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Limiting factors in optimizing seaweed yield in Chile

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Abstract

A number of factors influenced yield from natural beds of marine algae in Chile. These factors are related not only to biological and ecological knowledge of the algal resource, but also to external events, such as; (1) the pressure of international markets for raw material, (2) unemployment level of coastal workers, which increases the number of seasonal harvesters, (3) the low level of regulation enforcement along Chile's extensive coast, (4) the low level of education and income of algal harvesters, and (5) except for *Gracilaria*, the lack of a management plan for algal resources.

Introduction

In Chile, marine algae are exported as raw material, used locally in iridean and carrageenan industries, and consumed as food. Their importance as renewable resource has markedly increased over the last 20 years as has their export volumes, be it as raw material or refined products which have become generators of foreign currency (Santelices, 1983, 1989; Lopehandía, 1986).

Gracilaria has been economically and sociologically the most important of the Chilean algal resource over the last twenty years (Santelices & Ugarte, 1987; Santelices & Doty, 1989). During the sixties *Gracilaria* crops were mainly harvested from natural beds in Coquimbo, Concepción and Puerto Montt (Fig. 1). As these beds became overexploited, demand was absorbed by beds in southern Chile (Valdivia and Puerto Montt, Fig. 1) which now are providing almost 70% of the Chilean *Gracilaria* (Servicio Nacional de Pesca, 1991).

About 5000 t of dry *Iridaea ciliata* Kutzing and *Iridaea laminarioides* Bory are exported annually from Chile for carrageenan extraction (Santelices & Norambuena, 1987). Intertidal and subtidal beds of *Iridaea* and *Gigartina* are commonly harvested from Coquimbo to Puerto Montt (Fig. 1). However, some *Gigartina* species have been included under the item *Iridaea* due to the problems of recognition by harvesters.

Among the brown seaweeds the intertidal *Lessonia nigrescens* Bory and the subtidal *L. trabeculata* Villouta & Santelices are regularly exported from Chile as raw material for alginate production (Vásquez & Santelices, 1990). Most of the harvest is one in northern Chile, between Antofagasta and Valparaíso (Fig. 1), generally restricted to plants cast ashore (Vásquez & Santelices, 1990).

