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Ecological studies for harvesting and culturing *Gymnogongrus furcellatus* (Rhodophyta, Gigartinales) in Central Chile

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Abstract

Every year, several hundred tonnes of dry *Gymnogongrus furcellatus* are exported from Chile for carrageenan production. The present study provides ecological information for rational harvesting practices, including an understanding of the effects of environmental factors on growth. Field results indicate that the species is abundant in areas where disturbing factors do not destroy the crustose base of the plants, which can survive sand burial, but is grazing sensitive. In central Chile the erect axes have a clear seasonal pattern of growth which, as extrapolated from laboratory experiments, is most affected by seasonal changes in quantum dosage and photoperiod. Laboratory experiments show that vitamins and CO_2 additions also influence growth rates significantly. Field data indicate that harvesting in central Chile should be done bi-monthly, within the six most productive months of the year and be stopped before March, when the female gametophytes become fertile. Hand picking is the least destructive harvesting method. Even though the daily growth rate of the species could be raised to 7% in laboratory experiments, tank cultivation appears uneconomical. The cost of some of the factors required for the growth of this species, such as daily vitamin additions, aeration and CO_2 supplements, are unlikely to be recovered by the 25% average carrageenan content of this species. In addition, the high light requirements of the species would restrict culture to only 6 months a year at these latitudes. Therefore adequate management of the beds is required for sustained production.

Introduction

In central Chile, *Gymnogongrus furcellatus* (C. Agardh) J. Agardh is collected from wild crops and exported as raw material for carrageenan production. The amounts collected vary annually, depending on market demand, and are difficult to estimate because dry *G. furcellatus* is exported (Sernap, 1982) either under the trade name of "liguen gomoso" or mixed with other carrageno-phytes.

G. furcellatus occurs in South America, New Zealand, Tasmania and Southern Australia (Levring, 1941, 1960). Along the temperate coast of Pacific South America, it has been collected (Howe, 1914; Levring, 1960; Dawson *et al.*, 1964) in several localities between northern Peru (6 °S) and southern Chile (52 °S). In the Atlantic, it has been found also in the Falkland Islands.

In spite of its widespread geographic distribution and economic importance, we have only fragmentary information on its biology. In central

Chile, this species occurs in low intertidal-shallow subtidal levels and it seems to be particularly abundant in areas exposed to periodic sand invasion. Experimental removal of grazers led to significant increments in abundance in some low intertidal habitats (Moreno & Jaramillo, 1983). Life- history studies (Candia & Kim, 1977; J.L. McLachlan pers. comm.) have revealed that the erect, cylindrical axes arising from basal holdfasts correspond to the gametophytic phase of the species. The sporophyte is an independent, crustose phase. Chemical studies (Stancioff & Stanley, 1969; Lawson *et al.*, 1973; Penman & Rees, 1973) indicate that the fronds of the gametophytic phase yielded 20–25% of its dry weight in iota carrageenan. The sporophytic phase produces lambda carrageenan, but it is not collected for commercial purposes due to its crustose morphology and reduced stock per unit area.

Few of the above data allow for an understanding of the effects of environmental factors on the growth of this species in the commercial beds of central Chile and still fewer can be used to outline harvesting practices of the species in the field. Most studies of species of *Gymnogongrus* at other latitudes have focused on taxonomic or life-history problems and apparently only Markham & Newroth (1971) have considered ecological aspects of species of *Gymnogongrus*, including *G. linearis*, a species adapted to survive sand invasion. Likewise, only Mathieson *et al.* (1984) and Whyte *et al.* (1984) have reported on seasonal variation in carrageenan yield.

This study was designed to gather basic biological information on *G. furcellatus* in order to formulate an optimal harvesting strategy for the species in central Chile as a first step in managing this native resource. We studied temporal variation in standing stock, reproductive patterns and gel content of intertidal populations in central Chile and experimentally measured regeneration and recruitment capacities under various harvesting regimes. Simultaneously, we tested single and interactive effects of 11 selected abiotic factors on growth under laboratory conditions. These experiments were designed to understand space-time patterns of production and obtain a preliminary evaluation of the feasibility of tank cultivation as an alternative means of production.

Materials and methods

The species: In central Chile, *Gymnogongrus furcellatus* has a triphasic, heteromorphic life history (Candia & Kim, 1977; Lewis *et al.*, in verb.). Gametophytes are erect, filiform, terete or slightly flattened, dichotomously branched axes, 20–25 cm high, issued from expanded holdfasts. In female gametophytes, hemispherical cystocarps are borne on the medial and terminal portions of the thalli, which after fertilization give rise to carposporophytic stages. In central Chile the species is perennial and, using tags, erect axes have been followed in the field for almost 3 years.

