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INDUSTRIAL GROWING AND HARVESTING OF ALGAE.

Background paper for

EXPERT GROUP MEETING ON
INDUSTRIAL GROWING AND PROCESSING OF MARINE ALGAE
RIGA, USSR, AUGUST 1986

Göran Michanek.

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I VOLUME AND VALUE OF PRESENT PRODUCTION

A Major and minor producing countries.

UNIDO's Aide-Memoir for this meeting starts with an estimate of world seaweed production from which we can learn some basic essentials:

The three big ones:Japan,China and Republic Korea account for 69% of the tonnage harvested to a value of no less than 96.5% of the total world production.

The remaining 3.5% in value (31% in weight) has to be broken down on USSR,USA,UK and "Others",including a number of great non-tropical producers,e.g.Norway,Chile,France,Mexico,Canada, Portugal,Iceland.The conclusion is obvious:the seaweed production in the Tropics is a very small fraction of the present total world production.

From the same table we can also make an estimate of value/weigh I repeat the table with these figures entered (Table 1)

Table 1 **Estimate of world seaweed production**[1]

Location	10^3 tonnes net weight		Value US$ million		Value per t US $	
Japan	654	=69%	563.0	=96.5%	861	467
China	700		130.0		186	
Korea (Republic)	224		45.0		201	
USA	126	=31%	1.9	= 3.5%	15	33
USSR	100		5.8		58	
UK	24		0.4		17	
Others	572		18.9		33	
TOTAL WORLD	2400x10^3te.		765x106 US$			

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[1] Industrial Biotechnology, October/November 1985, p.73.

Far East seaweed products are worth 14 times as much per ton as those of the rest of the world. In the Far East algae are essentially used for human consumption,in the rest of the world essentially for technical products.Any advice for developing countries should include this basic fact.

Behind the spectacular differences between and within the two production blocks another basic fact must be understood: brown algae (kelp) are very rich in biomass and are easy to harve in pure stands of one species only.Therefor they can be produced at a very low price.Red algae are usually small as compared to brown and have a lower production per area unit.There is often a lot of work included in keeping natural or cultivated stands free from undesired species.

The difference between Japan and China - 4.6 to 1 in value - reflects a basic difference. The Japanese production is most diver fied with a large number of different species and still more different products.Up to the seventies brown algae dominated in bulk, red by far in value.From the eighties red algae have passed also in quantities. China´s seaweed production has been concentrated on one species only,*Laminaria japonica*.One or a few per cent of the production were red algae.Recently red algae have increased from 72 000 t in 1980 to 124 000 t in 1984 or 8% of the total wet weigh quantity.

Maybe the observation is surprising that the lowest value pe ton is payed for the US harvest followed by the UK.The low figures could be explained by the fact that these countries produce brown algae only. However,they may also reflect a general economic tren US and UK industries are interested in very cheap raw material. Harvesting is mechanized to the point where the least number possi of people are occupied.Any harvesting enterprise which cannot prod at a low cost is unprofitable and will close down.

From FAO Yearbook of Fishery Statistics (Table 2 and Appendi we learn that the three big in quantities also are the three big i increase: China in particular with regard to brown algae but now a advancing to the forth place in red,where the Philippines have recovered and hold the second place.

FAO Yearbook of Fishery Statistics. Catches and landings.
Countries with > 5000 t harvests Thousands of metric tons

	1975	1977	1980	1983	1984
Brown seaweeds, total	786	892	2 470	2 298	2 393
Red	460	470	789	823	1 036
Green	2.5	2.5	9	14	8
Misc	92	97	80	70	107
	1340	1461	3 348	3205	3 545
BROWN					
France	15.9	14.7	33.5	44.3	60.6
Iceland	1.4	3.8	9.9	15.8	16.8
Norway	60	57.5	126.8	136.7	136.4
UK, Scotland	26.2	22.3	60.7	10.4	10.7
S. Africa	45.5	54.4	10.6	12.3	3
China	959.6	1 333.3	1 517.4	1 387.8	1.504
Japan	294.7	306.3	292.7	329	301
Korea, Rep.	156.4	229.3	225.6	272	245
Mexico	27.5	41.7	23.3	3.3	19.7
USA	155.7	159.7	162.4	4.8	39
Chile	...	...	...	53.6	5.9
RED					
Canada	36.1	22.2	19.3	18.4	19.8
Portugal	...	...	13.2	13.2	17.4
Spain	5.2	5	6	3.6	4.1
Morocco	5	5	0.5	0.5	0.5
Argentina	16.7	20.7	14.3	10.3	7
China	...	...	72	100	124
Japan	290.2	290.7	367.5	371.2	409.4
Korea, Rep.	53.2	64.9	66.2	95.4	143.5
Indonesia	8.4	4.1	7.9	9.6	10.8
Philippines	0,07	0,13	115.7	132.7	145.
Mexico	4.4	17.6	10.3	7.7	10.9
Chile	30	30	74.5	136.8	123.8

The largest drop to be observed during the last ten years reported in statistics is that of USA,where 162 000 tons of brown algae were collected on the west coast in 1980 and barely 5 000 t three years alter. S.Africa,UK and Chile have sufferd great losses in brown seaweed,while France and Norway have gained a lot.Canada and Argentina have lost quantities in red,Chile has fourdoubled its lot.Among various reasons which could explain the losses one is well known: increase in oil prices has made harvesting and transports more expensive,and in particular drum-drying.

In total,however,the trend is strong and steady upwards.

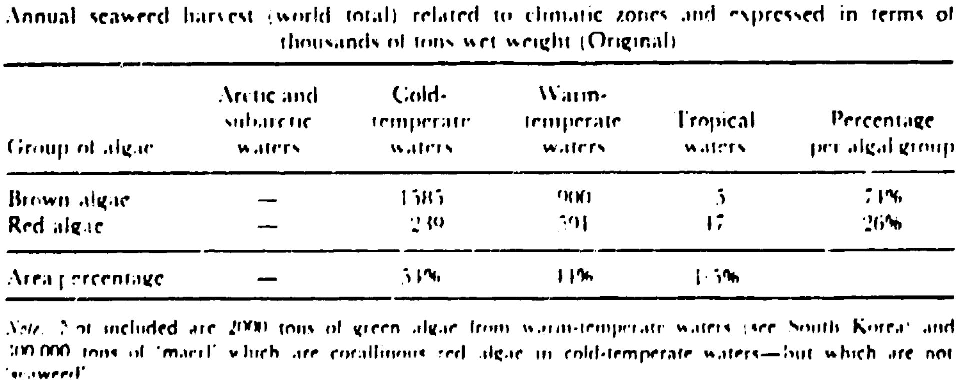
FAO has published "Seaweed Resources of the Ocean"(MICHANEK 1975),a review which surveys world resources by "Major fishing areas for statistical purposes" with breakdown on countries.

B CLIMATIC REGIONS AND SEAWEED PRODUCTION

Only two tropical countries have qualified to be entered into Tab 2,where only countries producing at least 5000 t have been included.

A well planned effort,economically and scientifically supported from the US has brought the Philippines to a second place in red algae production.Similar efforts more on their own has placed Indonesia on the list.

The importance of environmental factors is emphasized by a breakdown on climatic regions of 1978 world harvest figures (Tab.3)



Annual seaweed harvest (world total) related to climatic zones and expressed in terms of thousands of tons wet weight (Original)

Group of algae	Arctic and subarctic waters	Cold-temperate waters	Warm-temperate waters	Tropical waters	Percentage per algal group
Brown algae	—	1585	900	5	74%
Red algae	—	239	391	17	26%
Area percentage	—	54%	11%	1·5%	

Note. Not included are 2000 tons of green algae from warm-temperate waters (see South Korea) and 300 000 tons of 'maerl' which are coralline red algae in cold-temperate waters—but which are not 'seaweed'

Table 3. From MICHANEK 1983

Only 1.5% of the world seaweed harvest came from tropical waters. The dominance of the Far East is still more obvious, when the production is presented on a world map (Fig. 1)

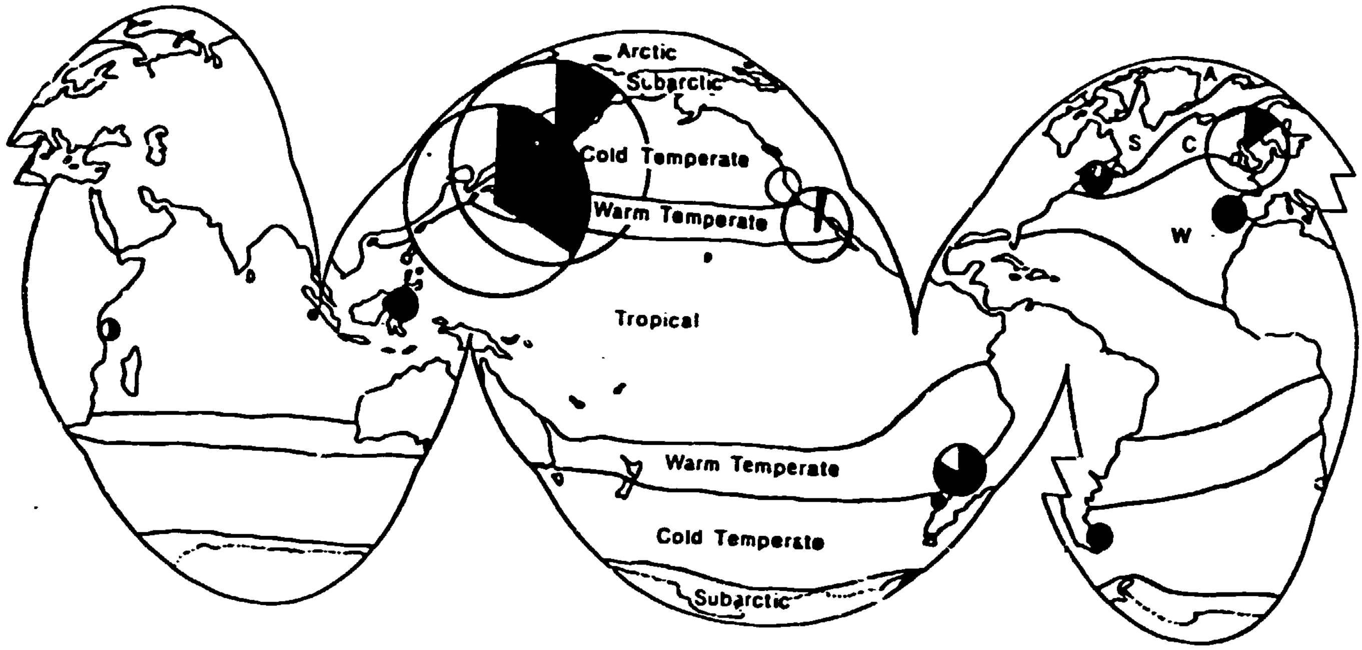


Fig. 1 World harvest of seaweed resources related to climatic regions.
Black sectors red algae, white sectors brown algae
A Arctic, S Subarctic, C Cold temperate, W Warm temperate, T Tropical
From MICHANEK 1983.

These productions volumes demonstrate above all the demand for algae for food in the Orient, but also the advantage of industrialized countries before developing.

As the harvest depends not only on biomass but also on weather (storms, rain), distance, harvesting effort and market demand it would be interesting to compare actual harvest with potentially harvestable quantities. These figures were assessed from known natural beds, but also including, to a minor degree,

Estimated annual potential of harvestable seaweed. Thousands of tons wet weight. World total (Original)

Group of algae	Subarctic waters	Cold-temperate waters	Warm-temperate waters	Tropical waters	Percentage per algal group
Brown algae	150	13 610	1136	1045	91%
Red algae	—	522	942	106	9%
Area percentage	0·9%	80·7%	11·9%	6·6%	

Table 4. From MICHANEK 1983

estimates of the outcome of a reasonably increased mariculture in a areas where such a trend is discernible (Table 4)

When outcome and estimate are compared,we find that some 50% of the resources of red algae are utilized,but only 16% of brown al algae. Five-sixths of thw world´s unexploited seaweed resources are made up of 12 million tons of brown algae in cold waters. However,there is no demand for such quantities of alginophytes (unless they could be produced at a very low price).Phycocolloids from red algae are more in demand,and as labour is cheapest in the Tropics, present demand seems to favour tropical red algae from mariculture.As a rough estimate it was calculated that the tropical production of 47 000 t red algae in 1978 could by a considerable effort be raised to 106 000 t.This figure has already been passed by the Philippines alone: 145 000 t in 1984 with an additional 10 800 t from Indonesia.

C REGIONS AND VOLUMES OF INDUSTRIAL PRODUCTION

The production of alginate,carragheen and agar is geographica localized in different ways.

Alginate industry is found close to the large resources of *Laminaria* and *Ascophyllum* in Scotland,Norway,France and Japan and of giant kelp,*Macrocystis* and *Nereocystis* in California and Mex (Fig.2).Its absence in the Tropics does not reflect technical difficulties to extract alginate,rather that comparable quantities of a suitable material is missing.However,*Sargassum* species and also *Turbinaria* can be used,and India produces alginates for textil printing at the Kathiawar peninsula.