Other economically important Chilean seaweed

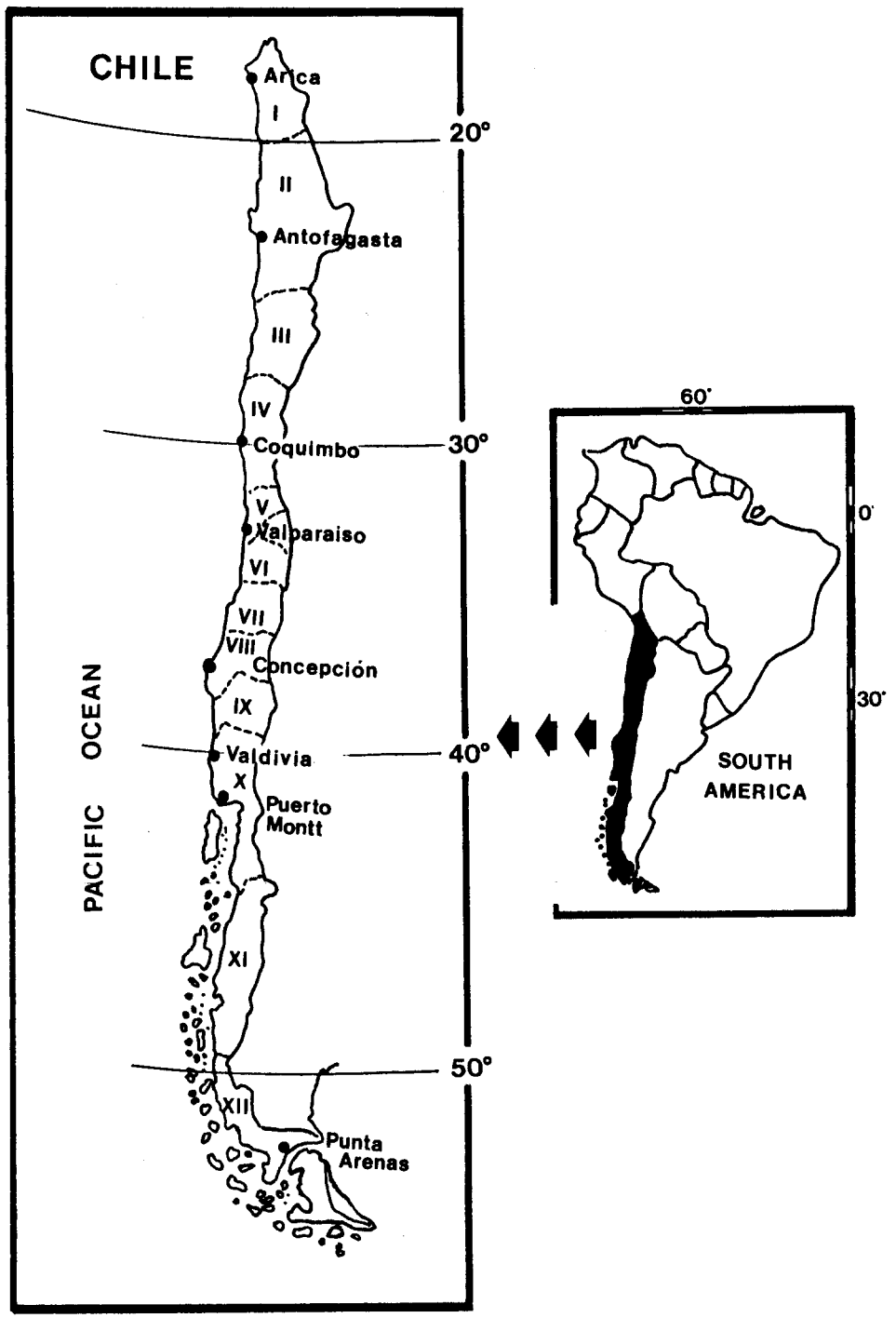

Fig. 1. Map of Chile. Roman numbers (I–XII) indicate the twelve Regions of Chile.

species are: *Macrocystis* spp, *Durvillaea antarctica* (Chamisso) Hariot, *Gymnogongrus furcellatus* (C. Agardh) J. Agardh, *Gelidium* spp, *Porphyra columbina* Montagne. Nevertheless, the harvests of these algal species has been temporally irregular and the crop volume not comparable with above mentionated species.

A number of factors influence the yield of the natural beds of marine algae in Chile. These factors are related not only to biological knowledge of the algal resource but also to external factors such as international demand, socioeconomic status of harvesters, and the role of state institutions in the management and use of algal resources. In this work we analyze, the effect of such factors on the sustained development of natural algal beds in Chile.

Economic factor

The annual landing statistics for benthic algae in Chile increased from some hundreds of tons at the beginning of the sixties, to approximately 35 thousand tons by the middle eighties (Lopehandía, 1986; Santelices & Ugarte, 1987; Santelices, 1989). Similarly, the foreign currency generated increased from under one million dollars to nearly 22 million $ US. This is due both to the sustained increase in harvests of a given species like *Gracilaria* (Westermeier, 1986; Santelices & Ugarte, 1987; Santelices, 1989) and to the increase in the number of species harvested (Santelices, 1983, 1989; Lopehandía, 1986).

The increased demand for some algal species was caused by a sustained rise in international price; by the end of the seventies, a ton of *Gracilaria* had a value of approximately US $ 200; by 1987 its price fluctuated between US $ 1400 and $ 1500. This marked increase in price in the international markets coincided with overexploitation of the *Gracilaria* beds along the Chilean coast (Santelices, 1989).

