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Case Study on Brazil in the Field of Marine Algae (Seaweed) Cultivation and Processing

by

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1. BACKGROUND MATERIAL

Reflecting a growing concern that science and technology are being increasingly directed towards destructive ends, the United Nations General Assembly in December 1983 called upon the international community to take the necessary steps to ensure that "the results of scientific and technological progress are used exclusively for the benefit of mankind and for promoting and encouraging universal respect for human rights." The UNIDO International Forum on Technological Advances and Development in Tblisi, USSR, in April 1983 expressed a similar concern, and a call was made for "a new form of international cooperation involving a limited number of new and advanced technologies to meet particular needs of a clear and urgent character to the human community." This concept of "Technologies for Humanity" was discussed further at the Fourth General Conference of UNIDO held in Vienna, Austria, in August 1984 (document ID/CON.5/36).

The underlying concept of "Technologies for Humanity" is to establish a limited number of specific cases where research, development and dissemination would be carried out in the public domain and coordinated on a world-wide basis, so as to achieve substantial results in the shortest possible time. The results would be measured in terms of the number of people beneficially affected and the relationship of the needs thus being met to their fundamental human right to a

decent and meaningful existence. It was, of course, realised that such an endeavour would involve not only the mobilization of financial resources and scientific talents, but also the will and commitment of all countries, as well as the dedication and participation of the international scientific and technological community.

The comprehensive utilization of marine algae to produce human food and animal fodder, in agriculture and industry was considered as fitting very well into the concepts of "Technologies for Humanity". Accordingly, a UNIDO Special Experts Group Meeting was held in Riga, the Latvian Capital, USSR, between 4-8th Aug. 1986 to discuss the current state-of-the-art of industrial growing and processing of marine algae, and to formulate recommendations and specific project concepts for consideration and possible implementation by UNIDO and interested countries.

The Brazilian Government expressed great interest in possible cooperation with UNIDO and/or other interested parties at a very early stage in the development of this programme. Thus a UNIDO Consultant (Dr Peter K Robinson, UK) was sent to Brazil with a brief as outlined in section 2.

2. TERMS OF REFERENCE FOR STUDY

The purpose of the mission to Brazil was to gather information and compile a report presenting a general picture of the development of cultivation and processing of marine algae in Brazil, including an analysis of the situation in terms of improvements of techniques used for processing of algae and better utilization of the Brazilian coastal zone.

Amongst the aspects of the problem to be specifically considered were :-

- seaweed cultivation in Brazil including potential development of new areas of cultivation,

- existing industrial and semi-industrial technologies used for processing of marine algae,

- identification of typical problems confronting the developing countries of the region,

- formulations of proposals for possible cooperation between UNIDO and Brazil, as well as on the regional and international levels,

- identification of the areas in which Brazil would be interested to engage in regional and international cooperation.

The report has been compiled according to the guidlines layed out in the UNIDO document UNIDO/EX/CPE/CS.14, "Notes to authors for UNIDO studies".

3. DETAILS OF MISSION

3.1. Itinirary of visit

The mission to Brazil comprised a 13 day visit between 17 Feb. 1987 and 01 Mar. 1987.

DATE	LOCATION	DETAILS
17/02/87	Leave UK	
18/02/87	Arrive Brasilia	p.m. Meeting Dr Campos Torres de Carvalho, Secretary for Biotechnology and staff.
19/02/87	Brasilia	a.m. Meeting at Ministry of the Marine with Interministerial Commission for Marine Resources. (CIRM). p.m. Meeting with the Secretary for Biotechnology to meet Dr Carlos Meirelas, Special Secretary From the Government of Bahia.
20/02/87	Leave Brasilia	a.m. Flight to Sao Paulo. p.m. Met by Dr Ribeiro dos Santos (President Cialgas) Travel to Ihla Bela.
21/02/87	Ihla Bela	Visit to Ubtuba research station.
22/02/87	Leave Ihla Bela	Travel to Sao Paulo.
23/02/87	Sao Paulo	a.m. Visit Inst. of Technological Research (IPT). Visit Univ. Sao Paulo. p.m. Visit Oceonographic Inst.
24/02/87	Sao Paulo	Visit Space Research Inst (INPE), Sao Jose dos Campos.
25/02/87	Leave Sao Paulo	a.m. Flight to Salvador p.m. Visit Univ. Salvador.

26/02/87	Salvador	a.m. Visit Centre for R&D (CEPED) p.m. Flight to Sao Paulo.
27/02/87	Sao Paulo	a.m. Meeting with the State Secretary of Industry, Commerce, Science and Technology, the Secretary for Biotechnology, and others for technical evaluation.
28/02/87	Leave Sao Paulo	p.m. Flight to UK.
01/03/87	Arrive UK	

3.2. Follow-up investigation

Whilst the mission enabled contact with many Academics, R&D workers, Industrialists and Government officials in and around Brasilia, Sao Paulo and Salvador, it was realised that significant areas of Brazil were not included in the itinirary. To obtain further information (particularly from industries in these unvisited regions) a follow-up letter was sent to identified companies utilizing or processing seaweed products, together with a questionnaire asking their opinion over a variety of related topics. With the help of the Brazilian Secretary for Biotechnology these letters have been circulated. A specimin copy of this correspondence is included below (page 11).

Copies of this letter have already been sent to the following companies:- Agar Brasileiro, Brazilian Alginate Co., CBA, Coralga, Fermisa, Fracema, and Frutos do Mar.

Continuation, and perhaps extension, of this follow-up survey is suggested as being highly important to the development of any subsequent programme of cooperation.

'Follow-up' correspondence to identified seaweed processing or utilizing companies which were not visited during mission

COMPANY .....
ADDRESS .....

Dear Sir,

I have recently visited your country, working on behalf of UNIDO to see if any assitance could be given to Brazil's seaweed industry. I was, however, unable to visit your company, and am now trying to get a more general picture of Brazil's industry. I wonder, therefore, whether you could respond to the following questions. If you have any additional information please enclose it. This information will be analysed and presented in a report to UNIDO and will likely be used to identify projects for assistance. Your assistance will, of course, be fully acknowledged and will be greatly appreciated.

1. Could you please give details of the products which you produce and the seaweeds which you use. If possible give details of the quantities of products produced and the quantities of each seaweed species used.
2. Could you please identify the major factors limiting your industrial development
   e.g. is it supply of weed, or training of workforce, or lack of equipment, or market demand?
3. Has your company any interest in seaweed cultivation and if so which species or genera would you consider to be most important to cultivate?
4. Do you import any raw materials or export any products? If no, would you like to export?
5. Have you any specific projects likely to appeal to UNIDO which could improve your industrial output (or productivity) which you would like to suggest?
6. Have you any plans to diversify your production, or are you likely to remain producing your current products in the forseeable future?
7. Have you currently any cooperative agreements with non-Brazilian companies? If no, would you have any interest in developing such agreements?
8. Have you any contacts with non-Brazilian universities or R&D establishments? If no, would you have any interest in developing such contacts?

Once again, may I thank you for your assistance.
Yours faithfully

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4. STATE-OF-THE-ART OF SEAWEED CULTIVATION AND PROCESSING IN BRAZIL

4.1. Utilization of seaweed products in Brazil

Brazil, in common with most other countries in the world uses large amounts of products derived from seaweed.