Carrageenan is a high-tech product.Details of the manufacturi process are kept secret,in particular how to meet special requirements on gel strength,melting and setting temperatures.The factorie are few and big and in industrialized countries: US,Denmark,France, smaller units in Spain and Japan. (Fig.3). The Philippines as only developing country has two companies producing carragheenan of a

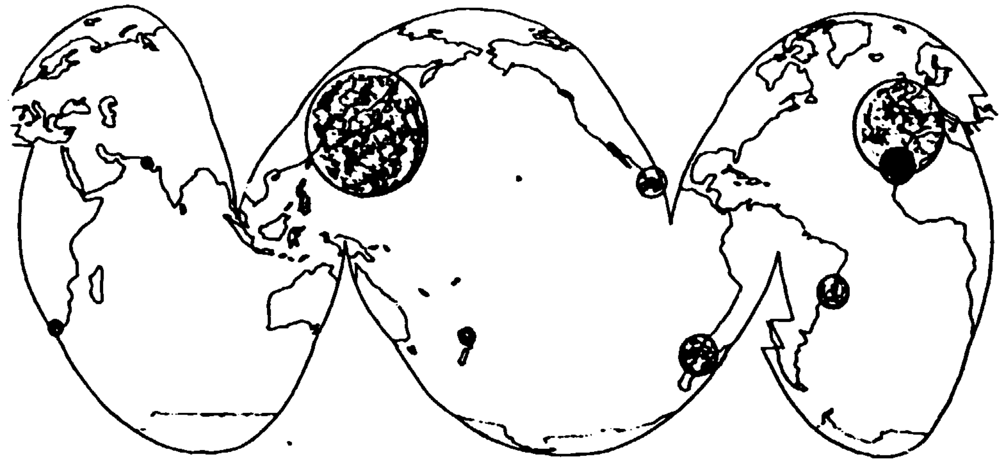


Fig. 2 World production of agar

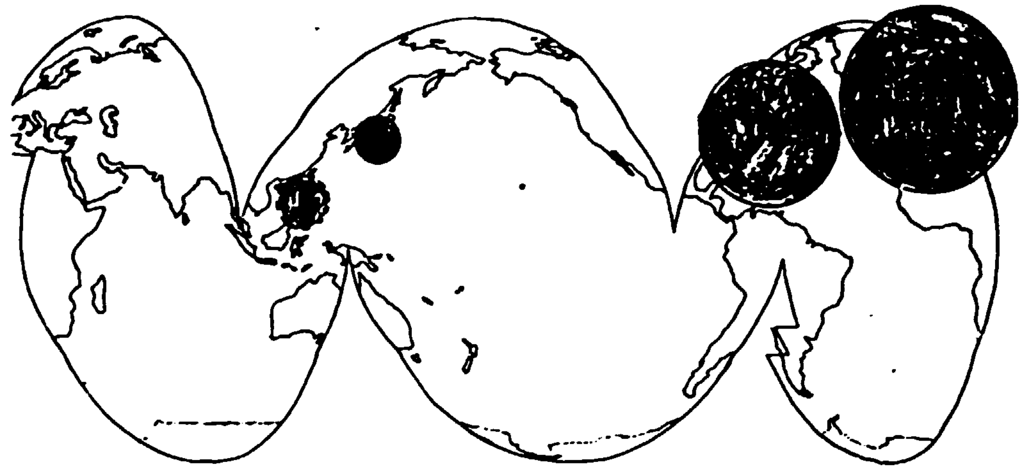


Fig. 3 World production of carrageenan (dotted line inferior quality)

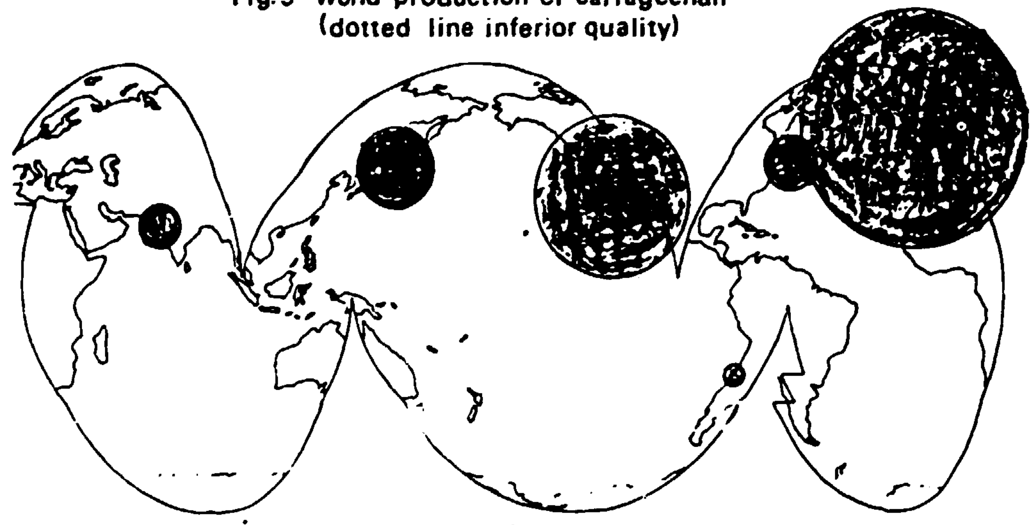


Fig. 4 world production of alginate

from MICHANEK 1984

lower quality.

Agar production is spread over the world. It is dominated by Japan, Republic of Korea and Spain (Fig.4), but also found in Portugal, Chile, Morocco, Mexico, Argentina, Taiwan, Brazil, France, S.Africa, New Zealand and India. There have been many more. During the world wars, when the Japanese monopoly production was cut off from world trade, small factories arouse in most countries. Most of them had to close down when peacetime opened trade for competition.

D WORLD TRADE.

Quantities and values of the main phycocolloids are shown in diagrams (Fig.5,6)

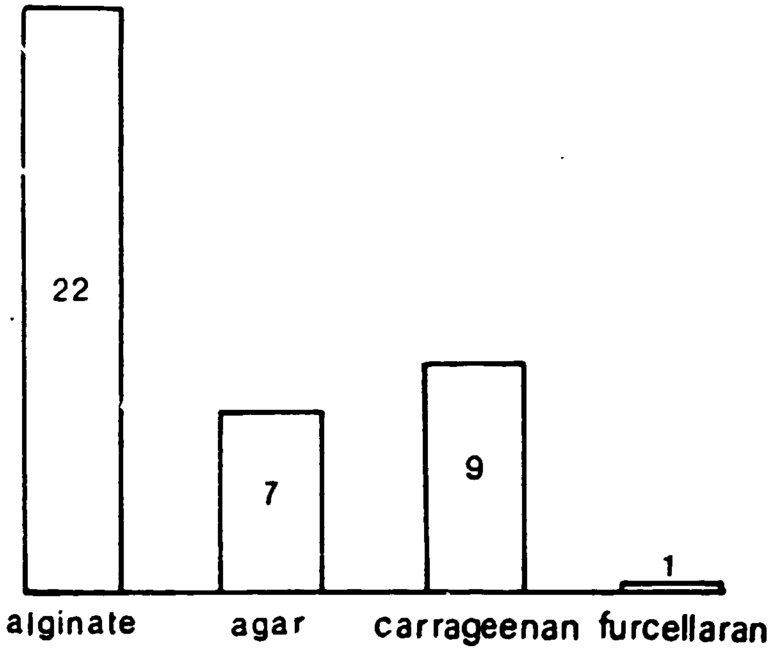


Fig.5. World trade in seaweed phycocolloids. Quantities in 1000t 1980.

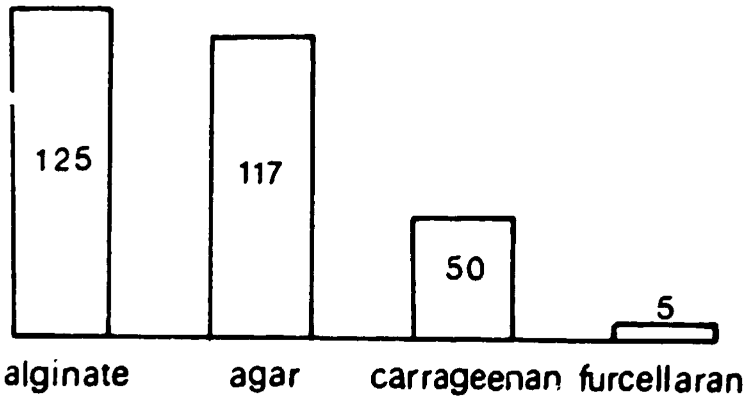


Fig.6. World trade in seaweed phycocolloids. Value in million US$ 1980.

Alginates dominate in quantity,furcellaran is a relatively small commodity.Agar is three times as expensive as the other phycocolloids. Prices fluctuate and many users react on changes in relative prices by switching from one commodity to another. This includes not only algal products,phycocolloids,but all hydrocolloids,industrial gums,which can be used as emulsifiers and stabilizers,including gelatine,pectin and various forms of starch and cellulose (Tab.5)

TAB. 5

Phycocolloids compared to other hydrocolloids. Price and usage 1978.

	US $/kg	US usage t
Gelling hydrocolloids		
Modified starch	0.60	91 000
Gelatine	3.30	6 000
Algin	4.40	360
Methyl cellulose	4.60	1 400
Pectin	5.15	1 800
Furcellaran	6.60	200
Kappa carrageenan	7.05	1 800
Agar	11.00	450
Agarose	350.00	3
Non-gelling hydrocolloids		
Modified starch	0.60	45 000
Carboxymethyl cellulose	2.20	7 300
Sodium alginate	4.95	1 800
Propylene glycol alginate	6.60	650
Lambda carrageenan	7.05	900

Data from Bixler 1979

The world trade is analyzed in a Pilot Survey of the World Seaweed Industry and Trade (ITC 1981).

II SEAWEED PRODUCTS

A Main uses

1 Human food

From much of what is written on seaweed utilization it appear that there is a strong push in favour of seaweed production for industrial demands but no such push for the alternative:use for human consumption.There is a demand,however, also for seaweed food products,and it appears that Japan can swallow any new resource. As emphasized already in the introductory chapter seweed prepared for human food are estimated at prices ten times higher or more than those produced for industrial purposes.

For export of food products the Japanese market is no longer the only alternative. In US and in Western Europe the "green wave" has brought an increasing interest in oriental cooking.

In addition to the direct use of dried algae for food there i also a considerable use of seaweed meal in bread and in health pill and of phycocolloids in food products such as icecream,milk and chokolate products. Origin,function,possible adverse effect and typical products are accounted for in Table 5.

For the home market in developing countries it should be most adviceable to support a revival of old customs of eating algae which have often disappeared during this century.

As phycocolloids are known to bind heavy metals and their radioactive isotopes there is an increasing demand for seaweed as food also in Western countries.

2 Medicine and prevention.

Malnutrition is still a plague in great parts of the world and all seaweed are rich in microelements and vitamines and many of them have remarkably high protein values.

In particular they are known to form a remedy for goitre, "the easiest of all human diseases to prevent",which affects some 300 million people. In general goitre areas coincide with high mountains (Fig.7)

E FOR ADDITIVES

E401	**Sodium alginate**
Origin	Prepared from alginic acid (E400) derived from brown seaweeds
Function	Stabilizing agent, suspending or thickening or emulsifying agent in the preparation of water-mixable pastes, creams and gels. Capable of emulsifying an equal volume of vegetable oil by simple agitation
Adverse Effects	No known toxicological problems
Typical Products	Desserts Puddings Packet cheesecake mixes Ice cream Packet cake mixes Processed cheese slices Barbecue sauce mixes Tinned fruit pie fillings

EMULSIFIERS, STABILIZERS AND OTHERS

E402	**Potassium alginate**
Origin	Prepared from alginic acid (E400) derived from native brown seaweeds.
Function	Emulsifier; stabilizer; boiler water additive; gelling agent.
Adverse Effects	None known.
Typical Products	—

E403	**Ammonium alginate**
Origin	Prepared from alginic acid (E400) derived from native brown seaweeds.
Function	Emulsifier; stabilizer; diluent for colouring matter; thickener.
Adverse Effects	None known.
Typical Products	—

E FOR ADDITIVES

E404	**Calcium alginate (Algin)**
Origin	Prepared from alginic acid (E400) derived from native brown seaweeds
Function	Emulsifier; stabilizer; thickening agent and gelling agent
Adverse Effects	None known.
Typical Products	Ice cream Synthetic cream

E405	**Propane-1, 2-diol alginate (Propylene gylcol alginate; alginate ester)**
Origin	Prepared from alginic acid derived from native brown seaweeds.
Function	Emulsifier or stabilizer, thickener, solvent for extracts, flavours or spices
Adverse Effects	None known.
Typical Products	Thousand Island dressing Cottage cheese with salmon and cucumber Mint sauce Seafood dressing Carton salad

EMULSIFIERS, STABILIZERS AND OTHERS

E406	**Agar (agar-agar; Japanese isinglass)**
Origin	A naturally occurring derivative of the stems of seaweeds belonging to the red algae family, especially *Gelidium amansii*.
Function	Thickening agent; stabilizer and gelling agent.
Adverse Effects	Agar is not digested; large quantities of it may temporarily increase flatulence and distension or cause intestinal obstruction but it is likely that amounts in food are too small to produce these effects.
Typical Products	Thickening agent for ice cream and for glazing meats when a firm jelly is needed Frozen raspberry trifle

E FOR ADDITIVES

E407	**Carrageenan (Irish Moss)**
Origin	Natural extract of several seaweeds, notably Carragheen (*Chondrus crispus*).
Function	Emulsifying, thickening, suspending and gelling agent.
Adverse Effects	Reported to be the possible cause of ulcerative colitis and, when degraded, may be carcinogenic. The most harmful form is when taken in a drink (*Lancet*, 7 Feb. '81, p. 338).
Typical Products	Ice creams Desserts Jellified fruit juices Decorations on cakes Pastries Biscuits Blancmanges Chocolate products Cheeses Quick-setting jelly mix Milk shakes Spray cream Frozen trifle Salad dressings Sour cream Infant formula Alcoholic beverages

Table 6. Phycocolloids as food additives

From Hanssen 1984, E for additives.

