FAO interests in promoting understanding of world seaweed resources, their optimal harvesting, and fishery and ecological interactions

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Abstract

The Food and Agriculture Organization (FAO) of the UN has, among its other responsibilities, a concern with the description and proper management of marine living resources, including seaweeds.

These interests relative to marine algae, include a better definition of commercial world seaweed resources by species synopses and catalogues, improved methods of assessing and managing the wild resources, and understanding the impact of seaweed harvesting on the other commercial resources for which seaweeds form a habitat, as well as determining the contribution of macroalgae to those marine food chains leading to commercial fish populations.

On the utilization side, FAO's interests also encompass methods of cultivation (mariculture), harvest of 'wild' stocks, and the processing, marketing and trade in the marine resources. In the present paper we will be dealing particularly with scientific management of these resources, and the initiatives that would be of value in promoting this approach: particularly with respect to improved dissemination of information on appropriate methodologies.

A brief outline of some areas of concern in resource management is followed by a discussion of possible actions to assist in achieving these goals, particularly through the applications of the existing skills of experts in marine algae to the proposed FAO initiatives outlined in this paper, preferably acting through an established body of experts such as the International Seaweed Association.

Introduction

Seaweeds are an economically important source of food and industrial products, and pose the same questions to the resource manager with respect to rational harvesting strategy as do commercially important marine animals on the one hand, and the optimal management of forest stands in the terrestrial context, on the other. The same important questions should be asked in relation to harvesting strategy, namely:

- Where are the resources, of what kind, and how much? What are the possible alternative uses and markets for these kinds of resources?
- What is the rate and timing of harvesting needed in order to maintain a sustainable optimal harvest of the wild resources?
- What are the appropriate levels of investment in manpower and equipment needed to achieve the above optimal harvesting rate in both wild and cultivated systems without wasting scarce economic resources?
- What if any are the indirect impacts of harvesting on other resources in the ecosystem? (i.e. what is the fate of the unharvested resource in the natural ecosystem).

A review of considerations in the first of the above categories is presented by Michanek (1975), and of the second by Naylor (1979) and McHugh & Lanier (1983).

Hydrobiologia 124, 111–121 (1985).

To date, the authors are unaware of a comparable body of literature on the other 3 important questions in applied marine phycology, comparable to that available for fisheries resources, although questions of harvesting strategy are of considerable importance to marine resource managers.

Two further categories of questions also need answering here: What are the appropriate and economically feasible methods of mariculture, and where can they be applied? What is the nutritional value of the alga or its yield of products (such as agar), and how can these, and the growth of the algae be enhanced by optimizing environmental conditions and by selective breeding?

All of these questions are of concern to national administrations, and should be included in comprehensive but easily readable texts for the use of non-specialists, for training and as practical guides to managers and scientists entering the field, including management of Seaweed Resources.

In general, national fisheries administrations for developing countries cannot afford to consider resources in isolation especially in view of growing recognition of species interactions in the marine ecosystem.

We note that in addition to their commercial importance, macroalgae together with a number of marine and estuarine angiosperms, play an important indirect role in many marine systems as habitats for commercially important marine animals, and also make a significant contribution to marine food chains leading to marine organisms of importance to man.

This contribution can be either viewed directly, as food substrate for commercially important herbivores (e.g. Abalone), as habitat (e.g. shelter for lobsters), or probably more importantly in areas where biomass is high, as a locally important source of organics leading especially to detrital food chains and demersal fish species.

The Fisheries Department of the Food and Agriculture Organization of the United Nations (FAO) is concerned with the development and rational management of the living resources of marine and freshwaters, including marine plants, and this encompasses all of the above-mentioned aspects, both for marine animals and marine plants. In the latter case however, the number of FAO publications produced to date have been relatively few. Notable, however are the FAO Fisheries Technical Reports by Michanek (1975) Naylor (1976) and Little (1979), several species synopses. (see App. IA), some of which however are in need of updating bearing in mind the considerations mentioned earlier. A forthcoming publication by McHugh & Lanier (1983) provides an up-to-date review of the world seaweed industry and trade and two publications reviewing seaweed mariculture methods in South East Asia, and relevant training aspects, by Trono *et al.* (1980) and (1981), were published by the FAO/UNDP Fisheries Development and Coordinating Programme in Manila.

Through its field programmes FAO also supports development programmes in fisheries, and in particular, under the FAO Technical Cooperation Programme, has worked with the People's Republic of China introducing new equipment and technology into the alginate production industry.

