FAO Fisheries Technical Paper, No. 138
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FIRS/T138
WAFR - Area Review

SEAWEED RESOURCES OF THE OCEAN

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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- MFS Editions provisoires des «Manuels FAO de science halieutique»
- WAFR Synthèses provisoires des ressources halieutiques et leur niveau d'exploitation, préparées, par régions ou groupes d'espèces, dans le cadre du Programme mondial pour l'évaluation des ressources halieutiques

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- CB Listas de periódicos, secciones especiales de la «Aquatic Sciences and Fisheries Abstracts (ASFA)», bibliografías especiales y trabajos relativos a los problemas de documentación
- MFS Ediciones provisionales de los «Manuales de la FAO de Ciencias Pesqueras»
- WAFR Reseñas provisionales de los recursos pesqueros y de su estado actual de explotación, por regiones o por grupos de especies, en el marco del sistema mundial para la evaluación de los recursos pesqueros

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SEAWEED RESOURCES OF THE OCEAN

by

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 1975

PREPARATION OF THIS DOCUMENT

This paper is a revision of "A Preliminary Appraisal of World Seaweed Resources", published as FAO Fisheries Circular No. 128, 1971, by G. Michanek, then of Marine Biology and Environment Branch, Fishery Resources Division, Department of Fisheries, FAO, Rome.

Support for the work of Dr. Michanek (who is now at the Marine Botanical Institute, Gothenburg, Sweden) has been received from the FAO/UNEP Project on Monitoring of Environmental Effects on Marine World Fishery Resources.

Distribution

FAO Department of Fisheries
FAO Regional Fisheries Officers
FAO Regional Fishery Councils
and Commissions
Selector SM
Author

Bibliographic entry

Michanek, G. (1975)
FAO Fish.Tech.Pap., (138):127 p.
Seaweed resources of the ocean

Seaweeds. Seaweed culture. Seaweed products. Seaweed statistics. Harvesting. Resource availability. Biomass. Commercial species. Human food. Geographical distribution. World ocean.

CONTENTS

INTRODUCTION

This review of the seaweed resources of the world is part of a continuing programme of evaluating the resources from the sea of food, in a wide sense. These studies of the potential harvest are an important step towards the better planning of the proper use and management of these resources. The area breakdown is that used by FAO in compiling and publishing fishery statistics (see chart at end).

Quantitative studies of seaweeds are much rarer than those of fish stocks. The exceptions could be indicated by a few spots on the world map – the southwest coast of Norway, Scotland, Nova Scotia, the Californian kelp beds. The rest of the map is a blank space. This review is a first attempt to fill that space, but is primarily a challenge to field phycologists to produce the data from which a better evaluation of the world's seaweed resources can be made.

Since this study concentrates on resource assessment, the potential harvest, and related quantitative studies, less emphasis has been given to studies on relative distribution, seasonal variation, mode of reproduction, etc. except where these are of direct interest to present or future utilization. However, for the areas for which suitable quantitative data are not yet available, ecological and similar information has been used to give an idea of the structure and composition of the flora, and thus provide a first approximation to the potential harvest.

Any study of this kind must distinguish between biomass (or standing stocks) on the one hand and production or potential harvest on the other; further, a distinction needs to be made between the theoretically attainable harvest and that which is feasible in the light of practical and economic constituents.

Locally we often see the richest kelp pastures on plumb battered rocks, where no boat can stay in the breakers, or in the surf area, where no diver can find a holdfast. Uninhabited arctic and cold temperate areas may be extremely rich in biomass, but even if collectors could be flown in from distant places, the transport costs for untreated seaweed or partly processed product put the resource out of all competition.

Rockweed of the genera Fucus and Cystoseira are among the richest producers if we estimate the bulk of seaweed in the ocean, but it is not yet solved how to use them. We know that certain laboratories study this problem, but have not yet seen their results being applied on an industrial scale. The same could be said about turtle grass, eel grass and other phanerogams, and mass occurrences of protein-rich Caulerpa green algae. A hindrance for the utilization of seaweeds in most areas is that they do not occur in single species stands but extremely mixed and entangled, often as epiphytes on each other.

Taken as a whole, seaweed resources are not greatly exploited. The potential for increasing the seaweed harvest depends as much on economic factors – the demand for the products and the costs of harvesting and processing – as on the overall biological production. Assuming no great changes – i.e. considering only the seaweed crops that consist of a sufficiently rich occurrence of a commercially attractive species occurring in areas where they can be really harvested, processed and marketed – the global production of the most important group, the red algae, could be increased by about 50 percent. The biomass of kelp and rockweed beds would permit a twentyfold increase in utilization of brown algae.

Several factors could act to support even greater expansion. On the production side seaweed harvesting can be labour-intensive; this could be a great advantage in the numerous developing countries where unemployment, and under-employment, are growing social problems. On the marketing side, the continuing growth of world population will produce an increase in demand not only for direct food but also for the various other products in which many seaweeds are rich. The possibilities for expansion may be judged by the temporary boom of seaweed industries in many parts of the world in the early 1940s, when local seaweed production expanded to fill the gap left by the failure of supplies from abroad. Under such changed balance of supply and demand a tenfold increase in present world harvest would not be unrealistic.

It is not the aim of this review to deal in detail with the technical and economic aspects of the processing and marketing of seaweeds, which have been discussed extensively elsewhere. Commercial products from seaweeds are encyclopedically treated in Levring, Hoppe and Schmid (1969). Another section of the same handbook takes into separate consideration those species of seaweeds which are of interest as raw material or foodstuff. Further references can be found in "Selected Bibliography on Algae", issued by Nova Scotia Research Foundation, P.O. Box 790, Dartmouth, Nova Scotia. This has appeared with 13 numbers containing references to scientific, technical and popular literature including most valuable sections on cultivation, utilization, economy, industrial methods and patents.

The economic and commercial aspects of seaweed utilization have been subject to remarkably few published investigations as compared to ecological and biochemical aspects. Haken (1958) gave a brief account of the major seaweed product industries in the mid-1950s; a more recent review of the major seaweed products and their origin with data on industries and value was prepared by Silverthorne and Sorensen (1971).

Information on seaweed trade, prices, market trends and technical literature is regularly reported by International Seaweed Exchange, 24 Southwark Street, London, SE1 1TU, in a market information bulletin, mainly intended for sellers and buyers transacting through the Exchange.

The Department of Fisheries of FAO is presently undertaking a comprehensive review of the economic and commercial potential of the world's algaic resources, to be published as one of its Commodity Study series; the study will examine trends in the production of seaweeds and seaweed products, their utilization, trade and consumption. In presenting perspectives of likely future demand for such products it will try to indicate possible opportunities, particularly in the developing countries, for achieving higher levels of production and utilization.

A revision and updating of figures and statements in this paper is foreseen. Readers are invited to send any comments and proposals to Aquatic Resources Survey and Evaluation Service, Fishery Resources and Environment Division, FAO, Rome, Italy, or directly to the author.

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FISHING AREA 18 : ARCTIC SEA

The Arctic Sea is not very hospitable for algal growth. Even when the shore waters are temporarily free from covering ice, ice floes are grinding on the shoreline during part of this time. Big rivers and melting snow often dilute shore waters and cause great variations in salinity. At low tide shores may be exposed to very low temperatures. Silt deposits cover the bottoms of vast areas. Therefore, the greatest mass of Arctic marine vegetation lies between depths of 10-25 m, whereas in temperate waters most of the vegetation lies above 15 m (Wilce, 1967).

1. U.S.S.R.

In the Kara Sea, Kjellman (1877) found 26 species among which three laminarian and one *Fucus*. The *Laminaria* species reached:

L. solidungula	78 cm
L. saccharina (as *L. agardhii*)	267 cm
L. digitata	197 cm

The littoral had no algae, not even when the bottom was favourable with rocks or boulders. The sublittoral findings were "unusually luxuriant". Conditions are somewhat better in the eastern parts of the Kara Sea at Tajmyr Island and further east in the East Siberian Sea.

2. Alaska

The absence of macroscopic benthic algae is the most striking feature of the marine biota of Point Barrow, the northernmost point of Alaska's north coast, according to Mohr, Wilimovskii and Dawson (1957). This is directly connected with the presence of sediments. There are however exceptions and the authors have examined a kelp bed near 71°N dominated by *Laminaria solidungula* (published as *Phyllaria dermatodea*). *Laminaria saccharina* and *Desmarestia viridis* were also abundant. The deeper part of the bed was occupied by red algae. One of these, *Phycodrys sinuosa*, was also strewn on the beach in large quantities after a week of heavy seas.

3. Canada

Ungava Bay, east of Hudson Bay, is described by Wilce (1959). It has a tidal amplitude of 13 m. Extensive mud flats are covered with silt. Large numbers of individuals of a few species of green and blue-green algae form a low continuous turf. Sheltered niches associated with the mud flats support meagre populations of *Fucus vesiculosus*, *F. distichus*, *Ascophyllum*, and temporarily rich populations of many annual green and brown algae. In protected shallows the bulk of the vegetation is formed by *Ascophyllum nodosum*, *Fucus distichus* and *F. vesiculosus*. On moderately exposed coasts the intertidal rocks are covered by *Fucus distichus evanescens* *Chordaria flagelliformis* may completely dominate the lower shore and upper sublittoral where this is uninhabited by large perennials. In the sublittorals of these moderately exposed coasts, Wilce found immense kelp in large and often discrete beds, forming veritable forests of vegetation, the bulk of which consists of *Laminaria longicruris* 10-12 m long. On fully exposed coasts the movements of the ice floes and water prohibit extensive plant growth in the littoral.

The sublittoral of exposed coasts is dominated by large populations of the laminarians *Agarum*, *Laminaria* and *Alaria*. Several red algae, e.g. *Kallymenia schmitzii*, occur in considerable amounts. As a fifth habitat type Wilce describes the low littoral tide pools which are densely colonized by *Fucus distichus* and towards the bottom by small kelp of which *Laminaria nigripes*, *L. saccharina* and *Alaria grandifolia* constitute the "nigripes" association. Up the mouth of a river in the southernmost part of the bay, the pool vegetation was dominated by Cladophora glaucescens and Calothrix scopulorum and also contained other annual euryhaline green and blue-green algae. (Of the species mentioned, Laminaria digitata and L. nigripes are subarctic and do not occur in the true arctic from a biogeographic point of view.)

CONCLUSION

Most of the Arctic Sea does not provide accommodation for seaweed resources in harvestable quantities. In a few favoured places considerable amounts occur, but at present it would be very hard to harvest them. Weather conditions and available labour are unfavourable and a possible harvest would have to be transported over long distances.

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FISHING AREA 21 : NORTHWEST ATLANTIC

Following the International Commission for the Northwest Atlantic Fisheries (ICNAF) this water area is divided into five subareas as follows:

1. West Greenland
2. Labrador
3. Newfoundland
4. Nova Scotia and Gulf of St. Lawrence
5. New England

A sixth area has been added statistically (facultatively) – the Chesapeake area.

Harvesting of natural resources of seaweeds, mainly Chondrus, and the processing of carrageenan is rapidly developing in the Atlantic provinces of Canada. The landed value of seaweeds in subareas 3 and 4 is approximately U.S.$3 million. In 1968 the carrageenan produced was worth U.S.$11 million.

1. West Greenland

No records on standing crops. According to Lund (1959, 1959a), 153 species of benthic algae are recorded from West Greenland (48 green, 60 brown and 45 red algae). Among these are seven kelp and three rockweed species: Saccorhiza dermatodea, Laminaria solidungula, L. groenlandica, L. longicruris, L. nigripes, Agarum cribrosum, Alaria pylaii, Fucus vesiculosus, F. distichus and Ascophyllum nodosum. Five of these have been recorded north of 78°N. Ascophyllum commonly occurs south of 67°N, where it would constitute a potential resource. The Eskimoes are reported to use young shoots of Ascophyllum as a dietary supplement (Baardseth, 1970).

Estimates of algal mass are given by Wilce (1963) but only in a relative way. According to his figure, the littoral algae of K'anak at 76°30'N on West Greenland amount to 12 percent of the algal mass at Halifax and Bergen, and the sublittoral algae amount to 28 percent. If, in order to obtain quantities from these relative figures, we estimate the wet weight of the algae of Halifax and Bergen to average 10 kg/m^2 in the littoral and 15 kg/m^2 in the sublittoral, we get roughly:

Wet weight kg/m^2	Littoral	Sublittoral
K'anak 76°30'	1.2	4.2
Godhavn 70°	2	7.5
Baffin Island 70° (Area 18)	1.1	3.3
Port Burwell 60°25' (Area 18)	4.4	9.2

It must be borne in mind, however, that Wilce's staple diagram "Estimates of Algal Mass" is not referred to any measurements and is presumably meant to express his personal impressions only. I would not have tried to recalculate these impressions into figures if they had not been the only indications on the possible size of algal quantities in arctic waters which I have seen in the literature.

2. Labrador

No quantitative records are available. An excellent description of the physical characteristics of the area and the ecology and distribution of the algae is given by Wilce (1959), already quoted in the Arctic Sea chapter (p. 3). Wilce reports his observations according to habitat types and does not differentiate between geographic areas. More than any other single factor, the Labrador Current flowing southward along the Labrador coast produces the greatest effect on the life, both marine and terrestrial, of this area. The seasonal influx of fresh water through May and June freshens and raises the temperature of the surface layers of the fjords (e.g. Hebron Fjord). This is the main reason for the lack of marine life in the littoral and upper sublittoral of the relatively quiet bays and fjords. Many such areas are almost completely devoid of algae and have the appearance of a freshwater lake shore. In protected shores there is a *Fucus* belt followed by *Ascophyllum*.

Moderately exposed coasts are richest in species, many of them annual. There are a few potentially useful species, *Fucus vesiculosus* and *F. distichus*, no *Ascophyllum*, and some *Laminaria longicruris*. By dredging, Wilce found areas of almost pure stands of *Agarum cribrosum* in Okak Bay and *Saccorhiza dermatodea* in Nutak Bay. Fully exposed coasts support meagre populations of algae. Deepwater communities are the largest. The dominant algae are *Laminaria nigripes* and *Alaria grandifolia*. Among the most prevalent red algae are *Halosaccion ramentaceum* and *Rhodymenia palmata* which can be eaten or used for fodder. In tide pools there are *Fucus* spp.

3. Newfoundland

There are no quantitative estimates.

The first attempt to survey the seaweed resources of Newfoundland was made by Humm (1948, 1950), who examined many of the more accessible areas of the east coast including the Avalon and Burin Peninsulas. Subsequent collections and surveys include those of Wilce (1959), who collected at four locations on the west coast and described the ecology of the west coast of Newfoundland in the Gulf of St. Lawrence; H. Lilly (1965), who examined much of the west coast for exploitable beds of *Chondrus crispus*; Lee (1968, 1969) who collected algae at various places on the Avalon Peninsula and in Port au Port Bay; G. Lilly (1968), who examined some aspects of the ecology of *Chondrus crispus* and associated seaweeds at several places around Newfoundland; Mathieson, Dawes and Humm (1969) who listed a total of 155 species of marine algae. South (1970) has produced a checklist of marine algae from Newfoundland, Labrador and the French Islands of St. Pierre and Miquelon in which are listed a total of 211 species and subspecies. For the entire eastern coast of Canada the total is 371 taxa, consisting of 157 Rhodophyceae, 127 Phaeophyceae and 87 Chlorophyceae (South and Cardinal, 1970).

The west coast of Newfoundland is characterized by a limestone substrate, a flat coastal relief and relatively high summer water temperatures, and although ice cover is often present during the winter, there is no severe exposure to ice movements (Wilce, 1959). The east coast is subject to much more severe scouring by ice, generally cooler sea water temperatures and extensive grazing by sea urchins, *Strongylocentrotus droebachiensis*. These factors combine to eliminate the bulk of the mid-sublittoral vegetation on the east and south coasts. The residual flora in such areas consists mostly of crustose corallines, *Agarum cribrosum*, *Desmarestia* spp. and occasional small plants of other species in crevices (Mathieson, Dawes and Humm, 1969). *Laminaria* spp., *Alaria*, *Saccorhiza*, *Ptilota* and *Rhodymenia* are common and locally abundant.

Harvesting of *Chondrus* which, during a trial period in 1941–43 gave 13, 7 t and 5 t respectively (Humm, 1948), has since 1968 been taken up again on the west coast. Humm estimated the quantities of moss would be sufficient to warrant commercial utilization, but not to the point of providing a factory with all its raw material requirements.

Ascophyllum nodosum is present in what could be commercial quantities in many areas, and has been used as a fertilizer in numerous parts of the island. South and Hill (1970) described extensive populations of the free-living *A. nodosum* form *mackaii* at 10 localities in Newfoundland; the largest population of 0.25–0.3 km^2 in extent occurs in Bonavista Bay.

Extremely large quantities of the red alga *Ptilota serrata* are found in the drift along much of the Newfoundland coastline, especially after autumn storms. These have been referred to by Humm (1948), Templeman (1966) and Levring, Hoppe and Schmid (1969). To date no suitable commercial use has been found for this species. Other Rhodophyta whose commercial potential is at present undetermined include *Rhodymenia palmata* (dulse) and *Halosaccion ramentaceum*. The former species does not occur in quantities comparable with those, for example, in New Brunswick and Nova Scotia. There is no traditional dulse consumption in Newfoundland, and the climatic conditions would not permit natural drying of the plants, so the species has not been commercially exploited. H. ramentaceum may contain commercially useful extractives and occurs abundantly in the upper subtidal and lower intertidal zones on rocky shores. The species is extremely variable in shape and size, depending on the ecological conditions. So far harvesting has not been attempted on a commercial basis.

4. Nova Scotia and Gulf of St. Lawrence

This area is one of the richest in seaweeds in the world. Like Scotland, Norway, Japan, Tasmania (Australia), Chile and the Pacific coast of Canada and U.S.A. it is characterized by rather cold waters which are rich in nutrients and by rocky shores. For Nova Scotia fishermen seaweed harvesting is an industry worth more than U.S.$1 million and is rapidly growing. Half a dozen seaweed corporations are now buying in Nova Scotia. Four drying plants are located in the province. So far, however, there is only one extraction plant, an alginate factory using Ascophyllum and Laminaria.

Since 1948, quantitative surveys have been carried out in areas with great quantities of seaweeds and a large amount of information is available; nevertheless it is still too early to try and give the total biomass for the whole area or even a total for its harvestable resources.

The Fundy Approaches are formed into a rich archipelago at the southwest end of Nova Scotia, with an estimated coastline of 525 km (in a bee-line 72 km). A survey by MacFarlane in 1952 showed that 225 km were harvestable, bearing approximately 200 000 t of rockweed, mainly Ascophyllum. The average density was 14 kg/m^2. Laminaria beds in the area totalling almost 50 km^2 and bearing 900 000 t were charted, giving an average of 18.5 kg/m^2. From these 1000–3000 t a year were exported up to 1949.

Of all seaweeds in Canada, "Irish moss", Chondrus crispus, is the most important commercially. In trade it is sometimes confused with Gigartina stellata, frequently called "false" Irish moss, sometimes just included. Both are raw materials for the carrageenan industry. In the Canadian Atlantic, Irish moss (with a small part of "false" included) constitutes approximately 86 percent of the weight of all seaweeds harvested and accounts for 96 percent of the total value. In 1969 the landings amounted to 18 568 t or U.S.$1.4 million in Nova Scotia, 23 540 t or U.S.$1.2 million in Prince Edward Island, and 1 625 t or U.S.$100 000 in New Brunswick (Ffrench, 1970).

The Irish moss industry in most areas has evolved as an adjunct field of endeavour to the lobster fishery. However, the increased demand in the second half of the 1960s led to a greater volume of moss being harvested. Market structure and behaviour were comprehensively studied by Ffrench (1970). In the southwestern subarea of Nova Scotia, the Fundy Approaches, the density varied from 5–12 kg/m^2. It was not possible to estimate the total standing crop in the havestable areas. The main difficulty was that it often occurred as undergrowth to Laminaria.

The regrowth of harvested Chondrus populations has been studied by Foster (1955), MacFarlane (1952) and Mathieson and Burns (1975). Summer harvests allowed regrowth to control level of biomass after 5–6 months, while comparable winter plots took a year or more to reach control levels. After total harvesting (only holdfast remaining) undertaken in summer it took approximately one year for regrowth to control level of biomass, and comparable winter plots took two years (Mathieson and Prince, 1973).

The northwest coast of Nova Scotia facing the Bay of Fundy is markedly different to the dissected semi-protected archipelago of the southwest. It has a remarkably straight shore line of basalt and sand. Certain areas with boulders are especially difficult to harvest. Other obstacles for scientific survey as well as for commercial harvesting are

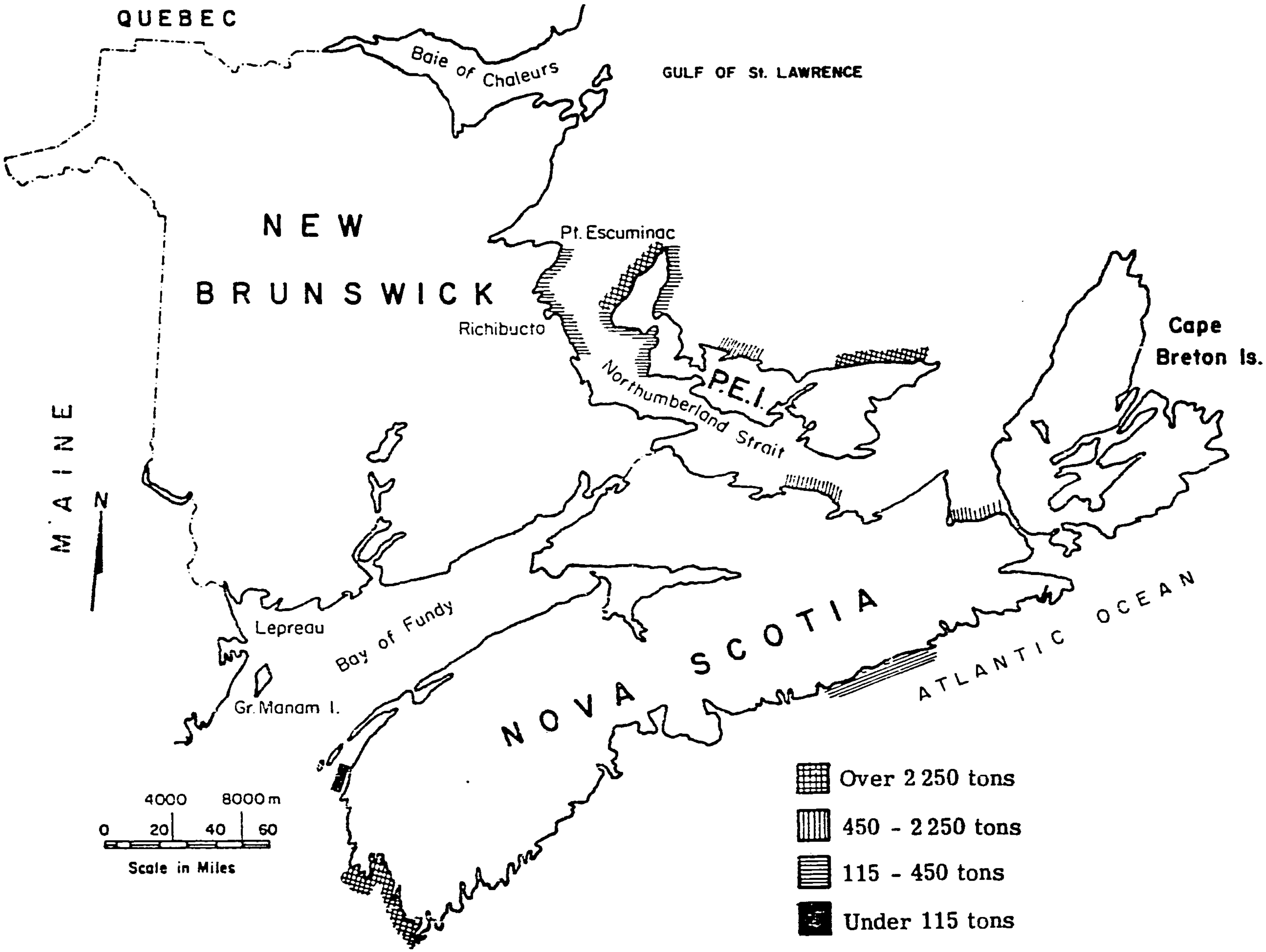

Figure 1. Estimated size of prevailing Irish moss beds. (After Ffrench, 1970)

the few low-water harbours and the high cliffs which make it impossible to reach the shore at certain stretches. Bad weather and constant ocean rolls from the Atlantic limit the number of survey and harvesting days.

The area is famous for its tremendous tides, which also contribute to great turbulence and turbidity. A coastline of 258 km, adjacent to the Fundy Approaches, was surveyed by MacFarlane in 1956. Ascophyllum and Fucus amounted to 80 000 t in a harvestable area of 10 km^2, giving an average of 8 kg/m^2. In a strip of 32 km there was estimated to be 8 000–10 000 t of Laminaria (mostly L. longicruris). The rest of this unsheltered shore offers no regular opportunities for harvesting and the total tonnage was not assessed. Where Laminaria grows on very steep sides it may become very thin and of little use. The Laminaria population fluctuates according to the grazing by the sea urchin population. Other kelp species in order of abundance are: L. digitata, Alaria esculenta, Agarum cribrosum (forming a fringe at the deeper edge of the Laminaria belt) and Phyllaria dermatodea. Outside the Agarum, there is often good hard bottom without seaweeds owing to scouring actions of silt carried by the currents.

In the Fundy Bay area Chondrus is replaced by Gigartina stellata. It occurs in extensive beds between the fucoid and laminarian belts; the density varies from 5–15 kg/m^2 and the plant is easily harvested at low water of spring-tides.

The Atlantic coast of Nova Scotia is steep and exposed, with constant ocean swell, many protected bays, much granite and slate, and small tides (MacFarlane, 1961). On the steep rocks there is a sharply delimited zonation with striking, almost pure stands of Chondrus between low water neap-tide and low water spring-tide below fucoids and above Corallina. Laminaria beds are narrow, and except in a few areas harvesting is hazardous.

Edelstein, Craigie and McLachlan (1969) describe the sublittoral flora. They found a Laminaria-Desmarestia association down to 15 m. Below 10 m an Agarum-Ptilota association dominated and at 30–40 m a Phyllophora-Polysiphonia association is present. Mann (1972, 1972a) investigated biomass, productivity and turnover in St. Margaret's Bay, with 129 km shoreline and an average width of the seaweed bottoms of 369 m. Laminaria spp. and Agarum constituted 83 percent of the seaweed growth with a maximum density of 16 kg/m^2. The total biomass per metre of shoreline averaged 1 481 kg fresh weight or 326 kg dry weight or 98 kg carbon. The annual production per metre of shoreline was estimated at 648 kg C, that is 6.6 times the biomass. The annual production of various species was 4 to 10 times the summer biomass, of laminarians 7 to 10 times. The apparent change in kelp size was much less than the true production, possibly laminarians release 35 to 40 percent of their gross production as dissolved organic matter.

Northumberland Chondrus, green in summer, dark in winter, is difficult to bleach because of iron oxide in the region. Most Chondrus occurs below low water, beyond spring ice, and is usually associated with Fucus serratus and Furcellaria fastigiata. In sheltered bays it is largely replaced by Phyllophora spp. and Trailiella intricata. Laminaria digitata is rare, Ascophyllum infrequent and Fucus serratus luxuriant, all in contrast to the other parts of Nova Scotia (MacFarlane, 1961). According to Tseng (1947) the eastern part of the mainland shores of the Northumberland Strait constitutes one of the areas with the greatest quantities of Chondrus in Canada. The beds of greatest densities extend from 4.5 to 6 m, are usually about 100 m wide, and are situated 200 or 300 m from shore. Sudden storms are frequent, especially in late summer and autumn, tearing large quantities of algae from the substratum and casting it ashore (MacFarlane, 1966).

The Prince Edward Island harvest of Chondrus is the largest in the Northwest Atlantic. In 1967 it amounted to 21 700 t wet weight (MacFarlane, 1968); a small percentage of Furcellaria is included in this figure. In 1970 it amounted to 30 000 t, or U.S.$1.6 million, as compared to 14 000 t or U.S.$1 million in Nova Scotia. Furcellaria is found in great quantities in the eastern parts of Prince Edward Island where it has become a valuable crop, and 7 000–9 000 t a year are harvested (Idler, 1971, Christensen, 1971). There are no assessments of the standing crop. An estimated 11 500–13 500 t wet weight of Irish moss is harvested annually in P.E.I., according to Morrison (1973), as compared to [illegible]50 t in New

Brunswick. A.R.A. Taylor (1970, 1972, 1972a) investigated the biology and ecology of Prince Edward Island *Chondrus* populations. Along one of his established transects he found 11 000 fronds per m^2 for approximately 1 000 m in a seaward direction. The mean dry weight per m^2 was 426 ± 104 g. With a conversion factor of 5 this would correspond to a wet weight of 2.13 kg/m^2. Another transect had approximately half this density.

Some 200 t wet weight of *Rhodymenia* (dulse) were harvested in New Brunswick in 1960 as compared to 6 t in Nova Scotia. Tseng (1947) mentions the coast from Richibucto to Point Escuminac (mainland west of West Point to North Point on P.E.I.) as yielding particularly a great deal of *Chondrus*. For 1970 figures in dry weight are given by Idler (1971): 25 t in New Brunswick and 1.5 t in Nova Scotia.

The New Brunswick side of the Bay of Fundy has been investigated at two stations by Colinvaux (1966) with the main interest in vertical range. Tidal amplitudes were 9 m. Much of the littoral was carpeted with *Fucus vesiculosus*, often dominated by *Ascophyllum nodosum*. The lower littoral at St. Andrews was characterized by *Chondrus crispus*, being generally more common than *Gigartina stellata* and frequently occurring in relatively pure strands. *Rhodymenia* was not mentioned. At Lepreau, *Laminaria saccharina* and *Rhodymenia palmata* were at times almost dominant in the lower littoral. Colinvaux states that "... periodic dulse cropping disturbed numerous intertidal communities" but does not explain this further.

At Grand Manan, N.B., in the mouth of the Bay of Fundy, *Rhodymenia* (dulse) is harvested along the rocks of a lagoon, spread to dry in the sun, rolled up like a carpet and then packed in bags for distribution. It is priced at U.S.$95/kg (Gillespie, 1960). *Chondrus* and *Gigartina* resources were mapped by A.R.A. Taylor in 1957.

In Charlotte County, N.B., inshore populations of kelp were surveyed to provide information on distribution, abundance and harvestability of *Laminaria* species suitable for the production of kelp food. There is an unsatisfied demand for kombu in the North American health food market, and oriental cooking is gaining in popularity. The production of kombu was suggested for Grand Manan Island, where it would be a useful adjunct to the dulse industry. In preliminary tests it was found that a product satisfactory for marketing but not premium grade could be produced. The standing crop of *Laminaria* spp. was estimated at 13 000 t fresh weight in the Grand Manan archipelago (Neish, 1972, 1973).

A technological programme to develop the economic cultivation and impoundment strategy for the New Brunswick dulse industry was carried out on Grand Manan (Applied Marine Research Ltd., 1974). Tanks of ferro-cement with V-bottoms and air agitation were successfully used for vegetative propagation of dulse. The tanks cleansed dulse of silt, sand and epiphytes, upgraded dulse which had been of poor quality or had been held in burlap sacks for too long, allowed dulse to grow and allowed for the regulation of raw material flow through a processing facility.

Along the north coast of the Baie des Chaleurs (Gaspé, Province de Québec) Cardinal (1966) investigated eight stations on the possibility of harvesting *Chondrus*, but he found only three of these to hold quantities appropriate for a limited collection.

At Rivière du Loup, at the southeast side of the St. Lawrence mouth, Cardinal (personal communication) found 1 080 t/km shore line of fucoids, especially *Ascophyllum*. *Chondrus crispus* does not occur in the St. Lawrence estuary.

Craigie (1972) classes *Rhodymenia palmata*, *Furcellaria fastigiata*, *Ascophyllum nodosum* and *Laminaria longicruris* as under-utilized seaweeds in the Canadian Atlantic. These species offer possibilities of fairly immediate development. A second group of species which require more extensive research and development (ten years or more) include the red algae *Ahnfeltia plicata*, *Gracilaria foliifera*, *Phyllophora* spp., *Polyides rotundus* and

Porphyra linearis as well as the brown algae Agarum cribrosum, Alaria esculenta, Fucus spp., Laminaria spp. and Stilophora rhizodes.

5. New England

In contrast to the rest of the U.S. east coast, New England, down to Boston, has rocky shores, a rich archipelago and a boreal flora very similar to that of Canada. Maine is known for a considerable harvest of Chondrus; in 1967 it was nearly 1 500 t wet weight (MacFarlane, 1968). An evaluation of the resources has recently been undertaken (Vadas and Ring, 1969; not seen). Ffrench (1970) estimated the sustainable yield of moss which could be harvested annually in Maine at between 5 500 and 9 000 t wet weight.

Growth and reproduction of Gigartina stellata were studied in New Hampshire by Burns and Mathieson (1972). At the most favourable levels, +0.5–+1 m to zero tidal datum point, the Gigartina biomass was 7–8 kg/m^2. Summer harvest allows maximum regrowth if care is taken not to damage the holdfast. August harvest provided maximum biomass, and carefully or moderately harvested the plots recovered in one year. Severe harvesting in August sacrificed two seasons of reproduction.

Data on biomass are found in Conover's study (1958) on seasonal growth related to environmental factors in a tidal estuary near Woods Hole. Here the standing crop of benthic marine plants was in excess of 4 kg wet weight/m^2 during July and August and less than 1.5 kg in January. Gracilaria confervoides gave the highest value for a single species in July and August with 2.3 and 3 kg/m^2 respectively.

Marine Colloids, Inc., probably the word's greatest producer of seaweed extracts, has a carrageenan plant in Rockland, Maine. This state has another of the world's six or eight carrageenan factories, Kraft Foods at Portland. Raw material is also imported from Canada.

The total harvest of Chondrus in the United States (Northwest Atlantic) amounted to 3 300 t in 1968.

6. The Chesapeake area

The flora from southern New England to New Jersey is principally boreal rather than tropical in its affinities. There is a great change in the algal flora between New Jersey and North Carolina. The coastline of Delaware and Virginia is so sandy and inhospitable to marine algae that few are recorded from this region (Humm, 1969).

Moeller (1964) has estimated the standing crop of some marine plants in Barnegat Bay, New Jersey. In 44 quadrats he found the mean fresh weight/m^2 for Zostera marina was 380 g, Gracilaria verrucosa 61 g, Agardhiella tenera 32 g, and Ulva lactuca 58 g. The total standing crop of these four species was calculated to be 19.5 t, 3 t, 1.5 t and 2 t, respectively. Gracilaria covered 44 km^2 of the total 120 km^2 of the bay, but it is often entangled in the eelgrass; an approximate value of the total standing crop would be U.S.$350 000.

Humm (1962) reports on marine algae of Virginia as a source of agar and agaroids. He gives gel strengths, gelatin temperatures, viscosity, etc., for products from Agardhiella, Gracilaria, Hypnea and Gelidium.

Codium fragile, a green alga eaten in Japan, which is adapted to moderately diluted and polluted waters and is also found on stones and shells in soft bottoms, is spreading within the area from Cape Cod to New Jersey (J.E. Taylor, 1967). As a result of strip harvest studies, J.E. Taylor (1970) gives the biomass for some algae in Barnegat Bay. The highest value from his SCUBA divings in wet weight/m^2 is 64 g for Gracilaria confervoides

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FISHING AREA 27 : NORTHEAST ATLANTIC

The main areas of seaweed utilisation in the Northeast Atlantic are in Norway (*Ascophyllum*), Denmark (*Furcellaria*), Scotland, Ireland and Normandy, France (*Laminaria*, *Ascophyllum*, *Chondrus*), and Spain and Portugal (*Gelidium*).

1. Greenland

The seaweeds are not utilised. However, there are considerable quantities of kelp in particular. The best known districts are Scoresby Sund and Kejser Frans Josephs Fjord as far north as 70°-74°N. From 0-3 m there is a *Fucus inflatus* community, more scattered and mixed at greater depths but still recorded at 38 m, and also encountered on loose bottoms. *Laminaria saccharina* ranges from a few metres down to almost 40 m; fully developed specimens reach a total length of 240 cm and a width of nearly 40 cm. *Laminaria solidungula* is prevailing in deeper waters in the outer part of the area. Other sublittoral communities are dominated by *Punctaria glacialis*, *Desmarestia aculeata* and *Phycodrys rubens* - *Phyllophora brodiaei* (Lund, 1959, 1959a).