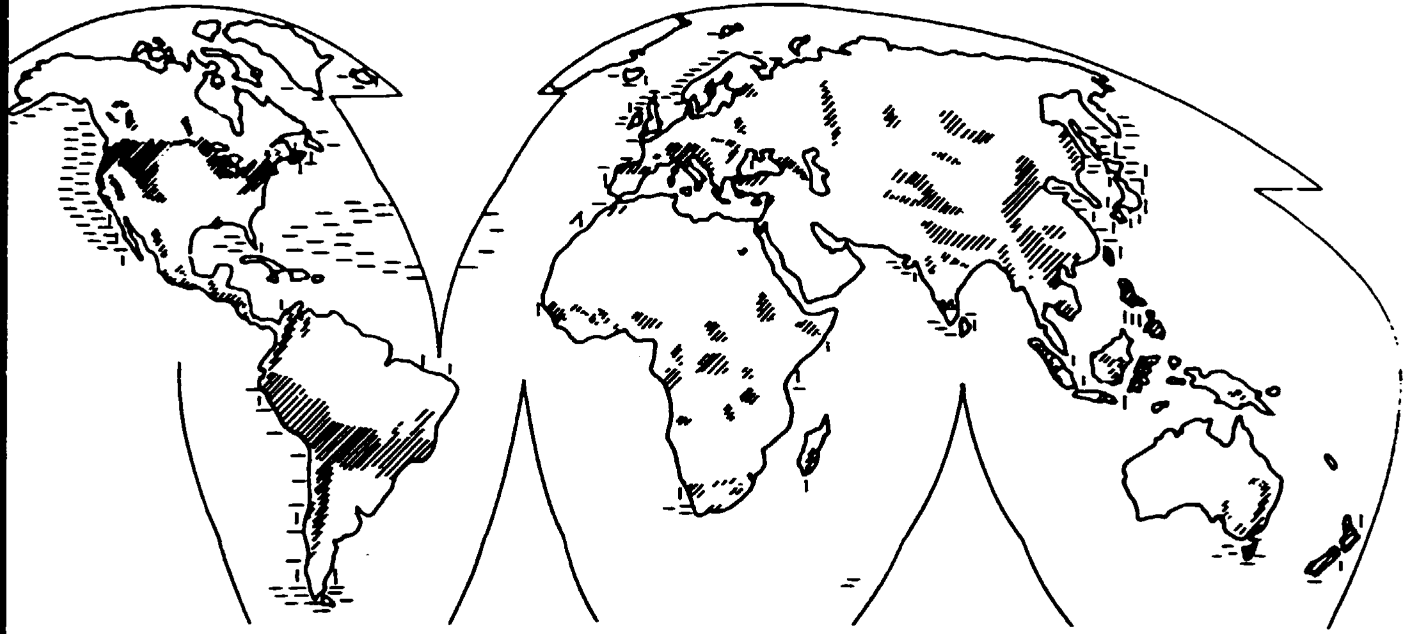


Fig. 7 Distribution of endemic goitre and of seaweed resoures. Hatched: areas where endemic goitre has been found. (After KELLEY and SNEDDEN, 1960); horizontal dashes: areas rich in resources of brown algae; vertical dashes: areas rich in red algae. (From MICHANEK, 1979b; Goode Homolosine Equal-area Projection; reproduced by permission of the University of Chicago)

> " A need, a resource, a distance. Would it be possible to bridge the difficulties, including the introduction of a strange food-stuff? The last point would probably not present the most difficult problem. Pilot projects have already been cariied through. *Durvillea* seaweed meal has been added to children's food in Chile in account of its high iodine content (Etcheverry 1953). There are also remnants of a competent folk medicine. Some Indian tribes in the Andean region used *Phyllogigas* as 'goitre sticks' to counter high incidence of thyroid enlargement. *Sargassum bacciferum* was also used by South American Indians to cure goitre (and renal disorders) (Schwimmer and Schwimmer 1955). In Peru the marine algae have formed part of the human diet since the pre-Inca and Inca periods. — — — These algae are still brought to the market places of the interior in considerable quantities (Acleto 1971). It seems reasonable to suggest that an attack on the goitre problem ~~in South America~~ should start with an ethno-botanical study of lost habits and surviving uses to explore the possibility of breathing new life into salutary old customs."

(from MICHANEK 1979,where pp 219-231 deal with the problem of endemic goitre.)

Algae in medicine are reviewed in "Seaweed resources for pharmaceutical uses" (MICHANEK 1979 = APPENDIX 2). Personal viewes were expressed in "Getting seaweed to where it´s needed" (MICHANEK 1981 = APPENDIX 3)

Unfortunately, importers know what they want and can pay for it. Goitrous tribes in the mountains and beriberi victims in the plains may not even realize that they are sick, because everyone in their community is. They may know nothing about possible remedies and certainly they have a low purchasing power. They need help from their governments, and these need international as assistance. In particular for inland countries like Zambia, Bolivia or Nepal help through seaweed would require action through UN agencies.

3 Industrial products.

Agar has a clear definition. The term should be reserved for phycocolloids from red algae, which are insoluble in cold water, but soluble in hot water. At 32° to 39°C, a 1.5% solution settles into a solid gel, which does not melt until at 85°C. Related phycocolloids, like phyllophoran, which do not completely comply with the definition, are called agaroids, a term which often includes Gracilaria gum.

This definition is necessary, because in nature agar consists of mixtures of polysaccharides with the same backbone structure; mainly neutral agarose, but also pyruvated agarose and some sulphated galactan. (YAPHE and DUCKWORTH 1972). Sulphated members of the family are non-gelling, viscous, and agar quality depends on the proportions of neutral agar and some sulphated galactans. As an exemple, Kobe-agar has a stronger gelling power, Yokohama-agar a better solubility

The common view is, that the rich variety of properties is the reason for the demand of phycocolloids in food industry and in the cosmetic market, and that the more purified and the more exactly defined a product is, the better.

Carrageenan contains sulfate groups, which pure agar does not. Carrageenans therefore are chemically active, while the best agar is uncharged.

In nature the sexual generation of Irish moss cannot be distinguished morphologically from the spore-producing generation. In the lab it can, also in a chemical lab, because kappa-carrageenan is predominant in sexual plants and lambda carrageenan in the spore-producing For a merchandize the difference is enormous; kappa-carrageenan means highest gelling quality, lambda-carrageenan means no gelling. The first commercial reaction on the finding was, that kappa-carrageenan was wanted, lambda-carrageenan unwanted. It is surprising to find that both are sold at the same price (Table 5).

Alginic acid is the most useful polysaccharide, produced by brown algae. To a non-chemist "acid" sounds to be something basically different from "sugar". Actually the difference is small; the single carbon, which has its place outside the carbon-oxygene ring, forms a $-CH_2OH$ group in a sugar molecule, while in brown algae this group is replaced by the functional group of acids, $-COOH$. The single units will therefore be called mannuronic acid and guluronic acid. They have a tendency to appear in blocks of about 20 units, each followed by a block of the other acid, these blocks interspersed by sections of mixtures. Guluronic acid has a strong affinity for Ca^{++}ions, and gel strength is depending on the combination of units in the polymere, as calcium ions fill into folds of the guluronic acid chains, stabilizing the whole structure (PERCIVAL 1979).

A property of practical value is, that alginic acid or sodium alginate, which form viscuous solutions, can be made to gel by the addition of calcium ions. The gel strength can be varied by control of the pH.

This rich variation within the phycocolloids has consequences not only for gel strength but also for all other qualities of gels and emulsifiers such as solubility (ROECK-HOLTZHAUER 1970)

Production methods are scematically described in flow sheets for alginic acid (Fig.8) and for agar production (Fig.9).

FAO published a study on "Production,Trade and Utilization of Seaweeds and Seaweed Products." (NAYLOR 1976).

International Trade Centre UNCTAD/GATT published a "Pilot Survey of the World Seaweed Industry and Trade" in 1981.This excellent study reviews:

Production by countries of seaweeds for agar,alginate,carrageenan	p.11
Production capacities by countries of agar,alginate,carrageenan	p.12
Exports by countries of agar,alginate,carrageenan	p.13
Prices of agar,alginate,carrageenan	p.17 -19
Prices of Gelidium,Gracilaria,Eucheuma et.al.	22 -24
Markets for agar,alginate,carrageenan	27-29,34-36, 41 -44
Industry and trade in selected countries	49-75
Manufacture of agar,alginates,carrageenan	79 -84

ADB/FAO INFOFISH devoted their Market report 6 to "The World Seaweed Industry and Trade.Developing Asian Producers and Prospects for Greater Participation (McHUGH and LANIER 1983). A review of the world seaweed industry is followed by studies of India,Indonesia,Malaysia,Republic of Korea,Philippines and Sri Lanka (Appendix 4).

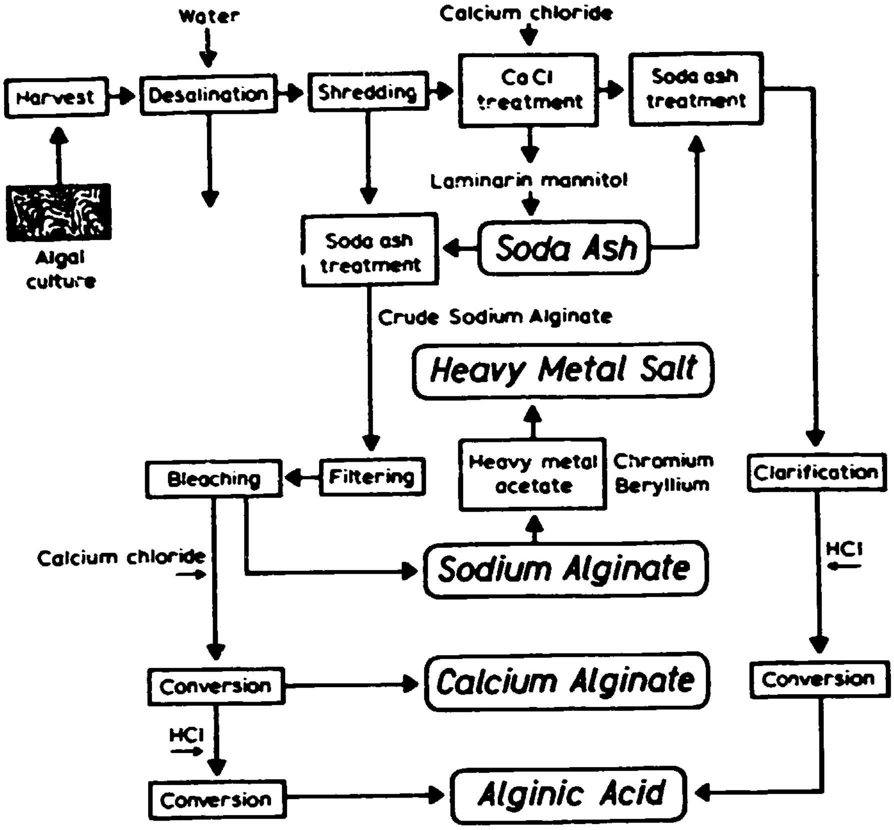
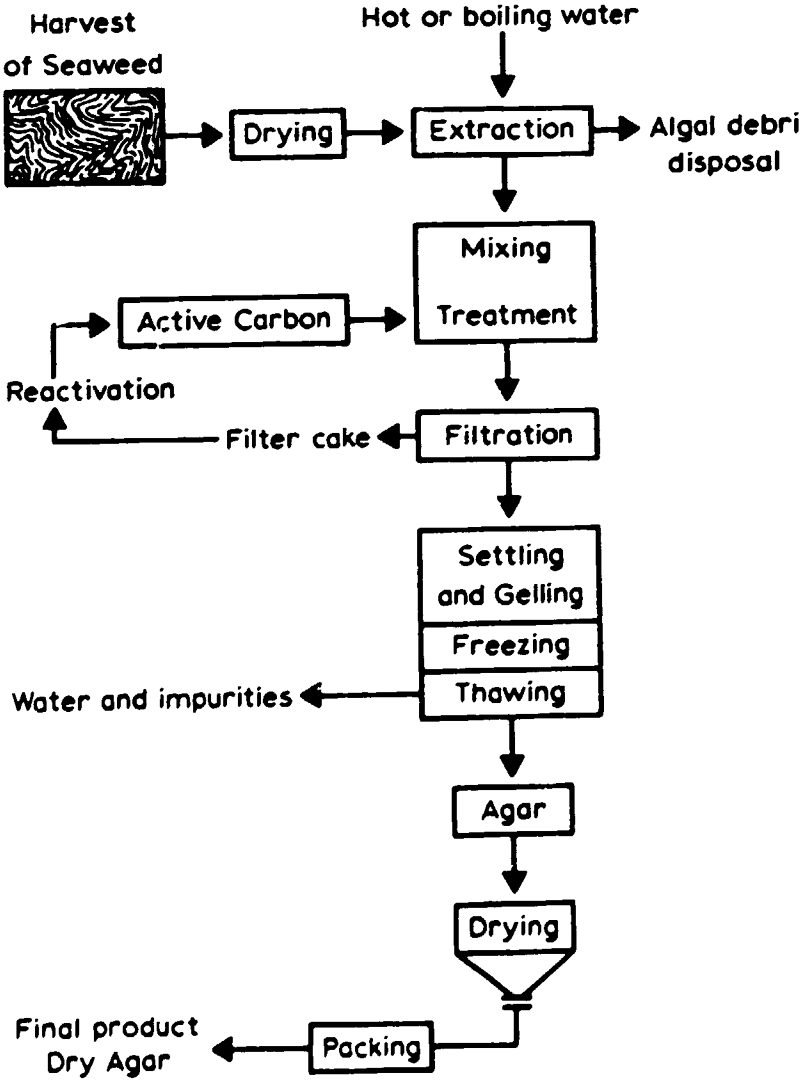


Fig. 8. Schematic for alginic acid production.



from Volesky, Zajic and Knettig 1970

Fig 9. Agar production from seaweed.

4 Fodder

There is a remarkable discrepancy between the very favourable results obtained at a number of investigations with seaweed as fodder and the totally low number of such investigations.

5 Manure and foliar spray

SENN and KINGMAN 81978) revied more than 20 years of research concerned with seaweeds for agricultural usage,as well as for greenhouse and other horticultural crops.Among the numerous exemples that can be mentioned,liquid spray of *Ascophyllum nodosum* resulted in significant increases in soluble solids of tomatoes,protein content of soyabean,and even in the quality of *Chrysanthemum*. The observed physiological responses exceeded those explainable on the basis of known chemical seaweed composition.