Optimal harvesting strategy

Although in some parts of the world marine macroalgae may form one of the few underutilized renewable marine resources, in others there are dangers from over-harvesting.

Providing manuals for managers of cultivated and wild seaweed resources on methods of resource management is considered a high priority, especially for developing countries with significant resources and opportunities for development, and this question of resource management has several important aspects, which are outlined below.

The definition of optimal harvesting time for monocultures of terrestrial plant species has been given extensive consideration in agriculture, forestry, and also in the aquaculture of aquatic animals. Presumably for culture of seaweeds a body of practical information also exists on this subject, and on the associated questions of growth rates in terms of the biomass or linear dimensions of the individual plants as a function of temperature, hydrographic conditions, salinity etc. This information should perhaps be systematised, together with other relevant biological information on the culture process and its associated economics.

For harvesting wild seaweed resources on a continuous year-round basis, the conventional fisheries yield models described in e.g. Gulland, 1969 and Ricker, 1975 obviously could, after modification to

take into account the biological features and sedentary nature of the algal resources, be applied to harvesting of marine plant resources also.

Among the special features that would need to be taken into consideration here in formulating analytical harvesting models (based on a knowledge of growth, reproduction and mortality) are the duality between on the one hand, vegetative growth and regeneration, and on the other, the sexual reproduction of marine plants. Their nature as stationary resources makes them compatable in some respects with models of sedentary shellfish populations (e.g. Allen, 1979; Gales & Caddy, 1975).

The definition of harvesting efficiency and the measurement of the size of standing stocks, new recruitment, and rates of indirect loss of resources due to herbivore grazing and harvest wastage, may also need to be taken into account.

Statistically valid systems of surveying these resources and their harvests are also needed to provide the necessary quantitative information for fitting such models to the fisheries in question and using them as a guide to rational management.

Other sets of data needed in this respect to fit models of production from this type of fishery would be data on the fishing effort exerted by the fleet, possibly expressed per area of the grounds fished, together with some measure of the cost of harvesting (fuel, crew wages, harvesting and processing equipment).

Definition of the legal framework (territorial user rights) is also a necessary precondition for both culture of seaweeds, and economically viable harvesting of wild stocks. Logically in this latter case, rotational harvesting is the ideal strategy, and to be effective this requires limited access and proper leasing arrangements.

Marine macroalgae as habitat, and indirect effects of plant harvesting

Marine macroalgae, together with sea grasses and mangroves stands, fulfil an important role as habitat or shelter for commercially important marine organisms, e.g. lobsters, and as primary settlement substrates for some important shellfish species, as well as providing egg-laying sites for commercially valuable resources such as the Pacific Herring. For this reason extensive removal of the seaweed canopy due to human intervention or natural causes may have direct effects on habitat availability in addition to those other effects described later.

The persistence or otherwise of natural seaweed beds is dependent in nature on whether a balance is maintained between natural grazing and physical attrition, versus growth and reproduction. As noted in Pringle, *et al.* (1980) this balance may be disrupted by the explosion of populations of grazing organisms (sea urchins in the case of S.W. Nova Scotia). This explosion of herbivores in itself was hypothesised to have resulted from overharvesting of those species (e.g. lobster, some bottom fish) that formally controlled urchin abundance (Mann, 1977), and similar control mechanisms have been postulated in the case of California kelp beds by Estes & Palmisaro (1974) and by Leighton *et al.* (1966).

These types of ecological interactions may be paralleled by significant fisheries interactions; thus Scarratt (1973) investigated indirect damage to lobsters in beds of Irish moss (*Chondrus crispus*) as a result of raking operations by seaweed harvesters. Up to 5% of the lobsters present in the path of a dredge are killed by each passage of the rakes. The conclusion was that, in some circumstances, the marginal increase in seaweed yield from a further increase in effort will be outweighed by the losses to the other fisheries in the area. This conclusion and the considerations it involves may be worth considering elsewhere, since few fisheries operate independently of other harvesting activities in the same area.

Inputs of macrophytes to marine food chains

Mann (1982) has reviewed the role of macroalgae in supporting the productivity of coastal waters through the production of dissolved organics and detritus which locally increases biomass, standing stocks and fish production from nearshore waters: perhaps contributing over 50% of the total marine primary productivity in some areas, and doing so on a year-round basis, rather than just during the peak periods often characteristic of phytoplankton blooms. The role of macrophytes in such systems may be more important than previously suspected, and further developments of these studies are awaited with interest.

FAO publications and summaries on marine resources

The relatively few publications on marine plants by FAO to date should not obscure the fact that several series of publications exist which could and should be supplemented by new publications on the important topic of scientific management of marine plant resources.