The study site

Field studies were done at Matanza (33 °S, 71 °W), a sandy beach with abundant granitic rocky outcropings. In the most wave-exposed rocky habitats (Fig. 1), *G. furcellatus* covers 10–30% of the rocky surface. The kelp, *Lessonia*

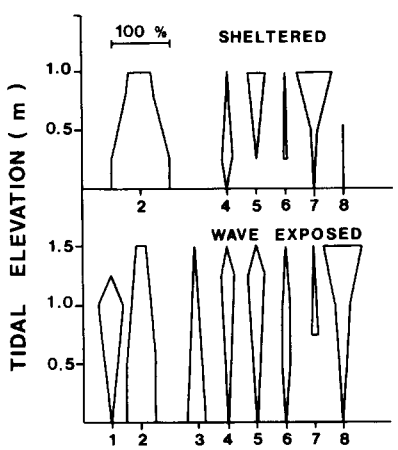

Fig. 1. Patterns of species distribution in the low and middle intertidal levels of sheltered and wave exposed habitats of Matanza. Numbers indicate the following species: 1. *Lessonia nigrescens*, 2. *Gymnogongrus furcellatus*, 3. *Durvillaea antarctica*, 4. *Leptophytum* sp., 5. *Gelidium lingulatum*, 6. *Iridaea membranacea*, 7. *Ulva* sp., 8. *Ceramium* sp.. Scale refers to cover values.

nigrescens Bory and the bull-kelp *Durvillaea antarctica* (Chamisso) Hariot, are the dominants at low intertidal levels here. In sheltered places, *G. furcellatus* covers 50 to 90% of the rocky surface and extends from 0.20 below to 1.00 m above mean low water levels and often has epiphytic loads of *Ulva* and *Ceramium*.

Commercial gathering of the species is limited normally to sheltered habitats, where there is a larger standing crop and easy access to the beds.

Field studies

Field studies were done at the sheltered habitats of Matanza, at tidal levels (0.5 to 1.2 m above mean low water level) not affected by sand invasion. Seasonal variation in standing crop was determined with monthly samples (July 1986–September 1987), using five 900-cm^2 square quadrats placed haphazardly within the *G. furcellatus* belt. The minimum number of quadrats required was determined by the running mean technique (Kershaw, 1964). All the erect axes within the quadrats were removed using a spatula. The samples were then transported in numbered plastic bags to the laboratory for analysis.

To evaluate seasonal variation in productivity and the effects of different harvesting methods on regeneration capacity, twenty 900-cm^2 permanent quadrats were marked haphazardly in a *G. furcellatus* bed located 30–50 m north of the place where the biomass samples were being removed. The following three harvest methods were tested:

(a) *Hand plucking*: The thalli were pulled off by hand, imitating the way the alga is harvested by seaweed collectors. The method removes some of the erect axes but leaves in place the shortest erect axes.
(b) *Scissor cutting*: Thalli were cut with scissors 2 to 3 cm above the base of the stipe. Using this method, the apical ends of large and small thalli are removed.
(c) *Spatula scraping*: Complete plants, including erect thalli and the holdfasts were removed with a spatula. The first times, the rock surface was burned with a blowtorch, to ensure that no crusts were left on the quadrats. Regeneration had to take place through vegetative growth from the borders or through spore settlement. Burning was not repeated in subsequent months.

Each treatment was repeated in five permanent quadrats that were considered as replicates; another five quadrats that were marked but not harvested were used as controls. Algal cover was measured before and after harvesting, using a 900-cm^2 quadrat with 100 intersecting points. Each experimental quadrat was harvested every two months, from July 1986 through September 1987. The collected material was carried to the laboratory in labelled plastic bags.

In the laboratory the samples were washed in seawater and cleaned to eliminate sand and large epibionts. Fronds were then sorted by reproductive stages and wet and dry weights determined. The dry material was used for gel analysis.

Gel analysis

Carrageenan content was determined, in oven-dried thalli (60 °C), following the procedures described by Craigie & Leigh (1978) and expressed as yield (% dry weight). Viscosity was determined with a Brookfield Viscosimeter run at 30 r.p.m. with a No 2 spindle. Five 2.50-g carrageenan samples were dispersed in 170 ml distilled water, whereby a 1.5% concentration was obtained, and heated to 75 °C, when viscosity was measured.

