall concept is to cultivate macroalgae on artificial structures, to periodically harvest these plants, to convert then to methane, and to provide the resultant SNG to distributors or users of natural gas. From the gas industry's concept initialization in 1974, until the initiation of the New York State Site and Species Study in December, 1979, the only marine resource being examined was the California giant kelp, *Macrocystis pyrifera*. A large amount of data now exists for a *Macrocystis* to methane system, and much of the experience gathered in acquiring this data can be directly translated to similar system concepts using other species.

In December, 1979, the Gas Research Institute (GRI) and the New York State Energy Research and Development Authority (NYS-ERDA) began a jointly funded effort to evaluate seaweeds indigenous to New York State as potential biomass to methane feedstocks. This work was contracted to the General Electric Company, Advanced Energy Programs Department (GE-AEPD) for compositional analysis, systems studies, and overall program coordination, and to the Marine Sciences Laboratory, State University of New York, Stony Brook, N.Y. (MSL) for seaweed growth and nutrition studies.

During 1980, GE-RSD performed a literature search to identify the chemical constituents likely to be present in those seaweeds known to be found in New York State waters. The major finding of this literature search was that there was very little pertinent compositional data in the literature, and much of the data found could not be used because it was mutually contradictory, or contained some numbers which made the entire report suspect (for example, one author reported 5 percent of the dry weight of M. pyrifera was ash when the true range is 40 - 50% and another reported that less than 50% of the freshly harvested weight of one seaweed species was water.) Another factor making it difficult to compare data from different papers was the variety of analytical techniques and reporting conventions used.

In order to have an internally consistent set of analyses which could be used to compare the different candidate seaweeds, we developed a complete specimen handling and analysis protocol which was valid for red, green and brown seaweeds (Tompkins 1981). Several analytical procedures were screened for their applicability to this program. The methods selected were checked by spiking Macrocystis pyrifera specimens with known quantities of the materials of interest, and determining the recovery efficiencies. Those methods exhibiting poor recoveries were discarded.

After the verification of the analytical procedures, field gathered specimens of several species were analyzed for their major chemical constituents.

Theoretical gas yields calculated from the carbon, hydrogen, oxygen, and nitrogen content of the plants represent the theoretical upper limit attainable from that plant. These numbers were calculated for each specimen received. However, we found that the high sulfur levels in some seaweeds can significantly decrease the theoretical upper limit by diverting carbon and hydrogen away from methane. We therefore modified the theoretical gas yield equation to account for this effect.

Bomb calorimetry is one analytical method currently in routine use for evaluating the maximum realizable energy content of all types of biomass, including marine macroalgae. Since this looked like a good selection technique for this program, we gave it a thorough evaluation. When the data were normalized to BTU per pound of organic matter, a definite trend was observed between this value and the percent ash in the specimen. A regression analysis showed that for each one percent ash in the sample, the calorific value decreased by 44 BTU per pound. Thus, for specimens ranging from 40 to 50% ash, this decrease (error) amounted to 1760 to 2200 BTU/pound (i.e. up to 24 percent). Apparently, under the temperatures and pressures in the bomb the ash exhibits a very strong endotherm, and causes misleading results if the data are to be interpreted as the ultimate to be achieved from anaerobic digestion, where these pressures and temperatures do not occur. We thus recommended that bomb calorimetry not be used to screen specimens containing significant ash.

A small scale, (100 ml) batch reactor system was evaluated as a bioassay technique to screen macroalgae for their ultimate digestibility. While some problems were encountered in trying to obtain consistent results with this technique, we felt it was worth pursuing further.

3.0 OBJECTIVES FOR 1981

1 Obtain sufficient analytical data on the macroalgal species indigenous to New York State waters to allow the development of a relative ranking scheme based on composition.

2 Obtain gasification data on the macroalgal specimens analyzed in objective 1.

3 Begin a first order systems study using parameters specific to the New York State site.

4 Narrow the number of species to undergo further detailed analysis to a maximum of three.

4.0 WORK PLAN FOR 1981

4.1 Composition

Obtain specimens from MSL and perform analyses to quantitate their major constituents. These specimens fall into three catagories:

i) Specimens collected from nature during different seasons of the year.

ii) Specimens from the MSL controlled growth greenhouse cultures.

iii) Specimens obtained from raft cultures as they become established in sites near Long Island Sound.

The results of these analyses will be reported back to MSL on a regular basis, and will be used to develop relative species ranking criteria.

4.2 Gasification

a) Perform theoretical gas yield calculations on the specimens received above. Use these data to scale the sample sizes for the bioassay experiments.

b) Establish a 10 liter digestor to be used as a source of inoculum for the bioassay experiments. This digestor will be fed a mixed feedstock containing representatives of as many New York seaweeds as can be conveniently obtained. This is to insure that the inoculum has had a chance to adapt to all constituents present in any seaweed being evaluated.

c) Perform bioassay experiments on each specimen received for compositional analysis. These data will be used as estimates of the maximum methane attainable at very long detention times.

d) Establish a 10 liter mixed feedstock digestor to determine whether satisfactory gas yields can be obtained from such a feedstock and, by implication, whether most of the major seaweed constituents can be gasified.

4.3 Systems Study

a) Obtain preliminary specifications for a New York State seaweed to methane system. These will include factors such as no upwelling to obtain nutrients, capital and debt requirements, nutrient availability, range of mooring depths, etc.

b) Based on the inputs above, modify the BIOEC systems analysis program which was originally developed for the Southern California deep ocean farm concept.

c) Use the New York State specific code (NYBIOEC) to analyze the effect of selected system parameters on the cost of the methane output.

4.4 Reduction of the Number of Species

Meet with MSL personnel to evaluate all chemical and biological data obtained for each species, and use these data to eliminate the least promising species.

5.0 WORK COMPLETED IN 1981

5.1 Database Implementation

The large amount of compositional data being generated on this program required a rapid, accurate method of storage, retrieval, and compilation. We evaluated the use of several on-line, computerized database systems, and finally selected the "BOOKKEEPER" system on our Honeywell Level 66 computer. Although this database system is not as powerful or sophisticated as the others we examined, it meets the current and projected needs for this program. Our reasons for selection were that it runs more cheaply than the more sophisticated systems (by a factor of 10), and it doesn't require the extensive programming needed to make use of the other systems.

All compositional data generated on this program, plus those generated for *Macrocystis pyrifera* by the different labs working on the Marine Biomass program, are input to the database as they are generated. Any of this data can be called out in real time, and in any format desired. It can also be dumped to formatted files which are then used by statistical analysis routines. All of the data for each specimen analyzed are presented as Appendix A to this report.

5.2 Compositional Analysis

5.2.1 Introduction

The purpose of this task was to determine the composition of seaweed indigenous to New York State waters, with the final objective being the use of these data to aid in the selection of those macroalgae exhibiting the greatest potential as candidate species for cultivation in a biomass to methane system. Since different organic materials are degraded at different rates, and to different final extents, a knowledge of the plant composition is essential for ranking the utility of different seaweeds as biomethanation feedstocks.

Summary data are presented in Tables 2 through 10, while the actual, detailed data for each lot are presented in Appendix A. Table 1 is a summary of the literature data, against which the experimental data is compared. The one factor which stands out in Table 1 is that much of the data required for decision making is not readily available in the literature.

The mean data values presented in Tables 2 through 10 are, by themselves, of only limited utility. The variation around the means can be of equal importance to the means themselves. Data scatter is presented as the standard deviation, and as the coefficient of variation, which is the percentage value of the standard deviation divided by the mean. These tables also present the highest and lowest observed values, which can represent another important factor when interpreting the significance of a particular number.

TABLE 1.

SELECTED LITERATURE VALUES FOR COMPOSITION OF CANDIDATE MACROALGAL GENUS (1)

	New York State Candidates										Other
	Agardhiella	Agarum	Alaria	Ascophyllum	Chondrus	Codium	Fucus	Laminaria	Palmaria	Ulva	Macrocystis
Type (2)	R	B	B	B	R	G	B	B	R	G	B
% Dry Weight		18-25		20-30	19-27	7	18-32	12-24	14-22	19-22	10-18
Volatile Solids [Percent of Dry Weight]		66		76	72-75	58	78-87	59-83	73	79-84	55-62
Ash [Percent of Dry Weight]		34		24	25-28	42	13-22	17-41	27	16-21	27-46
Carbon [Percent of Dry Weight]		32		38			35			36	26-31
Hydrogen [Percent of Dry Weight]				5.4			2.2			5.1	3.7-4.7
Nitrogen [Percent of Dry Weight]			1.6	.1-3	0.7-3		1-3	0.7-3	1.8-3.7	0.9-5.4	1-4
Sulfur [Percent of Dry Weight]								0.4		2.7	0.8-1.2
Algin [Percent of Dry Weight]			30-35	19-30			18-28	12-40			13-24
Carrageenan/Agar [Percent of Dry Weight]		0	0	0	37-64	0	0	0		0	
Cellulose [Percent of Dry Weight]				2	2		1-3	3-8	2		3-8
Fucoidan [Percent of Dry Weight]											0.5-2
Laminarin [Percent of Dry Weight]		2-4	3-9	1-7			1-7	0-34			6-7
Mannitol [Percent of Dry Weight]				3-13			8-16	4-30			8-20
Starch [Percent of Dry Weight]						16				37	
Temperature Range				5-22	10-20	10-25					10-18
C/N RATIO											

(1) Sources: Chapman (1970), De Boer (1977), Jackson and North (1973) Mateus et al (1975), Percival and McDowell (1967), Powell and Meeuse (1964), Simpson and Shacklock (1977), and Wilson (1977).

(2) R = red, B = brown, G - green.

5.2.2 Solids Content

Total Solids

The percent of the harvested weight of each species represented by total solids is presented in Table 2, and in Figure 1. All species except Codium fragile have a higher total solids content than does the benchmark species Macrocystis pyrifera. Only Palmaria palmata had a mean total solids content outside the range of the literature data reported in Table 1. This may have been due to the small number of specimens, although 2 of the 3 specimens were below the 14% minumum literature value.

The very large data scatter within a species, indicated by a coefficient of variation of up to 32% of the mean, can have important effects on the economics of the entire process. As a result, we must learn what factors cause, or control, this variation. Since this same comment can be made for almost all of the analyses, it will be discussed in more detail later in this report.

Volatile Solids

While the total solids are important from a materials handling point of view, a more important parameter from the systems viewpoint is the percent volatile solids. The term "Volatile Solids" is the weight loss when ashing under standardized conditions. It represents an estimate of the total organic matter present. The mean values for each species are contained in Table 2, and are presented graphically, in two different formats, in Figure 2. When presented on a percent dry weight basis, as in Figure 2B, no one candidate appears dramatically different than any other.

FIGURE 1. TOTAL SOLIDS AS PERCENT OF HARVESTED WEIGHT

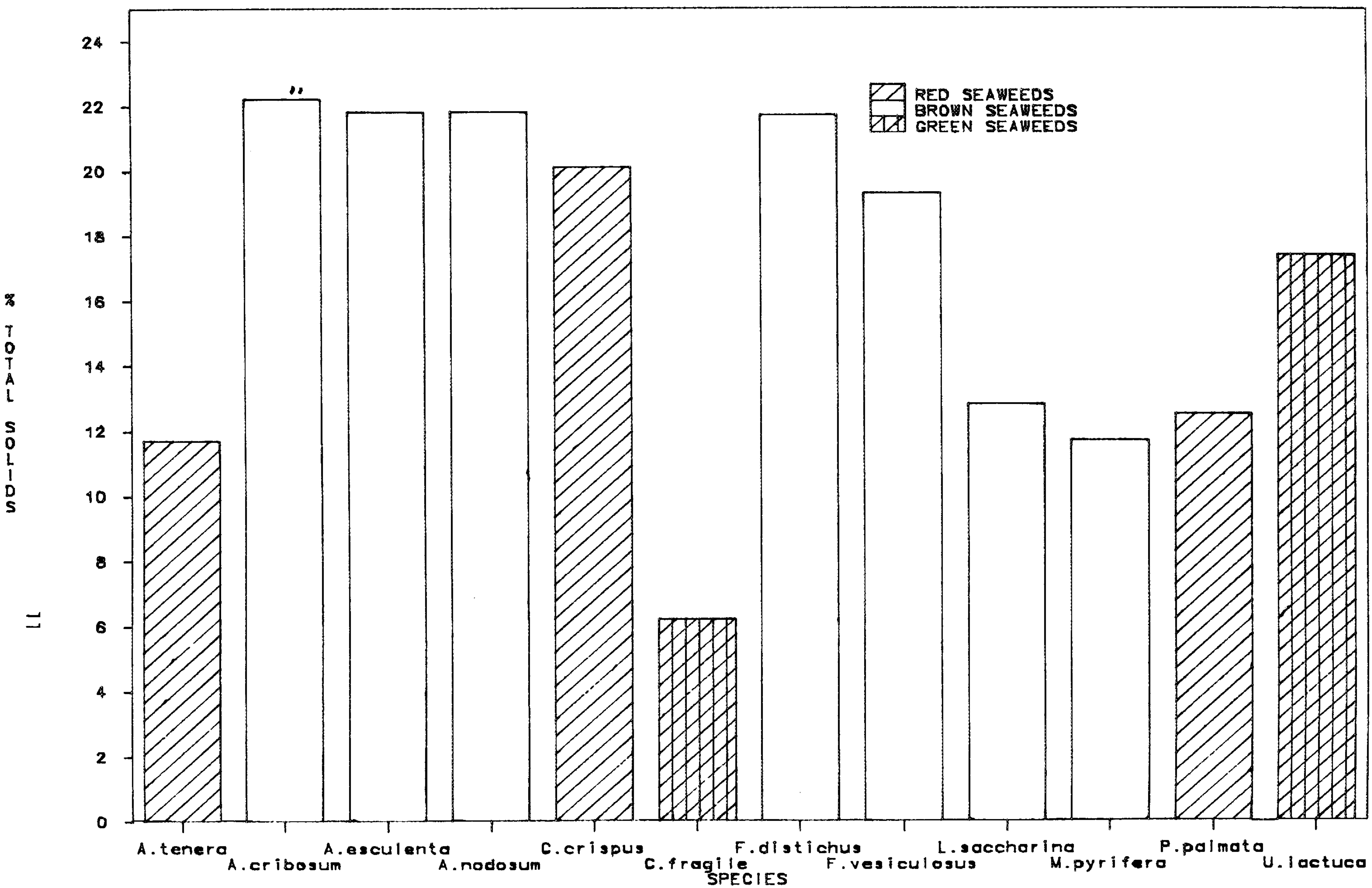


FIGURE 2 VOLATILE SOLIDS AS PERCENT OF HARVESTED WEIGHT

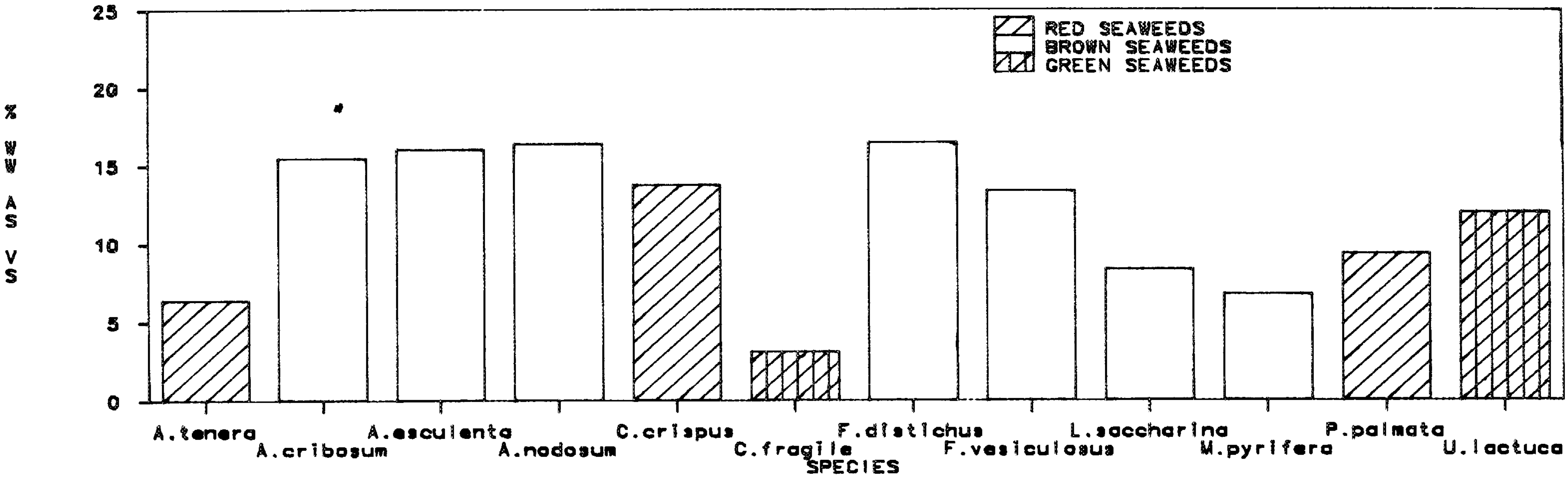
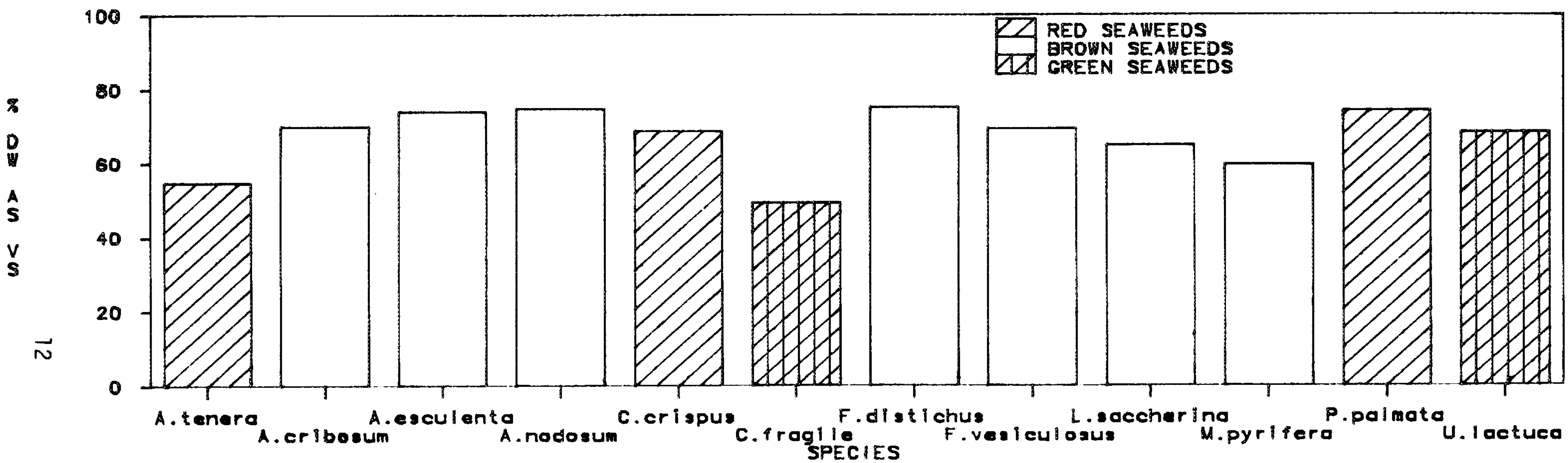


FIGURE 2B. VOLATILE SOLIDS AS PERCENT OF TOTAL SOLIDS



However, when presented on a percent harvested weight basis, C. fragile appears to be significantly less desirable than does any other candidate. Only A. tenera and C. fragile contain less volatile solids, on a harvested weight basis, than does M. pyrifera. Six species contain over 10 percent of the harvested weight as volatile solids, and 3 of these (A. esculenta, A. nodosum, and F. distichus) contain over 16 percent. The advantage to reporting this data on a harvested weight basis is that it is immediately evident that one must grow, harvest, and process 3 to 5 times the mass of Colium fragile to provide the same total quantity of organic matter as is provided by any of the other candidate species. On a dry weight basis, the volatile solids contents of Chondrus, Fucus, and Ulva were below the range of the literature data reported in Table 1.

Ash

Ash, the residue remaining after combustion under standardized conditions, represents an estimate of the inorganic matter present in the specimen. The majority of this material is alkaline metal salts of sulfate, carbonate, phosphate, silicate, and chloride (Show 1981). It is completely non digestible, but does represent material to be handled through every step of the process, and to be disposed of at the end of the process. These salts are highly corrosive to metal components in the system, and can form abrasive precipitates under the right conditions. Therefore, from a systems viewpoint, low ash (i.e. high percent of total solids as volatile solids) is a desirable selection criterion.

FIGURE 3 . ASH AS PERCENT OF HARVESTED WEIGHT

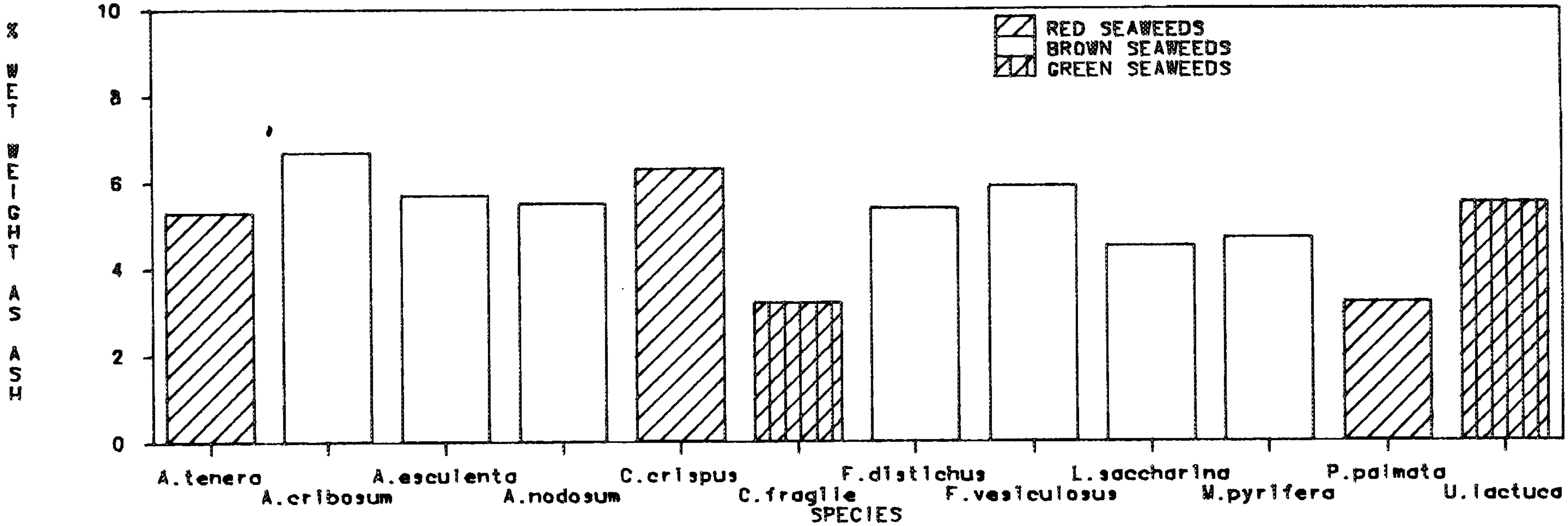
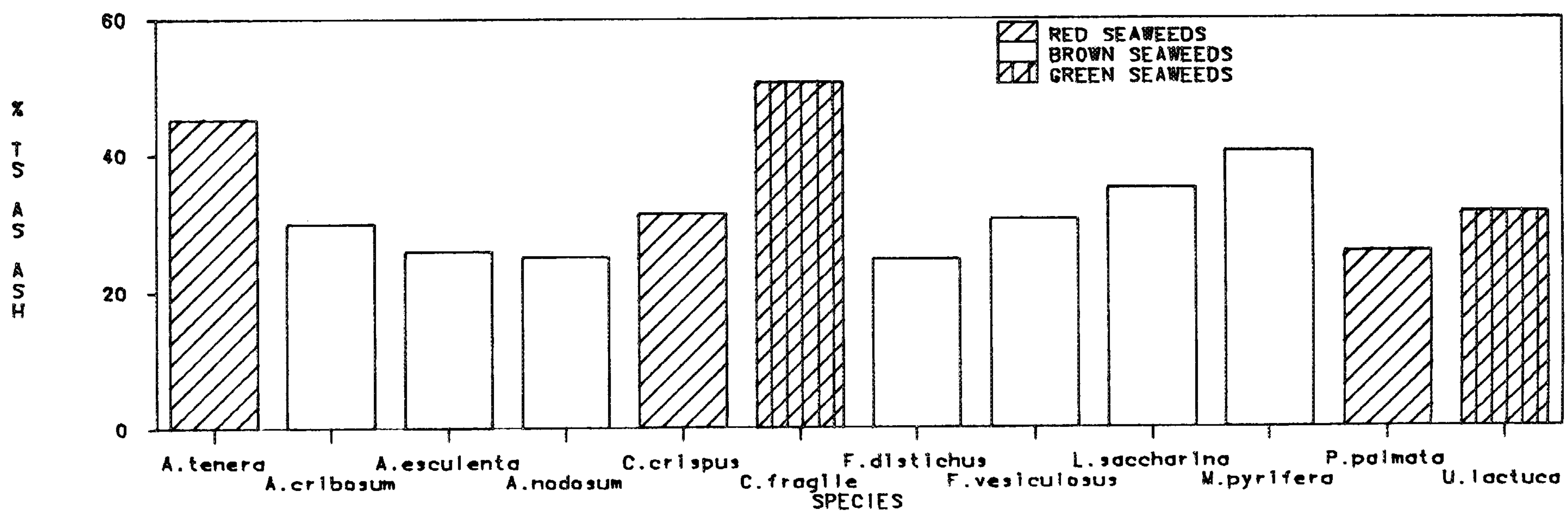


FIGURE 3B. ASH AS PERCENT OF TOTAL SOLIDS



The data in Table 2, and in Figure 3, show that A. tenera and C. fragile have the highest percent of the total solids as ash. All other species contain a lower percentage of ash than does M. pyrifera. Those species containing less than 30% of the total solids as ash were A. esculenta, A. nodosum, F. distichus, and P. palmata.

TABLE 2

MEAN VALUES FOR MACROALGAL SOLIDS CONTENT (1) (2)

SPECIES	COLOR (3)	Percent total solids as: Volatile Solids					Ash					Percent harvested weight as: Total Solids					Volatile Solids				
		$\bar{X}$	S.D.	C.V.	Low	High	$\bar{X}$	S.D.	C.V.	Low	High	$\bar{X}$	S.D.	C.V.	Low	High	$\bar{X}$	S.D.	C.V.	Low	High
Agardhiella tenera (4)	R	54.7	-	-	-	-	45.3	-	-	-	-	11.7	-	-	-	-	6.4	-	-	-	-
Agarum cribosum (4)	B	69.9	-	-	-	-	30.1	-	-	-	-	22.2	-	-	-	-	15.5	-	-	-	-
Alaria esculenta (4)	B	74.0	-	-	-	-	26.0	-	-	-	-	21.8	-	-	-	-	16.1	-	-	-	-
Ascophyllum nodosum	B	74.8	3.0	4	68.2	79.7	25.2	3.0	12	20.3	31.8	21.8	2.0	9	17.9	24.6	16.4	1.9	12	12.2	18.9
Chondrus crispus	R	68.6	3.3	5	64.3	72.6	31.4	3.3	10	27.3	35.7	20.1	2.6	13	17.0	25.9	13.8	1.8	13	11.0	17.0
Codium fragile	G	49.3	9.5	19	37.6	66.8	50.7	9.5	19	33.2	62.4	6.2	1.3	20	4.4	7.8	3.1	1.2	39	2.0	4.9
Fucus distichus	B	75.2	5.7	8	68.5	82.5	24.8	5.7	23	17.5	31.5	21.7	4.2	19	16.1	25.7	16.5	4.0	24	11.1	20.0
Fucus vesiculosus	B	69.4	3.7	5	63.9	79.0	30.6	3.7	12	21.0	36.1	19.3	2.9	15	13.0	24.9	13.4	2.3	17	8.7	17.2
Laminaria saccharina	B	64.9	7.5	12	52.7	82.1	35.1	7.5	21	17.9	47.3	12.8	3.0	24	9.4	18.0	8.4	2.8	33	6.3	14.4
Palmaria palmata	R	74.2	-	-	71.2	79.8	25.8	-	-	20.2	28.8	12.5	-	-	10.0	17.0	9.4	-	-	7.1	13.6
Ulva lactuca (5) (6)	G	68.4	8.5	12	58.8	79.1	31.6	8.5	27	20.9	41.2	17.4	1.7	10	16.2	20.1	12.0	2.3	19	9.6	15.9
Macrocystis pyrifera (7)	B	59.7	3.9	6	52.6	66.1	40.5	3.9	10	33.9	47.4	11.7	0.9	7	10.3	12.1	6.8	0.9	13	5.7	8.5
Macrocystis pyrifera (8)		62.1	3.6	6	57.9	66.4	37.9	3.6	10	33.6	42.1	12.2	0.4	3	11.9	12.7	7.6	0.6	8	6.9	8.2

(1) $\bar{X}$ = mean value, S.D. = standard deviation, C.V. = coefficient of variation. S.D. and C.V. were not calculated for species containing fewer than 4 specimens.
(2) Actual data for each lot are presented in Appendix A.
(3) R = red, B = brown, G = green.
(4) Only 1 specimen received for this species.
(5) Data for lot 2 were omitted. This mud flat specimen was apparently contaminated with mud.
(6) May be Ulva rigida.
(7) Data from USDA Western Regional Research Center.
(8) Data for 4 specimens analyzed by GE.

5.2.3 Fiber Analysis

Fiber analyses were performed in order to estimate the amount of fibrous material present in the candidate seaweeds. The technique used was that of Hart et al (1978), which eliminates the errors introduced by the presence of algin. It should be noted that the materials assaying as "lignin", "cellulose", and "hemi-cellulose" may not be the same as those found in the land plants for which the original ARS analytical procedure was developed. The fiber analysis data are presented in Table 3, and in Figures 4 through 6. All fiber data are presented on two bases, as percent of total solids (dry weight) and as percent or organic matter.

The large data scatter between samples from the same species (coefficients of variation of up to 51%) is probably real. All analyses were performed in triplicate, with the relative percent standard error for a given determination being 15.9% for cellulose and 10.8% for lignin (16 triplicate determinations for each assay). The Kolmogorov-Smirnoff normality test indicated the error terms were normally distributed about a mean of zero.

Lignin

"Lignin" in seaweeds is that material which assays as such by the standard forage fiber methods of Goering and van Suest (1970) as modified by Hart et al (1978). It behaves like lignin in several standard tests, contains phenolics, and appears to be refractory to anaerobic digestion (Hart et al 1978). For the purposes of this screening study, a low lignin content is a desirable selection criterion.