Seaweed as manure and soil conditioner has been objective for some studies.The results are either extraordinary in favour of seaweeds before other kinds of manure or they show no difference at all. An explanation could be that on soils poor in one or more micronutrients the effect is as strong as determined by Liebig´s law; on soils rich in such elements the effect may be none

Another component of value is that phycocolloids have a high capacity of retaining water and can help plants overcome a drought period.

B Identification of useful species

"List of multicellular algae of commercial use" (BONOTTO 1976) enumerates 341 species (27 green,87 brown and 227 red algae) APPENDIX 5

„Drogenkunde" (HOPPE 1977) gives an annotated review,rich in references of 375 algae (28 green,104 brown and 243 red),which are mentioned in literature as used in pharmacology or in folk medicine. The same author gives a similar presentation in LEVRING,HOPPE,SCHMID 1969.

The correct naming of a number of commercially interesting algae is a great problem. *Chondrus* should mean *Chondrus crispus* which is also known under the trade name 'Irish moss'. However, a shipment of 'Irish Moss' from Canada may well contain a mixture of *C. crispus* and *Gigartina stellata* which has a very similar appearance and occurs in similar or identical localities. In each of the genera *Eucheuma* and *Hypnea* more than 20 species names are being used. Most species are difficult to determine taxonomically even for a specialist and some are known to be confusing. 'Zanzibar Weed' is the trade name for a mixture of *Eucheuma* species. One of these is referred to by commercial firms as *E. cottonii*, but is probably *E. striatum*. Another one, commercially sold as *E. serra*, was identified as *E. spinosum* (MSHIGENI, 1973). The agaroid *Gracilaria* is found in commercial quantities all around the world. The common type is called *G. verrucosa* (syn: *G. confervoides*). However, it is very much doubted whether the *Gracilaria verrucosa* found in Chile, Florida, the Mediterranean Sea, India, Thailand, Philippines, Taiwan, Japan, South Africa, and Australia is indeed the same species.

A long-desired investigation of confusions in some of the most important commercial genera was recently performed (ABBOT and NORRIS 1985):

C Chemistry of phycocolloids

see also II A 3 Industrial products.

Various handbooks treat the subject,e.g.
Physiology and Biochemistry of Algae (Lewin 1962)
Marine algae:a survey of reserch and utilization (Levring-Hoppe-Schmid 1969)
Handbook of Water-Soluble Gums and Resins (DAVIDSON 1980)

Important papers for the understanding of present conceptions areREES 1972, YAPHE and DUCKWORTH 19/2.

Progress is fast and for correct details it is recommended to consult recent papers,e.g. PERCIVAL 1979,GYIRY (1979),LARSEN (1981),HANSEN;PACKARD and DOYLE (1981),ABBOT and CHENEY (1982).

While starch is very monotonously built up by maybe 25,maybe 1000 identical α-glucose sugar units,and cellulose by 10 000 identical β-glucose,gums from red algae are polymerized from a variety of different sugars,essentially galactoses and related compounds,like galactose sulfate,anhydrogalactose,methyl-galactose,galactopyranose and so on,causing a very rich variety of polymers with different qualities (Tab.7). Occasionally ramnose,xylose and other sugars are included. The proportions and arrangements of these units differ from different genera,species,nuclear phases and local collects.

TAB. 7 Chemical structure of phycocolloids

Polysaccharid	Predominant units	% Ester sulfate
A. Red algae		
Agarose	D-galactose	little or none
Hypnean Furcellaran	D-galactose D-galactose sulfate 3,6-anhydro-D-galactose	12 - 16 %
Kappa carrageenan	D-galactose-4-sulfate 3,6-anhydro-D-galactose	20 - 25 %
Lambda carrageenan	D-galactose-2-sulfate D-galactose-2,6-disulfate	30 - 35 %
B. Brown algae		
Alginic acid	β-D-mannuronic acid α-L-guluronic acid	none
"Algin"	Na-alginate	none
"Alginate"	Ca-alginate and other salts of alginic acid	none
"Fucan"	A family of polymers containing galactose, mannose,	contain ester sulfate

With this rich variety in chemical forms follows a gret variety in uses (Tab.8).

TAB. 8

Properties and utilization of phycocolloids

	Properties	Utilization
Agar	Forms well defined gels uncharged (chemically indifferent)	Food 12-14%, bacteriological culture medium (suppositories, laxative, creams, lotions)
Agarose	Same, purified from a small sulphated fraction	
"Danish agar" (= furcellaran)	Forms strong gels, withstands autoclavation	>90% in foodstuffs, tablet disintegrators, emulsifier in pharm. prep., tooth pastes
Kappa carrageenan	More sulphur, more ash than agar. Forms a variety of gels, which can be "tailor-made" to control texture, mouth-feel, stability, solubility ... withstands autoclavation	Food, ice-cream, pet food, suspending cocoa in milk, suspending fat in evaporated milk. Dental impressions, smoothener in shampoos, hydrating agent in lotions, creams
Lambda carrageenan	Does not form gels. Thickens solutions by increasing viscosity	Lotions
"Algin"	Extremely viscous solution. Hydrophobic, can be made to gel by addition of Ca	Dairy and bakery industries. Paper industry. Shampoos, lotions
Alginates	Form gels, thickens, disperses. Show good acceptability with starch, dextrin, pectin, glycerin, methyl-cellulose. Gel strength can be varied by control of pH	Textile printing 50%. Food 30 %. Pharmaceuticals 5%. Thickener in medicines.
Propylene glycol alginate	Readily soluble. High viscosity at low concentrations. Not gelled by acid ions.	Stabilizer in dressings, sauces and frozen fruit
"Fucan" (Fucoidan, Funoran, Laminarin)		Anticoagulant activity. Sizing, hairwaving preparations. Surgical dusting poroder, tumour inhibiting effects

D Biology of useful species.

The life history of most algae includes a change between a sexual generation forming gamets and one or more asexual sporophyte stages. In Porphyra one of the sporophyte generations lives in mussel shells. This discovery made it possible to cultivate the microalgae belonging to the winter phase and to produce large quantities of spores, which could be seeded on ropes or nets. Artificial seeding almost doubled the production in 1959 of 1 800 million sheets of nori to 3 500 million sheets in 1960 and enabled the deep freezing technique for young plants, which rose production to 4 500 million sheets in 1964. The release of spores can be controlled by temperature, light intensity, length of daylight and chemically (MICHANEK 1975 pp 89-91).

The fact that Chondrus crispus, Irish moss, produces high-gelli kappa-carrageenan and non-gelling lambda-carrageenan in sexual plan and in spore-producing respectively was mentioned in II C 2. Studies of life-cycles, fertility and seasonal variations in biomass phycocolloid content and quality are necessary for a successful cultivation of commercial species:

Table 9 Hypnea musciformis in India

Quantities high only in	Dec	Jan	Feb		
Hypnean content high only in		(Jan)	Feb	Mar	
Gel strength high only in				Mar	Apr

A considerable part of the phycological literature deals with biological problems of the algae. An early treatise was given b BONEY (1965). During the years numerous papers were published in the proceedings of the International Seaweed Symposia. A periodical with a particular ambition to cover utilization aspects was Botanic Marina.

Changes in temperature and light will rapidly change the chemistry of the cell wall,which explains differences in agar quali between winter and spring.

Another biochemical observation of a commercial interest is that on the same tidal coast the red algae which emerge for a long time produce agar with galactans heavily loaded with sulphates while other plants of the same species,which have grown immerged fo a long time do not.(BODARD,CHRISTIAEN and STAEDLER 1984).
In conclusion an agar manufacturer could amend his quality by collecting raw material from greater depth or during neap tides. He could also increase gel strength of his agar by submersing lots of agarophytes,collected at higher levels,for a time before starting the extraction.

To a biologist it is a fascinating point,that a plant can adapt itself to severe conditions,like wave action,by producing stiffer gels.This is achieved,biochemically, by the removal of "kinks" in the polysaccharide chain,which permits more extensive double helix formation,which in its turn results in a more compact, rigid gel framework (PERCIVAL 1979).A manufacturer could either treat separately lots harvested from very exposed shores or also amend quality by adding the enzyme which is capable of removing the "Kinks".

Ecological factors of importance for seaweed production in the Tropics are dealt with in MICHANEK 1983 pp.800-810.

III TECHNOLOGY FOR GROWTH AND HARVESTING

Recent reviews are given by HANSEN,PACKARD AND DOYLE 1981, and by MATHIESON 1982. Area reviews with a general interest are given for Indonesia (MURABAK 1980),China (TSENG 1981) and for East Africa (MSHIGENI 1983)

A A capital intense exemple:California.

Along the coast of California rich natural stands of giant ke Macrocystis,grow at such depths,that they can be harvested directl fromlarge vessels engulfing the canopies floating on the surface. This rich biomass,rapidly recovering after each ahrvest,in combination with the high technology of the area created the conditions for an industry. In the 1940´s the kelp beds started to deteriorat intense studies were conducted and from the 1960´s millions of dol were spent on a research and restoration program.There is a rich literature on control of predator,transplant technique and mass culture.

In Tasmania similar beds of Macrocystis were likewise harvested by a specially designed vessel,which cut the weed at a depth of 1.2 m below surface.In spite of large quantities and high technology the company collapsed. The Californian harvest declined from 155 - 160 000 t in the 70´s to 5 000 t in 1983 and 39 000 t in 1984 (Table 2 and Appendix) High levels of arsenique and mercury has ma the sale of a Californian "health product" forbidden in Sweden. Even if the full reasons are not known,the decline shows how vulnerable even a high technique enterprise may be.

B A labour intense exemple:Brazil

As unemployment is a severe problem in the northern states o Brazil,a seaweed company was organized some years ago with the obligation to provide work for 4 000 people. New governmental support was granted under condition that 10 000 people were employe later the obligation was raised to 24 000 collectors.These gathere

4 000 t of agarophytes, 50 000 t of alginophytes and 45 000 t of unspecified seaweed a year.No scientist adviced on optimal harve ting and resource conservation.The company collapsed.

Is this an exemple of what we have to expect in other, comparable areas: Seaweed enterprises are started and developed not based on considerations of supply and demand but on employment policy desires?

C Fishing of wild crop or mariculture?

Fishing of wild crop has dominated all seaweed production except the Japanese nori cultivation. It is still of importance for brown algae,while the production of red algae has shifted abruptly to mariculture.The main reasons are:1/ with ropes,nets and rafts coastal waters can be used at greater depths and independent of suitable substratum 2/ mariculture gives the possibility to favour the desired species by growing its sporesand by combating compeatin species, 3/ in many countries wild crops are common property,while a cultivation is always owned by the sea farmer. Actually this last reason is most important as whenever seaweed harvesting is successf and prosperous it attracts lots of people who arrive at the best season and usually overharvest the growth to the point where furthe work is very little profitable.

In Chile <u>Gracilaria</u> collection became an occupation of last resource..When mines closed down,the unemployed found no other chan chances,which led to conflicts with the settled fishermen.Any similar situation will cause problems for a government:to balance the need for work of unemployed against the desire to let the established fishermen reach a satisfactory standard of living.As mariculture cannot occupy all - the world needs hundreds of millions of new jobs - thereis no sense in promoting situations,which will most likely result in overharvesting and finally less job.The policy for govenments in coastal countries must be to plan for a development of mariculture by regional plans for the use of coastal areas,by regulations,and of course by promoting research on useful species,their biology and cultivation.

Mariculture in this context is not only the culture of seaweed,but also of fish,shrimps and mussels.In many cases ther is a favourable interaction:algae increase oxygen in water,animals release phosphates and nitrates through their fekalia.A dense growth of algae gives food and protection for fish fry or for a host of small animals which feed wild or cultivated fish. See also polyculture III D 10.

D Technologies used for growing of marine algae.

1 Habitat manipulation.

Seaweed fishermen have old traditions to help desired specie by weeding the bottoms from undesired ones.On soft bottoms rocks ar planted.In Japan stone-planting has been practised for 300 years. Very big stones are necessary,usually between 600 and 700 kg,in order to stand against wave action on open coasts.Concrete boulder and cementing over existing rocs are also practices and is still the basis of <u>Gloiopeltis</u> cultivation in Japan.This genus occurs in a narrow tidal level range where the substrate can be extended by filling low crevices creating a fl-t shelf.

In Chile iron nets were placed on sand bottoms as substrate for <u>Gracilaria</u>.A drawback is that iron has short survival in sea water.

2 Ropes,nets and rafts.

World seaweed production has totally changed over a short period with the introduction of artificial substrates.As mentioned III C this means in particular economically private ownership of t growths,the possibility to use vast areas of the sea,which would otherwise not produce any macroalgae and the possibility to grow particular species or even selected strains of these.Further it gives the chance to enhance growth by adding nutrients and by bringing the cultures to the surface or to the level where growth conditions are optimal.

The shift to cultivation technique started in Japan 1938-47 with the introduction of horizontal nets for Porphyra, their economically most important alga.In addition to the advantages mentioned the nets could be placed at such a level that at low water they remained hanging in the air,which killed compeating green algae,while Porphyra has an extreme capacity of surviving desiccation.