Effects of environmental factors on growth

In the laboratory, freshly collected thalli were cleaned, wet weighed and inoculated in glass dishes (Pyrex 3250) containing SWM-3 (McLachlan, 1973) culture medium. The dishes were incubated in environmental cabinets (Forma Scientific, model 24) for 15 days under controlled conditions of photon flux density (50 μmol m^{-2} s^{-1}), temperature (15 °C) and photoperiod

(12 : $\overline{12}$). These cultures were used in the various experiments (Table 1).

The experimental temperature was 15 °C except when the effects of temperature (10, 15 and 20 °C) were studied. Incident illumination inside the growth chambers was provided by Cool-White, 40-W fluorescent tubes with a maximum of 200 μmol m^{-2} s^{-1} of photosynthetic active radiation (Li-Cor 190 S sensor). Removal of fluorescent tubes allowed decrements of incident radiation. A light : dark cycle (LD) of 12 : $\overline{12}$ h was used in all experiments, except when daylength effects (8 : $\overline{16}$; 12 : $\overline{12}$ and 16 : $\overline{8}$) were tested.

The culture medium was SWM-3 changed every 3 or 6 days. Some of the experiments included (Table 1) SWM-3 medium lacking addition of trace metals or vitamins or with varying concentrations of NaH_2PO_4 (0, 10, 20, 40 μM) and $NaNO_3$ (0, 2, 5, 10, 15 mM).

The effects of water movement were studied using rotary shakers (Lab Line) adapted to receive eight dishes (Pyrex 3250). The experimental thalli were attached to glass rods specially designed to prevent the thalli floating during the experiments. The shakers were set to rotate the dishes at 50, 100 and 150 r.p.m.

Air was provided continuously during the 12 h of light by means of oil-free compressors (Schulz) and pressure was adjusted to keep the seawater constantly moving.

Variations in the pH of the culture medium were used to determine frequency and duration of CO_2 additions. The pH was allowed to range from 7.0 to 8.5. Whenever the pH rose above this, CO_2 was injected to the cultures. CO_2 additions were stopped when the pH fell to 7.0.

The effects of sand burial were evaluated with laboratory experiments, using two 40 × 30 × 30 cm glass tanks filled with filtered seawater (0.45 μm, Sartorius). Three bundles of sterile fronds and three bundles of cystocarpic fronds, of 0.5 g fresh weight each, were placed in each tank and covered with 5 cm sterilized fine sand. One of the tanks was provided with continuous aeration. Fronds were examined at weekly intervals during four weeks to check for signs of growth (new branches, apical elongation) or decay (necrotic areas, fragmentation). Fresh weight of the bundles was also determined.

In all, the effects of 11 single factors and the interacting effects of 4-factor combinations were tested on growth rates (Table 1). The experimental work was designed to determine which combination of factors would increase significantly the growth rates. All the experiments lasted 30 days and were performed between May 1986 and December 1987. Relative growth rate was defined as increment in wet weight per unit of time and was calculated using a compound interest program. Depending on the experiment, results were subjected either to simple or factorial analysis of variance after arcsine transformation. *A posteriori* tests (LSD and Tuckey; Sokal & Rohlf, 1981) were used whenever necessary.

Results

Seasonal biomass

The standing crop of the low intertidal beds of *Gymnogongrus furcellatus* varied little during the 15-month sampling (Fig. 2). However, there was a slight increase in wet weight at the end of the summer and beginning of autumn. On a dry weight basis, the standing crop of this bed remains most of the year at 1.5–1.7 kg m^{-2}.

This population showed a clear seasonal variation in the proportions of cystocarpic and male/vegetative female fronds (Fig. 3). During fall and winter, the proportions of both types of fronds was around 50%, whereas from the end of winter (August) to mid-summer (February) the representation of fertile cystocarpic fronds decreased markedly. By the end of the summer the proportion of cystocarpic plants had increased rapidly to 70%, decreasing thereafter and remaining at about 40% during winter.

Regeneration capacity and productivity

Regeneration capacity and productivity varied according to the method used to harvest the

Table 1. Summary of experiments and experimental conditions used.