FIGURE 4 "LIGNIN" AS PERCENT OF ORGANIC MATTER

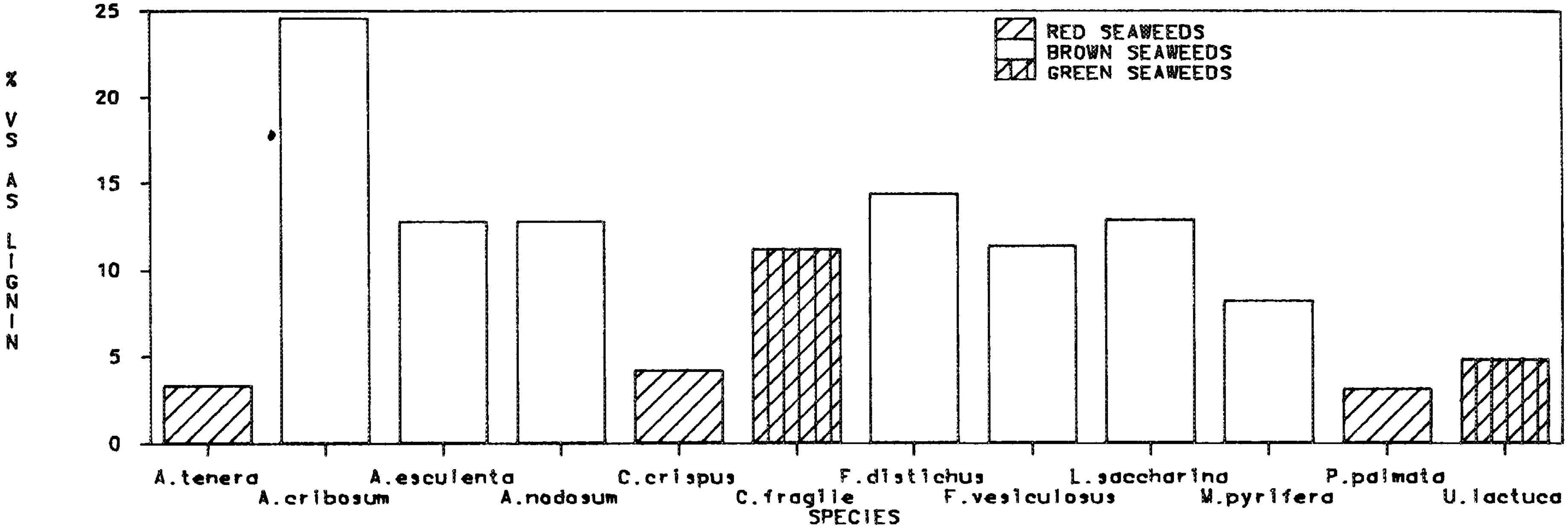
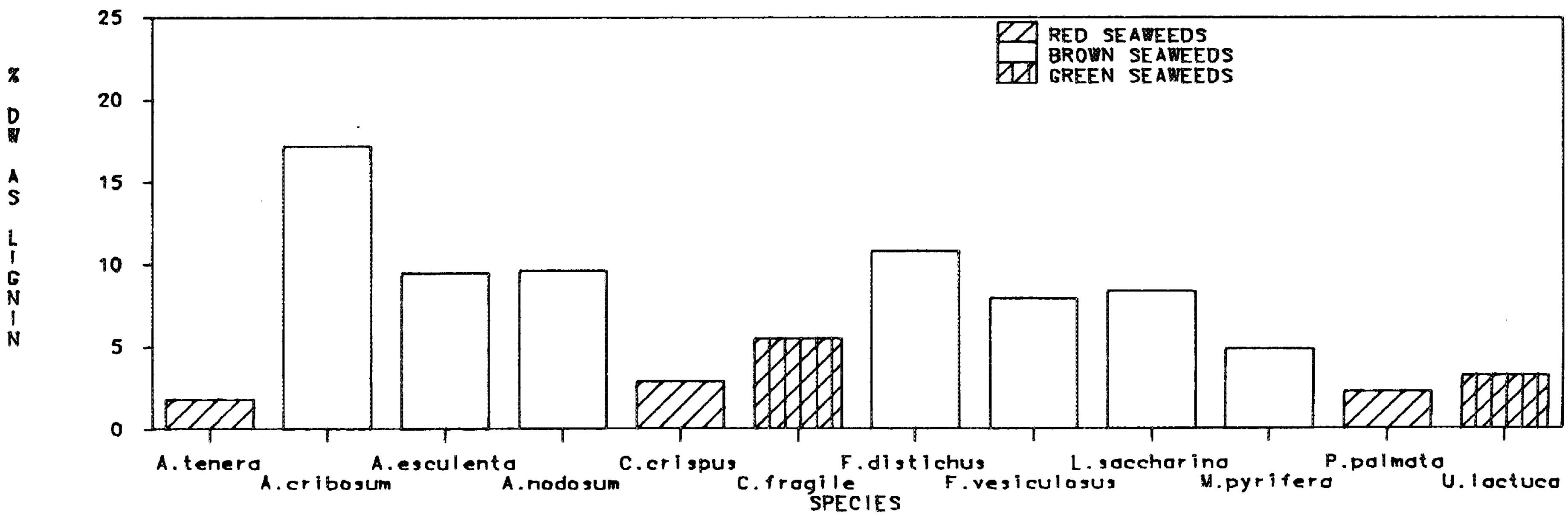


FIGURE 4B. "LIGNIN" AS PERCENT OF TOTAL SOLIDS



The lignin data are presented in Table 3, and in Figure 4. The highest content, at 17% of the total solids, and 25% of the organic matter, was found in Agarum cribosum. Whether this is typical of this species, or simply a specimen at the upper end of the species range, is unknown at this time because only one specimen was received for analysis. Lot 2 of A. nodosum contained 19% of the dry weight and 25% of the organic matter as lignin. However, the low value for this species was 3.4% of the dry weight and 4.4% of the organic matter, while the corresponding mean values were 9.6% and 12.8%. The mean lignin content, as a percentage of the organic matter in A. tenera, C. crispus, P. palmata and U. lactuca was lower than that of the benchmark species M. pyrifera. All other species were higher. Those species for which enough specimens were analyzed to provide meaningful statistics all exhibited a very large data scatter, with coefficients of variation ranging up to 54 percent of the means. We do not yet have enough data to determine whether this variation is seasonal, or is due to some other cause.

Cellulose

"Cellulose" in seaweeds is that material which assayed as such in our fiber analysis scheme. Since Hart et al (1978) demonstrated that this material contains glucose, and that it is more than 90% solubilized by cellulase, it is cellulosic in nature. Cellulose is digestible to methane, but the rates of digestion in kelp fermentations are unknown. The kelp fermentation-based enrichment cultures and pure cultures isolated in our lab all degrade crystalline cellulose very slowly. Therefore, at this time, we do not have sufficient rate information

FIGURE 5 CELLULOSE AS PERCENT ORGANIC MATTER

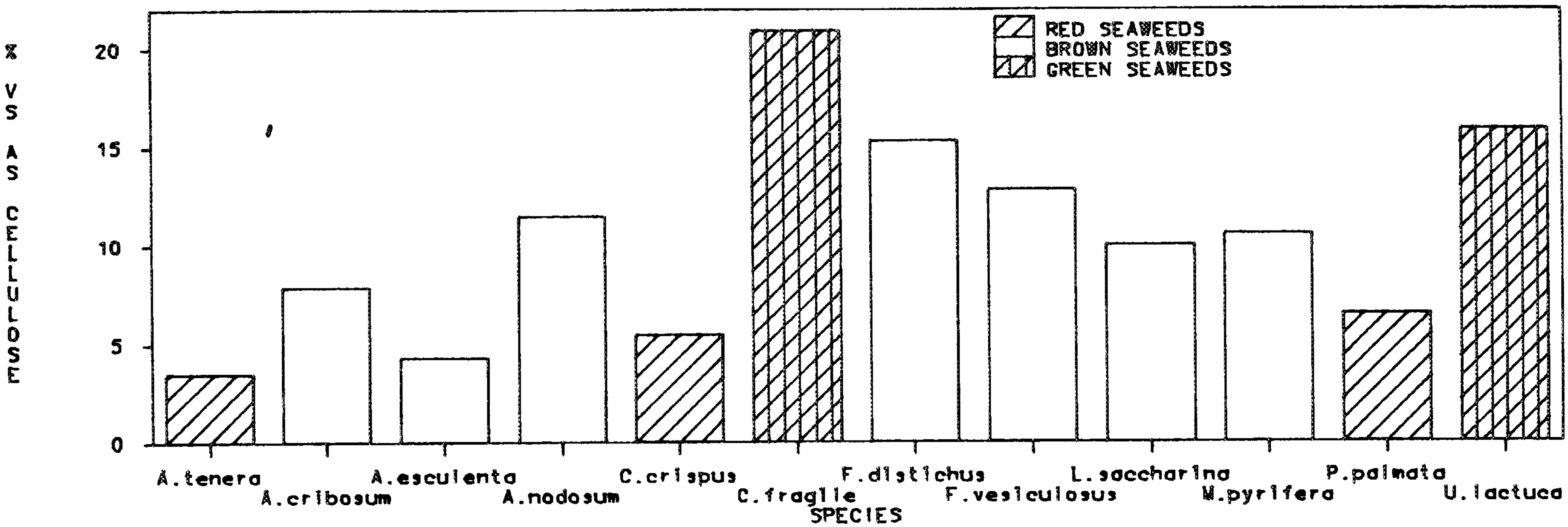
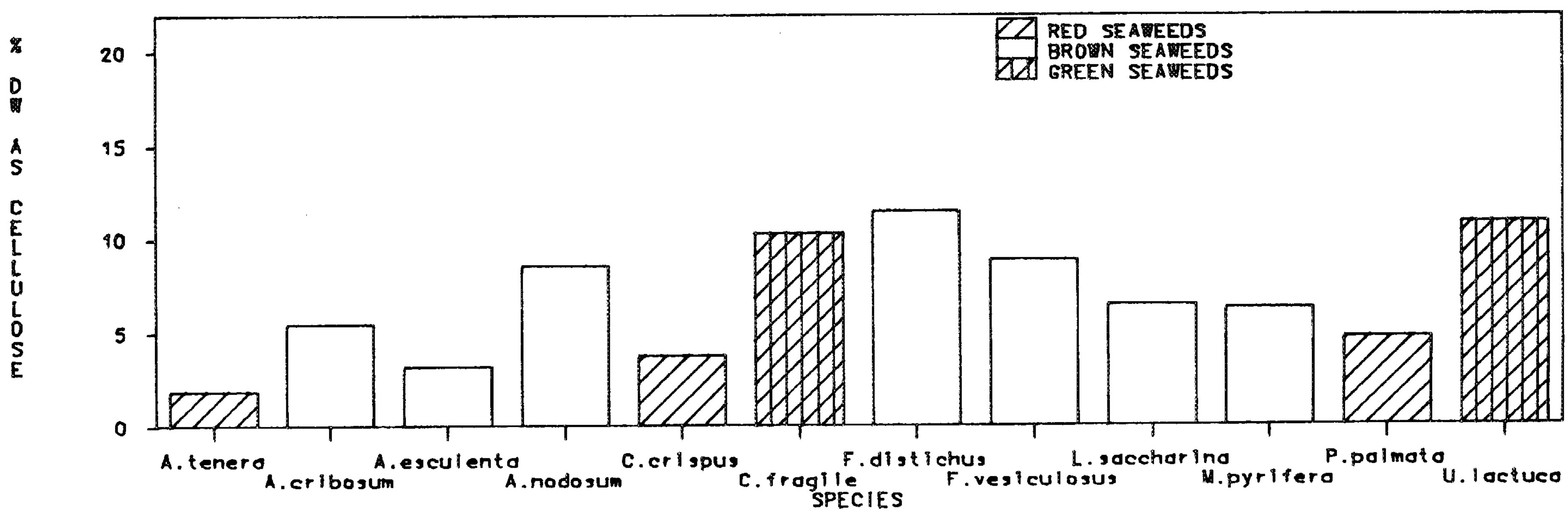


FIGURE 5B. CELLULOSE AS PERCENT OF TOTAL SOLIDS



to determine whether high cellulose is desirable in our screening protocol.

When presented on a percent total solids basis, the highest cellulose concentration occurred in F. distichus, but on a percent organic matter basis, both green species exhibited higher values. The lowest concentrations occurred in the red seaweeds, with P. palmata having only 3 percent of its organic matter as cellulose. The cellulose content of Fucus was significantly higher than the literature range reported in Table 1. Although Ascophyllum and Chondrus also exceeded their literature values, their literature data comprised single point determinations which fell at the lower end of our data range. Since cellulose accounted for up to 20 percent of the organic matter in the green seaweeds, and up to 15 percent in the browns, some research effort should be directed toward determining both the rate, and the extent, of its utilization in seaweed fermentations.

Hemi-Cellulose

"Hemi-cellulose" in this study represents material which assayed as such in our fiber analysis procedure. Whether this material is hemicellulose, or even a poly pentose, is unknown at this time. The data, presented in Table 3 and in Figure 6, show that it is a major constituent of seaweeds. Also, when converted from a percent total solids base to a percent organic matter base, the relative ranking of some species is changed. In general, the reds and greens exhibit the highest concentrations of their organic matter as hemi-cellulose, with values exceeding 30 percent. All New York State species values exceeded those of M. pyrifera.

FIGURE 6 HEMICELLULOSE AS PERCENT OF ORGANIC MATTER

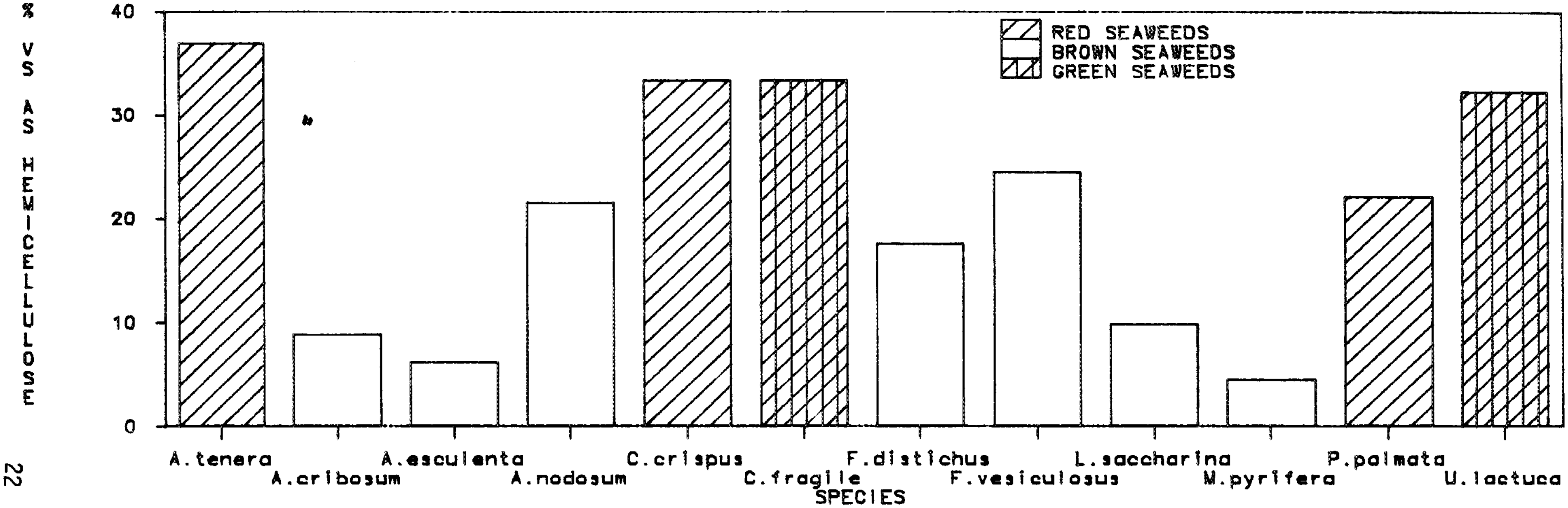


FIGURE 6B. HEMICELLULOSE AS PERCENT OF TOTAL SOLIDS

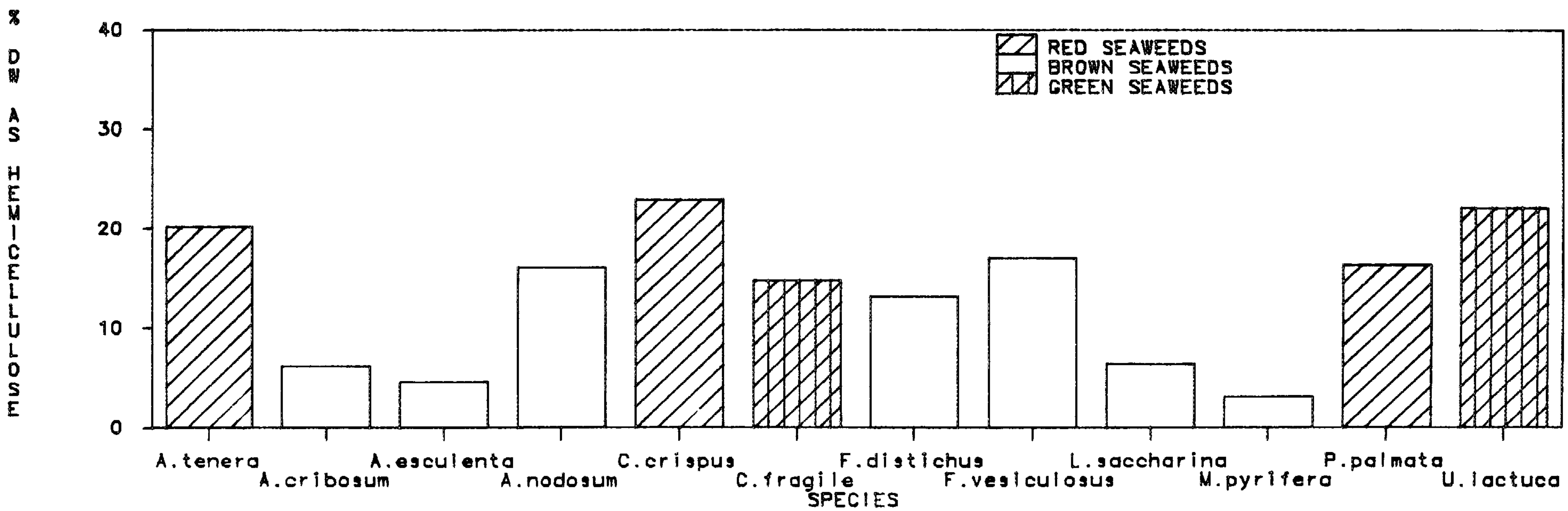


TABLE 3

MACROALGAL FIBER CONTENT (1)

SPECIES	(3) COLOR	PERCENT TOTAL SOLIDS AS: LIGNIN (2)					CELLULOSE (2)					HEMI-CELLULOSE (2)					MEAN PERCENT ORGANIC MATTER AS: LIGNIN	CELLULOSE	HEMI-CELLULOSE
		$\overline{X}$	S.D.	C.V.	LOW	HIGH	$\overline{X}$	S.D.	C.V.	LOW	HIGH	$\overline{X}$	S.D.	C.V.	LOW	HIGH			
Ahardhiella tenera (4)	R	1.8	-	-	-	-	1.9	-	-	-	-	20.2	-	-	-	-	3.3	3.5	36.9
Agarum cribosum (4)	B	17.2	-	-	-	-	5.5	-	-	-	-	6.2	-	-	-	-	24.6	7.9	8.9
Alaria esculenta (4)	B	9.5	-	-	-	-	3.2	-	-	-	-	4.6	-	-	-	-	12.8	4.3	6.2
Ascophyllum nodosum	B	9.6	4.2	44	3.4	19.1	8.6	3.7	43	1.6	13.5	16.1	5.4	34	8.9	26.1	12.8	11.5	21.5
Chondrus crispus	R	2.9	1.1	38	1.1	4.3	3.8	1.0	26	2.4	4.4	22.9	5.6	24	16.7	36.4	4.2	5.5	33.4
codium fragile	G	5.5	3.0	54	0.0	10.5	10.3	8.4	82	4.1	32.0	14.8	3.2	22	11.4	20.9	11.2	20.9	30.0
Fucus distichus	B	10.8	4.2	39	5.9	15.4	11.5	3.7	32	7.3	16.1	13.2	5.8	44	6.2	18.2	14.4	15.3	17.6
Fucus vesiculosus	B	7.9	2.2	28	4.5	10.7	8.9	2.0	22	4.9	13.5	17.0	2.9	17	11.0	22.7	11.4	12.8	24.5
Laminaria saccharina	B	8.4	3.6	43	3.1	14.0	6.5	2.6	40	3.5	10.8	6.4	4.2	66	0.6	13.5	12.9	10.0	9.9
Palmaria Palmata	R	2.3	-	-	1.9	2.8	4.8	1.0	21	4.0	5.9	16.4	6.9	38	11.5	24.3	3.1	6.5	22.1
Ulva lactuca (5) (6)	G	3.3	0.4	12	1.1	7.8	10.9	6.0	55	2.5	20.8	22.1	7.4	34	15.4	35.8	4.8	15.9	32.3
Macrocystis pyrifera	B	4.9	2.5	51	1.9	5.7	6.3	1.2	19	4.7	7.2	3.1	0.8	26	1.9	3.4	8.2	10.6	4.5

(1) $\overline{X}$ = mean, S.D. = standard deviation, C.V. = coefficient of variation. S.D. and C.V. were not calculated for species containing fewer than 4 specimens.
(2) Actual data for each lot are presented in Appendix A.
(3) R - red, B - brown, G = green.
(4) Only 1 specimen received for this species.
(5) Data for lot 2 were omitted. This mud flat specimen was apparently contaminated with mud.
(6) May be Ulva rigida.

Neither the rate, nor the extent, of the digestibility of this material is known. Since it is a major seaweed constituent, some research should be directed toward determining its identity, and its digestibility. If it is truly a hemi-cellulose, then it should be readily digested but, since its identity is unknown, this must be determined empirically.

5.2.4 Sugars and Sugar Polymers

Algin

Algin, a copolymer of L-guluronic and D-mannuronic acids, is a structural polymer in brown seaweeds. The data presented in Table 4, and in Figure 7, show that the highest values occur in the brown seaweeds. The "algin" found in the reds, and in the greens, is present only in low concentrations, and may not be algin, since this polymer is not known to be present in these plants. Algin represents a major constituent in some of the brown seaweeds, with concentrations upward of 19% of the organic matter in *Agarum*, *Laminaria*, and *Macrocystis*.

The concentrations found in *Alaria*, *Ascophyllum* and *Fucus* were below the levels reported in the literature, as were the values for some of the *Laminaria* specimens.

Jain et al (1981) demonstrated the degradation of this polymer in pure culture studies, and both Hart et al (1978) and Chynoweth et al (1981) demonstrated its degradation in kelp fermentations. At present, its rate of degradation, and whether or not its degradation products are readily converted to methane, are unknown and some research effort should be directed to this area. Since we feel algin is convertible to methane, we are giving its presence a positive weighting in our screening efforts.

FIGURE 7   ALGIN AS PERCENT OF ORGANIC MATTER

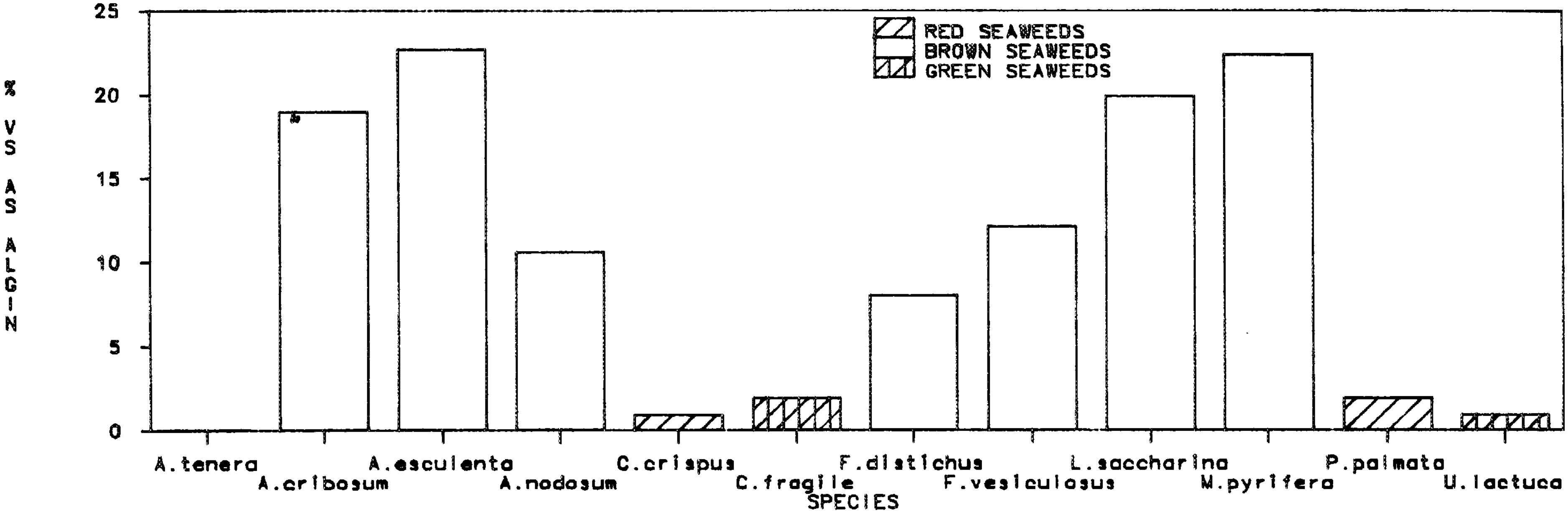


FIGURE 7B. ALGIN AS PERCENT OF TOTAL SOLIDS

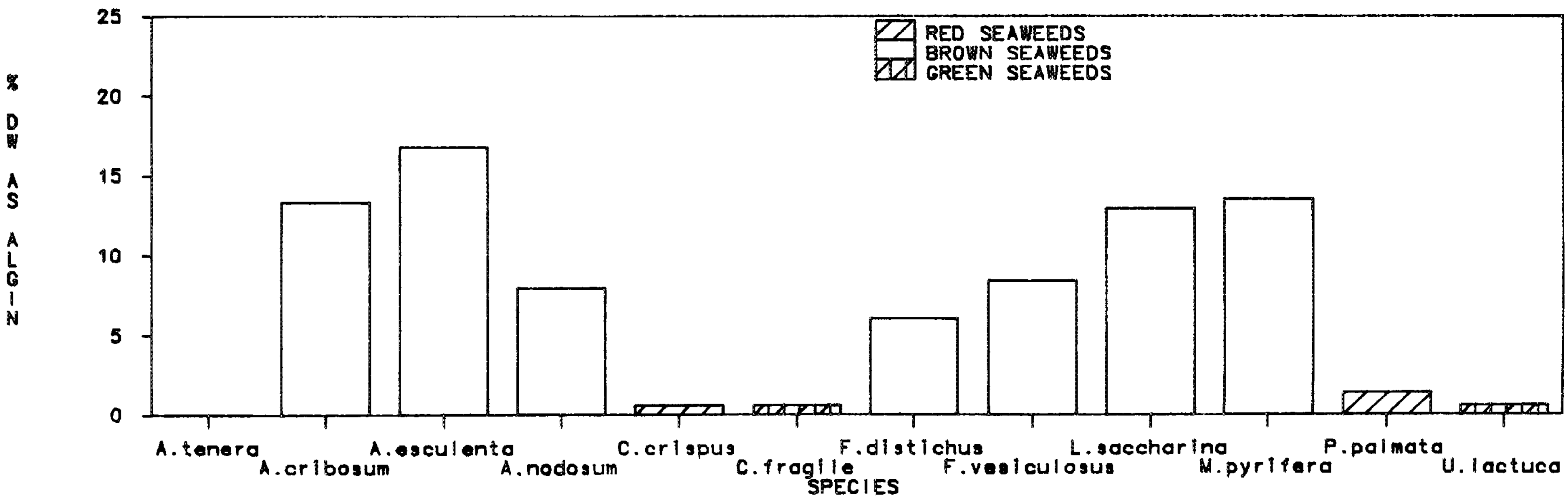


TABLE 4

MACROALGAL ALGIN CONTENT (1) (2)

SPECIES	COLOR (3)	Percent of Total Solids: $\bar{X}$	S.D.	C.V.	LOW	HIGH	Percent of organic Matter
Agardhiella tenera (4)	R	-	-	-	-	-	-
Agarum cribosum (4)	B	13.3	-	-	-	-	19.0
Alaria esculenta (4)	B	16.8	-	-	-	-	22.7
Ascophyllum nodosum	B	7.9	4.0	51	3.2	14.1	10.6
Chondrus crispus	R	0.6	-	-	-	-	0.9
Codium fragile	G	0.6	-	-	-	-	1.2
Fucus distichus	B	6.0	1.6	27	3.9	7.5	8.0
Fucus vesiculosus	B	8.4	3.1	37	3.4	14.6	12.1
Laminaria saccharina	B	12.9	4.7	36	5.9	19.2	19.9
Palmaria palmata	R	1.4	-	-	-	-	1.9
Ulva lactuca (5) (6)	G	0.6	0.1	17	0.5	0.8	0.9
Macrocystis pyrifera (7)	B	13.4	3.6	27	8.4	19.5	22.4
Macrocystis pyrifera (8)	B	13.5	1.8	13	11.5	15.3	21.7

(1) $\bar{X}$ = mean, S.D.=standard deviation, C.V.=coefficient of variation. S.D. and C.V. were not calculated for species in which fewer than 4 determinations were made.
(2) Actual data for each lot are presented in Appendix A.
(3) R = red, B = brown, G = green.
(4) Only 1 specimen received for this species.
(5) Data for lot 2 were omitted. This mud flat specimen was apparently contaminated with mud.
(6) May be Ulva rigida.
(7) Data from USDA Western Regional Research Center.
(8) Data for 4 specimens analyzed by GE.

Fucoidan

Fucoidan, an admixture of sulfated polyfucose plus some undefined polymers, is an anti dessicant mucilagenous material found in brown seaweeds (Percival and McDowell 1967). The data in Table 5 and in Figure 8 demonstrate mean concentrations of great than 8 percent of the organic matter in A. nodosum, F. vesiculosus, P. palmata, and U. lactuca. The high concentrations in Palmaria and Ulva would not be expected from the literature data which indicates these species should not contain any fucoidan. In the case of P. palmata, this material cannot be fucoidan because the plant's sulfur content is too low. The colorimetric method used to determine this compound measures methylpentoses, but pentoses will interfere (Ashwell 1957). Although hexoses and uronic acids do not interfere, it is not known whether sulfated hexoses, such as the sulfated galactans found in some green seaweeds (Percival and McDowell 1967) will interfere. It thus appears that this analytical procedure is not as specific for fucoidan as one would desire. As will be discussed below, high levels of sulfated compounds are undesirable for a variety of reasons. The large data scatter (coefficients of variation of greater than 100%) are indicative of wide variations in the fucoidan content of natural populations.