It is clear that there is in Brazil a small demand for the seaweeds themselves for direct human consumption, and it is likely that this market is localized largely around the 'oriental' community of Sao Paulo. It is also probable that such populations will use seaweed products in herbal-type medicinal treatments. However these markets are difficult to assess, and discussions with several informed observers would suggest that neither market would be large enough to necessitate any major industrial development within Brazil itself, although this position should perhaps be regularly monitored since seaweeds grown for human consumption are able to retail at far higher prices than those grown for extraction of colloids.

Of more importance, however, is the utilization of large quantities of alginate, carrageenan and agar, primarily within the food industry as gels and gums (phycocolloids). It would seem that the utilization of such phycocolloids is essentially the same as in most other countries in the world. Brazil does not appear to have any specific major

uses of such gums which are unique to the country. (Those unaware of the extensive uses of such products in the food industry should, perhaps, consult Glicksman, 1962.)

Since the use of phycocolloids is greatest in some of the highly refined and processed foods (including tinned and preserved meats, pastries and sweet foods) it does seem likely that demand within Brazil will be greatest in the more affluent south of the country and around major cities. With the likely progressive urbanization of the country, together with a rapidly increasing population, it seems likely that demand for such foods (and therefore for the seaweed products used in them) will continue to increase over the forseeable future.

Seaweeds are also used for agricultural purposes within the country. Schmid and Hoppe (1962) report of Hypnea being used as coconut manure in Brazil, though this would now seem to be of localized and relatively minor importance. However, the calcareous alga Lithothamnion is used extensively as a soil conditioner to neutralize the naturally acidic soils of the country.

4.2. Seaweed imports/exports

Typical of many developing and industrializing countries, Brazil imports considerable quantities of processed seaweed products.

Figures of Brazil's trade in seaweed products for the years 1979-1983 have been supplied by the Ministry of the Marine, and must be taken as indicative of the present state-of-affairs in the country since more up-to-date figures are unavailable.

Brazil currently imports some 380,000 kg (dry-weight) of seaweed products annually (table 1), worth about US $5.5 million (table 2). Alginate is the most costly seaweed commodity to import, making up about 50-55% of the total import bill, with carrageenan making up about 35-40% of the import bill and agar making up about 5-10% of the bill. The other minor imports of seaweed products only make up about 5-10% of the import bill, in total.

Thus, as a rough estimate, the importation of alginate costs Brazil some US $2.8 million per annum; the importation of carrageenan cost some US $2 million per annum; and the cost of agar costs some US $0.4 million per annum.

Table 1. Quantity (kg dry-weight) of seaweed and seaweed products imported into Brazil, 1979-83 (CIRM, 1985).

KEY
1 - Medicine
2 - Human food
3 - Agar
4 - Carrageenan
5 - Alginate
6 - Other uses

YEAR	USES						
	1	2	3	4	5	6	TOTAL
1979	13,185	17,583	31,525	226,651	182,396	-	471,340
1980	7,975	13,307	19.788	213,766	150,222	-	405,058
1981	4,845	2,618	15,463	160,984	154,882	2,000	340,792
1982	2,595	12,864	19,634	147,421	149,565	2,000	334,079
1983	7,370	10,503	12,456	185,619	140,416	-	356,364
MEAN	7,194	11,375	19,773	186,888	155,496	800	381,527

Table 2. Value (x US $1000) of Brazilian imports of seaweed products 1979-83 (CIBM, 1985).

KEY

1 - Medicine
2 - Human food
3 - Agar
4 - Carrageenan
5 - Alginate
6 - Other uses

FOB = Free on Board (= actual cost of product)
CIF = Cost Insurance Freight (= cost including transportation, insurance and delivery)
VF = Final value

YEAR	USES						
	1	2	3	4	5	6	TOTAL
1979							
Authorized FOB	62.8	82.8	419.1	1838.0	1082.3	-	3485.0
Actual FOB	45.2	35.1	262.2	1765.2	1187.5	44.8	3340.1
CIF	64.1	45.7	277.9	1876.9	1285.1	50.0	3599.7
VF	71.1	77.5	315.2	2219.3	3010.2	95.7	5789
1980							
Authorized FOB	32.6	60.9	305.6	1938.9	1150.4	-	3488.4
Actual FOB	38.3	98.8	465.2	1623.8	960.1	45.6	3231.8
CIF	55.6	144.2	501.5	1721.0	1052.4	50.6	3525.3
VF	60.6	270.9	563.7	2190.3	2363.1	97.4	5546.0
1981							
Authorized FOB	21.4	43.9	263.7	1504.6	1396.3	3.0	3232.9
Actual FOB	39.3	44.6	191.0	1330.4	1311.8	66.4	2983.5
CIF	50.3	49.8	203.9	1411.8	1422.1	73.5	3211.4
VF	53	49	232	1832	3143	142	5451
1982							
Authorized FOB	35.2	95.7	309.0	1423.6	1260.8	3.0	3127.3
Actual FOB	31.2	95.3	298.0	1392.8	1146.7	46.0	3010.0
CIF	41.9	108.4	356.3	1467.5	1243.5	55.5	3273.1
VF	45.6	114.0	397.7	1893.2	2788.3	111.5	5350.3
1983							
Authorized FOB	12.2	141.5	193.3	1918.0	1335.7	-	3600.7
Actual FOB	11.2	71.4	185.1	1772.9	1427.1	102.4	3570.1
CIF	-	-	-	-	-	-	-
VF	-	-	-	-	-	-	-

4.3. Seaweed resources

Brazil's coastline ranges from latitude 4°N to latitude 34°S, and thus includes areas possessing tropical and subtropical floras. An intensive survey of this coastal flora (Oliveira, 1977) has revealed more than 500 seaweed species, several of which are of actual or potential economic value. Details of the main genera of importance in this respect are given in table 3.

Table 3. Principal potential uses of Brazilian seaweeds (CIRM, 1985).

GENUS	USES				
	FOOD	FERTILIZER	AGAR	CARRAGEENAN	ALGINATE
Laminaria	+	-	-	-	+
Sargassum	-	+	-	-	-
Porphyra	+	-	-	-	-
Gelidium	-	-	+	-	-
Pterocladia	-	-	+	-	-
Gracilaria	+	-	+	-	-
Calcareous algae	-	+	-	-	-
Gigartina	-	-	-	+	-
Meristotheca	-	-	-	+	-
Solieria	-	-	-	+	-
Eucheuma	-	-	-	+	-
Gymnogongrus	-	-	-	+	-
Hypnea	-	-	-	+	-

As can be seen from table 3, several species of seaweed able to provide the raw materials for the agar, carrageenan and alginate industry grow along the Brazilian coastline - the most important genera will be considered further.

On the north-east coastline of Brazil, and in the state of Espirito Santo, commercially exploited beds of Gracilaria are found (fig.1). Species of Gracilaria found in Brazil include G. verrucosa, G. debilis and others. Gracilaria provides a good raw material for the agar extraction and processing industry. No commercially exploitable beds of Gelidium have been documented.