Variable factors	Levels	Constant factors						
		T °C	Quantum dose	LD cycle	Air bubbling	Culture medium	Vitamins addition	Frequency of change of medium
Single factor experiments								
1. Temperature (°C)	10. 15, 20	–	50	12 : 12	No	SWM-3	No	6 days
2. Quantum dose (μmol m^{-2} s^{-1})	10–15, 25–50, 85–100	15	–	12 : 12	No	SWM-3	No	6 days
3. LD cycle (h)	8 : 16, 12 : 12, 16 : 8	15	100	–	No	SWM-3	No	6 days
4. Vitamins addition	Yes No	15	200	12 : 12	Yes	SWM-3	daily	3 days
5. Trace metals	Yes No	15	50	12 : 12	Yes	SWM-3	No	6 days
6. CO_2 added	Yes No	15	150	12 : 12	Yes	SWM-3	every 3 days	3 days
Two factors experiments								
7. Water movement (rpm)/ medium change (days)	0, 50, 100, 150 3, 6	15	50	12 : 12	No	SWM-3	No	–
8. Nitrate (mM)/ Phosphate (μM)	0, 2, 5, 10, 15 0, 10, 20, 40	15	50	12 : 12	No	SWM-3	No	6 days
9. Vitamins/ air bubling	Yes No Yes No	15	50	12 : 12	–	SWM-3	–	6 days
10. Quantum dose/ medium change	100, 200 3, 6	15	–	12 : 12	Yes	SWM-3	daily	–
11. Sand burial/ seration	vegetative thalli cystocarpic thalli Yes No	10	–	–	–	sea water	No	6 days

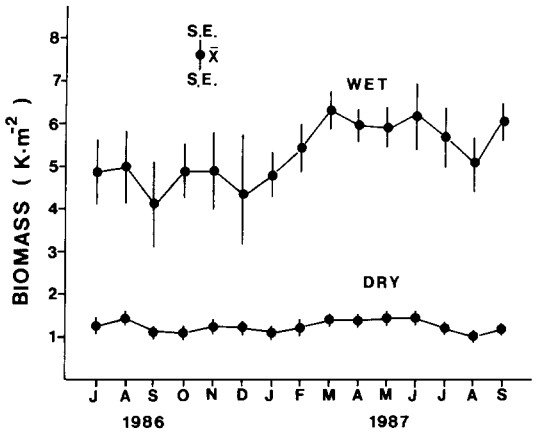

Fig. 2. Temporal changes in standing stock values of *Gymnogongrus furcellatus* in the low intertidal habitats of Matanza, central Chile.

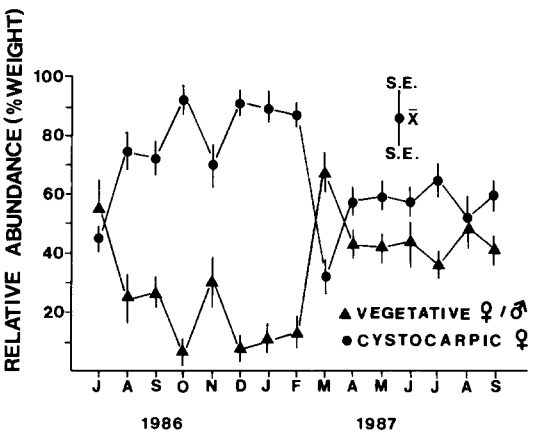

Fig. 3. Relative abundance of biomass fertile cystocarpic and vegetative gametophyte in the population of *G. furcellatus* from Matanza.

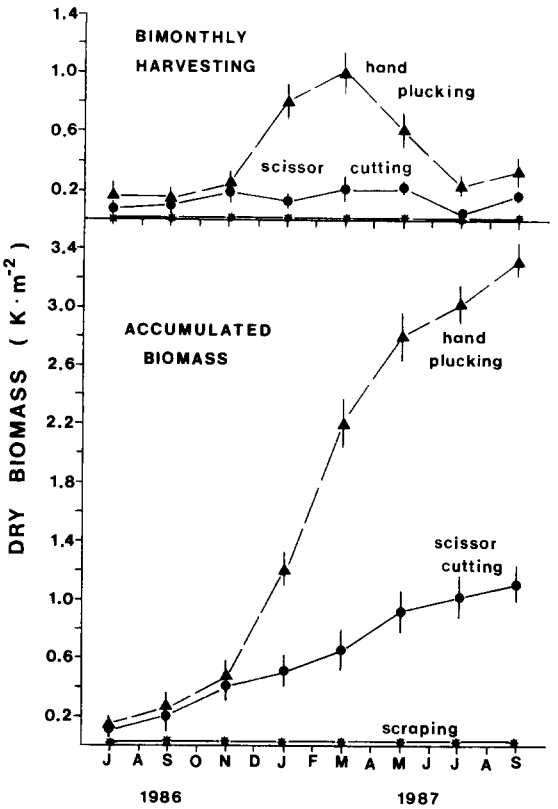

Fig. 4. Regeneration capacity and productivity of *G. furcellatus* under 3 experimental harvesting techniques.

species (Fig. 4). Hand plucking proved to be the most productive harvesting method and the only one under which the species exhibited a markedly seasonal regeneration response. Between late winter and late spring, productivity was 1.5 to 2.0 g m^{-2} day^{-1} (dry weight). By November, productivity began to increase, reaching a maximum of 17 g m^{-2} day^{-1} during late summer (March), and gradually decreasing thereafter.