2. Iceland

One of the largest untapped seaweed resources in the world is found in Iceland. Utilization has old traditions; there is evidence in Icelandic sagas that *Rhodymenia palmata* was eaten as long ago as 961. *Alaria esculenta*, *Chondrus crispus*, *Gigartina mamillosa* and *Laminaria digitata* have also been eaten, and in times of starvation other species as well.

Rhodymenia is now only occasionally collected and dried, and seaweeds are no longer used for fuel, potash, iodine or for dyeing homespun cloth. However, sheep still graze on *Rhodymenia palmata* and *Alaria*; at least 10 000 ewes, about 1 percent of the total stock in Iceland, are fed on fresh seaweed. Production of seaweed meal from *Ascophyllum* was started in 1960 and the product sold as supplementary fodder on the home market. Cast weed is still collected by gardeners (Hallsson, 1964).

The algal vegetation of southern Iceland has a warmboreal character. The lava blocks are covered by belts of rockweed - *Pelvetia canaliculata*, *Fucus spiralis*, *F. vesiculosus*, *Ascophyllum nodosum* and *F. distichus*; among these the broad belts of *Ascophyllum* dominate, covering vast areas of the littoral slope. Considerable amounts of agar-yielding species are also found; *Gigartina stellata* occupies the lower littoral slopes, and *Chondrus crispus* is found in tidal pools (Munda, 1970).

The west coast is influenced by Atlantic water, the east and north coasts by arctic water. In the south and west the sea water never freezes, in the north and east only rarely and then usually for a short time. Exposed areas in the west are characterized by extensive underwater meadows of *Corallina officinalis*, in the east by *Acrosiphonia* and in the sublittoral by *Laminaria hyperborea* and *Alaria esculenta* (Munda, 1969). *Saccorhiza dermatodea* and *Laminaria hyperborea* are also luxuriant.

The most common and abundant littoral algae, some of which could possibly be used as raw material for industrial products, have been investigated with regard to ecology and chemical composition (Munda, 1972; distribution maps are given for 31 species). The protein content of a number of species from various localities was determined. Notably high values were found in some species: 22-26 percent of the dry substance in *Scytosiphon* and *Dictyosiphon*; 25 percent in *Cystoclonium*, *Plocamium* and *Polysiphonia*, and 30-37 percent in *Ceramium rubrum*, *Plumaria* and *Porphyra*. The highest fat values found were 7 percent of the dry substance in *Fucus distichus*, 6 percent in *Pelvetia*, 5 percent in *F. vesiculosus*, and 4 percent in *Ascophyllum*. Highest mannitol values were 15 percent of the dry substance in some samples of *Laminaria* and *Alaria*, and 11 percent in *Fucus* and *Ascophyllum*. Alginic acid was as high as 20 percent in *Desmarestia* and *Scytosiphon*, 35 percent in *Laminaria digitata* and *L. hyperborea*, 29 percent in *Fucus*, and 26 percent in *Ascophyllum*.

Munda (1970a) found the densities for some important species (average of 10 to 25 parallels) were in kg/m^2: Chordaria 3; Fucus vesiculosus, depending on exposure of locality, up to 7; F. disticus up to 5.6; Ascophyllum up to 7.7; Porphyra umbilicalis up to 2.3; Gigartina stellata up to 5.6, and Rhodymenia palmata up to 3.6.

3. U.S.S.R. (Arctic Sea)

The Barents Sea has rich resources of brown algae, in the Ascophyllum bed a biomass of up to 28 kg/m^2. It has been estimated that more than 500 000 t wet weight of rockweed can be obtained from the whole Murman littoral. The sublittoral is dominated by Laminaria saccharina and L. digitata, with an estimated 500 000–600 000 t wet weight on the Murman coast.

The White Sea supply of algae exceeds that of the Murman Peninsula; there are 800 000 tons of Laminaria, 250 000 t of Fucus, and 400 000 t of the sea grass Zostera (Zenkevitch, 1963).

4. Norway

The area covered with rockweed and kelp is as large as the area of cultivated ground in Norway (Haug and Myklestad, 1960).

Spitsbergen, at 76°6' to 80°N, has a richer marine flora than any other point so close to a pole. The amount of weed cast ashore readily reveals that the Laminariaceae are luxuriant. Alaria grandifolia is very abundant and common in exposed localities, where it is found from 1–15 m or more and grows to 4 m in length. Laminaria saccharina occurs in abundance in exposed as well as sheltered localities, to a depth of [illegible] m though also observed to 30 m. Specimens up to 370 cm have been measured. L. digitata also very commonly occurs in different forms, and specimens up to 220 cm in length have been noted (Svendsen, 1959).

On the Norwegian mainland coasts, quantities of Laminaria spp. and Ascophyllum have been assessed through the Norwegian Institute of Seaweed Research (Grenager, 1952, 1953, 1954, 1955, 1956, 1958, 1964; Baardseth, 1954). These assessments constitute one of the few serious efforts to evaluate standing crop of harvestable species in an area rich in seaweeds, and still as a total they cover only fractions of the Norwegian coast and archipelago.

Laminaria hyperborea is the predominating species along the exposed coast, estimated at 80–90 percent by weight of the total algal vegetation (Printz, 1957). It is dominating in the sublittoral to a depth of 12–15 m, and below this level gradually becomes more sparse. Densities of up to 30 kg/m^2 have been recorded at 5 m in an old kelp forest. The mean density however is assessed at 7.2 kg/m^2, and with a regrowth time of 3–4 years this would give a mean yearly yield of 2.4–1.8 kg/m^2 (Svendsen, 1972). In [illegible] coastal area of 18 km bee-line, Grenager (1952) estimated there were 319 000 t, or a mean of 18 000 t/km.

Drift weed is cast ashore in exceptional amounts. In the months of frond-shedding – April, May and June – the drift weed consists mainly of old fronds. During autumn and winter, on the other hand, large, well developed stipes of Laminaria hyperborea are washed ashore after stormy weather in "innumerable thousands of tons" and in a fairly unmixed state. The largest occurrences of drift weed are around the southwest end of Norway and in the area Ålesund–Kristiansund, while there is a marked lack of it or very little along considerable parts of the coast. In northern Norway, there are large occurrences of drift weed on the seaward side of Lofoten and northeastwards (Printz, 1957; also contains maps of drift weed distribution).

Ascophyllum nodosum is the most harvested species together with L. hyperborea. It occurs in large quantities intertidally on firm substratum, preferring protected localities but also found in most semi-exposed and certain fully exposed areas. It usually forms a belt immediately below the Fucus vesiculosus belt. The weight ratio between these species in an investigated area in southern Norway was 100:30. In a district further north (64°–67°N), the weight ratio Ascophyllum:F. vesiculosus:F. serratus was found to be 100:39:41. Within the rocky portion of an area between the upper and lower borders of the Ascophyllum belt, the density of this species varied between zero and 26 kg/m^2, with a general mean of 5.2 kg/m^2. If mean values for three well known districts are extended to the whole Norwegian mainland coast, the total estimate would be of the order of 1.8 million t fresh weight (Baardseth, 1970).

According to official statistics, 79 500 t of seaweed were utilized in Norway in 1970 and in the previous six years the total varied between 55 000 and 85 000 t. Since the harvesting of Gigartina has now ceased completely, all of this can be accounted for as brown algae: Ascophyllum and Laminaria spp. Commercial harvesting of Laminaria hyperborea from the sea bottom has been carried out since 1964. This kelp, together with L. digitata and Ascophyllum nodosum, is used for alginate production. In 1969 and 1970 about [illegible]5 000 t of L. hyperborea were cut each year, corresponding to 25 percent of the Norwegian alginate industry's total consumption of brown algae. In 1964 the alginate production was about 700 t, of which 95 percent was exported to some 50 countries. A new factory has a capacity of 1 000 t of alginate, corresponding to 10–15 percent of world production (Svendsen, 1972).

Most of the Ascophyllum harvest goes to the seaweed meal industry which uses some 50 000 t of fresh weed per annum for a production of 15 000 t of meal; the alginate industry used approximately one-third of that quantity in 1965 (Jensen, 1966). The total quantity of Ascophyllum available in Norway for industry is 1.8 million t fresh weight or about half a million tons dry weight. If we put the yearly percentage of a possible exploitation at 10 percent, as a conservative estimate, then Norway would be able to produce about 50 000 t of seaweed meal annually (Baardseth, 1970).

The bottle-neck has been harvesting, with a decreasing number of people active in this seasonal job. Recently, however, the trend has changed; there are increasing difficulties for conventional fishing and an increasing number of fishermen join the weed cutters. The largest quantity of Ascophyllum is cut in an area west of Trondheim. Laminaria is taken very evenly along the southern part of the west coast.

The value of seaweed meal to domestic animals has been recorded in numerous investigations. Many of those are reviewed by Jensen, Nebb and Saeter (1968) and Jensen (1972). In a feeding experiment with twin cows the test group was given 200 g daily of fortified Ascophyllum meal over a period of seven years. The total milk yield of the test group was found to be about 6 percent higher than that of the control group fed on identical rations except that the seaweed meal was replaced by 100 g daily of a Norwegian standard mineral mixture. These mineral supplements cost approximately the same as the seaweed meal. When all costs were deducted, the additional milk yield obtained by the Ascophyllum meal test group resulted in around 13 percent increase in net income.

The red alga Gigartina has until a few years ago been collected in more modest quantities. This harvesting, however, has now ceased completely.

5. Sweden

The west coast is very rich in algae, but in the Baltic quantities are decreasing with the decreasing salinity. The first systematic investigation ever made of quantities in hard bottom communities – and still the most comprehensive – was carried out by Gislén (1930) in a Swedish west coast fjord. Within the associations characterized by the respective species he found average raw weights in kg/m^2 were: Ascophyllum 15.[illegible]; [illegible] 10; Fucus serratus 8.4; Laminaria digitata 8; F. vesiculosus 7.6; F. spiralis 6; L. hyperborea 5.7; Zostera 4.6; L. saccharina 3.6; Furcellaria 3.2; Corallina 3; Chordaria 2.3 and Ulva 2.

Over past centuries seaweed has been utilized in a number of ways. It has been used as fodder, as manure, fresh Fucus was used to cover the ridges of straw-thatched houses; Zostera was used in cradles instead of straw, dry rockweed was used for firewood in the southern coastal area.

At present, however, seaweed is not utilised, except for very small amounts locally used for manure or for frost protection cover for potato stacks. Sweden is the only industrialized country with rocky shores which has no seaweed industry whatever. The absence of tidal fluctuations makes the rockweed fringe less accessible for harvesting, and the calm water and high level of nutrients give rise to luxuriant growth of undesirable epiphytes on possibly useful species; finally, high wages would make raw material too expensive for competition on the world market.

6. Finland

Seaweed is not utilized. Fucus vesiculosus is quantitatively the most important species, forming perennial trees and descending from the water line to 10–12 m. It appears in a variety of forms. One plant usually houses hundreds of isopodes, amphipods and other macroscopic animals.

7. U.S.S.R. (Baltic coasts)

Furcellaria fastigiata is found attached to stones along the open coast between Klaipeda and Ventspils in quantities estimated at 80 000–90 000 t, and has also been encountered in the Irben Strait and the Gulf of Riga (9 000–10 000 t). In 1960, loose-lying resources found on soft bottoms, particularly in the islands of Hiumaa and Saaremaa, were estimated at 150 000 t. The Baltic findings of Furcellaria exceed the total quantities of most other agaroid resources of the Soviet Union, e.g., the Ahnfeltia of the White Sea (14 000 t) and of the Sea of Okhotsk and the Sea of Japan (170 000 t). Only Phyllophora spp. in the Black Sea exceeds the supply of Baltic red algae and the quantities are 20 times greater.

Along the Baltic coasts, at least 27 000 t of Furcellaria a year have been brought together and in favourable years as much as 40 000 t. Kireeva recommends that Furcellaria should be gathered along the coasts but not from the open sea.

The standing crop of Fucus in the Baltic states was estimated at 70 000–80 000 tons (Kireeva, 1965, 1965a).

8. Poland

The quantities of Furcellaria fastigiata cast ashore after autumn, winter and spring storms would be about 20 t dry weight with an agar content of 40–50 percent (Czapke, 1960, 1964).

9. German Democratic Republic

No utilization of seaweed.

10. Federal Republic of Germany (Baltic coasts)

The entire length of the Baltic coast was investigated from Flensburger Förde to Lübecker Bucht. On 184 km the total biomass of Fucus was estimated at 40 000 t, giving a mean value of 217 t/km. This is more per unit coastline than Walker found in Scotland (209 t/km), but in the Baltic Fucus is spread over vast areas down to at least 6 m; consequently, the German Fucus quantities are low per unit area: 1–2.5 kg/m^2 as compared to a maximum value in the Hebrides of 20.5 kg/m^2. Profitable harvesting of Baltic Fucus will therefore be most questionable and would probably give only 20–30 percent of the biomass. With three years for regrowth a reasonable catch would be only 3 000 t wet weight or 600 t dry weight a year.

The method of the German survey could not be employed for Furcellaria fastigiata, growing in depths of 5–20 m either in dense fields on boulders or loose-lying; in the latter state it is, under particular hydrographic conditions, brought together in large quantities (Hoffmann, 1952).

11. Denmark

The first quantitative assessments of marine productivity were made by Petersen and Boysen Jensen (1911) and Petersen (1913). The method introduced for the sampling of fixed areas of soft bottoms was the Petersen grab. These investigations are basic in particular for the study of the relationship between available food and stocks of commercial marine animals. Already at this initial stage Petersen regards the benthic flora as the basis for fish life in the Lime fjord and in many other coastal waters. Petersen's (1912) assessment of the annual productivity of benthic plants along the west European coast are of particular interest for the botanist; also his paper (1914) on annual productivity of the eelgrass Zostera in Danish waters, which was estimated at double the standing crop or 8 232 million t dry weight. This was four times the annual production of hay in Denmark at that time.

The quantities of Fucus spp. are next in importance to Zostera, but for various reasons would not be suitable for harvesting (Lund, 1941).

Furcellaria fastigiata, the cartilaginous, cylindrical, densely tufted red alga, constitutes the only industrial raw material actually utilized at present. It is found from 2–30 m attached to stones, pebbles or algae. There is also a detached form, thriving well adrift in protected places where the seabed is sandy. Over a period of 20 years the total Danish collection for industrial purposes was taken from a locality, Tangen, in the central part of Kattegatt off the northern coast of the peninsula of Djursland, where circulating currents are created; this locality is fairly moderate in extent and the depth is mainly 3–4 m. The quantities collected, through trawling, are almost free from other species. The appearance of most of the plants indicates an age of at least 3–5 years. From a few thousand tons a year during the 1940s, the yearly collections rose to 20 000–30 000 t in the early 1960s, resulting in heavy overfishing and finally a depletion of the stock. Since 1967 an economic collection has not been possible from Tangen. This harvesting area has now been substituted by several smaller ones. Gathering of cast Furcellaria from the shore has been started and has gained a certain importance.

Chemically the "Danish agar" or furcellaran is different from Japanese agar in containing a greater number of acidic groups binding greater quantities of alkaline salts, thus having a higher ash content. It sets more rapidly and at a higher temperature and the setting point rises substantially with the degree of concentration. During 20 years of production agar gain rose from 2.5 to 4 percent of the raw material (Lund and Bjerre-Petersen, 1953, 1964; Lund and Christensen, 1969).

In addition to the processing of indigenous resources by the furcellaran industry there is also a Danish phycocolloid industry working up imported material. Chondrus crispus from the Canadian Maritimes is the predominant raw material in the processing of carrageenan but the same type of material is also bought along the European coast and in the northern part of the Asian coastline. Eucheuma and other agaroids are imported from the Far East and smaller quantities from Africa and South America (K. Nielsen, personal communication).

12. Federal Republic of Germany (North Sea coast)

Quantities of seaweed are not large enough for commercial utilization. In this area hard bottoms are exceptional. Lüning (1969, 1970) found on Heligoland mean standing crops in fresh weight per m^2 of: Fucus serratus, 3.7 kg at 0 m; Laminaria digitata vegetation, 5.6 kg at 0.5 m; L. saccharina, 7.1 kg at 1 m, and L. hyperborea, a maximum of 11.1 kg at 2 m. Closed vegetation of L. hyperborea was found only between 1.5 and 4 m, single specimens down to 8 m, compared to 33 m in western Scotland, which is explained by a less favourable light climate.

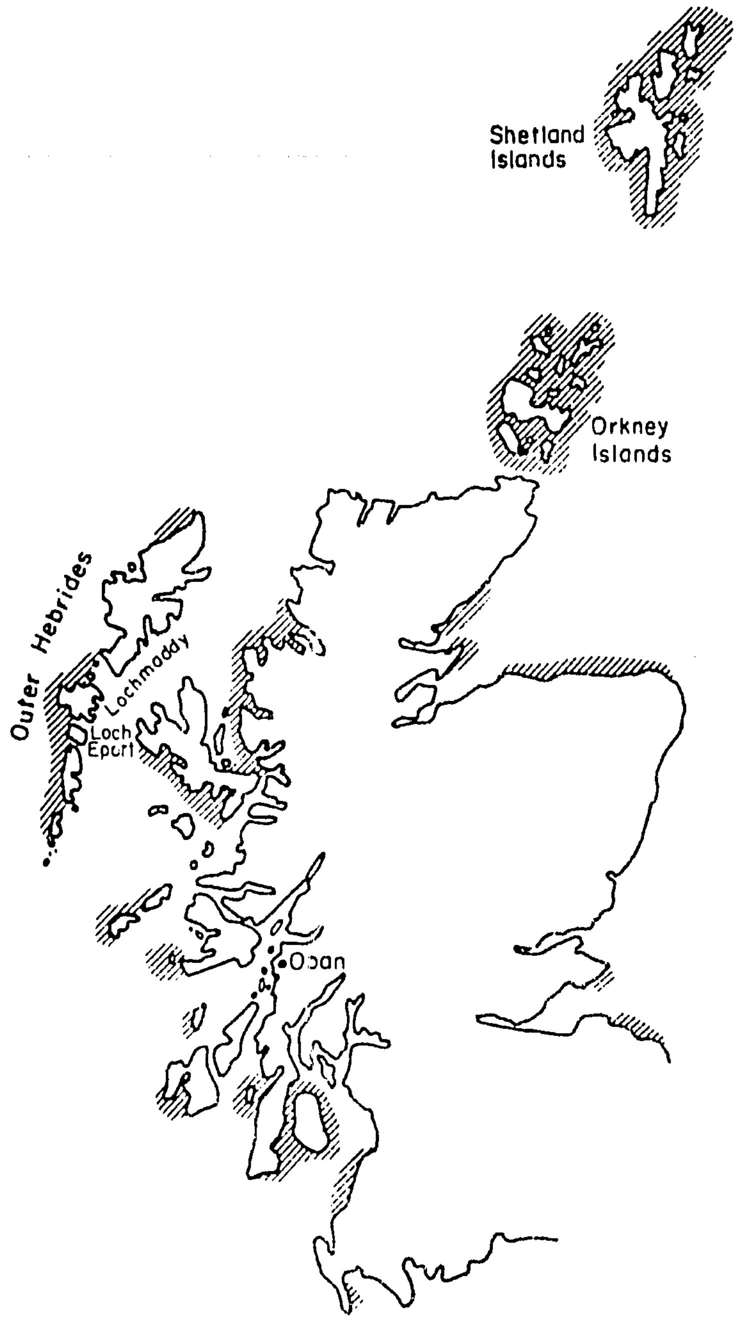

Figure 2. The distribution of the Laminariaceae around the coast of Scotland. (For details on quantities see Walker, 1954)

13. The Netherlands

In spite of the fact that the Netherlands has no natural hard bottoms, man has created extensive suitable substrates for epilithic algae when constructing moles, dikes, piers and harbours. However, existing vegetations are also destroyed through various measures of renovation with the result that pioneer communities consisting of a small number of species take their place. The most harmful measure is bituminization; this causes a persistent depauperation and the original vegetation is unable to regain its lost position.

Exploitation of algae for economic purposes is not profitable. In Zeeland there was for a short time an industry which used Fucaceae, especially Ascophyllum, as raw material. The algae were cut on the dikes, which did not cause lasting damage; in a few years the algal growth was completely regenerated (den Hartog, 1959).

Seaweed products, such as cattle feed additives, have been imported or prepared on imported weed or weed collected in the island of Schouwen and the province of Zeeland. Fucus vesiculosus is used as fodder for pigs (Koster, 1953).

14. Belgium

No utilization recorded.

15. United Kingdom

Scotland has been the object of one of the most extensive assessments of seaweed quantities ever carried out. For littoral resources of rockweed, a first survey of 80 percent of the more than 10 000 km of marine coast of Scotland was organized by the Scottish Seaweed Research Association in 1945.

In this littoral area 180 000 t of rockweed were distributed over 870 km with a density of not less than 4 000 t/km^2 or 4 kg/m^2; 70 percent of this quantity was located in the Outer Hebrides and 22 percent in the Orkney Islands. The dominant species is Ascophyllum nodosum. The greatest concentration was found in Loch Maddy and Loch Eport in North Uist. Fucoid algae were also surveyed by Gibb (1950).

For sublittoral kelp a new method was worked out. Stereoscopic aerial photography was supplemented with detailed sampling of selected seabeds down to 18 m by means of calibrated spring grabs. During the whole period of sublittoral surveying, 1946 to 1955, 100 000 quadrats were measured. It was estimated that over 8 500 km of coastline representing 8 000 km^2, 10 million tons of Laminariaceae were growing from 0–18 m, an average of 1.25 kg/m^2. Of this quantity 4 million tons were located in concentrations of economic significance covering 1 000 km^2 or 2 700 km of coastline, with an average density of 3.7 kg/m^2 (Walker, 1947, 1953, 1954, 1958). There is a variation with depth: 6 kg/m^2 at 1 m, 3 kg/m^2 at 5 m, 1.2 kg/m^2 at 10 m.

The Institute of Seaweed Research (now closed down) summarized that from the 10 million tons, predominantly Laminaria hyperborea, which are growing around Scotland, 1 million t wet weight of seaweed or 200 000 t dry weight could be harvested each year, enabling full recovery of the harvested area (Scotland, Institute of Seaweed Research, 1956).

Laminaria hyperborea dominates in most cases, and areas supporting a dominant crop of this species were chosen for the investigation. Here its total for all depths from 0–13 m ranged from 80–100 percent in various areas and months, while L. digitata reached 0–5 percent and L. saccharina 0–15 percent. With increasing depth L. hyperborea gives place to L. saccharina. In southwest Scotland at 13 m L. saccharina reached 87-97 percent in [illegible] months. From 5.5–9 m Saccorhiza polyschides could take 1 percent of the fresh weight of the Laminariaceae (Walker and Richardson, 1955).

In 1973, 24 100 t of brown algae were harvested in Scotland, quantities during preceding years varying between 22 500 and 29 700 tons. There used to be a harvest of some 100 t of carrageen moss, but in the last few years this seems to have ceased totally.

Special surveys of England, Wales and Scotland are given by Chapman (1948) and Marshall, Newton and Orr (1949) and referred to in books on seaweed utilization by Chapman (1970), Newton (1951) and Stephenson (1968). The data given by Chapman and by Walker are compared by Boney (1965).

The biology and chemistry of Laminaria hyperborea has been reviewed by Kain (1971), including data on standing crop extracted from various authors and countries as well as methods of harvesting, regrowth and utilization.

Gigartina and Chondrus are available in harvestable quantities on the west coast from Cornwall to Scotland and in the southeast of Scotland and northeast England. For Scotland the harvestable standing crop was estimated at 360 t (Marshall, Newton and Orr, 1949). In Wales some dulse (Rhodymenia) is still dried and eaten as a kind of healthy forerunner to chewing-gum.

16. Ireland

The Irish west coast waters are relatively shallow and seaweed beds extend to a considerable distance from the shore. As the waters are cold and rich in nutrients individual plants can grow to very large dimensions compared to specimens from most other areas. "The seaweed beds can be regarded as inexhaustible." On the other hand, these waters are not navigable to boats fitted for weed collection and much of the coast is inaccessible by land. The amount of weed must be related to its accessibility.

"Irish moss" (Chondrus crispus) is picked on spring tides during summer months. In one of the war years 600 t was collected but later quantities decreased considerably. It is abundant along the west coast and most easily available on the boulder beach of South Connemara (de Valéra, 1958).

Laminaria hyperborea stipes, "sea-rods", are collected among the drift weed thrown up by gales during winter and spring and dried to serve as raw material for alginates. During the 1950s, 3 000 t per annum were collected, including limited amounts of L. digitata (Flood, 1953). In recent years the quantities harvested varied from 1 000 to 1 700 t of air dried stipes (H. Boylan, personal communication, 1974).

A century ago, however, Ireland produced 6 000 t of kelp annually, much of which was shipped to Glasgow for the extraction of iodine. In addition to Laminaria, Alaria and Halidrys were also recommended for iodine production (Chapman, 1970).

Ascophyllum and Fucus are cut by hand and are used together with drift weed in the manufacture of seaweed meal. The standing crop of Ascophyllum has been estimated at 150 000 wet tons. Drift weed would probably supply another 50 000 tons. Regrowth of weed cut by sickles or knives requires three to four years. The quantities harvestable are sufficient to support an output of approximately 10 000 t of seaweed meal per annum (H. Boylan, personal communication, 1974).

Saccorhiza polyschides used to be one of the most widely used kelp species for the extraction of iodine and in the manufacture of glass and soap. The mean standing crop in Lough Ine Rapids, Cork, is given as 8.8 kg/m^2, which is more than double the highest values obtained in Spain, Norway and Scotland (Norton, 1970).

In the Aran Islands, off the west coast of Ireland, seaweed is used to make soil. The seaweed is mixed with sand or sandy soil and this, often laid on top of bare rock, makes "lazy beds" for growing potatoes. By putting down alternate layers of sand and seaweed it is possible to raise a potato crop where otherwise none could survive. A wide range of crops and vegetables, including peas, parsnips, carrots, cauliflowers and cabbages, are also grown on seaweed soil, and the standard of husbandry is high (Stephenson, 1968).

17. France

For a number of years the French figures submitted to the FAO Yearbook of Fishery Statistics have not been included in the totals of aquatic plants as "they refer to products not clearly defined". It is doubtful that the figures could reflect the total amounts landed; they possibly cover only seaweeds used for industrial purposes, and probably do not include those directly used for fodder and manure. This interpretation may be supported by the figures given for 1970 in French statistics:

	Quantities landed, 1965 (tons)	Quantities landed, 1970 (tons)	Value, 1970 (thousand Frs)	Price per kg (Frs)
"Carragaheen"	1 883	3 192	1 387	0.43
"Goëmon iodé"	6 033	7 374	1 886	0.25
Other marine plants	6 937	7 472	1 165	0.15

When compared to the 1965 figures the three groups show an upward trend. Understanding "carragaheen" as Chondrus and "goëmon iodé" as Laminaria, a comparison with 20 year-old records from the Comité central des Pêches maritimes is less encouraging; in 1950 and 1951 the landings of fresh Laminarians amounted to 56 000 t and 45 000 t respectively. The decrease in Laminaria harvesting followed the cessation of kelp burning for the iodine industry. These old figures therefore show that there was sufficient potential to meet a higher demand. In the same period, 4 400 t of Chondrus crispus and Gigartina mamillosa were produced annually, and it was estimated that 100 000 t of Fucus were used for fodder after crushing (Feldmann, 1953). At the beginning of the century, however, the quantities landed annually along the Atlantic coast of France corresponded to 267 000 t dry weight (Lund, 1936, estimated on data from Videment, 1909). Ancient forms of seaweed utilization are comprehensively described by Sauvageau (1920) and briefly by Dangeard (1947).

The quantities actually utilized by French alginate industries are at least five times the landed quantities as given in the figures for 1970. If, as has been reported, France produces 1 200 t of alginate per year, this would require at least 30 000 t wet weight of Laminaria. In "France Pêche", February 1969, the French production of dry seaweed is estimated to correspond to at least 100 000 t wet weight.

Brittany is the centre of seaweed utilization; kelp for industrial purposes, rockweed for fodder, drift weed for manure. The latter is widely used but no estimates are available. In addition to Laminaria and Fucus large quantities of thong weed, Himanthalia, are cast ashore and used to improve the quantity and quality of artichoke crops and barley for beer.

On the Normany coast east of the Cotentin peninsula, Audoin and Pérez (1970) made a cartographic study of the populations of Laminarians along 100 km of the Calvados coastline. In 17 km^2 of Laminaria digitata fields they evaluated a standing crop of 100 000 tons. The number of kelp plants per m^2 was about 25, compared to 45 in Brittany. The alginate content was 2-7 percent lower than in Brittany but, on the other hand, of top quality. Data on the biology, chemistry and utilization of Laminaria digitata are given by Gayral and Cosson (1973).

Chondrus crispus is common in the Cotentin peninsula and the Channel Islands, abundant along the rocky northern shores of Brittany, and even more abundant along the west and south coasts of Brittany. It is also found, but in smaller quantities, north and south of this area of abundance wherever the bottom offers a suitable substrate. Commercial harvesting is carried out extensively in Normandy and Brittany (MacFarlane, 1968 on communication from Dizerbo). Even if the present harvesting figure is just 1/16 of that for Canada, France may still rank as second in the world production.

There is one utilization of algae known only in France. The calcareous red alga *Lithothamnion calcareum*, which has for a long time been applied on acid ground to improve the soil, is now also being used in the treatment of acid drinking water; such water, if untreated, attacks and dissolves the metals of the distribution system. If filtered through *Lithothamnion* the pH is raised to 8.3, where Pb, Cu and Zn ions are precipitated. Also other undesired ions are eliminated through adsorption or ion exchange, including radioactive elements (Neveu, 1961).

Other resources of a potential value are *Gymnogongrus patens*, *Gelidium sesquipedale* and *G. spinulosum*. The algae collected along the French coasts are of the order of 20-30 percent of what is manufactured in France (R. Delépine, personal communication).

18. Spain

The Spanish seaweed industry is centred primarily on the manufacture of agar from *Gelidium* and is the second largest producer in the world, exceeded only by Japan. As the local consumption is small, Spain is the leading exporter of agar on the world market (Spain, S.N.I.Q., 1968). In 1970, 8 900 t of the raw material *Gelidium* were harvested. According to figures for the last few years, 1 100 t of the carrageenous "Liquen" (*Gigartina stellata* and *Chondrus crispus*) and, surprisingly, no brown algae were harvested.

Species of industrial interest are well investigated with regard to their ecology and distribution (Seoane Camba, 1960, 1964, 1965, 1965a, 1966, 1967, 1968, 1969) and various industrial aspects of seaweed utilization have been treated (Arawio-Torre and Villegas, 1959; Cabrero Gomez, 1951; López-Benito, 1963; Spain, S.N.I.Q., 1968).

Sixty to seventy five percent of the harvested *Gelidium* is picked up on the beaches after autumn and winter storms. The gathering of storm cast seaweed has the drawback that undesirable species have to be sorted out. As storm cast weed is predominant in rainy seasons and areas, it may have to be transported to the inland for drying. This may be one reason why several seaweed processing factories are located around Madrid and Burgos. Regional requirements have also been considered when two new carrageenan factories, with a joint official capacity of 580 t/year, were built in the "development areas" of Vigo and Burgos.

From May to October, at low tide, some *Gelidium* and 70-80 percent of the harvested "Liquen" is torn off the rocks and dried in the sun. A higher quality of *Gelidium* is collected by frogmen during these months; 100 small ships are operating with a skipper, a mechanic and four divers. Fifteen to twenty percent of the *Gelidium* is harvested in this way.

There are seven plants for the processing of agar and 90 percent of the products are exported. Until recently all the carrageenan algae were exported as raw material. Animal fodder is manufactured from *Fucus* (Spain, S.N.I.Q., 1968, with maps of species distribution and sites of manufacture plants; abstracted by Durrant, 1969).

19. Portugal

The coast of Portugal is favoured by suitable substratum, temperature, salinity, light conditions and tidal amplitudes. Actually, along the nearly 600 km of coastline as much as 500 km^2 are found inside the 20 m isobate. Most of these bottoms are rocky (da Fonseca, 1966).

Consequently there is a rich marine flora. Taxonomy, ecology and distribution are comprehensively treated by Ardré (1970, 1971) who also sums up earlier investigations and discusses possible causes for variation in time. Special aspects are elucidated in some other studies: the protection of resources by Palminha (1958) and agar-producing and agar-consuming industries by Venguinha (1951). For regrowth studies seaweed reserves are established in strongly and moderately exposed areas at depths of 6-10 m and divided into subareas. These are treated in various ways and observed monthly in order to assess growth rhythms and regrowth in relation to different harvesting methods (Palminha, 1971).

There are six factories with a total capacity of 1 620 t of agar. Four of them, located in continental Portugal, use almost exclusively Gelidium sesquipedale, while the two on the Azores are working primarily with Pterocladia capillacea. Gelidium attenuatum, G. latifolium and G. pusillum are also collected, but in smaller quantities (Palminha, 1971). An estimate of what could be collected gives in dry weight figures 6 000 t of agarophytes on the mainland coast and another 2 000 t on the Azores. The carrageenophytes Chondrus crispus, Gigartina mamillosa, G. acicularis and G. stellata occur in quantities which could give 1 200 t. Alginophytes such as Laminaria digitata, L. hyperborea, Saccorhiza polyschides and Himanthalia lorea could give about 5 000 t. For a comparison with most other data founded on wet weight, these estimates should be increased, say, five times. The predicted output in commercial products was 1 300 t of agar, 400 t of carrageen and 1 000 t of algin; the last figure, however, is hypothetical as no processing is planned (cf. Fonseca, 1966; Palminha, 1971).

Much of the red algae is collected in the tidal area at low water, outside this divers work from small boats. On the mainland and in the Azores, 114 boats and 560 semi-autonomous divers and 110 autonomous divers operate.

Collection of seaweeds fixed to the substrate is by legal regulations restricted to the second half of the year. The growth and reproduction period of Gelidium and Pterocladia starts between January and March. Estremadura is the most important region for Gelidium, followed by the southern provinces.

In 1970 the quantities actually forwarded to the industries were 23 500 t of wet algae (Palminha, 1971).

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FISHING AREA 31 : WESTERN CENTRAL ATLANTIC

The seaweed resources are moderate or small, but not nearly as small as might appear from the recorded utilization of close to zero.

The marine flora is well known in areas where the laboratories have been popular among botanists: Bermuda, Bahamas, Puerto Rico and the Dry Tortugas, Florida. From less accessible parts there is still little information. The history of algological investigations, distribution, ecology and taxonomy is comprehensively reviewed by Taylor (1955, 1960).

1. U.S. Atlantic coast

Early in 1942 agar was classified as a "critical war material" and its use restricted to bacteriological purposes. As a result an agar industry was developed in Beaufort, North Carolina. The harvest of Gracilaria verrucosa reached a maximum in 1944, when 125 t dry weight was collected, at a value of U.S.$27 500. In 1946, the North Carolina collection of Gracilaria foliifera was 55 t ($12 000) and of Hypnea musciformis 12 t ($2 700). When it appeared that Gracilaria verrucosa might have poor years because of excessive rainfall and low salinities, a year-round operation of the industry was assured by stockpiling of a supply of Gracilaria foliifera at Sebastian, Florida (Humm, 1951, 1951a).

In North Carolina Gracilaria verrucosa occurs in two different forms. The normal attached form never reaches great abundance and has little economic value. The other is composed of loose, drifting plants that apparently never form spores of any kind; such pieces may increase ten times in weight within two weeks. In July large bushy plants adrift through the sounds begin to accumulate in masses, sometimes several feet thick, in areas where tidal currents and winds concentrate them. Minimum salinity is about 15 per mille.

Gracilaria foliifera is found farther up the estuaries than G. verrucosa and grew well during a low salinity year, when G. verrucosa failed to develop in quantity (Humm, 1951). It can stand fresh water for short periods and is found in good condition also during the coldest months when G. verrucosa is absent. Growth rates of Gracilaria foliifera as related to light and temperature were compared at two stations about 1 250 km apart. Five-gram portions were fastened at different depths. Plants at the highest light intensities (5 cm depth) gained 14-16 times their original weight during a 25-day growth period; at 1 m they had gained only 2½-10 times their weight (Kim and Humm, 1965).