In the Philippines overharvesting depleted the resources of Eucheuma which had given work to many people.A project was started with US assistance and with reserch and farming as main components.From this activity emanates two posters on how to bring information to the public,which cannot be quoted to often.(Fig.10,11

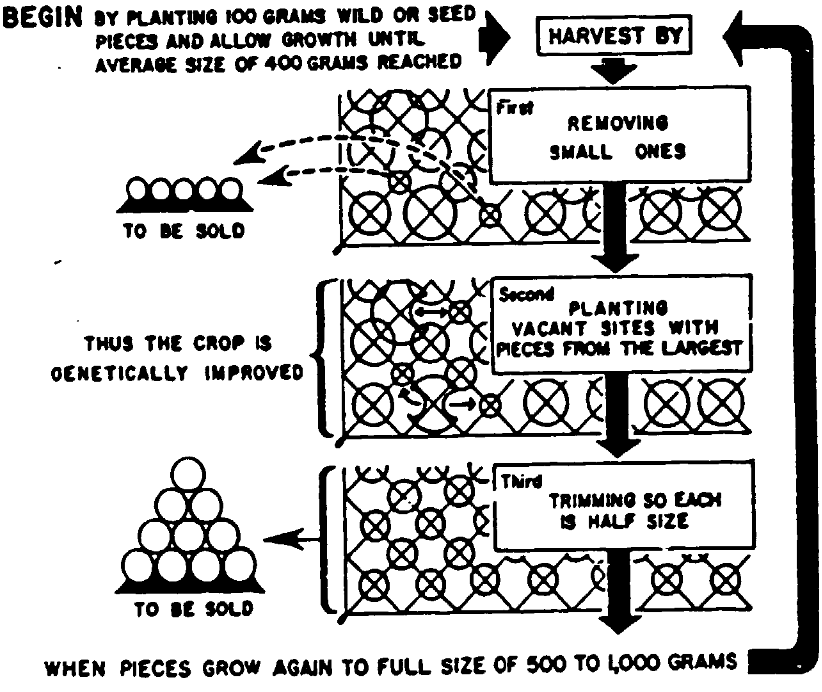


Fig. 10. Net unit method of Eucheuma farming: once begun in a non-seasonal area the harvest and regrowth cycle (broad arrows at right) can be repeated about once a month. With this method genetic improvement of a strain especially suited to higher productivity at particular site is continuous.

from Doty 1973,Doty 1977.

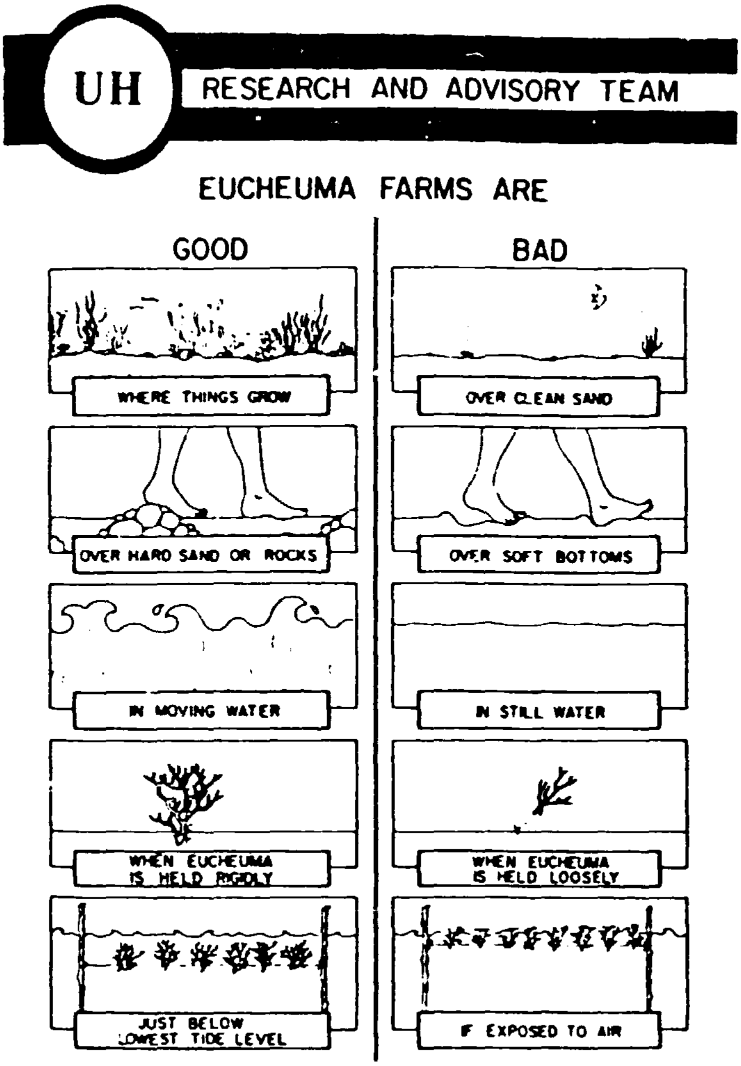


Fig. 11. Poster produced as aid in teaching selection of sites for _Eucheuma_ *farms (also produced in 8½ by 11 inch pads with no words for use of teachers in different colloquial language areas). When sent home with students as a homework assignment, the information is spread to adults in the communities.*

from DOTY 1973,DOTY 1977.

Normally _Eucheuma_ grows continuously and can be propagated vegetatively:when a plant has grown to 800 g or 1 kg it is pruned back to 200 g and just left to continue growing.However,if light is too strong,as it may be over a shallow sand bottom,a phenomenon of "ageinf" occurs and the plants have to be replaced by fresh material.

3 Sowing of spores.

In its natural habitat the water column may contain sufficient of spores to provide a dense culture on lines and nets.Sometimes it fails,and sometimes lots of other species are merging into the desired growth.In 1949 a study of "Conchocelis",an almost microscop shell-boring red alga revealed that actually this is a stage in the life-cycle of Porphyra. Now oyster shells are collected,cleane infected with spores and submersed in grat hatchery ponds ,where nets and lines can be dropped at the proper time and sown with spores.

4 Vegetative propagation.

As mentioned for Eucheuma (III D 2 and fig 10) vegetative propagation is preferable when it is feasable,which is the case with two more economically important red algae:Chondrus and Gracilaria. In nature it is a rule to leave during harvesting the parts which may most rapidly recover into new plants.In cultur it is possible to tear large plants into pieces and let them continue to grow.

5 Tank cultures and greenhouse cultivation.

Considering that open-sea seaweed resources are estimated at 17 million tons.annually one wonders what a few tanks could add to that quantity.For particular growths,however,contolled conditions are essential.In Chondrus for exemple a vegetative cultivation in suspended culture produces the desired kappa-carrageenan.A fast-growing strain is found,which fragments spontaneously,when it reaches the size where it should otherwise have had to be torn into pieces.

In Canada tank cultivation in greenhouses is thought to be a suitable spare-time occupation for fishermen and their families.

6 Upgrading

Other advantages with tank cultivation is the possibility of nutrient addition -- and of nutrient starvation.If a growth is give all nutrients except for nitrogen,it cannot form protein.Among the proteins necessary for a plant are the enzymes which form chlorophyll,phycocyan and other assimilation pigments.A nitrogen-starved alga will very soon lose its colour.To the manufacturer starved alga will very soon loose its colour. To the manufacturer bleeching of his product is expensive,he is willing to pay more for a naturally bleached shipment. Further,when the possibility for the alga to form proteins is blocked,it will increase its carbohydrate content - which is an advantage if the crop is to be used for the extraction of phycocolloids.

7 Pond cultivation and polyculture.

Pond cultivation is suitable for <u>Gracilaria</u> which thrives well in brackish waters.In Taiwan there are considerable areas with ponds which are used for polyculture algae/milkfish or algae/shrimps.

8 Waste recycling.

An application of polyculture systems has the primary aim to remove nutrients from sewage. One of the greatest human wastes is that of waste water.Enormous quantities of nutrients are dumped into rivers and seas where they cause a series of problems. Reasonably they should be brought back to agriculture,and,where this is not feasable,be used in aquaculture and mariculture. A large number of studies has been performed,for references see MICHANEK 1978. See also MATHIESON 1982,Polyculture p 51-53.

9 Bio-gas through large-scale ocean farming or small-scale family units?

In the shadow of the oil crises methane production from algal biomass was tried and a system for extensive cultivation in "marine farms" was designed. The pilot plant broke during the first storm and large-scale fermentation plants did not succeed economically.When oil resources were found to be greater than expected interest in ocean farnming went out of focus. Artificial upwelling was one part of the ocean farm concept, wave energy another.If these two basic prerequisites will be solved,the idea may attract new interest.

Small-scale plants on the other hand have been most successful in the warm-temperate parts of China. In country-side areas, where energy has to be produced locally, a large number of fermentation chambers has been constructed.In Szechwan there were 30 000 units in 1973, 410 000 in mid-75 and in august 1976 2.8 million farmers in Szechwan had their own biogas for light and cooking (IVA 1976).The gas produced has an energy value of 5 300 to 6 300 kcal/m^3 (pure methan gives 9 345 kcal/m^3),and in addition the process gives an organic manure of a very high quality

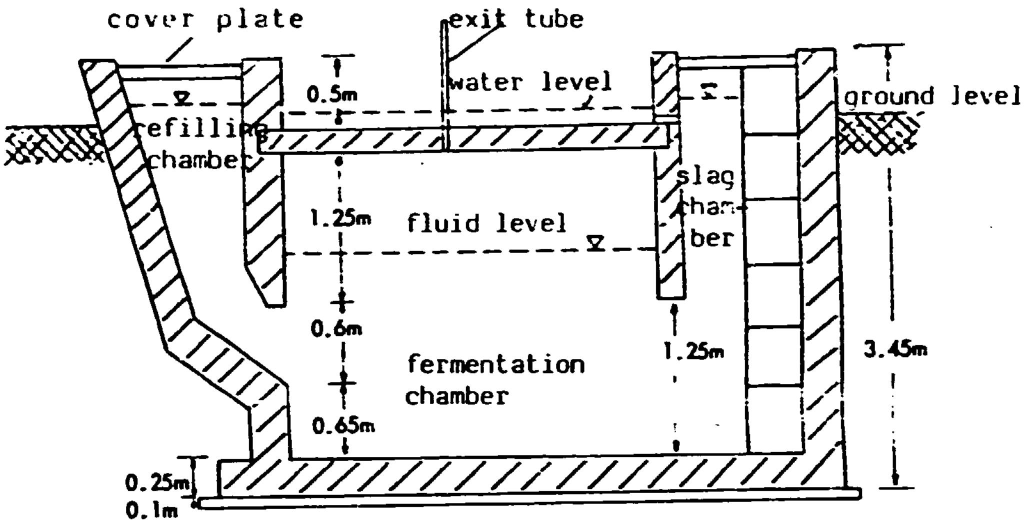


Fig.12 Profile of a typical biogas plant from Szechwan (not to scale) Water flow through a narrow hole (Ø = 5 mm) in the wall between fermentation- and slag chamber effects a stable pressure in the plant. The exit tube is from metal or hard plastic, ca 1 m long and with an inner diameter ca 2 mm.

A typical plant (Fig.12) of 10-15 m^3 consists of three chambers for refilling,fermentation and slag products.It requires a good 100 kg of cement and the price was in 1976 about US$ 13. The best combination of added material was 10% "human garbage", 30% "animal garbage", 10% grass 50% water <u>or</u> 20% "human",30% pig manure and urine, 50% water.The content should be stirred regularily and the chambers carefully cleaned twice a year. Methanogenic bacteria propagate very slowly and are very sensitive to environmental factors. At "mesophilic fermentation" optimal temperature is 28-45°C and should not fluctuate more than 2°C. "Thermophilic fermentation" at 55-60°C is still more sensitive to temperature. The pH should be neutral, 6.8-7.4. Where large quantities of algae are cast ashore,these could contribute largely to the biomass raw material.If seaweed wracks contain living algae,this could include a hazard,as algae produce biocides to protect themselves from bacteria. Therefor they should be sundried before utilization.

10 Microalgae

An astonishing high proportion of academic and governmental resources for studies on algae for food has been spent on research on microalgae. These may under favourable conditions reach very high protein production per area unit.This,however demands high technology and a high level of control measures.It appears that most projects have functioned as long as the experts were present and research money available. It is doubtful if at present any such project is surviving in free competition on the open market.Most promising are microalgae cultivation in the Israel desert and - due to very high prices for the product - Spirulina cultivation in Mexico,Japan and other places.

Rich information on the subject is found in the publications of World Mariculture Society, European Mariculture Society and in a textbook with the misleading title "Algae Biomass"(SHELEF and SOEDER 1980).

11 Summary

A matrix of necessary activities and considerations for successful mariculture is quoted (Tab.10)

E. TECHNOLOGIES USED FOR HARVESTING OF MARINE ALGAE

1. Beach collection

Stranded and floating material is often made up of a mixture of numerous species and therefore not suitable for food or as industrial raw material.It is used all over the world for manure and is especially valuable where the soil is poor in micronutrients,on rock islands where there is no or little soil ,and in arid zones with mineral soils poor in organic material.Due to high water-holding capacity seaweed manure is a very good soil conditioner.

In certain areas one species is so dominating that wracks of stranded seweed may be more or less monospecific. This is the rule in Gracilaria ares.As this alga can grow on sand bottoms,it has no competitors.When it grows in estuaries, there are usually no or few other species,which endure the brackish water.