Cutting with scissors yields less than 30% of the production obtained with hand plucking (Fig. 4). Scissor-cut experimental plots showed a productivity value of 1–2 g m^{-2} day^{-1} during most of the year with no seasonal increase in production during spring and summer.

When whole algae, including crustose base, were removed with a spatula, no plants grew in the quadrats, from the borders or through spore settlement or recruitment. However, by the end of the experiment (July–September 1987) juveniles of *G. furcellatus* covered 8–10% of the rocky surface. During the 15-month experimental period, a diversity of other species settled on the cleared plots, the most permanent of which was *Iridaea membranacea* J. Agardh.

Cumulative annual day production of the species (Fig. 4) was 3–3.2 kg m^{-2} when harvested by hand and 0.9–1.1 kg m^{-2} with scissors. When the fronds were removed from the base, no production accumulated during the first year.

Harvesting of fronds modified the proportions of cystocarpic/male-vegetative female plants (Fig. 5). Hand plucking as well as scissor cutting

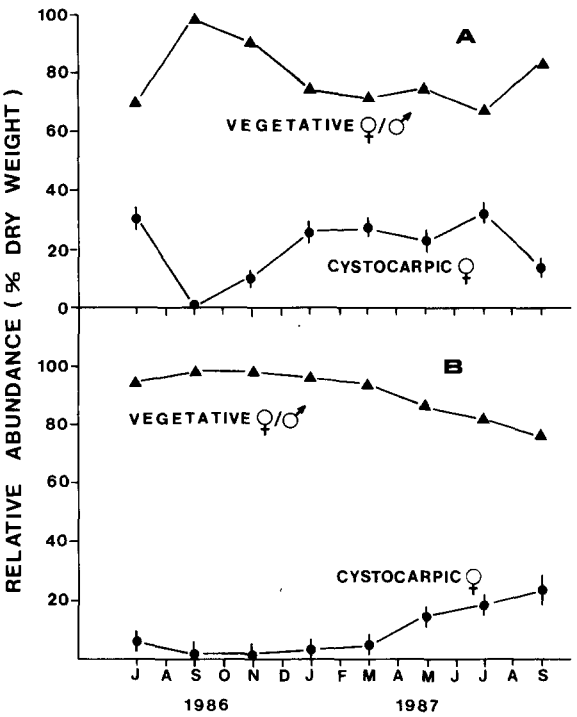

Fig. 5. Relative abundance of cystocarpic and vegetative gametophytes in the populations subjected to experimental harvesting techniques. A. Hand Plucking, B. Plants cut with scissors.

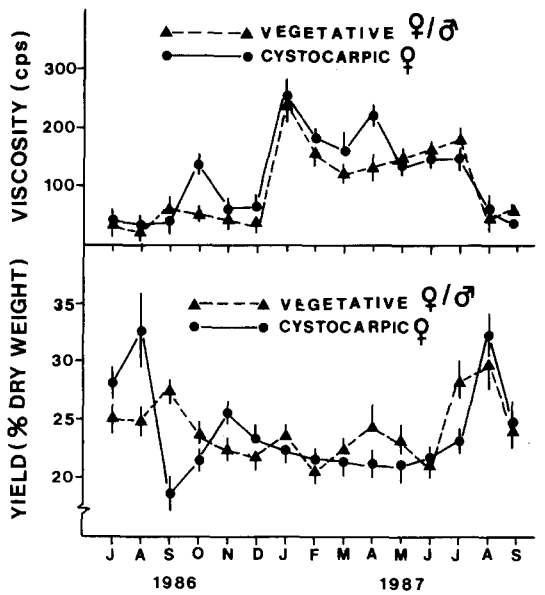

Fig. 6. Temporal variations in yield and viscosity of carrageenan from the low intertidal stands of *G. furcellatus*.

produced a decrease in the percentage of cystocarpic plants compared to the proportions found in natural populations, and the reduction was greater in the quadrats harvested with scissors. It should be noted, however, that the seasonal increase in the proportion of cystocarpic fronds in the hand-harvested quadrats began almost two months earlier than in the natural populations and almost four months earlier than in the scissor-harvested quadrats.