FIGURE 8   FUCOIDAN AS PERCENT OF ORGANIC MATTER

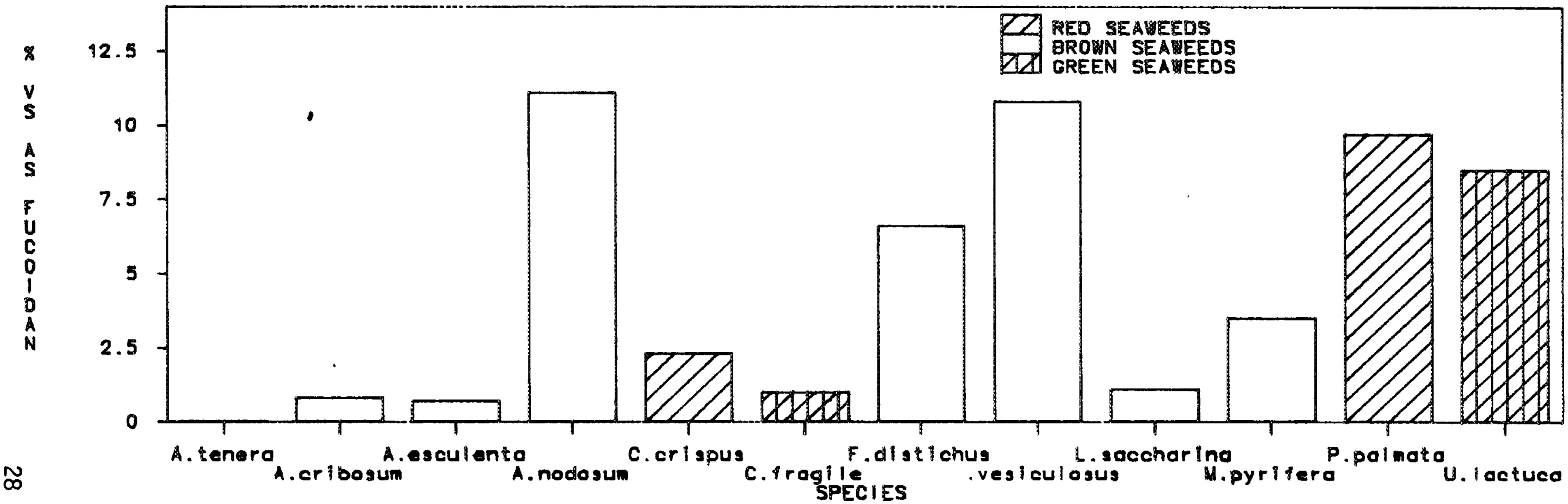


FIGURE 8   FUCOIDAN AS PERCENT OF TOTAL SOLIDS

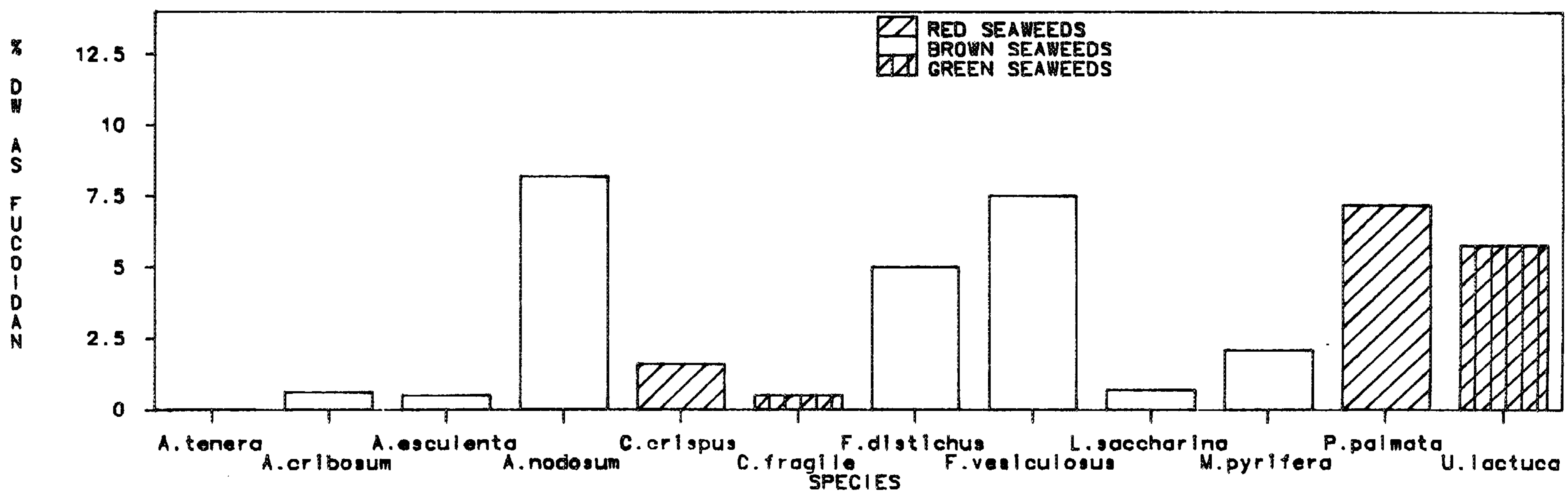


TABLE 5

MACROALGAL FUCOIDAN CONTENT (1) (2)

SPECIES	(3) COLOR	Percent of Total Solids					PERCENT OF ORGANIC MATTER
		$\bar{X}$	S.D.	C.V.	LOW	HIGH	
Agardhiella tenera (4)	R	-	-	-	-	-	-
Agarum cribosum (4)	B	0.6	-	-	-	-	0.8
Alaria esculenta (4)	B	0.5	-	-	-	-	0.7
Ascophyllum nodosum	B	8.2	6.5	80	3.4	21.5	11.1
Chondrus crispus	R	1.6	2.1	132	0.0	6.2	2.3
Codium fragile	G	0.5	0.3	60	0.0	0.9	1.0
Fucus distichus	B	5.0	1.7	34	3.1	6.5	6.6
Fucus vesiculosus	B	7.5	3.2	43	2.5	14.9	10.8
Laminaria saccharina	B	0.7	0.6	86	0.1	2.0	1.1
Palmaria palmata	R	7.2	-	-	0.0	12.0	9.7
Ulva lactuca (5) (6)	G	5.8	2.2	38	2.9	8.0	8.5
Macrocystis pyrifera	B	2.1	2.1	100	1.2	2.2	3.5

(1) $\bar{X}$ - mean value, S.D. = standard deviation, C.V. = coefficient of variation. S.D. and C.V. were not calculated for species containing fewer than 4 specimens.
(2) Actual data for each lot are presented in Appendix A.
(3) R = red, B = brown, G = green.
(4) Only 1 specimen received for this species.
(5) Data for lot 2 were omitted. This mud flat specimen was apparently contaminated with mud.
(6) May be Ulva rigida.

Mannitol

Mannitol, the primary photosynthetic product in brown seaweeds is known to accumulate in significant quantities in some species. Since this material is easily converted to methane, high mannitol levels are considered desirable. The data presented in Table 6, and in Figure 9 show that the mannitol content of the brown seaweeds exceeds that of the reds and greens, and that the mean mannitol content exceeds 12 percent of the organic matter in *L. saccharina*, and in *M. pyrifera*. The maximum observed values were 16.0, 22.3, and 39.5 percent of the organic matter in *F. vesiculosus*, *L. saccharina*, and *M. pyrifera*, respectively. No significant quantities were found in either the red, or the green, seaweeds. The concentrations in *Ascophyllum* and *Fucus* were below the literature ranges reported in Table 1. The large data scatter for mannitol is due to known seasonal variation, and to local nutritional conditions.

The standard mannitol determination method used in other labs is the periodic acid oxidation method of Cameron et al (1948). We found this procedure to be cumbersome, and other compounds present in seaweeds are known to interfere. For example, algin, fucoidan, and laminarin react to a limited extent with periodic acid (Percival and McDowell 1967). We selected a High Performance Liquid Chromatography method which is not subject to these interferences. We evaluated several HPLC techniques, and finally selected the Bio-Rad HPX-87 lead form column, which resolves all the hexoses, pentoses, and hexitols. Severe interferences due to aromatic materials and salts in the seaweeds were eliminated by incorporating a dual guard

FIGURE 9 MANNITOL AS PERCENT ORGANIC MATTER

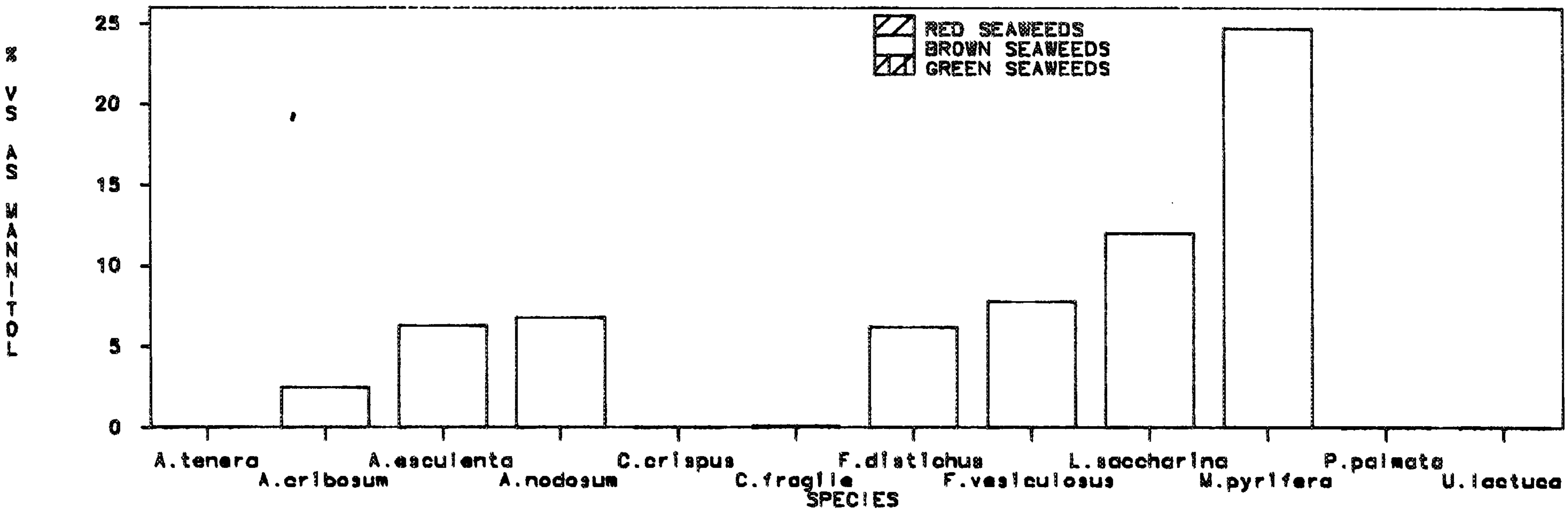


FIGURE 9 MANNITOL AS PERCENT TOTAL SOLIDS

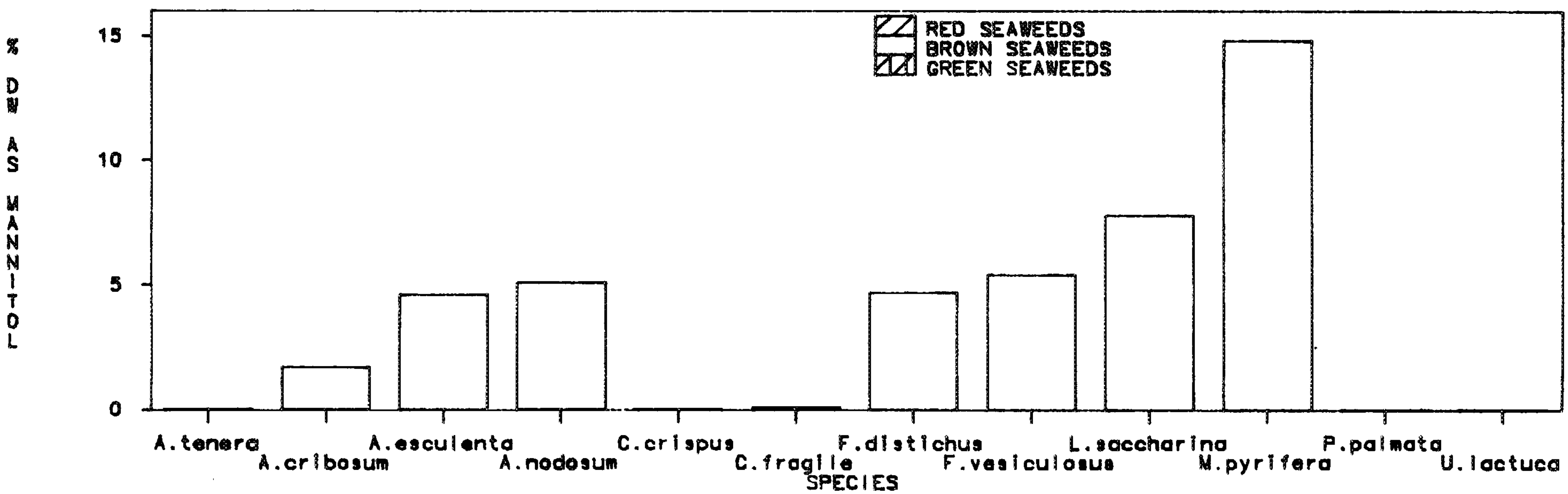


TABLE 6

MACROALGAL MANNITOL, GLUCOSE, AND GALACTOSE CONTENT (1) (2)

SPECIES	COLOR (3)	MANNITOL Percent of Total Solids $\bar{X}$	SD	CV	LOW	HIGH	Percent of organic matter ($\bar{X}$)	GLUCOSE Percent of Total Solids $\bar{X}$	SD	CV	LOW	HIGH	Percent of organic matter ($\bar{X}$)	GALACTOSE Percent of Total Solids $\bar{X}$	SD	CV	LOW	HIGH	Percent of organic matter ($\bar{X}$)
Agardhiella tenera (4)	R	0.0	-	-	-	-	0.0	0.0	-	-	-	-	0.0	0.0	-	-	-	-	0.0
Agarum cribosum (4)	B	1.7	-	-	-	-	2.4	-	-	-	-	-	-	-	-	-	-	-	-
Alaria esculenta (4)	B	4.7	-	-	-	-	6.4	-	-	-	-	-	-	-	-	-	-	-	-
Ascophyllum nodosum	B	5.1	1.6	31	1.6	7.5	6.8	0.6	0.7	117	0.0	2.1	0.8	0.2	0.8	400	0.0	2.6	0.3
Chondrus crispus	R	0.0	-	-	-	-	0.0	0.0	-	-	-	-	0.0	3.5	0.9	26	1.9	4.4	5.1
Codium fragile	G	0.1	0.4	400	0.0	1.3	0.1	0.2	0.5	250	0.0	1.3	0.4	0.0	-	-	-	-	0.0
Fucus distichus	B	4.7	1.3	28	3.2	6.3	6.2	0.0	-	-	-	-	0.0	0.1	0.2	200	0.0	0.4	0.1
Fucus vesiculosus	B	5.4	2.3	45	2.9	11.4	7.8	0.0	0.1	-	0.0	0.3	0.0	0.1	0.3	300	0.0	1.2	0.1
Laminaria saccharina	B	7.8	6.2	79	0.0	18.3	12.0	0.4	0.3	75	0.0	0.8	0.6	0.0	-	-	-	-	0.0
Palmaria palmata	R	0.0	-	-	-	-	0.0	0.8	-	-	-	-	1.1	6.1	-	-	-	-	8.2
Ulva lactuca (5) (6)	G	0.0	-	-	-	-	0.0	0.0	-	-	-	-	0.0	0.0	-	-	-	-	0.0
Macrocystis pyrifera (3)	B	14.8	5.7	39	5.2	24.9	24.8	-	-	-	-	-	-	-	-	-	-	-	-
Macrocystis pyrifera (8)		15.6	6.5	42	7.1	22.5	36.2	0.0	-	-	-	-	0.0	0.0	-	-	-	-	0.0

(1) $\bar{X}$ = mean value, SD = standard deviation, CV = coefficient of variation. SD and CV were not calculated for species containing fewer than 4 species.
(2) Actual data for each lot are presented in Appendix A.
(3) R = red, B = brown, G = green.
(4) Only one specimen received for this species.
(5) Data for lot 2 were omitted. This was a mud flat specimen, and was apparently contaminated with mud.
(6) May be Ulva rigida.
(7) Data from USDA Western Regional Research Center.
(8) Data for 4 specimens analyzed by GE.

column system composed of 2 Bio-Rad microguard holders in series. One holder contained a cation exchange resin microguard refill (AMINEX ® HPX- 85H) to remove positive ions, and the other contained an anion exchange resin microguard refill (AMINEX ® A125) to remove negative ions and phenolics. Jackson, et al (1980) compared known and unknown standards of sugarcane samples in a round robin of different laboratories using different sugar analysis precedures, including a Bio-Rad carbohydrate column HPLC method. This procedure was at least as accurate as enzymatic methods for quantitating glucose, fructose, and sucrose.

A lot-by-lot comparison of WRRC (periodate oxidation) and GE (HPLC) data is presented in Table 7. The GE data is consistently lower than that of WRRC, which is reasonable because the HPLC method is specific for mannitol (and for each of several other compounds) while the periodate oxidation method can be biased to the high side by known interferences such as algin and fucoidan.

Glucose and Galactose

One result of utilizing the HPLC method for determining mannitol is that sugars such as glucose and galactose, among others, are detected, identified and quantitated with essentially no extra effort. The glucose levels reported in Table 6 average less than about 1 percent of the organic matter in the seaweeds examined, with a maximum value of 2.8% observed for *A. nodosum*, lot 14. Significant galactose levels were found in the red seaweeds *Chondrus crispus* and *Palmaria palmata*. These averaged over 5 percent of the organic matter as galactose, with a maximum values of 6.4 percent

TABLE 7

COMPARISON OF THE PERIODIC ACID OXIDATION AND THE HPLC METHODS OF QUANTITATING MANNITOL IN MACROCYSTIS PYRIFERA

	MANNITOL (1)	
LOT	HIO_4 (2)	HPLC (3)
48	8.8	7.1
49	24.0	18.1
51-3	24.2 24.0 (4)	22.5
53-1	21.4 17.1 (4) 19.9 (4) 17.3 (4)	14.6

(1) Percent of total solids.
(2) Periodate method of Cameron et at (1948), performed by USDA Western Regional Research Center.
(3) HPLC method using Bio Rad HPX-87 plus dial guard columns, performed by GE.
(4) Redetermined by WRRC on blind samples prepared by GE.

of the organic matter being observed in C. crispus, and 8.2 percent in P. palmata. Chondrus is a carrageenophyte, and its galactose pool may represent material which has not yet been converted to carrageenan. As P. palmata does not contain the polygalactans agar or carrageenan, the reason for its high galactose levels are not immediately evident. However, in red seaweeds, galactose can also be converted to florideon starch or, more likely, it can act as low molecular weight storage products. From a methanogenesis viewpoint, both glucose and galactose are desirable because they are easily converted to methane.

Unidentified HPLC Peaks

Two unidentified peaks were found eluting near the void volume of the HPLC column, in the region for large molecular weight polysaccharides. Whether these materials are polysaccharides, or are representatives of some other class of compounds, is unknown. For lack of a better reference material, these compounds were "quantitated" with the mannitol standard curve even though this will produce erroneously low results if they are, in fact, polysaccharides. Even with potentially low estimates, up to 12 percent of the total solids can be accounted for by these compounds. They are listed in the Appendix A database printout as Compound A and Compound B. If these materials represent soluble polysaccharides, then their presence is desirable because they can be easily converted to methane.

Agar/Carrageenan

Agar and carrageenan are mucilagenous, sulfated polygalactans produced by some red seaweeds. Carrageenan is more highly sulfated, and is more viscous, than is agar (Percival and McDowell 1967), but neither is a pure compound. The composition of each varies between species, and also within a given species as environmental factors change. The data are presented in Table 8.

The analytical procedure used to detect the 3, 6-anhydrogalactose moity of these compounds will also respond to several other sugars. For example, P. palmata contained large quantities of a compound assaying as carrageenan, even though it doesn't produce this compound, and doesn't contain enough sulfur to have significant quantities of any sulfated polymers. The identity of this material is unknown but, since xylose is not supposed to respond to this assay (Yaphe and Arsenault 1965), it is probably not the xylan that Percival and McDowell (1967) reported in P. palmata. The concentration of this unknown material, referenced to a carrageenan standard curve, ranged from 16 to 30 percent of the organic matter. The carrageenan content of C. crispus ranged from 2 to 24 percent of the total solids. Expressed on an organic matter basis, its concentration averaged 13 percent, but its maximum value exceeded 30 percent.

Both the Palmaria and the Chondrus materials are probably soluble polysaccharides, with that in Chondrus actually being carrageenan. Both materials should be readily digestible, but the high sulfur content of carrageenan is undesirable. Therefore, the Palmaria

TABLE 8

CARRAGEENAN CONTENT OF RED MACROALGAE

	PERCENT OF TOTAL WEIGHT					Percent of Organic Matter ($\overline{X}$)
SPECIES	$\overline{X}$	SD	CV	LOW	HIGH	
Chondrus crispus	8.8	7.4	84	2.4	22.7	12.8
Palmaria palmata (3)	23.0	10.5	46	15.6	30.5	31.0

(1) $\overline{X}$ = mean, SD = standard deviation, CV = coefficient of variation.
(2) Actual data for each lot are presented in Appendix A.
(3) P. palmata does not contain carrageenan, nor does it contain enough sulfur for this material to be a sulfated polymer. This material is reported here only because it assayed as carrageenan.

material was rated as desirable, while the carrageenan of *Chondrus* was given only a slightly positive weight because the sulfur content partially offsets the easy digestibility.

5.2.5 Elemental Analyses

Analyses for carbon, hydrogen, nitrogen, and sulfur were performed on each specimen received. These values are required for calculating theoretical gas yields, for estimating whether nitrogen supplementation will be required for successful digestion, and for determining whether the candidate species will present problems related to having a high sulfur content. The elemental data, and the C/N ratios, are presented in Table 9. The mean C/N ratio and sulfur data are also presented in Figures 10 and 11, respectively.

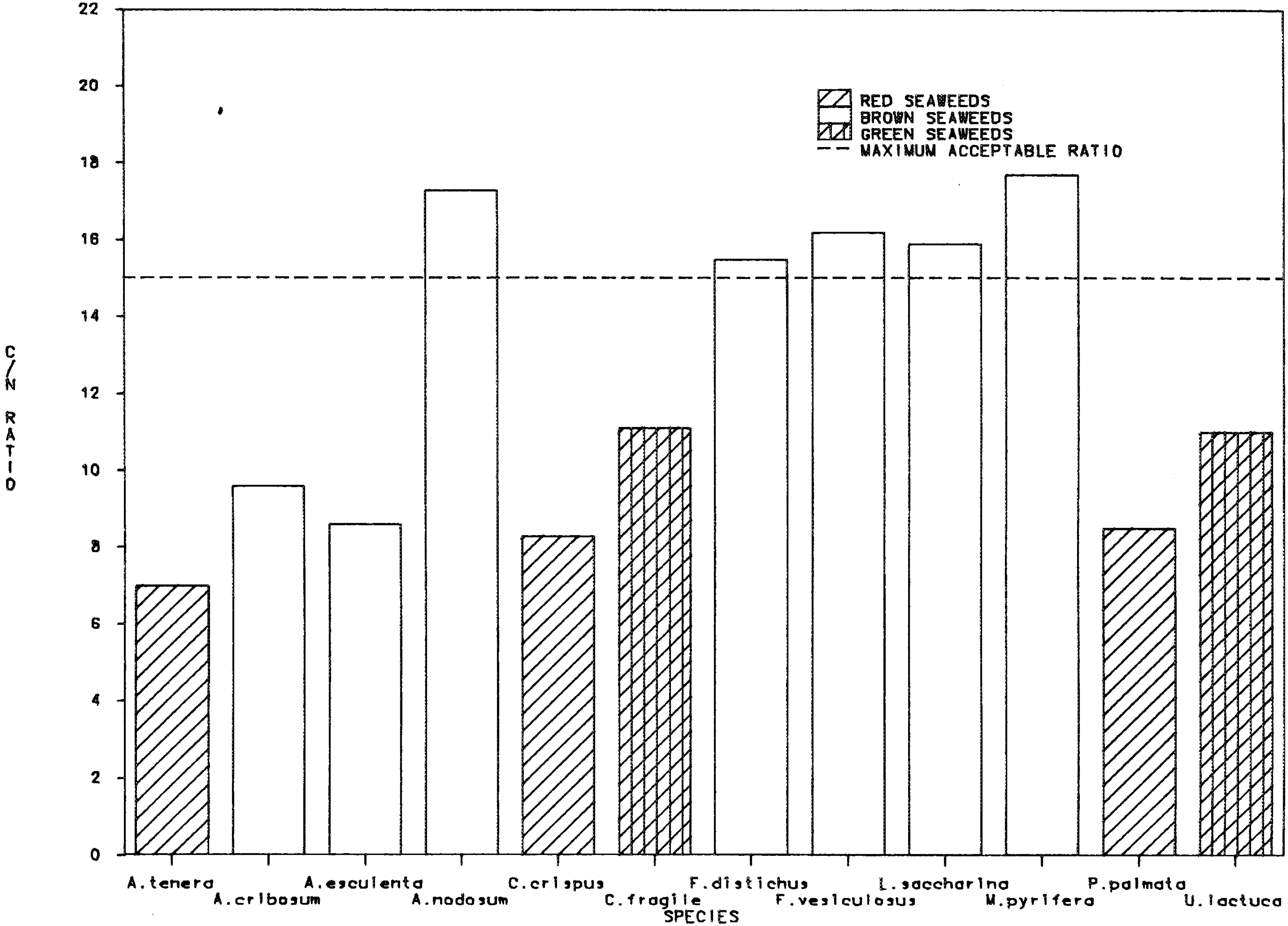
With the exception of *Ulva lactuca*, which was below the literature range, the carbon content of the specimens examined agreed with the limited literature data in Table 1. The *Fucus* hydrogen data, at almost 5 percent, were well above the 2.2 percent reported in the literature. Nitrogen in seaweeds is present mainly in the form of proteins, and is known to vary significantly with season (Chynoweth et al 1981, Show et al 1979), and with the nitrogen concentration in the water around the plants (North et al 1978). Since the plant nitrogen is incorporated into proteins, and since many of these proteins represent enzymes required for the synthesis of plant biomass, an adequate nitrogen level must be maintained for optimal growth to occur. Thus, it may be possible to use the plant nitrogen level as an indication of the health of the plants, and as a check on the time weighted average nitrogen available in the water. The observed levels in all *Chondrus crispus* specimens were higher than the literature range, as were those of two of the three Palmaria palmata specimens.

One important criterion for digestibility under anaerobic conditions is the carbon to nitrogen (C/N) ratio. If this exceeds a value of about 15, then the digestion rates are slowed because there is inadequate nitrogen to manufacture the enzymes required for optimal bacterial growth. These ratios are presented in Table 9, and in Figure 10. The brown seaweeds are the only ones exhibiting mean C/N ratios exceeding the upper desirable limit of 15. However, even within the browns, the detailed data in Appendix A demonstrate that some specimens of each species exhibit favorable values. In a marine farm environment, if water nitrogen levels can be controlled, we would expect most species to exhibit favorable C/N ratios. If, for some reason, these values cannot be maintained, then it will be necessary to supplement the digestors with nitrogen.

Sulfur is an integral constituent of all living cells and, therefore, some is expected in all specimens. However, at high levels, most of the sulfur is in the form of the sulfate component of sulfated polymers. Under anaerobic conditions, most of this will be converted to hydrogen sulfide. (D'Alessandro et al 1973). Since the formation of hydrogen sulfide from sulfate requires hydrogen, this hydrogen will no longer be available for methane formation. An additional problem with sulfur is that the sulfides produced will present disposal problems. They are toxic, and produce extremely objectionable odors. As a result of these problems, we rate high sulfur as a negative selection factor in our screening studies.

The sulfur data presented in Table 9, and in figure 11, show that Chondrus crispus, at 4.9 percent, contains the highest levels, with

FIGURE 10. MEAN C/N RATIOS



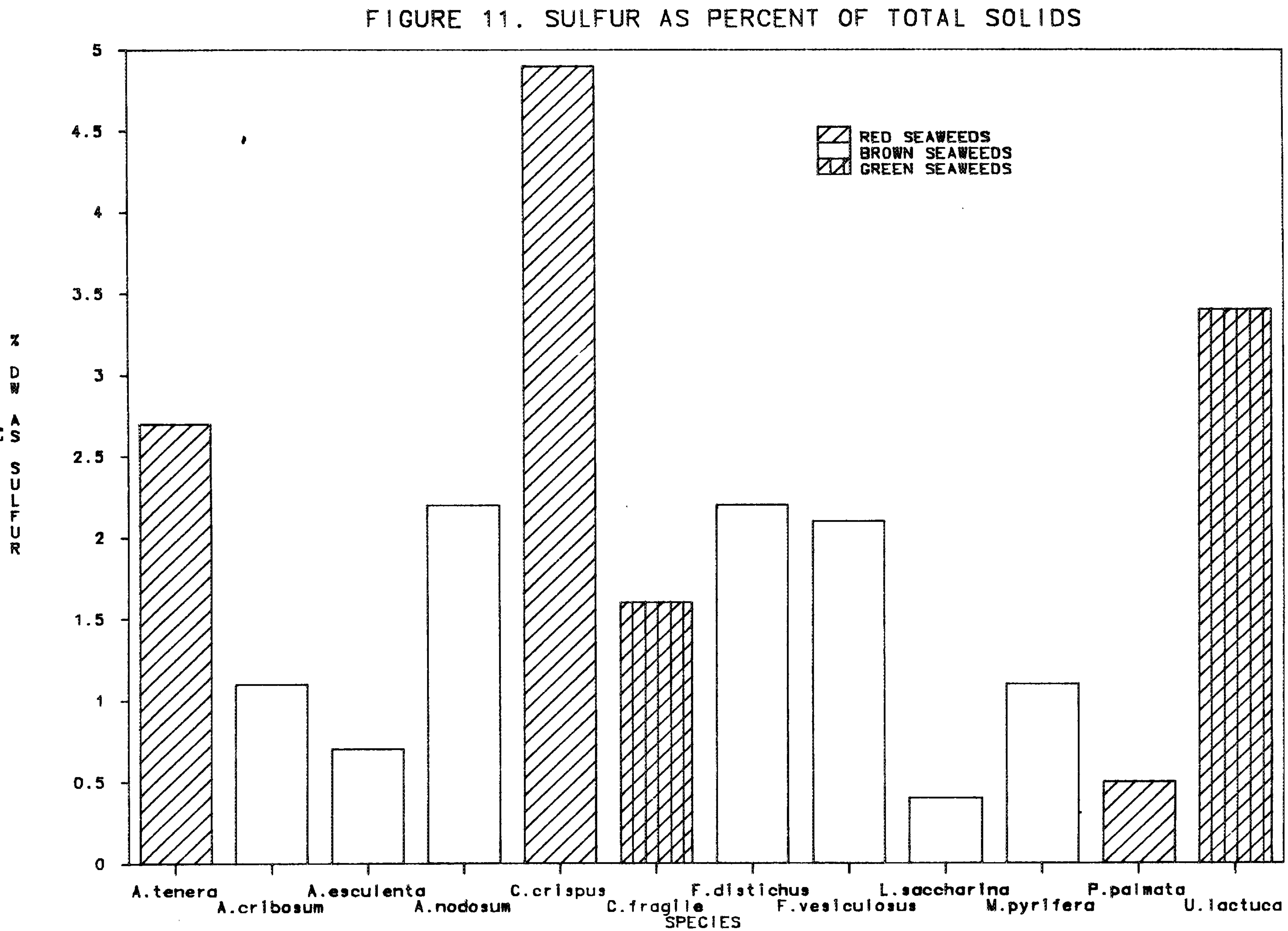


FIGURE 11. SULFUR AS PERCENT OF TOTAL SOLIDS
RED SEAWEEDS
BROWN SEAWEEDS
GREEN SEAWEEDS
% DW AS SULFUR
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
A.tenera
A.cribosum
A.esculenta
A.nodosum
C.crispus
C.fragile
F.distichus
F.vesiculosus
L.saccharina
M.pyrifera
P.palmata
U.lactuca
SPECIES

TABLE 9

ELEMENTAL ANALYSIS OF MACROALGAL SPECIMENS (1) (2)

		PERCENT OF TOTAL SOLIDS																								
		CARBON					HYDROGEN					NITROGEN					SULFUR					C/N RATIO				
SPECIES	COLOR (3)	$\bar{X}$	SD	CV	LOW	HIGH	$\bar{X}$	SD	CV	LOW	HIGH	$\bar{X}$	SD	CV	LOW	HIGH	$\bar{X}$	SD	CV	LOW	HIGH	$\bar{X}$	SD	CV	LOW	HIGH
A. tenera (4)	R	24.3	-	-	-	-	3.7	-	-	-	-	3.5	-	-	-	-	2.7	-	-	-	-	7.0	-	-	-	-
A cribosum (4)	B	30.5	-	-	-	-	4.0	-	-	-	-	3.2	-	-	-	-	1.1	-	-	-	-	9.6	-	-	-	-
A. esculenta (4)	B	31.9	-	-	-	-	4.7	-	-	-	-	3.7	-	-	-	-	0.7	-	-	-	-	8.6	-	-	-	-
A. nodosum	B	33.8	1.3	4	31.7	36.5	4.8	0.3	6	4.1	5.4	2.2	0.7	32	0.9	3.4	2.2	0.4	18	1.5	2.9	17.3	8.1	47	9.8	42.4
C. crispus	R	27.7	2.1	8	24.6	30.8	4.5	0.2	4	4.0	4.7	3.6	0.9	25	2.2	4.7	4.9	0.6	12	3.8	5.9	8.3	2.4	29	5.9	12.6
C. fragile	G	19.8	3.3	17	14.4	25.0	3.4	0.4	12	2.9	4.0	1.0	0.7	70	1.4	2.3	1.6	1.0	62	1.4	4.1	11.1	2.4	22	8.0	16.2
F. distichus	B	35.9	1.5	4	34.8	38.1	4.9	0.2	4	4.6	5.1	2.5	1.0	40	1.7	3.9	2.2	0.6	27	1.5	2.8	15.5	4.6	28	9.7	20.9
F. vesiculosus	B	32.9	1.8	6	30.7	35.4	4.6	0.3	6	4.2	5.2	2.2	0.6	27	1.0	3.4	2.1	0.2	10	2.0	2.4	16.2	6.4	40	10.0	34.9
L. saccharina	B	28.9	2.7	9	23.8	29.8	4.2	0.7	17	2.8	4.9	2.0	1.3	65	1.0	4.0	0.4	0.1	25	0.3	0.8	15.9	6.7	42	9.3	30.3
P. palmata	R	31.1	-	-	28.5	34.9	4.8	-	-	4.2	5.6	3.7	-	-	3.1	4.1	0.5	-	-	0.5	0.5	8.5	-	-	7.9	9.2
U. lactuca (5)(6)	G	29.2	4.9	17	21.8	35.4	4.7	0.6	13	3.5	5.3	2.8	1.6	57	1.3	4.9	3.4	0.6	18	2.3	4.1	11.0	5.0	46	6.8	18.4
M. pyrifera (7)	B	28.2	2.2	8	25.5	29.8	3.6	0.4	11	2.8	4.0	1.8	0.5	28	0.9	2.8	1.1	0.4	36	0.9	1.6	17.7	5.9	33	13.1	32.7
M. pyrifera (8)	B	27.2	2.6	10	23.7	29.7	3.9	0.8	20	2.8	4.4	1.5	0.5	33	1.0	2.0	0.7	0.1	14	0.5	0.8	20.4	7.7	38	13.6	29.7

(1) $\bar{X}$ = mean, SD = standard deviation, CV = coefficient of variation. SD and CV were not calculated for species containing fewer than 4 specimens.
(2) Actual data for each lot are presented in Appendix A.
(3) R = red, B = brown, G = green.
(4) Only 1 specimen received for this species.
(5) Data for lot 2 were omitted. This mud flat specimen was apparently contaminated with mud.
(6) May be Ulva rigida.
(7) Data from USDA Western Regional Research Center.
(8) Data for 4 specimens analyzed by GE.

even its lowest value of 3.8 percent being above the highest levels of all other species except U. lactuca. Only A. esculenta, L. saccharina, and P. palmata contained less than one percent sulfur.