When considering an algal species as an economically valuable resource, it must be realized that there will be a relationship between price, resource abundance and potential harvesting effort. Species of high economic value will be harvested even at low abundance levels. However, species of low economic value will only be harvested when their biomass and/or densities are high over a wide area. The latter is the situation for the most of the economically important Chilean seaweed, because the international price for phycocolloids is not high (except for *Gracilaria* at the end of 80s), neither is the price for species used locally for food. An undocumented example, is the collapse of a single natural *Chondrus* bed in the intertidal/subtidal area of Puerto Aldea, in the North of Chile. The international demand for carrageenans caused an increase in harvest pressure during the early 1980s, which in only three months destroyed this resource of approximately 60 hectares. In the past 10 years there is little sign of recovery. Similarly, in northern Chile during 1981 and 1982 the international demand for *Lessonia* doubled the harvested over former years. For *Iridaea* and *Gigartina*, however, the foreign demand has not been intensive enough to cause overexploitation of natural beds. The production of *Eucheuma* species on the coasts of the Philippines and Indonesia, and *Chondrus* in Canada seem sufficient to meet world demand for carrageenans (Santelices, 1989).

Although level of international demand is a prime factor in overexploitation of natural beds, national enterprises have strongly influenced harvest levels of commercially important algal species throughout Chile. In this context, factors such as drying and storing capacity and transportation have been important in the seasonal variation of the exploitation of natural beds in northern, central and southern Chile. Often, benign drying condition, high storing capacity together with low international demand, have decreased the extraction pressure over natural algal beds along the Chilean coast.

Social factor

Together with their growing economic importance, seaweed harvests have also become an important social factor. An estimated 9000 to 11 000

fishermen depend on algae for part or all of their income. These fishermen may belong to cooperatives or work independently. Some collect algae permanently along the beach, this being their only source of income. Some others harvest algae only occasionally or seasonally, at the time periods when they are more abundant. This group includes family members of permanent collectors and unemployed workers looking for additional or subsistence income. In this way, over the last 15 years, a number of macroalgal genetic reserves (Santelices *et al.*, 1984; Westermeier, 1986) have virtually disappeared owing to factors outside the production system. The largest genetic reserve of *Gracilaria* in the North of Chile, in the Bay of La Herradura, at the beginning of the 1980s was destroyed by overexploitation generated by members of the unemployed coastal populations (Santelices *et al.*, 1984; Santelices, 1989). During that period, there were up to 30 to 40 divers, each collecting about 300 kg a day.

Unemployed farm workers, miners, construction workers and other groups of seasonal workers contribute significantly to the algal harvest workforce. The activity of these collectors often does greater harm to the stocks than that of permanent collectors. These itinerant collectors possess no basic harvest training nor do they have an awareness of the need for conservation.

An important factor in maintaining a sustainable biomass through time, is no doubt the educational level of the harvesters. There are no current studies available on the sociocultural characteristics of this sector of the Chilean society, however we do know that, at best, their level of schooling does not go beyond elementary school. It is necessary to study the social, economic and cultural characteristics of these groups in order to develop educational programs for seaweed management and culture.

In 1991, the Chilean Ministry of Work and Social Security implemented a programme of occupational training, directed at people of low income. Specifically these coordinated the programme, 'Training and Development of Technical Education', which had the main objective of generating opportunities for economic and social integration for the chronically unemployed, particularly for young people. This program has already trained a number of artisanal fishers in the management of natural and artificial *Gracilaria* beds, through seeding and harvesting activities, in the north and south of the country. Eventually these training courses will be extended to other algal resources.

Generally, the Chilean artisanal fishermen exploit a single resource. This has been a negative factor when trying to manage these resource as a function of restricting the catch for prolonged periods. In this way, an important factor to be considered is the technical training, which may allow the artisanal fisherman to diversify his harvest. A diversified harvest minimizes exploitation pressure over a single resource and generates alternative fisheries in times of closed season.