Gel content and viscosity

Carrageenan content of cystocarpic and vegetative fronds was similar. Yields fluctuated between 20% and 25% of the dry weight during most of the year, except August when the gel content increased to 30%, again without significant differences between cystocarpic and vegetative gametophytes (Fig. 6).

Gel viscosity ranged between 20 and 60 cps from autumn through spring, 1986. It increased to a maximum value of 240 cps in January 1987 and remained high (120 to 200 cps) until July 1987, to return to low values (30–40 cps) in later winter. Gel from cystocarpic plants showed significantly higher viscosity values than male or vegetative plants, from February to April 1987. No clear difference was evident during the rest of the study period.

Effects of environmental factors on growth

The growth effects of several environmental factors are illustrated in Figure 7. Increasing photon-flux densities and photoperiods significantly stimulated the relative growth rate of the fronds (Figs. 7A & 7B). Growth under 16 h of daily light was significantly higher than under 8 h. However, the growth rate under long days (16 h) was not significantly different than from 12 h of daily light.

Growth rates were maximal (Fig. 7C) at 10 °C, and tended to decrease at higher temperatures, although differences were rather small. Different degrees of water motion provided by the rotary

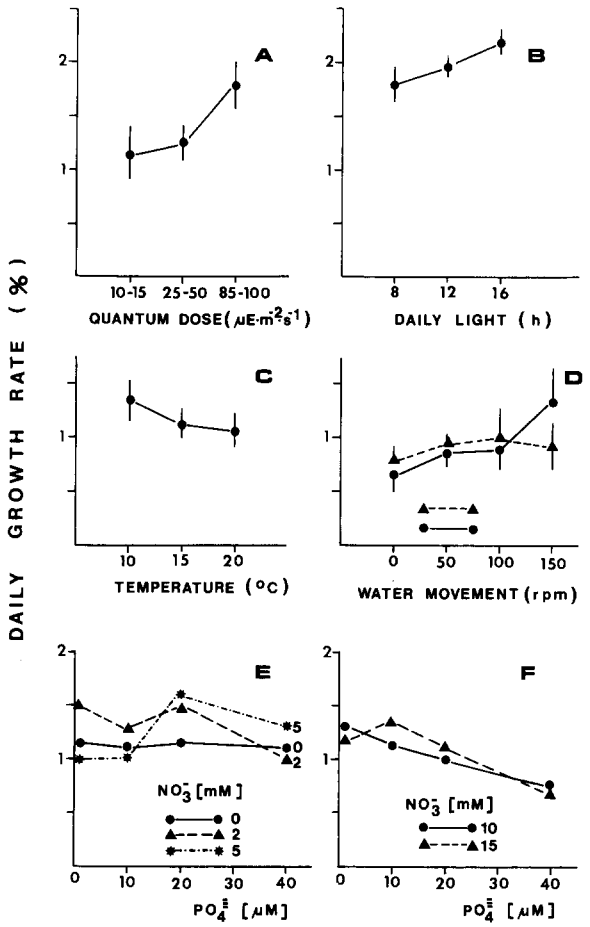

Fig. 7. Daily growth rate of *G. furcellatus* as a function of quantum dose, photoperiod, temperature, water movement and concentrations of phosphate and nitrate.

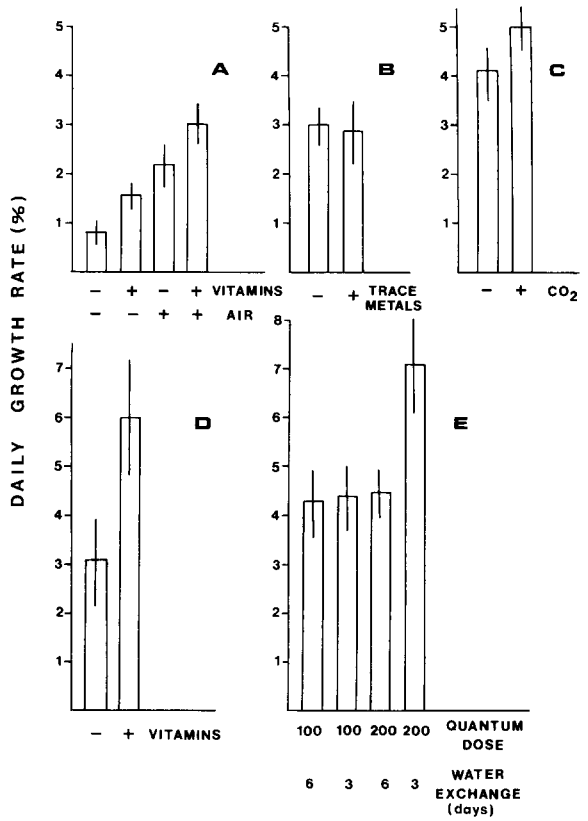

Fig. 8. Daily growth rates of *G. furcellatus* as a function of vitamins, aeration, water exchange and quantum dosage.