Hypnea musciformis has a short period of abundance, typically from six to eight weeks. Like G. foliifera, all plants grow attached at first but may drift free when large (Humm, 1951a).

The abundance of drifting seaweed may have been coincidental with the disappearance of eelgrass (Zostera marina) which, before it was exterminated by a parasitic fungus, occupied the habitats of Gracilaria growth and may have consumed much of the nitrate content of the waters. The drifting seaweed, until then a net fouling nuisance, was collected commercially by shrimp trawlers when occurring in deeper water. The trawls are not entirely satisfactory for collecting, as a full trawl is too heavy to handle. Two factories in North Carolina using raw material taken from the same area at the same time of year obtained very different agars, one gelling at about 38°C and the other at 55°C or slightly higher. One used a process involving boiling, the other cooking under steam pressure; one product was purified by freezing, with the other this step was omitted. One firm developed a method for using fresh seaweed and omitted the drying step (Humm, 1944, 1951, 1951a).

On Florida's Atlantic coast, the agarophytes are only moderately abundant. In the "Indian River", a coastal lagoon along the east coast, Gracilaria verrucosa was collected for commercial production during the last war. Along the overseas highway between Miami and Key West, Gracilaria cervicornis, Hypnea musciformis and Eucheuma isiforme occur in moderate abundance (Humm, 1944). Gulf weed Sargassum natans and S. fluitans are most abundant among the seaweeds washed up on the beaches in quantities. Considering the enormous demand for fertilizer in Florida, where much of the soil is seriously deficient, Florida State Board of Conservation suggests commercial seaweed fertilizer production from this resource.

The sea grass Thalassia occurs in almost unbroken dense matted beds from Miami over Key West to the Dry Tortugas (Voss and Voss, 1955).

2. Gulf of Mexico

U.S. Gulf coast

Florida's seaweed resources of commercial abundance are located along the lower west coast from Cape Sable northward through Tampa Bay. During the winters 1942-43-44, thousands of tons of several species of Gracilaria, Hypnea musciformis and Agardhiella tenera were present in these waters. Digenea simplex, abundant north of Tampa Bay on the central part of Florida's west coast, produces an agar of high gel strength.

The data on the southern U.S. Atlantic and the east Gulf coast resources so far given are derived from a survey sponsored by the U.S. War Production Board in the early 1940s (Humm, 1944). The survey was extended as far west as New Orleans but not a single finding is recorded for the northern parts of Florida, Alabama, Mississippi or Louisiana.

During the last few years, however, comprehensive surveys have been published (Earle, 1969; Edwards, 1969, 1970). Earle states that "extensive areas of the northern Gulf support a considerably varied tropical flora, especially in offshore waters. In addition, a temperate seasonal flora exists during the winter and spring along the entire eastern Gulf coast, with certain characteristically cold water species present only in the northern Gulf".

Edwards (personal communication) gives information on his research area west of the Mississippi: "The Texas coast, at least in the bays behind the barrier island which runs the length of the state, is not inhospitable for marine algae. The number of species is fairly small (in the Port Aransas area, 57 in the bays, 90 when open sea is included) but seaweed species occur in vast amounts in the bays during the summer. This phenomenon of a few species occurring in vast amounts generally occurs in rigorous environments. During rainy periods, which may last for several years, the salinities in the Texas bays are comparable to those of the Baltic, but the largest amounts of seaweed in Texas occur during "normal" or dry periods when the salinities are at least as high as average sea water or even higher. The Laguna Madre, which stretches from Corpus Christi to the Mexican border about 240 km away, may support species of potential commercial value, e.g. Gracilaria verrucosa and G. foliifera."

These recent discoveries within the U.S.A. of an algal flora unexpectedly rich in species and quantities should be taken as a reminder that, with few exceptions, the resources of the coastlines of the world are most insufficiently known.

Mexico

In the southern Gulf of Mexico the number of algae species increases considerably. Humm (1963) indicates a total of 300 as a preliminary result of collection in three places.

Gulf of Mexico, deep sea

In open waters there are considerable amounts of free-floating Gulf weed, Sargassum; 90 000 t, according to an estimate by Parr (1939). Probably concentrated at a few places and easy to harvest, this quantity would produce close to 2 000 t of algin (Davis, 1950).

3. The Caribbean

The Caribbean flora is extremely rich in species and is well known from a taxonomic point of view, mainly through the works of Børgesen (1913-1920), Taylor (1942, 1960) and Chapman (1961, 1963). Taylor recognizes 760 species in the area from Bermuda and North Carolina to southern Brazil; with few exceptions these will all be found in the Caribbean.

Seaweed utilization was reviewed by Richardson (1958, 1959), who circulated a questionnaire to agricultural officers and other possible sources of information. He points out that many of the seaweeds growing in this region are utilized in various parts of the world; for example, the brown genera Hydroclathrus and Sargassum are used for fertilizing peanuts, sweet potatoes, coconuts and coffee in China. Many edible algae are present, such as Ulva lactuca, Caulerpa racemosa, Grateloupia filicina, Hypnea musciformis, Acanthophora spicifera and Laurencia obtusa. Important agar producers are Gracilaria verrucosa and G. compressa.

There is no large-scale utilization of marine algae in any part of the Caribbean in spite of the rich marine flora and a population devoted mainly to agriculture and fishing. This may be because nowhere do the useful algae occur in sufficient quantities for this to be practicable. Utilization on a small scale, however, is in fact quite widespread. There are no reliable figures on the quantities of algae involved but it has often been stressed that they were small.

Crop fertilizer, mulch and compost is the kind of use which may be especially important, and was reported from five islands: Grenada, Barbados, St. Lucia, Jamaica and Cuba, and from Belize (British Honduras). The only figures available are for St. Lucia: 50-70 t per annum. It is not known what species of algae are utilized but they are collected in the form of "cast weed". In some cases, species of Thalassia, a marine angiosperm, are probably the "seaweed" reported (Jamaica).

The algae are used direct as a fertilizer on coconut palms (Belize) or on cocoa plants (Grenada), or are composted with animal manure and other organic matter and then applied as a heavy mulch (Grenada); they are also quite often used in private gardens (Grenada, Barbados).

Human consumption for food or medicinal usage was reported from eight islands: Trinidad, Grenada, Barbados, Antigua, St. Kitts, Barbuda, Jamaica and Cuba, and from Belize. Species of Ulva are said to be eaten fresh as a salad (Trinidad and Jamaica) or brewed into a "bush tea" which is reputed to have some medicinal value (Barbados); these are typical uses of this genus throughout the world.

In Trinidad, jellies are prepared from species of Gracilaria, which in Jamaica are eaten hot as a porridge or cooled as a blancmange or are taken as a drink. According to Richardson's questionnaire answers, the most important alga, which is prepared in a similar manner, is known as "sea moss". This term probably covers various seaweeds, one of which might be a species of Codium, in Barbados C. decorticatum. There is some inter-island trade in this alga. Barbados exports the dried product, Trinidad and Grenada import it. It is difficult to trace origins as the trade is carried out by small inter-island schooners and only small quantities are involved. At one time another "sea moss", evidently some red alga, was exported from Barbados to an American drug firm for agar preparation but this trade has now ceased.

It is reported that the red alga Eucheuma isiforme is eaten in Antigua and Barbuda (Richardson, 1959).

In the U.S. Virgin Islands two marine angiosperms are used for poultry litter and for stuffing mattresses (Richardson, 1958).

Very little information on utilization and quantities is found in the ordinary phycological literature. Distribution maps for Ulva lactuca, Sargassum filipendula, Caulerpa sertularioides, Dictyota dentata and some less useful species are found in Taylor, 1955. Typical habitats such as coastal shallows, mangroves and reefs are described and illustrated by Taylor (1960) who also gives a historical survey with references to reports on collections within the area. Some available data on seaweed occurrences in the region are briefly reviewed below, thus also identifying gaps in our present knowledge.

Belize

Apart from the abovementioned use as fertilizer for coconut palms there is no information on utilization or quantities.

Guatemala, Honduras, Nicaragua, Costa Rica

No information available. It has been said that the far western Caribbean and the east coast of Central America constitute an almost barren section of the sea. "Here rocky reefs, ordinarily ideal for littoral algae, are completely destitute of plants." (Prescott, 1969).

The Atlantic coast of Costa Rica is dominated by sand beaches that stretch monotonously along most of the shore, but towards the southeast calcareous strata provide small areas for the development of coral and coralline reefs favourable to a great diversity of tropical marine algae. Dawson (1962) lists 196 species from Costa Rica and reports 24 species from a lava reef in Nicaragua.

Panama

The algal flora of the Panamanian shores close to the Canal is not rich in macroscopic algae, the rocks, when present, being more or less covered with mud. On a visit to an area 250 km west of the Canal it was found that the flora there is considerably better, and about the same distance to the east it is quite rich indeed. No doubt there are good shores much closer than those recorded (Taylor, 1942).

Colombia

Colombian algae as recorded in the literature were reviewed by Acevedo (1968) who lists 146 species on the Atlantic coast. From his own collections Schnetter (1966) published 56 species and in 1969 a further 107 species, out of which 73 were noted as new to Colombia. Many of these algae are of interest for agar extraction. Schnetter and Schnetter (1967) record Gracilaria cylindrica as being common in many areas where it develops well at a depth of 1 m; G. mammillaris was abundant in all beaches examined and G. domingensis was found in greater quantities. Agardhiella tenera was also abundant in most of the places investigated.

During the Allan Hancock expedition in 1939 Sargassum filipendula was collected as drift weed in various places up to 30 km off the coastline. Extensive beds were seen in shallow water; off Cabo de la Vela it was dredged from 9–24 m. In the same locality the edible green alga Caulerpa prolifera was also found abundantly down to 24 m; at the same depths Codium isthmocladum was found in some quantity. In Bahia Honda, on a bottom of coralline algae the Sargassum beds had a greater variety in characteristic associates with Halymenia, Chrysymenia and other Rhodophyceae (Taylor, 1942).

Venezuela

A list of 144 species is given by Gessner and Hammer (1967) who also describe the algal vegetation in relation to topography, hydrography, shore types and other ecological factors, including mangrove and corals. The most important factor for species selection as well as for biomass is water movements. Protected bays were almost devoid of algae even if light and substrate were optimal. On exposed coasts, on the contrary, there was always a rich growth of algae.

Most of the species found belong to the typically Caribbean flora. On the north coast of Margarita Island, however, upwelling of "cold" water (19–23°C) during almost the whole year favours the establishment and development of great populations of eurytherm tropical or subtropical species within which specimens of exceptional sizes are found. These environmental conditions have also permitted the establishment of an ecologic enclave of algae characteristic for the temperate zones, such as Porphyra, Plocamium and Acrosorium spp. (Díaz-Piferrer, 1967). The marine communities of Margarita Island were described by Rodriguez (1959).

Alginophytes are represented by Sargassum spp., of which Díaz-Piferrer mentions nine indicating depth range and temperature preferences. Agarophytes of many kinds are found, such as Gelidium, Gelidiella, Pterocladia, Gracilaria, Bryothamnion, Hypnea and Digenea. Some 25 species are known to give an excellent agar; of these 19 are found in quantities. In the "cold" upwelling waters the most abundant are Gelidium serratulum, Gelidiella acerosa and Gracilaria venezuelensis. In many places along the coasts and on the islands extended populations of G. domingensis are found at moderate depths.

Hypnea species constitute the most important source of carrageenan found in the Caribbean. Especially rich in Venezuela are H. cervicornis and H. musciformis. There are even more agaroidophytes, some 55 species among which are three Eucheuma. The anti-helminthic Digenea simplex is one of the richly occurring agarophytes, and a number of green algae could well serve to produce a meal rich in nutrients (Díaz-Piferrer, 1967).

On Tortuga Island, Taylor (1942) describes a belt of green algae followed by extensive beds of Sargassum with Padina in shallower pools. "The most striking feature of the location was, however, the large drift of seaweed floating and washed ashore. This was characteristic material of submerged, old coral reefs or other rocky substrata. There was no reef within view ... but it appeared that there were a coral bed and certainly a heavy algal growth between Los Tortuguillos islets... Notable elements in the driftweed mass (which naturally was dominated by Sargassum) were as follows: in Chlorophyceae Ulva fasciata was frequent; in Phaeophyceae only Dictyopteris delicatula was abundant with the Sargassa; in Rhodophyceae, however, several species were noteworthy. The group in greatest abundance includes Laurencia poitei, Lophocladia trichoclados, Delesseria hypoglossum, Hypnea musciformis, Spyridia aculeata, and Halymenia floresia."

On Cubagua, Rhodophyceae in situ were more important than on Tortuga Island, probably because of the more stable character of the rocky bottom. Very abundant were Gracilaria confervoides, Laurencia papillosa and Hypnea musciformis.

Netherlands Antilles: Aruba, Curaçao, Bonaire

The algal vegetation types along the open coasts have been described by van den Hoek (1969) and in bays and lagoons by van den Hoek et al (1972). Horizontal and vertical distribution as well as covering is given for more than 200 species. Some of these are known to be eaten or industrially utilized in other areas: Cladophora, Enteromorpha, Ulva and Valonia spp., Sargassum polyceratium, Gelidiella acerosa, Hypnea musciformis and spinella, Laurencia papillosa.

4. Trinidad and Tobago

Richardson (1969) observed the zonation along a permanent line transect on Trinidad. Enteromorpha dominated the upper part of the intertidal levels, Gymnogongrus the middle, and Hypnea the lower part followed by a distinctive band of Sargassum vulgare. There was a decrease in algal cover from March to May as a result of desiccation.

On Tobago Island, Taylor (1942) observed a considerable mass of algae adrift and lying close inshore although the accumulation on the beach was not great. Most of the drift weed was Rhodophyceae, with a peculiar form of Agardhiella tenera and Galaxaura marginata very common. Large masses of Lyngbya majuscula were observed on calcareous sand, more or less buoyed up by gas.

5. Windward Islands

Grenada, St. Vincent, St. Lucia, Martinique

No information on quantities and utilization apart from that reported from answers to Richardson's questionnaire (p. 32).

6. Leeward Islands

Dominica

Most of the island's coastline is dominated by black volcanic sand, inhospitable to algal attachment. The windward shore is generally bordered by precipitous cliffs, and fringing reefs are practically non-existent. Possibly useful species among the rather few mentioned as abundant by Taylor and Rhyne (1970) are Chondria littoralis, Gracilaria domingensis, Grateloupia filicina and Gymnogongrus tenuis. Shaded tide pools yield large amounts of Hypnea musciformis, Gelidiella acerosa (both also on open shores) and Spyridia aculeata. Various green algae and Sargassum vulgare may also occur in abundance.

Guadeloupe

In spite of an extensive treatment of the flora a century ago (Mazé and Schramm, 1870–1877) there is no recent information.

Montserrat

No information available.

Antigua, Barbuda, St. Kitts-Nevis

No further information to that already quoted from Richardson on human consumption of Eucheuma (p. 32).

Netherlands Antilles: St. Martin, St. Eustacius, Saba

The arrangements of algae in belts, their dependence on substrates, topography and hydrography and their distribution are treated by Vroman (1968).

Anguilla

No information available.

Virgin Islands

The biomass of subtidal seaweeds was studied in Great Lameshur Bay. A wide range of measurements was found at similar depths and no consistent pattern was evident. Thus the maximum and minimum biomass values recorded (780 g/m^2 and 28 g/m^2 respectively) were found at the same depth – 18 m. The major contributors to biomass were the brown Pocockiella variegata and the green Anadyomene stellata, Avrainvillea nigricans, Halimeda incrassata and Udotea conglutinata (Mathieson et al., 1971).

7. Greater antilles

Puerto Rico

Aspects of seaweed ecology are given by Almodovar (1962, 1964, 1964a), Biebl (1962) and Dahl (1973); Burkholder, Burkholder and Almodovar report on the antibiotic activity of some marine algae (1960) and on their amino acid content (1971).

The agar-producing algae have been investigated by Díaz-Piferrer and Caballer de Pérez (1964). Agarophytes were collected by hand from samples of 1 m^2 of bottom. The highest yields in ten stations investigated were from Gracilaria debilis, 1.4 kg/m^2 dry weight, and about 1 kg/m^2 dry weight from G. verrucosa, G. domingensis, Hypnea musciformis and Bryothamnion triquetrum.

When investigated chemically 22 species were classified as agarophytes, 20 as agaroidophytes. The highest return in agaroid from dry weed was found in Eucheuma echinocarpum, 59 percent, E. gelidium, 48 percent, and Gracilaria domingensis, 44 percent. The highest return in agar was 50 percent from Gracilaria debilis, and from 45–38 percent was obtained from Hypnea musciformis, Gracilaria crassissima, G. cervicornis, G. cylindrica and G. verrucosa. The best agar qualities for bacteriological use were obtained from Gracilaria debilis, G. curtissiae, Digenea simplex and Gelidiella acerosa.

Most abundant among the promising agarophytes are Digenea simplex, Hypnea musciformis, Gracilaria verrucosa and Bryothamnion triquetrum, the latter also observed in great quantities as a drift alga.

During summer storms and winter high tides hundreds or even thousands of tons of drift algae are cast ashore, mostly on the south coast. Generally the material is rather heterogeneous but sometimes agarophytes are dominating. Distribution maps are given for drift weed and for 15 species by Díaz-Piferrer and Caballer de Pérez.

Some beaches are often covered with great landings of drift weed, principally red algae (Díaz-Piferrer, 1965); among these Cryptonemia spp. are dominating.

Dominican Republic, Haiti

No information on quantities and utilization.

Jamaica

One of the big floras of the Caribbean is that of Chapman (1961, 1963). His work, however, has not yet been followed up by any assessment of quantities.

Chapman recognizes a number of natural ecological habitats: flat beach rock with seaward edge occupied by a dense growth of Sargassum; offshore coral reefs with turf of Laurencia; inshore coral reefs, where in deeper waters there is a dense growth of Galaxaura and Hypnea; vertical rock cliff in which there are cracks, gullies and rock pools, with Gelidium on vertical faces, Laurencia on more horizontal slopes; boulder beaches, usually with an abundance of Acanthophora, Gracilaria, Spyridia, Hypnea and Digenea; consolidated limestone and coral rock forming flat, jagged platforms with innumerable rock pools, Myxophyceae and a turf of Gelidium; eelgrass association; mangrove swamp.

Cuba

There is very little information on seaweed quantities. However, quite extensive investigations have been carried out on the taxonomy, ecology and nutritional value of Cuban marine algae, in particular on alginophytes from the Oriente province (Díaz-Piferrer and López, 1959; Díaz-Piferrer, 1961; Díaz-Piferrer, Navia de la Campa and Saavedra

Losa, 1961; Soloni Toural, 1954). 317 species are known from the Cuban waters (Díaz-Piferrer, 1964). It still remains to investigate the numerous archipelagos around the island. From six stations on the Cuban coasts some 80 species are listed by Kusel (1972), all with sketches for identification.

According to Díaz-Piferrer and López there exists on most of the rocky south coast of the province of Oriente an extensive brown-greyish littoral carpet in which the brown algae predominate.

In areas with heavy breakers of clean water there are belts where Sargassum polyceratium forms a pure stand. More common in areas where these environmental factors are less pronounced is a community of S. polyceratium and Turbinaria turbinata with fronds of exceptional sizes. Other species of attached Sargassum which are common but appear in strikingly smaller quantities are S. hystrix, S. platicarpum, S. vulgare, S. lendigerum and S. filipendula. In addition to these, there are two species of pelagic Sargassum, S. natans and S. fluitans, which are deposited in considerable quantities on the coasts of the province of Oriente as well as in other parts of the island. All the year round these floating Sargassum arrive at the coasts, during June and July however in extraordinary quantities. One single mass of floating Sargasso weed collected in the entrance to the port of Santiago de Cuba in March 1957 produced 45 kg of dry matter.

Red algae communities appear together with brown algae in modest depths. Among abundant species certain are edible and although not eaten in Cuba are known to be used for food in the Far East: Liagora farinosa, Laurencia obtusa, L. papillosa, Acanthophora specifera. Some of the agarophytes most in demand for industrial use are also found: Gelidiella acerosa, Hypnea musciformis (the latter reaching exceptional sizes in these regions), and Gracilaria foliifera, G. blodgetti and G. verrucosa, as well as the famous antihelminthic Digenea simplex.

On the north coast of the province of Oriente the most common community is composed of Ulva fasciata and Enteromorpha lingulata (Díaz-Piferrer and López, 1959).

The productivity of the Ulva belt expressed as weight of seaweed meal was assessed through regular collections, over one and a half years, on selected localities. The total growth area of the Ulvaceae was estimated at some 10 000 m^2, producing about 7 t of algal meal a year, corresponding to approximately 0.7 kg algal meal a year per m^2 of the Ulvaceae distribution area (Díaz-Piferrer, Navia de la Campa and Saavedra Losa, 1961).

Baardseth (1968), who concentrated on the agarophytes near La Habana, appears to be less optimistic and concludes: "The search for industrial quantities of agarophytes on Cuba did not give satisfactory results, even if some harvestable banks were seen from which samples were taken and the harvesting conditions of which were investigated." The drawback is that a considerable part of the coast consists of mangrove and mud, which prevents the growth of algae. There are also extensive sand beaches, and the remaining parts are not very rich in algae.

Gracilaria domingensis and Hypnea musciformis are found in abundance locally, but limited to restricted parts of the coastline and never sufficient to sustain an industry.

Baardseth (1968) also describes six parts of the shore visited, of which only two had quantities over one ton. In Río Banes a man collected 510 kg of Hypnea musciformis in some four hours using an ordinary rake. When dried in the sun the weight was reduced to 40.5 kg, the dry material thus corresponding to 8 percent of the wet algae. In addition to the quantities which were harvested, there still remained in this breeding place about one ton; similar banks of Hypnea were not found in any other part. In Playa de los Franceses a bank of Gracilaria domingensis contained some 3-4 t fresh weight; the dry weight was about 9 percent of this. If we assume that Cuba needs 50 t of agar a year, the required fresh weight of agarophytes would be 1 000-2 000 t. The banks which Baardseth has seen would scarcely produce a total of more than 10 t per harvest.

Cayman

No information on seaweeds.

8. South America east of the Caribbean

Guyana, Surinam, French Guyana

No information on seaweed quantities and utilization.

9. Atlantic

Turks and Caicos Islands

No information on seaweeds.

Bahamas

In spite of an early investigation of the flora (Howe, 1920) and a sociological investigation (Newell et al., 1959) there are still no records on quantities.

Bermuda

An early publication on the flora by Collins and Hervey (1917) has been followed only by taxonomic studies included in Taylor (1960).

Sargasso Sea

Since Columbus in 1492 found "la mar cajuda de yerbas" there have been many theories on the origin of the Sargassum weed. One suggestion is that it constitutes the remains of the flora of a sunken Atlantis (Germain, 1935), and there are controversial schools advocating that the weed has accumulated from detached plants torn away by storms in the Caribbean area and growing vegetatively into sterile forms, and that the Sargassum flora consists of separate species living separately. It is significant that our knowledge of Sargassum quantities in possible replenishment areas is so scarce that no authors have looked for arguments from this source.

Parr (1939) gives the area of the Sargasso Sea as 5 million km^2 and estimates the quantities of Sargassum at 0.8 to 2.15 t/km^2, which would correspond to a total of 4 to 11 million tons.

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FISHING AREA 34 : EASTERN CENTRAL ATLANTIC

1. Northern subtropical region between 36° and 20°N

Morocco is one of the great producers of agar-agar (following Japan, Korea, Spain and Portugal). Some 3 000 t a year of Gelidium sesquipedale are harvested in the sector between Casablanca and Qualidia. Important Gelidium fields are also found near Tarfaya in the southernmost part of Morocco, but they are less known as exploitation is difficult with the present state of communications. Other red algae are exported. There are laminarians in the sector of Safi (Aubray, 1970). At present there are four factories working up algae: in Casablanca, Barrechid, Tanger and Kenitra. The latter has used Japanese technicians and has a capacity of 1 000 t/year (de Craene, 1971).

In the Canary Islands the dominating species occur in the following order:

(i) at half-tide, a yellow fringe can be seen 20 to 40 cm wide, formed by Cystoseira abies-marina;
(ii) immediately below, there is another fringe, some 25 cm wide, formed by beautiful violet-red Gelidium arbuscula;
(iii) below this, there is a wide dark belt - almost black - which corresponds to Gelidium cartilagineum.

There are greater quantities of Gelidium on the coasts facing north and northeast than on the coasts exposed to the south and east. The richest region of Tenerife is between Buenavista Point and Viento Point and includes the Bay of Garachico and La Cruz Harbour (Rodriguez, 1953). According to Rodriguez, the yield of Gelidium from the shores of the Canary archipelago can be reckoned at approximately 100 t/year, even though the Spanish Government has, by legislation, enforced "closed zones". A later survey, however, merely states that there is very little seaweed in the Canary Islands (Spain S.N.I.Q., 1968).

Johnston (1969, 1969a,b) has estimated standing crops and production in algal communities on Lanzarote, the northernmost of the main islands of the Canary archipelago. No Gelidium was found here. In areas dominated by Cystoseira abies-marina, the standing crop amounted to 1 000-1 600 g dry weight/m². In Padina-Halopteris-Jania communities, standing crops were only 300-400 g dry weight/m². Below the 0-15 m belt, the rocks were almost devoid of algae but on sandy bottoms Caulerpa prolifera was found at depths of 3-50 m. At 35 m the standing crop was found to be 56 g dry weight/m². Johnston also gives the daily production rate for species and communities. The production in the three above-mentioned communities was 8-11, 2-3 and 0.07 gC/m²/day, respectively.

In the areas of Ifni and Cape Juby Gelidium sesquipedale appears in quantity and great size (over 40 cm). It is accompanied by Gelidium attenuatum and G. spinulosum. Among brown seaweeds the Saccorhiza bulbosa particularly, and also Laminaria ochroleuca extend all over the coast, forming great fields at low tide which are now and then interrupted by sandy beaches. On these, and fixed to small rocks covered by sand, one finds strands of Gracilaria, like a horse's tail and over 1 m long. In the Villa Cisneros area of Spanish Sahara, at the Tropic of Cancer latitude, Gelidium and Gracilaria, as well as Fucus, do not grow in sufficient quantities to be considered of industrial interest (Primo, 1953).

In the Cape Verde Islands, the Portuguese Centre for Fisheries Biology reported a search for agar-bearing seaweeds. Insufficient amounts were found for commercial exploitation (Anon., 1960).

2. Tropical region

In sharp contrast to the well-known riches of plankton and fish in the offshore upwellings related to the Benguela Current stands the surprisingly poor algal vegetation in most of the area. Existing species are in general represented by small specimens not worth collecting. There are many reasons for this: open coasts without any archipelago, unsuitable substratum like laterite rocks, sand bottoms or other moving substrata, thousands of kilometres of mangrove swamps lining the edge of lagoon systems, dilution of the waters along the shores with fresh water from heavy rainfalls and large rivers which also involves high turbidity. At low water, organisms in the tidal belt may have to withstand abnormally high salinities under the tropical sun, or abnormally low ones during tropical rains. Such areas are, of course, uninhabitable for all organisms which have not developed protective mechanisms against such fluctuations in salinity. The closed or temporary lagoons are flooded seasonally rather than daily. In Kpeshie lagoon, Ghana, a salinity of 72°/oo has been recorded. During the rainy season salinity drops almost to zero (Lawson, 1966). Such brackish (occasionally almost fresh) water, often rich in particles, may separate the Atlantic shores and bottoms from the nutrient-rich and salinity-stable Gulf of Guinea water from the water line at least as far out as algae could be expected to grow. There is also a tremendous grazing. For example, in western Ghana and elsewhere one may find in the lower parts of rocky shores practically nothing but thousands of individuals of the sea urchin Echinometre lucunter (Lawson, 1966).

Senegal

Hypnea species occupy a large part of the submarine prairies southeast of Dakar where they are deposited in great quantities on about 120 km of shore between Dakar and Pointe de Sangomar from January to April. At times the height of the deposited seaweeds is more than 1 m. They grow subtidally down to 8 m; the width of the prairie depends on the smoothness of the bottom slope and exceeds 12 km between Mbour and Pointe de Sangomar. Most of these populations consist of Hypnea musciformis, but eight species of this genus are distinguished (Bodard, 1968; J. Malick, personal communication). Extraction and composition of carrageenan were investigated by Mollion (1973).

In February 1972 the construction of a factory in N'Gazobil was started with a foreseen capacity of 2 000 t dry weight/year (corresponding to 12 000 t wet weight) from which 1 000 t of treated algae products should be produced — all for export. The company, Sénégalgues, a dependent of the French Iranex, calculates investment costs at U.S.$200 000. Two thousand collectors are already working and another 10 000 will be employed along the whole of Petite Côte. It is estimated that each man will collect 200-300 kg wet weight of Hypnea a day, earning about U.S.$1.5 to $3 a day.

Other agar-producing algae which could possibly be exploited and which are at present being studied are Gracilaria camerunensis, G. henriquesiana, Gigartina pistillata and Anatheca montagnei. Ulva lactuca is accumulated in great quantities.

Ivory Coast

The littoral ecology of a number of readily accessible rocky out crops along 200 km of coast was studied with a particular interest in patterns of zonation (John, 1972). Mats of Gelidium, Grateloupia filicina and Bryocladia were found over much of the littoral at the seaward side of the entrance of the Tavore River. There is a striking difference between this well developed, but poor in species, algal "turf" and the almost complete absence of larger algae at the entrance to the San Pedro River. Most likely this difference would be related to the pressure of grazing. Among the grazers are herbivorous and omnivorous fish and sometimes also sea urchins.

Other countries

There are no other reports from the tropical region that seaweeds are collected for human consumption or for industrial use. Some useful species occur, however, rather frequently. Among red algae, Gelidium species are reported from Mauritania, Senegal, Guinea, Sierra Leone, Ghana, Nigeria and Cameroon, but are poor both in size and quantity.

Gelidiopsis and Gigartina occur in most of these countries and Gracilaria foliifera is dominant in some localities in Mauritania. Gracilaria and Gigartina are very localized and in small patches. The brown alga Ecklonia muratii and some Cystoseira species are present in fairly large amounts in Mauritania and Senegal, Sargassum species in Senegal, Sierra Leone, Ghana and Cameroon (Lawson, 1966). Sargassum vulgare in Sierra Leone is accompanied by vigorous growth of grape-like masses of the green alga Caulerpa racemosa (Longhurst, 1958). Only these two species could be considered as a resource of some importance (A.A. Aleem, personal communication).

Little is known about quantities, but Lawson (1959) has analyzed statistically the weight of plant material per unit area for certain algae (Ulva, Sargassum, Gracilaria) in relation to wave exposure and other factors. In a tide pool in Ghana the standing crop of Sargassum vulgare was 2.5 kg/m^2 and of Hypnea musciformis growing with it, 0.4 kg/m^2 (D.M. John, personal communication).

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FISHING AREA 37 : MEDITERRANEAN AND BLACK SEA

The seaweed recources of the Mediterranean are not very rich. Nevertheless it is surprising that there is scarcely any utilization at all, apart from small agar factories in Egypt and Italy and a Russian production of phyllophoran on the Black Sea.

Among possible reasons for this is the fact that the tidal range is so low that there are no vast intertidal flats promoting large areas with a uniform vegetation, easily accessible for harvesting. Another drawback to possible utilization is the poor value of two quantitatively dominating populations: the sea-grass Posidonia, covering vast areas of soft bottoms, and some 30 species of the genus Cystoseira, large bushy brown algae from which the extraction of algin is not at present economically feasible (see, however, Bulgaria).

1. Spain

A small amount of Laminaria grows from the Strait of Gibraltar to Malaga but it is by no means comparable to the quantities of the northwestern coasts and is not being collected (Spain, S.N.I.Q., 1968). These plants "must surely constitute a real meadow" and "their abundance may permit industrial exploitation" (Bellón, 1953).

2. France

There are no records on quantities harvested along the Mediterranean coast, but a factory in Marseille, Iranex, uses imported raw material. A species of potential value is Rissoella verruculosa, which is rather abundant (Feldmann, 1953).

Bellan-Santini (1969), describing subtidal rocky shore communities southeast of Marseille, also accounts for quantities, thus giving an easily apprehended idea of this flora, here represented through selected data:

Wet weight g/m^2 in some characteristic communities

		Winter	Summer
Clean agitated water	Cystoseira stricta	6 930	13 215
	other algae	562	646
	Corallina mediterranea	1 707	1 615
	other algae	1 570	809
	Plocamium coccineum	1 443	1 703
	other algae	412	547
	Petroglossum nicaeense	242	432
	other algae	450	1 081
Clean calm water	Cystoseira crinita	5 880	5 163
	other algae	1 271	2 856
	Halopteris scoparia	3 779	1 530
	other algae	302	202
	Padina pavonia	613	267
	other algae	680	1 187
Medium polluted	Corallina officinalis	3 457	4 872
	other algae	410	199
	Ulva lactuca		1 965
	other algae		312
Harbour environment	Algae (Enteromorpha + Corallina)		21–1 017

Phytosociological and biometrical aspects were studied by Boudouresque (1969). A population of Cystoseira mediterranea at Banyuls-sur-mer varied from 1 800 g/m^2 in January to 10 100 g/m^2 in June. These communities are typical for vast areas; Cystoseira stricta with subspecies and ecotypes forms an almost uninterrupted belt all around the western Mediterranean. Even where other shores have other species, the general picture is still representative for the Mediterranean in one respect: species reaching quantities worth mentioning are usually either brown algae or chalk-encrusted reds, in both cases of dubious value.

The soft-bottom Caulerpa - Cymodocea association had in two testing areas a wet weight of 2.2-4.4 kg/m^2, dry weight of 0.4-0.7 kg/m^2 and a total green surface of 8-11 m^2/m^2 sea bottom. The primary yield varied between 5.4 and 18.7 gC/m^2 24 h. In comparison with associations of littoral algae on hard grounds these productivity values are to be regarded as high (Gessner and Hammer, 1960).

3. Italy

There are certain quantities of useful algae and a conspicuous activity in research towards their utilization. Numerous recent studies contribute to the knowledge of the chemical composition of possibly useful species (Lokar, 1967; Cossini-Lokar and Baradel, 1967; Cossini-Lokar and Bruni, 1967; Pertoldi-Marletta, 1967; Pertoldi-Marletta and Favretto-Gabrielli, 1967; Bruni and Cossini-Lokar, 1968; Bruni et al., 1968; De Goracuchi, 1969; Favretto-Gabrielli, 1969; Favretto-Gabrielli and Pertoldi-Marletta, 1969; Davanzo et al., 1970; Cossini-Lokar, 1970). The use of algae in therapy was treated by Giordani Soika (1966).

Gracilaria verrucosa is the only red alga actually used as a raw material for agar production in Italy. The primary source of this material for the industry is the lagoon of Venice, where it prefers dirty water and is found from 0.4 to 0.9 m, a favourable factor for the collection (Maldura, 1952). Distribution and polymorphism of this and other Gracilaria species in the lagoon are accounted for by Minio and Spada (1950) and also Schniffner and Vatova (1938).

Extended populations have also been found in the Goro bay near Ferrara in the southern part of the Po delta. The "Sacca di Goro" offers excellent conditions for the development of Gracilaria. The natural habitat is shallow with an average depth of 1 m. Fresh water inflow limits critical temperature rise during summer and near places of such inflow there are large amounts of nutrients. Nitrate values are five times higher, and phosphate values 15 times higher, than in the Grado lagoon on the north coast of the Adriatic. This nutrient enrichment comes from irrigation channels crossing agricultural areas treated with fertilizers. As there is an intense sedimentation from the turbid water to the muddy bottom, competing species, phanerogams as well as other algae, are absent and the Gracilaria population is almost mono-specific. However, there is an epiphytic fauna of filter-feeding animals which may amount to 30-40 percent of the total weight of the algal material (Simonetti, Giaccone and Pignatti, 1970). Under these favourable conditions the alga develops quantities of 2-4 kg/m^2 with a mean of 3 kg/m^2 giving a dry weight of 14 percent. Of the dry weight material the agar outcome is 36 percent. The total mean productivity of the bay should be 20 000 t/year providing 1 040 t of agar.