5.2.6 Theoretical Gas Yields

Theoretical gas yields were calculated by the equation of Buswell and Mueller (1952):

$$C_m H_a O_b N_c + \left[m - \frac{a}{4} - \frac{b}{2} + \frac{7c}{4}\right] H_2O$$

$$\rightarrow \left[\frac{m}{2} - \frac{a}{8} + \frac{b}{4} - \frac{5c}{8}\right] CO_2 + \left[\frac{m}{2} + \frac{a}{8} - \frac{b}{4} - \frac{3c}{8}\right] CH_4 + [c] NH_4HCO_3$$

Where m, a, b and c represent, respectively, the molar quantities of carbon, hydrogen, oxygen, and nitrogen present in the specimen. Carbon, hydrogen, and nitrogen were determined experimentally. Oxygen was determined by difference as:

Oxygen = (Dry weight)- Ash - C - H - N - S.

The above oxygen determination method was utilized simply to assure inter-laboratory consistancy. At the high sulfur levels in some of the seaweeds, most of the sulfur is present as sulfate, which is accounted for in the ash. Therefore, sulfur is, in reality, being double counted.

Sulfur, in the form of sulfate, can be used as an electron acceptor by some anaerobic bacteria such as Desulfuvibrio (D'Allesandro et al 1973), with a concomitant production of CO_2 from organic compounds in order to provide the hydrogen required to convert sulfate to hydrogen sulfide. The carbon converted to CO_2, and the hydrogen going to H_2S and H_2O production, are no longer available for methane production.

Therefore, the presence of sulfur, as sulfate, will reduce methane yields. In order to account for this effect in the theoretical gas yields, we modified the Buswell and Mueller equation:

$$C_m H_a O_b N_c + [SO_4]_d + \left[m - \frac{a}{4} - \frac{b}{2} + \frac{7c}{4} - d\right] H_2O \longrightarrow$$

$$\left[\frac{m}{2} - \frac{a}{8} + \frac{b}{4} - \frac{5c}{8} + d\right] CO_2 + \left[\frac{m}{2} + \frac{a}{8} - \frac{b}{4} - \frac{3c}{8} - d\right] CH_4 + [c] NH_4HCO_3 + [d] H_2S.$$

In the above equation, oxygen was calculated as O = VS - C - H - N where VS = volatile solids =(dry weight - ash). This method for determining oxygen eliminates the double counting of sulfur.

The theoretical gas yield data are presented in Table 10, and in Figures 12 and 13. When the data are presented in the standard manner of standard cubic feet per pound of volatile solids, there does not appear to be much of a difference between species. However, when recalculated as SCF per pound harvested, the difference between species is dramatic. In this latter format, Codium fragile is clearly inferior to all other species. In order to obtain a given theoretical volume of methane, one must harvest, transport, and process 2.5 to 6 times as much Codium as any other species.

Only A. tenera and C. fragile have poorer gas yields/pound harvested than does the reference species Macrocystis pyrifera. Table 10 also presents the mean percent decrease in theoretical gas yields for each species. This data, presented graphically in Figure 14, demonstrates that high sulfur levels can significantly decrease the theoretical gas yields. Chondrus, Codium, and Ulva all exhibited decreases of greater than 10 percent when the sulfur correction was applied, with the decrease in Chondrus exceeding 15 percent. Only the reference species, M. pyrifera, exhibited a decrease of less than 5 percent.

FIGURE 12. UNCORRECTED THEORETICAL GAS YIELDS
SCF PER POUND HARVESTED WEIGHT

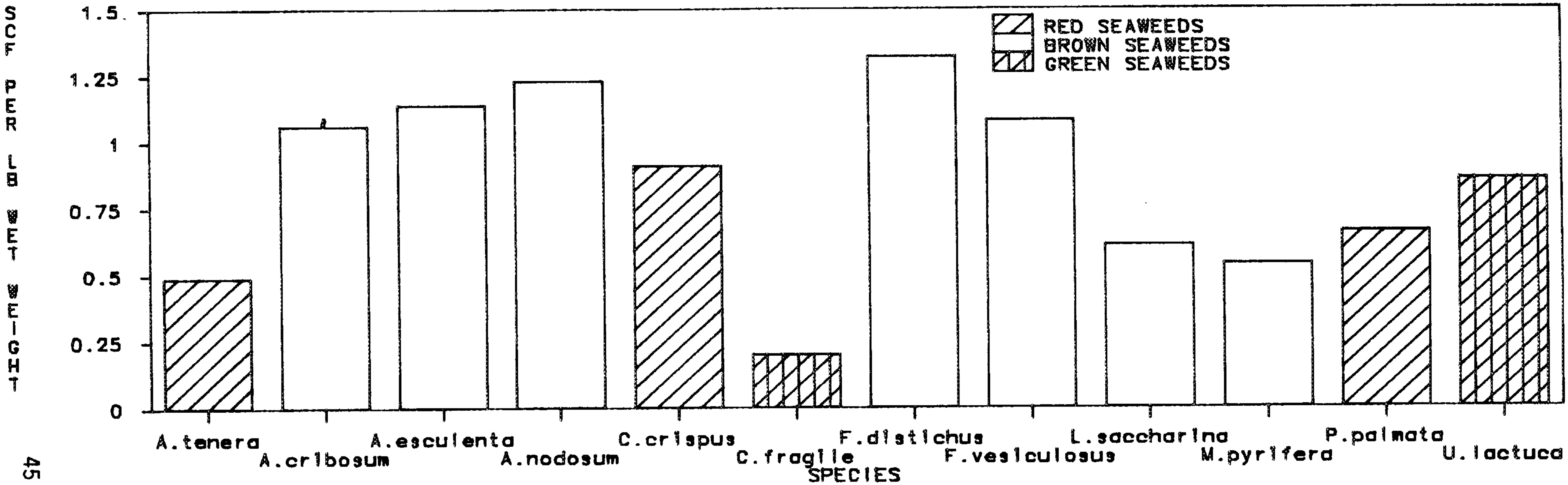


FIGURE 12 UNCORRECTED THEORETICAL GAS YIELDS
SCF PER POUND VOLATILE SOLIDS

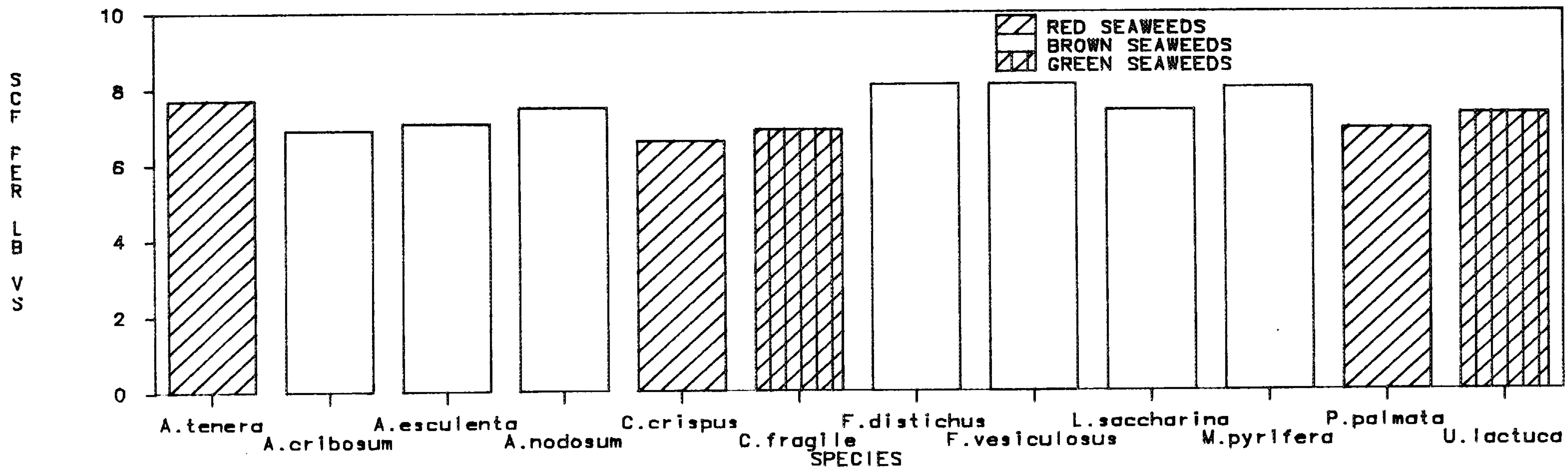


FIGURE 13 SULFUR CORRECTED THEORETICAL GAS YIELDS
SCF PER POUND HARVESTED WEIGHT

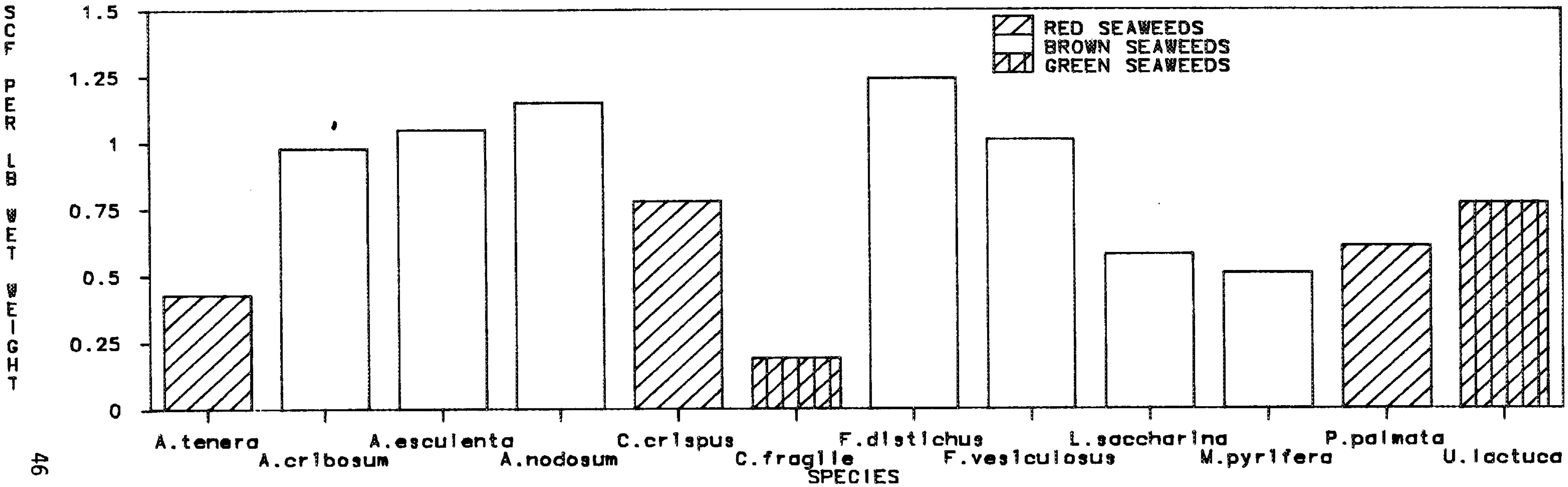


FIGURE 13 SULFUR CORRECTED THEORETICAL GAS YIELDS
SCF PER POUND VOLATILE SOLIDS

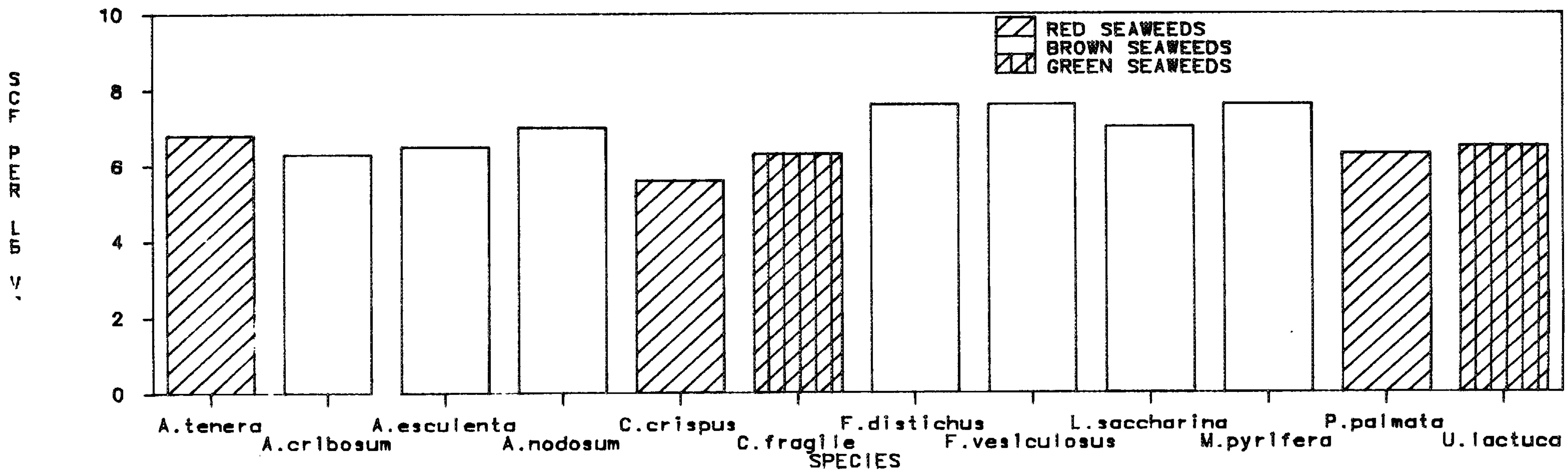


FIGURE 14. MEAN PERCENT DECREASE IN THEORETICAL GAS YIELDS DUE TO MACROALGAL SULFUR CONTENT

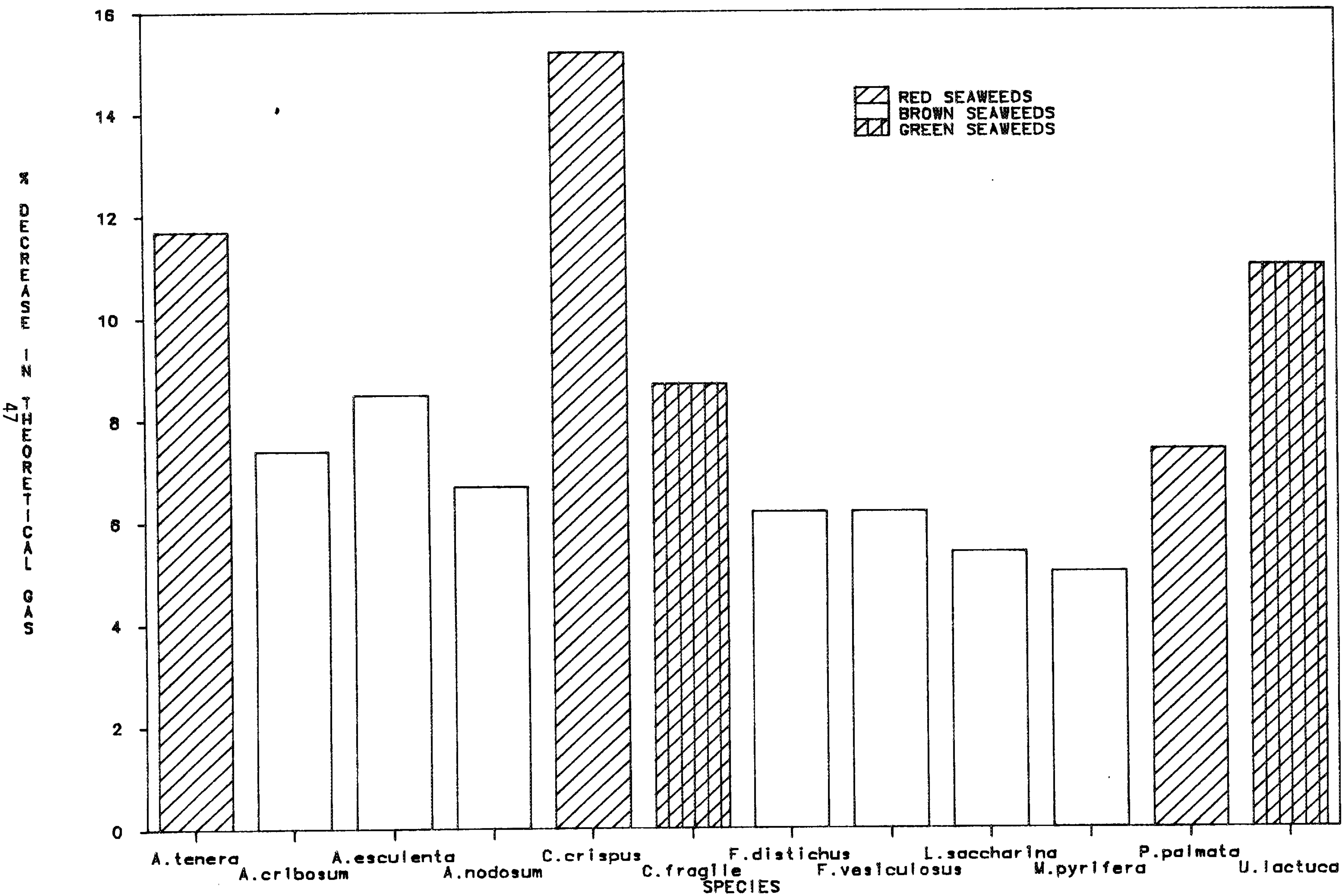


TABLE 10

THEORETICAL METHANE YIELDS (1) (2)

		UNCORRECTED FOR SULFUR										CORRECTED FOR SULFUR										Mean Percent Decrease Due to Sulfur Correction
		SCF/LB Volatile Solids					SCF/LB Harvested Weight					SCF/LB Volatile Solids					SCF/LB Harvested Weight					
SPECIES	COLOR (3)	X̄	SD	CV	LOW	HIGH	X̄	SD	CV	LOW	HIGH	X̄	SD	CV	LOW	HIGH	X̄	SD	CV	LOW	HIGH	
Agardhiella tenera (4)	R	7.7	-	-	-	-	0.49	-	-	-	-	6.8	-	-	-	-	0.43	-	-	-	-	11.7
Agarum cribosum (4)	B	6:8	-	-	-	-	1.06	-	-	-	-	6.3	-	-	-	-	0.98	-	-	-	-	7.4
Alaria esculenta (4)	B	7.1	-	-	-	-	1.14	-	-	-	-	6.5	-	-	-	-	1.05	-	-	-	-	8.5
Ascophyllum nodosum	B	7.5	0.6	8	6.5	8.5	1.23	0.13	11	0.97	1.45	7.0	0.6	9	5.8	8.2	1.15	0.13	11	0.92	1.35	6.7
Chondrus crispus	R	6.6	0.4	6	6.0	7.2	0.91	0.13	14	0.73	1.09	5.6	0.4	7	5.0	6.3	0.78	0.11	14	0.64	0.96	15.2
Codium fragile	G	6.9	1.4	20	4.2	8.7	0.20	0.06	30	0.12	0.30	6.3	1.4	22	3.5	8.0	0.19	0.05	26	0.15	0.28	8.7
Fucus distichus	B	8.1	0.7	9	7.6	9.0	1.32	0.26	20	1.00	1.57	7.6	0.7	11	7.0	8.5	1.24	0.24	19	0.94	1.47	6.2
Fucus vesiculosus	B	8.1	0.7	9	7.0	9.7	1.08	0.19	18	0.84	1.51	7.6	0.8	10	6.4	9.3	1.01	0.19	19	0.81	1.42	6.2
Laminaria saccharina	B	7.4	0.6	8	6.7	8.3	0.61	0.16	26	0.46	0.97	7.0	0.7	10	6.2	8.2	0.58	0.15	26	0.43	0.91	5.4
Palmaria palmata	R	6.8	-	-	6.0	7.6	0.66	-	-	0.45	1.03	6.3	-	-	5.6	7.1	0.61	-	-	0.42	0.96	7.4
Ulva lactuca (5) (6)	G	7.3	2.0	27	5.4	10.8	0.86	0.22	26	0.50	1.06	6.5	1.9	29	5.4	10.1	0.77	0.21	27	0.50	1.06	11.0
Macrocystis pyrifera (7)	B	8.0	1.1	14	7.0	10.8	0.54	0.07	13	0.47	0.64	7.6	1.0	13	6.7	10.2	0.51	0.07	14	0.42	0.58	5.0
Macrocystis pyrifera (8)	B	7.0	1.2	17	5.7	8.7	0.54	0.12	22	0.39	0.67	6.7	1.2	18	5.3	8.3	0.52	0.11	21	0.37	0.64	4.3

(1) X̄ = mean value, SD = standard deviation, CV = coefficient of variation. SD and CV were not calculated for species containing fewer than 4 specimens.
(2) Actual data for each lot are presented in Appendix A.
(3) R = red, B = brown, G = green.
(4) Only 1 specimen received for this species.
(5) Data for lot 2 were omitted. This was a mud flat specimen, and it was apparently contaminated with mud.
(6) May be *Ulva rigida*.
(7) Calculated from USDA Western Regional Research Center Data.
(8) Data from 4 specimens analyzed by GE.

5.3 Bioassays

Bioassays were performed on each lot of each macroalgal specimen received. Unfortunately, the data exhibited severe interpretational problems, and as a result, specific data were omitted from this report. The one major interpretational problem was that several lots produced methane levels which were significantly higher than the theoretical yields. After evaluating alternative explanations, we felt that the problem might be akin to some of our findings on the Marine Biomass Program when we examined factors which might affect the rate, or extent, of methanogenesis from Macrocystis pyrifera. In that study we discovered that trace mineral solutions could increase the degradation of otherwise refractory materials contained in the bioassay inoculum.

In light of this finding, and of our interpretational problems, the bioassay inoculum fermentor should be supplemented with trace minerals to remove this source of error. Since the levels of these minerals in any given lot of seaweed are both uncontrolled, and unknown, we felt that the inclusion of the individual data points would be of limited utility, or could even cause readers to draw unwarrented conclusions regarding the methane yields attainable from a given seaweed.

5.4 Mixed Feedstock Digestor

On June 16, 1981, we started a mixed feedstock digestor. The purpose for this experiment was to develop a fermenter containing organisms capable of degrading constituents of all classes of compounds found in all macroalgae, and to determine whether mixed feedstocks would exhibit good digestibility.

The 1500 ml working volume digestor was constructed from a 21 inch long, 7.5 inch ID x 0.25 inch wall plexiglas cylinder. The top and bottom were machined from 0.5 inch plexiglas sheet stock and were bonded in place. There is a 0.5 inch ID outlet port near the base of the cylinder. Top penetrations include a 1 inch septum port for gas sampling, a 1 inch ball valved feed tube, and a 0.25 inch ID gas line which is connected to a 10 liter gas displacement bottle containing the gas displacement solution recommended by Standard Methods (Taras et al 1971). Methane concentrations were determined by gas chromatography immediately prior to feeding the fermenter and purging the gas accumulated in the gas displacement bottles.

The data presented in Table 11, and in Figure 15, show that this fermenter was producing better than 5 standard cubic feet of gas per pound of volatile solids added. Although these data must be interpreted with caution, since the digestor did not achieve steady state prior to being put in a standby mode, they do indicate that New York State seaweeds are convertible to methane in reasonable yields. Obviously, once enough controlled culture and raft culture feedstocks are available, gasification studies should be performed on each individual feedstock.

5.5 Systems Analysis

5.5.1 Introduction

The primary objective of the Marine Biomass Programs is to provide an optimized integrated process for producing substitute natural gas (methane) from seaweeds cultivated in the ocean, and to do so at a price which is competitive with that of alternative energy sources, and with that of methane from other sources (e.g. coal gasification or natural gas wells). A key element necessary for attaining this goal is a model capable of describing the entire production and conversion system. This model must be comprehensive, in that all major technological, operational, economic,

FIGURE 15. METHANE YIELDS FROM MIXED FEEDSTOCK DIGESTOR

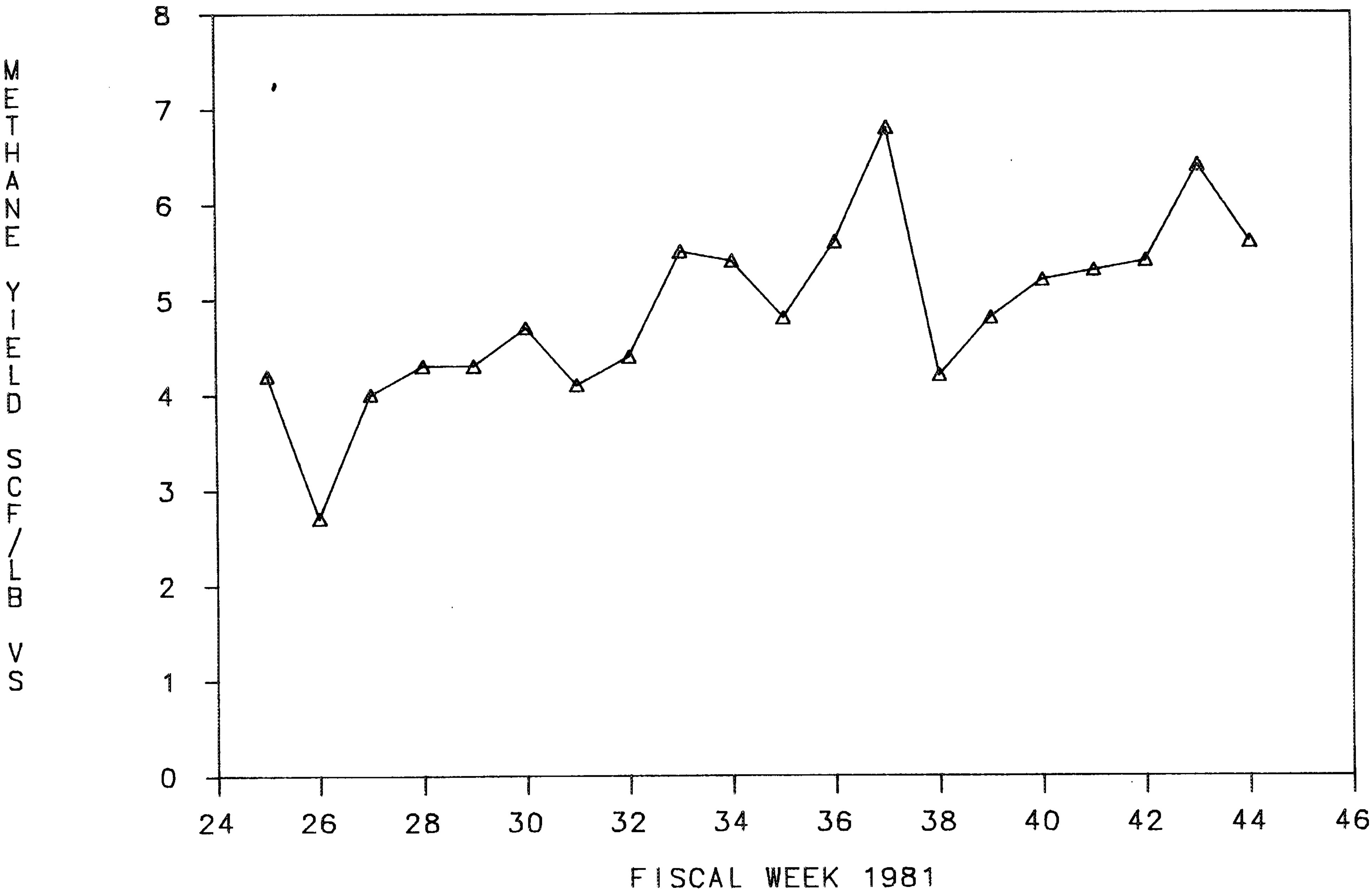


TABLE 11

METHANE YIELDS FROM MIXED FEEDSTOCK DIGESTOR (1) (2)

FISCAL WEEK	METHANE YIELD (SCF/LB VS)
25	4.2
26	2.7
27	4.0
28	4.3
29	4.3
30	4.7
31	4.1
32	4.4
33	5.5
34	5.4
35	4.8
36	5.6
37	6.8
38	4.2
39	4.8
40	5.2
41	5.3
42	5.4
43	6.4
44	5.6

(1) Feed = 0.1 lb volatile solids/cubic foot on an alternate day basis. Temperature = 37°C, Volume = 1500 ml

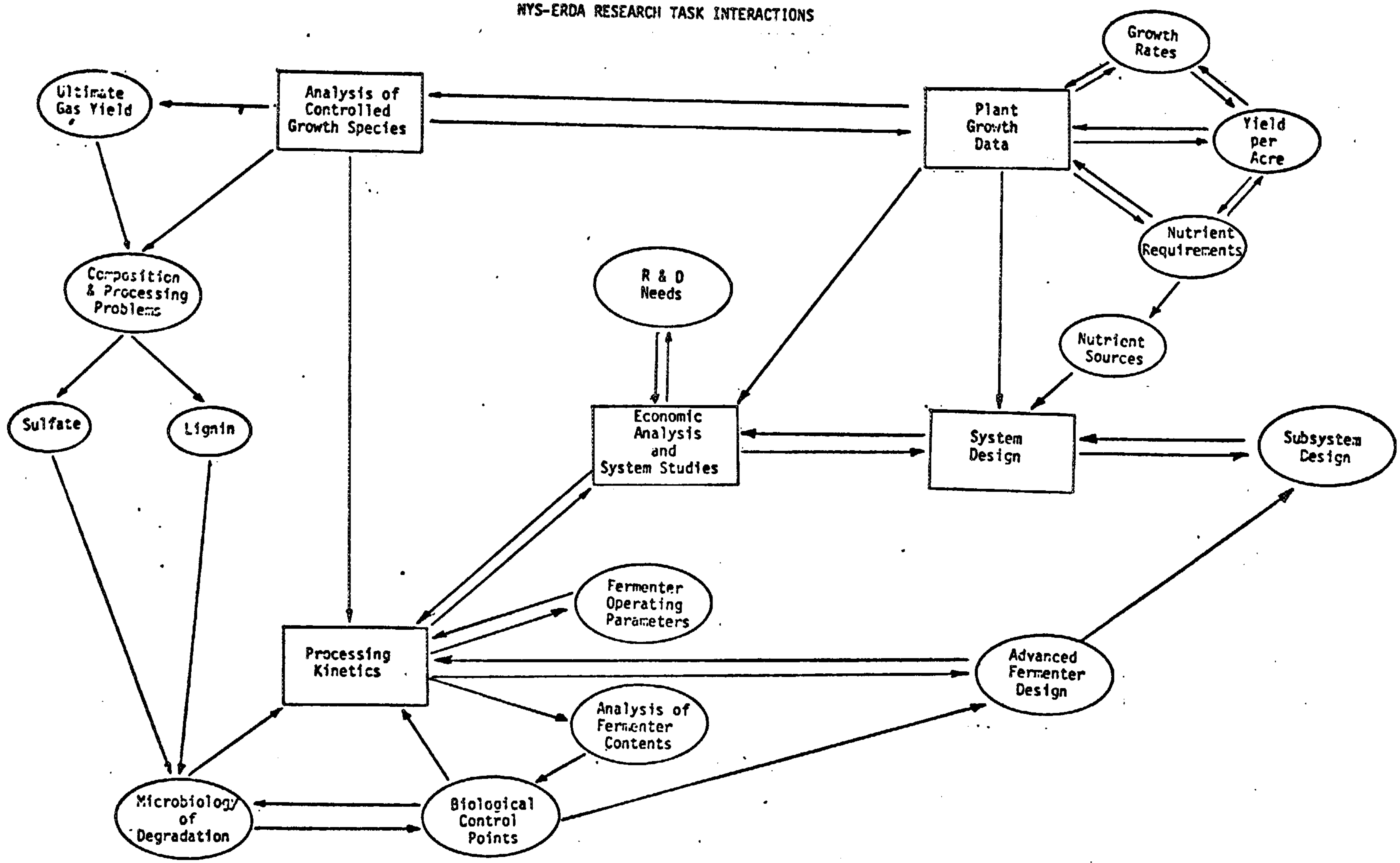
(2) Mixed feedstock composition: 33% *A. nodosum*, 21% *L. saccharina*, 13% *M. pyrifera*, 9% *P. palmata* and 24% *U. lactuca*.

and environmental factors must be included. It must also be versatile enough to incorporate successive levels of refinement as laboratory data and field experience accumulate. In order to be useful as a decision making tool, the model must be flexible enough to incorporate the requirements of various systems designs, and it must provide quantitative information which can be used for rational decision making when evaluating alternative technologies, configurations, or scales of operation. Where hard data do not exist, it should be capable of estimating the sensitivity of the final economics and energetics to the uncertainties involved in making educated guesses. The resultant sensitivity data can then be utilized to direct research efforts to those areas where the effect of this uncertainty is greatest.