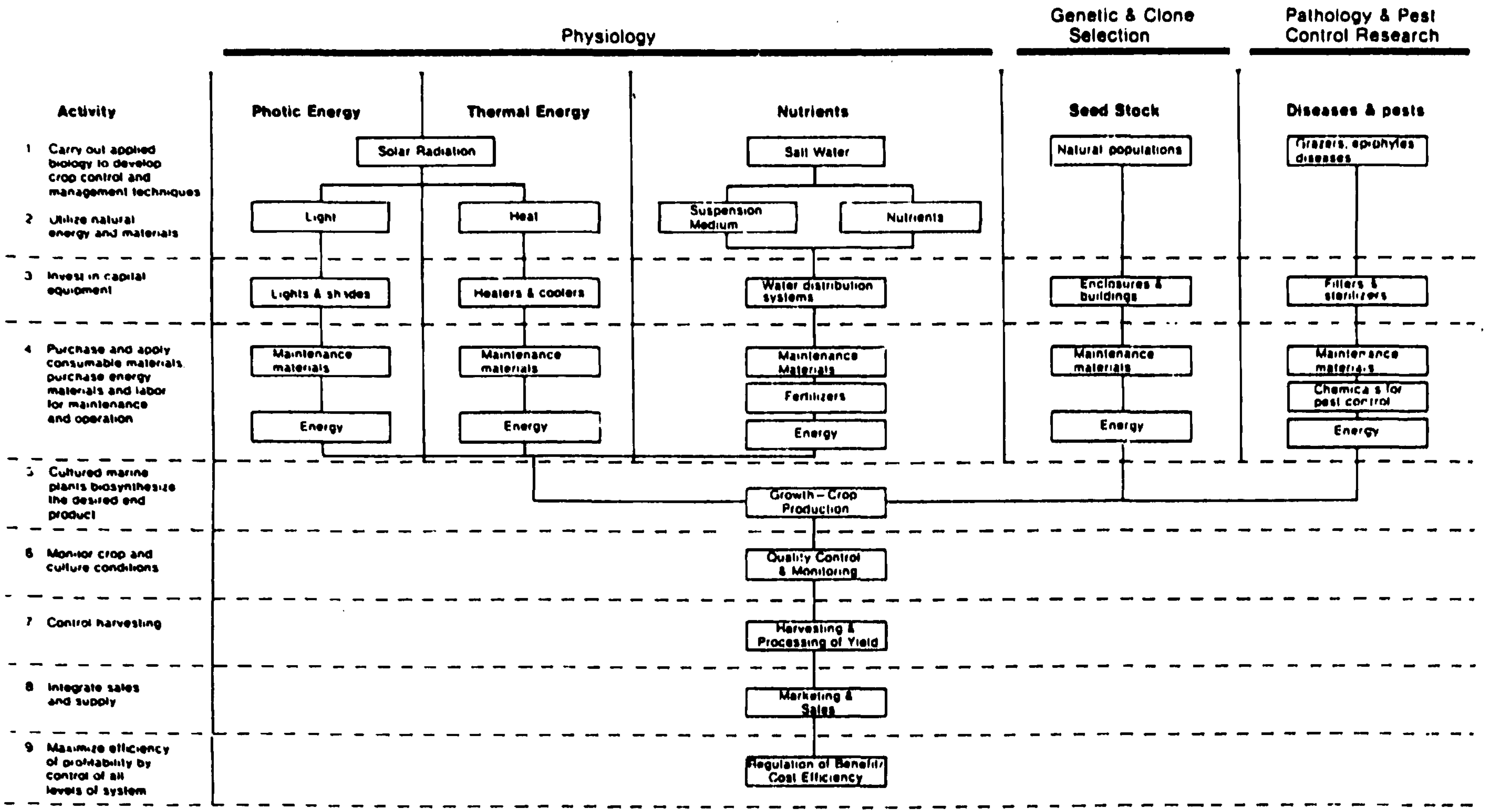
In tourist areas there are places where drift algae are collected primarily in order to clean beaches from nuicance for swimmers.

In stormy regions large amounts of Laminaria,Saccorhiza or Durvillea may be cast ashore where they are easily available for collectors.In Ireland the stipes only were collected.

Intensive Algal Mariculture—A Working Matrix

Permits and Regulations

1. Land Use: watershed, tidal waters, ocean bottom, leasing
2. Building: engineering, architecture
3. Water usage, discharge, monitoring



Tab. 10 A matrix of activities and considerations that must be integrated for the successful mariculture of an alga. (Modified from I. C. Neish, 1979)

from Hansen, Packard & Doyle 1981. Mariculture of red seaweeds

2. Near-shore collection of growing algae.

In tidal areas seaweed is collected at low water.This may appear primitive.but for certain species,like Gelidium in Portugal,conditions favour this simple method.

Among the alginophytes Ascophyllum grows in the intertidal belt.At low water sea farmers go down with tractors and buckets and load their trailors.It is not mentioned if this method follows the rule that 15 cm of the base of the plant should be left to permit a rapid regrowth.

An unusual tool is used in Chile in shallow waters on sandy bottoms in rather open shorelines with heavy surf.Men and boys jump in man-deep water on stilts which entangle and pull up Gracilaria specimens.

In Canada Chondrus is collected with hand rakes.These are designed to remove the mature "moss" fronds and leave the small plants and holdfasts undisturbed. There are primitive hand rakes remaining of a cowberry rake,there are more sophisticated apparatuses on long handles and with a plastic hose into which the cut moss is sucked,carried to the surface and dumped into the boat automatically.On greater depths drag rakes are pulled after boats.

3 Diving for algae

is used both as primitive as sponge diving and with scuba equipment.In Japan it appears that diving for Gelidium is a female profession.

4 Tools for harvesting of natural populations.

A pattern-card of the rich vaiety of tools thought of by brilliant investors is given by OKAZAKI (1971) Fig.13-16. As an exemple of an admirable efficiency I recall asking two boys in a small boat in the Maullín estuary in southern Chile how much they had collected and during how much time.They had gathered two tons in four hours.Their tool was an araña (spider), with eight hooks pulled after the boat. Here,where the collectors gathered ten times as much per unit effort as on other beaches the buyers paied a tenth of the price given in other areas.

In Denmark Furcellaria is loose-lying on bottoms where currents bring them together in large quantities.Trawlers collect it with modified trawls. The Macrocystis ships with "hay-movers" in their sterns,going astern when they collect,and with conveyor belts directly to the store space have already been mentioned (IIIA).

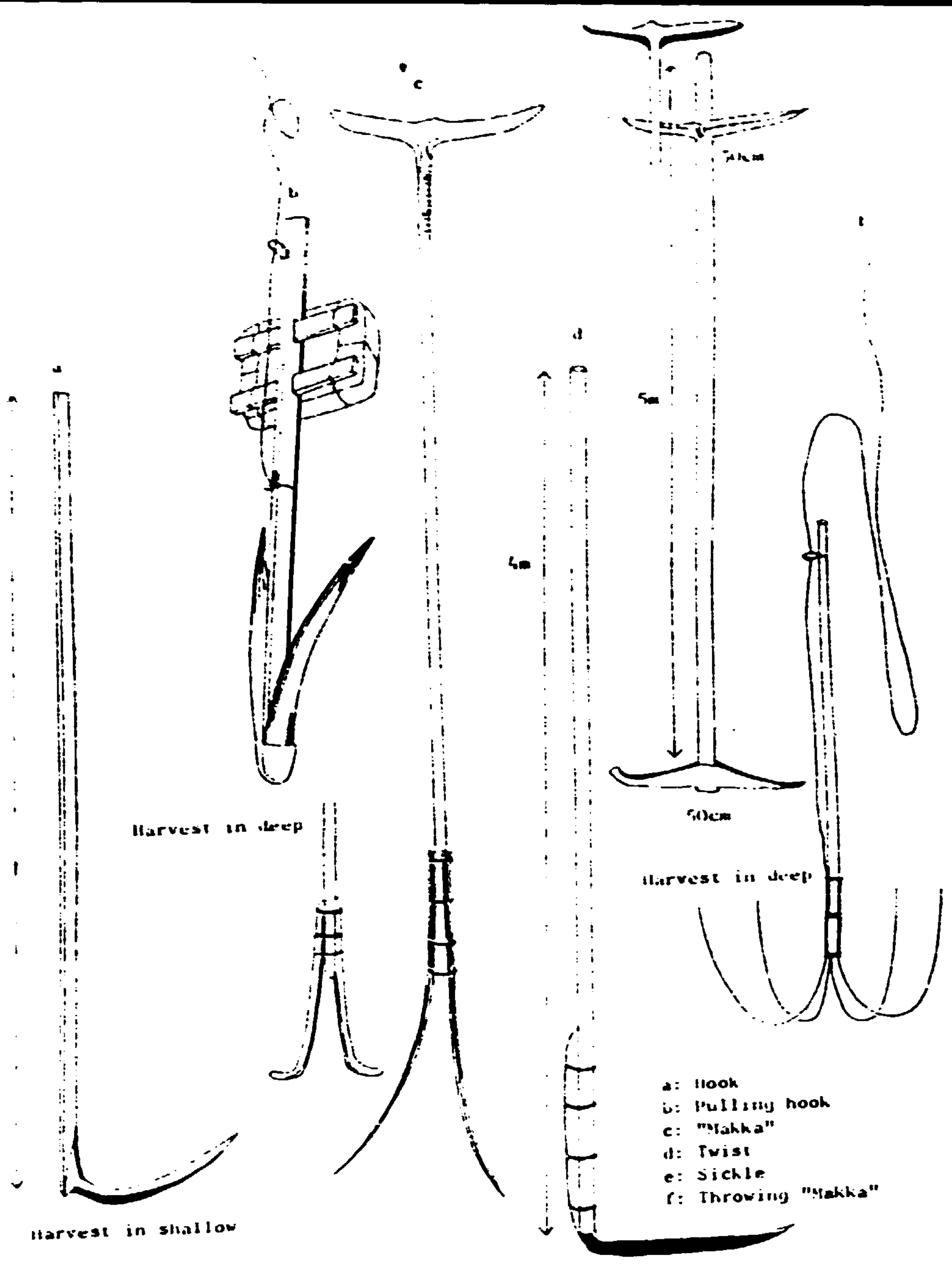
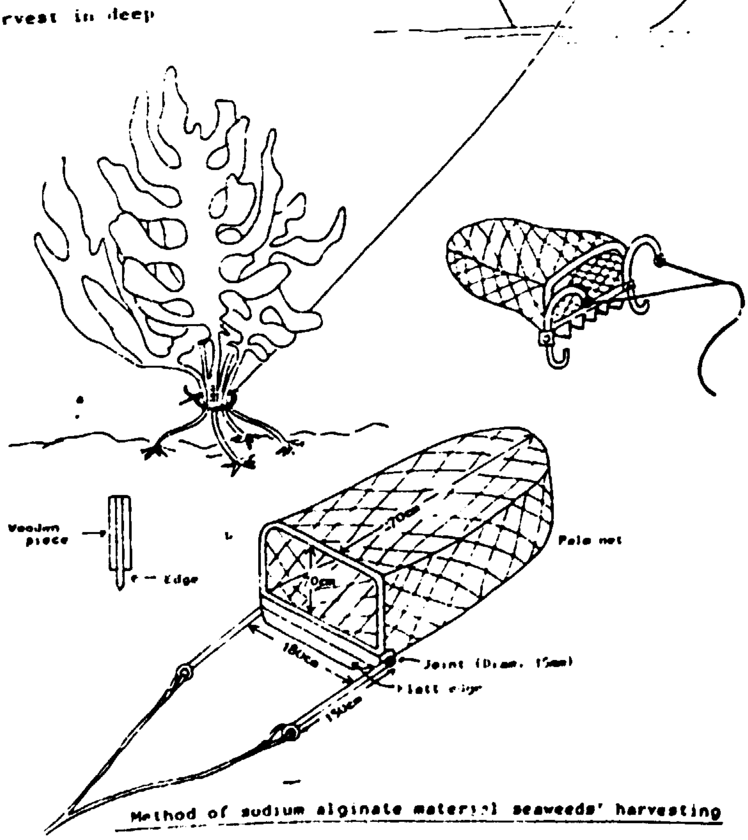


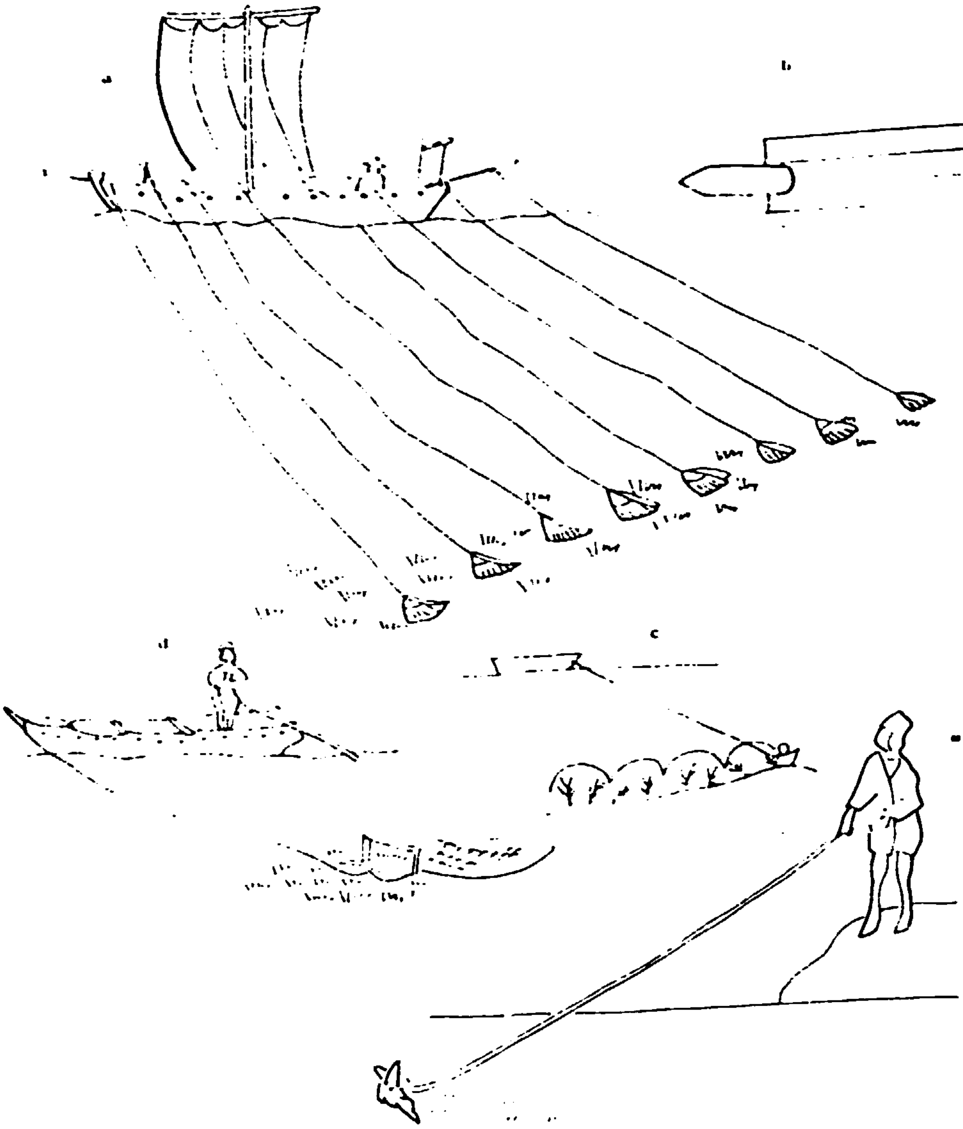
Fig.13. Harvesting tools of "Laminaria"