Not being favoured by agricultural fertilizers, the Grado lagoon is also subject to limited natural circulation and, for the algae, inconvenient water temperatures of 30°C. On the other hand, the inner Adria has a tidal amplitude of 120 cm - a high value for the Mediterranean. This makes a particular kind of environment improvement possible: through an appropriate closing system the surface water can be replaced in a few minutes with a lowering of temperature of 7°C. The effects of enrichment with nutrients are also investigated by Simonetti (1970).

In Lago di Faro at the northeast end of Sicily, a rich occurrence of Gracilaria dura has been recorded by Cavaliere (1969). Other algae present here and known to give agar of a high quality are also found in the Venice lagoon system, but more dispersed and not grouped in masses, as for example Gelidium (seven species) and Gigartina acicularis (Maldura, 1952). Hypnea musciformis should also be taken into account. The biomass of well developed populations is about 1.5 kg/m^2. This annual alga grows on rocky substrates in 1-2 m depth and reaches its maximum growth in summer (Giaccone, 1970).

The best conditions for extraction of phycocolloids from Italian Gracilaria verrucosa, G. compressa (synonym G. bursa-pastoris) and Hypnea musciformis with respect to temperature, time and pH have been examined by Coassini-Lokar and Bruni (1970).

There is, however, another alga which may rather unexpectedly be close to industrial utilization - the green alga Cladophora prolifera. In the Gulf of Taranto in southeast Italy this species occurs in a dense population at depths of 29-34 m from Gallipoli to Porto Cesareo. The Cladophora bottom covers an area of 32 km from NW to SE and has a breadth of 4-8 km. Calculating with a vegetation depth of 30 cm of algae and a dry weight of 15 kg/m^2 the total biomass should reach 1.4 million tons (Parenzan, 1970). The estimated quantity per m^2 is 20 times as high as that known from surface water communities of other Cladophora species. In addition to the high biomass content of the population Parenzan states that it is growing vigorously in spite of the considerable depth for a green alga. He also draws attention to the protein value, close to 25 percent of the dry weight, as compared to 20 percent for Caulerpa prolifera and 15 percent for Ulva lactuca. It seems, however, that industry has become interested because of the microelements. At present 10 t/month are processed on a trial scale and a production based on 50 t/month is foreseen for use as fertilizer and possibly fodder enrichment.

Fucus virsoides, a brown alga containing alginic acid and alginates at about 20 percent of the dry weight, inhabits the littoral where it builds up a biomass of about 2.5-3 kg/m^2 with a dry weight of 21-24 percent (Lausi, 1967). It is present all the year round. Being dependent on tidal fluctuations, rich supplies of nutrients and not too high temperatures it is restricted to the inner Adria exclusively. Variations in content of alginic acid, saccarid composition, industrial utilization and the technique of extraction and purification have been described by Lausi and de Cristini (1967), Coassini-Lokar (1967), Cerma (1968) and Cerma et al. (1968).

Cystoseira is quantitatively a dominating genus. The nitrophile species C. barbata and C. fimbriata in the inner Adria reach a wet weight biomass of 1.1-2.2 kg/m^2. At the Tremiti Islands in the middle Adriatic, the fresh weight of C. spicata is 6.9 kg/m^2 and of C. corniculata 5.2 kg/m^2. In the lower Tyrrhenian Sea C. fimbriata has a mean value of 6.7 kg/m^2 and C. spinosa 4.2 kg/m^2. The cell wall carbohydrates of C. abrotanifolia were examined by Coassini-Lokar and Audoli-Tamburini (1967).

Cystoseira is not even mentioned as a possible raw material in reviews of economically valuable algae by Mautner (1954), Lewin (1962), Hoppe and Schmid (1969) and Chapman (1970). However, it has been stated that C. abrotanifolia, C. barbata and C. mediterranea can be regarded as a raw material for the production of alginic acid and alginates (Smith and Montgomery, 1959; Hoppe, 1969).

4. Malta

This island is rich in algae, the ecology of which is described by Crosset and Larkum (1966), Larkum, Drew and Crosset (1967) and Drew (1969).

5. Yugoslavia

The indented coastline of about 6 360 km (including 4 024 km of island coasts) with mostly rocky shores and a high water quality offers excellent conditions for algal growth. The genus *Cystoseira* is treated by Ercegović (1952); Munda (1962, 1964) discusses variations in chemical composition of the algae.

Sargassum and *Cystoseira* are found in remarkable quantities, as mentioned by Maldura (1952). Špan is more restrained and concludes from his investigation on distribution and biomass of *Cystoseira* that the quantities of such algae are small. On over 1 300 km of shore the estimated quantities are 9 850 t fresh weight, growing on a small area of 4.23 km^2. There are 13 t of fresh weight per km of mainland shores but only a scanty 5 t/km of island shores. The width of the beds on the mainland is around 8.2 m, on the steep shores of the islands only 3.9 m. The biomass of sublittoral samples on mainland shores was about 2.5 kg/m^2, a little more than on the island shores where it was 2 kg/m^2 (Špan, 1969). In the eulittoral and upper sublittoral on western Istria, Munda (1972) undertook a comprehensive study of algal biomass. Mean values of the fresh weight of seaweed varied during the year between 1.2 and 2 kg/m^2 with a maximum for a single sample of 9.5 kg in a *Cystoseira* settlement in June. Average protein content was 22–27 g/m^2, alginic acid 40–69 g/m^2.

Size and periodicity of growth in *Cystoseira barbata* were studied as part of a team work investigation of artificial fertilization of a bay and its influence on hydrography, plankton, fish and shellfish (Špan, 1969a, Buljan *et al.*, 1969). An annual growth of 3–8 cm was found in mature plants, in young specimens 2–5 cm. In a protected area the growth rhythm was rather uniform; in a slightly exposed part of the bay there was a spring maximum followed by a summer minimum. It was supposed that fertilization had a positive effect on the process of growth.

With regard to the important beds they create in certain areas two red algae could be considered as possible raw materials: *Hypnea*, from which the agar-like substance hypnean can be produced, and *Vidalia*, a perennial red alga of the family Rhodomelaceae (Maldura, 1952).

6. Albania

No information is available on quantities or utilization.

7. Greece

Most of the submarine flora consists of the flowering plant *Posidonia oceanica*. Of the true seaweeds, the important ones are *Sargassum linifolium*, *Cystoseira squarrosa* and *C. barbata*. *Fucus* has disappeared and *Dictyopteris* appears as a common brown alga. Various kinds of *Enteromorpha* are common on boulders and as epiphytes on *Cystoseira*. After storms much *Codium tomentosum* is washed up. *Ulva* is often cast up in quantities together with seagrass and forms an important manure for the fields. *Corallina* is prized as an efficient vermifuge and is collected and sold to chemists (Gordina, 1953).

Among the red algae some could be used for extraction of agar. Diannelidis (1949) recommends cultivation of *Gelidium latifolium*, *G. crinale*, *Gigartina teedii*, *Gracilaria verrucosa*, *G. compressa*, *G. dura*, *Hypnea musciformis*, *Porphyra atropurpourea* and *Pterocladia capillacea*.

A recent study by Nizamuddin and Lehnberg (1970) of the algae on some Cyclades islands confirms the impression that the algal flora is very poor. Giaccone (1968) tries to interpret the ecological requirements of some algal species with a particularly interesting distribution in the Mediterranean.

The seagrass Halophila stipulacea has immigrated through the Suez Canal almost a century ago and now inhabits the whole Greek archipelago where it extends westwards to Cape Matapan in the Peloponnesus (Pérès and Picard, 1964).

8. Bulgaria

The total standing crop of algae is in the order of 100 000 t, out of which 50 000 t grows in commercially harvestable beds. From this latter standing crop 5 000 t a year could be harvested. At present, however, there is no production from algae (L. Ivanov, personal communication, 1970).

Phyllophora nervosa could provide raw material for production of the agaroid phyllophoran as in the Soviet parts of the Black Sea.

Cystoseira barbata can be regarded as a potential raw material for alginate. The possibilities of utilizing this species are being investigated, apparently with good results (Decheva and Khardalov, 1970).

9. Romania

During summer enormous amounts of Ulothrix zonata, the thallus of which consists of a single cell-row, covers the banks of the salt lake Laou Sarat with a green, compact mat, reaching a dry weight of more than 460 g/m^2. This dry matter was obtained by sun-drying followed by stove-drying and is not comparable with only sun-dried material. It contained 30 percent protein and 8 percent lipids. Investigations into the cultivation of this alga have been carried out (Ionescu, 1970).

10. U.S.S.R. (Black Sea)

With the passage from the Mediterranean to the Black Sea the macroflora is much less impoverished than the animal forms; only with the passage into the low saline waters of the Sea of Azov does the number of species of benthic algae drop markedly. Dominant forms are Phyllophora nervosa and Cystoseira barbata. In a favourable environment the eelgrasses Zostera marina and Z. nana reach a biomass of 5 kg/m^2, and average 1.5 kg/m^2. In the shallows of Karkinitsk Bay, northwest of Krim, they form a mass of no less than 200 000 t. The total amount in the Black Sea has been determined as 1 million tons.

Phyllophora is found along the whole shore of the Black Sea, but 95 percent of its total mass is concentrated in the northwest, in a region called Zernov's Phyllophora Sea. Here, at a depth of 30 to 60 m, it covers the mud-shell gravel floor in a huge mass over an area of about 15 000 km^2. On the average the density of Phyllophora is 1.7 kg/m^2, but in maximum accumulation it reaches 13 kg/m^2. The total Phyllophora is estimated at 5–6 million tons, which should be compared with the bulk of all other macrophytic algae in the Black Sea which total half a million tons. This is possibly the mightiest accumulation of red alge throughout the world ocean. A Russian industry for the production of the agaroid phyllophoran is based on this resource (Zenkevitch, 1963; Kalugina and Lachko, 1968).

The Caspian Sea has a total biomass of macrophytes in the order of 3 million t wet weight. The only commercial plant is Zostera nana. The resources of this sea grass constitute about 700 000 t wet weight. Along the west coast red algae have a biomass of up to 3.6 kg/m^2, consisting mostly of Laurencia paniculata (Kireeva and Schapova, 1957; Zenkevitch, 1963).

11. Turkey

Phyllophora from the Turkish Black Sea coast has been used for the production of iodine. It has been shown to have antilipaemic properties also observed in Cystoseira (Güven and Aktin, 1964). Cystoseira species are well developed along the coasts of Turkey.

12. Cyprus
13. Syria
14. Lebanon

No information on quantities or utilization.

15. Israel

Ulva and Laurencia are most easily accessible for a possible harvesting.

Ulva, Enteromorpha and Jania make up a considerable part of the cover on a coastal platform recorded in an investigation of selectivity in herbivorous fish. Laurencia papillosa, Sargassum vulgare, Acanthophora, Cladophora and Centroceras spp. are present in smaller quantities; on the vertical wall Jania, Corallina, Gigartina and Pterocladia (B. Lundberg, unpublished).

16. Egypt

Seaweeds cast ashore at Alexandria after rough seas and storms have been estimated at 4 000– 6 000 t fresh weight annually. A considerable portion of this is made up of agarophytes such as Pterocladia capillacea and Gracilaria species, and of alginophytes such as Cystoseira and Sargassum. Pterocladia grows in abundance on exposed rocks just below the midwater level. Nevertheless manual harvesting is not practicable as the tidal range is too low (30–50 cm) and the wave effect too strong. For some years seaweeds cast ashore were dried and sold to Japan. Now they are extracted as a side production in a food canning industry in Alexandria.

The Arabs of Abu Qir have for long used certain seaweeds for pharmaceutical purposes. A laxative is prepared locally by pharmaceutical firms. Digenea simplex serves as a vermifuge (Aleem, 1969).

The quantity and quality of agar in Egyptian seaweeds were investigated by Mohammed and Halim (1952) and Samaan (1960); alginic acid from Cystoseira barbata was studied by Salem, Abdel-Fattah and Hussein (1971), and the nutritional value of seaweeds for livestock and poultry by Aleem (1961).

The structure and evolution of the sea grass communities Posidonia and Cymodocea in the southeastern Mediterranean have been described by Aleem (1959) also accounting for the algae included in these communities.

The recent migration of certain Indo-Pacific algae from the Red Sea into the Mediterranean has been discussed by Aleem (1948, 1950) and Neushul (1969).

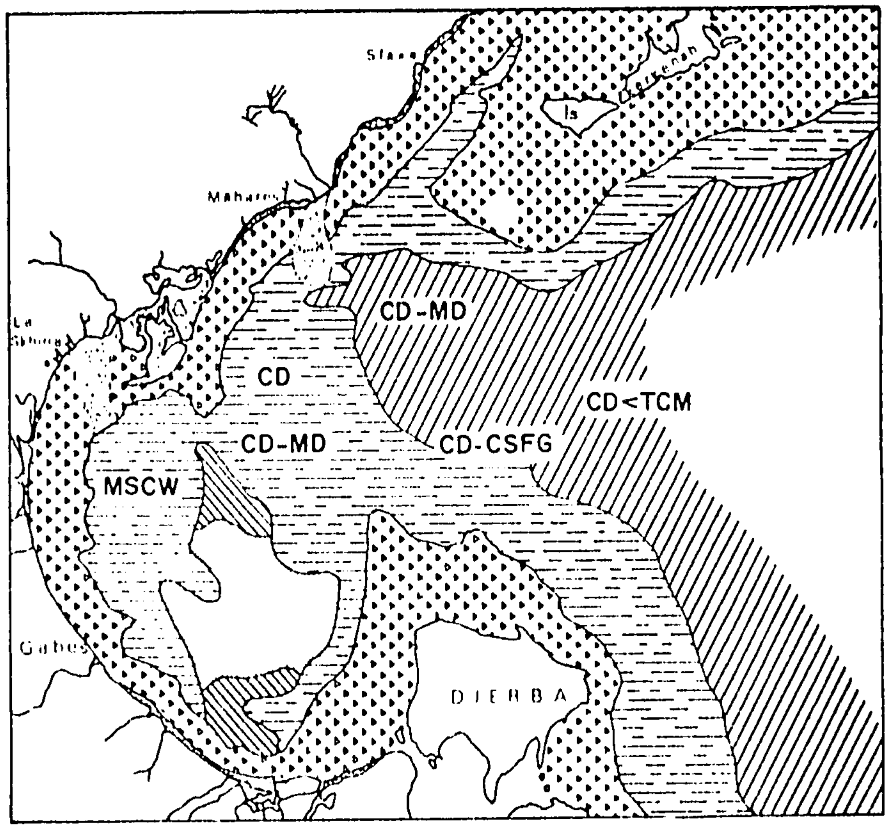
17. Libya

The Government has acquired equipment for processing seaweeds to fertilizers. The flora was described by De Toni and Forti (1913).

18. Tunisia

As early as the 1920s a study was made on the possibilities of utilizing Tunisian marine plants for fodder. Zostera marina, Z. nana, Cymodocea nodosa and Posidonia oceanica were especially considered, but also Ruppia maritima, and among the algae Caulerpa prolifera and Halimeda tuna.

The submarine prairies in south Tunisian waters (south of 35°15'N) were estimated to cover 4 000 km^2 in depths of less than 5 m and 10 000 km^2 in less than 30 m. This vegetation was considered to represent an immense nutritional reserve to be used in case



(blank box)	Biocenosis of muddy sediments in calm water (MSCW)
(diagonal hatching)	Biocenosis of terrigenous coastal mud (TCM)
(dots)	Posidonia prairie
(dashes)	Caulerpa lawn
(hatching)	Offshore zone
CD	Biocenosis of coastal detritus
MD	Biocenosis of muddy detritus
CSFG	Biocenosis of coarse sands and fine gravel under the influence of bottom currents

Figure 3. Map of soft bottom communities in the Bay of Gabes. (From de Gaillande, 1970)

of emergency (Pottier, 1929). Recently a Belgian firm has shown interest in exploiting these resources, in particular Caulerpa prolifera. Their analyses show 29.3 percent proteins, 25 percent cellulose, 17.5 percent starch and 1.65 percent fats in the dry substance. (H. Mignot, Imurex SA, Berchem, personal communication).

There are four maps of Posidonia prairies and Caulerpa lawns in Pottier's 1929 survey and one of the Gulf of Gabes in de Gaillande (1970) (Fig. 3).

Ben Alaya (1970) has listed the species of the Gulf of Tunis.

The heavily polluted Tunis lake in autumn has an enormous and explosively quick development of benthic algae, Ulva, Enteromorpha and Chaetomorpha, which rise quickly to the surface of the lake and float in a dense green carpet. The biomass of these algae is on average a little less than 1 kg/m^2. The yearly production of Ulva alone comes to 5 000 t. It has been suggested that a permanent special service should remove these algae from the lake and that they be used as a fertilizer for agriculture (Stirn, 1968).

19. Morocco

No information on quantities or utilization from the Mediterranean coast.

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FISHING AREA 41 : SOUTHWEST ATLANTIC

1. Brazil

In the north of Brazil an extensive programme for seaweed utilization is being launched. The Algimar company has built three factories in the states of Rio Grande do Norte, Ceará and Paraíba and organized 165 collection centres over about 2 000 km of coastline, giving work to 24 000 people. Strong support is given by the Brazilian Government; the enterprise constitutes part of a project for developing the northeast coastal region. The main harvests are of Hypnea and Gracilaria; other species being collected are Agardhiella, Eucheuma, Digena, Gelidiella, Gelidium, Pterocladia, Dictyota and Sargassum. The factories making agar, alginates and carrageenan have a capacity of 500 t of each, and also make seaweed meal. Most recent figures for production (1973?) comprise 144 t agar, 960 t alginates and 11 520 t seaweed meal, corresponding to harvests of some 14 400 t agarophytes, 96 000 t alginophytes and 55 000 t wet weight of unspecified seaweeds. The production is correlated to the development of stock-raising in the inner parts of the country. There are close to 100 million head of cattle in Mato Grosso. The transport of meat to coastal consumption areas could not be carried out without considerable losses in quantity and quality if the pieces of cut meat were not given a thin cover of alginate before deep freezing. It is anticipated therefore that any quantity which can be produced will be consumed within the country and only dry raw material in excess of the factories' capacity will be exported (de Sternberg, personal communication). The algae of the whole area were described by Taylor (1931, 1960).

Out of 201 species of marine algae found in the northeastern states of Brazil by Pinheiro-Vieira and Ferreira (1968) they selected 21 species, all red algae, as being of industrial interest. Of these, four are very abundant: Gracilaria ornata, Gracilariopsis sjoestedtii, Hypnea musciformis and Bryothamnion seaforthii. A further seven are mentioned as abundant: Gracilaria cearensis, G. debilis, G. ferox, G. foliifera, Amansia multifida, Vidalia obtusiloba and Agardhiella tenera. The geographical, ecological and seasonal occurrence of these species is given. The bottom communities of the northeast Brazilian shelf are described by Kempf (1970). The most important feature is the dominance of calcareous algae such as Halimeda and Melobesiae.

For central and southern Brazil there are some extensive investigations of the flora: Joly, 1965, 1967; Yoneshigue-Braga, 1970, 1970a, 1971, 1972, 1972a. Humm and Williams (1948) have studied the agar from two Brazilian seaweeds. Hypnea musciformis var. hippuroides should contain more than 35 percent of its dry weight of an excellent quality agar.

No quantitative records are available.

2. Uruguay

A number of small shrubby red algae species inhabit the intertidal levels. Some are said to be processed by a branch factory of an Argentine industry. High relative humidity in the air is a problem for drying.

3. Argentina

The seaweed production of Argentina increased from 2 000 t in 1958 to 24 800 t in 1968. In 1973 the harvested quantities were composed of 1 700 t of brown algae, 21 400 t of red algae, and 1 200 t of miscellaneous aquatic plants (FAO, 1974).

Exports of marine algae and agar-agar amounted to U.S.$2.3 million in 1967, U.S.$1.3 million in 1968 and U.S.$1.1 million in 1969. They represented about 55 percent of the total exports of fishery products (H. Barlind, personal communication).

The seaweed flora has been treated by Taylor (1939), red algae by Pujals (1961, 1963), brown algae by Asensi (1966) and species of economic importance by Kühnemann (1970, 1970a). In the north of Argentina seaweed quantities are low. An investigation of trophic levels in the vicinity of Mar del Plata, 38°S, mentions Codium spp. and Dictyota sp. as the main primary producers among macroscopic algae (Olivier, Bastida and Torti, 1968a). A treatise on the littoral ecosystems between 12 and 70 m in the Mar del Plata region states that algae are absent in the studied area, which could be related to the lack of light below 12-15 m depth due to muddy waters (Olivier, Bastida and Torti, 1968).

In Golfo Nuevo at 42°37'S, another investigation of marine ecosystems has been performed giving a detailed classification of the biocenoses at different levels (Olivier, Kreibhom de Paternoster and Bastida, 1966). In the rocky sublittoral level of Puerto Pardelas, instead of the great Laminariales which are found in other areas, there is a rich community of Codium fragile, C. vermilara marking the upper boundary of that level.

A research station, initially for marine algae and now covering the whole field of marine biology, was set up near Puerto Deseado in Patagonia at 47°45'S. The Deseado River mouth bears tidal oscillations up to 6 metres. As the coast is often a smooth slope, there are very wide littoral and sublittoral belts with densely populated biotopes (Kühnemann, 1964, 1971). In this region, the marine flora is exceptionally abundant. There is kelp growing in 70 m of water. The Macrocystis holdfasts examined by M. Neushul resembled those of M. integrifolia. In Ushuaia, Tierra del Fuego (water temperature 5°C) Macrocystis grew luxuriantly in about 2 m of water. Here it had the appearance of M. angustifolia (North, 1958).

Macrocystis predominates amongst the seaweeds on the Patagonian and Tierra del Fuego coasts up to the Malvinas (Falkland) Islands. Together with the Macrocystis beds of Chile this may very well constitute one of the largest seaweed resources of the seas. Ecology and norms for exploitation are being investigated. Other seaweeds are of the genera Corallina, Gymnogongrus, Porphyra, Gigartina and Polysiphonia (Nicola and Pecora, 1953). A comprehensive study of the species of the region was made by Skottsberg (1921, 1923).

Primarily Gracilaria and Gigartina are actually being exploited on the Patagonian coast, and on a smaller scale Porphyra and Macrocystis (A.O. Asensi, personal communication).

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FISHING AREA 47 : SOUTHEAST ATLANTIC

The sparse information from Angola and Namibia seems to indicate that for the African west coast, south of Congo to the Tropic of Capricorn, the same can be said as for the coastline north of the Congo estuary: the shore waters do not provide such favourable conditions for the benthic algae as do the highly productive offshore waters for plankton.

1. Angola

From the north southward to the Moçamedes area the coast of Angola is rocky. The southern parts are sandy like the Southwest African ones.

Gelidium cartilagineum, Hypnea benguelensis and Peyssonnelia capensis are agarophytes growing in quantities (Granger, 1964; Palminha, 1961, 1967, 1969; Palminha, Torres and Granger, 1963).

2. Namibia

Gracilaria verrucosa has been recorded from Walfish Bay and Lüderitz Bay (Isaac, 1956). No data on quantities are available.

3. Union of South Africa

The seaweed resources have been investigated by Isaac and Molteno (1953). According to their account, the two commercially important agarophytes are Gracilaria verrucosa and Gelidium pristoides. Gracilaria is cast up in amounts of about 1 000 t of dry weed annually along the 26 km of the Saldanha-Langebaan Lagoon northwest of Cape Town. For maps and details see Isaac, 1956. Originally, South African agar was obtained exclusively from this species, but since 1951 agar has been produced also from Gelidium pristoides. This species is not cast up and has to be collected from mid-tide levels. It is widely distributed in moderately warm waters and commercially collected along 120 km of coastline in the southern part of the east coast at the rate of about 80 to possibly 100 t dry weight per annum.

Of potential value for the manufacture of phycocolloids is Hypnea spicifera, which is abundant. Aeodes orbitosa and Gigartina radula have both been used for beer fining. An indication of the abundance of the latter is afforded by the claim that up to 100 t dry weight per annum can be obtained. Further potential agarophytes are Iridophycus capensis, Gelidium cartilagineum, G. amansii, Suhria vittata and Caulacanthus ustulatus. Porphyra capensis occurs in quantities but is not being utilized.

Algin-yielding kelps in sufficient amounts to be potential resources are Ecklonia maxima, Laminaria pallida and Bifurcaria brassicaeformis. The latter is abundant only between Cape Town and Cape Agulhas. Ecklonia is known as "bamboo seaweed", prefers warmer waters and is found on the west coast between Cape Agulhas and the Tropic of Capricorn, where it is cast up throughout the year in large quantities. Shuttleworth (1951) has estimated the drift weeds of Ecklonia and Laminaria at "many hundreds of thousands, if not millions, of tons". He does not indicate how he arrives at this estimate, and Isaac and Molteno (1953) state "there can be no doubts that Shuttleworth exaggerates the quantities of kelp on South African coasts". Nevertheless, Shuttleworth's extremely high values seem to be more frequently surviving in later selections of references even if, from the point of view of probability, Isaac and Molteno's reservations are the most appropriate. The latter give as an indication of quantities the estimate that from five enumerated localities only some 6 000 t dry weight of mostly Ecklonia can be collected annually. These localities represent but a small part of the total coastline along which kelp grow. Much of the west coast, however, is very inaccessible for commercial collection.

Suhria vittata is consumed in jellies.

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FISHING AREA 51 : WESTERN INDIAN OCEAN

1. Mozambique

No information available.

2. Madagascar

The south coast is rich in Gelidium. Some 300 t a year are harvested, of which 100 t are imported by Japan.

3. Mauritius

Very large amounts of seaweeds, in particular Gracilaria, are cast up on the beaches, but not used. Several people are employed to keep a hotel beach clean from decomposing algae.

4. Tanzania

The most important seaweed commercially is Eucheuma striatum and three or four other species of the same genus. The export of somewhat more than 700 t of dried matter (3 000 t wet weight) brings local incomes around 1.5 million shillings. Eucheuma growth is luxuriant – one single specimen of E. platycladum may weigh almost 1 kg. There is still plenty of Hypnea, which is not used. Potential resources not utilized are found in Sargassum and Turbinaria. The green sea lettuce Ulva appears as four species and is usually found in considerable amounts; in December it appears in masses (Jaasund, personal communication).

5. Kenya
6. Somalia
7. Ethiopia

No information available.

8. Sudan

The amounts harvested are estimated at 1 000 t a year.

9. Egypt

The lower littoral belt at Ghardaga on the Red Sea coast is rich in brown algae such as Sargassum, Cystoseira and Cystophyllum. The tidal amplitude (100–120 cm) would permit harvesting by hand (Aleem, 1969).

10. Saudi Arabia

From the Farasan archipelago in the southern part of the Red Sea, Klausewitz (1967) reports a kelp forest strip of Sargassum latifolium and Turbinaria decurrens. Inside this there are sparse populations of Cystoseira myrica, and outside Laurencia. Good illustrations are given by Simonsen (1968). Species list and bibliography of Red Sea benthic algae are found in a comprehensive review by Papenfuss (1968).

11. Yemen Arab Republic
12. Democratic Yemen

No information available.

13. Oman

In four areas recently surveyed the total standing crop could be in the order of some 2 500 t of Hypnea and 28 000 t of Sargassum. These resources could form a base for the development of a seaweed fertilizer and feed additive industry in southern Oman.

14. United Arab Emirates
15. Qatar
16. Bahrain
17. Kuwait
18. Iraq
19. Iran

No information available.

20. Pakistan

There are nearly 900 km of shore to the Arabian Sea with upwelling water, rich in nutrients and plankton, but the open coastline, often with loose substrates, makes the shores less accessible for seaweeds and collectors.

Seaweed communities on various levels were described by Salim (1965). Most interesting as a possible resource is *Gelidium pusillum*, the dominant species from mid-tide level to the low water mark, which forms a dense matted growth on the rocks, especially on the shaded sides. The drift algae which are cast ashore by the incoming tide accumulate in large amounts especially in certain nooks and pockets on the rocky shore. Three communities of such landed drift algae are described. Along sandy coasts *Sargassum*, *Botryocladia* and *Hypnea* are dominant. In drift communities on rocky shores the same genera are represented among the dominant species, as are also *Calliblepharis*, *Halymenia* and *Dictyota*. *Agardhiella* and *Gracilaria* may also appear abundantly.

Only one investigation of quantities has been made covering the intertidal belt in two localities close to Karachi over a period of one year (Saifullah, 1973). It was found that production of seaweeds was high during the northeast monsoon season and low during the southwest monsoon, a period of strong winds and turbulent seas.

In the eastern parts of the localities investigated, brown algae made up 94 percent of the total weight of attached seaweeds, green algae the rest, while in the drift portion brown and red algae were present in almost equal proportions. In the other locality green algae dominated the samples of attached species, while red algae made up 98 percent of the drift. The dominant species was *Hypnea musciformis* which comprises 92 percent of the total algae. Evidently the drift material consisted of subtidal material only, which was cast ashore in a heap 2 m wide and with an average weight of 11 kg/m^2. The almost monospecific finding of a much demanded species seems promising while the quantities on the investigated part of the shore appear less encouraging for utilization.

The subtidal material still remains to be investigated but judging from the drift weed it will certainly contain considerable amounts of *Hypnea*. It seems reasonable to assume that *Hypnea* should be suitable for cultivation where the natural stands are so abundant. At Paradise Point the author found a rich cover of *Porphyra* sp. (Michanek, unpublished) not previously recorded from Pakistan but known since 1951 as an immigrant on the Visakhapatnam coast (Umamaheswara Rao and Sreeramulu, 1963). It should also be worth investigating the possibilities of cultivation of *Porphyra*.

21. India

21.1 Demand

Sixty percent of the population of India is estimated to be vegetarian. Considering the high total protein content in seaweeds, the algae constitute a potential resource of valuable supplementary food. Their possible contribution towards a complete nutrition further depends on the fact that their composition of amino acids differs from that of land plants and varies between species. Aspartic acid is the dominant one, followed closely by glutamin acid. In some algae proline, histidine, leucine and phenylalanine are found in large amounts (Central Salt and Marine Chemicals Research Institute, 1971).

At present, however, seaweeds are not used for human consumption in India to any extent comparable with the other countries in the Far East. The quantities harvested are taken by industry and it must be foreseen that all production in the near future resulting from increased harvesting of natural resources as well as that from marine cultures will most likely be used as industrial raw material. On the other hand, the seaweed chemists in the Central Salt and Marine Chemicals Research Institute propose to extract seaweed proteins and blend them into suitable food preparations. It has been

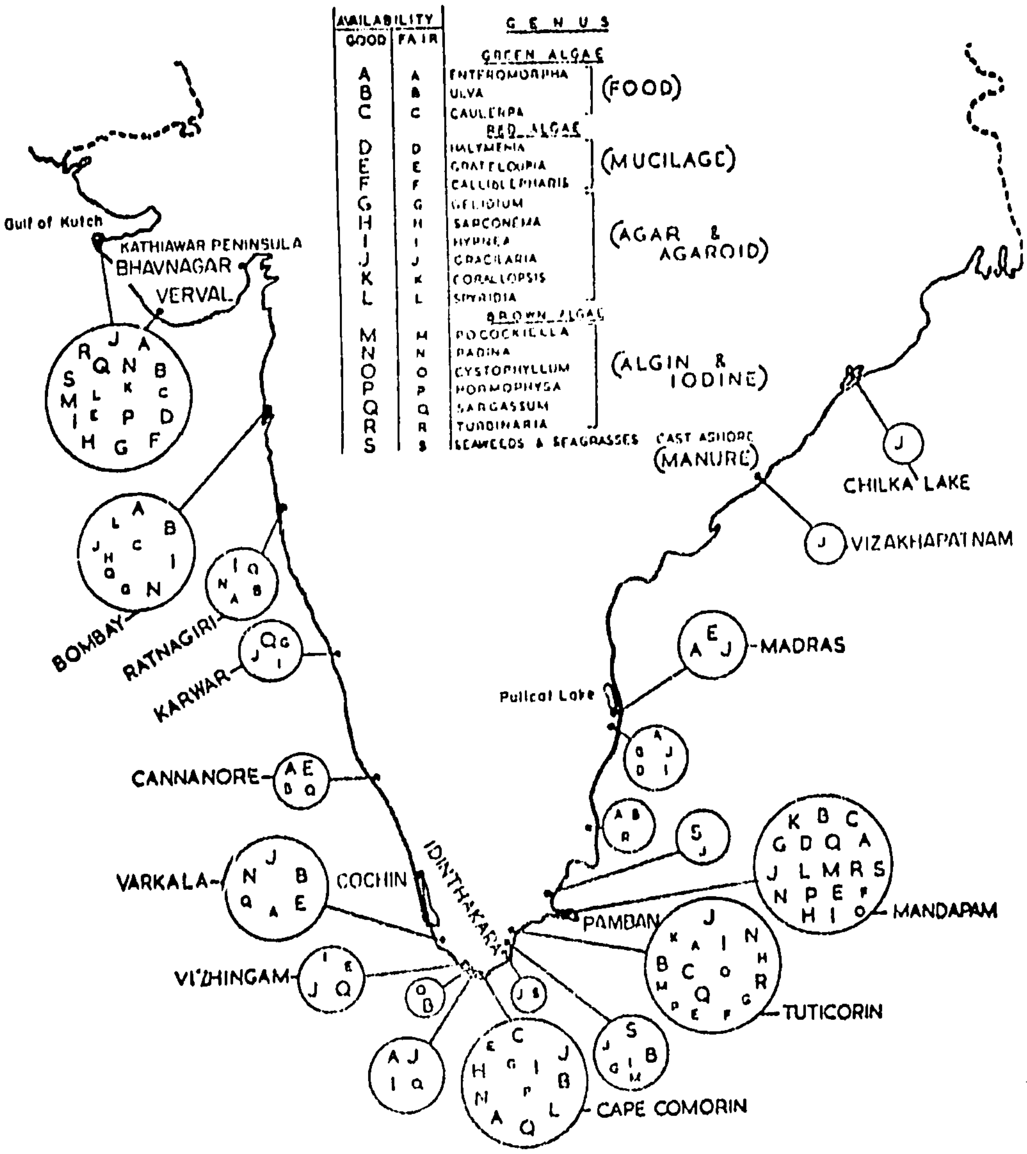

Figure 4. The distribution of the economic seaweeds of India.
(After Thivy, 1958)

claimed that proteins from green leaves are cheaper to extract, but they lack certain essential amino acids present in seaweeds. The industrial demand for seaweed raw material exceeds present production. About 60 t of alginate (for the textile industry) and 30 t of agar are imported every year. Demands are increasing and imports restricted (Desai, 1967). The agar is needed mainly for the preparation of cholera vaccine. The demand is 100 t, the present production only averages 50 t a year. About 60–70 t of sodium alginate per year is produced from about 700 t of dried Sargassum, harvested on the southern coast. There are plans for expansion in the near future and then the demand for raw material will be doubled (Chinoy and Vaidya, 1970). Even though export of dried seaweeds is now prohibited, the raw material is not sufficient for the present demands and cultivation of seaweeds is being taken up.

21.2 Distribution

Along the coastline of India, rocky or coral formations occur in the Mandapam and Kathiawar peninsulas and in the vicinities of Bombay, Ratnagiri, Karwar, Goa, Varkala, Vizhinjam, Visakhapatnam and a few other places like Chilka and Pulicat Lakes. Indian seaweed resources are restricted to these areas and to the Laccadive, Andaman and Nicobar Islands. The richest resources, however, and at present the only exploited ones, are found in the area from Mandapam, the tongue of land stretching towards Sri Lanka, down to Cape Comorin, the southernmost point of the Indian mainland, and along the Kathiawar peninsula, in the northern part of the west coast. The Indian seaweed resources, their taxonomy, chemistry, ecology and utilization are reviewed by Umamaheswara Rao (1970) who also gives a comprehensive list of literature.