A biomethanation system which grows seaweed in the ocean will require a substrate for plant attachment, a method of harvesting and transporting the crop, a facility for converting the crop to methane, and a method for cleaning and compressing the gas to pipeline quality. Clearly, one must examine the system as a whole instead of simply optimizing each subsystem individually. Figure 16, which is generalized for all biomass systems, demonstrates the complex interactions among the major research areas. For example, the experiments on plant growth rates and growth yields directly impact the system design and the system capital costs by defining the size of the farm, the number of harvesters, and all else being equal, the size of the processing subsystem. However, it is known that all else is not equal. Changing the growth conditions changes the chemical composition. Thus, one must know how this changed composition affects the rate and the extent of gas production. This, in turn, requires research into the mode of degradation, and the identification of the control modes for each major seaweed constituent. These biological

FIGURE 16

NYS-ERDA RESEARCH TASK INTERACTIONS



control points may then dictate the design and configuration of the conversion subsystem. When integrated at the systems level, it may turn out that the highest growth rate produces less than optimal economics, or that one million dollars spent in research aimed at obtaining ten percent more gas in the conversion system may have a larger potential payoff than that same one million dollars directed toward increasing farm yields by ten percent.

In 1978, as part of an internal, Company funded study, the General Electric Company developed the initial, computerized systems economics model of the GRI "seaweed to methane" system. This model was developed around the philosophy of large scale, open ocean cultivation of a bottom-attached, non-seasonal giant kelp. The code is modularized via individual algorithms and, although clearly specific to a west coast scenario, novel manipulation of the algorithms affords insight into the generalized picture of methane costs from east coast seaweeds. It was the intent of this task to use this system model, albeit limited in nature, to initiate the study of east coast marine energy farming. As indicated in the General Electric proposal, "the development of the specific algorithms is planned to reflect the developing data base on a continuing basis". As "hard" data would become available from the New York Sea Grant Institute's experimental program, the algorithms would be re-developed and the system model re-defined with the specifics of the east coast scenario. Some typical examples of the "hard" data (or "hard" estimates) ultimately needed are; seasonal biomass yields, environmental parameters affecting ocean structures, designs and costs of cultivation systems, harvesting requirements and costs, nutrient needs and strategies and gasification potentials. Since the techniques for acquiring this type of data are just beginning to be developed, the systems task for 1981 was clearly defined as limited in scope. As GRI's work statement indicates, the major emphasis of General Electric's work in 1981 would be on Species Evaluation, Screening and Processing. A limited effort would be devoted to initiating the systems analysis concepts of east coast marine farming.

With the above limitations in the foreground, the Gas Research Institute directed General Electric to perform a number of specific economic analyses, with specified input parameters(1). These analyses were to be done using the west coast systems model with a zero-order adaptation for the east coast farming scenario. These studies have been completed and are available as separate documents through the Gas Research Institute(2). Two of the most significant conclusions that can be inferred from these limited studies are; (1) if an artificial substrate is needed to cultivate the seaweeds, it will undoubtedly be the driving costs element in the ultimate cost of the methane produced and (2) the gas costs will be extremely sensitive to seasonal variations in plant growth and multi-crop concepts must be utilized in order to maximize the use of the significant capital investments in growth, harvesting, and processing facilities.

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(1)(a) 8/21/81 and 9/18/81 - Letters from J. Peterson (NYS-ERDA) to R. Sullivan (GE)

(b) 10/12/81 - Letter from J. Frank (GRI) to A. Tompkins (GE)

(2)

(a) Biomass Yield and Mooring Depth Variations on Capital Costs, R. Sullivan (GE) to J. Frank (GRI), 8/18/81

(b) Capital Investment - Marine Farm, New York State, R. Sullivan (GE) to J. Frank (GRI), 8/19/81

(c) New York State Commercial Farm Study, R. Sullivan (GE) to D. Squires (SGI), 8/14/81

(d) Interest Rate and Equity Return Studies, R. Sullivan (GE) to J. Peterson (NYS-ERDA), 10/8/81

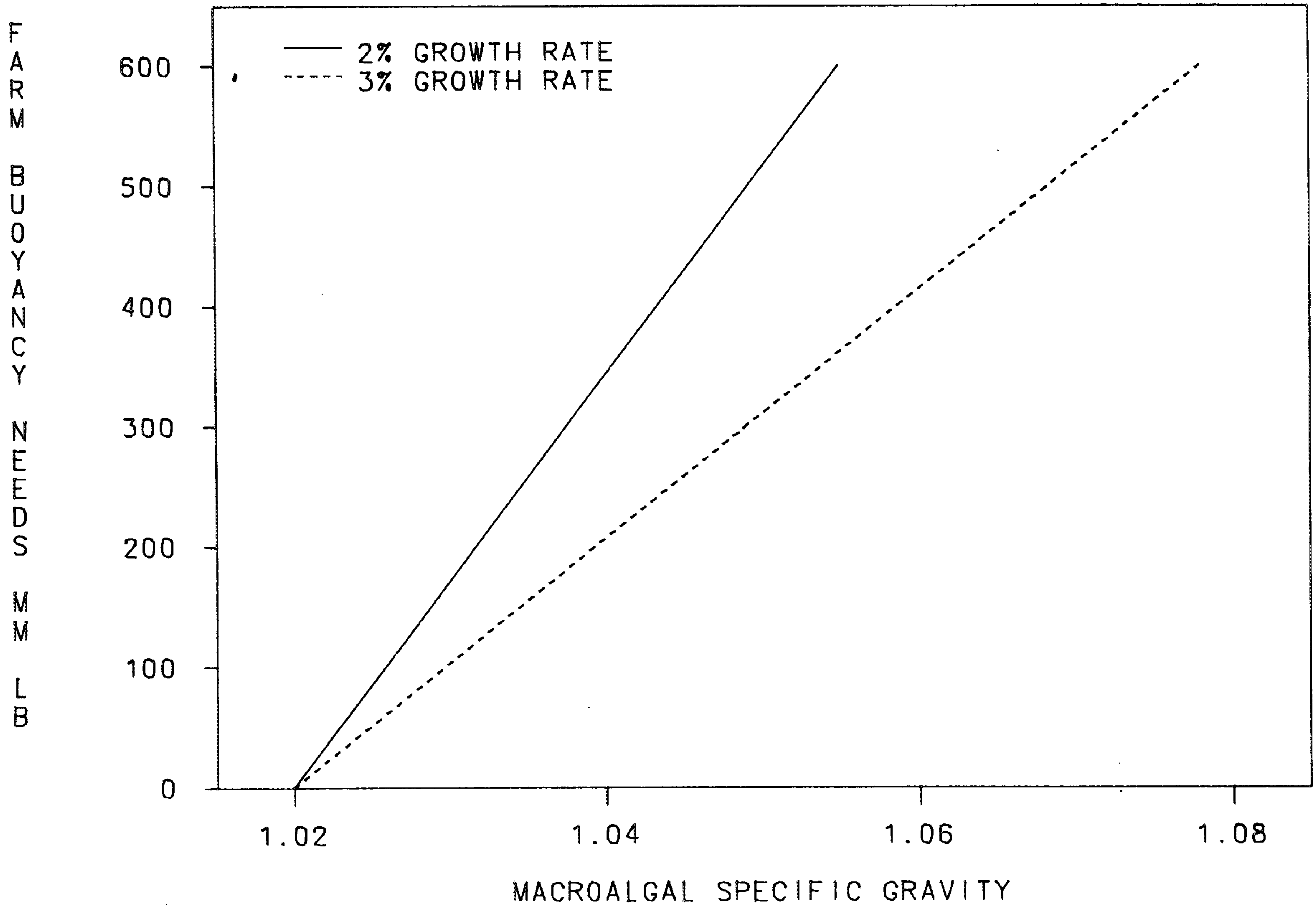
(e) Study of Gas Cost Variations for Systems Producing SNG from Marine Biomass in New York State - R. Sullivan (GE) to J. Frank (GRI), 11/16/81

5.5.2 Important Considerations in Large Scale Farm Designs

In order to begin to identify plant characteristics which will have a significant impact on the cost of the farm structure, a 100 square mile farm utilizing a modular rope, anchor and buoy system was conceptually designed. It must be emphasized that the sole purpose of this design was to provide an idealized framework for examining the effect of seaweeds on a farm structure, typical of that which might finally be designed. The one characteristic exhibiting the largest effect on the farm substrate cost is the negative buoyancy of the plant. The negative buoyancy characteristic will also have a major effect in conceptual designs for any harvesting scenario.

In Figure 17, data on the plant specific gravity versus the farm buoyancy requirements, in millions of pounds, are presented for growth rates of 2 and 3 percent per day. The reason there is a higher buoyancy requirement for the 2 percent rate is that a larger standing crop must be maintained in order to achieve the required harvest. Buoyancy costs range between 8 and 12 cents per pound. Assuming a 10 cent per pound buoyancy cost, a plant specific gravity of 1.04, and a growth rate of 2 percent per day, the buoyancy requirement will cost $24 million. If the plant specific gravity is 1.06, this requirement increases to $53 million. Thus, a change of only 0.02 in plant specific gravity results in an incremental farm cost of $29 million. This large cost sensitivity to the plant specific gravity suggests that this parameter should be determined as a function of growth stage, and that specific gravity should be included as a screening factor.

FIGURE 17. FARM BUOYANCY REQUIREMENT AS A FUNCTION OF MACROALGAL SPECIFIC GRAVITY

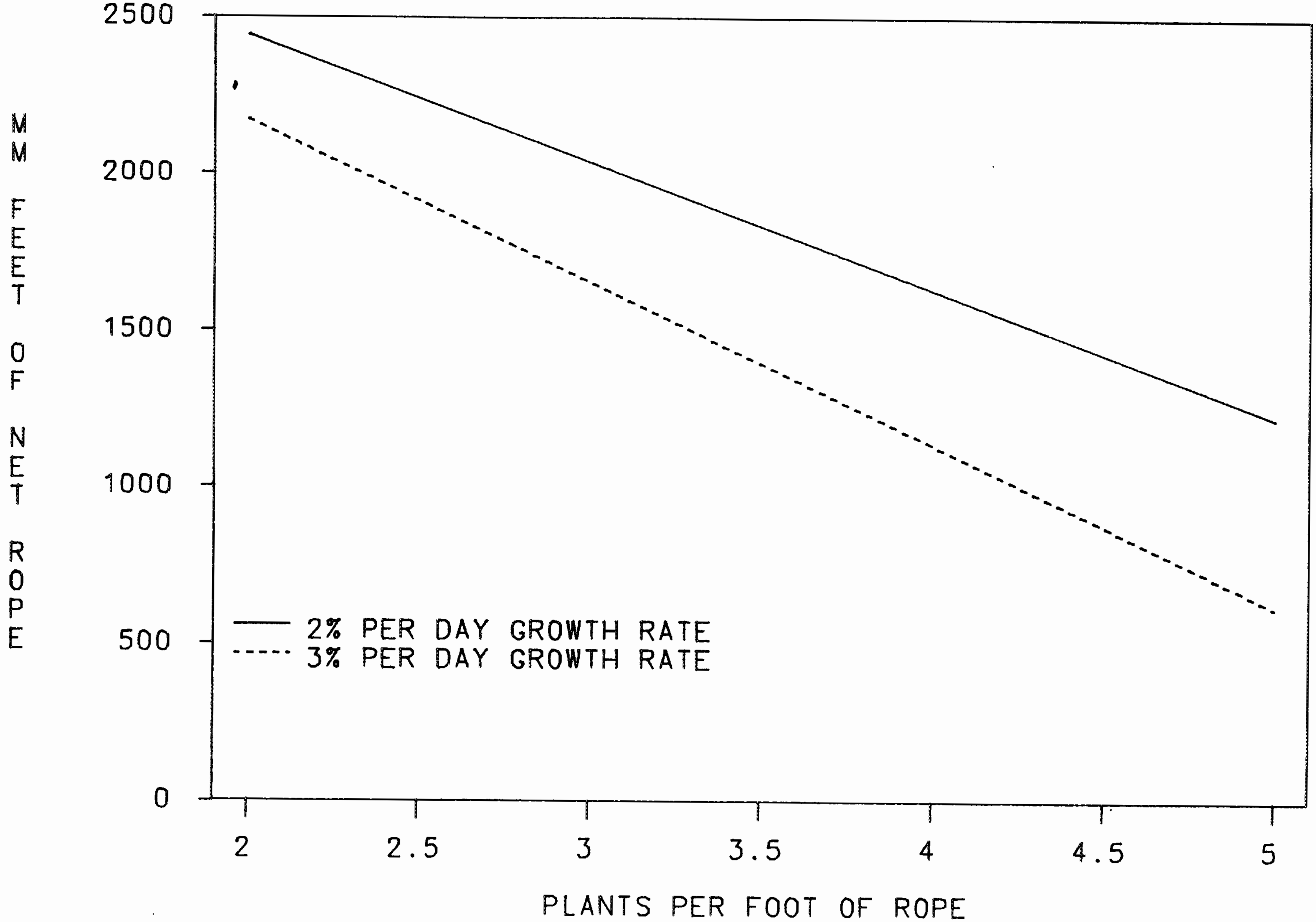


The negative buoyancy of most of the species being evaluated in this study also presents some challenges in devising a harvesting scenario. The methods which appear, at first glance, to offer the greatest potential are harvesting with a submersible, or devising some method of lifting the ropes out of the water and cutting the free-hanging seaweed. This latter method has the advantage that the seaweed can be harvested to a fixed length without having to compensate for streaming due to currents, and without having to worry about the harvester either becoming entangled in, or cutting through, the rope structures as it moves up and down in the swells.

If a rope net design is selected for the farm substrate, the cost of rope will be a significant factor in the cost of the substrate. The amount of rope required will depend on the number of plants which can be accommodated per foot of rope. Obviously, if more plants can be placed per unit rope length, then fewer rope sets will be required to obtain a given number of plants per acre. If the growth rate is 3 percent per day instead of 2 percent then, to obtain a given harvest yield, fewer plants and rope sets will be required. This concept is illustrated in Figure 18. These curves were based on a yield of 35 dry ash free tons per acre per year, 8 percent of the fresh weight as volatile solids, and a harvesting efficiency of 80 percent. Data obtained from Japan by the Marine Biomass engineering team that toured the world's seaweed farms indicate that *Laminaria* achieves lengths ranging from 8 to 11.5 feet. We assumed a length at harvest of 6 feet, and plant weight of 3 pounds.

Using 2.5 plants per foot and a 2 percent growth rate, the farm will require 22.3 X 10^8 feet of rope to achieve a harvestable crop of 35 DAFT/AY. If one assumes 4.5 plants per foot, and a growth rate of 3 percent per day,

FIGURE 18. NUMBER OF PLANTS/FOOT VS FEET OF ROPE TO OBTAIN A GIVEN STANDING CROP



then only 8 X 10^8 feet of rope will be required. With rope costs ranging from 2.5 to 3.5 cents per foot, and using a nominal 3 cents per foot, the rope cost for the first case (2.5 plants/foot, 2%/day) is $66.9 million, and for the second case (4.5 plants/foot, 3%/day) is only $26.1 million, for a cost difference of $40.8 million. Since some given percentage of the ropes will need to be replaced per unit time, operating costs will also be significantly affected by the difference in growth rate, and in achievable planting density.

5.5.3 Multiple Crop Scenario Considerations

New York State waters differ from those of Southern California in several respects. One of the major differences is the large seasonal temperature swings, ranging from -2°C in January to 28°C in August (Lettau et al 1976). No one seaweed species can grow over this entire temperature range. If the seaweed to methane system is to be commercially viable, a crop must be produced in warm seasons, and in cold seasons. Since there are species which grow best in cold water, and others which grow best in warm water, it should be possible to design a sequential crop system in which the two types can be cultivated to provide a year round crop. While such a scenario can be envisioned, it does present problems not previously encountered in any of our studies. One major problem to be addressed is the possibility of a transition period as the farm is changed from one crop to another, and during which no harvesting can occur. The resultant system downtime will increase the methane cost because, for this portion of the year, no gas is being produced (unless storage is possible), but the capital amortization must still be applied.

The above considerations have been continual points of discussions among the program participants and as such, they will be key factors that guide the on-going research of the New York State Marine Program.

5.6 Species Ranking

5.6.1 Species Ranking Factors Based on Composition

One of the major outputs of this study will be a set of compositional ranking factors, and a relative ranking for each species based on its composition. The ranking factors for composition are developed below, and the resultant species rankings are presented in Table 12. It must be borne in mind that these rankings are based strictly on composition, and do not reflect other important factors such as growth temperature, growth rates, plant handling characteristics, etc. Reliable data for most of these other factors are not yet available, although some of them are in the process of being developed by the Marine Sciences Laboratory at the State University of New York under a sister contract to this study.

Volatile Solids as Percent of Harvested Weight

Since this parameter represents an estimate of the organic matter in the harvests, high values are desirable. Also, since this parameter has a large effect on the cost of gas, it was assigned a large weighting factor.

Ash as Percent of Total Solids

This component represents non-digestible, inorganic matter which is corrosive to metal tankage, and which must be disposed of in an environmentally sound manner. The rating assignments in Table 12 are highest for lower ash values.

Lignin as Percent of Organic Matter

Since the "lignin" fraction, whatever its true identity, seems to be non-digestible in seaweed to methane fermentations, higher rating factors were assigned to low values.

TABLE 12

COMPOSITION BASED RANKING FACTORS FOR MACROALGAL SPECIES EVALUATED FOR NEW YORK STATE SITES (1)

Volatile Solids		Ash		Lignin		Hemi-cellulose	
Percent of Harvested Weight	Ranking Factor	Percent of Total Solids	Ranking Factor	Percent of Organic Matter	Ranking Factor	Percent of Organic Matter	Ranking Factor
<4	0	<30	12	<4	16	<10	0
4-6	5	30-35	10	4-6	14	10-15	1
6-8	10	35-40	8	6-8	12	15-20	2
8-10	15	40-45	6	8-10	10	20-25	3
10-12	20	45-50	4	10-12	8	25-30	4
12-14	25	50-55	2	12-14	6	30-35	5
14-16	30	>55	0	14-16	4	>35	6
>16	35	-	-	16-18	2	-	-
-	-	-	-	>18	0	-	-

Algin		Mannitol		Sulfur		C/N Ratio		Theoretical Yield	
Percent of Organic Matter	Ranking Factor	Percent of Organic Matter	Ranking Factor	Percent of Total Solids	Ranking Factor	Ratio	Ranking Factor	SCF per pound Volatile Solids	Ranking Factor
<4	0	<4	0	<0.5	16	<12	6	<6.4	0
4-6	2	4-6	3	0.5-1.0	14	12-15	3	6.4-6.6	3
6-8	4	6-8	6	1.0-1.5	12	>15	0	6.6-6.8	6
8-10	6	8-10	9	1.5-2.0	10	-	-	6.8-7.0	9
10-12	8	10-12	12	2.0-2.5	8	-	-	7.0-7.2	12
12-14	10	12-14	15	2.5-3.0	6	-	-	7.2-7.4	15
14-16	12	14-16	18	3.0-3.5	4	-	-	7.4-7.6	18
16-18	14	16-18	20	3.5-4.0	2	-	-	7.6-7.8	21
18-20	16	18-20	24	>4.0	0	-	-	7.8-8.0	24
>20	18	>20	27	-	-	-	-	>8.0	28

(1) See text for discussion of ranking factors.

Cellulose

Since the digestibility of this material is unknown at the present time, no ranking factors were assigned.

Hemi-cellulose as Percent of Organic Matter

While the true identity and digestibility of this material are unknown, if it is a hemi-cellulose, it should be readily degraded to methane. The relatively low weighting factor assignments are due to the uncertainty of its true identity.

Algin as Percent of Organic Matter

This polymer, which is a major fraction of the organic matter in some brown seaweeds, appears to be convertable to methane in our digestors. High values are considered desirable.

Fucoidan

Since there is considerable doubt regarding the identity of the material assaying as fucoidan, no rating factors were assigned.

Mannitol as Percent of Organic Matter

This soluble sugar alcohol is readily converted to methane in an anaerobic digestor. High rating factors were assigned to high values. Since mannitol appears to be broken down more rapidly than algin, the weighting factors assigned for a given concentration were higher.

Sulfur

The effect of sulfur on the theoretical gas yields and, as a result, on the cost of the methane produced demonstrate that low values are desirable. In addition to its potential for decreasing methane values, the hydrogen sulfide produced in an anaerobic digestor is toxic, and presents a significant odor control problem.

C/N Ratio

Value above 15 are expected to produce digestibility problems because there will be insufficient nitrogen for the digestion to proceed at an acceptable rate unless the digestors are supplemented with additional nitrogen.

Theoretical Gas Yields per pound of Volatile Solids

The higher values for theoretical gas yields mean that for each pound going into the digestor, more methane will be produced, all else being equal. The economic analyses performed in this study demonstrated how sensitive the economics of the entire process are to the value of this parameter. As a result, it was given heavier weighting factors than were most other rated constituents.

5.6.2 Relative Species Ranking

The eleven New York State species, plus the benchmark species Macrocystis pyrifera, were ranked for each of the constitients described above, using the weighting factors in Table 12. The results of this weighting exercise are presented in Table 13. Based on compositional elements, three species scored more than 100 points. These were, in order of their scores, Alaria esculenta, Macrocystis pyrifera, and Fucus distichus. Two species, Fucus vesiculosus and Ascophyllum nodosum, scored in the 90's. Laminaria saccharina and Agarum cribosum scored in the 80's, while Palmaria palmata and Ulva lactuca scored in the 70's, and Agardhiella tenera and Chondrus crispus scored in the 60's. The overall score of 39 for Codium fragile was much worse than that for any other species.

It must be remembered that the above rankings are based only on composition. In the final species selection, other factors must also be considered. For example, Laminaria may present the best growth rates

TABLE 13

WEIGHTED RANKINGS, BASED ON COMPOSITION OF SEAWEEDS EVALUATED

ON THE NEW YORK STATE SITE AND SPECIES STUDY (1) (2)

	CONSTITUENT										
Species	Volatile Solids (3)	Ash (4)	Lignin (5)	Hemi-cellulose (5)	Algin (5)	Mannitol (5)	Sulfur (4)	C/N Ratio	Theoretical Yield (6)	Total Points	Relative Ranking
Agardhiella tenera	10	4	16	6	0	0	6	6	21	69	9
Agarum cribosum	30	10	0	0	16	0	12	6	6	80	7
Alaria esculenta	35	12	6	0	18	6	14	6	12	109	1
Ascophyllum nodosum	35	12	6	3	8	6	8	0	18	96	5
Chondrus crispus	25	10	16	5	0	0	0	6	3	65	10
Codium fragile	0	2	8	4	0	0	10	6	9	39	11
Fucus distichus	35	12	4	2	6	6	8	0	28	101	3
Fucus vesiculosus	25	10	8	3	10	6	8	0	28	93	4
Laminaria saccharina	15	8	6	0	16	12	16	0	15	88	6
Palmaria palmata	15	12	16	3	0	0	16	6	6	74	8
Ulva lactuca	20	10	14	5	0	0	4	6	15	74	8
Macrocystis pyrifera	10	6	10	0	18	27	12	0	24	107	2

(1) The selection of rating factors is discussed in the text. The applied factors are from Table 17.
(2) Note: these ratings are strictly based on composition, and do not take into account factors such as growth rate, temperature range, etc.
(3) Based on percent of harvested weight.
(4) Based on percent of total solids.
(5) Based on percent of organic matter.
(6) Based on yield per pound of volatile solids.

and physical handling characteristics of those species which will grow in the winter. Thus, compositional rankings are important in species selection, but are not the only factors to be considered.

5.6.3 Reduction of Number of Species

In September, 1981, we met with MSL and GRI personnel to pool our available data in an effort to reduce the number of species to be subjected to detailed, intensive research evaluation to a maximum of three. This reduction is required because the program is moving into a stage where more intensive studies are to be performed on a few species rather than the current, more generalized, screening studies. Both manpower and space considerations preclude carrying all species into this next program stage.

Summary of Discussions

The consensus of this meeting was that at least two species will be required for the New York State program to be viable. Due to the large annual changes in ambient temperatures, the New York State system will require a species which grows optimally during the colder months, and a second species which grows optimally during the warmer months. This dual species consensus was simply a feeling by the group. Economic tradeoffs have not been performed because (a) this is a completely unexplored concept and (b) the growth data required to make the required tradeoffs will not be available until the end of 1982.

Cold Water Species

Only one candidate, *Laminaria saccharina*, emerged as a cold water species worth pursuing at this time. This species grows best when water temperatures are below 16°C. In the 16-20°C range, it exhibits signs of stress. The Chinese have isolated a strain more tolerant to warm water than is normal for this species, and it may be possible to extend the growing season off New York State by a similar selection process.

Warm Water Species

Four warm water species were identified as suitable candidates for further study on this program. They are, in order of choice; (a) *Gracilaria tikvahiae*; (b) *Agardhiella tenera*; (c) *Codium fragile*; (d) *Fucus vesiculosus*.

(a) *G. tikvahiae* - was selected because it is a species with which Dr. Hanisak had considerable experience prior to joining MSL, and it is growing well in the Flax Pond greenhouse. A major potential problem is that the existing clone is a sterile, unattached strain. This could present problems for a farm which will also grow *Laminaria*.

(b) *A. tenera* - was selected because it is very closely related to *G. tikvahiae*, and is similar in almost all respects. However, the level of knowledge of its growth characteristics is not as well developed. The greenhouse clone of this species is fertile and grows in an attached mode, which might make it more compatible with a system on wich one also plans to cultivate *Laminaria*.

(c) *Codium fragile* - was selected on the basis of its good growth rates in the greenhouse. It should be compatible with a *Laminaria* system. However, it does exhibit a major compositional problem in that only about 3% of its fresh weight is volatile solids. This low solids content implies more material must be handled per unit of gas produced, but this problem may not be insurmountable. Work should be performed in the next contract period to determine whether a simple pretreatment step such as light pressing might solve the problem, or whether the economics of a high growth rate outweight the added materials handling costs.

(d) Fucus vesiculosus - was the last species selected. It was selected over Ascophyllum nodosum because it exhibited better overall compositional characteristics, and it supposedly tolerates environmental stresses better.

All other species were deleted from the list of those to receive major additional work because they failed, in some manner, to measure up to the three primary (L. saccharina, G. tikvahiae, & A. tenera), or two secondary (C. fragile, and F. vesiculosus) species. The major research efforts will now be directed toward the three primary species and, to a lesser extent, toward the two secondary species.

6.0 MAJOR ACHIEVEMENTS DURING THE CURRENT YEAR

1) Complete chemical analyses were performed on 60 macroalgal specimens supplied by MSL. These data, in conjunction with our 1980 results, provide a valuable, internally consistent database on the composition of seaweeds indigenous to New York State waters. These data, coupled with the biological work at MSL, provided the data required to rationally reduce the number of species which will be carried into future, more intensive studies.

2) A new method of quantitating sugars and sugar alcohols in seaweeds was developed. This development was required because all other methods evaluated were subject to interferences from other compounds present in the seaweeds. An additional advantage to this method, besides its unambiguous quantitation of mannitol, is that it will, with almost no extra effort, unambiguously identify and quantify any hexoses, hexitols, and pentitols which might be present in the specimen.

3) With the large amount of data being generated on this program, it was becoming difficult to tabulate and correlate it as required for different purposes. This problem will get worse in the future, as more specimens are analyzed, and as enough data becomes available to allow more statistical correlations. To solve this problem, we investigated several types of computer database systems, and selected one for our use. All data generated on this program, plus all Macrocystis data generated on the Marine Biomass program, are now in this database and can be called out in any manner required by the particular application requiring those data.