From OKAZAKI 1971



Method of sodium alginate material seaweeds' harvesting

Fig.14.From OKAZAKI 1971



a The boat moves by sail and trawls "Manga"
b The ship with motor engine trawls "Manga"
c Action of "Manga" in the seabottom
d Seaweed thrown on the seabottom is harvested by trawling tool
e Umbralla type harvester (see Fig.20-g)

Fig.15.From OKAZAKI 1971 "Gelidium" harvesting method

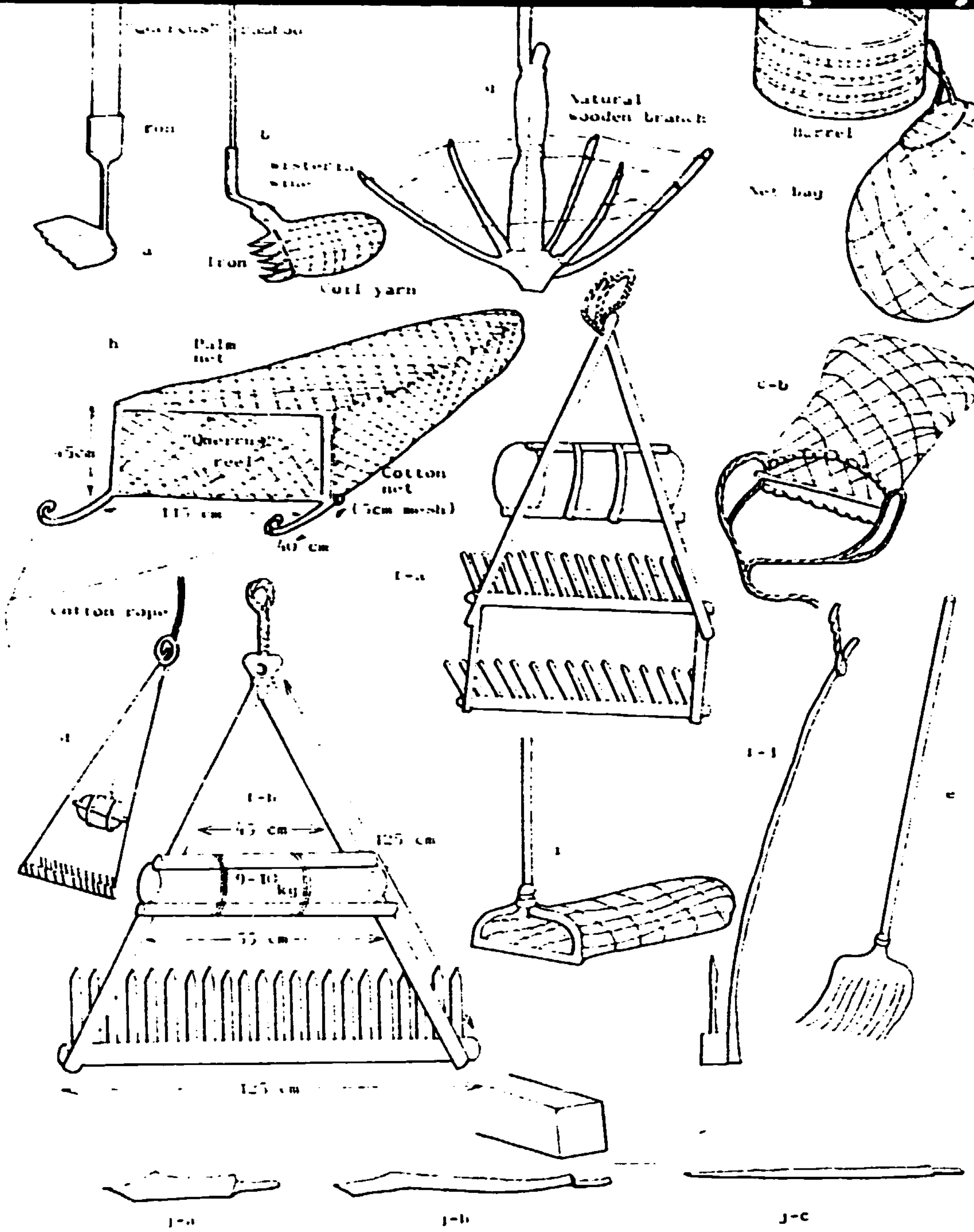


Fig.16.From OKAZAKI 1971 Agar material seaweed harvesting tools

5 Harvesting of cultivated specimen.

There is not much mechanization in the handling of seaweed,known to be very labour-intense.On the contrary, instead of full harvesting a pruning down (Fig.10) is often more economical. Another exemple can be taken from Laminaria cultivation in China.When the band-formed fronds are 2 m long, more than half of them is cut off.The tip is the oldest part and the frond regenerates from a meristeme between stipe and blade.By cutting off the oldest part this is harvested while still in a good condition before it attracts epiphytes and looses matter from its margin. Further the full-grown parts do not longer shadow the younger parts,which can now profit from all the available light and nutrients and grow faster during the remaining part of the vegetative season.

REFERENCES

ABBOT,I.A.and D.P.CHENEY,Commercial uses of algal products:introduction and bibliography. In:Selected Papers in Phycology 2. edited by J.R.ROSOWSKI and B.C. PARKER.Phycological Soc.of America,Lawrence,Kansas 1982. 866p.

ABBOT,I.A.and J.N.NORRIS (Eds) Taxonomy of Economic Seaweeds.With reference to some Pacific and Carribean species. La Jolla,California Sea Grant College Program,Univ.of California. 1985, 167p.

ACLETO OSORIO,C. Algas marinas del Perú de importancia económica. Univ.Mayor de San Marcos,Perú,Museo Hist.Nat."Janvier Prado" Ser.Divulg.5. 1971.85p.

BIXLER,H.J. Manufacturing and marketing of carrageenan.In Actas I Symp.Algas Marinas Chilenas.Edited by B.Santelices.Santiago de Chile 1979 :259-274

BODARD,P.,D.CRISTIAEN and T.STAEDLER, L'agar,phycocolloide des algues rouges. In Plantes et Algues en Cosmétologie et en Phytothérapie.Edited by Y.de Roeck-Holtzhauer.Nantes,1984: 57-69.

BONEY,A.D. Aspects of the biology of the seaweeds of economic importance. Adv.mar.Biol.3. London,Ass.Press 1965.:259-274.

BONOTTO,S.Cultivation of plants.Multicellular plants. In Marine Ecology III edited by O.KINNE. 1976: 467-529.

DAVIDSON,R.L. (Ed.),Handbook of Water-Soluble Gums and Resins. New York, McGraw-Hill,1980

DOTY,M.S., Seaweed farms:a new approach for U.S.Industry. In Mar.Techn.Sos., Proc.Ann.Conf.9. 1973: 701-708

DOTY,M.S. Eucheuma-current marine agronomy In The Marine Plant Biomass of the Pacific Northwest coast.Corvallis.Oregon State Univ.Press. 1977: 203-214.

FAO, Yearbook of Fishery Statistics.Catches and Landings. Rome.

GUIRY,M.D. Commercial exploitation of marine red algal polysaccharides - progress and prospects.Trop.Sci.21 1979: 183-195.

HANSEN, . E for additives. 1984

HANSEN,J.E.,J.E.PACKARD and W.T.DOYLE, Mariculture on red seaweeds.Calif.Sea Grant Coll.Progr.Publ.,La Jolla,1981. 42 p.
(A limited number of copies are available from the California Sea Grant Program,Univ.of California,A-032,La Jolla.California,92093)

HOPPE,H.A.Drogenkunde. 8 ed.Vol.2. Berlin,de Gruyter. 1977. 1-98

INDUSTRIAL BIOTECHNOLOGY oct/Nov 1985

ITC= INTERNATIONAL TRADE CENTRE UNCTAD/GATT.,Pilot Survey of the World Seaweed Industry and Trade. Geneva. 1981. 111p.

IVA=INGENJÖRSVETENSKAPSAKADEMIEN = THE ROYAL SWEDISH ACADEMY OF ENGINEERING SCIENCES, Stockholm,Specialrapport Kina 7704 Biogas - alternativ energikälla 540/500 Stockholm,juni 1976 8p.

KACHROO,P.(Ed.) Proceedings of the Symposium on Algology. Indian Council of Agricultural Research,New Dehli. Kampur. 1960. 406p.

KELLEY.F.C. and W.W.SNEDDEN: Prevalence and geographic distribution of endemic goitre. In Endemic Goitre.World Health Organization Monograph Series,44. 1960. 27-233.

LARSEN,B. Biosynth of alginate. in Int.Seaweed Symp.10. 1981 : 7-34.

LEVRING,T., H.A.HOPPE and O.J.SCHMID. Marine algae: a survey of research and utilization. Bot.Mar.Handb. (1) Berlin,de Gruyter. 1969. 421 p.

LEWIN,R.A.(Ed.),Physiology and biochemistry of algae. New York,Academic Press, 196 929p.

McHUGH,D.G.andB.V.LANIER; The World Seaweed Industry and Trade: Developing Asian producers and Prospects for Great Participation.ADB/FAO INFOFISH Market studies 6 (P.O.Box 899 Kuala Lumpur,Malaysia),1987. 30p.

MATHIESON,A.C.Seaweed cultivation: a review. In Proc.6th US-Japan Meeting on Aquaculture.Edited by C.J.SINDERMAN. U.S.Dept.Commerce Rep.NMFS Circ.442 1982: 25-66.

MICHANEK,G.,Seaweed Resources of the Ocean. FAO Fish.Techn.Pap.(138). 1975.127p.

MICHANEK,G.,Trends in applied phycology. With a literature review:Seaweed ferming on an industrial scale. Bot.Mar. 1978:469-475.

MICHANEK,G.,Seaweed resources for pharmaceutical uses. In Marine Algae in Pharmaceutical Science,edited by H.A.HOPPE,T.LEVRING and Y.TANAKA,Berlin, de Gruyter, 1979:203 235

MICHANEK,G.,Getting seaweed to where it´s needed.Ceres (FAO) Rome,jan-feb 1981

MICHANEK,G.,World resources of marine plants. In Marine Ecology Vol.5,Pat 2 edited by O.KINNE.London,John Wiley and Sons. 1983: 795-837.

MICHANEK,G.Ressources algales pour cosmétologie et phytothérapie. In Plantes et algues en cosmétologie et en phytothérapie.Ed. Y.de Roeck-Holtzhauer.Nant 1984: 261-273.

MSHIGENI,K.E.,Algal resources,exploitation and use in East Africa. In Progress in Phycological Research,Vol.2.Edited by Round and Chapman.Elsevier 1983:387-41

MSHIGENI;K.E. Exploitation of seaweeds in Tanzania: the genus Eucheuma and other algae. Tanzania Notes and Rec.72, 1973: 19-36.

MUBARAK,H. Indonesian seaweed,its resources and culture. FAO,IPFC/80/SYMP/EXP/27 1980. 14p.

NAYLOR,J. Production,Trade and Utilization of Seaweeds and Seaweed Products. FAO Fish.Techn.Pap.(159) 1976. 73p.

OKAZAKI,A.,Seaweeds and their uses in Japan. Tokyo, Tokai Univ.Press,1971. 165p.

PERCIVAL,E. The polysaccharides of green,red and brown seaweeds:their basic struct biosynthesis and function.Br.Phycol.J.14, 1979: 103-117.

REES,D.A. Shapely polysaccharides.Biochem.J.126, 1979: 257-273.

ROECK-HOLTZHAUER,Y.de, Excipients d´origine algosique en cosmétologie et en dermopharmacie. In La France et les Parfums,68, 1970: 11-171

SCHWIMMER,M.and D.SCHWIMMER, The role of algae and plankton in medicine.New York, Grune and Stratton 1955. 85p.

SENN,T.L.and A.R.KINGMAN, Seaweed research in crop production 1958-1978. Clemson,S.C.29631,Dept.of Horticulture,Clemson Univ.1978. 163p.

SHELEF,G.and C.J.SOEDER: Algae Biomass. Production and Use.Amsterdam,Elsevier. 1980. 852p.

TSENG,C.K., Marine phycoculture in China. Proc Xth Int Seaweed Symp.Berlin, de Gruyter ,1981: 123-152.

VOLESKY,B.,J.E.ZAJIC and E.KNETTIG: Algal products. In Properties and products of algae. Edited by J.E.ZAJIC. New York,Plenum Press, 1970: 49-82.

WHISTLER,R.L.(Ed), Industrial Gums.Polysaccharides and their derivates.2 ed. New York,Academic press.

YAPHE;W.and M.DUCKWORTH,The relationship between structures and biological properties of agars. Proc.Int.Seaweed Symp.7., 1972: 15-22.