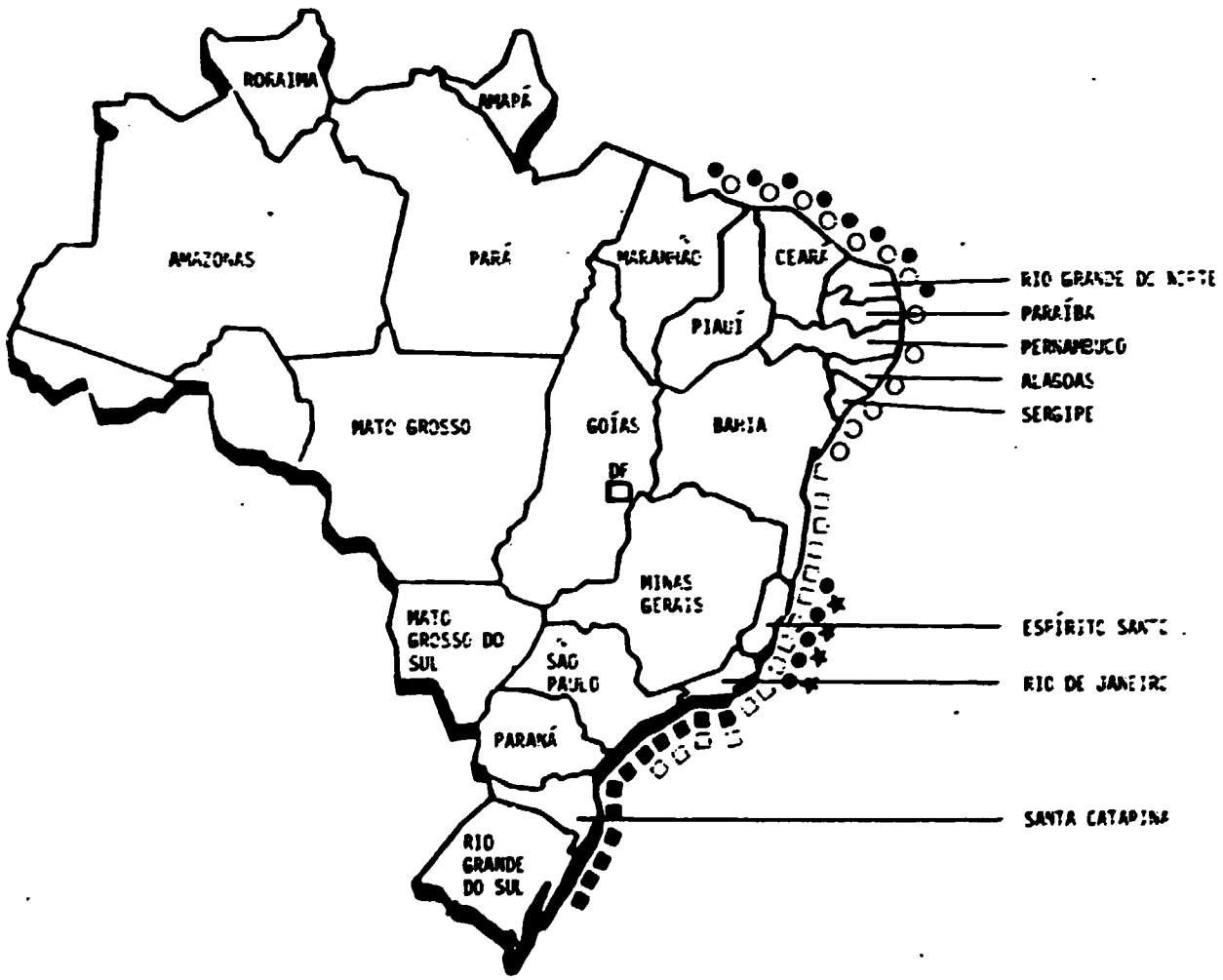
On the north-east coastline of the country are found populations of Hypnea (fig.1) which are used for the manufacture of carrageenan.

The only readily exploitable resources of seaweed for alginate manufacture in Brazil are the Sargassum beds on the southern coast of the country (fig.1). The standing crop of Sargassum (mainly S. cymosum, S. stenophyllum and S. vulgare) has been estimated along the coast of Sao Paulo State to be about 600km long, with a crop of 388 tonnes (fresh-weight) available by hand pulling. Regeneration would allow this crop to be harvested at intervals of 6-8 months (Oliveira and Edison, 1979).

FIGURE 1. Map of Brazil showing locations of seaweed resources.

LEGEND

- ● = Gracilaria
- ○ = Hypnea
- ■ = Sargassum
- □ = Laminaria
- ★ = Lithothamnion



Additional to the supply of Sargassum for alginate extraction, there are known to be extensive beds of Laminaria along the coasts of Sao Paulo State up to Bahia State, with most of the beds located between the north of Rio de Janeiro State and Espirito Santo State (fig.1). However, these are found at depths of 20-100m and are thus far from easily exploited.

Brazil possesses considerable resources of the calcareous alga Lithothamnion especially in the Espirito Santo State area (fig.1).

4.4. Existing cultivation industry

Essentially there is no deliberate cultivation of any seaweed species in Brazil. The existing processing industry (section 4.5) simply relies on the harvesting of natural populations of seaweed as raw material. This harvesting includes harvesting of driftweed (i.e. seaweeds washed ashore) together with the more deliberate harvesting of attached populations. This feature of the Brazilian seaweed industry undoubtedly results in a greater fluctuation in the quantity and quality of raw material, and thus introduces a major seasonal factor into the output of the Brazilian processing industry. Currently, this fluctuation in output cannot simply be rectified through importation of seaweed since this is apparently subject to fairly rigid Government control.

4.5. Existing processing industry

Whilst Brazil imports large amounts of alginate, carrageenan and agar, this is not to say that the country does not possess its own seaweed industries. In fact there are several companies within the country processing seaweed for a variety of uses.

Table 4 Quantity of seaweed (kg dry-weight) used by Brazilian processing companies, 1979-83 (data courtesy of Ministry of the Marine).

YEAR	COMPANY				
	AGAR BRASILEIRO	CIALGAS	CORALGA	FRUTOS DO MAR	TOTAL
1979	184,219	69,204	385	319,250	573,058
1980	278,861	131,323	352	357,369	767,905
1981	382,222	137,000	530	323,000	842,752
1982	485,781	264,871	640	187,500	938,792
1983	684,594	437,145	775	367,000	1,489,515
MEAN	403,135	207,909	536	310,824	922,404

Table 5 Production of agar (kg dry-weight) in Brazil (Sao Paulo and Paraiba States), 1976-84 (data courtesy of Ministry of the Marine).

YEAR	SAO PAULO	PARAIBA	TOTAL
1976	25,800	-	25,800
1977	44,300	6,327	50,627
1978	34,800	10,553	45,353
1979	24,400	17,189	41,589
1980	36,400	33,830	70,230
1981	12,100	25,225	37,325
1982	29,300	35,274	64,574
1983	44,400	44,184	88,584
1984	-	6,154	6,154
MEAN	31,438 *	22,342 *	55,897 **

\- Data not available.
* Based on years when data is available.
** Based on years when data from both states is available.

Table 6 Production of other seaweed products (kg dry-weight) in Brazil (Sao Paulo, Paraiba and Rio de Janeiro States), 1976-84 (data courtesy of Ministry of the Marine).