A Year Book of World Fisheries Statistics is produced annually, in which information on fish and seaweed production provided to FAO by national offices is included. Other FAO publications on scientific aspects of fisheries are issued in six main series:

(a) *FAO Mannuals on Fisheries Science.* These are major priced publications.
(b) *FAO Fisheries Technical Papers,* which are the definitive repository for most papers on technical subjects.
(c) *FAO Fisheries Circulars,* which are used as a repository for preliminary studies that may be reissued as Technical Papers in definite form later on.
(d) *FAO Species Identification Sheets,* published by major fishing area.
(e) *FAO Species Synopses,* for marine organisms of particular importance.
(f) *FAO Species Catalogues,* for species of major economic importance.

A new series of National Field Guides for species of commercial importance is also now being initiated.

The Fisheries Manuals and Fisheries Technical Reports and Circulars published by the Fisheries Department of FAO could accommodate a wider range of topics, ranging from harvesting and culture methods, resources, management methodologies and reviews, and questions of the economics and processing and marketing of seaweed resources. In addition, on a more strictly scientific plane, the series of Species Synopses prepared for key marine resources, already include 5 seaweed species and the Identification Sheets prepared for many world oceans for commercial and potentially commercial species, could and should be adapted to include the main species of marine algae of commercial importance. Appendix I gives some ideas for possible FAO initiatives on seaweed resource publications. Further information can be obtained from: Dr. Walter Fischer, Marine resources Service, Fishery Resources and Environment Division, Fisheries Department, FAO, Via delle Terme di Caracalla, 00100 Rome – Italy.

Since the FAO Fisheries Department does not at present have the services of an expert on marine algae, this meeting of the XIth International Seaweed Symposium, and representation by the International Seaweed Association which sponsored it, presents an opportunity for FAO to obtain expert guidance on these matters, and to allow an optimal plan of action to be developed to rectify the above deficiencies in available publications. It is hoped that both the Symposium and the Association will assist in coordination of responses to these above proposals, as well as suggesting priorities for action in view of the limited funds available.

Official statistics

Improvements to quantitative information on marine algal harvests extends also to the FAO Year Book of Fisheries Statistics, which reports landings of seaweed resources by member governments of FAO. As seen from Tables 1 to 3, these landings are as present only broken down into Phaeophycae; Chlorophycae and Rhodophycae, and preliminary figures for world total landingsrecorded in 1981 (metric tons, wet weight) were 2.183×10^6 t, 4.483×10^3 and 0.799×10^6 t, respectively. These seem to be significant underestimates if harvests of drift weed were to be included. Problems of accurate reporting stem to some extent from financial constraints within national statistical services in many countries, but also reflects the limited access most seaweed experts have to the national departments of Agriculture and Fisheries which make annual reports on fish catches. This neglect of the potential and actual importance of these resources is incidentally shared with many other tidal and sublittoral marine resources, principally shellfish where hand gathering by coastal populations is not always recorded. Despite the key roles all of these organisms play in coastal artisanal economies and diet, they are largely underreported for reasons stemming largely from the small-scale local nature of production units, and better information on the size of seaweed harvest could perhaps be provided through inputs to the national office concerned.

Hand-gathering of intertidal and subtidal orga-

Table 1. Brown seaweeds*

Species	Fishing area	1978 MT	1979 MT	1980 MT	1981 MT
Brown seaweeds		Phaeophyceae 7,71 SWB			
France	27	32 716	27 672	33 506	26 866
Iceland	27	12 270	15 840	9 900	8 100
Norway	27	121 221	110 000	126 813	148 365
Spain	27	23	738	681	396
USSR	27	-	2 799	3 709	2 218
UK Scotland	27	96 964	98 583	60 690	9 500
Area total	27	263 194	255 632	235 299	195 445
Argentina	41	1 626	329	449	449F
Area total	41	1 626	329	449	449F
South Africa	47	25 737	13 815	10 576	1 907
Area total	47	25 737	13 815	10 576	1 907
Australia	57	1 080F	1 080F	1 080F	1 080F
Area total	57	1 080F	1 080F	1 080F	1 080F
China	61	1 508 472	1 440 822	1 517 442	1 317 108
Japan	61	245 679	272 756	292 669	261 664
Korea Rep	61	184 919	177 680	225 595	335 537
USSR	61	-	800	462	810
Area total	61	1 939 070	1 892 058	2 036 168	1 915 119
USA	67	200	200	-	-
Area total	67	200	200	-	-
Mexico	77	30 049	34 151	24 289	20 401
USA	77	160 000	160 000	162 351	48 703
Area total	77	190 049	194 151	186 640	69 104
Item total	S	2 420 956F	2 357 265F	2 470 212F	2 183 104F
Group total	S	2 420 956F	2 357 265F	2 470 212F	2 183 104F