TABLE
TABLEAU **B-91**
CUADRO

BROWN SEAWEEDS
ALGUES BRUNES
ALGAS PARDAS

SPECIES ESPECE ESPECIE	COUNTRY PAYS PAIS	AREA ZONE AREA	1975 MT	1976 MT	1977 MT	1978 MT
	FRANCE	27	15937	14882	14716	32716
	ICELAND	27	1350	5810	3750	12270
	NORWAY	27	60733	55401	57547	66250
	SPAIN	27	479	979	189	83
	UK SCOTLAND	27	26714	26214	22276	22815
	AREA TOTAL	27	104513	103286	98478	134134
	ARGENTINA	41	1300	722	2061	2061
	AREA TOTAL	41	1300	722	2061	2061
	SOUTH AFRICA	47	45448	43025	54363	25737
	AREA TOTAL	47	45448	43025	54363	25737
	AUSTRALIA	57	0	1080	...	...
	AREA TOTAL	57	0	1080	...	...
	JAPAN	61	294714	327309	306251	245473
	KOREA REP	61	156435	190884	229349	184919
	AREA TOTAL	61	451149	518193	535600	430392
	USA	67	462	250	200	200
	AREA TOTAL	67	462	250	200	200
	AUSTRALIA	71	0	0	...	...
	AREA TOTAL	71	0	0	...	...
	MEXICO	77	27480	41570	41746	30049
	USA	77	155670	155726	159662	160000
	AREA TOTAL	77	183150	197296	201408	190049
	AUSTRALIA	81	0	0	...	...
	AREA TOTAL	81	0	0	...	...
	ITEM TOTAL	5	786022	963852	892110	782573
	GROUP TOTAL	5	786022	963852	892110	782573

SPECIES ESPECE ESPECIE	FISHING AREA ZONE DE PECHE AREA DE PESCA		[illegible] MT	[illegible] MT	[illegible] MT	[illegible] MT
FRANCE		27	[illegible]	25772	35979	[illegible]
ICELAND		27	4423	9733	[illegible]	[illegible]
NORWAY		27	[illegible]	[illegible]	[illegible]	[illegible]
SPAIN		27	587	495	[illegible]	[illegible]
USSR		27	[illegible]	2279	2952	[illegible]
UK SCOTLAND		27	[illegible]	[illegible]	[illegible]	[illegible]
AREA TOTAL		27	[illegible]	[illegible]	[illegible]	[illegible]
ARGENTINA		41	455	343	[illegible]	[illegible]
AREA TOTAL		41	455	342	[illegible]	[illegible]
SOUTH AFRICA		47	[illegible]	[illegible]	[illegible]	[illegible]
AREA TOTAL		47	[illegible]	[illegible]	[illegible]	[illegible]
AUSTRALIA		57	[illegible]	[illegible]	[illegible]	[illegible]
AREA TOTAL		57	[illegible]	[illegible]	[illegible]	[illegible]
CHINA		61	[illegible]	[illegible]	[illegible]	[illegible]
JAPAN		61	[illegible]	[illegible]	[illegible]	[illegible]
KOREA REP		61	[illegible]	[illegible]	[illegible]	[illegible]
USSR		61	[illegible]	[illegible]	[illegible]	[illegible]
AREA TOTAL		61	[illegible]	[illegible]	[illegible]	[illegible]
USA		67	-	-	-	-
AREA TOTAL		67	-	-	-	-
MEXICO		77	[illegible]	23401	[illegible]	[illegible]
USA		77	[illegible]	45735	[illegible]	[illegible]
AREA TOTAL		77	[illegible]	[illegible]	[illegible]	[illegible]
CHILE		87	...	...	...	[illegible]
AREA TOTAL		87	...	...	...	[illegible]
ITEM TOTAL		5	2473218F	[illegible]	[illegible]	[illegible]
GROUP TOTAL		5	2473218	2181930	2275561	[illegible]

TABLE
TABLEAU **B-92**

RED SEAWEEDS
ALGUES ROUGES

SPECIES ESPECE	COUNTRY PAYS	AREA ZONE	1975 MT	1976 MT	1977 MT	1978 MT
	CANADA	21	36130	24396	22202	32051
	USA	21	1692	1814	938	551
	AREA TOTAL	21	37822	26210	23140	32602
	FRANCE	27	2813	3180	1336	2008
	SPAIN	27	5180	5180	4959	6745
	AREA TOTAL	27	7993	8360	6295	8753
	MOROCCO	34	5005	5005	5005	5005
	AREA TOTAL	34	5005	5005	5005	5005
	ARGENTINA	41	16700	14946	20683	20683
	URUGUAY	41	85	200	100	76
	AREA TOTAL	41	16785	15146	20783	20759
	SOUTH AFRICA	47	179	181	89	170
	AREA TOTAL	47	179	181	89	170
	MADAGASCAR	51	200	0	0	0
	AREA TOTAL	51	200	0	0	0
	INDONESIA	57	12	273	301	309
	AREA TOTAL	57	12	273	301	309
	JAPAN	61	290231	301804	290665	361763
	KOREA REP	61	53153	54987	64920	34677
	OTHER NEI	61	5749F	6940F	7449F	7449F
	AREA TOTAL	61	349133F	363731F	363034F	403889F
	USA	67	-	0	0	-
	AREA TOTAL	67	-	0	0	-
	INDONESIA	71	8414	3477	3797	3938
	PHILIPPINES	71	73	59	150	33938
	AREA TOTAL	71	8487	3536	3947	37876
	MEXICO	77	4361	4377	17584	6490
	USA	77	29	0	10	10
	AREA TOTAL	77	4390	4377	17594	6500
	NEW ZEALAND	81	0	0	0	0
	AREA TOTAL	81	0	0	0	0
	CHILE	87	30000	30000	30000	30000
	AREA TOTAL	87	30000	30000	30000	30000
	ITEM TOTAL	5	460006F	456819F	470188F	545863F
	GROUP TOTAL	5	460006F	456819F	470188F	545863F

CANADA	21	19318	24440	21580	18433
USA	21	458	-	-	-
AREA TOTAL	21	19776	24440	21580	18433
ANCE	27	2787	1817	1616	2566
PORTUGAL	27	13181	14810	11072	11270F
SPAIN	27	5972	4463	3758	3603
USSR	27	229	225	283	232
AREA TOTAL	27	22169	21315	16729	17671F
MOROCCO	34	5005F	5005F	5005F	5005F
AREA TOTAL	34	5005F	5005F	5005F	5005F
ARGENTINA	41	14284	12891	12276	10740
URUGUAY	41	-	-	-	-
AREA TOTAL	41	14284	12891	12276	10740
SOUTH AFRICA	47	663	661	1191	590
AREA TOTAL	47	663	661	1191	590
MADAGASCAR	51	0	0	0	0
TANZANIA	51	0	0	0	0
AREA TOTAL	51	0	0	0	0
INDONESIA	57	490	216	413	543
THAILAND	57	70	63	72	123
AREA TOTAL	57	560	279	485	666
CHINA	61	72120	70290	65150	99873
JAPAN	61	367535	349498	272430	282002F
KOREA REP	61	66221	88100	87323	95399
USSR	61	2300	2193	1197	1952
OTHER NEI A	61	10109F	11272F	10239F	10403F
AREA TOTAL	61	517983F	521290F	439309F	487601F
USA	67	-	-	-	-
AREA TOTAL	67	-	-	-	-
INDONESIA	71	7358	7035	7066	7529
PHILIPPINES	71	115652	86261	109239	132607
THAILAND	71	848	312	40	69
AREA TOTAL	71	123858	93608	116345	140205
MEXICO	77	10276	8874	5378	5000F
USA	77	-	-	-	-
AREA TOTAL	77	10276	8874	5378	5000F
NEW ZEALAND	81	26	12	7	31
AREA TOTAL	81	26	12	7	31
CHILE	87	74523	109631	173375	136762
PERU	87	361	325	275	300F
AREA TOTAL	87	74884	109956	173650	137062F
ITEM TOTAL	5	789484F	798309F	791955F	822801F
GROUP TOTAL	5	789484	798309	791955	822801

TABLEAU **B-93** ALGUES VERTES ET AUTRES ALGUES
CUADRO ALGAS VERDES Y OTRAS ALGAS

SPECIES ESPECE ESPECIE	COUNTRY PAYS PAIS	AREA ZONE AREA	1975 MT	1976 MT	1977 MT	1978 MT
GREEN SEAWEEDS ALGUES VERTES ALGAS VERDES			CHLOROPHYCEAE 7,01 SWG			
	MEXICO	02	–	7	–	200
	AREA TOTAL	02	–	7	–	200
	JAPAN	04	633	566	363	495
	AREA TOTAL	04	633	566	363	495
	ARGENTINA	41	10	2	5	5
	AREA TOTAL	41	10	2	5	5
	KOREA REP	61	1844	2763	2112	2107
	AREA TOTAL	61	1844	2763	2112	2107
	FIJI	71	5	5	7	7
	AREA TOTAL	71	5	5	7	7
	ITEM TOTAL	S	2492	3343	2487	2814
GROUP TOTAL		S	2492	3343	2487	281

GREEN SEAWEEDS AND OTHER ALGAE
ALGUES VERTES ET AUTRES ALGUES
ALGAS VERDES Y OTRAS ALGAS

SPECIES ESPECE ESPECIE	FISHING AREA ZONE DE PECHE AREA DE PESCA		1980 MT	1981 MT	1982 MT	1983 MT
GREEN SEAWEEDS ALGUES VERTES ALGAS VERDES			CHLOROPHYCEAE 7,01 SWG			
	MEXICO	02	133	–	–	–
	AREA TOTAL	02	133	–	–	–
	JAPAN	04	663	363	574	600F
	AREA TOTAL	04	663	363	574	600F
	ARGENTINA	41	–	–	–	2
	AREA TOTAL	41	–	–	–	2
	KOREA REP	61	8301	4111	8236	13150
	AREA TOTAL	61	8301	4111	8236	13150
	FIJI	71	13	7	10	11
	AREA TOTAL	71	13	7	10	11
	ITEM TOTAL	S	9110	4481	8820	13763F
GROUP TOTAL		S	9110	4481	8820	13763

TABLE
TABLEAU **B-94** MISCELLANEOUS AQUATIC PLANTS
CUADRO PLANTES AQUATIQUES DIVERSES
DIVERSAS PLANTAS ACUATICAS

SPECIES ESPECE ESPECIE	COUNTRY PAYS PAIS	AREA ZONE AREA	1975 MT	1976 MT	1977 MT	1978 MT
SEAWEEDS NEI ALGUES NCA ALGAS NEP			ALGAE 7,00 SWX			
	CANADA	21	3953	6398	12451	3258
	AREA TOTAL	21	3953	6398	12451	3258
	FRANCE	27	2534	1069	770	2115
	USSR	27	4526	1960	1520	1574
	AREA TOTAL	27	7060	3029	2290	3689
	ITEM TOTAL	S	11013	9427	14741	6947
AQUATIC PLANTS NEI PLANTES AQUATIQUES NCA PLANTAS ACUATICAS NEP			ALGAE 7,99 APL			
	KOREA REP	04	93	79	110	58
	AREA TOTAL	04	93	79	110	58
	USSR	07	–	–	–	1974
	AREA TOTAL	07	–	–	–	1974
	GERMANY FR	27	–	–	–	–
	AREA TOTAL	27	–	–	–	–
	MOROCCO	34	122	122	122	122
	SENEGAL	34	360	–	–	51
	AREA TOTAL	34	482	122	122	173
	USSR	37	–	–	–	8896
	AREA TOTAL	37	–	–	–	8896
	ARGENTINA	41	–	–	–	–
	AREA TOTAL	41	–	–	–	–
	USSR	47	–	–	1	–
	AREA TOTAL	47	–	–	1	–
	TANZANIA	51	50	81	100	110
	AREA TOTAL	51	50	81	100	110
	THAILAND	57	–	–	8	8
	AREA TOTAL	57	–	–	8	8
	JAPAN	61	41955	36323	41291	30889
	KOREA REP	61	35071	38745	37102	37096
	USSR	61	–	–	–	2534
	OTHER NEI	61	3280F	1440F	1632F	1632F
	AREA TOTAL	61	80306F	76508F	80025F	72151F
	THAILAND	71	148	608	1407	1439
	AREA TOTAL	71	148	608	1407	1439
	ITEM TOTAL	S	81079F	77398F	81773F	84809F
GROUP TOTAL		S	92092F	86825F	96514F	91756F

MISCELLANEOUS AQUATIC PLANTS
PLANTES AQUATIQUES DIVERSES
DIVERSAS PLANTAS ACUATICAS

SPECIES ESPECE ESPECIE	FISHING AREA ZONE DE PECHE AREA DE PESCA		1980 MT	1981 MT	1982 MT	1983 MT
AQUATIC PLANTS NEI PLANTES AQUATIQUES NCA PLANTAS ACUATICAS NEP			ALGAE 7,99 APL			
	KOREA REP	04	115	70	72	96
	AREA TOTAL	04	115	70	72	96
	CANADA	21	8599	5306	3474	5900
	AREA TOTAL	21	8599	5306	3474	5900
	FRANCE	27	1672	1167	3265	821
	USSR	27	1273	1701	753	485
	AREA TOTAL	27	2945	2868	4018	1306
	MOROCCO	34	122F	122F	122F	122F
	SENEGAL	34	51F	51F	51F	51F
	AREA TOTAL	34	173F	173F	173F	173F
	ITALY	37	2580	2670	2750	2850
	USSR	37	12509	11904	9649	8649
	AREA TOTAL	37	15089	14574	12399	11499
	ARGENTINA	41	–	–	–	–
	AREA TOTAL	41	–	–	–	–
	HONG KONG	61	12	5	5	4
	JAPAN	61	35153	36685	38413	41500F
	KOREA D P RP	61	...	–	–	–
	KOREA REP	61	16957	16419	5334	12464
	USSR	61	–	–	–	–
	OTHER NEI A	61	863F	310F	564F	500F
	AREA TOTAL	61	52985F	53419F	44316F	54468F
	COOK ISLANDS	77	24F	24F	24F	24F
	AREA TOTAL	77	24F	24F	24F	24F
	ITEM TOTAL	S	79930F	76434F	64476F	73466F
GROUP TOTAL		S	79930	76434	64476	73466