shakers and the two frequencies of exchange of the culture medium did not significantly influence the growth rate of this species (Fig. 7D).

Additions of nitrate and phosphate did not affect growth rates although some trends are clear (Figs. 7E and 7F). The more rapid growth rates (1.3% daily) were attained with 2–5 mM NO_3 and 20 μM PO_4. This is interesting as these are the respective concentrations of these elements in the SWM-3 medium. Higher concentrations of NO_3 and PO_4 tended to inhibit growth.

Aeration of the culture medium increased the growth rates significantly from 0.8% to 2.2% daily (Fig. 8A), and the addition of vitamins stimulated growth up to 3% per day. The addition of trace metals did not stimulate growth (Fig. 8B). CO_2 injections to the cultures increased growth rates (Fig. 8C), but differences between the treatment and the control were not statistically significant. Probably the air bubbling provided the control dishes with good levels of CO_2. Indeed, the pH differences between the treatment and the control dishes never ammounted to more than 1.8 pH units within a single day.

As a fast vitamin consumption was suspected during growth, vitamins were added daily to the culture medium. Results (Fig. 8D) indicate that the daily additions significantly increase the growth rate of this species, suggesting a rapid consumtion by the seaweed.

Having found that photon flux densities and vitamins could substantially control growth rates, an additional experiment was done to evaluate effects of water exchange on growth under higher photon flux densities (experiment 10 in Table 1). Results (Fig. 8E) confirmed some of the previous

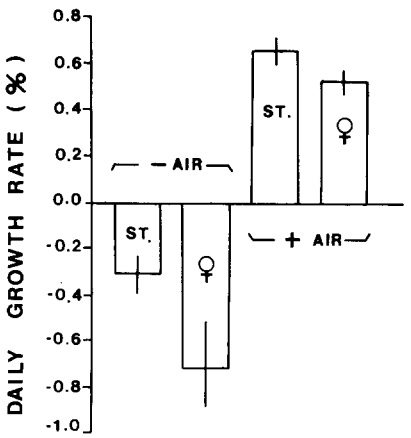

Fig. 9. Daily growth rates of sand-buried *G. furcellatus* plants as a function of seration.

results. If light were maintained at 100 μmol $m^{-2} s^{-1}$, differences in frequency of culture medium renewal did not affect the growth rate. Additionally, increased irradiance did not increase the growth rate when the medium was exchanged every six days. The maximum growth rate (7.1%) was obtained by combining a photon-flux density of 200 μmol $m^{-2} s^{-1}$ with a frequency of culture medium renewal every 3 days. In these experiments growth rates of 7.1% could be maintained only when vitamins were added daily and the plants were periodically prunned (every 6 days), removing the biomass produced by growth.

The effects of sand burial varied (Fig. 9) with presence or absence of aeration. Plants buried for 30 days with no aeration showed signs of necrosis and frond fragmentation and exhibited weight losses of 0.3% to 0.7% daily. Vegetative and cystocarpic fronds with aeration grew, in the same period, at a rate of 0.5% to 0.6% daily.

Discussion

The combination of results obtained permits an initial ecological characterization of *Gymnogongrus furcellatus*. The species is abundant in habitats where disturbing factors do not destroy the crustose base. The species can survive periodic sand burial, actively growing when uncovered and showing a seasonal pattern of production. Growth rates are most influenced by photon flux densities and vitamins.

Experimental data indicate that the crustose base of the plant regenerates slowly after damage as plants were unable to invade experimentally scraped quadrats. In addition, the growth of the erect, cylindrical axes depends entirely on the apical meristem. Therefore the species can be severely affected by factors, such as grazing, that consume either the growing tips or the crustose base. These findings explain previous results (Moreno & Jaramillo, 1983) describing significant increments in the abundance of *G. furcellatus* following grazer removal.