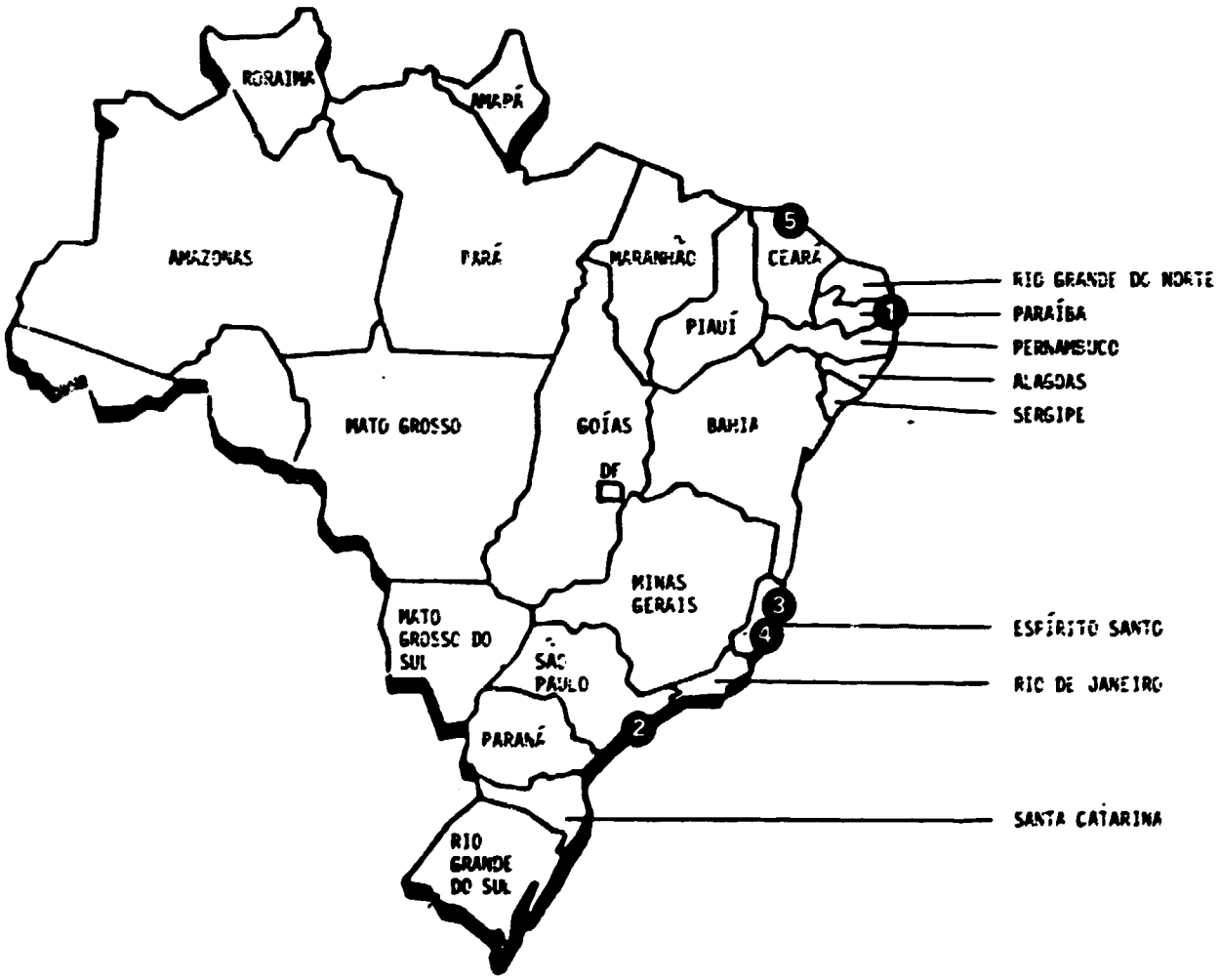
YEAR	TOTAL
1976	-
1977	6,800
1978	10,700
1979	-
1980	4,000
1981	1.100
1982	-
1983	1,516
1984	-
MEAN	4,823 *

\- Data not available.
* Based on years when data is available.

FIGURE 2. Map of Brazil showing locations of seaweed processing capacity.

LEGEND

1	=	Agar Brasileiro
2	=	Cialgas
3	=	Fermisa
4	=	Fracema
5	=	Frutos do Mar



Inspection of table 4 reveals that Brazilian seaweed processing companies harvested annually 0.6-1.5 million kg dry seaweed between 1979 and 1983. Though data as to how this weed was used is far from complete, table 5 shows that a large proportion of it must have been used to produce agar. About 57,000 kg agar was produced in the states of Sao Paulo and Paraiba during this same period, which would probably require about 500,000kg raw seaweed. The 5,000 kg of 'other products' produced annually during this period (table 6) could include colloid and non-colloid materials, and cannot be analysed more fully.

The list of Brazilian seaweed processsing concerns includes the following :-

AGAR BRASILEIRO

According to available statistics (table 4) this company is the largest consumer of seaweed in the country. Consumption, over the period 1979-83 increased by about 400%. The company is Brazil's main agar manufacturer and as such will probably utilize large amounts of Gracilaria (though this fact remains to be verified by the company). The company is situated to the north of the country in Paraiba State (fig.2) within close proximity to the beds of Gracilaria found on the north east coast of the country. Presumably agar products from this company make up the 'Paraiba' section of table 5, giving some indication of the annual

fluctuation in output.

CBA

This company is apparently setting up an alginate processing capacity, and is reportedly cooperating with Protan, a major European alginate manufacturer. However, as yet, no further details are available.

CIALGAS

Statistics (table 4) show that Cialgas is another major consumer of seaweed. Consumption, over the period 1979-83, increased by about 600%. The company is situated near to Sao Paulo (fig.2) and has traditionally been a manufacturer of agar. Presumably, since this is the only phycocolloid manufacturer in Sao Paulo State, agar products from the company make up the 'Sao Paulo' section of table 5. However the company now has, or soon will have, the capability to process a variety of products including agar, carrageenan and locust bean gum (a non-seaweed colloid). Currently it is claimed that the plant produces mainly carrageenan from Hypnea musciformis which it collects in the Rio Grande do Norte State in the north-east of the country.

CORALGA

This company is a small consumer of seaweeds (mainly Ulva) which it uses in the production of cosmetics.

FERMISA

Situated in Vitoria, Espirito Santo State (fig.2), this company harvests the calcium rich seaweed Lithothamnion and grinds it to form a powdered calcium-rich, basic, soil conditioner.

FRACEMA

Apparently just starting up operations, this company also intends to exploit the Lithothamnion reserves of the Brazilian coastline.

FRUTOS DO MAR

Using some 300-350,000 kg seaweed annually, this company apparently exports Gracilaria, presumably for use by the agar industry abroad. The company is based around Fortaleza, Ceara State (fig.2), on the north-east coast of the country.

4.6. Existing Infrastructure and Current Government Activities

Currently in Brazil, the monitoring of seaweed rescurces and their utilization is carried out by the Interministerial Commission for Marine Resources (CIRM), which liaises with the Ministry of the Marine, the Ministry of Science and Technology, and others.

Within Brazil a major initiative in the development of seaweed cultivation and processing technology began about 2-3 years ago. A report on the state-of-the-art of seaweed processing and cultivation (in Portuguese) was produced by CIRM in 1985, which prioritised areas for future development as follows:-

1) carrageenan,
2) alginate,
3) agar and agarose.