See paragraph 5 of the Introduction and paragraph 8 of the Notes on species items.
* F = Preliminary Figures.

nisms, plant and animal, and for plants, the collection of driftline material for industrial processing and for agriculture, can have considerable local importance in the diet and livelihood of coastal communities. By its nature this artisanal fishing information is more difficult to assess than for industrial fisheries, even though these forms of resource are the first to make the transition to intensive methods of mariculture, and as such should be the subject of more close scrutiny in the process of promoting fisheries development.

Table 2. Red seaweeds*

Species	Fishing area	1978 MT	1979 MT	1980 MT	1981 MT
Red seaweeds		Rhodophyceae 7,81 SWR			
Canada	21	25 474	25 506	19 318	24 440
USA	21	551	404	458	-
Area total	21	26 025	25 910	19 776	24 440
France	27	2 008	1 921	2 787	1 820
Portugal	27	18 352	18 704	13 181	14 810
Spain	27	6 745	5 988	5 972	4 463
USSR	27	-	186	229	225
Area total	27	27 105	26 799	22 169	21 318
Morocco	34	5 005F	5 005F	5 005F	5 005F
Area total	34	5 005F	5 005F	5 005F	5 005F
Argentina	41	21 530	14 974	14 283	14 283F
Uruguay	41	76	37	-	-
Area total	41	21 606	15 011	14 283	14 283F
South africa	47	170	568	663	641
Area total	47	170	568	663	641
Madagascar	51	0	0	0	0
Tanzania	51	110	0	0	0
Area total	51	110	0	0	0
Indonesia	57	138	197	490	306
Thailand	57	8	45	70	71
Area total	57	146	242	580	377
China	61	84 270	66 300	72 120	20 290
Japan	61	361 845	336 863	367 533	349 498
Korea Rep	61	34 677	55 412	66 221	88 100
USSR	61	-	1 780	2 000	2 190
Other Nei A	61	12 304F	11 563F	10 109F	10 100F
Area total	61	493 096F	469 918F	517 983F	520 178F
USA	67	-	0	-	-
Area total	67	-	0	-	-
Indonesia	71	5 483	5 748	7 358	6 093
Philippines	71	85 824	106 107	115 652	26 261

Table 2. (Continued).

Species	Fishing area	1978 MT	1979 MT	1980 MT	1981 MT
Thailand	71	1 219	2 087	848	794
Area total	71	92 598	113 942	121 858	93 148
Mexico	77	6 490	13 888	10 276	9 170
USA	77	10	20	–	–
Area total	77	6 500	13 908	10 276	9 170
New Zealand	81	0	0	0	12
Area total	81	0	0	0	12
Chile	87	30 000	65 000	74 523	109 631
Peru	87	326	286	361	323
Area total	87	30 326	65 286	74 884	109 954
Item total	S	702 687F	736 589F	798 457F	789 526F
Group total	S	702 687F	736 589F	789 457F	798 526F

See paragraph 5 of the Introduction and paragraph 8 of the Notes on species items.
* F = Preliminary Figures.

Table 3. Green seaweeds*

Species	Fishing area	1978 MT	1979 MT	1980 MT	1981 MT
Green seaweeds		Chlorophyceae 7,01 SWG			
Mexico	02	200	-	133	-
Area total	02	200	-	133	-
Japan	04	495	706	663	363
Area total	04	495	706	663	363
Argentina	41	5	2	2	2F
Area total	41	5	2	2	2F
Korea Rep	61	2 107	2 687	8 301	4 111
Area total	61	2 107	2 687	8 301	4 111
Fiji	71	7	8	13	7
Area total	71	7	8	13	7
Item total	S	2 814	3 403	9 112	4 483F
Group total	S	2 814	3 403	9 112	4 483F

See paragraph 5 of the Introduction and paragraph 8 of the Notes on species items.
* F = Preliminary Figure.