As described for *G. linearis* from the Pacific coast of North America (Markham & Newroth, 1971), *G. furcellatus* can survive sand burial for several months. Field observations indicate that the crustose base is the most resistant part of the plant, often regenerating new erect axes after being uncovered by sand. Similarly, the South American taxon has reduced growth during winter, when the individuals in the lower intertidal levels are invaded by sand. Growth in both species starts increasing in spring and becomes very fast in summer. The daily growth rates shown by *G. furcellatus* between January and March can be as high as 12–15% daily.

Uncalcified crustose morphologies in the seaweeds have been regarded as anti-herbivore adaptations (Lubchenco & Cubit, 1980; Slocum, 1980; Dethier, 1981). However, they also survive sand scouring, burial and wave shearing (Littler & Littler, 1983) or have the capacity to act as overwintering stages under harsh photoperiodic or temperature conditions (Lüning, 1980). Field observations at our study site indicate very high invertebrate mortalities (including grazers) in these low intertidal habitats at the times of sand invasion. Therefore, the abundance of *G. furcellatus* in these places seems determined, among other factors, not only by its capacity to survive sand burial, but also by the significant reduction in grazer numbers due to sand invasion. This supports the view that crustose morphologies can

represent adaptations to survive sand burial. In addition, they show that sand burial and herbivory result in contrasting, morphologically similar but functionally different adaptations, as the crust of *G. furcellatus* is sand-resistant while grazing-sensitive.

In the low intertidal stands at Matanza, *G. furcellatus* did not show significant fluctuations in standing stock. This suggests that, once established, few factors modified the population densities during the study period. Yet, the productivity of the species was clearly seasonal, being maximal in summer and much reduced during winter. Results from our laboratory studies point to light intensity as the seasonally changing factor most influencing this seasonal growth. Our laboratory experiments indicate also that in addition vitamins and aeration could influence significantly the growth of the species in culture. Several vitamins are present in the seawater in various amounts and have been found to influence differentiation and growth of several species of Chlorophyta and Rhodophyta (Provasoli & Carlucci, 1974). Likewise the growth of several Phaeophyta can be stimulated especially by vitamin B_{12} (De Boer, 1981). Our experimental data, however, point to a very rapid consumption of these growth factors by *G. furcellatus*. We ignore the possible seasonal fluctuation in vitamin content of the coastal waters in central Chile and can not conclude if these growth factors influence the very clear seasonal production pattern of the species in the field. However, given the growth rates reached by *G. furcellatus* in summer we must conclude these are not limiting factors then. Perhaps the organic decomposition following the increased mortality of invertebrates and seaweeds produced by the periodic sand invasions locally increases the bacterial populations and, by consequence, the vitamin content of seawater in these sheltered habitats.

In our cultures, aeration probably enhanced breakdown of diffusion barriers as well as supplying the cultures with CO_2. This last factor is perhaps proportionally more important as enhancement of diffusion produced by the movement of rotary shakers or different frequencies of culture medium exchange did not influence markedly the growth of the species. Supplemental carbon has been found to enhance growth of several different species in culture (DeBusk & Ryther, 1984; Bidwell & McLachlan, 1985). Elevated CO_2 concentrations are necessary to prevent the plants from suffering carbon malnutrition, a condition which, according to Bidwell & McLachlan (1985), is difficult to recognize because it has no obvious symptoms, except slow growth.

The results from the field experimental work suggest that in order to preserve the beds of *G. furcellatus* in central Chile several procedures should be observed. Harvest should not be extended for periods longer than the six months of active growth. In any event, harvesting should not be extended beyond March (late summer) to avoid cutting or damaging the cystocarpic thalli. In this species the season of maximal productivity coincides with the period of highest viscosity of the gel. In addition, plants should be harvested by hand only, which should leave some intact growing apices. Other harvesting methods retard regeneration and growth. Harvesting by means of spatula scraping should be avoided because, as our experiments showed, regeneration from the borders or recruitment through spore settlement is extremely slow. Furthermore, when the crustose base is removed, other species such as *Iridaea membranacea* are able to invade the vacated space. This is likely to delay the recovery by *G. furcellatus*.

The daily growth rate of *G. furcellatus* could be maintained at 7% under laboratory conditions. Even though we did not scale up these experiments to pilot-tank cultivation, several findings suggest such artificial cultivation of this species would not be economical. The pronounced effect of light flux and photoperiod on growth suggest no more than 6 months of effective production in central Chile, and provisions of aeration, CO_2 and vitamins represent expensive costs unlikely to be recovered by the 25% carrageenan yield produced by the species. Adequate management of the wild beds appears as a more realistic alternative to produce the resource.

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