Following this report CIRM drew up and circulated terms of reference for grants to fund projects on the mariculture of seaweeds for production of carrageenan and agar. These documents were sent to Universities and R&D Institutes. The only major prerequisite was that projects had to be cooperative ventures between Acaademic/R&D Institutions and Industry. To date, one major project has been given funding, that of agar production in Paraiba State, which is a cooperative venture between the University of Paraiba and an agar manufacturer (presumably Agar Brasileiro).

4.7. Current R&D Activities

As well as the major initiative outlined in section 4.6 there are, of course, several research areas that are being currently investigated in Brazilian Universities and R&D Institutes. Details of such work included in this section should be seen as an example of the work going on, rather than being an exhaustive list of all such activities.

There is little doubt that one of the main Brazilian centres of excellence in algal research is that of the University of Sao Paulo. Dr Oliveira and his colleagues have an international reputation in algal taxonomy, and are also currently investigating several areas of algal physiology. The international reputation of this group was, perhaps, demonstrated by the department hosting the 12th International Seaweed Symposium in July 1986, when Academics and Industrialists from all over the world visited the University for a six-day meeting.

Whilst the work done at the University of Sao Paulo is of great academic interest, it must be said that much of this work is not directly applicable to the industrial cultivation and processing of seaweeds. However, members of the University staff, particularly Dr Oliveira, are now cooperating with workers at the Instituto de Pesquisas Tecnologicas (Institute for Technological Research) (IPT) on

more applied projects, particularly the utilization of Brazilian Laminaria, including development of pilot-plant scale alginate extraction plant capable of producing kilogrammes of purified alginate on each 'run'.

Work within Bahia State, around the city of Salvador, is situated at two main centres. Within the University of Salvador, members of the Chemistry and Biology Departments are working on a small project to cultivate Gelidiella acerosa and extract agar from it. Preliminary studies on the nutritional quality of the algae are interesting, however shortages of equipment and external funding are undoubtedly restricting the advancement of this research programme. Close to the city of Salvador is the headqaurters of the Centro de Pesquisas e Desenvolvimento (Centre for Research and Development) (CEPED). Here again is another relatively new project looking at the culture of Hypnea for the production of carrageenan. Facilities (particularly analytical facilities) at this centre are excellent, and provided that culture facilities are constructed and manpower supplied this project should yield some interesting results. Further, the knowledge which this Centre possesses as regards liaising with industry may well be useful in bridging any gaps between R&D and industrial implementation.

5. IDENTIFICATION OF THE NEEDS OF THE COUNTRY TO IMPROVE CULTIVATION, HARVESTING AND PROCESSING OF MARINE ALGAE

In the previous section, the current state-of-the-art of exploitation of Brazil's seaweed resources was outlined. This section aims to use such information to identify broad directions in which industrial development should, perhaps, proceed. Section 7 will then include details of some specific project concepts which fall within the broader proposals considered herein.

When considering industrial developments, perhaps one of the first considerations to make is that of the size and stability of the market, and it can be seen from the previous section that the demand for phycocolloids within Brazil is large and stable (indeed likely to get larger). In fact the current demand for such products is actually likely to be higher than revealed by such a simple analysis, since the high taxation on imported goods keeps their price high, and subsequently depresses the market size. Also of relevance in this context is the fact that most Western countries are now turning away from artificial products in foods (e.g. artificial stabilizers, emulsifiers and antioxidants) towards more natural products, thus the market for such natural phycocolloids may reasonably be expected to increase over the next decade or so.

Brazil, like many developing and industrializing countries,

is thus in a position where a major proportion of a domestic market is being satisfied through importation. In a country with a high national debt, this is a highly undesirable situation. Since Brazil exports little seaweed or seaweed products the net cost of the seaweed-trade is a US $5.5 million trade deficit each year.

The country does, however, have a well developed processing capacity. As an example of the ability of Brazilian enterprise to compete in the world markets, the firm Cialgas has just finalized an arrangement with the Government of Morocco to build a plant in Morocco for the production of carrageenan from the Moroccan seaweeds. This contract was won in competition with companies from USA, the Far East and Europe, indicative of the ability of Brazilian processing industry. Indeed, even if the Brazilian seaweed processing industry was less efficient than foreign competition (and thus produced goods at a higher price to the consumer), there would still be some overall economic sense in developing the seaweed industry so as to improve the seaweed-trade deficit.

One question which remains to be answered, however, is whether Brazil's seaweed flora is of sufficient size so as to support an expanded processing industry. Informed opinion suggests that the local beds of kelps do seem big enough to supply the internal market for alginate (Oliveira, pers. comm.). Such a view seems optimistic, but even so it

strongly suggests that the beds are of sufficient size to support some domestic industry. As regards agar and carrageenan, the situation is similarly rather unclear, but it does seem that the already established processing capacity is currently limited (or is near to limitation) by the supply of raw material of sufficient quality as and when required (realising that supply is largely seasonal whereas demand is not).

Currently, therefore, it is unlikely that the natural domestic seaweed resources could supply a domestic processing industry such that imports of phycocolloids were totally unnecessary. A more realistic scenario would be that of a more carefully managed cultivation industry supplying raw material to the processing industry such that the country's seaweed-trade deficit could be cut substantially. The major industrial development in this scenario would thus be one of the cultivation industry not the processing industry.

The necessity for a developing or industrializing country to develop its seaweed cultivation capacity, rather than its seaweed processing capacity, was not discussed in detail at the Special Experts Group Meeting on the Industrial Growing and Processing of Marine Algae (Riga, USSR; 4-8 Aug., 1986). Rather, this group identified a more likely scenario where a country possessed considerable seaweed resources and needed to develop a processing capacity to satisfy domestic

requirements. The Brazilian position, however, should certainly merit consideration by UNIDO for cooperation.

Much of the rest of this section therefore deals with issues related to the establishment of a Brazilian seaweed cultivation industry to supply its processing industry. In the current situation where importation of raw material is very costly (because of high import tariffs) and sometimes even impossible (because of import restrictions and quotas) this seems a course of action worthy of close consideration, however it must be stated that this is not the only option worthy of consideration. One alternative which should not be overlooked is the possibility of Brazil dropping import restrictions and lowering tariffs on imported raw seaweed (but not processed seaweed products), and thus importing raw materials for processing.
Such a course of action would undoubtedly lead to a reduction in the annual US $5.5 million seaweed-trade deficit since importing the raw material would certainly be cheaper than importing processed goods. Further, action would almost certainly provide additional employment in the seaweed processing and transportation industries. Such a course of action could be quickly implemented and, provided a sensible tariff was placed on imported weed, would not interfere with the livelihood of those who already gather the seaweed from the Brazilian shores.

Similarly, immediate improvements could result if the

Brazilian Government granted tax relief on the R&D activities carried out by the seaweed processing industry (in order to stimulate such activities). Moves of this kind would undoubtedly act synegistically with any assistance which UNIDO may be able to offer.

Returning now to the problem of the determination of the size of Brazil's seaweed flora, one recommendation which was formulated at the Special Experts Group Meeting (Riga, USSR; 4-8 Aug,, 1986) was that of utilizing remote sensing apparatus (satellites) to detect:-

a) attached populations of seaweeds in remote locations, and

b) areas of coastline most suitable for seaweed mariculture ventures.