4) In order to determine whether most of the major seaweed constituents were degradable in a semi-continuous fermentation, we constructed a 10 liter plexiglas fermentor. When fed a mixed feedstock of all major seaweed

types found in New York State waters, this digestor produced methane at rates ranging between 5 and 6 standard cubic feet per pound of volatile solids added. These results indicate that most of the major macroalgal constituents are degradable to methane.

5) From analyzing the requirements of a hypothetical, generalized farm substrate concept, it was discovered that one of the major drivers of the farm substrate cost could be the negative buoyant density of the individual macroalgal plants. This effect is due strictly to farm structural loading requirements, and is completely independent of containment strategies if unattached plants are used.

6) In conjunction with MSL personnel, and utilizing all compositional and growth data available, the number of species to be examined in future phases of this work was reduced. Laminaria saccharina was the only viable candidate for growth during the cold months. Gracilaria tikahiae was selected as the prime warm water species (strictly on the basis of its growth characteristics, no samples were received for compositional analysis). In the possible event that Gracilaria is not a viable biomethanation candidate, we also selected three backup species. These were, in order of choice, Agardhiella tenera, Codium fragile, and Fucus vesiculosus.

7.0 MAJOR TECHNICAL PROBLEMS ENCOUNTERED DURING THE CURRENT YEAR

1) The analytical procedures available for quantiating mannitol were all subject to interferences from compounds present in seaweeds. Since mannitol is known to be a major constituent in many brown seaweeds, and since it is rapidly digested to produce methane, the erronious analyses could produce misleading results in the species ranking profiles. This problem was overcome by developing a new, HPLC based analytical method which is not subject to these interferences.

2) Some of the bioassay experiments to determine ultimate attainable gas yields produced results well in excess of theoretical yields. We now feel this effect was due to the presence of certain metal ions which allow the digestion of components in the inoculum which are not otherwise digestible. We will eliminate this problem in the future by adding these metals to the inoculum digestor.

8.0 CONCLUSIONS AND RECOMMENDATIONS

The compositional results have provided valuable data for determining the suitability of New York State seaweeds as candidate crops in a biomass to methane system. Since composition changes with temperature, and with nutritional conditions, the chemical composition of the MSL controlled growth greenhouse cultures, and of their raft cultures, should be determined. These compositional values should then be statistically correlated with the growth conditions in order to select the optimum combinations of species and nutritional regimen for each season. These correlations will also be required for setting some of the farm design specifications and, possibly, for selecting viable sites.

Bioassays, modified to eliminate the problems encountered in 1981, should be performed on each specimen for which compositional data is available. Statistical correlations between ultimate attainable gas yields and composition may then identify problem constituents. For example, "lignin" is known to be a problem in *Macrocystis* fermentations and, based on theoretical grounds, high sulfur is expected to be a problem. Since both *Gracilaria* and *Agardhiella* are high sulfur species, experiments should be performed to determine the true effect of sulfate on methane yields. Once enough growth and compositional data are available to evaluate the species in more detail, the program must obtain information on the steady state gas yields which can be achieved from each species grown under controlled conditions. These experiments must be performed under a variety of conditions, including temperature variations, and solid and hydraulic detention time variations. Increasing the yield by increasing the detention time in a CSTR may prove to be the most economic method, but the possibility of separating the acidogenic stages from the methanogenic stage should be evaluated. This is worth pursuing because a one percent increase in gas yield is much cheaper to obtain than a one percent increase in harvestable yield, and the effect on the system efficiency is the same.

The consensus of the MSL and GE-AEPD groups is that the New York State site will require two species in order to assure year round operation. Since the different species being considered have different chemical compositions, this could create significant digestion problems during the feedstock changeover period. The effect of such feedstock changeovers on steady state digestors should be evaluated and, if significant problems are encountered, then ways to minimize the problems should be evaluated. A second potential problem introduced by a sequential multiple feedstock scenario is the possibility of not being able to harvest during the changeover period. If data indicates that a significant overlap of crops is not possible, then the effect on the entire system economics must be evaluated. This evaluation should take place at the earliest possible moment, because it may force changes in the entire system design philosophy.

Since plant specific gravity appears to be one of the major drivers in the cost of the farm structure, the plant specific gravity should be determined as a function of growth and harvesting conditions.

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10.0 APPENDIX

Detailed source, composition, and comment data for the Macroalgal specimens analyzed on the New York Site and Species Study, and for benchmark Macrocystis pyrifera data gathered on the Marine Biomass Program.

Macroalgal Specimens

Genus	Species	Code	Lot	Color	% H2O (Tot Wt)	% Solids (Tot Wt)	% Ash	% V.S.	% Total VS (Tot Wt)	Date	Plant Source
Agardhiella	tenera	40	1	Red	88.30	11.70	45.28	54.72	6.40	12/03/80	Greenhouse
Agarum	cribosum	14	1	Brown	77.84	22.16	30.06	69.94	15.50	05/03/80	Natural
Alaria	esculenta	13	1	Brown	78.20	21.80	26.04	73.96	16.12	05/03/80	Natural
Ascophyllum	nodosum	5	1	Brown	76.04	23.96	23.65	76.35	18.29	03/09/80	Natural
Ascophyllum	nodosum	7	2	Brown	77.72	22.28	21.74	78.26	17.44	03/23/80	Natural
Ascophyllum	nodosum	15	3	Brown	75.47	24.53	23.12	76.88	18.86	05/03/80	Natural
Ascophyllum	nodosum	27	4	Brown	79.58	20.42	25.49	74.51	15.21	02/11/81	Greenhouse
Ascophyllum	nodosum	28	5	Brown	77.96	22.04	25.34	74.66	16.45	02/11/81	Greenhouse
Ascophyllum	nodosum	29	6	Brown	76.57	23.43	25.07	74.93	17.56	02/11/81	Greenhouse
Ascophyllum	nodosum	30	7	Brown	79.45	20.55	25.28	74.72	16.85	02/11/81	Natural
Ascophyllum	nodosum	31	8	Brown	80.34	19.66	22.83	77.17	15.17	01/28/81	Natural
Ascophyllum	nodosum	55	9	Brown	76.65	23.35	20.26	79.74	18.62	05/20/81	Greenhouse
Ascophyllum	nodosum	56	10	Brown	75.44	24.56	27.59	72.41	17.79	05/20/81	Greenhouse
Ascophyllum	nodosum	66	11	Brown	79.53	20.47	27.75	72.25	14.78	06/09/81	Greenhouse
Ascophyllum	nodosum	67	12	Brown	82.11	17.89	31.76	68.24	12.22	06/18/81	Greenhouse
Ascophyllum	nodosum	68	13	Brown	79.25	20.75	28.84	71.16	14.77	06/18/81	Greenhouse
Ascophyllum	nodosum	69	14	Brown	78.99	21.01	24.69	75.31	15.82	06/19/81	Natural
Chondrus	crispus	8	1	Red	80.19	19.81	27.34	72.66	14.39	03/00/80	Natural
Chondrus	crispus	11	2	Red	74.10	25.90	34.35	65.65	17.00	02/24/80	Natural
Chondrus	crispus	21	3	Red	80.95	19.05	35.70	64.30	12.25	07/22/80	Natural
Chondrus	crispus	33	4	Red	78.26	21.74	28.97	71.03	15.44	01/19/81	Natural
Chondrus	crispus	34	5	Red	80.73	19.27	28.06	71.94	13.86	12/02/80	Natural
Chondrus	crispus	35	6	Red	81.54	18.46	27.32	72.67	13.41	02/11/81	Greenhouse
Chondrus	crispus	32	7	Red	81.53	18.47	31.97	68.03	12.56	02/11/81	Greenhouse
Chondrus	crispus	71	8	Red	77.04	22.96	33.65	66.35	15.22	05/06/81	Natural
Chondrus	crispus	72	9	Red	81.32	18.68	31.43	68.57	12.81	06/18/81	Natural
Chondrus	crispus	73	10	Red	83.00	17.00	35.41	64.59	10.98	06/18/81	Greenhouse
Codium	fragile	16	1	Green	92.20	7.80	40.19	59.81	4.66	06/04/80	Natural
Codium	fragile	23	2	Green	93.35	6.65	57.67	42.33	2.82	02/18/81	Greenhouse
Codium	fragile	24	3	Green	94.76	5.24	59.35	40.65	2.13	02/18/81	Greenhouse
Codium	fragile	25	4	Green	93.84	6.15	62.44	37.56	2.04	01/20/81	Greenhouse
Codium	fragile	26	5	Green	94.54	5.46	57.61	42.39	2.31	02/16/81	Natural
Codium	fragile	57	6	Green	92.70	7.30	33.17	66.83	4.88	05/06/81	Natural
Codium	fragile	59	7	Green	95.50	4.50	54.84	45.16	2.10	05/30/81	Greenhouse
Codium	fragile	60	8	Green	94.11	5.89	56.35	43.66	2.58	06/04/81	Raft
Codium	fragile	61	9	Green	92.19	7.81	43.07	56.93	4.45	06/10/81	Greenhouse
Codium	fragile	62	10	Green	95.61	4.39	50.80	49.20	2.17	06/04/81	Raft
Codium	fragile	63	11	Green	92.40	7.60	42.16	57.84	4.14	06/02/81	Greenhouse

Macroalgal Specimens

Genus	Species	Code	Lot	Color	% H20 (Tot Wt)	% Solids (Tot Wt)	% Ash	% V.S.	% Total VS (Tot Wt)	Date	Plant Source
Fucus	distichus	20	1	Brown	76.18	23.82	17.47	82.52	19.66	07/22/80	Natural
Fucus	distichus	53	2	Brown	74.30	25.70	25.36	74.64	19.19	05/20/81	Greenhouse
Fucus	distichus	54	3	Brown	78.79	21.22	24.84	75.16	15.95	05/06/81	Natural
Fucus	distichus	65	4	Brown	83.87	16.13	31.46	68.54	11.08	06/09/81	Greenhouse
Fucus	vesiculosus	2	1	Brown	81.20	18.80	26.96	73.04	13.73	01/11/80	Natural
Fucus	vesiculosus	18	2	Brown	80.58	19.41	28.91	71.09	13.80	07/24/80	Natural
Fucus	vesiculosus	36	3	Brown	80.07	19.93	30.48	69.52	13.85	02/11/81	Greenhouse
Fucus	vesiculosus	37	4	Brown	78.28	21.72	21.05	78.95	17.15	01/19/81	Natural
Fucus	vesiculosus	38	5	Brown	81.68	18.32	28.29	71.71	13.14	02/11/81	Natural
Fucus	vesiculosus	51	6	Brown	87.01	12.99	33.19	66.81	8.68	05/20/81	Natural
Fucus	vesiculosus	52	7	Brown	82.24	17.76	28.74	71.25	12.66	05/20/81	Greenhouse
Fucus	vesiculosus	74	8	Brown	78.43	21.57	27.54	72.46	15.60	06/18/81	Natural
Fucus	vesiculosus	75	9	Brown	81.58	18.42	33.06	66.94	12.33	06/18/81	Greenhouse
Fucus	vesiculosus	76	10	Brown	83.90	16.10	36.09	63.91	10.29	06/05/81	Raft
Fucus	vesiculosus	77	11	Brown	79.83	20.17	33.63	66.37	13.40	06/05/81	Raft
Fucus	vesiculosus	78	12	Brown	83.08	16.92	33.79	66.21	11.20	06/05/81	Raft
Fucus	vesiculosus	79	13	Brown	79.38	20.62	33.71	66.29	13.67	06/04/81	Raft
Fucus	vesiculosus	80	14	Brown	82.57	17.43	33.04	66.97	11.69	06/04/81	Raft
Fucus	vesiculosus	81	15	Brown	75.13	24.87	31.94	68.06	16.92	06/04/81	Raft
Fucus	vesiculosus	82	16	Brown	76.84	23.16	29.81	70.19	16.25	06/18/81	Greenhouse
Laminaria	saccharina	9	1	Brown	87.04	17.96	35.78	64.22	11.53	03/23/80	Natural
Laminaria	saccharina	1	1-A	Brown	87.04	12.96	47.34	52.66	6.82	02/06/80	Natural
Laminaria	saccharina	10	2	Brown	85.56	14.44	29.87	70.13	10.13	04/09/80	Natural
Laminaria	saccharina	17	3	Brown	82.47	17.53	17.89	82.11	14.39	07/22/80	Natural
Laminaria	saccharina	39	4	Brown	89.31	10.69	38.10	61.80	6.61	01/19/81	Natural
Laminaria	saccharina	44	5	Brown	87.97	12.03	35.87	64.13	7.72	03/14/81	Natural
Laminaria	saccharina	45	6	Brown	89.69	10.31	39.19	60.81	6.27	05/06/81	Greenhouse
Laminaria	saccharina	46	7	Brown	90.56	9.44	33.35	66.65	6.29	06/05/81	Natural
Laminaria	saccharina	47	8	Brown	89.85	10.15	36.66	63.35	6.43	05/06/81	Greenhouse
Laminaria	saccharina	64	9	Brown	87.29	12.71	37.13	62.87	7.98	06/03/81	Natural
Palmaria	palmata	6	1	Red	90.04	9.96	28.83	71.17	7.09	03/00/80	Natural
Palmaria	palmata	22	2	Red	83.00	17.00	20.17	79.83	13.57	07/22/80	Natural
Palmaria	palmata	58	3	Red	89.52	10.48	28.45	71.55	7.50	05/06/81	Natural
Ulva	lactuca	3	1	Green	79.94	20.06	20.94	79.06	15.86	02/06/80	Natural
Ulva	lactuca	4	2	Green	88.41	11.59	49.34	50.66	5.87	01/11/80	Natural
Ulva	lactuca	19	3	Green	82.35	17.64	25.67	74.33	13.11	07/22/80	Natural
Ulva	lactuca	48	4	Green	85.01	14.99	26.88	73.13	10.96	05/20/81	Greenhouse
Ulva	lactuca	49	5	Green	81.92	18.08	33.75	66.25	11.99	06/04/81	Natural
Ulva	lactuca	50	6	Green	82.44	17.56	41.04	58.96	10.37	05/06/81	Natural
Ulva	lactuca	70	7	Green	83.79	16.21	41.24	58.76	9.59	06/04/81	Natural

Macroalgal Specimens

Genus	Species	Code	Lot	Color	% H2O (Tot Wt)	% Solids (Tot Wt)	% Ash	% V.S.	% Total VS (Tot Wt)	Date	Plant Source
Macrocystis	pyrifera		1	Brown			35.16	64.84		07/16/75	Natural
Macrocystis	pyrifera		2	Brown			33.93	66.07		07/23/75	Natural
Macrocystis	pyrifera		3	Brown			36.70	63.30		08/06/75	Natural
Macrocystis	pyrifera		4	Brown			39.27	60.73		05/06/80	Natural
Macrocystis	pyrifera		5	Brown			35.86	64.14		09/03/75	Natural
Macrocystis	pyrifera		6	Brown			39.44	60.56		09/17/75	Natural
Macrocystis	pyrifera		7	Brown			36.55	63.45		09/30/75	Natural
Macrocystis	pyrifera		8	Brown			46.30	53.70		10/23/75	Natural
Macrocystis	pyrifera		10	Brown			39.04	60.96		11/05/75	Natural
Macrocystis	pyrifera		12	Brown						11/17/75	Natural
Macrocystis	pyrifera		13	Brown			36.37	63.63		11/19/75	Natural
Macrocystis	pyrifera		14	Brown			39.91	60.09		12/09/75	Natural
Macrocystis	pyrifera		15	Brown			44.40	55.60		12/12/75	Natural
Macrocystis	pyrifera		16	Brown			47.35	52.65		02/09/76	Natural
Macrocystis	pyrifera		17	Brown			45.56	54.44		02/10/76	Natural
Macrocystis	pyrifera		18	Brown			47.44	52.56		02/23/76	Natural
Macrocystis	pyrifera		19	Brown			40.08	59.92		03/26/76	Natural
Macrocystis	pyrifera		20	Brown			46.14	53.86		05/06/76	Natural
Macrocystis	pyrifera		21	Brown			43.14	56.86		05/20/76	Natural
Macrocystis	pyrifera		22	Brown			38.81	61.19		06/09/76	Natural
Macrocystis	pyrifera		23	Brown			39.17	60.83		06/24/76	Natural
Macrocystis	pyrifera		24	Brown			40.63	59.37		06/30/76	Natural
Macrocystis	pyrifera		25	Brown			39.00	61.00		07/13/76	Natural
Macrocystis	pyrifera		26	Brown	88.8	11.2	42.1	57.9	6.48	09/30/76	Natural
Macrocystis	pyrifera		26	Brown			41.59	58.41		09/30/76	Natural
Macrocystis	pyrifera		27	Brown			44.50	55.50		01/17/77	Natural
Macrocystis	pyrifera		37	Brown	88.2	11.8	41.1	58.9	6.95	10/25/77	Natural
Macrocystis	pyrifera		37	Brown			38.88	61.12		10/25/77	Natural
Macrocystis	pyrifera		41	Brown	86.9	13.1	35.0	65.0	8.51	06/06/78	Natural
Macrocystis	pyrifera		41	Brown			38.53	61.47		06/06/78	Natural
Macrocystis	pyrifera		42	Brown	88.1	11.9	37.1	62.9	7.49	09/12/78	Natural
Macrocystis	pyrifera		42	Brown			40.00	60.00		09/12/78	Natural
Macrocystis	pyrifera		43	Brown			43.75	56.25		10/11/78	Natural
Macrocystis	pyrifera		44	Brown	89.7	10.3	39.6	60.4	6.22	11/01/78	Natural
Macrocystis	pyrifera		44	Brown			43.61	56.39		11/01/78	Natural
Macrocystis	pyrifera		45	Brown			37.37	62.63		11/28/78	Natural
Macrocystis	pyrifera		46	Brown	88.9	11.1	44.7	55.3	6.14	01/24/79	Natural
Macrocystis	pyrifera		46	Brown			47.01	52.99		01/24/79	Natural
Macrocystis	pyrifera		47	Brown	89.5	10.5	45.4	54.6	5.73	03/21/79	Natural
Macrocystis	pyrifera		47	Brown			45.44	54.56		03/21/79	Natural
Macrocystis	pyrifera		48	Brown	88.9	11.1	46.2	53.8	5.97	04/28/79	Natural
Macrocystis	pyrifera		48	Brown			46.85	53.15		04/28/79	Natural
Macrocystis	pyrifera	0	48	Brown	88.02	11.98	42.11	57.89	6.93	04/28/79	Natural
Macrocystis	pyrifera		49	Brown	87.9	12.1	37.3	62.7	7.59	10/16/79	Natural
Macrocystis	pyrifera		49	Brown			37.10	62.90		10/16/79	Natural
Macrocystis	pyrifera	12	49	Brown	88.14	11.86	36.76	63.24	7.50	10/16/79	Natural
Macrocystis	pyrifera		50	Brown	88.3	11.7	43.7	56.3	6.59	05/06/80	Natural
Macrocystis	pyrifera		50	Brown			43.74	56.26		05/06/80	Natural
Macrocystis	pyrifera		51	Brown			37.04	62.96		08/18/80	Natural
Macrocystis	pyrifera	43	51-3	Brown	87.57	12.43	33.64	66.36	8.25	00/00/00	Natural

Macroalgal Specimens

Genus	Species	Code	Lot	Color	% H2O (Tot Wt)	% Solids (Tot Wt)	% Ash	% V.S.	% Total VS (Tot Wt)	Date	Plant Source
Macrocystis	pyrifera	43A	51-3	Brown						00/00/00	Natural
Macrocystis	pyrifera		52-1	Brown			39.03	60.97		10/01/80	Natural
Macrocystis	pyrifera		52-2	Brown			35.92	64.08		10/01/80	Natural
Macrocystis	pyrifera		53-1	Brown						10/22/80	Natural
Macrocystis	pyrifera		53-1	Brown			39.35	60.65		10/20/80	Natural
Macrocystis	pyrifera	42	53-1	Brown	87.26	12.74	39.14	60.96	7.77	10/22/80	Natural
Macrocystis	pyrifera	42A	53-1	Brown						10/22/80	Natural
Macrocystis	pyrifera	42B	53-1	Brown						10/22/80	Natural
Macrocystis	pyrifera	42C	53-1	Brown						10/22/80	Natural
Macrocystis	pyrifera		53-2	Brown			38.98	61.02		10/21/80	Natural
Macrocystis	pyrifera		54	Brown			40.81	59.19		10/28/80	Natural
Macrocystis	pyrifera	41	NY-1	Brown	90.35	9.65	53.43	46.57	4.49	11/14/80	Greenhouse

Macroalgal Specimens

Genus	Species	Code	Lot	% NDF	% NADF	% Hemi-Cellulose	Lignin (%)	Cellulose (%)	Date
Agardhiella	tenera	40	1	28.63	8.44	20.19	1.84	1.86	12/03/80
Agarum	cribosum	14	1	29.66	23.48	6.18	17.18	5.53	05/03/80
Alaria	esculenta	13	1	17.84	13.27	4.57	9.47	3.24	05/03/80
Ascophyllum	nodosum	5	1	33.49	17.64	15.85	13.55	2.94	03/09/80
Ascophyllum	nodosum	7	2	37.61	22.79	14.82	19.14	4.02	03/23/80
Ascophyllum	nodosum	15	3	24.71	15.82	8.89	14.03	1.60	05/03/80
Ascophyllum	nodosum	27	4	30.03	16.30	13.73	7.03	11.88	02/11/81
Ascophyllum	nodosum	28	5	37.97	22.00	15.97	7.74	13.53	02/11/81
Ascophyllum	nodosum	29	6	37.07	16.79	20.28	5.99	12.51	02/11/81
Ascophyllum	nodosum	30	7	25.98	13.77	12.21	4.67	8.81	02/11/81
Ascophyllum	nodosum	31	8	19.66	10.25	9.41	3.35	8.60	01/28/81
Ascophyllum	nodosum	55	9	25.90	16.15	9.75	6.95	9.83	05/20/81
Ascophyllum	nodosum	56	10	33.61	18.73	14.88	8.85	10.41	05/20/81
Ascophyllum	nodosum	66	11	48.03	23.13	24.90	12.99	11.05	06/09/81
Ascophyllum	nodosum	67	12	39.65	19.46	20.19	9.67	8.24	06/18/81
Ascophyllum	nodosum	68	13	46.43	20.33	26.10	9.74	10.98	06/18/81
Ascophyllum	nodosum	69	14	35.72	16.81	18.91	11.27	5.66	06/19/81
Chondrus	crispus	8	1	28.46	6.60	21.86	2.20	2.37	03/00/80
Chondrus	crispus	11	2	34.31	17.62	16.69	2.20	3.32	02/24/80
Chondrus	crispus	21	3	36.48	14.49	21.99	3.05	4.79	07/22/80
Chondrus	crispus	33	4	44.78	8.40	36.38	4.15	4.18	01/19/81
Chondrus	crispus	34	5	31.34	6.77	24.57	3.17	3.99	12/02/80
Chondrus	crispus	35	6	26.86	6.85	20.01	4.32	2.46	02/11/81
Chondrus	crispus	32	7	30.60	9.30	21.30	4.34	4.40	02/11/81
Chondrus	crispus	71	8	20.41	6.33	17.78	1.07	2.77	05/06/81
Chondrus	crispus	72	9	34.93	8.05	26.89	2.01	5.07	06/18/81
Chondrus	crispus	73	10	28.16	6.90	21.26	2.09	4.44	06/18/81
Codium	fragile	16	1	27.52	11.35	16.17	6.97	4.10	06/04/80
Codium	fragile	23	2	29.65	17.77	11.88	3.47	4.96	02/18/81
Codium	fragile	24	3	19.99	8.61	11.38	3.81	6.79	02/18/81
Codium	fragile	25	4	30.08	18.65	11.43	0.00	19.90	01/20/81
Codium	fragile	26	5	26.33	12.16	14.17	6.00	32.00	02/16/81
Codium	fragile	57	6	30.46	9.56	20.90	5.42	4.28	05/06/81
Codium	fragile	59	7	28.72	15.10	13.62	6.40	8.31	05/30/81
Codium	fragile	60	8	31.86	19.18	12.68	6.98	7.42	06/04/81
Codium	fragile	61	9	32.59	14.80	17.79	2.44	9.06	06/10/81
Codium	fragile	62	10	40.73	26.05	14.68	10.45	10.45	06/04/81
Codium	fragile	63	11	35.17	16.67	18.50	8.74	5.82	06/02/81

Macroalgal Specimens

Genus	Species	Code	Lot	% NDF	% NADF	% Hemi-Cellulose	Lignin (%)	Cellulose (%)	Date
Fucus	distichus	20	1	22.59	16.43	6.16	12.91	7.29	07/22/80
Fucus	distichus	53	2	42.34	24.67	17.67	9.11	16.13	05/20/81
Fucus	distichus	54	3	26.61	15.92	10.69	5.86	10.53	05/06/81
Fucus	distichus	65	4	46.02	27.76	18.26	15.41	12.21	06/09/81
Fucus	vesiculosus	2	1	23.04	11.99	11.05	5.70	5.78	01/11/80
Fucus	vesiculosus	18	2	24.88	11.49	13.39	6.00	4.87	07/24/80
Fucus	vesiculosus	36	3	35.60	19.19	16.41	6.98	10.38	02/11/81
Fucus	vesiculosus	37	4	28.89	15.45	13.44	4.46	13.53	01/19/81
Fucus	vesiculosus	38	5	34.27	16.65	17.62	5.44	8.42	02/11/81
Fucus	vesiculosus	51	6	28.79	13.36	15.43	4.50	9.39	05/20/81
Fucus	vesiculosus	52	7	35.97	19.04	16.93	10.46	7.67	05/20/81
Fucus	vesiculosus	74	8	29.78	13.75	16.03	6.38	7.44	06/18/81
Fucus	vesiculosus	75	9	38.54	21.38	17.17	9.43	10.69	06/18/81
Fucus	vesiculosus	76	10	36.39	19.87	16.52	9.20	9.73	06/05/81
Fucus	vesiculosus	77	11	41.24	20.68	20.56	9.60	10.19	06/05/81
Fucus	vesiculosus	78	12	40.31	20.41	19.90	10.69	8.65	06/05/81
Fucus	vesiculosus	79	13	38.69	18.62	20.07	8.81	9.89	06/04/81
Fucus	vesiculosus	80	14	37.91	19.88	18.02	10.50	9.51	06/04/81
Fucus	vesiculosus	81	15	41.36	18.69	22.67	9.60	9.22	06/04/81
Fucus	vesiculosus	82	16	39.02	21.44	17.59	8.31	7.71	06/18/81
Laminaria	saccharina	9	1	24.15	13.08	11.07	6.57	6.79	03/23/80
Laminaria	saccharina	1	1-A	34.98	28.53	6.45	6.02	8.01	02/06/80
Laminaria	saccharina	10	2	21.53	16.88	4.65	11.07	3.68	04/09/80
Laminaria	saccharina	17	3	14.18	13.63	0.55	9.04	4.02	07/22/80
Laminaria	saccharina	39	4	19.80	16.22	3.58	7.27	8.89	01/19/81
Laminaria	saccharina	44	5	22.41	17.96	4.45	14.03	4.12	03/14/81
Laminaria	saccharina	45	6	21.12	15.10	6.02	5.68	10.84	05/06/81
Laminaria	saccharina	46	7	13.22	10.50	2.72	3.06	8.65	06/05/81
Laminaria	saccharina	47	8	30.83	17.35	13.48	14.01	3.49	05/06/81
Laminaria	saccharina	64	9	25.12	13.87	11.25	7.70	6.16	06/03/81
Palmaria	palmata	6	1	17.73	6.24	11.49	2.07	4.42	03/00/80
Palmaria	palmata	22	2	30.85	6.59	24.26	2.77	4.02	07/22/80
Palmaria	palmata	58	3	25.52	11.99	13.53	1.93	5.90	05/06/81
Ulva	lactuca	3	1	35.55	10.83	24.72	5.74	2.54	02/06/80
Ulva	lactuca	4	2	43.99	31.84	12.15	12.44	1.25	01/11/80
Ulva	lactuca	19	3	46.45	10.67	35.78	1.60	11.95	07/22/80
Ulva	lactuca	48	4	38.36	20.08	18.28	2.07	20.80	05/20/81
Ulva	lactuca	49	5	37.95	17.63	20.32	1.62	12.53	06/04/81
Ulva	lactuca	50	6	42.34	26.90	15.44	1.09	9.57	05/06/81
Ulva	lactuca	70	7	39.52	22.50	17.96	7.81	8.23	06/04/81

Macroalgal Specimens

Genus	Species	Code	Lot	% NDF	% NADF	% Hemi-Cellulose	Lignin (%)	Cellulose (%)	Date
Macrocystis	pyrifera		1						07/16/75
Macrocystis	pyrifera		2						07/23/75
Macrocystis	pyrifera		3						08/06/75
Macrocystis	pyrifera		4						05/06/80
Macrocystis	pyrifera		5						09/03/75
Macrocystis	pyrifera		6						09/17/75
Macrocystis	pyrifera		7						09/30/75
Macrocystis	pyrifera		8						10/23/75
Macrocystis	pyrifera		10						11/05/75
Macrocystis	pyrifera		12						11/17/75
Macrocystis	pyrifera		13						11/19/75
Macrocystis	pyrifera		14						12/09/75
Macrocystis	pyrifera		15						12/12/75
Macrocystis	pyrifera		16						02/09/76
Macrocystis	pyrifera		17						02/10/76
Macrocystis	pyrifera		18						02/23/76
Macrocystis	pyrifera		19						03/26/76
Macrocystis	pyrifera		20						05/06/76
Macrocystis	pyrifera		21						05/20/76
Macrocystis	pyrifera		22						06/09/76
Macrocystis	pyrifera		23						06/24/76
Macrocystis	pyrifera		24						06/30/76
Macrocystis	pyrifera		25						07/13/76
Macrocystis	pyrifera		26						09/30/76
Macrocystis	pyrifera		26						09/30/76
Macrocystis	pyrifera		27						01/17/77
Macrocystis	pyrifera		37						10/25/77
Macrocystis	pyrifera		37						10/25/77
Macrocystis	pyrifera		41						06/06/78
Macrocystis	pyrifera		41						06/06/78
Macrocystis	pyrifera		42						09/12/78
Macrocystis	pyrifera		42						09/12/78
Macrocystis	pyrifera		43						10/11/78
Macrocystis	pyrifera		44						11/01/78
Macrocystis	pyrifera		44						11/01/78
Macrocystis	pyrifera		45						11/28/78
Macrocystis	pyrifera		46						01/24/79
Macrocystis	pyrifera		46						01/24/79
Macrocystis	pyrifera		47						03/21/79
Macrocystis	pyrifera		47						03/21/79
Macrocystis	pyrifera		48						04/28/79
Macrocystis	pyrifera		48						04/28/79
Macrocystis	pyrifera	0	48	11.79	9.88	1.91	4.01	6.36	04/28/79
Macrocystis	pyrifera		49						10/16/79
Macrocystis	pyrifera		49						10/16/79
Macrocystis	pyrifera	12	49	15.87	12.08	3.79	7.80	4.67	10/16/79
Macrocystis	pyrifera		50						05/06/80
Macrocystis	pyrifera		50						05/06/80
Macrocystis	pyrifera		51						08/18/80
Macrocystis	pyrifera	43	51-3	13.43	10.33	3.10	1.91	7.11	00/00/00