The distribution of seaweed resources has been mapped by Thivy (1958) (Fig. 4) and by Umamaheswara Rao (1969). Thivy takes into account as many as 18 genera as well as seaweeds and sea grasses cast ashore and used as manure. Umamaheswara Rao concentrates on the four most important agar- and algin-producing genera: Gracilaria, Gelidiella, Sargassum and Turbinaria. Gracilaria species are found all around the coasts of India, G. lichenoides in lagoons and protected areas, attached to pebbles and shells on muddy substratum, G. crassa in shallow near-shore areas, G. verrucosa on sandy bottoms of the salt water lakes and other protected areas, its basal parts being buried in sand or attached to small stones. During the second world war agar was manufactured with Gracilaria species at the University of Travancore. A cottage industry method was developed at the Central Marine Fisheries Research Institute in Mandapam using G. lichenoides (Thivy, 1960). Gelidiella acerosa (= Gelidium rigidum) is found on surf-exposed areas of the coral reefs and is therefore restricted to the Mandapam area and the northwestern part of Kathiawar peninsula (Umamaheswara Rao, 1969). This is mentioned as the most important species for the manufacture of agar, giving the highest agar yield and its agar showing the highest gel strength. In the Mandapam area it occurs in quantities of about 1.5 kg wet weight/m^2 of reef. At the time it was identified as Gelidium micropterum (Thivy, 1952; Boney, 1965).

Turbinaria (T. conoides and two more species) needs hard bottom and is found mainly on sheltered parts in the two coral reef areas already mentioned. Sargassum (51 species such as S. wightii) has the widest horizontal as well as vertical distribution. Very detailed records on brown algae are given by Misra (1966) in his chapters on distribution and seasonal succession.

21.3 Quantities of alginophytes

The standing crop has been estimated by Sreenivasa Rao, Iyengar and Thivy (1964) at the northwest end of Kathiawar. On 0.015 km^2 of a reef area they found 60 t of fresh Sargassum, which makes 4 kg/m^2. Hornell (1918) estimated the amount of fresh Sargassum washed ashore along the Kathiawar coast at about 100 t annually.

In the Gulf of Kutch, north of the Kathiawar peninsula, Desai (1967) gives the very high estimate of 100 000 t of harvestable brown algae per year corresponding to 10 000 t dry weight. Chauhan and Krishnamurphy (1968) however, in the same area investigating a good 10 km^2, found 19 000 t fresh weight of algin-bearing seaweed, 12 000 t of which were Sargassum. Considering a life span of two years for Sargassum on the Gujarat coast, "it would be desirable to harvest only one-third of the available weeds in any one year". Four thousand tons of fresh Sargassum is sufficient to produce about 80 t of alginic acid.

21.4 Quantities of agarophytes

Prasanna Varma and Krishna Rao (1964) estimated the seaweed resources along the Pamban area in the Gulf of Mannar. In two sections covering 59 km^2, only 0.5 percent had coral or rocky reefs with economically harvestable seaweed resources; these 0.294 km^2 have an estimated wet weight of harvestable Gracilaria of 334.9 t, of Gelidium 18.9 t, of brown algae 657.9 t, or: agarophytes 1.2 kg/m^2, and alginophytes 2.2 kg/m^2. This estimate from these two localities equals or surpasses Thivy's (1960) estimate of the total Indian resources of dry agarophytes at possibly 35 t. Prasanna Varma and Krishna Rao state that on an average the red algae (Gelidium micropterum and Gracilarias) attained harvestable size in about two to three years while the brown algae (Sargassums, Turbinarias and Cystophyllum muricatum) required about four years. Recent studies by Raju and Venugopal (1971) and Umamaheswara Rao (1969, and unpublished) have shown that these brown algae grow to maximum height within one year and that Gracilaria spp. do not take more than six months to grow to harvestable size.

In Palk Bay, north of the Gulf of Mannar, Umamaheswara Rao (1968) estimated the standing crop in an area of 3.6 km^2. The mean values for two years of investigations were:

	Fresh weight (in tons)	kg/m^2
Agarophytes	140	0.04
Alginophytes	148	0.04
Edible algae	217	0.06
Other algae	428	0.12
Total	953	0.26
Sea grass	2 000	2.5

Sea grass quantities were calculated only for the area actually covered by phanerogams, 0.75 and 0.88 km^2 for the two years respectively. The mean total fresh weight was 2 000 t and mean density 2.5 kg/m^2.

A different kind of assessment, closer to the quantities available for industrial utilization, is given by Krishnamurthy et al. (1967). Over a period of three months they made daily collections of the drift seaweeds left ashore by the receding tide. At two stations - Pamban, the island ridge east of Mandapam, and Idinthakari, half way from there to Cape Comorin - they established ten sampling parcels of 10 m each within a distance of 1 km from the shoreline. The weeds were washed and sorted in seven groups, the fresh weight of which was recorded. Then they were separately dried and weighed again. The daily collections were added into monthly, for each of the seven species groups; the three months were, however, treated separately during the subsequent chemical investigations, which included moisture, ash, algin, agar and several inorganic components. Calculated total amounts of drift seaweed in tons fresh weight for both coastlines investigated were:

	Total	Sargassum	Other alginate weeds	Gracilaria	Hypnea	Other agaro-phytes	Other seaweeds
Idinthakari (10 km coastline)	61.5	45.4	0.7	2.1	0.7	0.4	11.3
Pamban (5 km coastline)	16.8	8.9	2.2	2.0	1.0	-	1.3

The total standing crop of agarophytes on Indian shores was estimated at 3 000 t fresh weight. This figure should be compared to estimates of 1 100 t for Korea and 700 000 t for Japan (Thivy, 1952; Boney, 1965).

Hypnea musciformis grows in abundance on the Gujarat coast and can be used as a source of agar-agar. Preparation and properties were studied by Ramarao and Krishnamurthy (1968).

Very high estimates exceeding 3 000 t of dry red algae were given by Desai (1967). From sampling in the Gulf of Kutch he concludes 20 t of dry Gracilaria can be harvested. Divers employed in the Gulf of Mannar in the richest ground for Gelidium in India observed a profuse 800 m wide growth all along the 32 km shoreline investigated between Mandapam and Tuticorn; 20 000 t of wet Gracilaria and 2 000 t of wet Gelidium, or 3 000 t and 300 t dry weight respectively, can be collected annually from this area.

Quantities of economic algae in three regions on the west coast of India were assessed and discussed in relation to substratum by Desai (1971).

Umamaheswara Rao and Nair have made a still unpublished study on seaweed resources, proceeding from data obtained during divings on the southwest and southeast coasts of India. The results will be available through the Director, Central Marine Fisheries Research Institute, Cochin 18, India.

21.5 Utilization

The dry weight and value of the agarophyte exports from India were:

1966	163 t	Rs.418 000	(U.S.$60 000)
1967	198 t	Rs.741 000	(U.S.$100 000)
1968	92 t	Rs.214 000	(U.S.$30 000)

Umamaheswara Rao (1969) pointed out that there was a vast scope for expanding the agar- and algin-yielding seaweed industry in the country. In order to ensure supplies to the local industry, export of such raw material is now prohibited.

One problem in prospecting the utilization of an agaroid resource is the fact that agar yield as found in laboratory extractions may be considerably higher than it is possible to obtain when working industrially.

	Percentage yield of agar	
	in laboratory	in industry
Gracilaria verrucosa	30–40	25–35
Gracilaria multipartita	40–50	17
Gracilaria edulis	up to 46	20–25
Gelidium amansii	35	23
Hypnea musciformis	53–57	15–20

(Desikachary, 1967)

It is claimed that the highest yield of agar in industrial scale extraction, viz. 37 percent, can be obtained by pulverizing the seaweed prior to extraction (Shrinivasan and Santhanraj, 1967).

In the district of Ramnad, porridge meal is prepared from sun-bleached, dry Gracilaria lichenoides and other Gracilarias, which are thoroughly washed in a grinding stone, soaked, ground fine and dried on organdy cloth in the sun.

In the districts of Ramnad, Tinnerelly and Cape Comorin, it is estimated that about 5 000 t of fresh seaweed and sea grasses are cast up on the shores annually yet, unaccountably, they are not conventionally used as manure. Their usefulness, however, was demonstrated in a field experiment with bendhi (Hibiscus esculentus) plants that received Hypnea compost and showed 73 percent increase in yield over those that received cow dung and ash, fruiting reaching its peak a month earlier in the former set of plants (Thivy, 1958, 1960). Bokil, Mehta and Datar (1972) studied the effect of seaweed manure, farmyard manure, inorganic fertilizers and certain combinations of those, on pearl mullet, Pennisetum typhoids, and groundnut, Arachis hypogea. The results were comparable, but mostly not statistically significant. In general, the performance of treatments in which seaweed manure is included is better than other treatments.

21.6 Cultivation

Life history, nutritional requirements, amino acid composition, etc., have been studied at the Central Salt and Marine Chemicals Research Institute, Bhavnagar, on species of the genera already mentioned as well as on Ulva, Cystoseira and Hormophysa spp.

Following experimental cultivations of Gracilaria edulis near the Mandapam field station, the ideal time for planting was observed to be June-July. It was also found that three harvests could be obtained, the first in five months after planting, the second three months later, and the third a further two and a half months later. The annual yield has been calculated at 3.5 kg of fresh seaweed per metre of rope (CSMCRI, 1971; Raju and Thomas, 1971).

In cultivation experiments it was observed that there is a time lag of about 9-10 months before Sargassum is able to settle on an artificial substrate such as fresh concrete cylinders. Then the growth is fairly rapid as near-mature plants are seen within nine months after the appearance of young plants (Raju and Venugopal, 1971).

In addition to the method of soaking the cultivation substrate with spore-emitting agarophytes, manual transplantation of plant fragments is also used. From Gracilaria edulis fragments of 2.5-3 cm were most suitable for inserting into the twists of 7/8 inch coir ropes, as shown by Raju and Thomas (1971) in a paper richly illustrated to demonstrate the method of growing Gracilaria on ropes.

Gracilaria corticata, generally growing in the clear coastal waters of Veraval, was successfully cultured in turbid waters near Gopnath thus demonstrating its ability to survive and proliferate in such waters (Sreenivasa Rao, personal communication).

22. Sri Lanka

Commercially worthwhile quantities of seaweeds are found in three principal areas: Kalpitiya and Mannar on the west coast, and Trincomalee on the east coast; all of them on the northern half of the island. A map is given by Durairatnam and Medoof (1954).

"Ceylon moss", Gracilaria lichenoides (syn. G. edulis), is collected by hand in shallow water in the Kalpitiya district. It is the base of a small industry. Exports to England of dried bleached Ceylon moss were approximately 2.6 t in 1913 and 7 t in 1940. During the second world war, 9 t a year were exported to India, then this trade ceased. Efforts are now being made towards an increased utilization. It has been estimated that a minimum of some 18 t of dried seaweed could be produced annually, or with a conversion factor of seven, 126 t wet weight. In Trincomalee alone, about 75 t of Gracilaria verrucosa was collected in 1960. It would be possible, however, to produce at least 250 t from this coast (Durairatnam, 1956, 1961).

Along the southwest coast of Sri Lanka Sargassum grows mostly on dead coral reefs which are exposed at low tides. The quantities were surveyed by Durairatnam (1966) who found a harvestable total of 775 t wet weight; the dry weight of this would be 129 t. The dominant species is Sargassum cervicone, mature receptacles were observed in December and January. The best period for harvesting is December.

The large fields of species of Sargassum and Turbinaria in the very shallow waters of the north do not appear to have received the attention they deserve (Holsinger, 1952).

Gracilaria lichenoides, locally known as chan-show parsi, is used by Sri Lanka fishermen to prepare a kind of soup as well as pudding and jelly. Padina commersonii and P. tetrastromatica are both either eaten as salad or used to make a gelatine-like sweet (Subba Rao, 1965).

23. Maldives

The Maldive Islands are poor in species and especially in large and conspicuous algae. Sargassum is absent as in many Pacific atolls. Only in the southernmost atoll is the littoral colonized by macroscopic algae and turfs exposed on the reef flats instead of being confined to crevices. Some limiting factors are probably lack of nutrients, isolation and grazing by herbivorous fishes (Hackett, 1969).

24. French Southern Territories

Kerguelen has a number of fjords and islands providing a very long coastline with enormous amounts of Macrocystis pyrifera and Durvillea antarctica kelps and also enough red algae (Iridaea) to support a carrageenan industry. Recently, Kerguelen and Crozet Islands were covered by infra-red photos, still not evaluated. Ile Amsterdam is volcanic and has no archipelago. (Delépine, personal communication)

In the Baie du Morbihan on the east coast of Kerguelen as assessment of quantities has been made (Grua, 1964). Macrocystis covers 45 km^2 in the bay. In clear waters the population extends from 8–15 m, in less transparent waters from 1–12 m.

Locality	No. of stipes/m^2	Medium length of vegetation (m)	Total of stipes per m^2 (in m)	Weight (kg/m^2)
Clear waters	20	25	500	95
Medium transparent	60	11–14	660–840	125–160
Least transparent	90–290	8–11	720–3190	137–606

The total biomass of Macrocystis in the bay was calculated at 6.3 million t. The undervegetation of Macrocystis in some of these stations amounted to:

Locality	Depth (m)	Inclination of substrate	Animals (%)	Algae (%)	Animals (kg/m^2)	Algae (kg/m^2)
Clear waters	15	horizontal	20	80	3.8	15.4
" "	15	vertical	80	20	10.2	2.5
Medium transparent	7	horizontal	11	89	[illegible].6	5
Least transparent	5	vertical	90	10	108	12

The total biomass of the Macrocystis undergrowth was estimated at 2.8 million t in the parts of the bay covered by the kelp (Grua, 1964). Thus the total biomass of the Baie du Morbihan is 9 million t according to Grua. This figure could be compared to the wet weight of the total world harvest of seaweeds as we know it from the statistics – 800 000 t. Even if Grua's total is an overestimate by as much as 10 times, the fact remains that Kerguelen has one of the world's richest seaweed resources. Other parts than the bay investigated are also rich in seaweeds.

The hydrographic conditions of this luxuriant vegetation are interesting: 4–6°C, 20 microgramatoms of N/l and about 1.75 of P/l.

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FISHING AREA 57 : EASTERN INDIAN OCEAN

Seaweeds are frequently consumed within the region. Large-scale harvesting for the manufacture of refined products with records on quantities is known only from Tasmania, Australia.

1. India (east coast N 10°N)

In the sea-connected Chilka Lake on the northeast coast it has been estimated that about 4-5 t of agarophytes are washed ashore annually.

In 1967 the harvesting centre Periypatnam on the Madras coast yielded in wet weight: Gelidiella acerosa, about 500 t, Gracilaria lichenoides, 155 t, Sargassum spp., 35 t (Umamaheswara Rao, 1969).

There are no records from the Andaman and Nicobar Islands.

2. Bangladesh

No information available.

3. Burma

Catanella impudica is sold in Rangoon for food. It is also known as Burmese moss or "Kyaukpwint". It is collected from the rocks at low tide, dried, dipped into hot water and eaten with oil, salt and prawns, like a salad (Kirby, 1953). Other red algae, mainly collected along the coasts of southern Burma, and regularly consumed, are Bostrychia radicans, Gracilaria, Caloglossa spp. and Catanella nipae (Boergesen, 1938; Subba Rao, 1965). Gelidium, Sargassum, Chaetomorpha and Enteromorpha are also eaten. Blue-green algae from fresh water (Microcystis) are taken from the water with a bamboo sieve squeezed and fried with dried shrimps.

4. Indonesia

See Area 71.

5. Australia

Tasmania, colder than most of the Australian continent, may have winter temperatures below 10°C, and is the only seaweed harvesting and processing area (Womersley, 1971, personal communication). The beds of Macrocystis pyrifera on the east coast of Tasmania have been estimated to yield 355 000 t fresh weight if three crops a year are taken. (This however is most likely an overestimate, maybe as much as 10 times too great, and may have contributed to certain difficulties for the processing factory.) They cover an area of 120 km^2, growing in depths of 3.5 to 30 m. The harvesting is highly mechanized. A specially designed vessel with blades similar to those on a hay mower cuts the weed at a depth of 1.2 m below the surface. The vessel has a crew of four men, a capacity of 20 t/h, with a carrying capacity of 45 t each trip. The company working in southeast Tasmania is now surveying prospects of harvesting new beds on the west coast of Tasmania and in Bass Strait (Anon., 1969).

In southern Australia there might be a further 1 400 000 t of Macrocystis (Chapman, 1970). It is not explained why this resource, alleged to be so much larger than that of Tasmania, is not utilized. The species in this area however is M. angustifolia, the sporophyte of which normally reaches 6 m (as compared to 60 m in Tasmanian M. pyrifera). It grows just above extreme low water to about 3 m below low water, usually forming a belt along the coast (Womersley, 1954). Consequently it is not available for mechanical harvesting.

An agar industry developed in Australia in the years of the second world war but ceased some years later when Japanese products came back on the market. It had been shown, however, that sufficient beds of Gracilaria confervoides existed in estuarine bays on the New South Wales coast and that a good quality of agar could be produced from it. A possible production of 100 t or more of agar per annum was estimated. At the end of the 1950s a Gracilaria export to Japan was started. In western Australia Eucheuma speciosum was used for agar, being harvested from drift weed only (Womersley, 1959). Storms, pollution and shipping have now removed the beds of Gracilaria in Botany Bay, near Sydney, which was one of the main regions (Womersley, personal communication).

The Australian Aborigines are reported to use certain species of seaweed, especially Sarcophycus potatorum, as food. The seaweed is dried and roasted, after which it is soaked in fresh water for about 12 h before consumption (Subba Rao, 1965). During the last century, and to some extent this century, Eucheuma speciosum and Pterocladia lucida were used for making jellies in Western Australia and Gracilaria was similarly used in Tasmania (Lucas, 1936; Wood, 1946).

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FISHING AREA 61 : NORTHWEST PACIFIC

Japan is by far the world's largest producer of seaweed products. Official data for China are not available but production must be assumed to be very high. The Russian figures for "miscellaneous aquatic plants" are of limited value as they also include unspecified quantities of shellfish.

1. China

The Chinese have appreciated seaweeds in their food for at least 25 centuries. Most of it has been imported, as much of the coast is unfavourable for algal growth due largely to reduced salinity, paucity in nutrients, silty water and muddy bottoms in the north under influence from the major rivers, and too high water temperatures in the south. During the last 20 years, however, there has been a boom in kelp production. The dry weight output rose from 54 t in 1952 to 24 000 t in 1959. In terms of fresh weight this is equivalent to 328 t and 145 680 t respectively. The 1959 figure corresponds to estimates of the Japanese Laminaria harvest of kombu at the same time. The enormous effort resulting in this increase in kelp production is not only part of a programme to meet the nation's increasing demand for food. Kelp certainly is an inexpensive dish, favoured also by inhabitants of inland provinces, and is especially popular during the season when green vegetables are not readily available. A special reason for the Government to support this crop is the demand for iodine in China.

Before 1949 as much as 40 000–50 000 t of dried seaweed were imported annually (Cheng, 1968); Kirby (1953) quotes an average of 326 000 t for the years 1935–37.
In 1962 it was forecast that China's annual production would exceed 100 000 t dry weight within a few years. Chinese experts estimate, however, that to adequately meet the nation's demand for kelp as food and industrial raw material, an annual production of approximately 1 million t dry weight would be required. It is considered that through a maximal exploitation of possible resources even this could be achieved.

The abovementioned kelp production boom refers to one species only – Laminaria japonica, known as Haidai, "sea belt" – and the figures reflect a development from kelp production based on the natural growth on rocky bottoms to large-scale cultivation on bamboo tube rafts and on ropes. Details are given for two provinces (Cheng, 1968):

	Liaoning Province		Shantung Province			Culture by
	Floating raft	Sea floor	Floating raft	Sea floor	Total	raft method (percentage)
1952	0	72	62	0	134	46.4
1953	0	451	169	68	688	24.5
1954	15	813	457	244	1 5[illegible]	31.0
1955	147	1 411	1 089	520	3 167	39.0
1956	243	701	2 107	305	3 356	70.0
1957	3 763	2 604	4 873	881	12 9[illegible]	65.4
1958	18 397	4 539	13 207	1 378	37 521	84.2

The Government input in promoting this mass cultivation of Laminaria japonica can be expressed by the figures for algologists – 10 in 1949 and 1 000 in 1963, or for research institutions – one in 1949 and 23 in 1963. The fishermen (marine farmers) have been engaged in the so-called "three-fix policy" of the commune system, i.e., fixed production quotas, fixed catch or harvest quotas for sale to the commune administration at cut-rate prices, and fixed territories for fishing or aquaculture. Additional taxes are imposed upon workers who fail to join a commune. Technicians and skilled workers are trained. In Fukien Province alone 20 000 people had mastered the technique of kelp cultivation by the early 1960s.

A most important innovation is the extension of kelp culture to south China. While in 1958 production was still confined to the Liaoning and Shantung Provinces, since 1959 transplantations have been successfully made in the provinces of Kiangsu, Chekiang, Fukien and Kwantung (from 39°N to 23°N). Nurseries in Lüta (an area including Shanghai) produce 3 800 million young plants for China's seven coastal provinces. The methods for long-distance transportation of living young sporophytes (temperature, oxygen, moisture and micro-organism control), as well as the growth in waters warmer than within the natural range of distribution of the species, are described by Cheng (1968). He also gives details for single- and double-line bamboo tube rafts, for sea floor culture and "tiered farms" for kelp cultivation in intertidal pools constructed by means of dams built of rocks and cement.

The waters of the Yellow Sea are generally deficient in nitrate nitrogen, the content rarely exceeding 5 mg/m^3, an inadequate supply for commercial growth of kelp without the aid of supplementary fertilizers. Waters along the east and south China coasts contain larger amounts, e.g., 88–227 mg/m^3 around Choushan archipelago in Chekiang Province, and 86–123 mg/m^3 in Fukien Province. Even the most hostile waters of the Yellow Sea, however, have been made receptive to successful cultivation. Porous cylinders containing nitrates are suspended from the rafts, and during the growth of the young plants nutrients slowly seep out through the walls of the clay cylinders (Cheng, 1968). Chinese authorities are now considering another substitute source of fertilizer for Laminaria: large-scale introduction of nitrogen-fixing blue-green algae and bacteria into the Yellow Sea (Bardach, Ryther and McLarney, 1972).

Raft culture is reported to yield 8 t dry weight/hectare. Kelp on rocks or on stones deposited on the sea floor may yield more than 10 t/hectare in fertile locations and half as much in other places. One labourer can manage 2 hectares of sea floor culture. The annual cost for labour and materials averages U.S.$400 per 2 hectares, while the market value of the kelp produced is U.S.$8 000.

Around the estuaries of the large rivers water transparency may be limited to 10 cm. The subsequently poor penetration of light energy, however, does not prevent these areas from being used for cultivation, and in fact kelp cultured in such turbid waters grows 1–2 cm a day in length (Cheng, 1968).

The kelp species Ecklonia cava, Sargassum fusiformis and Undaria pinnatifida are also eaten in China, as well as a number of blue-green, green and red algae (Kirby, 1953; Chiu, 1958; Johnston, 1966; Chapman, 1970). A blue-green land alga Nostoc commune and its variety Nematonostoc flagelliforme are still used by the Chinese of the interior for food. The green algae Monostroma nitidum and Enteromorpha spp. are used for making spring rolls. Ulva pertusa and U. lactuca are mostly used for medical purposes. All these green algae grow abundantly in rather sheltered places around the coast of Hsiamen (Amoy). Three red seaweeds are also eaten in the Hsiamen region: Porphyra suborbiculata, also consumed in large quantities in the interior of Fukien, Gelidium divaricatum and Gracilaria verrucosa (Kirby, 1953). Digenea simplex has great economic importance as an antihelminthic. From tetrasporic plants of Gloiopeltis furcata a paste is obtained which is used for silk sizing. Over 500 t a year are gathered (Hoppe and Schmid, 1962).

Agar was originally produced in China and was introduced into Japan in 1662. The industry declined, however, and in 1937 China had only three factories, producing about 35 t.

In the coastal provinces farmers have used Sargassum species, in particular S. horneri, as a fertilizer for sweet potatoes, groundnuts, coconuts and coffee; often the ash from burnt weed is applied to the crops. Farmers prefer this to other fertilizers (Kirby, 1953).

2. Hong Kong and Macao

Hong Kong is known for its seaweed trade. In some cases where seaweeds have been sold as having Hong Kong origin, the quantities are too large to have possibly been harvested within the area. Local resources of importance are Ulva lactuca, Sargassum spp. and Porphyra suborbiculata (Chiu, 1958). A tea brewed from Sargassum or Laminaria is used against fever and blood diseases. An antihelminthic from Digenea is important. A paste for sizing silk is obtained from tetrasporic plants of Gloiopeltis (Chiu, 1956).

3. Democratic People's Republic of Korea

No information is available.

4. Republic of Korea

This is probably the world's third largest producer of seaweeds with regard to quantity and second largest with regard to value. The main area of cultivation is the south coast. The eastern coastline is steep, has rough weather, and there is no cultivation; the west coast has a turbid brackish surface water, poor in certain nutrients. The most important seaweeds quantitatively are the kelp Undaria, mainly produced from marine fisheries, and the laver Porphyra, exclusively from aquaculture. The main market for Korean-produced laver is Japan and production depends on the Japanese demand. Laver culture has progressed from 10 000 t in 1965 to 36 000 t in 1970, and at present the Office of Fisheries has no specific plan to further increase the total production but is concentrating on improving the quality and reducing production costs (Honda, 1970).

The following quantities of seaweeds (in thousands of tons fresh weight) were harvested in 1970 (FAO, 1971):

Brown		47.2	Red	35.8
Aquaculture (Mal, Mi-Yók)		6.6	Aquaculture (Porphyra)	
Marine fisheries		40.6	Green	1.2
Mal (Sargassum)	2.2		Marine fisheries	
Mi-Yók (Undaria)	38.4			
Miscellaneous aquatic plants			32.4	
Aquaculture		1.9		
Marine fisheries		30.5		

The major species of laver currently cultured in Korea are Porphyra tenera (asakusa) P. yezoensis (susabi), P. seriata (ichimatsus) and P. kuniedai. Transplanting experiments have been carried out in the search for the best species and races. It is safe to transplant them from the time the sporelings can be seen with the naked eye until they have grown to [illegible] or [illegible] cm. During this time the sporelings can remain in a dry condition for three days and can therefore be transported long distances for transplanting. If the "green laver" Enteromorpha occurs, it can be eliminated by exposure to air for one day. This operation has to be done before the laver have reached more than 1 cm, as after that also the laver buds may be damaged by the drying.

As far as quality (lustre) and yield are concerned, horizontal culture methods are far superior to vertical culture methods. The "net hibi" installation produces a more tender laver than the generally used "split bamboo floating hibi" method. Laver collected after February shows gradual decline in quality standard. The main cause for this is the reduction of nutrient salts around the culture area at the same time as metabolism increases with rise in water temperature and increased hours of sunshine. The mean NO_3-N content at Chikuto, a south coast station, during November-February is 63 mg/m^3, while at Tayato on the west coast the corresponding mean value is 29. At the end of March both stations are down in low values, 15 and 17 mg/m^3 respectively. The minimum nitrogen requirement for healthy laver growth is 30 mg/m^3. It is clearly evident that the locations of laver farms in Korea coincide with the area of higher content of N. Selection of sites for new laver culture is also based on the results of surveys of nutrient levels.

In view of the fact that in a bad year laver production goes down to half that of a good harvest, Chyung and Kim (1966) investigated the reasons for success and failure. It was found that bad years were connected with high sea water temperatures; > 13°C during initial stage of growth after budding gave a bad year and so did the same temperatures at the initial period of harvest.

In addition to Porphyra, Sargassum and Undaria, which are accounted for separately in the statistics, numerous other genera are utilized. 1 800 t wet weight of Gelidium amansii and other Gelidium spp. are collected from natural habitats on rocks. Included in "miscellaneous aquatic plants" are Pachymeniopsis spp. and Chondrus ocellatus. Among the red algae there are also certain resources of Gracilaria verrucosa, Gigartina tenella, Laurencia spp. and Chondria crassicaulis (J.W. Kang, Pusan Fisheries College, personal communication).

In order to increase the production of agarophytes, in particular Gelidium amansii, rocks are laid out and reefs are built. The agar-yielding species do not develop much during the first year and production should not be expected until the second year of operation. Further, the natural rocks are scrubbed and transplantations carried out.

Almost all agar-agar material landed has been collected by female skindivers, sometimes with diving equipment. The harvest per diver per day is 7-10 kg dry weight, which with a conversion factor of 4-5 makes about 35-45 kg wet weight. From Japan, 50-55 kg wet weight a day has been recorded. Boney (1965) quotes Thivy's 1952 estimate of the total agarophyte standing crop for Korea at 1 103 t fresh weight.

The green algae are Ulva pertusa, Enteromorpha spp. and Monostroma spp.

The brown alga Undaria pinnatifida is collected from its natural habitats which are traditionally extended by rock laying. Also uninhabited islets like the Dok-Do (Liancourt Rocks) in the Sea of Japan are occasionally visited by women skindivers collecting Undaria pinnatifida (Kang and Park, 1969). Rope cultures, like those widely used in Japan and China, have been introduced but are making slow progress as they require rather much investment and there is already a large natural production.

The Sargassum harvest is mainly from S. horneri, S. thunbergii, S. sagamianum and S. fulvellum. Another important brown alga is Hizikia fusiforme with the local name "tot". Over 500 t per year is harvested. There are also conspicuous resources of Ecklonia cava, E. stolonifera and Scytosiphon lomentaria (J.W. Kang, personal communication).

5. Japan

Japan is the leading nation in seaweed utilization not only with regard to the quantities actually harvested but also to traditions, techniques and diversified preparation for human consumption. In seaweed research Japan holds a top position. Consequently, Japanese methods for the cultivation of seaweeds and preparation of seaweed products have been reviewed by many authors: Bardach, Ryther and McLarney, 1972; Boney, 1965; Chapman, 1970; Dawson, 1966; Hoppe, 1966; Iversen, 1968; Kirby, 1953; MacFarlane, 1968; Okazaki, 1971; Subba Rao, 1965; Sundene, 1962; Tanikawa, 1971. For illustrations of cultivating and harvesting arrangements see in particular MacFarlane, Okazaki and Sundene. Various aspects of Japanese seaweed cultivation are treated by Furukawa, 1972; Iwasaki and Matsudaira, 1958; Kurogi, 1963; Kurogi et al., 1971, and Yamada, 1959.

5.1 Importance and demand

The seaweed fraction of the total landings of fishery products, including fishes, molluscs, seaweeds, crustaceans, pearls, whales and other marine animals, amounts to 5 percent of the weight but 10 percent of the value. Within the seaweed fraction Porphyra stands for 30 percent of the weight but 75 percent of the value. Laminaria is greater in bulk, 33 percent, but much lower in value, 11 percent. Undaria comes third with 22 percent and 9 percent respectively. The agar-agar yielding species represent 4 percent only in quantity and, surprisingly, a mere 2 percent of the value (Yamamoto Nori Research Laboratory figures for 1969).

The number of processing plants for dried seaweed products is as high as 160 000, or more than 80 percent of the total number of land-based Japanese fishery processing plants (Statistics and Survey Department, 1972). These figures reflect the fact that seaweed processing, and in particular that of nori, requires much manual labour and is to a large extent managed in small units, which are generally family enterprises.

Average yield of main seaweeds in tons dry weight (Okazaki, 1971)

Green :	Ulva	4 018
	Enteromorpha	3 973
Brown :	Laminaria	36 600
	Undaria	12 586
	Eisenia, Ecklonia	5 427
	Hizikia	2 369
	Alaria	1 300
	Eckloniopsis	428
	Sargassum	354
	Endarachne	152
	Nemacystus (Mesogloia)	115
	Heterochordaria	74
Red :	Porphyra	6 660
	Iridophycus	776
	Gloiopeltis	608
	Chondrus	565
	Pachymeniopsis	492
	Digenea	281
	Others	147
agaroids:	Gelidium, Beckerella	4 050
	Gracilaria	1 654
	Acanthopeltis japonica	179
	Campylaephora	132
	Pterocladia tenuis	131
	Ceramium	70
	Others	233
	Total	73 374

In addition to the seaweed produced in Japan, increasing quantities of raw material are imported. The following data are taken from Fisheries Statistics of Japan, 1969 (Statistics and Survey Dept., 1972):

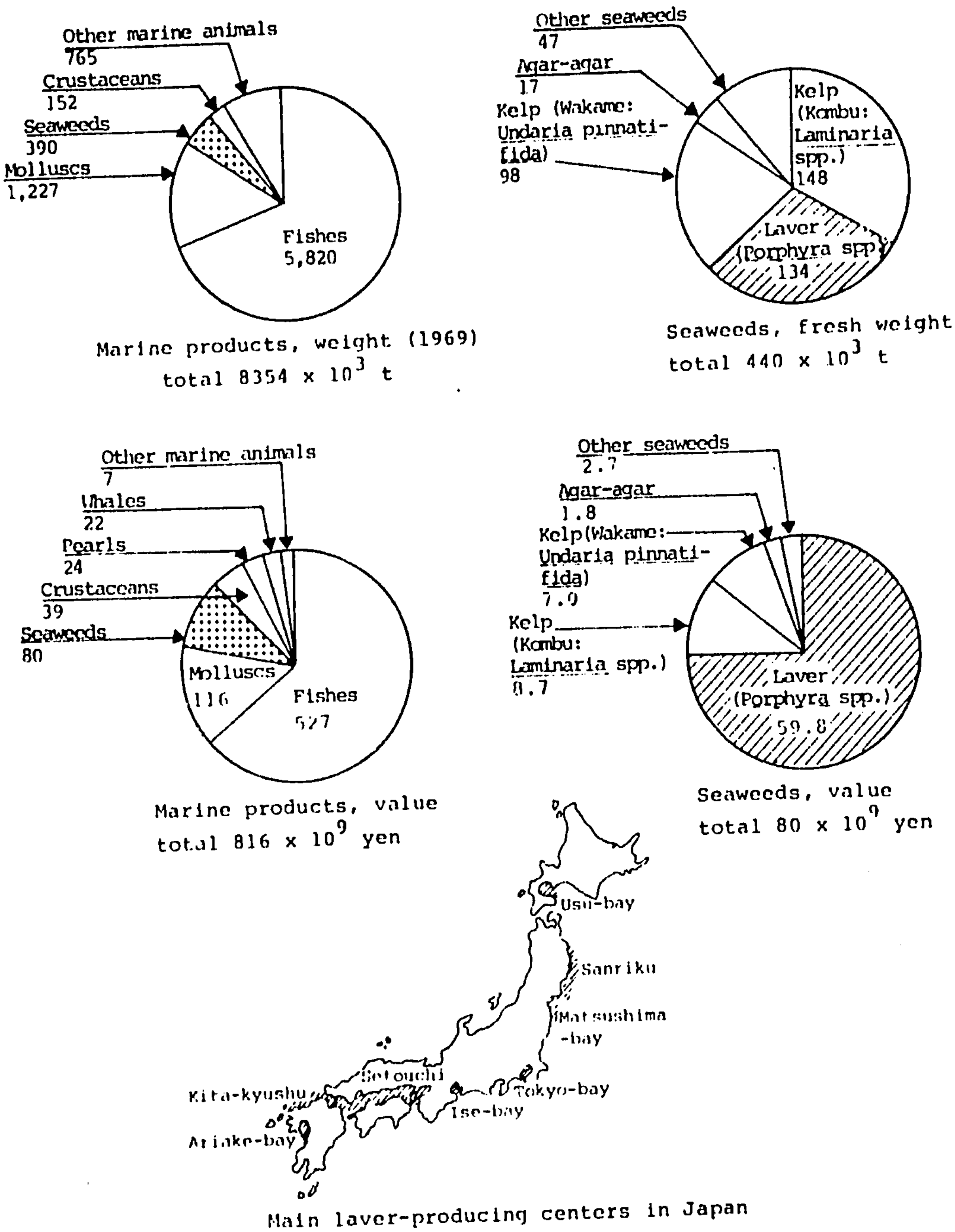

Figure 5. Quantities and value of marine products and laver production in Japan. (After Oohusa 1971)

Import of seaweed in million U.S. dollars

Year	Dried seaweeds	Raw agar-agar
1965	0	1.6
1966	9.7	5.3
1967	10.9	7.1
1968	16.5	2.3
1969	17.9	2.5

Country of origin and value of import in million U.S.$, 1969

Korea, Rep.	17.9	0
Chile		0.8
Argentina		0.6
South Africa		0.2
Australia		0.06
Mexico		0.06

It appears that "dried seaweed" means dried Porphyra and Korean "nori" only. The rapid growth of this importation explains why in Korea present efforts are directed towards meeting the quality demands and prices on the Japanese market. It also indicates how Japanese demand is growing faster than home production. "Raw agar-agar" may stand for certain dried red seaweed species only, which means that this breakdown does not cover the total import of seaweeds, brown algae like Macrocystis being omitted.