This proposal was discussed in some depth with members of the staff of the Instituto de Pesquisas Espaciais (Institute of Space Research) (INPE) in Sao Jose dos Campos, Sao Paulo State. From these meetings a specific project has been proposed and is included in detail in section 7. In essence, this project deals with the use of both aircraft and satellites to detect seaweed populations and identify areas suitable for seaweed culture. The proposed project would comprise a pilot-study to assess the suitability of various methods of remote sensing in a well charted area, and may (or may not) lead on to further work. However, discussions with personnel from both Cialgas and the University of Sao Paulo suggest that an essentially similar study was carried

out about five years ago with little success. Further, since Dr Oliveira has studied in such detail the algal flora of the Brazilian coastline (Oliveira, 1977), it is arguably unnecessary, even if feasible, to carry out a remote sensing operation in Brazil since it would be unlikely (though perhaps not impossible) that Dr Oliveira would have missed any seaweed beds large enough to be of commercial significance. Also, though the project is certainly likely to reveal attached seaweed populations in shallow waters, it is very unlikely to detect any of the Brazilian Laminaria beds, since these are at depths of 20-100m below the water surface, and are almost certainly too deep for detection by available remote sensing methods. UNIDO may, however, wish to investigate the use of remote sensing in Brazil as a case-study so as to assess whether remote sensing is a useful strategy for detecting seaweed populations elsewhere in the world.

If then we assume that the major commercially exploitable beds of seaweed are known, work undoubtedly needs to be done to demonstrate whether or not these beds are being harvested optimally and, once harvested, whether the phycocollloids are being extracted optimally.

Taking the latter point first, though little hard evidence is available it does seem that extraction of phycocolloids within Brazil is within the 'normal' range for large-scale extraction (though perhaps towards the bottom of this

range). Yields obtained by Brazilian agar processors are within the range 8-11% on a dry weight basis (Oliveira, pers. comm.) whereas Assad-Ludewigs and Oliveira (1986) obtained 28-33% yield of agar from Brazilian Gracilaria in the laboratory. Chapman (1970) quotes industrial scale extraction with a 14-23% yield from Japanese Gelidium, and suggests that whilst Gracilaria contains 55-65% agar, only 25-35% can be obtained in the laboratory, and that even these yields are unlikely using commercial equipment. Similarly, Brazilian yields of carrageenan from Hypnea are quoted as 10-12% (Santos et al., 1986). Whilst no great concern was aired over this matter in both formal and informal discussions with various workers in Brazil, this area should perhaps be investigated and this suggestion will be reiterated in a proposal in section 7.

Returning now to the optimization of harvesting of Brazil's seaweed flora, it is clear that much careful work must be done to ensure that productivity is optimized without overexploiting (and thus damaging) the resources. Apparently little of this work has been done in the country and this will undoubtedly need to be included in any sensible cultivation strategy. Similarly, there appears to have been only a little work done in Brazil on the extension of seaweed beds by providing new substratum (e.g. by reef blasting) or on more elaborate rope-type culture (similar to that practised in Japan, China and the Philippines). Although work on the intensive mariculture of seaweed is now

underway in one or two R&D Institutes in Brazil such work is in its earliest stages and could certainly be improved in a variety of ways e.g. improvements in domestic and international cooperation; sharing of common facilities; and coordination of effort to one or two key seaweed genera. These suggestions are expanded further in a project outlined in section 7.

However, before any major expansion of a Brazilian seaweed cultivation and harvesting industry can proceed, some important points must first be considered and decisions made at the highest levels of Government. First of all, the decision must be made as to whether or not to introduce any foreign seaweed species of potential economic value into Brazilian coastal waters, e.g. Eucheuma for carrageenan production. With this strategy comes the risk of altering perhaps detrimentally the marine ecosystem. Various examples of disasterous introductions of non-native organisms can be given; perhaps the best known (to the layman) are those of rabbits introduced to Australia or the water hyacinth (Eichhornia crassipes) to the southern states of the USA. As regards seaweeds, however there have been some noticeably successful introductions. For example, Laminaria japonica was introduced to the shores of China (albeit accidentally) in 1927 by ships travelling from Japan to Dalian, Liaonong Province, and since then there have been more deliberate transplantations to Yantai and Quindao Provinces, with apparently little detrimental effect to the ecosystem. Even

amongst the seaweeds, however, there is major concern over some of the plans to cultivate the giant kelp Macrocystis, since the long-term effects of such introductions are difficult to assess.

The alternative (and perhaps more safe) course of action to introducing new seaweed species is simply to intensively cultivate the indigenous species, as has been done with success in the Philippines with Eucheuma cottonii and E. spinosum. As regards agar production, the only species to be found naturally in any great quantity, Gracilaria, would also seem most worthwhile to culture; as regards carrageenan, cultivation of Hypnea would be most likely; and as regards alginate, cultivation of Laminaria would probably be most effective. However, cultivation of these three seaweed genera within Brazilian waters (and indeed elsewhere) is not without its problems.

Brazil has a special problem in the cultivation of its Laminaria resources, since these are normally found at great depth. Thus extension of natural beds would be a difficult task, probably necessitating teams of divers using SCUBA equipment. Even if this were possible it would be likely that light limitation would prevent any deeper colonization of the seaweed, whereas any shallower colonization would probably be limited by high temperatures (Laminaria typically colonizes cold waters). Perhaps more feasible would be the approach recently attempted by Yoneshigue and

Oliveira (1986) who took Laminaria from 70m depth and cultivated it on ropes at more moderate depths (24m) in an area of periodical upwelling (15-21°C). The early success of this approach suggests that more work of this type should be done to assess the viability of such cultivation at the commercial level.

Cultivation of red algae (particularly Gracilaria) has also been attempted in various areas of the world with some success. Such cultivation has included both the extension of natural beds and more elaborate rope-type mariculture techniques. Probably the most major problem in such projects has been that of keeping a monoculture devoid of contaminant species. However notable successes have been reported in South America notably in Chile (Santelices and Ugarte, 1986) through controlled management of such beds.

Though there is apparently little information on cultivation of Hypnea, it has been suggested that such cultivation suffers from the same problems as that of Gracilaria.

However, just because Laminaria, Gracilaria and Hypnea are the 'usual' algae now used by the colloid industry, this does not mean that any anticipated cultivation programme should overlook other indigenous Brazilian species. Cultivation of Pterocladia, for example, should be seriously investigated, towards the commercial production of agar (see, for example, Berchez and Oliveira 1986a,b); and similarly perhaps

Sargassum cultivation should be explored for commercial carrageenan extraction.

To consider a related issue, one point which was specifically mentioned at the Special Experts Group Meeting on the Industrial Growing and Processing of Marine Algae (Riga, USSR; 4-8 Aug., 1986) was that of encouraging developing counries to develop their own processing capacity for microbiological grade agar (i.e. a high grade of agar used in microbiological work which is more pure than that normally used by the food industry). With reference to this point, the current situation within Brazil does seem somewhat obscure. It has been suggested that processing capacity already exists to produce such agar, but that the raw material for such agar production is not available. This does seem strange since the Special Experts Group Meeting and other workers have suggested that Gracilaria (which is present in Brazil) should make a good raw material for such extraction. Since the economic and industrial development of Brazil is undoubtedly going to result in a greater demand for public health monitoring, medical assistance and related pure and applied research, it would seem that the area of microbiological grade agar production should be one which is considered specifically by both the Brazilian Government and industry, and by UNIDO.