Macroalgal Specimens

Genus	Species	Code	Lot	% NDF	% NADF	% Hemi-Cellulose	Lignin (%)	Cellulose (%)	Date
Macrocystis	pyrifera	43A	51-3						00/00/00
Macrocystis	pyrifera		52-1						10/01/80
Macrocystis	pyrifera		52-2						10/01/80
Macrocystis	pyrifera		53-1						10/22/80
Macrocystis	pyrifera		53-1						10/20/80
Macrocystis	pyrifera	42	53-1	15.91	12.47	3.44	5.73	7.20	10/22/80
Macrocystis	pyrifera	42A	53-1						10/22/80
Macrocystis	pyrifera	42B	53-1						10/22/80
Macrocystis	pyrifera	42C	53-1						10/22/80
Macrocystis	pyrifera		53-2						10/21/80
Macrocystis	pyrifera		54						10/28/80
Macrocystis	pyrifera	41	NY-1						11/14/80

Macroalgal Specimens

Genus	Species	Code	Lot	Caragheenan (%)	Fucoidan (%)	Algin (%)	Laminarin (%)	Date	Plant Source
Agardhiella	tenera	40	1			<4.7		12/03/80	Greenhouse
Agarum	cribosum	14	1		0.65	13.3	0.00	05/03/80	Natural
Alaria	esculenta	13	1		0.47	16.8	0.00	05/03/80	Natural
Ascophyllum	nodosum	5	1		3.80	3.7	0.00	03/09/80	Natural
Ascophyllum	nodosum	7	2		3.85	14.1	trace	03/23/80	Natural
Ascophyllum	nodosum	15	3		3.85	5.0	0.00	05/03/80	Natural
Ascophyllum	nodosum	27	4		21.51	<3.2		02/11/81	Greenhouse
Ascophyllum	nodosum	28	5		18.27	4.89		02/11/81	Greenhouse
Ascophyllum	nodosum	29	6		17.70	4.69		02/11/81	Greenhouse
Ascophyllum	nodosum	30	7		13.49	3.41		02/11/81	Natural
Ascophyllum	nodosum	31	8		6.94	12.4		01/28/81	Natural
Ascophyllum	nodosum	55	9		4.23	6.92		05/20/81	Greenhouse
Ascophyllum	nodosum	56	10		4.76	11.67		05/20/81	Greenhouse
Ascophyllum	nodosum	66	11		3.66	11.80		06/09/81	Greenhouse
Ascophyllum	nodosum	67	12		3.61	12.40		06/18/81	Greenhouse
Ascophyllum	nodosum	68	13		3.36	10.89		06/18/81	Greenhouse
Ascophyllum	nodosum	69	14		5.88			06/19/81	Natural
Chondrus	crispus	8	1	22.73	0.38	0.6	0.00	03/00/80	Natural
Chondrus	crispus	11	2	11.35	0.68	0.7	0.00	02/24/80	Natural
Chondrus	crispus	21	3	13.13	0.68	<2.6	0.00	07/22/80	Natural
Chondrus	crispus	33	4	2.42	0.11			01/19/81	Natural
Chondrus	crispus	34	5	4.02	0.04			12/02/80	Natural
Chondrus	crispus	35	6	3.44	0.88			02/11/81	Greenhouse
Chondrus	crispus	32	7	4.72	0.42			02/11/81	Greenhouse
Chondrus	crispus	71	8		4.76			05/06/81	Natural
Chondrus	crispus	72	9		1.86			06/18/81	Natural
Chondrus	crispus	73	10		6.20			06/18/81	Greenhouse
Codium	fragile	16	1		0.48	<2.9	0.00	06/04/80	Natural
Codium	fragile	23	2		0.01			02/18/81	Greenhouse
Codium	fragile	24	3		0.16			02/18/81	Greenhouse
Codium	fragile	25	4		0.67			01/20/81	Greenhouse
Codium	fragile	26	5		0.02			02/16/81	Natural
Codium	fragile	57	6		0.85	0.64		05/06/81	Natural
Codium	fragile	59	7		0.52			05/30/81	Greenhouse
Codium	fragile	60	8		0.49			06/04/81	Raft
Codium	fragile	61	9		0.70			06/10/81	Greenhouse
Codium	fragile	62	10		0.83			06/04/81	Raft
Codium	fragile	63	11		0.65			06/02/81	Greenhouse

Macroalgal Specimens

Genus	Species	Code	Lot	Caragheenan (%)	Fucoidan (%)	Algin (%)	Laminarin (%)	Date	Plant Source
Fucus	distichus	20	1		3.11	5.8	0.00	07/22/80	Natural
Fucus	distichus	53	2		6.46	6.83		05/20/81	Greenhouse
Fucus	distichus	54	3		6.33	3.87		05/06/81	Natural
Fucus	distichus	65	4		4.07	7.50		06/09/81	Greenhouse
Fucus	vesiculosus	2	1		2.50	10.8	0.00	01/11/80	Natural
Fucus	vesiculosus	18	2		4.28	6.1	0.00	07/24/80	Natural
Fucus	vesiculosus	36	3		8.19	10.5		02/11/81	Greenhouse
Fucus	vesiculosus	37	4		14.89	13.5		01/19/81	Natural
Fucus	vesiculosus	38	5		9.16	14.6		02/11/81	Natural
Fucus	vesiculosus	51	6		6.66	3.41		05/20/81	Natural
Fucus	vesiculosus	52	7		4.73	8.93		05/20/81	Greenhouse
Fucus	vesiculosus	74	8		11.77	9.24		06/18/81	Natural
Fucus	vesiculosus	75	9		6.30	5.07		06/18/81	Greenhouse
Fucus	vesiculosus	76	10		7.13	7.84		06/05/81	Raft
Fucus	vesiculosus	77	11		4.48	8.25		06/05/81	Raft
Fucus	vesiculosus	78	12		6.92	7.72		06/05/81	Raft
Fucus	vesiculosus	79	13		9.24	7.14		06/04/81	Raft
Fucus	vesiculosus	80	14		9.75	7.92		06/04/81	Raft
Fucus	vesiculosus	81	15		9.23	5.04		06/04/81	Raft
Fucus	vesiculosus	82	16		4.84			06/18/81	Greenhouse
Laminaria	saccharina	9	1		0.14	17.3	trace	03/23/80	Natural
Laminaria	saccharina	1	1-A		0.06	17.8	0.00	02/06/80	Natural
Laminaria	saccharina	10	2		0.14	19.2	0.00	04/09/80	Natural
Laminaria	saccharina	17	3		0.89	5.9	9.12	07/22/80	Natural
Laminaria	saccharina	39	4		1.96	14.5		01/19/81	Natural
Laminaria	saccharina	44	5		0.91	11.32		03/14/81	Natural
Laminaria	saccharina	45	6		0.57	13.04		05/06/81	Greenhouse
Laminaria	saccharina	46	7		1.02	9.58		06/05/81	Natural
Laminaria	saccharina	47	8		0.80	14.67		05/06/81	Greenhouse
Laminaria	saccharina	64	9		0.64	5.89		06/03/81	Natural
Palmaria	palmata	6	1	30.48	0.04	0.6	0.00	03/00/80	Natural
Palmaria	palmata	22	2	15.58	9.70	<3.1	0.00	07/22/80	Natural
Palmaria	palmata	58	3		11.96	0.58		05/06/81	Natural
Ulva	lactuca	3	1		7.95	0.5	0.00	02/06/80	Natural
Ulva	lactuca	4	2		4.84	0.7	trace	01/11/80	Natural
Ulva	lactuca	19	3		5.77	<3.0	0.00	07/22/80	Natural
Ulva	lactuca	48	4		2.85	0.55		05/20/81	Greenhouse
Ulva	lactuca	49	5		4.59	0.65		06/04/81	Natural
Ulva	lactuca	50	6		8.82	0.76		05/06/81	Natural
Ulva	lactuca	70	7		5.01			06/04/81	Natural

Macroalgal Specimens

Genus	Species	Code	Lot	Caragheenan (%)	Fucoidan (%)	Algin (%)	Laminarin (%)	Date	Plant Source
Macrocystis	pyrifera		1					07/16/75	Natural
Macrocystis	pyrifera		2					07/23/75	Natural
Macrocystis	pyrifera		3					08/06/75	Natural
Macrocystis	pyrifera		4					05/06/80	Natural
Macrocystis	pyrifera		5					09/03/75	Natural
Macrocystis	pyrifera		6					09/17/75	Natural
Macrocystis	pyrifera		7					09/30/75	Natural
Macrocystis	pyrifera		8					10/23/75	Natural
Macrocystis	pyrifera		10			12.00		11/05/75	Natural
Macrocystis	pyrifera		12			9.50		11/17/75	Natural
Macrocystis	pyrifera		13			9.40		11/19/75	Natural
Macrocystis	pyrifera		14			9.30		12/09/75	Natural
Macrocystis	pyrifera		15			8.40		12/12/75	Natural
Macrocystis	pyrifera		16			8.60		02/09/76	Natural
Macrocystis	pyrifera		17			9.40		02/10/76	Natural
Macrocystis	pyrifera		18			9.10		02/23/76	Natural
Macrocystis	pyrifera		19			10.40		03/26/76	Natural
Macrocystis	pyrifera		20					05/06/76	Natural
Macrocystis	pyrifera		21			12.50		05/20/76	Natural
Macrocystis	pyrifera		22			11.80		06/09/76	Natural
Macrocystis	pyrifera		23			12.85		06/24/76	Natural
Macrocystis	pyrifera		24			10.60		06/30/76	Natural
Macrocystis	pyrifera		25			11.05		07/13/76	Natural
Macrocystis	pyrifera		26					09/30/76	Natural
Macrocystis	pyrifera		26			17.04		09/30/76	Natural
Macrocystis	pyrifera		27					01/17/77	Natural
Macrocystis	pyrifera		37					10/25/77	Natural
Macrocystis	pyrifera		37			17.69		10/25/77	Natural
Macrocystis	pyrifera		41					06/06/78	Natural
Macrocystis	pyrifera		41			14.26		06/06/78	Natural
Macrocystis	pyrifera		42					09/12/78	Natural
Macrocystis	pyrifera		42			17.49		09/12/78	Natural
Macrocystis	pyrifera		43			12.63		10/11/78	Natural
Macrocystis	pyrifera		44					11/01/78	Natural
Macrocystis	pyrifera		44			16.90		11/01/78	Natural
Macrocystis	pyrifera		45			19.48		11/28/78	Natural
Macrocystis	pyrifera		46					01/24/79	Natural
Macrocystis	pyrifera		46			18.97		01/24/79	Natural
Macrocystis	pyrifera		47					03/21/79	Natural
Macrocystis	pyrifera		47			18.87		03/21/79	Natural
Macrocystis	pyrifera		48					04/28/79	Natural
Macrocystis	pyrifera		48			13.21		04/28/79	Natural
Macrocystis	pyrifera	0	48		2.07	11.5	0.00	04/28/79	Natural
Macrocystis	pyrifera		49					10/16/79	Natural
Macrocystis	pyrifera		49			14.45		10/16/79	Natural
Macrocystis	pyrifera	12	49		1.20	12.4	0.00	10/16/79	Natural
Macrocystis	pyrifera		50					05/06/80	Natural
Macrocystis	pyrifera		50			19.06		05/06/80	Natural
Macrocystis	pyrifera		51			18.84		08/18/80	Natural
Macrocystis	pyrifera	43	51-3		2.15	15.31		00/00/00	Natural

Macroalgal Specimens

Genus	Species	Code	Lot	Caragheenan (%)	Fucoidan (%)	Algin (%)	Laminarin (%)	Date	Plant Source
Macrocystis	pyrifera	43A	51-3					00/00/00	Natural
Macrocystis	pyrifera		52-1			16.23		10/01/80	Natural
Macrocystis	pyrifera		52-2			12.54		10/01/80	Natural
Macrocystis	pyrifera		53-1					10/22/80	Natural
Macrocystis	pyrifera		53-1			12.38		10/20/80	Natural
Macrocystis	pyrifera	42	53-1		2.05	14.7		10/22/80	Natural
Macrocystis	pyrifera	42A	53-1					10/22/80	Natural
Macrocystis	pyrifera	42B	53-1					10/22/80	Natural
Macrocystis	pyrifera	42C	53-1					10/22/80	Natural
Macrocystis	pyrifera		53-2			12.54		10/21/80	Natural
Macrocystis	pyrifera		54			13.08		10/28/80	Natural
Macrocystis	pyrifera	41	NY-1			25.2		11/14/80	Greenhouse

Macroalgal Specimens

Genus	Species	Code	Lot	Mannitol (%)	Glucose (%)	Galactose (%)	Compound A (%)	Compound B (%)	Date	Plant Source
Agardhiella	tenera	40	1	0.00	0.0	0.0	0.8	0.0	12/03/80	Greenhouse
Agarum	cribosum	14	1	1.68					05/03/80	Natural
Alaria	esculenta	13	1	4.65					05/03/80	Natural
Ascophyllum	nodosum	5	1	4.31					03/09/80	Natural
Ascophyllum	nodosum	7	2	1.65					03/23/80	Natural
Ascophyllum	nodosum	15	3	2.76					05/03/80	Natural
Ascophyllum	nodosum	27	4	5.00	0.6	0.0	0.0	0.0	02/11/81	Greenhouse
Ascophyllum	nodosum	28	5	5.50	0.0	0.0	0.0	0.0	02/11/81	Greenhouse
Ascophyllum	nodosum	29	6	5.20	0.4	0.0	0.0	0.0	02/11/81	Greenhouse
Ascophyllum	nodosum	30	7	5.00	1.1	0.0	0.0	0.0	02/11/81	Natural
Ascophyllum	nodosum	31	8	5.30	0.9	0.0	0.0	0.4	01/28/81	Natural
Ascophyllum	nodosum	55	9	6.50	0.3	0.0	0.0	0.0	05/20/81	Greenhouse
Ascophyllum	nodosum	56	10	6.70	1.0	0.0	0.0	0.3	05/20/81	Greenhouse
Ascophyllum	nodosum	66	11	4.30	0.0	0.0	0.0	0.0	06/09/81	Greenhouse
Ascophyllum	nodosum	67	12	4.60	0.0	0.0	0.0	0.0	06/18/81	Greenhouse
Ascophyllum	nodosum	68	13	7.30	0.0	0.0	0.0	0.0	06/18/81	Greenhouse
Ascophyllum	nodosum	69	14	7.50	2.1	2.6	1.6	0.4	06/19/81	Natural
Chondrus	crispus	8	1	0.00					03/00/80	Natural
Chondrus	crispus	11	2	0.00					02/24/80	Natural
Chondrus	crispus	21	3	0.00					07/22/80	Natural
Chondrus	crispus	33	4	0.00	0.0	3.9	4.3	0.0	01/19/81	Natural
Chondrus	crispus	34	5	0.00	0.0	3.9	2.6	0.0	12/02/80	Natural
Chondrus	crispus	35	6	0.00	0.0	3.9	4.0	0.0	02/11/81	Greenhouse
Chondrus	crispus	32	7	0.00	0.0	1.9	2.6	0.0	02/11/81	Greenhouse
Chondrus	crispus	71	8	0.00	0.0	2.8	4.4	0.0	05/06/81	Natural
Chondrus	crispus	72	9	0.00	0.0	4.4	0.9	0.0	06/18/81	Natural
Chondrus	crispus	73	10	0.00	0.0	3.7	0.7	0.0	06/18/81	Greenhouse
Codium	fragile	16	1	1.32					06/04/80	Natural
Codium	fragile	23	2	0.00	0.0	0.0	1.9	0.0	02/18/81	Greenhouse
Codium	fragile	24	3	0.00	0.0	0.0	0.4	0.0	02/18/81	Greenhouse
Codium	fragile	25	4	0.00	0.0	0.0	0.8	0.0	01/20/81	Greenhouse
Codium	fragile	26	5	0.00	0.0	0.0	0.9	0.0	02/16/81	Natural
Codium	fragile	57	6	0.00	0.0	0.0	2.2	0.3	05/06/81	Natural
Codium	fragile	59	7	0.00	0.0	0.0	1.0	0.0	05/30/81	Greenhouse
Codium	fragile	60	8	0.00	0.0	0.0	0.7	0.0	06/04/81	Raft
Codium	fragile	61	9	0.00	0.0	0.0	0.0	0.0	06/10/81	Greenhouse
Codium	fragile	62	10	0.00	1.2	0.0	0.0	0.0	06/04/81	Raft
Codium	fragile	63	11	0.00	1.3	0.0	0.0	0.0	06/02/81	Greenhouse

Macroalgal Specimens

Genus	Species	Code	Lot	Mannitol (%)	Glucose (%)	Galactose (%)	Compound A (%)	Compound B (%)	Date	Plant Source
Fucus	distichus	20	1	6.32					07/22/80	Natural
Fucus	distichus	53	2	3.20	0.0	0.0	2.4	0.0	05/20/81	Greenhouse
Fucus	distichus	54	3	5.10	0.0	0.4	6.3	1.8	05/06/81	Natural
Fucus	distichus	65	4	4.10	0.0	0.0	3.4	0.0	06/09/81	Greenhouse
Fucus	vesiculosus	2	1	5.77					01/11/80	Natural
Fucus	vesiculosus	18	2	11.37					07/24/80	Natural
Fucus	vesiculosus	36	3	5.20	0.0	0.0	0.0	0.2	02/11/81	Greenhouse
Fucus	vesiculosus	37	4	7.40	0.3	0.0	0.0	0.2	01/19/81	Natural
Fucus	vesiculosus	38	5	5.00	0.0	0.0	0.0	0.0	02/11/81	Natural
Fucus	vesiculosus	51	6	5.70	0.0	0.0	0.0	0.5	05/20/81	Natural
Fucus	vesiculosus	52	7	5.60	0.0	0.0	0.0	0.1	05/20/81	Greenhouse
Fucus	vesiculosus	74	8	9.80	0.2	1.2	0.0	1.5	06/18/81	Natural
Fucus	vesiculosus	75	9	4.40	0.0	0.0	0.0	0.0	06/18/81	Greenhouse
Fucus	vesiculosus	76	10	3.50	0.0	0.0	0.0	0.0	06/05/81	Raft
Fucus	vesiculosus	77	11	2.90	0.0	0.0	0.0	0.0	06/05/81	Raft
Fucus	vesiculosus	78	12	3.30	0.0	0.0	0.0	0.0	06/05/81	Raft
Fucus	vesiculosus	79	13	4.00	0.0	0.0	0.0	0.0	06/04/81	Raft
Fucus	vesiculosus	80	14	4.50	0.0	0.0	0.0	0.0	06/04/81	Raft
Fucus	vesiculosus	81	15	3.50	0.0	0.0	0.0	0.0	06/04/81	Raft
Fucus	vesiculosus	82	16	4.70	0.0	0.0	0.0	0.0	06/18/81	Greenhouse
Laminaria	saccharina	9	1	2.50					03/23/80	Natural
Laminaria	saccharina	1	1-A	0.00					02/06/80	Natural
Laminaria	saccharina	10	2	4.34					04/09/80	Natural
Laminaria	saccharina	17	3	18.30					07/22/80	Natural
Laminaria	saccharina	39	4	5.00	0.5	0.0	0.0	0.1	01/19/81	Natural
Laminaria	saccharina	44	5	4.80	0.6	0.0	0.0	0.0	03/14/81	Natural
Laminaria	saccharina	45	6	8.00	0.0	0.0	0.0	0.0	05/06/81	Greenhouse
Laminaria	saccharina	46	7	16.40	0.8	0.0	0.9	8.9	06/05/81	Natural
Laminaria	saccharina	47	8	13.50	0.2	0.0	0.0	1.2	05/06/81	Greenhouse
Laminaria	saccharina	64	9	4.90	0.5	0.0	0.0	0.0	06/03/81	Natural
Palmaria	palmata	6	1	0.00					03/00/80	Natural
Palmaria	palmata	22	2	0.00					07/22/80	Natural
Palmaria	palmata	58	3	0.00	0.8	6.1	8.1	0.0	05/06/81	Natural
Ulva	lactuca	3	1	0.00					02/06/80	Natural
Ulva	lactuca	4	2	0.00					01/11/80	Natural
Ulva	lactuca	19	3	0.00					07/22/80	Natural
Ulva	lactuca	48	4	0.00	0.0	0.0	0.0	9.7	05/20/81	Greenhouse
Ulva	lactuca	49	5	0.00	0.0	0.0	0.0	12.7	06/04/81	Natural
Ulva	lactuca	50	6	0.00	0.0	0.0	0.0	12.8	05/06/81	Natural
Ulva	lactuca	70	7	0.00	0.0	0.0	0.0	11.2	06/04/81	Natural

Macroalgal Specimens

Genus	Species	Code	Lot	Mannitol (%)	Glucose (%)	Galactose (%)	Compound A (%)	Compound B (%)	Date	Plant Source
Macrocystis	pyrifera		1						07/16/75	Natural
Macrocystis	pyrifera		2						07/23/75	Natural
Macrocystis	pyrifera		3	21.80					08/06/75	Natural
Macrocystis	pyrifera		4						05/06/80	Natural
Macrocystis	pyrifera		5						09/03/75	Natural
Macrocystis	pyrifera		6						09/17/75	Natural
Macrocystis	pyrifera		7	19.50					09/30/75	Natural
Macrocystis	pyrifera		8						10/23/75	Natural
Macrocystis	pyrifera		10	13.80					11/05/75	Natural
Macrocystis	pyrifera		12	11.50					11/17/75	Natural
Macrocystis	pyrifera		13	14.10					11/19/75	Natural
Macrocystis	pyrifera		14	13.60					12/09/75	Natural
Macrocystis	pyrifera		15	9.70					12/12/75	Natural
Macrocystis	pyrifera		16	6.30					02/09/76	Natural
Macrocystis	pyrifera		17	8.60					02/10/76	Natural
Macrocystis	pyrifera		18	7.00					02/23/76	Natural
Macrocystis	pyrifera		19	18.10					03/26/76	Natural
Macrocystis	pyrifera		20						05/06/76	Natural
Macrocystis	pyrifera		21	15.40					05/20/76	Natural
Macrocystis	pyrifera		22	19.90					06/09/76	Natural
Macrocystis	pyrifera		23	11.70					06/24/76	Natural
Macrocystis	pyrifera		24	14.90					06/30/76	Natural
Macrocystis	pyrifera		25	18.89					07/13/76	Natural
Macrocystis	pyrifera		26						09/30/76	Natural
Macrocystis	pyrifera		26	14.30					09/30/76	Natural
Macrocystis	pyrifera		27						01/17/77	Natural
Macrocystis	pyrifera		37						10/25/77	Natural
Macrocystis	pyrifera		37	14.89					10/25/77	Natural
Macrocystis	pyrifera		41						06/06/78	Natural
Macrocystis	pyrifera		41	19.67					06/06/78	Natural
Macrocystis	pyrifera		42						09/12/78	Natural
Macrocystis	pyrifera		42	13.05					09/12/78	Natural
Macrocystis	pyrifera		43	8.64					10/11/78	Natural
Macrocystis	pyrifera		44						11/01/78	Natural
Macrocystis	pyrifera		44	10.20					11/01/78	Natural
Macrocystis	pyrifera		45	21.64					11/28/78	Natural
Macrocystis	pyrifera		46						01/24/79	Natural
Macrocystis	pyrifera		46	5.19					01/24/79	Natural
Macrocystis	pyrifera		47						03/21/79	Natural
Macrocystis	pyrifera		47	5.18					03/21/79	Natural
Macrocystis	pyrifera		48	9.06					04/28/79	Natural
Macrocystis	pyrifera		48	8.83					04/28/79	Natural
Macrocystis	pyrifera	0	48	7.13					04/28/79	Natural
Macrocystis	pyrifera		49						10/16/79	Natural
Macrocystis	pyrifera		49	23.97					10/16/79	Natural
Macrocystis	pyrifera	12	49	18.13					10/16/79	Natural
Macrocystis	pyrifera		50						05/06/80	Natural
Macrocystis	pyrifera		50	8.27					05/06/80	Natural
Macrocystis	pyrifera		51	24.86					08/18/80	Natural
Macrocystis	pyrifera	43	51-3	22.50	0.0	0.0	0.0	0.0	00/00/00	Natural

Macroalgal Specimens

Genus	Species	Code	Lot	Mannitol (%)	Glucose (%)	Galactose (%)	Compound A (%)	Compound B (%)	Date	Plant Source
Macrocystis	pyrifera	43A	51-3	24.20					00/00/00	Natural
Macrocystis	pyrifera		52-1	20.01					10/01/80	Natural
Macrocystis	pyrifera		52-2	22.37					10/01/80	Natural
Macrocystis	pyrifera		53-1						10/22/80	Natural
Macrocystis	pyrifera		53-1	21.45					10/20/80	Natural
Macrocystis	pyrifera	42	53-1	14.60	0.0	0.0	0.0	0.0	10/22/80	Natural
Macrocystis	pyrifera	42A	53-1	17.12					10/22/80	Natural
Macrocystis	pyrifera	42B	53-1	19.88					10/22/80	Natural
Macrocystis	pyrifera	42C	53-1	17.33					10/22/80	Natural
Macrocystis	pyrifera		53-2	19.66					10/21/80	Natural
Macrocystis	pyrifera		54	15.35					10/28/80	Natural
Macrocystis	pyrifera	41	NY-1						11/14/80	Greenhouse

Macroalgal Specimens

Genus	Species	Code	Lot	% C	% H	% N	% S	C:N Ratio	Date	Plant Source
Agardhiella	tenera	40	1	24.32	3.72	3.47	2.69	7.01	12/03/80	Greenhouse
Agarum	cribosum	14	1	30.49	4.02	3.17	1.14	9.60	05/03/80	Natural
Alaria	esculenta	13	1	31.92	4.67	3.72	0.72	8.60	05/03/80	Natural
Ascophyllum	nodosum	5	1	35.69	5.03	2.76	2.40	12.93	03/09/80	Natural
Ascophyllum	nodosum	7	2	33.66	4.50	2.42	1.49	13.91	03/23/80	Natural
Ascophyllum	nodosum	15	3	33.12	4.09	3.32	2.91	10.00	05/03/80	Natural
Ascophyllum	nodosum	27	4	34.02	4.93	1.95	1.97	17.45	02/11/81	Greenhouse
Ascophyllum	nodosum	28	5	32.65	4.46	1.56	2.61	20.93	02/11/81	Greenhouse
Ascophyllum	nodosum	29	6	33.83	4.84	1.83	2.30	18.49	02/11/81	Greenhouse
Ascophyllum	nodosum	30	7	32.05	4.98	1.86	2.19	17.23	02/11/81	Natural
Ascophyllum	nodosum	31	8	33.56	5.00	3.42	1.78	9.81	01/28/81	Natural
Ascophyllum	nodosum	55	9	35.01	5.11	2.87	2.22	12.20	05/20/81	Greenhouse
Ascophyllum	nodosum	56	10	34.31	4.85	1.73	2.54	19.83	05/20/81	Greenhouse
Ascophyllum	nodosum	66	11	33.81	4.98	2.68	2.28	12.61	06/09/81	Greenhouse
Ascophyllum	nodosum	67	12	31.70	4.70	1.73	2.01	18.32	06/18/81	Greenhouse
Ascophyllum	nodosum	68	13	32.95	4.91	2.02	2.08	16.31	06/18/81	Greenhouse
Ascophyllum	nodosum	69	14	36.51	5.42	0.86	2.09	42.45	06/19/81	Natural
Chondrus	crispus	8	1	30.82	4.52	4.71	4.00	6.54	03/00/80	Natural
Chondrus	crispus	11	2	24.67	4.60	4.17	3.78	5.92	02/24/80	Natural
Chondrus	crispus	21	3	24.63	4.01	3.12	5.08	7.90	07/22/80	Natural
Chondrus	crispus	33	4	27.82	4.53	4.10	5.54	6.79	01/19/81	Natural
Chondrus	crispus	34	5	30.27	4.67	3.57	4.97	8.48	12/02/80	Natural
Chondrus	crispus	35	6	29.37	4.73	4.70	4.80	6.25	02/11/81	Greenhouse
Chondrus	crispus	32	7	27.30	4.49	3.47	4.65	7.87	02/11/81	Greenhouse
Chondrus	crispus	71	8	28.27	4.59	2.24	5.86	12.62	05/06/81	Natural
Chondrus	crispus	72	9	27.32	4.17	2.20	5.43	12.42	06/18/81	Natural
Chondrus	crispus	73	10	26.83	4.17	3.22	4.89	8.33	06/18/81	Greenhouse
Codium	fragile	16	1	19.22	3.39	1.60	4.06	12.00	06/04/80	Natural
Codium	fragile	23	2	17.54	3.01	2.19	1.54	8.01	02/18/81	Greenhouse
Codium	fragile	24	3	14.42	2.91	1.43	1.44	10.08	02/18/81	Greenhouse
Codium	fragile	25	4	17.35	3.06	1.92	1.63	9.04	01/20/81	Greenhouse
Codium	fragile	26	5	17.95	3.26	1.42	1.42	12.64	02/16/81	Natural
Codium	fragile	57	6	23.51	3.76	1.45	1.95	16.21	05/06/81	Natural
Codium	fragile	59	7	19.33	3.52	1.98	1.71	9.76	05/30/81	Greenhouse
Codium	fragile	60	8	17.89	3.25	1.92	1.67	9.32	06/04/81	Raft
Codium	fragile	61	9	23.25	3.90	2.09	1.57	11.12	06/10/81	Greenhouse
Codium	fragile	62	10	22.61	3.82	2.27	1.51	9.96	06/04/81	Raft
Codium	fragile	63	11	24.97	3.96	1.83	2.32	13.64	06/02/81	Greenhouse

Macroalgal Specimens

Genus	Species	Code	Lot	% C	% H	% N	% S	C:N Ratio	Date	Plant Source
Fucus	distichus	20	1	38.09	5.06	3.92	1.48	9.70	07/22/80	Natural
Fucus	distichus	53	2	35.56	5.03	2.35	2.75	15.13	05/20/81	Greenhouse
Fucus	distichus	54	3	35.09	4.63	1.68	2.31	20.89	05/06/81	Natural
Fucus	distichus	65	4	34.77	4.87	2.14	2.47	16.25	06/09/81	Greenhouse
Fucus	vesiculosus	2	1	34.52	4.27	3.44	1.48	10.00	01/11/80	Natural
Fucus	vesiculosus	18	2	31.20	4.27	2.85	1.99	10.90	07/24/80	Natural
Fucus	vesiculosus	36	3	31.28	4.43	2.54	2.15	12.31	02/11/81	Greenhouse
Fucus	vesiculosus	37	4	36.70	5.24	2.77	2.14	13.25	01/19/81	Natural
Fucus	vesiculosus	38	5	31.76	4.29	2.51	1.92	12.65	02/11/81	Natural
Fucus	vesiculosus	51	6	35.38	5.06	1.28	2.05	27.64	05/20/81	Natural
Fucus	vesiculosus	52	7	32.81	4.61	1.83	2.01	17.92	05/20/81	Greenhouse
Fucus	vesiculosus	74	8	35.26	5.11	1.01	2.01	34.91	06/18/81	Natural
Fucus	vesiculosus	75	9	30.73	4.23	2.46	2.25	12.49	06/18/81	Greenhouse
Fucus	vesiculosus	76	10	31.84	4.63	2.50	2.06	12.74	06/05/81	Raft
Fucus	vesiculosus	77	11	31.27	4.57	2.01	2.29	15.56	06/05/81	Raft
Fucus	vesiculosus	78	12	33.01	4.63	2.31	2.13	14.29	06/05/81	Raft
Fucus	vesiculosus	79	13	32.16	4.64	1.86	2.41	17.29	06/04/81	Raft
Fucus	vesiculosus	80	14	31.03	4.55	2.24	2.25	13.85	06/04/81	Raft
Fucus	vesiculosus	81	15	33.84	4.98	2.10	2.37	16.11	06/04/81	Raft
Fucus	vesiculosus	82	16	32.99	4.83	2.00	2.13	16.50	06/18/81	Greenhouse
Laminaria	saccharina	9	1	27.53	3.83	2.68	0.32	10.27	03/23/80	Natural
Laminaria	saccharina	1	1-A	23.84	2.84	2.56	0.44	9.30	02/06/80	Natural
Laminaria	saccharina	10	2	29.84	4.16	4.05	0.37	17.64	04/09/80	Natural
Laminaria	saccharina	17	3	33.85	5.36	3.16	0.40	10.80	07/22/80	Natural
Laminaria	saccharina	39	4	28.15	3.98	2.60	0.77	23.50	01/19/81	Natural
Laminaria	saccharina	44	5	28.68	4.17	1.83	0.35	15.67	03/14/81	Natural
Laminaria	saccharina	45	6	26.90	3.94	2.57	0.36	10.47	05/06/81	Greenhouse
Laminaria	saccharina	46	7	31.47	4.94	1.04	0.32	30.26	06/05/81	Natural
Laminaria	saccharina	47	8	28.82	4.32	1.67	0.40	17.25	05/06/81	Greenhouse
Laminaria	saccharina	64	9	29.80	4.36	2.19	0.38	13.61	06/03/81	Natural
Palmaria	palmata	6	1	29.99	4.50	3.81	0.48	7.87	03/00/80	Natural
Palmaria	palmata	22	2	34.94	5.63	4.10	0.54	8.50	07/22/80	Natural
Palmaria	palmata	58	3	28.47	4.15	3.08	0.50	9.24	05/06/81	Natural
Ulva	lactuca	3	1	35.38	5.00	4.88	2.31	7.25	02/06/80	Natural
Ulva	lactuca	4	2	18.40	2.44	2.50	1.57	7.36	01/11/80	Natural
Ulva	lactuca	19	3	29.21	4.90	2.77	4.10	10.60	07/22/80	Natural
Ulva	lactuca	48	4	31.72	5.02	4.68	3.05	6.78	05/20/81	Greenhouse
Ulva	lactuca	49	5	25.39	4.24	1.38	3.78	18.40	06/04/81	Natural
Ulva	lactuca	50	6	21.79	3.51	1.27	3.23	17.16	05/06/81	Natural
Ulva	lactuca	70	7	31.93	5.30	1.99	3.72	16.05	06/04/81	Natural