The exportation of agar from Japan totalled 700 t, valued at more than U.S.$ 4 million in 1967. The same year Japan imported 12 000 t of agarophytes. A Japanese top import of 2 285 t of Gracilaria in 1967 was abruptly cut down to 158 t the following year causing serious socio-economic problems for fishermen and dealers in exporting countries (Kim, 1970).

5.2 Distribution

Phytosociological aspects of the intertidal marine algae all around the coasts of Japan have been studied by Taniguti (1962), who regrettably gives no data on quantities. Hokkaido Island in the north and the northernmost part of the east coast of the main island, Honshu, are regarded as belonging to the subarctic region. In the natural flora the dominating community type is the Fucus evanescens-Laminaria longissima association.

The rest of the Japanese waters are under the influence of the warm current and are almost entirely classified as temperate. A typical open sea community is the Hizikia fusiforme-Eisenia bicyclis association, while the protected areas host various communities depending mainly on salinity. Most dominating and widely distributed is the Monostroma nitidum-Scytosiphon lomentaria association.

The south coast of Kyushu island is defined as subtropical. It is recognized by the Gelidium pusillum-Corallina pilulifera association. Since the repatriation of the Ryukyu Islands in 1972 the subtropical part of Japan extends almost to the tropic of Cancer. The barrier reef algal flora was described by Tanaka (1964).

5.3 Standing crops and total resources

A few examples of the standing crop of natural floras are given by Hayashida and Sakurai (1969) who found 1.1-1.2 kg/m^2 in the low tidal level not far from Shizuoka (southwest of Tokyo). Sargassum ringgoldianum was found as a dominant species all the year round; in August as the only dominant, in January together with Pachymeniopsis lanceolata, in April with Eisenia bicyclis and Myagropsis myagroides, and in June with Hypnea charoides.

Mukai (1971), in a study of the phytal animals living on Sargassum serratifolium, found standing crops of the alga of 4.9 and 3.5 kg/m^2 in the most luxuriant season and 0.5–0.5 kg/m^2 in the off-season. The change in the standing crop/m^2 agreed with the change in wet weight of the individual alga, since no change in density of number of plants was obtained.

The distribution of the utilized species as reflected in harvest records is particularly interesting. The entire production of Laminaria, Heterochordaria and Alaria is restricted to the subarctic region, within which on the other hand only 1 percent of the Porphyra yield is produced. In the far south the very small area of subtropical water produces 80 percent of the Digenea and 5.5 percent of the Gelidium yield. Undaria is distributed and collected all around the main and southern islands, including the subtropical waters, as well as in the north along the west and southwest of Hokkaido. Of the total production, however, at least two-thirds is yielded within the comparatively minor part of the distribution area which is classified as subarctic (Okazaki, 1971).

Average total harvest in tons dry weight (dominating genera indicated)

Prefectures with coasts in subarctic waters

Hokkaido	40 667	Laminaria, Undaria, Alaria
Miyagi	3 993	Undaria, Laminaria, Porphyra
Iwate	3 847	Undaria, Laminaria
Aomori	1 831	Undaria

Prefectures with coasts in temperate waters (southeast of Honshu)

Mie	7 424	Ulva, Eisenia/Ecklonia, Enteromorpha
Chiba	5 976	Porphyra, Enteromorpha, Gracilaria
Shizuoka	1 833	Gelidium, Ulva, Eisenia/Ecklonia
Aichi	1 784	Porphyra
Tokyo	1 659	Gelidium, Porphyra

Subtropical coast prefecture

Kagoshima	919	[illegible], Digenea, Gelidium

A breakdown into 26 genera groups for all 38 prefectures in Japan is found in Okazaki (1971) from which these data were selected. A present trend, however, is that Porphyra in Tokyo (780 t in Okazaki's table) cannot be cultivated any more, due to sea water pollution and reclamation. A Porphyra cultivation should be added to Mie prefecture (previously 290 t) where it now flourishes remarkably (T. Oohusa, personal communication).

5.4 Quantities and cultivation of Porphyra – "Nori", "Asakusanori"

Porphyra species grow intertidally, forming gelatinous, purple sheets, as a rule consisting of a single layer of cells only. After harvesting they are dried and processed into a product called nori, which is sold in bundles of ten sheets measuring 19x17 cm. The weight of each sheet is 3 g.

A nori sheet is the result of drying a mixture of chopped laver and fresh water on a framed screen, and should not be mistaken for the dried leaf-like thallus of one Porphyra plant. The word "nori" is used for the Porphyra plant as well as for the marketed product. It is extended by the addition of prefixes to include, for example, Gracilaria – "ogonori", Gloiopeltis – "funori", and even brown algae such as Endarachne – "habanori", and green

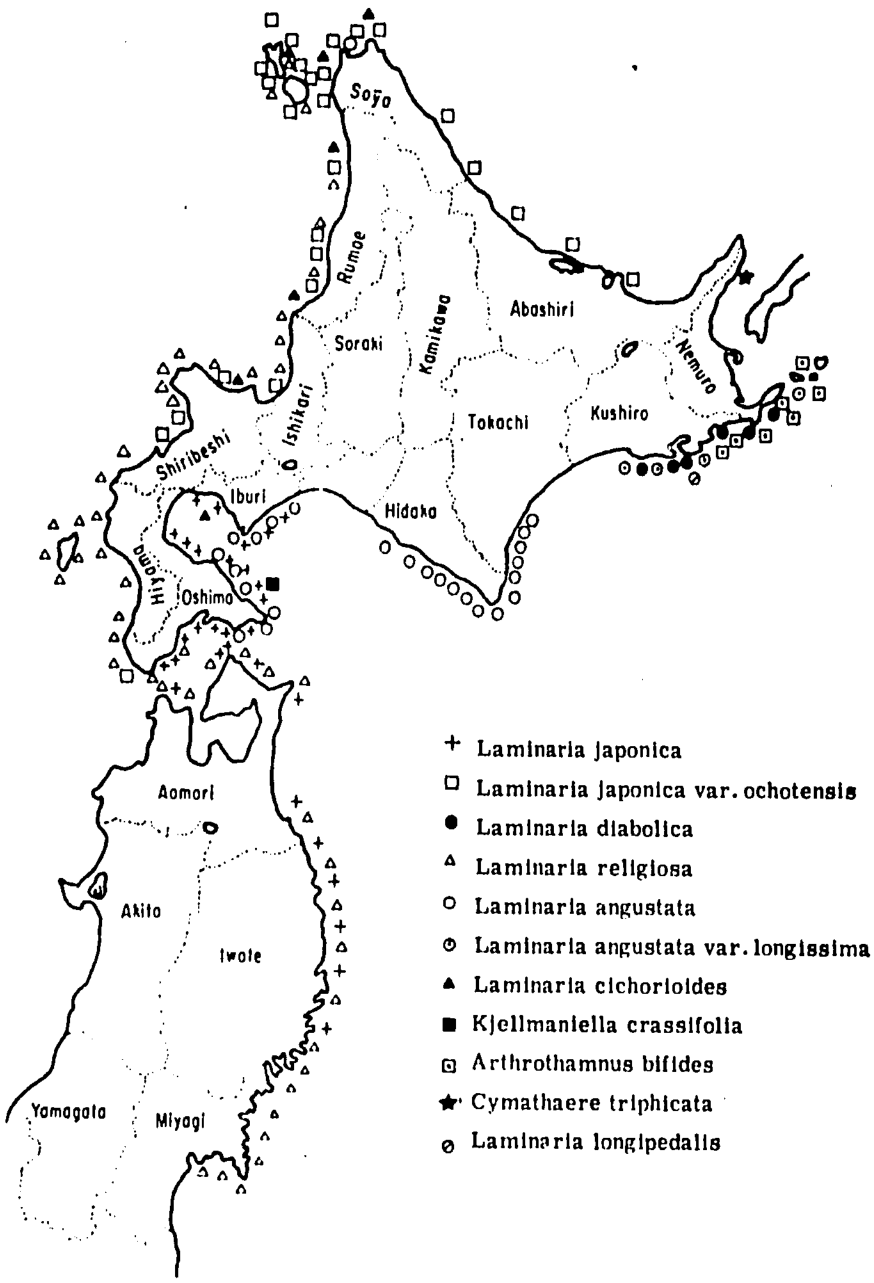

Figure 6. Harvesting sites of edible Laminaria, Kjellmaniella, Arthrothamnus and Cymathaere. (From Okazaki, 1971)

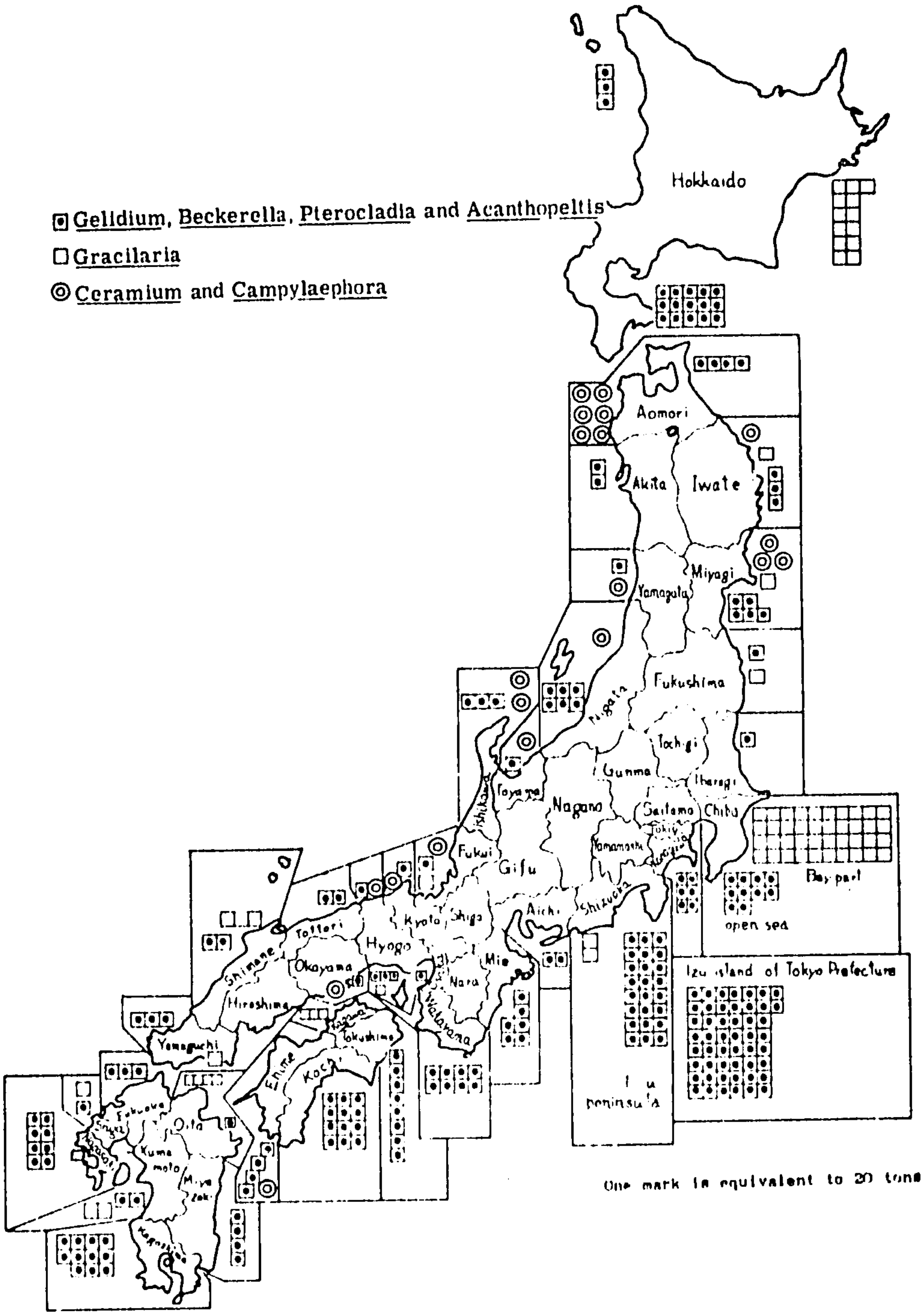

Figure 7. Distribution of agarophytes. (From Okazaki, 1971)

algae such as Enteromorpha - "aonori". In order to distinguish it from these other varieties the "nori" deriving from Porphyra can be specified as "asakusanori".

A number of species are cultivated along the temperate coasts of Japan, at present preferably in shallow waters in bays and between islands. Recently, however, an off-shore cultivation method has been developed. The dominating species in cultivation over both areas of inner and outer seas is P. yezoensis. Locally cultivated in the inner seas are P. tenere and P. kuniedai, while P. angusta is characteristic of the outer sea.

The plants are given an artificial substrate of nets or bamboo blinds. Leafless bamboo brushes or oak tree branches were once used. The introduction in the 1930s of horizontally hung nets meant a new epoch in Porphyra cultivation, as the whole sets can be moved to favourable ground and also vertically adjusted to the optimum level for the growing plants (Suto, 1966). There are now 8.7 million nets with a total area of 191 million m^2 and 171 000 blinds covering 18 million m^2. The yield of nori was estimated at 2 955 million sheets (Furukawa, 1972; all figures for 1968). The yield doubled for the following year, 1969; it was 5 592 million sheets, according to the Japanese Tariff Association, 1971. This increase is due to the enlargement of cultivating grounds through the expansion and popularization of the floating net method. (See also table below on harvest development.) Cultivation of nori in 1973 employed more than 60 000 families.

Culturing of Porphyra began in Tokyo Bay in 1736. In 1949 the mystery of the origin of the spores was solved in an account showing that the life cycle of Porphyra includes a shell-penetrating filamentous stage. In winter carpospores are released from the Porphyra plants, sink to the bottom and grow in mollusc shells. This sporophyte stage of various species had been described as a separate species and given the genus name Conchocelis. It is found all the year round, but first in September at shorter day length and lower temperatures it releases floating monospores, called "conchospores". Following this discovery, methods have been developed during the 1950s for artificial seeding of nets and blinds and for inhibiting or accelerating monospore liberation. The Conchocelis stage is cultivated in large quantities in oyster shells. From these the spores are released when temperature is lowered to 17-20°C, when the shells containing Conchocelis are exposed to 2 000 -3 000 lux for not more than 8-10 hours a day or to B-indol-potassium acetate in 1/20 000 - 1/10 000 solution. Half-dried young stages of 2-3 cm in length as well as plant remainders on recently harvested nets can be stored at -20°C until the next favourable season for setting the nets. It is estimated that in 1970 half the culture nets were refrigerated. The nets are often first placed in nutrient-rich estuaries and later moved towards the open sea. They must be changed according to tide water, should be exposed to the air for 3-4 hours a day in order to kill possible infections of other species, in particular green algae, and will have to be moved in case of pollution or unfavourable conditions. Optimum salinity is at a special gravity of 1 018-1 025 and optimum temperatures during seed collection are 20-25°C, during culture, 15-18°C, and during harvesting, 12-13°C. If necessary, 600 mg of fertilizer/m^2 is applied over 2-3 days in order to obtain a higher survival rate of young nori and to prevent the discoloration of grown nori (Furukawa, 1972). Fishermen who set nets or other carpospore collectors in the sea must pay royalty to the fishermen's association which has the fishery right of seed collecting in the sea (Okazaki, 1971). Figure 8 is a manual on conditions for artificial cultivation of Porphyra used at the Yamamoto Nori Research Laboratory.

The density of growing Porphyra has no importance. In a well grown state, the yield per 10 cm of hibi string was about 2 g whether there were 400 or 2000 individuals. The "law of constant final yield" proposed by Kida is applicable to the community of cultivated Porphyra (Yoshida, 1972).

During mild winters when the water remains warm, the yield of nori is very poor and the nori itself is attacked by a serious fungus disease. The only treatment known to be effective against this disease is the same as against competing species, i.e. to move the racks higher so that the nori will remain out of the water for about three hours a day (Suto, 1953).

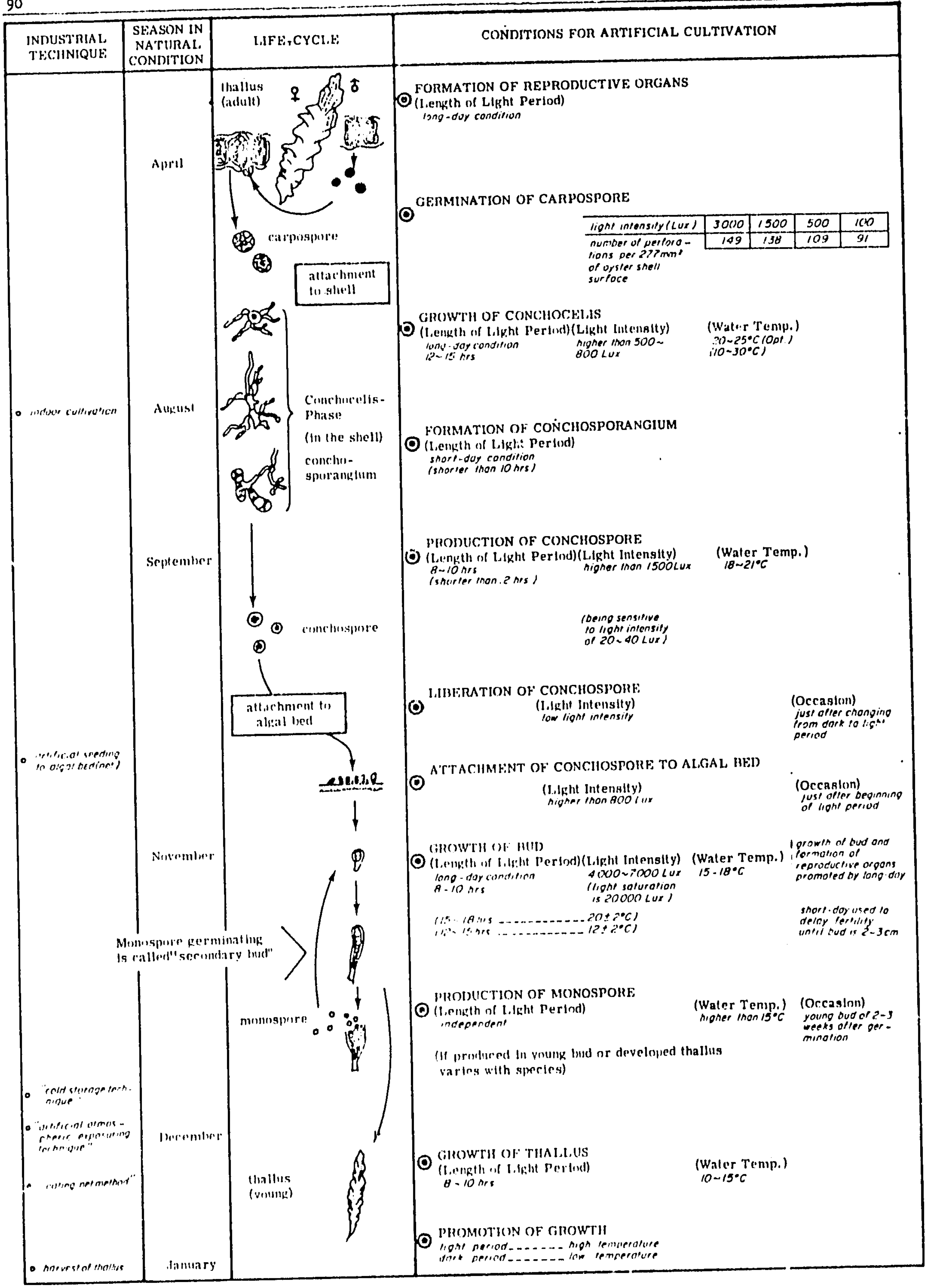

Figure 8. Technique for indoor cultivation of Porphyra tenera and P. yezoensis. Edited by Yamamoto Nori Research Institute. By courtesy of T. Oohusa.

The development of the Japanese nori production can be attributed to major innovations in cultivation methods:

Year	Harvest 10^8 sheets	Cultivation technique innovations
1938–47	mean 8.6	Introduction of horizontal net bed
1957	15	
1958	17	
1959	18	Development of artificial seeding
1960	35	
1961	34	
1962	41	
1963	32	Development of cold storage technique
1964	45	
1965	30	
1966	37	
1967	35	Development of floating net method
1968	29	
1969	60	
1970	60	

(Yamamoto Nori Research Laboratory, 1971)

An estimate of the economics of nori production has been prepared, based on a medium-scale enterprise with 50 culture nets. There were 105 days of operation and 1 750 working hours a year. Gross income per culture season was U.S.$3 333 and the total expenditure per annum U.S.$1 660 (Furukawa, 1972).

Porphyra cultivation is described by Furukawa, 1972; Kurogi, 1963; Kurogi *et al.*, 1971 (in Japanese); MacFarlane, 1968; Maruyama, 1966 (in Japanese); Okazaki, 1971; Subba Rao, 1965; Suto, 1966; Yamada, 1959. There have been numerous investigations into cultivation problems of *Porphyra*; further reference may be made to Chyung and Kim, 1966; Iwasaki and Matsudaira, 1958, Kurogi, 1961, 1972; Kurogi, Akiyama and Suto, 1962; Shimo and Nakatani, 1969.

5.5 Quantities and cultivation of Laminaria

The standing crop of the alginophytes along the entire coast of Hokkaido island is estimated at about 1.5 million t, exclusive of *Laminaria* and *Undaria* used as food, the production of which amounts to 150 000 t and 50 000 t respectively (according to Kinoshita, *et al.*, 1947, quoted from Nakamura, 1968). The *Laminaria* fishery was about double until the loss, during the last war, of the Kuril and Sakhalin Islands where *Laminaria* was being fished in particularly large amounts. It is claimed that the U.S.S.R. does not utilize the *Laminaria* crop (Sundene, 1962).

To a large extent the natural growth of *Laminaria* is harvested in depths of 3–8 m with the help of various tools (Chapman, 1970; Sundene, 1962; Okazaki, 1971). The waters are too cold to allow collecting by divers.

As demand is greater than the supply, ways have been sought to increase the crop, such as planting of stones or concrete blocks, rope cultivation, digging the flat reefs when they are exposed at low water or dynamite blowing to create new rock bottoms (*Laminaria* does not attach well on rocks covered by crustaceous algae) and even blowing of shelves in steep mountains on a suitable depth. Methods of cultivation such as the long lines used in China are still in the experimental stage (Hasegawa, 1971, 1971a).

Stone-planting has been practised for about 300 years. Andesite is preferred as it best resists deterioration. Very big stones are necessary, usually between 600 and 700 kg, in order to stand firm against wave action on the open coasts, which are preferred by most

Laminarians. On sandy bottoms it is necessary to arrange the stones with consideration to water movements as they could otherwise easily be covered by moving sand.

Another reason for failure of stone-laying is the growth of species other than Laminarians on the stones, in particular coralline algae. Some years ago this phenomenon spread dangerously in Japan, not only on set out stones but also on the beds of naturally occurring Laminaria. The phenomenon is called "reef burn". A possible cause could be sudden influxes of fresh water, killing off other algae. Actually vast surfaces all around Japan are now covered by coralline algae, crustaceous as well as articulate. It has been noted that the initial development of the corallines is very rapid; for example, in Amphiroa ephaedre a spore gives 32 cells in 12 hours (Yamada, 1959).

There are some 15 genera and 50 species of Laminariales around Japan, 19 of these species belonging to the genus Laminaria. Of the species most utilized, L. japonica, L. religiosa, L. fragilis and L. ochotensis prefer a less cold water and L. angustata and L. diabolica a colder water.

The dried and packed products from Laminaria and related kelp genera are called "kombu". There is a large variety, all with different prefix names, some of which refer to the species used, others to size, form, mode of preparation (such as softening with acetic acid) or flavour additions. Details on preparation are given by Subba Rao (1965) and Okazaki (1971).

Eisenia, Ecklonia and Laminaria unsuitable for food are used as a raw material for sodium alginate. A good 30 000 t dry weight is put to this purpose, and also about 3 000 t of imported seaweeds, mainly Macrocystis pyrifera. The production is 1 264 t of sodium alginate and 161 t of propylene-glycol-ester of alginic acid (Okazaki, 1971).

5.6 Undaria

Of the total seaweed harvest, 11-15 percent is Undaria - "Wakame", of which 65-85 percent is harvested on the west side of Hokkaido and the northeast of Honshu. The product has the softest qualities among the brown seaweeds and is consumed in particular with miso-soup. In addition to stone-laying, bottom-cleaning with dynamite and rope-cultures, the growth of Undaria is also promoted by the removal of other seaweeds with tools or a specially designed machine (Okazaki, 1971).

Culture of Undaria may be done at any depth down to about 6 m, depending upon the clarity of the water. Since relatively high salinities and low temperatures are required, the most favourable locations are in fairly open areas. One bamboo raft, 36.6 m x 1.8 m with hanging ropes to a total of 100 m of string, produces about 1 t wet weight or 112.5 kg dry weight. On the Ojika peninsula there are 1 333 such rafts, which annually produce a total of 145 t of dry Undaria (Bardach, Ryther and McLarney, 1972).

5.7 Agaroids and agar production

Prior to the second world war, Japan enjoyed a world monopoly on agar by virtue of the development of the industry in the Orient and the abundant supply of agar-bearing seaweeds along Japanese coasts (Humm, 1947). As a consequence of trade stoppage during the war, the production of agar or agar substitutes was started in many parts of the world. The pre-war Japanese production was 2 260 t of agar of which 1 600 t was exported (1937 figures). After a bottom year of 275 t in 1946, production has steadily grown and since 1966 has surpassed pre-war figures, agar export however being much lower - a mere 875 t in 1970.

The main agaroid genera have already been enumerated with their respective average yields in dry weight according to Okazaki (1971) (p. 83). The total dry weight was given as 7 500 t. Statistics and Survey Department (1972) give the following fresh weight figures: 1967, 21 300 t; 1968, 15 700 t; 1969, 17 000 t, with a value of 5.4, 3.5 and 5 million U.S. dollars respectively. In addition to this comes the raw agar import for 7.2, 2.3 and 2.5 million U.S. dollars respectively, the biggest constributors being Chile, Argentina and South Africa.

The Gelidium harvest derives from three species: G. amansii, 3 100 t, G. subcostatum, 620 t, and G. japonicum, 330 t. The total yields were: 3 800 t in 1966, and 4 925 t in 1967 of which as much as 1425 t came from the Shizuoka prefecture (Yamada, personal communication).

The manuring for Gelidium has been studied by Yamada (1967) and Yamada and Iwahashi (1964).

Agaroid distribution and harvesting, and in particular agar manufacture and uses, are described by Hoppe and Schmid (1969) and Okazaki (1971), who also give the Japanese export standard for colour, shape, uniformity, gel strength, moisture, etc. for different agar types.

5.8 Green algae

Monostroma commands the highest price of any seaweed in Japan. It is grown on nets suspended horizontally at intertidal levels near river mouths. Only 700 t was produced in 1973, a good per mille of the total seaweed production. The product is made into sheets like Porphyra. From 1955 to 1960 an average of 255 million sheets of such "aonori" were produced annually in Japan as compared to over 2 billion sheets of "asakusanori" (FAO, 1974; Bardach, Ryther and McLarney, 1972).

6. U.S.S.R.

On the Siberian coast of the Pacific some Laminaria beds (mainly L. japonica) have been estimated (quoted from Chapman, 1970):

NE Vladivostok, 1 200 km coastline	429 000 t
Strait of Tartary	552 000 t
Localities on Sea of Okhotsk	117 000 t
Localities on Kamchatka	784 000 t
Lesser Kuril Islands	70 000 t

Tokida (1954) investigated the marine algae of southern Sakhalin, where he found 182 species of which 75 are considered as useful in Japan, 46 as edible and 18 were actually used for articles of commerce. In 1935 the production exceeded a value of 1½ million yen.

Laminaria japonica, L. diabolica, L. cicorioides var. sachalinensis,
Arthrothamnus kurilensis and Kjellmaniella crassifolia gave 4 253 t of kombu
Ahnfeltia gave 143 t of kanten (agar)
Porphyra 6 t of nori
Iridophycus and Rhodoglossum 24 t of ginnanso, and
Gloiopeltis 8 t of funori

In order to preserve the stock the annual consumption of dry Ahnfeltia was limited to about 750 t dry weight corresponding to 10 percent of the presumed amount of biomass in Lake Tobuchi. Dried prepared Alaria was called sarumen, Gelidium was used only for local consumption, other species unutilized or underutilized at the time are also commented on. Halosaccion and Fucus were used as food by the Kamtschadales, as well as Alaria, Chordaria and Porphyra. For the cultivation of Porphyra 1.8 km^2 of artificial bottoms were created by pouring cement over the natural rocky reefs.

L. japonica is found only in the southern part of Sakhalin, and *L. sachalinensis* grows along all coasts. *Porphyra umbilicalis* is very abundant around the southernmost peninsula. It used to be collected directly from the rocks, not cultivated; grows during summer (J. Tokida, personal communication).

There are also estimates of the *Ahnfeltia* beds: in Peter the Great Bay near Vladivostok 104 000 t, Busse Lagoon on Sakhalin 24 000 t, and Izmen Bay in the Kurils 48 000 t. In Busse Lagoon the density ranges from 1–3 kg/m^2 and the weed forms a bed 20 cm thick at a depth of 4–4.5 m. *A. plicata* is the most important raw material for "Russian agar" or "Sakhalin agar".

Growth rate of commercial thickets of unattached *Ahnféltia* depends on, in addition to environmental factors, the quantity of *Ahnfeltia* left on the bottom after collection or transplantation, how evenly they are distributed on the bottom and on fragmentation of the thallome in the case of artificial transplantation. In the Busse Lagoon the thickets are usually restored within two or three years under favourable conditions and within three or five years under less favourable conditions, the initial quantity of *Ahnfeltia* being 0.3–0.4 kg/m^2 (3 or 4 t per hectare) (Sarochan, 1966).

The seaweed ecology on the coasts of the Sea of Okhotsk is described by Vozzhinskaya (1966) in a paper rich in data on biomass per area unit of the more important species. Among the areas described, the north coast is here taken as an example. It is indented but exposed, has intense surf and often dense fog, the tidal amplitude varies from 4.5 to 7.5 m (the littoral is subdivided into three horizons – I, II, III).

Seaweed quantities in g/m^2 on the north coast, Sea of Okhotsk

Unprotected sectors

I *Halosaccion glandiforme*, scattered 570, dense 3 850
I–II *Porphyra ochotensis* 615, slimy colonial diatoms 552
II *Halosaccion*
III *Lessonia laminarioides* 2 400, *Laminaria gurjanovae* 2 500, *L. subsimplex* 2 600

Protected sectors, littoral

I *Gloiopeltis capillaris* 812
II *Fucus evanescens* 250
III *F. evanescens* 4 900–5 100, *Halosaccion ramentaceum* 330, *H. microsporum* 500, *Rhodymenia ochotensis* 1 110, *Ulvaria splendens* 315, *Ulva lactuca* 380, *Porphyra amplissima* 318, *Petalonia fascia* 150, *P. zosterifolia*, *Chordaria flagelliformis*, *C. magellanica* 800, *Rhodomela tenuissima* 165, *R. larix* 110, *Halosaccion microsporum* 733, *Ceramium rubrum* 314, *Scytosiphon lomentarius* 160, *Antithamnion* 154, *Chorda filum*, *Hypophyllum middendorfii*, *Laingia pacifica* 600

Plant cover of depressions:

Ahnfeltia 600, *Chondrus crispus* 900, *Rhodymenia* 2 100, corallines 3 500, heterochordarias 2 500, irideas 3 000, polysiphonias 4 000

Sublittoral

Lessonia laminarioides, *Laminaria gurjanovae*, *L. saccharina* 3 000–5 000
Alaria ochotensis, *A. dolichorhachis* 2 000–3 000, and from 4–5 m, *Laminaria digitata*, *L. subsimplex*, *L. ruprechtii*, *L. platymeris* 4 000–6 500, *Phyllariella ochotensis* 3 000
Soft bottoms, *Zostera marina* 2 000–2 500

This luxuriant cold-water flora with many useful species could evidently provide raw material for a seaweed industry similar to that existing on the Sea of Japan and on Sakhalin.

Floating algae are rare in the central Pacific but common along the coast of Asia. The greatest accumulations are noted at the junction area of currents off the coasts of Kamchatka, and the Commander, Aleutian, Kuril, Japanese and Philippine Islands, New Guinea and New Zealand. The number of floating plant species is more abundant than in the Atlantic and Indian Oceans. In some areas the mass of floating algae may be compared to the waters of the Sargasso Sea (Vozzhinskaya, 1966a).

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FISHING AREA 67 : NORTHEAST PACIFIC

The whole area is dominated by kelp species. The giant kelps Macrocystis and Nereocystis are the most important from the point of view of utilization, but a total of 32 species of Laminariales fringe the coasts.

1. U.S.A.

A survey of kelp quantities of the U.S. Pacific coasts was conducted in 1911-13, when there was a demand for potash (Rigg, 1912; Cameron, 1915). Acetone and calcium acetate were also derived from Macrocystis, as well as iodine and a bleaching agent called "kelp-char". The following data refer to productivity of kelp beds within the U.S. part of the Northeast Pacific fishing area as determined 60 years ago:

	Area of kelp beds (km^2)	Tons fresh weight
Western Alaska	46.5	3 567 000
Southeast Alaska, surveyed area	183	7 833 000
Southeast Alaska, estimated additional	183	7 833 000
Puget Sound	13	520 000

The survey accounts for three species only: Macrocystis (actually two species confused at that time), Nereocystis luetkeana and Alaria fistulosa. In the case of Macrocystis, which is a perennial, determination of the yield of such beds was based on two cuttings per annum. The southeastern Alaska survey was incomplete and covered perhaps less than half of the region. The figures obtained in the surveyed area therefore were repeated in order to reach a total for Alaska, as it was estimated that the region not surveyed supported a similar weight. Tseng (1947), concluding from quantities harvested in Southern California, believes that area could produce slightly more than 5 percent of the 1911-13 estimate and assumes the same reduction should be made of all figures in the Pacific kelp beds survey. Later authors, however, seem to disregard Tseng's objections and adopt the figures of Cameron and his collaborators. There are also some recent up-datings; it seems dangerous, however, to take over data as there are so many confusing changes (the data for "productivity" are re-termed "standing crop" without taking into account that Macrocystis figures are derived from two harvests, the doubling of Alaska figures is left out, etc.) that possibly well founded amendments of the 1911-13 figures are hard to sort out.

All edible seaweeds used in the U.S.A. are now imported from the Far East. Prices of these products, which come from countries in which the plants are already in short supply, are very high. The Northwest Fisheries Center is now exploring the possibility of culturing marine algae, and whether suitable quantities can be produced to support an industry. A preliminary study of Porphyra showed rapid growth, substantial bulk and the possibility of spacing several species over a year-round growing season. P. miniata grows in the spring and reaches a length of over 4 m; P. perforata, a summer species, reaches a length of over 2 m. One stand of 460 m^2 at Manchester Experiment Station near Seattle produced over 680 kg wet weight (Northwest Fisheries Center, 1973).

2. Canada - British Columbia

The British Columbia Research Council and the Fisheries Research Board did a Canadian kelp resource inventory in 1946 using methods similar to those employed in the survey of U.S. kelp resources. This survey covered only readily accessible areas along the north mainland coast, the northeast coast of Vancouver Island and the area between Vancouver Island and the mainland coast south to the U.S. boundary. The Queen Charlotte Islands and the west coast of Vancouver Island were not surveyed. The quantities of readily accessible kelp were estimated at 22 500 t of Macrocystis and 370 000 t of Nereocystis based on one harvest per year. These estimates are regarded as on the low side. Scagel's (1948) more detailed investigation in the Hardy Bay area suggested that the figure for Macrocystis was perhaps half or one-third of the true value because of the unfavourable stage of tide at which it had been necessary previously to examine many of the beds of floating kelp. According to this amended estimate, Scagel (1961) arrived at 750 000 to 1 000 000 t of readily accessible floating kelps available annually. If Laminaria, Alaria and Hedophyllum were added, the total algin sources available [illegible] British Columbia would reach at least 1 500 000 t annually. Other estimates have suggested that 3 to 20 times this amount is to be expected (Hutchinson, 1953).