Thus, having suggested that Brazil could benefit from a more developed seaweed cultivation industry, it is quite

clear that there are several major issues to be settled before any major programme of work could (or should) be introduced. In essence, two main questions remain to be answered :-

a) Which seaweed (or seaweeds) does Brazilian industry most require to expand their production of carrageenan, alginate and agar?

b) Can this (or these) seaweeds be cultivated in Brazilian coastal waters?

Such questions need to be answered clearly before any rational integrated investigations can begin; and the answer to the first question must come directly from the Brazilian processing industry itself.

It is hoped that the follow-up work suggested in this report, and already underway, together with the assistance of the Brazilian Government, would enable these problems to be resolved quickly such that further consideration can be given to the programme.

Turning now to a related issue, various Academics, R&D workers, and Government officials in Brazil showed great interest in the recommendations which came from the Special Experts Group Meeting (Riga, USSR; 4-8 Aug,, 1986) regarding :-

a) the possible establishment of UNIDO Centres of Excellence in industrial seaweed culture and processing, and

b) the possibility of 'twinning' Academic and R&D Institutes from developing and developed countries.

With respect to the former consideration (point a), there was great interest in such a venture being placed in Brazil, both to coordinate (and no doubt implement) Brazilian expansion of its own seaweed industry, but also to act as a centre for such work throughout South America. This possiblity should certainly merit serious consideration. However it must be emphasized that whilst this was a recommendation of the Special Experts Group, such a commitment has not been formalized by UNIDO. Additionally there does perhaps need to be further consideration of the rationale behind the setting up such centres of excellence. For example, will such centres be set up only in countries which already possess a fully developed seaweed cultivation and processing industry such that workers from abroad could visit to be taught? Or would countries still developing such an industry be more suitable, such that experts could visit the centre to teach? It is clear that Brazil does possess a considerable body of academic excellence in phycology especially at the University of Sao Paulo. Also the country possesses considerable experience and expertise in the industrial processing of seaweed products. Currently, however, the country (unlike, for example, Japan, China and the Philippines) does not possess any developed industrial

cultivation technology. The suitability of the country to host a UNIDO Centre of Excellence is thus open to some debate but merits serious consideration.

As to the possiblity of twinning Brazilian institutes with those from abroad, great interest was shown by many workers who felt somewhat isolated in South America, and who could undoubtedly improve technology transfer by visiting educational and industrial establishments abroad. Considering the possibility of twinning establishments it is clear that after consideration of the flora (mainly red seaweeds growing in tropical or subtropical warm waters) and the major limiting factor to industrial development (the absence of an established seaweed cultivation and/or management programme) then the most useful country to make such arrangements with would be the Philippines, which possesses a highly developed industry to cultivate and process the red alga Eucheuma. The possibility of funding any worthy individuals (rather than those from just one or two 'twinned' centres) to travel abroad should, however, not at this stage be excluded. Of particular importance in this respect may be the funding of research workers to undertake doctorates (PhDs) at foreign Universities on projects related to the medium or long-term strategy of the country in seaweed culture and processing.

It is clear, therefore, that much useful work can be done to improve the productivity and stability of the Brazilian

seaweed industry. It is also reasonably clear that further clarification of several important points is necessary in order to identify with absolute certainty the needs of this industry. The next section therefore sets out a recommended strategy to enable development of the project.

6. RECOMMENDATIONS

It is clear that there are various ways by which the Brazilian seaweed industry could be aided; this section therefore includes a coordinated series of proposals which would be likely to make a major influence on the industrial exploitation of seaweeds in Brazil, and should be considered by UNIDO in developing global plans of assistance for seaweed industries in 'developing' and 'industrialising' countries.

1) The agreement of the Government of Brazil should be sought as to the necessity and desirability of developing its domestic seaweed resources for industrial exploitation. Cooperation between UNIDO, the offices of the Brazilian Secretary for Biotechnology, and CIRM should be sought at all stages of any programme to ensure efficiency and to avoid duplication of effort.

2) Implementation of a 'follow-up' study of the type described in section 3.2 should be carried out and extended, such that the requirements of industry are clearly established.

3) Associated with the implementation of any programme of work by UNIDO, it may be useful if the Brazilian Government consider the easing of any import

restrictions on raw seaweed, such that Brazilian industry can easily import and produce processed materials for use in domestic markets, thereby aiding the current trade deficit in seaweed based products.

4) Having established from recommendations 1 and 2 the desirability and necessity for a domestic cultivation industry, the particular seaweed resource or resources most required by the Brazilian seaweed processing industry should be established and agreed upon by both the Brazilian Government and UNIDO. Particular attention should be given to the desirability of processing microbiological grade agar, and the species of seaweed required for this extraction

5) UNIDO should investigate further the need for a single centre within Brazil to coordinate work on industrial aspects of seaweed culture and processing. Of particular relevance to the positioning of such a centre should be the location of natural seaweed populations identified as of prime importance from recommendation 4. In this respect, assistance in the development of one (or more) existing establishments should be considered, depending on the academic and industrial competence of personnel already within such institutions. It is strongly recommended that UNIDO assistance should only be provided to such a

centre if the full cooperation of the Brazilian seaweed industry is given in respect to the centre's terms of reference, and to the planning and implementation of the individual projects to be carried out. Results from projects carried out within such a centre should be seen not as the 'property' of one particular company, but should be made readily available to interested parties upon request.

6) In connection with recommendation 5, this centre could (but need not) be considered officially a UNIDO centre of excellence in industrial seaweed technology. In either case, however, it would be envisaged that this centre would assist industrial development throughout the South American continent.

7) Preferably in conjunction with recommendation 5, UNIDO should consider assistance for the 'twinning' of either an already established or (more desirably) a newly established (or expanded) Brazilian institute with an institute expert in the cultivation and processing of algae. Consideration of the Brazilian seaweed flora would suggest that such a joint venture would be most profitable with a cultivation and processing institute situated in the Philippines.

8) Preferably (though certainly not necessarily) in connection with recommendation 5, assistance should

be given to worthy personnel for study abroad, particularly for work leading to a doctorate. A prerequisite for such assistance, however, should be that study be directly related to the long term strategy of Brazil in seaweed cultivation and processing previously established.

9) The Brazilian Government should look into the possiblity of encouraging more industrial development from the processing industry itself by viewing R&D into the cultivation and processing of seaweeds as an action worthy of support by enabling the costs of such activities to be offset against taxes (i.e. making such R&D a valid tax deduction from the tax burden of such companies).

10) UNIDO should also consider the use of Brazilian expertise and facilities of remote sensing at INPE to assess the feasibility of such operations in detecting seaweed populations, for application to other countries. In respect to this proposal the relevant project proposal in section 7 and the comments made in section 5 should be consulted.