Management factor

In conceptual terms, algal resource management has only been rarely documented and the extant cases are not adaptable to the Chilean situation. The commercial exploitation of *Macrocystis* beds in California (McPeak & Barilotti, in press) and of subtidal *Chondrus crispus* beds in the Canadian Atlantic coast (Pringle & Sharp, 1980; Pringle & Mathieson, 1986) have relied on a number of scientific and stock assessment studies allowing for conservative harvesting practices. However, considering our socio-economic level and the Chilean idiosyncrasy, few conceptual contributions have been applicable to our seaweed resources. It must be added that the technological and/or socioeconomic background where such studies have been developed is far from being comparable to that of Chile. For instance, the harvesting systems used in the northern hemisphere include several levels of automation while harvesting and drying procedures on our coast are preferentially manual and artisanal (Santelices, 1989). In North America, the state regulates and controls resource harvest, but in our country it has not always been possible to implement the minimal rules for regulating algal resources.

As well, a great number of economically important Chilean algal species are either endemic to South-America, or are species with subantarctic affinities. Hence, although it is possible for us to adopt part of the management and culture technologies developed in other countries for similar species, it is quite clear that the basic biological knowledge for the management of such species must be achieved through local research.

In a few algal species, recent scientific contributions allowed the initiation of culture practices as an alternative mechanism to the management of natural beds. It is worth noting that the limit between management and culture is not always clear. The less sophisticated culture methods are just a step beyond the fishing of wild crops and consist of maintaining the alga in the culture area without precise spatial limits and under similar conditions prevailing in areas where the species grows naturally. In more complex methods, culture is carried out in defined spaces and under conditions that artificially reproduce the more determinant ecological factors for algal productivity (Santelices, 1989).

There are at least three governmental bodies with jurisdiction on algal resources. The Subsecretaría de Pesca (Fisheries Undersecretariat), depends on the Ministry of Economy, Development and Reconstruction, which deals with the administration of renewable marine resources. The Subsecretaría de Marina (Navy Undersecretariat), which depends on the Ministry of Defense, regulates the granting and control of areas for culture, recreation and management; and the National Fisheries Service within the Fisheries Undersecretariat, is in charge of the supervision and control of regulations issued by technical bodies related to laws on renewable marine resources. Besides the above, each of Chile's twelve Regions (Fig. 1) have local agencies, which in turn, have jurisdiction over nearshore renewable resources. This suite of agencies has produced a 'paradoxical situation in Chile, where good resource sciences wants for sound resource management plans' (Pringle & Sharp, 1990).

The current legislation of Fisheries and Aquaculture (in force since 1991) states that for each marine species declared under full exploitation, recovery or incipient development, there must be a State Fisheries Undersecretariat sponsored management plan approved by the corresponding Zonal Fishery Council. The management plan of each fishery shall include at least the following aspects: (a) geographic distribution of the species; (b) biological fishing data on the species and its exploitation strategy; (c) preservation measures and access regimes; (d) data on the catch, production and marketing of the products, and (e) research requirements for conservation and management.

The most deficient level of management is the one dealing with the supervision and control of the regulations issued by the technical-legislative bodies. Given the great extent of the Chilean coast (*ca* 5000 km in Continental Chile), this aspect hinders and usually prevents the implementation of proposed management plans. Beside the inadequate legal regulations, and the inefficiency of the state control, lack of cooperation among harvesters has contributed to the lack of reasonable and effective management of Chile's naturally occurring beds.

Biological factor

Over the last few years many bio-ecological studies have been conducted on Chile's economically important algae. This has resulted in a body of knowledge that allows us to formulate some recommendations for the management and harvesting of eight algal groups: *Lessonia* (Santelices, 1982; Vasquez & Santelices, 1990), *Macrocystis* (Santelices & Oieda, 1984 a, b; Westermeier & Möller, 1990), *Durvillea* (Santelices *et al.*, 1980), *Porphyra* (Santelices & Avila, 1986), *Gelidium* (Santelices *et al.*, 1981; Montalva & Santelices, 1981), *Gracilaria* (Santelices *et al.*, 1984; Poblete, 1986; Westermeier *et al.*, 1988 a, b; Westermeier *et al.*, 1991), *Iridaea* and *Gymnogongrus* (Santelices & Norambuena, 1987; Westermeier *et al.*, 1987; Gómez & Westermeier, 1991). Notwithstanding this basic biological information, the exploitation pressures upon natural beds have been

too great, or the management measures (except for some *Gracilaria* beds in the south of Chile) have either arrived too late or have not been practical.