In the period 1965–67 a private firm inventoried the kelp resources of the northwest and northeast coasts of Vancouver Island. Their estimates were based not only on the area and average density of accessible kelp but also took into account only that portion of the thallus within 1.5 m of the water surface at zero tide. In this way their estimates indicate the tonnage actually available to a commercial harvester. Accordingly they found 457 061 t of commercially available Nereocystis along the northwest coast of Vancouver Island and 82 007 t of Nereocystis and 21 924 t of Macrocystis along the northeast coast.

Through the medium of a cost-sharing agreement, the Federal Fisheries and Marine Service and the Provincial Marine Resources Branch initiated a series of marine plant inventories in 1972. To date the following inventories have been completed:

1. North coast, Queen Charlotte Islands	Macrocystis	75 417 t	(total biomass)
	Nereocystis	54 089 t	" "
	Laminariales	13 931 t	" "
2. Skidegate and Cumshewa Inlets, Queen Charlotte Islands	Macrocystis	24 240 t	" "
	Laminariales	5 486 t	" "
3. Central Georgia Strait	Iridaea	1 650 t	(available)

Collating inventory data from surveys which employed different techniques is a risky business at the best of times. Nevertheless it would appear that the British Columbia kelp resources total approximately 1 000 000 t. The Iridaea resources, while quantitatively much smaller, are located in dense beds in highly accessible areas closer to shipping and marketing centres.

In addition, inventories of kelp resources in the Port Hardy-Malcolm Island area along the northeast coast of Vancouver Island and of Iridaea resources in the northern section of Georgia Strait were made in the summer of 1974 (data not yet available at time of writing). Future inventories of kelp stocks are planned for the whole north mainland coast, in areas of the Queen Charlotte Islands not yet surveyed, and on the west coast of Vancouver Island. Agarophyte surveys will also soon be under way as will an inventory of Sargassum muticum in Georgia Strait (provided that preliminary investigations of its chemical composition indicate its suitability for commercial utilization).

One strong feature of recent British Columbia seaweed inventories is that standard inventory methods have been or are being developed. These standard methods employ large-scale aerial photography supported by ground truth sampling and have been developed to provide a basis for comparison of data collected in different areas and in the same area over a period of time.

3. Northeast Pacific – general

Nereocystis luetkeana is dominating in quantities and is recorded for 78–94 percent of the floating kelp beds in Oregon, Washington, British Columbia and southeast Alaska. In western Alaska there is 55 percent Nereocystis, 12 percent Alaria and 33 percent of a mixture of the two. The total distribution of Nereocystis almost coincides with the present delineation of the Northeast Pacific. To the west it reaches the Aleutian Island of Unalaska at 167°W. To the south it approaches 35°N in California.

Nereocystis or bull kelp is essentially an annual plant. Nevertheless, it reaches a stipe length of 30 m, may grow in waters down to 18 m and may weigh 11 kg or more. It is most useful to navigators as parts of the thallus float on the surface indicating shallows and off-shore rocky reefs.

Macrocystis integrifolia accounts for 6–18 percent of the beds within its area of distribution, which is smaller than that of Nereocystis. In western Alaska it is not included at all in the quantities recorded and the westernmost finding is at Kodiak Island 159°W. In spite of being found in smaller quantities, Macrocystis is economically perhaps the most important seaweed in the area, as it is the most demanded for the algin industry. Macrocystis is perennial from the holdfast. It is restricted to areas near the open ocean. In British Columbia it occurs usually inside an outer protecting fringe of Nereocystis and grows from zero tide level down to 9 m. Near Deer Island most of the Macrocystis occurs in less than 4 m of water at zero tide, and 50 percent of it in less than 2 m. The plants may exceed 30 m and weigh 45 kg. Under favourable conditions major stipes grow more than 5 cm a day. The maximum elongation recorded was an average of 7.8 cm a day for a period of 29 days. For practical purposes a tonnage of 4.9 kg/m^2 was estimated when the surface coverage was approximately 30–50 percent.

These two giant kelp species have been particularly successful in North American industry as they grow sufficiently deep to allow collecting with mechanical harvesters cutting the stipes at a depth of 1.2 m and hoisting the kelp on board by means of a chain elevator (Tseng, 1947; Scagel, 1948, 1961; Druehl, 1970).

Looking for a total, we find that of Cameron's estimate, 20 000 000 t fall within the U.S. parts of the Northeast Pacific. If we extend Tseng's conclusion from his California check of actual harvests and reduce to 5 percent, there might be only 1 000 000 t of Macrocystis and Nereocystis to harvest annually. For a guess within this span we assume that Scagel's figures are representative. Extrapolating from British Columbia the whole area of the Northeast Pacific might have about 4 million t of giant kelp.

Among other kelp species there are in particular three which could be regarded as potential resources in British Columbia even if none of them constitutes a commercial quantity in itself.

Hedophyllum sessile are metre-high, much-frilled blades growing at 1–2 m above zero tide level just below the range of Fucus, where it has to be hand-collected. Some growth continues after the top portion of the plant has been cut off, provided the holdfast and a basal portion of the blade are left intact. Alaria marginata grows from 1 m above down to zero tide level, and occurs in fairly extensive patches which are easily accessible at low tide. They also require hand-harvesting. It may be possible to cut off the upper portion of these plants, leaving the basal portion bearing the sporophylls, and thus prevent damage to the reproductive structures of the plants. Laminaria saccharina grows from zero tide level downwards several metres. Reproduction takes place in the main portion of the blade, which might be able to regenerate from the base. They could be hand-harvested or taken with rakes in deeper water. Most harvesting methods, however, would tear loose the whole plant and probably bring in small rocks and boulders as well in many cases, which could damage cutters (Scagel, 1948).

If we want to add these and other kelp species to the total for alginophytes in the Northeast Pacific, we could also follow Scagel (1961) in British Columbia and assume they reach 50–100 percent of the quantities of the giant kelps, say some 3 million tons. As Macrocystis disappears in western Alaska, Laminaria, and in particular Alaria, flourish in northern latitudes, such an assumption would be on the low side.

The distribution of Laminariales in the Northeast Pacific in a wider sense from Baja California to the westernmost Aleutian Islands was studied by Druehl (1970) (see Fig. 9). Richest in species is the Vancouver Island region with 28 species. Five species have their northern end points in this region, eight their southern. In the Gulf of Alaska, 22 species are recorded of which five continue no further southeast and two no further southwest. From the Alaska peninsula to the Aleutian Islands the number of species goes down from 17 to 13.

Other algae than kelp are also plentiful. "Gracilaria and Gracilariopsis are fairly abundant in British Columbia, especially along the southeast coast of Vancouver Island. Under favourable conditions they grow rapidly and reach a remarkable length. Other species of agarophytes are also known in these waters. As yet abundance and distribution have not been determined comprehensively for any agarophyte." (Scagel, 1961). Agardhiella, Ahnfeltia, Gelidium, Gigartina, Gloiopeltis, Iridaea, Rhodoglossum and Rhodymenia could be mentioned as other examples.

Iridaea cordata and Gigartina exasperata have received a good deal of attention in British Columbia and in the Puget Sound area of Washington. In British Columbia, Austin et al. (1973) and Austin and Adams (1974) have developed a method for inventorying Iridaea, applied the method and determined its accuracy, studied Iridaea's seasonal growth and reproductive cycles, studied the effects of harvesting on regrowth and begun studies on cultivation. Fralich (1971) has studied the effect of harvesting Iridaea on the algal community in northern Washington. Waaland (1973), working in the same area, has determined some of the optimal environmental parameters for Iridaea and Gigartina.

Washington has a similar marine flora, as investigated in Puget Sound (Rigg, 1912; Neushul, 1967) and Hood Canal (Phillips and Fleenor, 1970).

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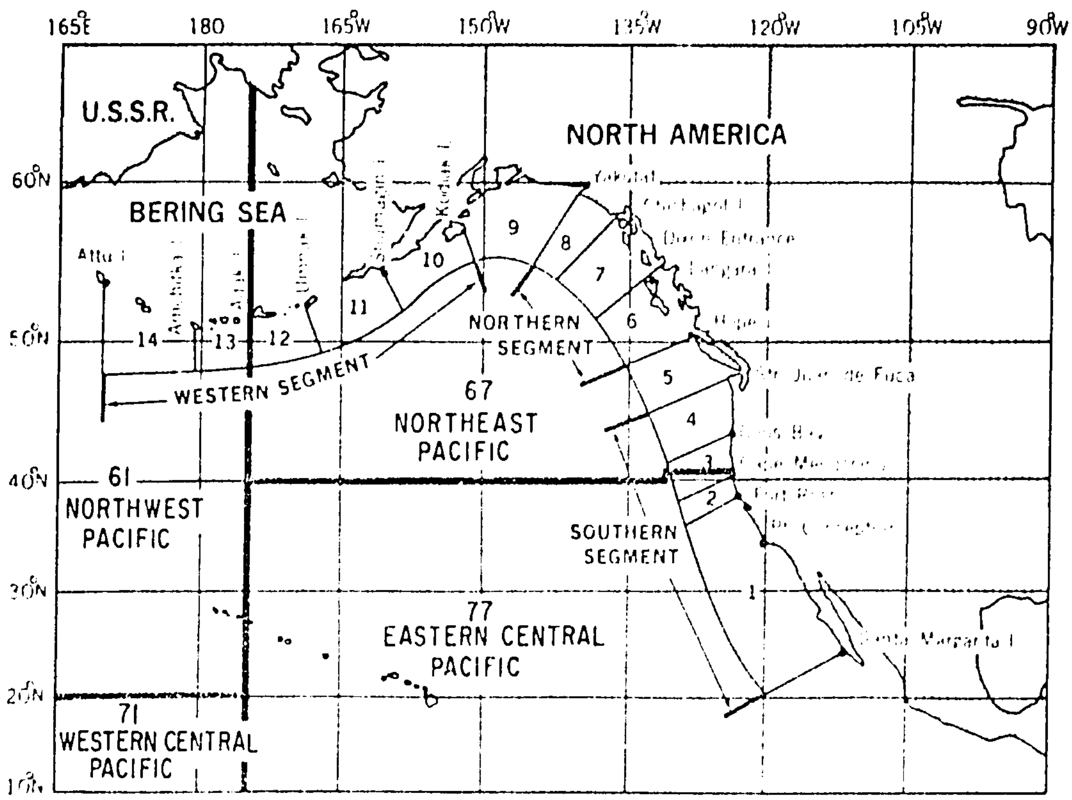

Figure 9. Distribution of Laminariales in the Northeast Pacific. There are three distinct coastal floras and a number of transitional regions (odd numbered) and non-transitional regions (even numbered). Limits of Fishing Areas for statistical purposes entered. (After Druehl, 1970)

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FISHING AREA 71 : WESTERN CENTRAL PACIFIC

This region is well known for its extensive use of algae for human consumption. Probably it comes next to the Northwest Pacific in this respect. "Nevertheless, it should be remarked that the utilization of marine algae as human food, particularly in the Malay Peninsula and in Indonesia, seems nowadays by no means as general as one would suppose, when reading the earlier authors like Rumphins and von Martens" (Zaneveld, 1955).

1. Indonesia

In 1971, 2 300 t were harvested. In 1940, 1 300 t raw seaweed were exported (Kirby, 1953).

The human consumption of seaweeds is widespread. They are particularly used when the rice harvest is bad or when the prices have risen. Subba Rao (1965) mentions more than 20 species, how and where they are used. The green algae Caulerpa, Chaetomorpha, Codium and Ulva are used raw or in soups or gelatine-like sweets (marshmallows). Brown algae such as Dictyota, Padina, Sargassum and Turbinaria are eaten raw or cooked with coconut milk, pickled or preserved by smoke-drying. The red algae, especially Eucheuma muricatum but also Acantophora, Corallopsis, Gelidium, Gracilaria, Hypnea and Sarcodia, are either eaten fresh or prepared in similar ways to the brown algae or the jellies are extracted for various kinds of gelatines. When extraction is intended, the first step might be that the seaweeds are dried, bleached and stored.

The agar, funorin or algin content and quality of samples from a number of species of possible commercial value have been investigated by the Laboratory for Chemical Research in Bogor on western Java (Eisses, 1952). Gracilaria lichenoides was at that time by far the most important raw material for the small Indonesian agar factories. Gelidium rigidum gave stronger gels but seems to be found in smaller quantities. Hypnea musciformis hippuroides is also a potential agar source. Eucheuma species form the greatest part of the seaweeds exported from Indonesia under the name of raw agar.

For these species there is a high commercial demand and a sure export market. Despite the abundance of natural resources in the eastern part of Indonesia (Lesser Sunda Islands) the supplies lag behind, and Soerjodinote (1969) suggests cultivation of Eucheuma spinosum and E. edule on selected localities in the western Java Sea. An interesting part of his paper is a detailed cost-profit calculation.

Hypnea [illegible] is used as an antihelminthic.

2. Malaysia

"Agar-agar" is a Malay word for those seaweeds, like Gracilaria, which yield a gelatinous jelly used for making sweetmeats. Seaweeds have old traditions in Malayan cooking. They are used fresh or cooked or for jellied sweets. Subba Rao (1965) mentions Caulerpa, Codium, Enteromorpha, Ulva, Sargassum, Turbinaria and Gracilaria species. Caulerpa has a piquant taste and is used as a relish. The seaweeds may also be dried, then boiled, strained, sugar added and re-boiled with an egg which brings scum and clears the final product. Weeds are also used in the Malay delicacy "kerabu", described by Kirby (1953). According to Zaneveld (1949), Sargassum species occur principally in the Malayan archipelago.

3. Brunei

No information available.

4. Singapore

A certain seaweed commerce is centered in Singapore, but the local flora is rather poor under the influence of pollution and dilution. Ulva has a popular local use by Chinese market gardeners as a pig and duck food (H.M. Burkhill, personal communication). Eucheuma has been produced, but the beds suffer from overharvesting (Parker, 1974).

5. Thailand

The Thai west coast flora is extremely thin and poor in species. Many areas render little or no growth. Controlling factors are sharp shifts in salinity following the monsoon period, calm, unmoving waters with lack of aeration, silting, heat and pollution from tin mines. Grazing may play a role, but to what extent is unknown (Egerod, 1974, 1975). On the east coast larger specimens are found. Porphyra is seen on many shores but it is not collected. A species similar to Furcellaria, however, is actually gathered. The algae are used in Thai cooking and the amount of algae imported from China and Japan is considerable (Vagn Hansen, Phuket Marine Biological Center, personal communication).

6. Cambodia

No information on use or quantities.

7. Republic of Viet-Nam

The species most frequently found and probably the most abundant and used is Gracilaria lichenoides, the "Ceylon agar". The species of Eucheuma, Gloiopeltis and Gymnogongrus available do not seem to leave good gels (Lami, 1953).

Agar freshly extracted from seaweeds is eaten mixed with rice. On the southern coast of Viet-Nam the red alga Griffthsia corallina is eaten with sugar after it has been bleached, compressed and cut up (Subba Rao, 1965). Gracilaria verrucosa, Gigartina and the brown algae Sargassum cinctum and Cnoospora fastigiata are also eaten by fishermen and sold in the markets (Kirby, 1953).

Some species of Sargassum are said to be utilized for animal feed, especially for pigs. Lami has also observed remarkable results by feeding horses suffering from lymphangites with Hizikia fusiformis.

Pham Hoang Ho (1961) has studied the algal populations of rocky littorals.

8. Democratic Republic of Viet-Nam

No information available.

9. Philippines

The coastlines of the 7 000 islands of the Philippines do, in general, provide good substrata for seaweeds. A very great part of its 35 million inhabitants live close enough to the sea to have access to seaweeds, which also form a part of their diet. Velasquez (1953) states that "it is quite noticeable that the people living in the coastal regions are more industrious and healthier than those living inland".

Eucheuma is commonly offered for sale in the market. It is eaten raw as salad. Commercially it is the most important of the seaweeds as a carrageenin raw material and has been exported to Japan and the U.S.A. The biggest natural grounds and best areas for farming are the wide shallow areas in the Sulu Archipelago. Due to poor conservation practices by gatherers, who take all the available seaweeds of the area and leave nothing to grow, the yearly export of this product has been diminishing for the past five years (Cases-Borja, 1973). Therefore Eucheuma biology has been studied and cultivation introduced. E. cottonii, E. spinosum and E. striatum are generally found on shallow reef flats and in lagoons at a water depth of less than 2 m at high tide. Best cultivation results were obtained with plants suspended 0.6 m above the bottom on nylon lines attached to stakes driven into the sand. They thrive best in salinities above 34 per mille, in considerable wave action or currents. Excessive light might damage thalli and induce premature "ageing". For example, Eucheuma planted over light-reflecting sandy bottoms has frequently failed. Fertilizing cultivated areas may dramatically improve growth rates. E. spinosum test plant growth rates increased by 40–50 percent when 4.8 kg of ammonium sulphate was applied to the test area over a ten-day period. However, fertilizing is not yet economical.

When plants reach an average size of 800 g about two months after planting, they are ready to be pruned back to 200 g again. This method eliminates the need to replant. In 1973 Filipino farmers had established 86 Eucheuma farms in the Sulu Archipelago. These farms contained over half a million plants. It is estimated that cultivation will account for more than half of the Philippine commercial production by 1975.

Productivity was estimated at 13 t dry weight per hectare and year at a pilot farm in Tapaan Island, where the growth rate of cultivated Eucheuma was 2 percent per day. This yield compares favourably with yields reported for the most productive land and marine crops. Nevertheless Doty (1973), on results of smaller scale farms in other parts of the Philippines, estimates that 30 t per hectare and year may be expected. The difference is found in growth rate; in other areas it has frequently been more than twice that of the Tapaan pilot plant.

Considering that a farming family can effectively tend one to three modules and assuming the lower of these productivity assessments, 13 t/hectare, we can calculate an expected return. If two modules are farmed, annual production should be about 6.6 t dry weight or a monthly harvest of 550 kg, yielding an annual net income about six times the current annual salary of an agricultural worker earning a minimum wage (Parker, 1974).

Porphyra, here called "gamet", has been cultivated for a long time in north Luzon. Long bamboo poles with branching ends are erected close together in rows along the shore. After 4–6 months the algae can be collected by hand during low tide. When partially dried, it is pressed and sold in the market or bartered for an equivalent amount of rice. "Gamet" is shipped to interior municipalities and barrios where it is relished as food.

In south Luzon the green algae Enteromorpha intestinalis, Cladophora sp., and Chaetomorpha aerea serve as food for milkfish in ponds, giving the fish a much better taste. They are grown on twigs and branches of mangrove trees set in the water. Several phaeophyceae are used as fertilizers (Velasquez, 1953; Villaluz, 1949).

The quantity of seaweeds gathered and consumed as human food is not assessed. Seaweeds are sold fresh in the markets in coastal towns. Caulerpa racemosa, which is planted in large containers, has to be sold within a few hours after collection, otherwise it will shrink and deteriorate. Recipes for the preparation of 12 species are given by Bersamin et al. (1961); Subba Rao (1965) gives three recipes developed by the Philippines Bureau of Fisheries. The most frequently used species belong to the genera Gracilaria, Hypnea, Caulerpa and Sargassum. Laurencia papillosa is also very popular as a vegetable. The methods of preparation for 19 species, which are eaten fresh, dried or cooked in Ilocos Norte, are indicated by Velasquez (1972), their distribution and occurrence by Galutira and Velasquez (1963).

Seaweed protein for animal feed has been evaluated (Bersamin, Banania and Rustia, 1969). Tons of Gracilaria are harvested every day during the dry season to supplement the fish pond algae, the growth of which is stunted during this period due to high salinity. The utilization of seaweeds as fish food enables fish pond owners to continue the cultivation of fish unhampered (Sulit, Navarro and San Juan, 1953).

Because of the very rich resources of Gracilaria verrucosa from January to June, especially along the shallow shores of Manila Bay, Sulit, Salcedo and Paganiban (1955) undertook a study of its properties and preparation. Here an estimate of quantities is given: at the peak season no less than 1 000 tiklis (a round basket taking 35 kg of seaweed) is harvested daily. Gracilaria is the main source of agar-agar, or gulaman. There is a growing demand for Gracilaria and possible methods for its cultivation are being studied (Cacas-Borja, 1973).

Discharge of pollutants from an oil refinery has caused poor growth of algae in the Bataan area west of Manila as compared to Batangas south of the capital.

Sargassum, Hydroolathrus, Eucheuma, Gracilaria and Halymenia species are being studied for their chemical and nutritive values (Velasques et al., 1971).

The Philippine seaweed harvest dwindled from a peak of 1 100 t in 1966 to 318 t in 1970; the export from 805 t dry weight in 1966 to 264 t in 1968, of which 229 t went to the U.S.A. The decrease in harvests indicated an over-exploitation of the natural Eucheuma resources, so that culture had to be started. In 1972 exports were up to 570 t (Caces-Borja, 1973).

10. Micronesia and Melanesia

There is no information on quantities. Seaweeds are eaten and prepared in similar ways to Indonesia.

Phycological literature referring to the Caroline and Mariana Islands, Wake Island, and the Marshall, Gilbert and Ellis Islands is listed in Tsuda (1966). A systematic account of the algae of the Caroline Islands is given by Trono (1968, 1969).

11. New Guinea

There is no information from any part.

12. Australia (Arnhem Land, Gulf of Carpentaria and Great Barrier Reef area)

No information on quantities.

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FISHING AREA 77 : EASTERN CENTRAL PACIFIC

Two main resources are being utilized: the giant kelp beds of California-North Mexico and certain agaroid red algae of the Baja California peninsula.

1. U.S.A.

1.1 Alginophyte

Macrocystis pyrifera is distributed from the Monterey peninsula in central California to the middle of the Baja California west coast. North of Monterey this giant kelp is replaced by *M. integrifolia* and *Nereocystis leutkeana*, the latter intruding into the northernmost part of the *M. pyrifera* area (Druehl, 1970).

In 1968 the combined harvest from California and Mexico was 148 305 metric tons of fresh kelp, according to Silverthorne and Sorensen (1971) with reference to a communication from Philip R. Park Company. This total is consistent with other known data, while the official U.S. figure as forwarded to the FAO Yearbook of Fishery Statistics is confusing: 0.1 thousand metric tons for the Northeast Pacific fishing area, no figures for Eastern Central Pacific. Assuming that the official figure for Mexico - 28 200 tons - is founded on the same estimate as the total, the California part would be 120 100 t for 1968. Of the total California and Mexico harvest 124 700 t were used by Kelco Company of San Diego for the manufacture of algin, the remaining 23 600 t were processed to seaweed meal by two other manufacturers. Kelco also imported about 1 460 t of dried seaweed to produce an estimated 3 880 t of algin, or 30 percent of the world production.

Among the natural seaweed resources of the world the giant kelp of California is the most comprehensively investigated. The present knowledge of the biology of giant kelp beds is summarized in a 600-page volume (North, 1971). An earlier summing up concentrated on the impact of man on the kelp environment and the kelp itself (North and Hubbs, 1968). Continuous reports are given from 1957 to 1963 by the Kelp Investigation Program (North, Ed., 1957-63), since 1963 reorganized in the Kelp Habitat Improvement Project (North, Ed., 1965-74).

Of more than historical interest are early investigations (Cameron, 1912, 1915; Setchell, 1912; Turrentine, 1912; Wohnus, 1942; Tseng, 1947; Scofield, 1959). This resource is also accounted for more or less in detail in reviews such as by Kirby (1953), Boney (1965) and Chapman (1970). As this abundant literature will fill any need for thorough information, only the main problems and the main investigations will be mentioned here.

The 1911-13 survey of kelp quantities on the U.S. and Mexico Pacific coasts (already quoted for the Northeast Pacific area) gave as annually harvestable quantities:

	Nereocystis	Mixed	Macrocystis
Cape Flattery-Point Conception	3 349 540	279 180	748 680
Point Conception-San Diego			18 195 000
San Diego-Cedros Island			16 980 000

The first of these coastlines corresponds to the northern two-thirds of California, but also includes Oregon and most of Washington which are here assigned to the Northeast Pacific. A very rough breakdown should set the Californian part at 2.5 million t, giving a total for California of 20.7 million t and Eastern Central Pacific of 36.7 million t. These figures do not correspond to standing crop but to the result of two annual harvests at 1 m below the sea surface. Tseng (1947), starting from the actually harvested quantities, such as 0.4 million t in 1917 between Point Conception and San Diego, and judging that 1 million t per annum could be harvested in this area, concludes that these early estimates should be reduced to 5 percent of the data given. On the same basis, the productivity of the total U.S. Pacific kelp beds may be placed at about 3 million t per annum. For 1940–45 the Californian mean annual harvest was 56 000 t, or one-seventh of those obtained during 1917 and 1918.

Old data give an idea of the potential productivity of the area, but must not be used for an estimate of the quantities now available. In the 1940s and 1950s there was extensive depletion of the kelp beds. The direct cause of the disappearance was usually identified as overgrazing by dense populations of sea urchins (California Water Quality Control Board, 1964). The indirect cause is in many cases pollution, which seems to favour the development of sea urchins. In polluted areas these may be found in quantities of 100 individuals per m^2. In other cases overpopulation of sea urchins and vanishing kelp beds have been the biological consequence of the extermination of sea otter, an urchin predator, which was hunted for its valuable fur.

The California kelp programmes include various studies of the depletion of beds and sea urchin biology (e.g., Leighton, 1966; Leighton and Jones, 1968) and in particular studies and experiments aiming at the restoration of beds. This can be achieved through sea urchin combating. The most successful technique is quicklime operations, accounted for in all the annual reports by North (Ed., 1965–74) mentioned above.
The chemical is dispersed in large lumps into the wake of a moving vessel. If a lump settles on an urchin, tissue is destroyed and the animal dies. Quicklime rapidly combines with water to form harmless calcium carbonate, so no lasting poison is introduced into the environment by the method. Total elimination of the urchins can be accomplished in a small area if divers crush the urchins with hammers (North, Ed., 1967, 1971).

Where Macrocystis has disappeared totally, it can be restored by cultivation and transplantation (North, 1964; North (Ed.) in Annual reports cited: 1967, 1970, 1971; North and Mitchell, 1968; North and Neushul, 1968; North, Mitchell and Jones, 1969; Parker, 1971). When a suitable kelp bottom has been freed from sea urchins, mature kelp plants are moved to it or embryonic sporophytes, raised in artificial cultures, are "seeded". If not, other seaweed species from the local flora will take over the liberated surfaces.

The kelp beds are rich in fish and are much esteemed by sport fishermen. No adverse effect of harvesting on fishing was observed (Quast, 1968). Actually kelp-bass fishing was found to be better in harvested beds than in uncut beds (Davies, 1968).

Drifting kelp is also associated with fish, this however recruited from pelagic stocks. In the shelter of the kelp they are pursued less often, for shorter periods, and captured less frequently by a predator. Near drifting plants there is a fishing for yellowtail, albacore and occasionally dolphin fish (Mitchell and Hunter, 1970).

The impact of pollution on the kelp ecosystem is considerable (California Water Quality Control Board, 1964; Pierce et al., 1970)

In the extensive literature from the kelp projects there is no information on tonnages; in studies of correlation to regrowth and other factors the quantities harvested are merely given as relative figures with year of maximum harvest arbitrarily taken as a base. It is revealed only that approximately one-third of the beds provide two-thirds of the state-wide harvest. It seems reasonable to conclude that the potential is considerably higher than the harvests actually drawn.

Aleem (1956, 1973), diving at La Jolla through the community of which Macrocystis is the dominating component, assessed quantities by the quadrant method. In shallow water the sea grass Phyllospadix scouleri covered 80–100 percent of the rock surface to an average of [illegible] kg/m^2. The standing crop of the Macrocystis plants was estimated at 6–10 kg/m^2 with an average annual yield of 10–15 t/ha (only some 15 percent of the biomass). Deeper than the sea grass community, two laminarian kelps, Pterygophora and

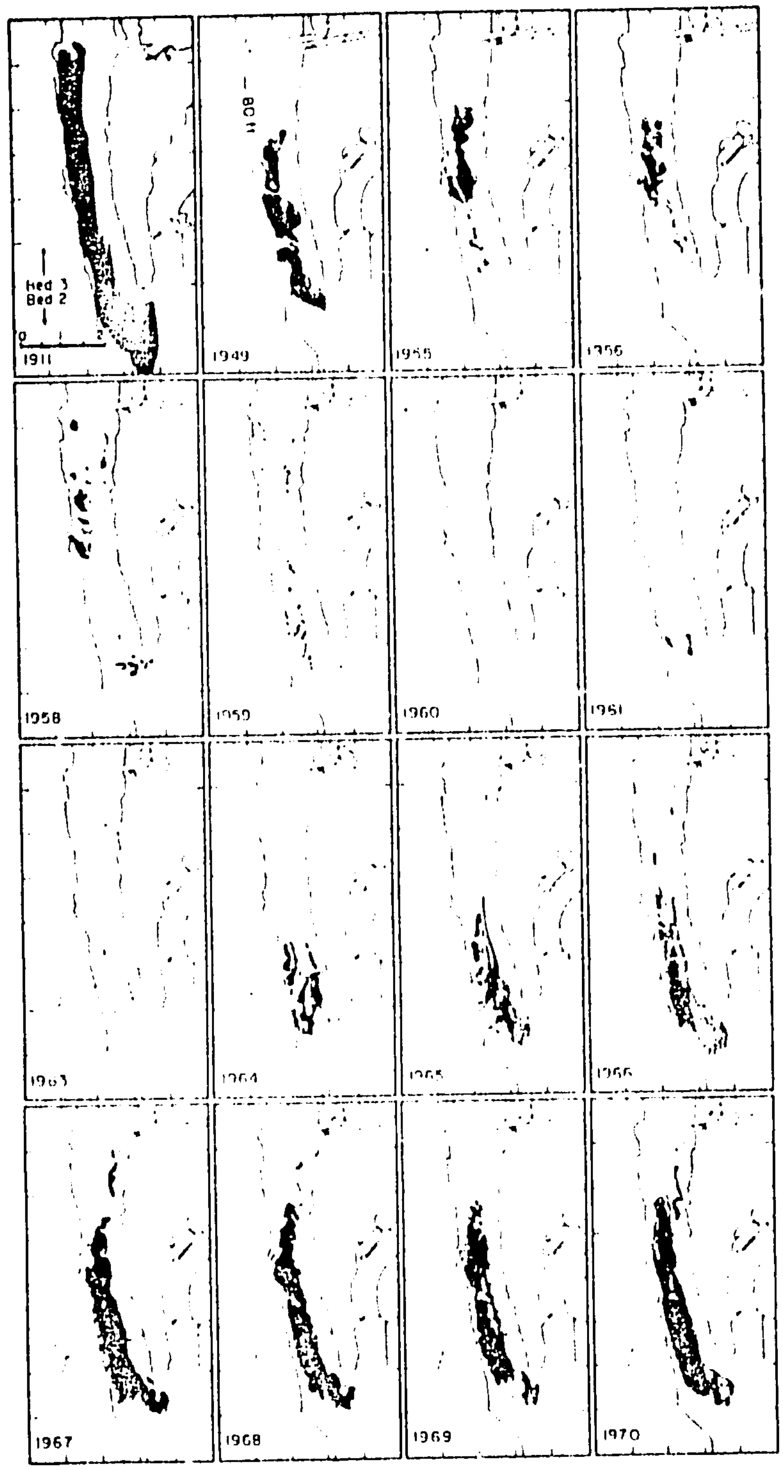

Figure 10. Historical charts of the Point Loma kelp bed (shown as black). 1963 to 1966 from oblique photos, courtesy Kelco Company. Years 1963 to 1971 represent fall conditions. Scale: nautical miles. (From North, 1971)

Eisenia, form, together with Laminaria farlowii, a "forest" under the large Macrocystis plants; this sub-forest is best developed between 10 and 20 m, its biomass was estimated at 3.15 kg/m^2. A bottom stratum of coralline algae and associated animals forms a cover under the larger kelps. The weight of the turf algae, which prefer shadow, averaged 1.6 kg/m^2 in the bed as a whole. An average figure for the standing crop of the organisms inhabiting the rocky bottom of the kelp beds, including Macrocystis itself, would approach 9.4 kg/m^2 of sea bottom (Aleem, op.cit.)

In Paradise Cove, McFarland and Prescott (1959) found in a similar investigation 4-5.3 kg/m^3 of giant kelp. From 25 to 43 percent of the wet kelp biomass was found in the canopy. The undergrowth, even when containing dense stands of young Macrocystis, was very poor compared to that assessed by Aleem and never exceeded 0.5 kg/m^2. Beneath dense kelp canopies in the centre of the bed it gave an average wet standing crop of 0.004 kg/m^2. It was calculated that undergrowth constitutes about 2 percent of the total plant biomass within the kelp bed.

1.2 Agarophyte

The high cost of labour in the United States discourages any extensive harvesting of seaweed for agar. Several years ago the American Agar and Chemical Company attempted unsuccessfully to mechanize the harvesting of the agar weed. Until some means of mechanical harvesting can be developed, it is unlikely that significant amounts of red algae will be gathered off the U.S. coast (Durrant, 1967).

Gelidium cartilagineum is the most important agaroid. An indication of the quantities available can be obtained from data on harvested amounts during the last world war. In 1944, 240 t wet weight, or about 80 t dry weight, was collected. The agarweed resource of southern California waters is undoubtedly many times the 240 t actually gathered since harvesting was then limited to only a few readily accessible shores very close to Los Angeles. A small fraction was taken close to San Diego. Wartime restrictions prevented operations in numerous places. Even where Gelidium was gathered, more was probably left than harvested. There are reasons to believe that southern California, if thoroughly but sensibly exploited, could yield more than 1 500 t of fresh agarweed per annum (Tseng, 1947).

Gelidium grows abundantly from Point Conception in the north to Magdalena Bay in Baja California. Beginning in 1920, commercial agar production in the United States has undergone several booms and crises. Today only one firm, American Agar and Chemical Company of San Diego, remains in operation. This firm manufactures high grade bacteriological agar using Gelidium from Mexico and many other parts of the world (Silverthorne and Sorensen, 1971).

2. Mexico

In continuation of its distribution in California, Macrocystis pyrifera grows in extensive but interrupted sectors to Punta San Hipólito and very rarely to Isla Magdalena. The wet weight production has been increasing: 10 000 t in 1956, 14 000 t in 1960 and 37 000 t in 1974. This is still very modest compared to the early estimates of harvestable quantities amounting to 8 500 000 t (Cameron, 1915) or 425 000 t (Tseng, 1947). With the aid of aerial photographs Guzmán del Próo et al. (1971) map the beds and also give a breakdown of harvests on years and areas. In spring and summer the harvest is 14-35 kg/m^2, in winter 5-10 kg/m^2. The exploitable biomass is estimated at 65 000 t and maximum harvestable at 147 500 t (Guzmán del Próo, in press). Other large brown algae are Egregia laevigata and Pelagophycus porra, known as "bule", which live associated with the Macrocystis beds. The volumes are far from those of Macrocystis, however they appear as a small fraction mixed with this species during harvesting. Eisenia arborea has rather much the same distribution, grows in volumes of considerable magnitude, is cast ashore in enormous quantities after storms, but is not exploited. The quantities are no doubt commercial.