7. SPECIFIC PROJECT PROPOSALS FOR POSSIBLE COOPERATION BETWEEN UNIDO AND BRAZIL

Owing to a variety of problems, it was not possible during the mission to Brazil to both identify specific projects and to confirm that such projects were agreeable to Brazilian Government officials. Most of the various projects outlined in this section thus came from Academics and R&D workers who were carrying out research related to this area but who requested some assistance in their work. The one project which does not fit into this category is that of remote sensing of seaweed populations which was proposed directly as a consequence of the possibility of such a project being recommended in the Special Experts Group Meeting (Riga, USSR; 4-8th Aug. 1986).

As currently described these project proposals are very brief since at this stage of the programme it was considered more important to evaluate and agree upon broad and coordinated strategies of development rather than to suggest one or two isolated projects The projects included below should thus be viewed as examples of those likely to be necessary under the broader recommendations layed out in section 6.

1) Scale up of alginate pilot-plant

Rationale : Brazil currently imports all of its alginate, yet local beds of Laminaria seem large enough to supply the internal market (Oliveira, pers. comm.). IPT has developed a pilot-plant capable of producing 1kg of alginate in each 'run'. Further development of this pilot plant would seem a worthwhile venture, especially in conjunction with a study of techniques for harvesting natural (deep water) stocks of Laminaria in Brazil, and artificial (rope-type) cultivation of Laminaria. Industrial collaboration is essential to the success of such a venture.

2) Improvement of agar production technology

Rationale : The actual yield of food grade agar obtained by Brazilian industry is too low, ranging from 8-11% (Oliveira, pers. comm.). Technological development to enable the extraction of more colloid material from Brazilian seaweeds is thus desirable. However the industry itself must identify more specifically any problem before UNIDO would be able to offer any assistance.

3) Survey of algae of economic importance along Brazilian coast

Rationale : Oliveira suggests that the available data are too fragmentary and do not allow a realistic picture of the potential of the natural beds of the country. Further the survey would also permit selection of suitable sites for mariculture projects. Presumably this survey would be carried out using conventional techniques, but could be linked to project 5.

4) Assessment of the value of seaweed fertilizers in Brazil

Rationale : Many colloid extraction processes produce large quantities of treated seaweed as a waste product. The potential use of this extracted weed should be investigated with respect to its use as animal feed and as a fertilizer. Together with this, research into the use of liquid seaweed fertilizers, and into the true value of Brazilian Lithothamnion as a fertilizer may generate considerable awareness (and hopefully demand) for such products in Brazilian agriculture.

5) Evaluation of Brazilian seaweeds by remote sensing

Rationale : To evaluate the usefulness of remote sensing methods for identification of :-

a) seaweed populations of commercial value and

b) areas of potential value for mariculture programmes.

Work will involve selection of an area of coastline approximately 250km long for appraisal of the use of Landsat TM (thermal mapping) and low-level (<1000m) airborne photography techniques in the detection of seaweed populations. As regards the Landsat imagery, suitable data is already available for the majority of the Brazilian coastline (see fig.3) and will need analysis within the wavelengths suitable for such a study (these also need to be determined). As regards the airborne detection, the suitability of a variety of standard and non-standard photographic emulsions will be assessed.

The cost of this pilot-study has been suggested as being $50,000.

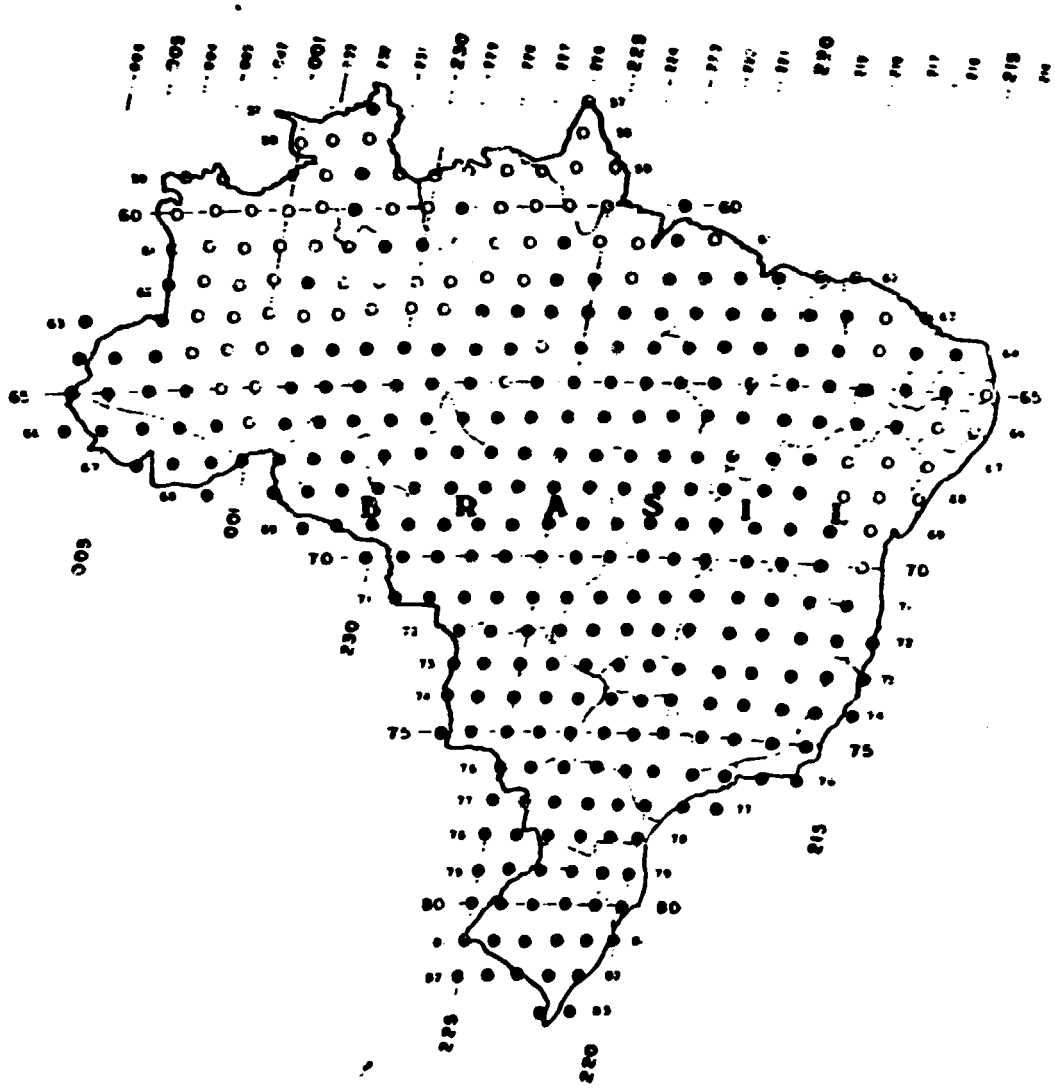
The usefulness of available remote sensing techniques for the detection of seaweed populations will be assessed from this study. Such methodology should be applicable anywhere in the world, and may thus be of use both to Brazil, and to other countries with similar problems.

FIGURE 3. Map of Brazil showing availability of Landsat TM imagery .

LEGEND

● = Areas for which TM data is available, and in which cloud cover is present in less than 10% of cases (i.e. most suitable for suggested study).

o = Areas for which TM data is available, but in which cloud cover is present in greater than 10% of cases (i.e. less suitable for suggested study).



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