Frequently, commercially important algae are locally the most abundant and hence harvestable and are the most ecologically important. These algae are not only the basis of the benthic trophic chain, but they constitute to the areas of larval/juvenile recruitment or refuges for invertebrates and fishes (Santelices *et al.*, 1980; Santelices & Ojeda, 1984 c; Cancino & Santelices, 1984; Villouta & Santelices, 1984; Vásquez & Santelices, 1984, 1990). They also act as modifiers of the environment for other algal species. Furthermore, these algae, and invertebrates and fishes may be of commercial importance. Thus, their exploitation plan must be based on scientific and technical knowledge, which even if it does not preserve the whole system, will permit the prediction of main changes and consequences derived from such exploitation. In spite of ecological studies relating to a few algal species of economic importance (Santelices, 1989; Vásquez & Santelices, 1990) there is scarce information which permits prediction of the ecological consequences of massive harvesting of benthic macroalgae.

Furthermore, despite the great social and economic importance of Chilean algae, few scientific evaluations and regulations have contributed to a sustained production (Vásquez, 1991). This is true for most of the algal resources, except for *Gracilaria* for which there is solid biological information. Over the last few years, it has been possible to manage local populations of these species using massive culture techniques. Nevertheless the information is still deficient for understanding the behavior of *Gracilaria* populations over the long term.

For example, despite the importance of the recurring 'El Niño' phenomenon, we lack studies showing the actual consequences of this oceanographic event on subtidal populations of economically important algal species in the north of Chile. In this context, it is urgent to conduct evaluations monitoring pre and post events in order to estimate biomass fluctuations, and minimize (through management and re-population) the effects of this catastrophic oceanographic phenomenon.

A crucial point for a successful seaweed industry, over the longterm, is research in the field of biology (Pringle & Sharp, 1990). Traditionally, scientific research has been conducted in Chile by the universities and by a few state organizations. Over the last years, few private companies have developing biological expertise for *Gracilaria* in order to maximize the harvestable biomass of artificial beds. In this sense, the ownership rights granted through concessions for aquaculture have been crucial, since they allow planned management activities, seeding under optimal conditions, and adequate harvesting times in given areas of the Chilean shore.

Conclusions

The diversity of the issues considered in this work indicate that the production of the natural algal beds along Chile is influenced by multiple events involving not only biological but also legal, economic, cultural and social factors. These have been included among the six essential requirements for a longterm successful seaweed industry elsewhere (see Pringle & Sharp, 1990).

Besides the necessary body of biological and ecological information on the different benthic macroalgae of commercial interest, the following should be considered in order to maintain a sustained economic harvest:

(1) The pressure of international markets for raw material, which maximizes the harvest pressure on the wild benthic macroalgal stocks;

(2) Unemployment levels of non-fisher coastal workers, which increases the number of occasional macroalgae harvesters, and introduces an uncontrollable perturbation. Such occasional collectors ignore or are not interested in the preservation of in the implementation of management plans;

(3) The low level of supervision and control, even when adequate regulations are available, together with Chile's extensive coast, markedly affects the possibilities of sustained maintenance of the natural macroalgal beds;

(4) The low level of education and income of algal harvesters prevents an improvement in the care and management of algal resources. The prevailing rationale of the coastal artisanal fishermen seems to be 'do not leave for tomorrow what you can collect today' or 'tomorrow is another day'. It is essential to improve the social and educational level of artisanal fishers. Any management measure tending to preserve the natural beds requires an awareness of conservation, and;

(5) Except for *Gracilaria*, there is no management plan for algal resources. Concessions for *Gracilaria* culture have introduced the concept of ownership, which has motivated the care and management of this resource. Unfortunately, there are no other algal resources in a similar situation.

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