Gelidium cartilagineum is the dominating agarophyte. The harvests are rapidly increasing: 59 t in 1955, 264 t in 1960, 800 t in 1965. These values are dry weight

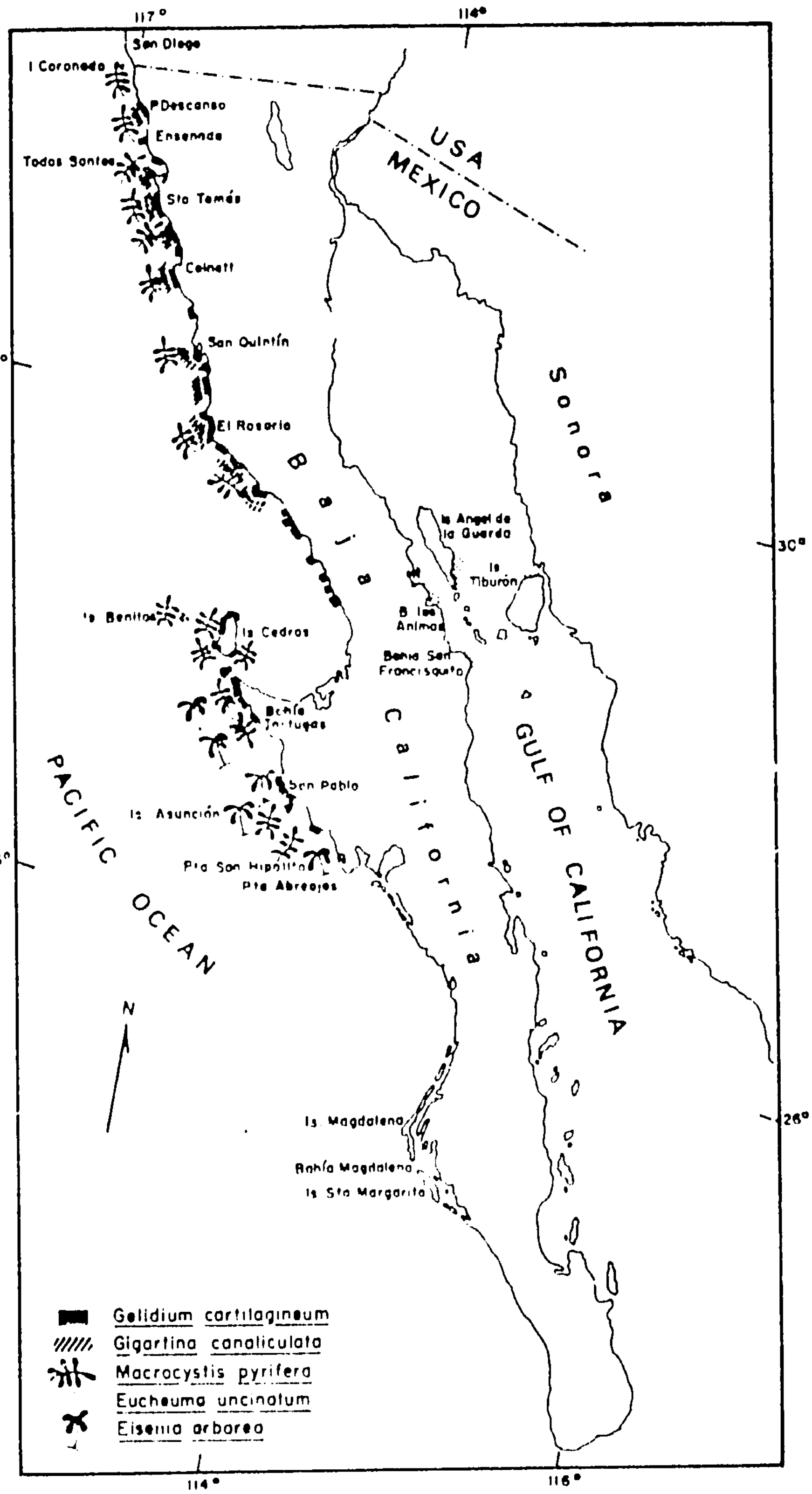

Figure 11. Mexican marine algae in commercial quantities. (After Guzmán del Próo, 1969)

values (Guzmán del Próo, 1969). The harvests of red algae increased further to a maximum of 2 451 dry t in 1974. The resources are found from the low-water line to 15 and 17 m, most of them exploited between 4 and 8 m. Most of the harvest is collected by skin-divers. The Agar-Mex factory in Ensenada consumes a great part of the present harvest, but some quantities are exported to plants in San Diego. One problem is to get enough fresh water in Baja California, another is that 70 percent of the *Gelidium* plants are covered by bryozoan colonies (Guzmán del Próo *et al.*, 1974).

Gigartina canaliculata has been exploited only for a few years, but the harvests are rapidly increasing; in 1974, 638 t dry weight. It is collected by hand at low water (Guzmán del Próo *et al.*, 1974).

Eucheuma uncinatum is not yet utilized but an assessment of quantities arrived at an estimate of 1 650 t wet weight corresponding to 165 t dry weight. Further potential resources are *Porphyra perforata*, *Agardhiella tenera*, *Eucheuma isiforme*, *Gracilaria verrucosa* and *Hypnea musciformis* (Guzmán del Próo, 1969). A review in Spanish of the preparation of agar was given by Osorio Tafall (1946).

3. Guatemala

There are no records of species or quantities.

4. El Salvador

A bilingual flora of intertidal algae was drawn up by Dawson (1961).

5. Nicaragua

A number of species are identified by Dawson (1962).

6. Costa Rica

The algae have been described by Taylor (1945) and Dawson (1957, 1962).

7. Panama
8. Colombia
9. Ecuador

Several localities in these countries were investigated during the Allan Hancock Pacific Expedition in 1934 (Taylor, 1945). Particular interest was devoted to the Archipelago de Colón (Galapagos Islands). Additional information on the Galapagos Islands has been given by Dawson (1963).

10. Clipperton Island

The algal vegetation of this solitary atoll southwest of Mexico was recorded by Dawson (1959).

11. Samoa

As in Hawaii, seaweeds are collectively known as "limu" and a great number of species are eaten. A list of 25 vernacular terms related to edible seaweeds is given by Garlovsky (1971), together with 20 species identified by Drumgole. Besides the ones eaten as food, the red alga *Chronidria* is mentioned as very useful for eliminating *Ascaris* worms from the intestine of man and pigs.

Reference to the marine benthic algae of the island groups of Fiji and Niuafoou (in Western Central Pacific, Area 71), and Samoa, Tonga, Cook, Society, Tubai, Tuamotu and Easter Islands are found in Tsuda, 1966.

12. Hawaii

Fish and taro paste were the staple food of the native Hawaiians. During famine and war their only food came from the sea and there are over 70 distinct species of algae used for food. In the beginning of the century 40 of these were in general use. Reed (1907) estimates the quantities sold each year in the Honolulu fish market at 2 200 kg of "limu", algae. Of this total about 900 kg is "limu kohu", Asparagopsis sanfordiana, about the same amount of "limu eleele" and "limu oolu" or Enteromorpha spp. and Chondria tenuissima respectively; the rest is made up of a high number of comparatively scarce species of Laurencia, Gracilaria, Dictyota, Haliseris, Hypnea and Naias. At the time every Hawaiian who bought a fish or a lobster also bought his plate of "limu".

Setchell (1905) gives a dictionary of more than 100 Hawaiian words for various kinds of limu, discussing their identity and use. Generally they are divided into two classes, one which will keep in condition for eating for as long as a year, one called "one day limu". All the fishermen agree that limu are eaten raw, occasionally some kind is boiled with fish or shrimps, so as to dissolve and form a jelly when cooled, or is used to wrap around a pig or a dog when cooked underground, when those portions smeared with fat or drippings are much esteemed.

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FISHING AREA 81 : SOUTHWEST PACIFIC

1. Australia

On the Australian continent Gracilaria verrucosa is the dominant resource of the east coast. In the Botany Bay area south of Sydney, trawling with a crew of three men brought 270–360 kg/h (Chapman, 1970). Along the 1 370 km coastline of New South Wales there has been estimated to be enough seaweeds to supply 100 t of agar annually, according to Chapman. He gives the conversion 21 t of wet Gracilaria to 1 t of agar. More than 2 000 t of Gracilaria, however, seems excessive. Attempts have also been made to cultivate Gracilaria.

Eucheuma grows on coral reefs off the coast of Queensland. Only drift weed would be possible to harvest.

2. New Zealand

Pterocladia occurs in two species which give the raw material for a small agar-extracting factory. Owing to the shortage during the war, these weeds were investigated and found to yield a gel of a strength superior to that of Japanese Kobe (Forsdike, 1950). Moore (1944, 1946) discusses aspects of the early stages of agar production in New Zealand, quoting as an example of catch per unit effort, that a good collector can gather about 20–35 kg dry weight in one tide in a good place. Kirby (1953) reviews processing properties and economics in detail. Schwartz (1953) gives an account of seaweed utilization in New Zealand with emphasis on manufacturing problems such as the discolouration of agar by metal ions and the conditions under which metal ion contamination occurs.

Agarophytes, principally P. lucida, grow mainly on North Island shores and are collected by hand from rocks about low tide or are gathered from drift after storms. The weed is sun-dried and packed for dispatch to the factory in the South Island. Watkinson and Smith (1972) list figures of dry weed gathered for processing in the years 1962–71, giving an average of 126 t/year. For a number of years agar could be manufactured in New Zealand only under licence; although this restriction no longer applies the original firm is still the only processor.

Gelidium spp. in New Zealand are too small and the Gracilaria spp. of too low quality to have any potential value at the present time.

Macrocystis pyrifera grows in Foveaux Strait and Cook Strait in beds which have been estimated to yield about 5 200 t of dried seaweed per annum on the basis of 80 percent harvestable, one and a half harvests per year (Rapson, Moore and Elliot, 1943). No results have been published of recent aerial surveys.

Durvillea, bull kelp, is a very massive fucoid growing on exposed rocky coasts in two species, D. antarctica having a wider distribution than the endemic D. willana. Where the two occur together, D. antarctica grows just inshore of D. willana and is more easily harvested. A single plant of either species can reach a length of 4–5 m and a wet weight of 50 kg (15–20 kg dry weight). Methods of harvesting, drying and packing are being investigated, but the economic prospects are still uncertain. Harvesting for commercial use began in 1971 and currently exploitation is restricted to the southeast section of the South Island. After drying the bull kelp is pulverized for export. No production figures are available (Watkinson and Smith, 1972). Formerly, the Maoris made air-tight bags from Durvillea in a truly masterly fashion, described by Schwartz (1953), who regrets that this primitive art is dying.

Large amounts of beached seaweeds exceeding amounts occurring in California are found along the coast of the South Island. Farmers salvage considerable amounts for soil conditioning purposes. The figure given by ZoBell (1971), 20 000 t/year in the Canterbury Plains alone, is regarded as exaggerated by New Zealand phycologists.

Other brown algae reaching a length of more than 1 m, such as species of Cystophora, Carpophyllum, Lessonia and Ecklonia, might be used for fertilizer or alginate production, but present use is restricted to gardening. Liquid fertilizers are extensively advertised in New Zealand but apparently the partly processed material is all imported from other countries (M.J. Parsons, personal communication).

Gigartina is represented by 20 species offering a range of carrageenans of different properties and qualities. Small amounts are collected for domestic use and perhaps about 1 t wet weight/year is used to manufacture custard-like commodities and by one or two breweries for fining beer.

Porphyra is traditionally eaten by the Maoris but only in small quantities and it is not on sale. They have also used Gigartina, Macrocystis and green seaweeds as food.

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FISHING AREA 87 : SOUTHEAST PACIFIC

1. Chile

At present Gracilaria spp. are the most important seaweeds from an economical standpoint. Kim (1970) approximates the quantities in the 11 principal Gracilaria beds, totalling 7.7 km^2, to 130 000 t wet weight (22 000 t dry weight). Of these, 24 000–30 000 t are exploited annually (4 000–5 000 t dry weight). In 1968, 1 600 t dry weight were exported, or four times more than the total export of Iridea, Gelidium and Gigartina (295 t, 61 t, and 18 t respectively).

There are two main areas of harvesting of Gracilaria: in the vicinity of Concepción (37°S) and of Canal de Chacao (42°S). Methods for collecting and drying and the activities of a fishing cooperative are described by Cable (1974). Two factories in Chile are working with seaweeds as raw products; one for alginates, with a production capacity of 50–60 t, and the other for agar-agar, with a capacity of 300 t a year.

The useful species were treated by Etcheverry (1953, 1958, 1960) and Llaña (1948). Kim (1968), in a plan for further investigations of industrially useful marine algae, recommends 21 areas in 11 provinces from Tarapacá (20°S) to Chiloé (42°S). An FAO/UNDP fisheries project (unpublished) surveyed northern Chile and found that, apart from the Coquimbo area, the seaweed resources were insufficient for industrial exploitation. A transplant of Gracilaria was made into what appeared a suitable area in the north, but although it grew, the rate of growth was very inferior to that in the south or in central Chile and the venture was not considered a success (J. Molteno, personal communication).

It is likely that the total bulk of algal mass is larger in the southern third of Chile. Here kelp species are dominating, such as Macrocystis, which may grow down to depths of 20 m and can then be harvested at some distance from the shoreline. In Chile, however, this kelp does not occur in a continuous fringe along the coast but in separate patches between which very little or nothing is found (Kim, 1968). The Straits of Magellan are assumed to hold one of the largest fairly untapped seaweed resources in the world. Its quantity and possible utilization is being investigated, and this might be expected to result in an alginate factory. There are, however, technical disadvantages – lack of communications, distance from markets and very poor weather conditions. On the other hand, collection and processing of Macrocystis would contribute essentially to the development of the region.

The most important seaweed species are brown algae: Macrocystis pyrifera and Durvillea antarctica, found in south and central Chile, and Lessonia nigrescens, also found in north Chile. Other kelp species are Lessonia flavicans and Durvillea harveyi, in south Chile. Red algae: in addition to Gracilaria, Iridea, Gelidium and Gigartina already mentioned, there are Chondrus, Ahnfeltia, Gymnogongrus and Agardhiella spp. of industrial interest.

The laver species Porphyra columbina and the sea lettuce Ulva lactuca are marketed for human consumption. The holdfast and stipe of Durvillea antarctica are cooked or eaten raw in salads; they are also used by pharmaceutical producers in children's food on account of their high iodine content (Etcheverry, 1953).

2. Peru

Hilde Juhl-Noodt (1958) has made assessments of the "great and famous resources of marine algae" in Peru, as stated in her species list.

Gigartina chavinii and other Gigartina species are frequently found in the littoral as well as in the sublittoral. They are eaten; the vernacular name for dried algae is "uyo". *Ahnfeltia durvillaei* is characteristic for the supralittoral. Dense tufts appear almost everywhere on the rocky coast at the splash levels and are missing only in a few sheltered places. In the far north they seem to avoid the points with the strongest breakers. They are also found in the entire littoral, where they are differently developed; darker, more slender and slack. *Gelidium*, *Chondrus*, *Rhodymenia* and *Dendrymenia* species are also recorded.

Macrocystis pyrifera is found in many places in the sublittoral (from 3–12 m) in thick stands together with *Lessonia nigrescens*. *Macrocystis integrifolia*, littoral and sublittoral to 20 m, is found as far to the north as 9°S, *M. pyrifera* only to 12°S. The genus is said to have its distribution limit in waters at the 20°C isotherm for the warmest month. *Lessonia nigrescens* may cover vast sublittoral areas in pure stands and may also occur in thick stands together with *Macrocystis*. The possible utilization of the undoubtedly rich seaweed resources of Peru was discussed by Juhl-Noodt (1959) and Acleto Osorio (1970, 1971).

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FISHING AREA 48 : ANTARCTIC ATLANTIC
58 : ANTARCTIC INDIAN OCEAN
88 : ANTARCTIC PACIFIC

Only part of Graham's Land between 55° and 65°W reaches north of 65°S. It is here that most phycological work has been done.

The Macrocystis fringe as well as Lessonia and Durvillea, all characteristic of subantarctic waters as in Fuegia or Falkland, is absent in genuine Antarctic waters as around the South Shetlands or the Antarctic Peninsula (Skottsberg, 1964).

The vertical distribution of the marine flora has been investigated (Skottsberg, 1941, 1964; Neushul, 1965; Delépine et al., 1966; Zaneveld, 1966; McCain and Stout, 1969). The last four papers mentioned are based on observations made during SCUBA divings. Ice-free littoral shores are few and more or less devoid of algae; the sublittoral vegetation, however, is rather rich down to 42 m (the deepest point reached by diving scientists) and dominated by the kelp Phyllogigas grandifolias. Certain species of Picconiella and Plocamium brought up on fish lines from depths down to 100 m indicate that they might have been growing attached as deep as that.

In the sublittoral region, there is abundant algal growth, also under ice covers 2-3 m thick (Zaneveld, 1966). The distribution of important species has been mapped (Balech et al., 1969).

No quantitative assessment has been made.

The sector most frequently investigated is the one which lies closest to another continent, South America. It must be borne in mind, however, that there are difficulties for the utilization of the extremely rich resources of Chile and Argentina, arising from the fact that already these resources are regarded as being situated too far from available labour, communications and consumers to be economically attractive and in an area where climatic conditions limit desired activities to a rather short period each year. These difficulties must be much more serious for any utilization of the comparatively much poorer resources of the Antarctic continent. They do not provide a possible resource for utilization.

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ANNEX

SEAWEEDS

Summary of Resources and their Availability

(prepared by Fishery Resources and Environment Division, FAO)

General

In this section an attempt has been made to give quantitative figures for the feasible production of seaweeds in the different fishing areas. This has proved very difficult, and the figures used should be treated with considerable care, though these are believed to provide a reasonable guide as to where the greatest potentials lie, and of the order of magnitude of the possible harvest. The difficulties of estimation are mainly due to the absence of any good estimates of potential harvest, even in those few areas where there has been extensive research or exploitation. The quantitative data are generally confined to figures of current harvest or of standing stock. There is little direct evidence of how either of these are related to sustainable annual harvest. Seaweeds grow continuously during most of the year, and at the same time are decreased by grazing and erosion, so that the annual production can for some species exceed, possibly by several times, the standing stock present at any moment. The potential harvest must be less than the production, but could well be as high as the standing stock. Some supporting evidence for this is given by the ability for some patches of weed to recover within a year of intense cropping. On the other hand, the standing stock of some species, especially in colder or deeper water, may represent the accumulation of several years growth, and the sustainable harvest may only be a fraction of the standing stock. For example, Furcellaria fastigiata harvested off Denmark appeared to be three to five years old, and too intense harvesting led to a decline in the abundance. Estimates of the potential harvest off Scotland were only a tenth of the standing stock. This seems low, implying a period of regrowth of ten years compared with an average of three to four years off Ireland. For the present purposes, and in the absence of a more reliable procedure, figures equal to one-quarter of the standing stook, where available, will be used to give a rough and probably conservative estimate of potential annual harvest.

Finally, it should be noted that, in general, it is highly unlikely that these potentials will ever be fully realized. The problem of accessibility, of harvesting difficulties and transport costs will probably deter the commercial exploitation of many stocks in the foreseeable future. Particularly in the case of species in greatest commercial demand, increasing emphasis is more likely to be placed upon cultivation than upon the cropping of naturally-occurring stocks.

Arctic Sea : Area 18

The region generally does not favour large algal growth. In those limited areas where productivity is reasonably high harvesting will be difficult because of the climate and distance from markets. Prospects are poor for significant production, say not more than a few thousand tons.

Northwest Atlantic : Area 21

This includes, in the Nova Scotia area, some of the most productive seaweed beds in the world. Red algae are cropped fairly intensively in several parts of the area (e.g., Prince Edward Island) but harvest could be significantly increased, perhaps threefold. Very large standing stocks of brown algae occur, with an estimated 900 000 t of Laminaria in southwest Nova Scotia. If the total stock for the whole area is little more than twice the figure, the potential would be 500 000 t (using a ratio of standing stock:potential of 4:1).

Northeast Atlantic : Area 27

This is another area with regions of very high productivity, particularly along the open Atlantic coast from northern Norway to Ireland. The area provides some of the major harvests of red and brown algae (in the southern and northern areas respectively). The potential of brown algae off Scotland is estimated at 1 million t. Bearing in mind the further production from the great length of the Norwegian coastline and other areas, the Scottish potential may be not more than one-third of the total. Red algae offer fewer prospects for expansion, but it should be possible to double present harvests.

Western Central Atlantic : Area 31

The area is not rich in coastal seaweeds and there is presently no significant harvest. However, both red and brown algae occur in scattered locations in all parts of the area, and total potential from small-scale operations might be significant, at least some thousands of tons. In addition the standing stock of floating Sargassum weed amounts to some millions of tons, so that the potential from this source, if harvestable, could be a million tons or more.

Eastern Central Atlantic : Area 34

Moderate quantities of algae occur in the northern part of the area, but the southern, tropical area seems poor in seaweeds. The present harvest of red algae in Morocco is limited to certain areas, partly due to communication difficulties. If the present harvest rate near the factories could be extended to all the coast southward to Senegal, harvest could be increased five to ten times, or more.

Mediterranean and Black Sea : Area 37

Though densities of seaweed are low, except on the Black Sea, the long coastlines of the area ensure at least a moderate total standing stock, and harvests of red algae are considerable. In the Black Sea a standing stock of 5–6 million t of Phyllophora may be the biggest accumulation of red algae in the world. A harvest of 1 million t annually from this resource seems not unreasonable.

Southwest Atlantic : Area 41

Some of the richest stocks of brown algae occur in the southern part of the area. The extent (10–15 degrees of latitude) is similar to that in the Northwest Atlantic, and the potential may be similar (i.e., about 2 million t). Further north, stocks of both red and brown algae are considerable, if less spectacular, and significant harvests are now being taken. These can probably be increased, and the total potential of red algae might be some 100 000 t.

Southeast Atlantic : Area 47

This area is generally poor in seaweeds, especially in the northern part. Published figures of potential of "hundreds of thousands, if not millions of tons" are almost certainly too high. Extrapolation of quantities of red algae cast ashore (40 t dry weight per km), and of surveys of local stocks of brown algae (6 000 t dry weight in five places) suggest figures of potential in terms of wet weight of 100 000 t upwards.

Western Indian Ocean : Area 51

Resources are generally no more than moderate. Information from the coasts of Africa and the Arabian Peninsula is scarce. Comparison with other areas would suggest resources of perhaps a few tens of thousands of tons. Data from India and Pakistan are more abundant but somewhat inconsistent. Estimates from the best studied (and probably most productive) areas are quite high, e.g., 20 000 t of red algae potential annual harvest from 32 km. For the whole Indian peninsula the potential of both red and brown algae is probably at least 100 000 t.

In the southern Indian Ocean there are enormous quantities of brown algae round Kerguelen which could well yield a million tons or more if transportation and other practical problems were solved.

Eastern Indian Ocean : Area 57

Information is sparse from the tropical part of the region from India to northwestern Australia, but what there is does not suggest the existence of a rich resource. Substantial quantities of brown algae have been harvested off Tasmania, and greater quantities (1 400 000 t standing stock) exist off southern Australia, though these cannot be easily harvested mechanically. The total potential of brown algae for the whole region might be as much as 500 000 t, but that of red algae substantially less (possibly 50 000 t by extrapolation from other areas).

Northwest Pacific : Area 61

Large quantities are harvested in Japan, Korea and China. Demand seems in excess of supply, and harvest from natural stocks is increasingly supplemented by culture. This suggests that in these countries there is not much opportunity for increasing harvest from natural resources. There is a large standing stock (estimated at a little under 2 million tons) off the coasts of the U.S.S.R., and the potential harvest from this could be added to existing production to provide a reasonable estimate of the total potential (plus say 25 percent to allow for some increased harvest even from the other countries).

Northeast Pacific : Area 67

The region is very rich in kelps. Surveys have been made from 1911 onwards but there appears to be some confusion in the reported figures between standing stock, productivity, and potential harvest. However, even with the most conservative interpretation of the survey data and of the possible cropping rate, the potential harvest is very high, probably at least 1 500 000 t. Red algae are very scarce.

Western Central Pacific : Area 71

Seaweeds are widely eaten in the region, but there is little quantitative data on the current harvest, still less on the potential. Allowing for non-reporting of some parts of the present harvest, and for increased harvest from the less intensively harvested grounds, it is likely that the potential might be at least five times the presently reported figures.

Eastern Central Pacific : Area 77

This area is very rich in seaweeds and supports one of the larger seaweed industries. Estimates of potential harvest of kelps (mainly Macrocystis) run as high as 35 million t. This may be high, but a very safe conservative figure, an order of magnitude lower, is still a very large harvest. Red algae are harvested locally in both the U.S.A. and Mexico, and production could be increased.

Southwest Pacific : Area 81

Moderate quantities of red algae occur off Australia and New Zealand, and there is some commercial harvesting. Brown algae occur in more substantial quantities in the southern parts of New Zealand.

Southeast Pacific : Area 87

This area, and the coast of Chile in particular, is very rich in seaweeds. Red algae are mainly found from central Chile northwards, while brown algae dominate the southern waters, where the Magellan Straits hold one of the richest untapped seaweed resources in the world.

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Potential and Actual Harvests of Seaweeds

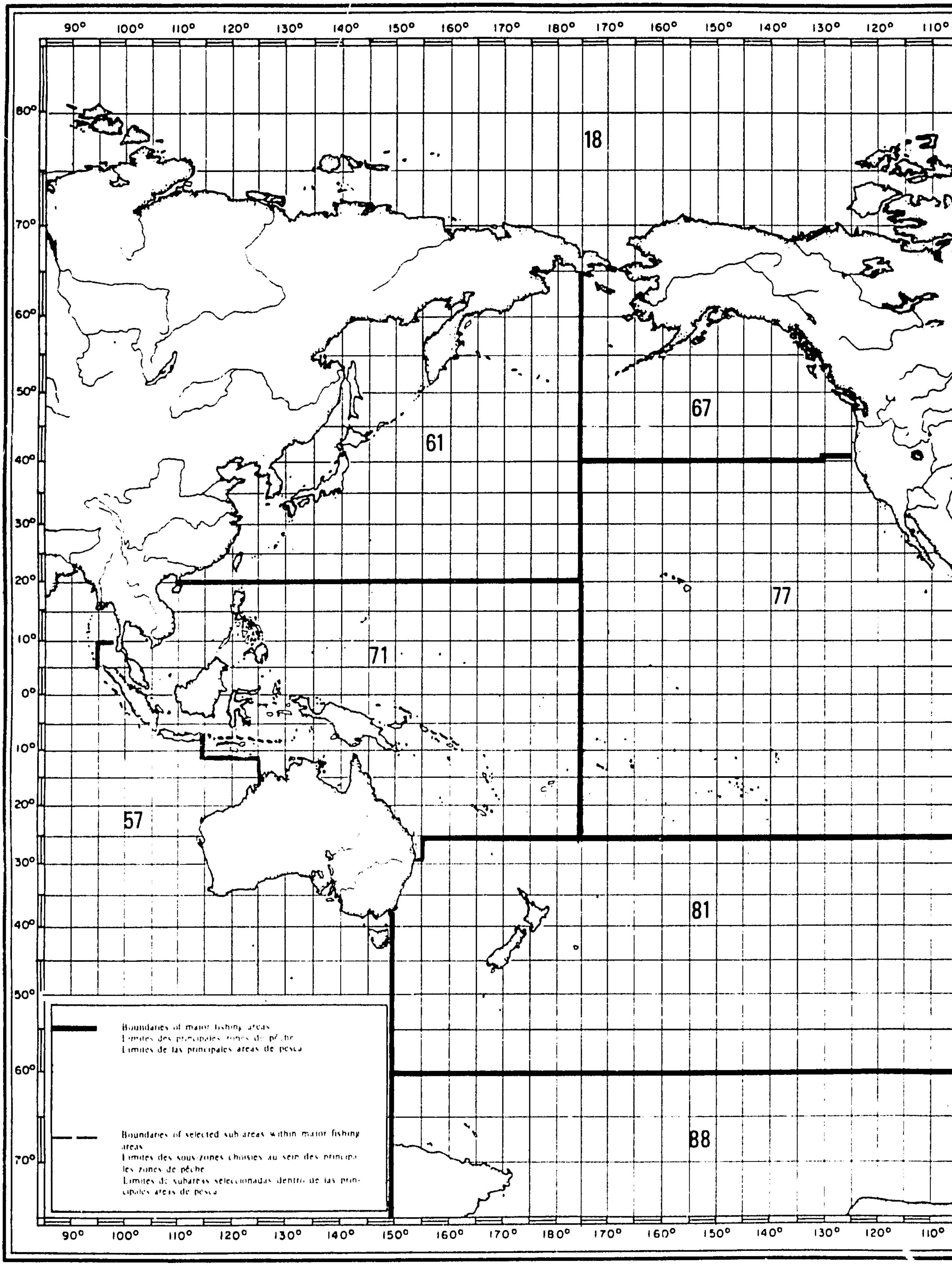
(thousands of tons wet weight)

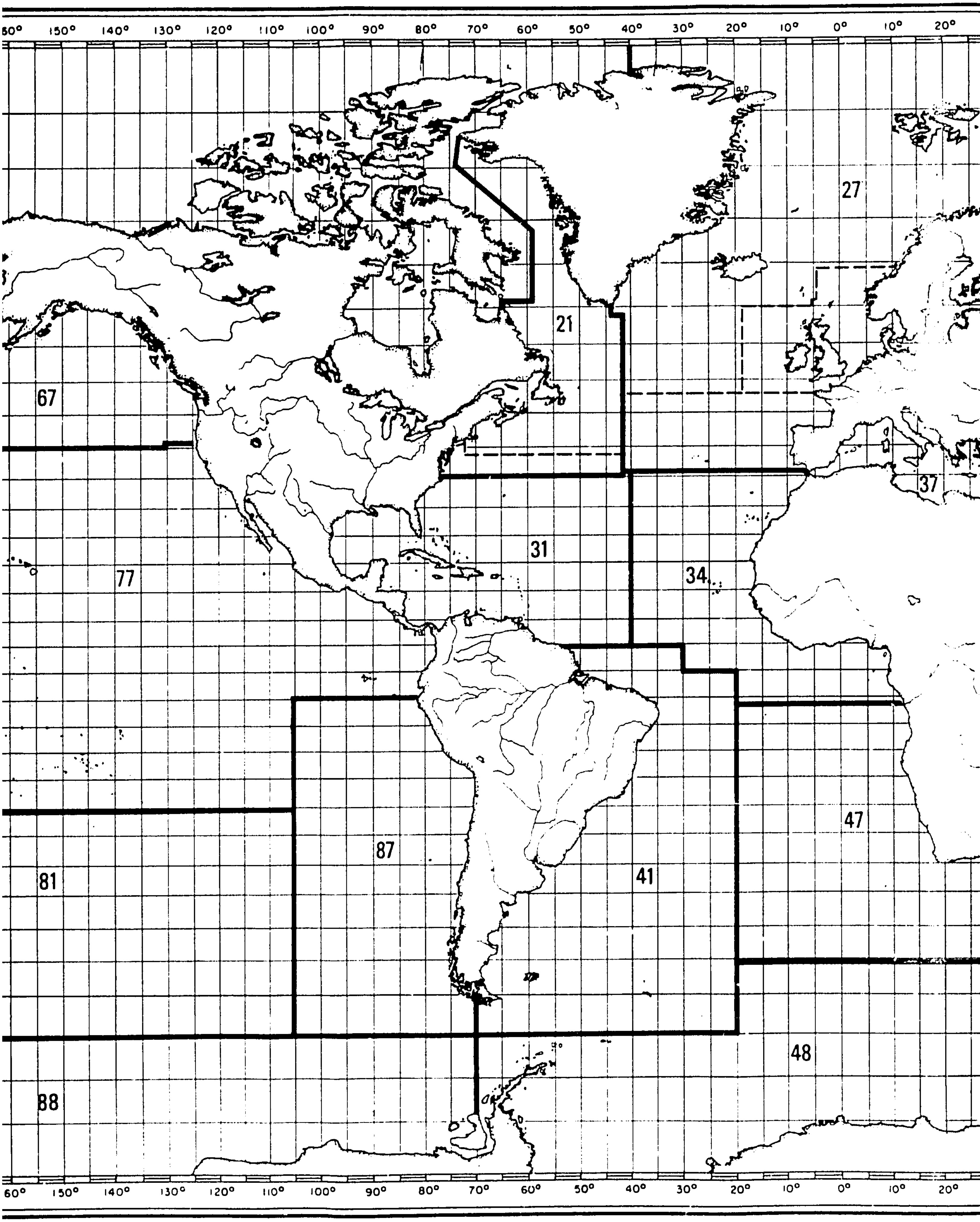
Area	Red algae		Brown algae	
	Recent harvests 1/	Potential output 2/	Recent harvests 1/	Potential output 2/
18 Arctic Sea	-	-	-	-
21 NW Atlantic	35	100	6	500
27 NE Atlantic	72	150	208	2 000
31 WC Atlantic	-	(10)	1	1 000
34 EC Atlantic	10	50	1	150
37 Mediterranean/ Black Sea	50	1 000	1	50
41 SW Atlantic	23	100	75	2 000
47 SE Atlantic	7	100	13	100
51 W Indian Ocean	4	120	5	150 (1 000, Kerguelen)
57 E Indian Ocean	3	100	10	500
61 NW Pacific	545	650	825	1 500
67 NE Pacific	-	10	-	1 500
71 WC Pacific	20	50	1	50
77 EC Pacific	7	50	153	3 500
81 SW Pacific	1	20	1	100
87 SE Pacific	30	100	1	1 500

1/ Recent levels of harvests based upon estimates for 1971-73.

2/ Broad indications of possible annual output.

MAJOR FISHING AREAS FOR STATISTICAL PURPOSES PRINCIP





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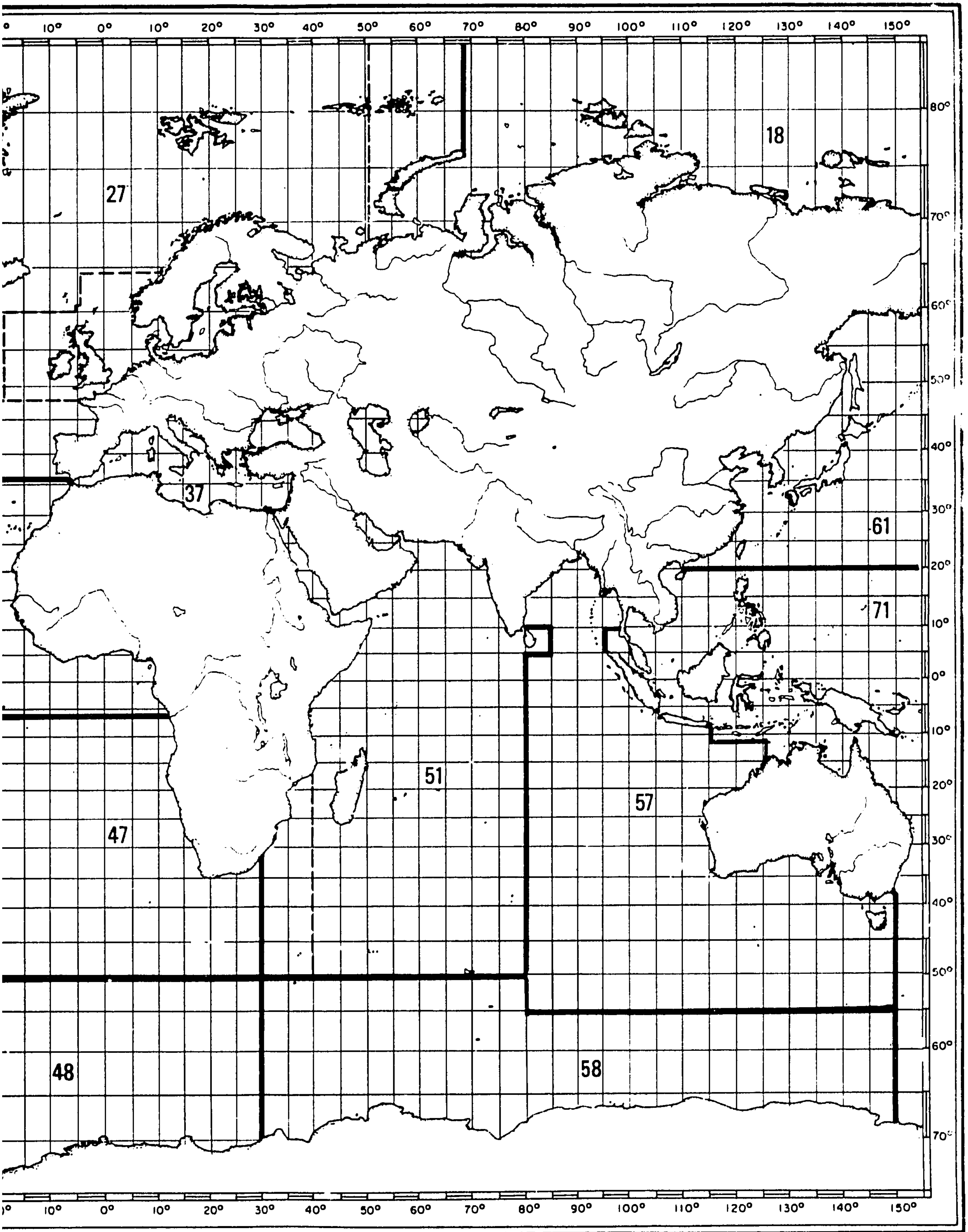
ISTIQUES

AREAS PRINCIPALES PARA ESTADISTICAS PESQUERAS



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