Conclusions

This short and rather general communication attempts to present a very broad perspective in trying to identify appropriate directions for further quantitative work needed on the part of algologists and fisheries workers in support of scientific management and understanding of marine macroalgal resources and the important fisheries systems associated with them. One concrete result of this review might be the synthesis of those facts most relevant to commercial harvesting of seaweed resources in the form of one or more FAO manuals or technical reports. This would be of great use to managers, and others concerned with investigations on the marine plants resource. This new reference and training material should expand on the Technical paper by Michanek (1975), not only to include record estimates of resources, but to cover questions of harvest, culture methodology, methods of resource assessment and management of stocks, and some of those interdisciplinary aspects of marine macroalgae touched upon in this report which are of importance to other marine fisheries and the coordinated management of all renewable resources in a given area. Such initiatives should ideally be implemented following coordinated input of advice to FAO from the International Seaweed Association.

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APPENDIX 1: Seaweeds of the world

Some Proposals for concerted international action that should lead to better coordination of ongoing activities in seaweed resources research and management.

1. Preparation of a worldwide annotated and illustrated seaweed catalogue including all species of present or potential interest to man

This would comprise the following:

1.1 Introductory section

- General information on seaweed resources
- Illustrated glossary of technical terms
- Illustrated key to families and genera (possibly even to species) used by man

1.2 Species section, including for each species:

- Valid scientific name and synonyms still in use
- Alpha-numerical code (FAO S.I.S. system)
- International (FAO) colloquial species names
- Local names where available
- Diagnostic key characters illustrated by sketches and figures
- Geographical distribution with a map showing the range of the species
- Size
- Habitat and ecology (depth range, salinity tolerances, biological parameters relevant to fisheries management, etc.)
- Interest to fisheries – notes on annual yield, type of harvesting, utilization, etc.
- Most relevant literature

1.3 Geographical section

A listing of species by major marine fishing areas, which will allow the user easy retrieval of information by area

1.4 Literature list

1.5 Composite index of scientific and vernacular names used in the publication

This document should follow the established FAO format (samples attached) and be published as an FAO Species Catalogue.

It could be prepared by a single author, or by a team of experts; in the latter case, one of these should be the coordinator.

The author, or the coordinator, should work in close collaboration with the editor of FAO Species Catalogues, who will assist him with technical editing, art-work, vernacular species nomenclature, coding preparation of the geographical section and the index of names. The document would be typed on a wordprocessor to facilitate future up-dating. A short sejour of the author or coordinator at FAO, Rome would be desirable in an advanced phase of the work.

2. Species synopses on seaweeds

The seaweed synopses published so far are the following:

- FIRM/S37 *Ascophyllum nodosum* by *E.* Baardseth, 1968
- FIRM/S39 (Provisional Version) *Monostroma latissimum* by T. Segi & W. Kida, 1968
- FIRM/S83 *Saccorhiza polyschides* by T. A. Norton, 1970
- FIRM/S38 (Rev. 1) *Ascophyllum nodosum* by E. Baardseth, 1970
- FIRM/S87 *Laminaria hyperborea* by J. M. Kain, 1971
- FIRM/S89 *Laminaria digitata* by P. Gayral & J. Cossou, 1973

Seaweed experts should be encouraged to prepare new or revised synopsis for those species on which more or less comprehensive (but scattered) information is available. They should contact the FAO editor of the series to enquire about format and timing of publications. American authors should be made aware of the possibility to have their 'FAO Species Synopsis' published by NMFS.

3. Species identification sheets for fishery purposes

These publications have a strictly regional character and they are prepared by major marine fishing areas. They are designed as field guides for identification of species and should serve, at the same time, as coded and illustrated regional species inventories. So far, seaweeds have not been included in any publication of this series, but supplementary sheets to the existing series might be prepared (Mediterranean/Black Sea (Fishing Area 37), Eastern Indian Ocean/Western Central Pacific (Fishing Area 57/71), Western Central Atlantic (Fishing Area 31), Eastern Central Atlantic (Fishing Area 34/47 in part) and Western Indian Ocean (Fishing Area 51, currently in press)). Furthermore, seaweeds should be included in the forthcoming FAO set of Species Identification Sheets for the Southern Ocean, currently in preparation.

4. Storage, handling and diffusion of data and information on seaweeds

There is obviously a need for coordinated international action in this field. The proposed FAO Species Catalogue 'Seaweeds of the World' might be used as the basis for establishing – possibly at FAO HQ – a computerized seaweed species data base. The primary file of such a system would comprise the codes and valid scientific names of all species included in the catalogue, thus representing the basic nomenclatorial authority on which secondary subject files would be based.

The data base should then be enriched through continued collaboration with the seaweed experts who have generated the basic information as well as through a feedback of information from users of the various system outputs, in particular the catalogue and the species identification sheets. This should eventually lead to the development of a worldwide seaweed data and information service for the benefit of all those concerned with research management, processing technology and marketing of these resources.