Macroalgal Specimens

Genus	Species	Code	Lot	% C	% H	% N	% S	C:N Ratio	Date	Plant Source
Macrocystis	pyrifera		1			1.16			07/16/75	Natural
Macrocystis	pyrifera		2	26.5	2.78	1.74		14.89	07/23/75	Natural
Macrocystis	pyrifera		3			1.11			08/06/75	Natural
Macrocystis	pyrifera		4			1.87			05/06/80	Natural
Macrocystis	pyrifera		5			2.17			09/03/75	Natural
Macrocystis	pyrifera		6			1.93			09/17/75	Natural
Macrocystis	pyrifera		7			1.84			09/30/75	Natural
Macrocystis	pyrifera		8			2.20			10/23/75	Natural
Macrocystis	pyrifera		10			2.10			11/05/75	Natural
Macrocystis	pyrifera		12			2.59			11/17/75	Natural
Macrocystis	pyrifera		13			2.36			11/19/75	Natural
Macrocystis	pyrifera		14			2.34			12/09/75	Natural
Macrocystis	pyrifera		15			2.62			12/12/75	Natural
Macrocystis	pyrifera		16			2.37			02/09/76	Natural
Macrocystis	pyrifera		17			2.46			02/10/76	Natural
Macrocystis	pyrifera		18			2.40			02/23/76	Natural
Macrocystis	pyrifera		19			1.35			03/26/76	Natural
Macrocystis	pyrifera		20			1.94			05/06/76	Natural
Macrocystis	pyrifera		21			1.23			05/20/76	Natural
Macrocystis	pyrifera		22			1.02			06/09/76	Natural
Macrocystis	pyrifera		23			1.90			06/24/76	Natural
Macrocystis	pyrifera		24			1.79			06/30/76	Natural
Macrocystis	pyrifera		25			1.34			07/13/76	Natural
Macrocystis	pyrifera		26	27.80	3.73	1.63	1.05	17.06	09/30/76	Natural
Macrocystis	pyrifera		26			1.59			09/30/76	Natural
Macrocystis	pyrifera		27			2.23			01/17/77	Natural
Macrocystis	pyrifera		37	28.00	3.92	1.86	1.09	15.05	10/25/77	Natural
Macrocystis	pyrifera		37			1.90			10/25/77	Natural
Macrocystis	pyrifera		41	28.90	4.00	1.23	1.06	23.50	06/06/78	Natural
Macrocystis	pyrifera		41			1.52			06/06/78	Natural
Macrocystis	pyrifera		42	28.30	3.61	1.18	1.35	23.98	09/12/78	Natural
Macrocystis	pyrifera		42			1.24			09/12/78	Natural
Macrocystis	pyrifera		43			2.47			10/11/78	Natural
Macrocystis	pyrifera		44	27.9	3.51	1.89	1.62	14.76	11/01/78	Natural
Macrocystis	pyrifera		44			1.87			11/01/78	Natural
Macrocystis	pyrifera		45			0.88			11/28/78	Natural
Macrocystis	pyrifera		46	25.5	3.24	1.95	1.37	13.08	01/24/79	Natural
Macrocystis	pyrifera		46			2.03			01/24/79	Natural
Macrocystis	pyrifera		47	32.87	3.50	2.22	1.33	14.81	03/21/79	Natural
Macrocystis	pyrifera		47			2.15			03/21/79	Natural
Macrocystis	pyrifera		48	25.5	3.39	1.89	1.01	13.49	04/28/79	Natural
Macrocystis	pyrifera		48			1.95			04/28/79	Natural
Macrocystis	pyrifera	0	48	23.72	2.78	1.74	0.76	13.63	04/28/79	Natural
Macrocystis	pyrifera		49	31.4	4.01	0.96	1.10	32.71	10/16/79	Natural
Macrocystis	pyrifera		49			1.06			10/16/79	Natural
Macrocystis	pyrifera	12	49	26.97	4.09	1.14	0.76	23.66	10/16/79	Natural
Macrocystis	pyrifera		50	26.5	3.53	1.78	1.12	14.89	05/06/80	Natural
Macrocystis	pyrifera		50			1.92			05/06/80	Natural
Macrocystis	pyrifera		51			1.00			08/18/80	Natural
Macrocystis	pyrifera	43	51-3	28.23	4.40	0.95	0.54	29.72	00/00/00	Natural

Macroalgal Specimens

Genus	Species	Code	Lot	% C	% H	% N	% S	C:N Ratio	Date	Plant Source
Macrocystis	pyrifera	43A	51-3						00/00/00	Natural
Macrocystis	pyrifera		52-1			1.51			10/01/80	Natural
Macrocystis	pyrifera		52-2			1.51			10/01/80	Natural
Macrocystis	pyrifera		53-1	29.8	4.05	2.05	0.93	14.54	10/22/80	Natural
Macrocystis	pyrifera		53-1			1.80			10/20/80	Natural
Macrocystis	pyrifera	42	53-1	29.71	4.40	2.02	0.80	14.71	10/22/80	Natural
Macrocystis	pyrifera	42A	53-1						10/22/80	Natural
Macrocystis	pyrifera	42B	53-1						10/22/80	Natural
Macrocystis	pyrifera	42C	53-1						10/22/80	Natural
Macrocystis	pyrifera		53-2			1.83			10/21/80	Natural
Macrocystis	pyrifera		54			1.99			10/28/80	Natural
Macrocystis	pyrifera	41	NY-1	20.92	3.15	1.74	1.05	12.02	11/14/80	Greenhouse

Macroalgal Specimens

Genus	Species	Code	Lot	Date	Harvest Location	Data Source	Plant Source	Water Temperature	MSL Lot #
Agardhiella	tenera	40	1	12/03/80	Flax Pond, L.I.	GE	Greenhouse		034
Agarum	cribosum	14	1	05/03/80	Nahant, Mass.	GE	Natural	10	
Alaria	esculenta	13	1	05/03/80	Nahant, Mass.	GE	Natural	10	
Ascophyllum	nodosum	5	1	03/09/80	Flax Pond, L.I.	GE	Natural	4	
Ascophyllum	nodosum	7	2	03/23/80	Orient Point, L.I.	GE	Natural	4	
Ascophyllum	nodosum	15	3	05/03/80	Nahant, Mass.	GE	Natural		
Ascophyllum	nodosum	27	4	02/11/81	Stony Brook, L.I.	GE	Greenhouse		037
Ascophyllum	nodosum	28	5	02/11/81	Stony Brook, L.I.	GE	Greenhouse		039
Ascophyllum	nodosum	29	6	02/11/81	Stony Brook, L.I.	GE	Greenhouse		038
Ascophyllum	nodosum	30	7	02/11/81	Flax Pond, L.I.	GE	Natural		
Ascophyllum	nodosum	31	8	01/28/81	Stamford, Conn.	GE	Natural		
Ascophyllum	nodosum	55	9	05/20/81	Stony Brook, L.I.	GE	Greenhouse		054
Ascophyllum	nodosum	56	10	05/20/81	Stony Brook, L.I.	GE	Greenhouse		025
Ascophyllum	nodosum	66	11	06/09/81	Stony Brook, L.I.	GE	Greenhouse		057
Ascophyllum	nodosum	67	12	06/18/81	Stony Brook, L.I.	GE	Greenhouse		068
Ascophyllum	nodosum	68	13	06/18/81	Stony Brook, L.I.	GE	Greenhouse		066
Ascophyllum	nodosum	69	14	06/19/81	Flax Pond, L.I.	GE	Natural		
Chondrus	crispus	8	1	03/00/80	Conn.	GE	Natural	5	
Chondrus	crispus	11	2	02/24/80	Orient Point, L.I.	GE	Natural	3	
Chondrus	crispus	21	3	07/22/80	Orient Point, L.I.	GE	Natural	24	
Chondrus	crispus	33	4	01/19/81	Montauk Point, L.I.	GE	Natural		
Chondrus	crispus	34	5	12/02/80	Old Field Point, L.I.	GE	Natural		
Chondrus	crispus	35	6	02/11/81	Stony Brook, L.I.	GE	Greenhouse		040
Chondrus	crispus	32	7	02/11/81	Stony Brook, L.I.	GE	Greenhouse		030
Chondrus	crispus	71	8	05/06/81	Montauk Point, L.I.	GE	Natural		
Chondrus	crispus	72	9	06/18/81	Long Island Sound, L.I.	GE	Natural		
Chondrus	crispus	73	10	06/18/81	Stony Brook, L.I.	GE	Greenhouse		044
Codium	fragile	16	1	06/04/80	Long Beach Bay, L.I.	GE	Natural	22	
Codium	fragile	23	2	02/18/81	Stony Brook, L.I.	GE	Greenhouse		005
Codium	fragile	24	3	02/18/81	Stony Brook, L.I.	GE	Greenhouse		015
Codium	fragile	25	4	01/20/81	Stony Brook, L.I.	GE	Greenhouse		023
Codium	fragile	26	5	02/16/81	Captree Island, L.I.	GE	Natural		
Codium	fragile	57	6	05/06/81	Montauk Point, L.I.	GE	Natural		
Codium	fragile	59	7	05/30/81	Stony Brook, L.I.	GE	Greenhouse		074
Codium	fragile	60	8	06/04/81	Flax Pond, L.I.	GE	Raft		
Codium	fragile	61	9	06/10/81	Stony Brook, L.I.	GE	Greenhouse		070
Codium	fragile	62	10	06/04/81	Flax Pond, L.I.	GE	Raft		
Codium	fragile	63	11	06/02/81	Stony Brook, L.I.	GE	Greenhouse		

Macroalgal Specimens

Genus	Species	Code	Lot	Date	Harvest Location	Data Source	Plant Source	Water Temperature	MSL Lot #
Fucus	distichus	20	1	07/22/80	Orient Point, L.I.	GE	Natural	24	
Fucus	distichus	53	2	05/20/81	Stony Brook, L.I.	GE	Greenhouse		046
Fucus	distichus	54	3	05/06/81	Montauk Point, L.I.	GE	Natural		
Fucus	distichus	65	4	06/09/81	Stony Brook, L.I.	GE	Greenhouse		048
Fucus	vesiculosus	2	1	01/11/80	Flax Pond, L.I.	GE	Natural		
Fucus	vesiculosus	18	2	07/24/80	Flax Pond, L.I.	GE	Natural	25	
Fucus	vesiculosus	36	3	02/11/81	Stony Brook, L.I.	GE	Greenhouse		035
Fucus	vesiculosus	37	4	01/19/81	Montauk Point, L.I.	GE	Natural		
Fucus	vesiculosus	38	5	02/11/81	Flax Pond, L.I.	GE	Natural		
Fucus	vesiculosus	51	6	05/20/81	Flax Pond, L.I.	GE	Natural		
Fucus	vesiculosus	52	7	05/20/81	Stony Brook, L.I.	GE	Greenhouse		046
Fucus	vesiculosus	74	8	06/18/81	Flax Pond, L.I.	GE	Natural		
Fucus	vesiculosus	75	9	06/18/81	Stony Brook, L.I.	GE	Greenhouse		062
Fucus	vesiculosus	76	10	06/05/81	Flax Pond, L.I.	GE	Raft		
Fucus	vesiculosus	77	11	06/05/81	Flax Pond, L.I.	GE	Raft		
Fucus	vesiculosus	78	12	06/05/81	Flax Pond, L.I.	GE	Raft		
Fucus	vesiculosus	79	13	06/04/81	Flax Pond, L.I.	GE	Raft		
Fucus	vesiculosus	80	14	06/04/81	Flax Pond, L.I.	GE	Raft		
Fucus	vesiculosus	81	15	06/04/81	Flax Pond, L.I.	GE	Raft		
Fucus	vesiculosus	82	16	06/18/81	Stony Brook, L.I.	GE	Greenhouse		064
Laminaria	saccharina	9	1	03/23/80	Orient Point, L.I.	GE	Natural		
Laminaria	saccharina	1	1-A	02/06/80	Orient Point, L.I.	GE	Natural		
Laminaria	saccharina	10	2	04/09/80	Orient Point, L.I.	GE	Natural	3	
Laminaria	saccharina	17	3	07/22/80	Orient Point, L.I.	GE	Natural		
Laminaria	saccharina	39	4	01/19/81	Montauk Point, L.I.	GE	Natural		
Laminaria	saccharina	44	5	03/14/81	Montauk Point, L.I.	GE	Natural		
Laminaria	saccharina	45	6	05/06/81	Stony Brook, L.I.	GE	Greenhouse		050
Laminaria	saccharina	46	7	06/05/81	Montauk Point, L.I.	GE	Natural		
Laminaria	saccharina	47	8	05/06/81	Stony Brook, L.I.	GE	Greenhouse		052
Laminaria	saccharina	64	9	06/03/81	Shinnecock Inlet, L.I.	GE	Natural		
Palmaria	palmata	6	1	03/00/80	Conn.	GE	Natural	5	
Palmaria	palmata	22	2	07/22/80	Orient Point, L.I.	GE	Natural	24	
Palmaria	palmata	58	3	05/06/81	Montauk Point, L.I.	GE	Natural		
Ulva	lactuca	3	1	02/06/80	Flax Pond, L.I.	GE	Natural		
Ulva	lactuca	4	2	01/11/80	Flax Pond, L.I.	GE	Natural		
Ulva	lactuca	19	3	07/22/80	Orient Point, L.I.	GE	Natural	24	
Ulva	lactuca	48	4	05/20/81	Stony Brook, L.I.	GE	Greenhouse		003
Ulva	lactuca	49	5	06/04/81	Shinnecock Bay, L.I.	GE	Natural		
Ulva	lactuca	50	6	05/06/81	Montauk Point, L.I.	GE	Natural		
Ulva	lactuca	70	7	06/04/81	Shinnecock Bay, L.I.	GE	Natural		

Macroalgal Specimens

Genus	Species	Code	Lot	Date	Harvest Location	Data Source	Plant Source	Water Temperature	MSL Lot #
Macrocystis	pyrifera		1	07/16/75	Monterey, California	WRRC	Natural		
Macrocystis	pyrifera		2	07/23/75	Monterey, California	WRRC	Natural		
Macrocystis	pyrifera		3	08/06/75	Monterey, California	WRRC	Natural		
Macrocystis	pyrifera		4	05/06/80	Southern California	WRRC	Natural		
Macrocystis	pyrifera		5	09/03/75	Santa Cruz Point, Calif.	WRRC	Natural		
Macrocystis	pyrifera		6	09/17/75	Santa Cruz Point, Calif.	WRRC	Natural		
Macrocystis	pyrifera		7	09/30/75	Santa Cruz Point, Calif.	WRRC	Natural		
Macrocystis	pyrifera		8	10/23/75	Monterey, California	WRRC	Natural		
Macrocystis	pyrifera		10	11/05/75	Santa Cruz Point, Calif.	WRRC	Natural		
Macrocystis	pyrifera		12	11/17/75	Soquel Point, California	WRRC	Natural		
Macrocystis	pyrifera		13	11/19/75	Soquel Point, California	WRRC	Natural		
Macrocystis	pyrifera		14	12/09/75	Soquel Point, California	WRRC	Natural		
Macrocystis	pyrifera		15	12/12/75	Soquel Point, California	WRRC	Natural		
Macrocystis	pyrifera		16	02/09/76	Soquel Point, California	WRRC	Natural		
Macrocystis	pyrifera		17	02/10/76	Soquel Point, California	WRRC	Natural		
Macrocystis	pyrifera		18	02/23/76	Soquel Point, California	WRRC	Natural		
Macrocystis	pyrifera		19	03/26/76	Soquel Point, California	WRRC	Natural		
Macrocystis	pyrifera		20	05/06/76	Soquel Point, California	WRRC	Natural		
Macrocystis	pyrifera		21	05/20/76	Soquel Point, California	WRRC	Natural		
Macrocystis	pyrifera		22	06/09/76	Soquel Point, California	WRRC	Natural		
Macrocystis	pyrifera		23	06/24/76	Monterey, California	WRRC	Natural		
Macrocystis	pyrifera		24	06/30/76	Soquel Point, California	WRRC	Natural		
Macrocystis	pyrifera		25	07/13/76	Monterey, California	WRRC	Natural		
Macrocystis	pyrifera		26	09/30/76	Soquel Point, California	IGT	Natural		
Macrocystis	pyrifera		26	09/30/76	Soquel Point, California	WRRC	Natural		
Macrocystis	pyrifera		27	01/17/77	Monterey, California	WRRC	Natural		
Macrocystis	pyrifera		37	10/25/77	Soquel Point, California	IGT	Natural		
Macrocystis	pyrifera		37	10/25/77	Soquel Point, California	WRRC	Natural		
Macrocystis	pyrifera		41	06/06/78	Southern California	IGT	Natural		
Macrocystis	pyrifera		41	06/06/78	Southern California	WRRC	Natural		
Macrocystis	pyrifera		42	09/12/78	Soquel Point, California	IGT	Natural		
Macrocystis	pyrifera		42	09/12/78	Soquel Point, California	WRRC	Natural		
Macrocystis	pyrifera		43	10/11/78	Soquel Point, California	WRRC	Natural		
Macrocystis	pyrifera		44	11/01/78	Soquel Point, California	IGT	Natural		
Macrocystis	pyrifera		44	11/01/78	Soquel Point, California	WRRC	Natural		
Macrocystis	pyrifera		45	11/28/78	Southern California	WRRC	Natural		
Macrocystis	pyrifera		46	01/24/79	Soquel Point, California	IGT	Natural		
Macrocystis	pyrifera		46	01/24/79	Soquel Point, California	WRRC	Natural		
Macrocystis	pyrifera		47	03/21/79	Soquel Point, California	IGT	Natural		
Macrocystis	pyrifera		47	03/21/79	Soquel Point, California	WRRC	Natural		
Macrocystis	pyrifera		48	04/28/79	Southern California	IGT	Natural		
Macrocystis	pyrifera		48	04/28/79	Southern California	WRRC	Natural		
Macrocystis	pyrifera	0	48	04/28/79	Southern California	GE	Natural		
Macrocystis	pyrifera		49	10/16/79	Southern California	IGT	Natural		
Macrocystis	pyrifera		49	10/16/79	Southern California	WRRC	Natural		
Macrocystis	pyrifera	12	49	10/16/79	Southern California	GE	Natural		
Macrocystis	pyrifera		50	05/06/80	Southern California	IGT	Natural		
Macrocystis	pyrifera		50	05/06/80	Southern California	WRRC	Natural		
Macrocystis	pyrifera		51	08/18/80	Soquel Point, California	WRRC	Natural		
Macrocystis	pyrifera	43	51-3	00/00/00	Southern California	GE	Natural		

Macroalgal Specimens

Genus	Species	Code	Lot	Date	Harvest Location	Data Source	Plant Source	Water Temperature	MSL Lot #
Macrocystis	pyrifera	43A	51-3	00/00/00		WRRC	Natural		
Macrocystis	pyrifera		52-1	10/01/80	Santa Cruz Point, Calif.	WRRC	Natural		
Macrocystis	pyrifera		52-2	10/01/80	Soquel Point, California	WRRC	Natural		
Macrocystis	pyrifera		53-1	10/22/80	Santa Cruz Point, Calif.	IGT	Natural		
Macrocystis	pyrifera		53-1	10/20/80	Santa Cruz Point, Calif.	WRRC	Natural		
Macrocystis	pyrifera	42	53-1	10/22/80	Santa Cruz Point, Calif.	GE	Natural		
Macrocystis	pyrifera	42A	53-1	10/22/80		WRRC	Natural		
Macrocystis	pyrifera	42B	53-1	10/22/80		WRRC	Natural		
Macrocystis	pyrifera	42C	53-1	10/22/80		WRRC	Natural		
Macrocystis	pyrifera		53-2	10/21/80	Santa Cruz Point, Calif.	WRRC	Natural		
Macrocystis	pyrifera		54	10/28/80	Santa Cruz Point, Calif.	WRRC	Natural		
Macrocystis	pyrifera	41	NY-1	11/14/80	Stony Brook, L.I.	GE	Greenhouse		

Macroalgal Specimens

Genus	Species	Code	Lot	Color	Comments
Agardhiella	tenera	40	1	Red	
Agarum	cribosum	14	1	Brown	Drift sample from rocky beach; not dessicated
Alaria	esculenta	13	1	Brown	Drift sample from rocky beach; not dessicated
Ascophyllum	nodosum	5	1	Brown	At low tide, in mud and Spartina grass
Ascophyllum	nodosum	7	2	Brown	Drift sample; not dessicated
Ascophyllum	nodosum	15	3	Brown	From rocks at low tide
Ascophyllum	nodosum	27	4	Brown	Greenhouse-unenriched
Ascophyllum	nodosum	28	5	Brown	Greenhouse-unenriched
Ascophyllum	nodosum	29	6	Brown	Greenhouse-unenriched
Ascophyllum	nodosum	30	7	Brown	
Ascophyllum	nodosum	31	8	Brown	
Ascophyllum	nodosum	55	9	Brown	Greenhouse-enriched
Ascophyllum	nodosum	56	10	Brown	ecad scorpioides; Greenhouse-unenriched
Ascophyllum	nodosum	66	11	Brown	Greenhouse-unenriched
Ascophyllum	nodosum	67	12	Brown	ecad scorpioides; Greenhouse-unenriched
Ascophyllum	nodosum	68	13	Brown	ecad scorpioides; Greenhouse-enriched
Ascophyllum	nodosum	69	14	Brown	ecad scorpioides
Chondrus	crispus	8	1	Red	Extensive subtidal bed
Chondrus	crispus	11	2	Red	Mixed species bed; plants healthy, small to medium size
Chondrus	crispus	21	3	Red	Large plants with some pigment loss; rocky bottom
Chondrus	crispus	33	4	Red	
Chondrus	crispus	34	5	Red	
Chondrus	crispus	35	6	Red	Greenhouse-unenriched
Chondrus	crispus	32	7	Red	Greenhouse-unenriched
Chondrus	crispus	71	8	Red	
Chondrus	crispus	72	9	Red	Near Flax Pond, L.I.
Chondrus	crispus	73	10	Red	Greenhouse-unenriched
Codium	fragile	16	1	Green	Intertidal; scattered mature and young plants; pebble bottom
Codium	fragile	23	2	Green	Greenhouse-unenriched
Codium	fragile	24	3	Green	Greenhouse-unenriched
Codium	fragile	25	4	Green	Greenhouse-unenriched
Codium	fragile	26	5	Green	
Codium	fragile	57	6	Green	
Codium	fragile	59	7	Green	Greenhouse-unenriched
Codium	fragile	60	8	Green	WM2, 3 foot cage
Codium	fragile	61	9	Green	Greenhouse-enriched
Codium	fragile	62	10	Green	10 foot cage, M & F mesh
Codium	fragile	63	11	Green	from reserve greenhouse cultures, for use in batch digester stock

Macroalgal Specimens

Genus	Species	Code	Lot	Color	Comments
Fucus	distichus	20	1	Brown	Rock bottom; 2-3 m deep; healthy, variable pigment
Fucus	distichus	53	2	Brown	Greenhouse-enriched
Fucus	distichus	54	3	Brown	
Fucus	distichus	65	4	Brown	Greenhouse-unenriched
Fucus	vesiculosus	2	1	Brown	Above low tide mark; rock; extensive healthy bed
Fucus	vesiculosus	18	2	Brown	Healthy; mixed with Spartina grass
Fucus	vesiculosus	36	3	Brown	variety spiralis; Greenhouse-unenriched
Fucus	vesiculosus	37	4	Brown	
Fucus	vesiculosus	38	5	Brown	variety spiralis
Fucus	vesiculosus	51	6	Brown	variety spiralis
Fucus	vesiculosus	52	7	Brown	variety spiralis; Greenhouse-enriched
Fucus	vesiculosus	74	8	Brown	variety spiralis
Fucus	vesiculosus	75	9	Brown	variety spiralis; Greenhouse-enriched
Fucus	vesiculosus	76	10	Brown	variety spiralis; 3 foot cage, MM1
Fucus	vesiculosus	77	11	Brown	variety spiralis; 3 foot cage, FM1
Fucus	vesiculosus	78	12	Brown	variety spiralis; 3 foot cage, WM1
Fucus	vesiculosus	79	13	Brown	variety spiralis; 10 foot cage, WM1
Fucus	vesiculosus	80	14	Brown	variety spiralis; 10 foot cage, MM1
Fucus	vesiculosus	81	15	Brown	variety spiralis; 10 foot cage, FM1
Fucus	vesiculosus	82	16	Brown	variety spiralis; Greenhouse-unenriched
Laminaria	saccharina	9	1	Brown	Drift sample from beach; large, complete plants
Laminaria	saccharina	1	1-A	Brown	1.5m, in surf zone; medium size, healthy; originally list as agardhii
Laminaria	saccharina	10	2	Brown	2-3 m deep; sand/rock bottom; large, healthy
Laminaria	saccharina	17	3	Brown	2-4 m deep; rocky; plants large; some epiphytism
Laminaria	saccharina	39	4	Brown	
Laminaria	saccharina	44	5	Brown	
Laminaria	saccharina	45	6	Brown	Greenhouse-enriched; harvested from culture (all blade material)
Laminaria	saccharina	46	7	Brown	
Laminaria	saccharina	47	8	Brown	
Laminaria	saccharina	64	9	Brown	Greenhouse-unenriched; harvested from culture (all blade material)
Palmaria	palmata	6	1	Red	Subtidal rock; patchy bed; healthy
Palmaria	palmata	22	2	Red	Rocky; healthy, but some pigment loss
Palmaria	palmata	58	3	Red	
Ulva	lactuca	3	1	Green	Pebble bottom; 1 m deep; extensive bed; mature, healthy
Ulva	lactuca	4	2	Green	Mud flats at low tide; long, mature, healthy
Ulva	lactuca	19	3	Green	May be Ulva rigida; rocky bottom; 2-3 m deep; healthy
Ulva	lactuca	48	4	Green	Greenhouse-enriched
Ulva	lactuca	49	5	Green	
Ulva	lactuca	50	6	Green	
Ulva	lactuca	70	7	Green	May be Ulva rigida; extra for batch digester

Macroalgal Specimens

Genus	Species	Code	Lot	Color	Comments
Macrocystis	pyrifera		1	Brown	
Macrocystis	pyrifera		2	Brown	
Macrocystis	pyrifera		3	Brown	
Macrocystis	pyrifera		4	Brown	
Macrocystis	pyrifera		5	Brown	
Macrocystis	pyrifera		6	Brown	
Macrocystis	pyrifera		7	Brown	
Macrocystis	pyrifera		8	Brown	
Macrocystis	pyrifera		10	Brown	
Macrocystis	pyrifera		12	Brown	
Macrocystis	pyrifera		13	Brown	
Macrocystis	pyrifera		14	Brown	
Macrocystis	pyrifera		15	Brown	
Macrocystis	pyrifera		16	Brown	
Macrocystis	pyrifera		17	Brown	
Macrocystis	pyrifera		18	Brown	
Macrocystis	pyrifera		19	Brown	
Macrocystis	pyrifera		20	Brown	
Macrocystis	pyrifera		21	Brown	
Macrocystis	pyrifera		22	Brown	
Macrocystis	pyrifera		23	Brown	
Macrocystis	pyrifera		24	Brown	
Macrocystis	pyrifera		25	Brown	
Macrocystis	pyrifera		26	Brown	
Macrocystis	pyrifera		26	Brown	
Macrocystis	pyrifera		27	Brown	
Macrocystis	pyrifera		37	Brown	
Macrocystis	pyrifera		37	Brown	
Macrocystis	pyrifera		41	Brown	
Macrocystis	pyrifera		41	Brown	
Macrocystis	pyrifera		42	Brown	
Macrocystis	pyrifera		42	Brown	
Macrocystis	pyrifera		43	Brown	
Macrocystis	pyrifera		44	Brown	
Macrocystis	pyrifera		44	Brown	
Macrocystis	pyrifera		45	Brown	
Macrocystis	pyrifera		46	Brown	
Macrocystis	pyrifera		46	Brown	
Macrocystis	pyrifera		47	Brown	
Macrocystis	pyrifera		47	Brown	
Macrocystis	pyrifera		48	Brown	
Macrocystis	pyrifera		48	Brown	
Macrocystis	pyrifera	0	48	Brown	Stauffer Lot 687-164
Macrocystis	pyrifera		49	Brown	
Macrocystis	pyrifera		49	Brown	
Macrocystis	pyrifera	12	49	Brown	Stauffer Lot 687-166
Macrocystis	pyrifera		50	Brown	
Macrocystis	pyrifera		50	Brown	
Macrocystis	pyrifera		51	Brown	
Macrocystis	pyrifera	43	51-3	Brown	

Macroalgal Specimens

Genus	Species	Code	Lot	Color	Comments
Macrocystis	pyrifera	43A	51-3	Brown	Rerun of mannitol numbers by WRRC to compare to GE numbers
Macrocystis	pyrifera		52-1	Brown	
Macrocystis	pyrifera		52-2	Brown	
Macrocystis	pyrifera		53-1	Brown	
Macrocystis	pyrifera		53-1	Brown	
Macrocystis	pyrifera	42	53-1	Brown	Hand harvested lot; 50,000 lbs.; species analyzed prior to harvest
Macrocystis	pyrifera	42A	53-1	Brown	Rerun by WRRC to compare to GE numbers
Macrocystis	pyrifera	42B	53-1	Brown	Ground by K.Farley;Mannitol run by WRRC
Macrocystis	pyrifera	42C	53-1	Brown	Ground by J.Lazur; Mannitol derermined by WRRC for comparison to GE
Macrocystis	pyrifera		53-2	Brown	
Macrocystis	pyrifera		54	Brown	
Macrocystis	pyrifera	41	NY-1	Brown	