Tissue Nitrogen- and Phosphorus-Content of *Gracilaria coronopifolia* J. Agardh from Iligan Bay in Relation to the Seawater Nutrient Concentration

PATRIA ROSALES-APAO
WINFRID SCHRAMM

Abstract

Tissue nitrogen- and phosphorus-content of ***Gracilaria coronopifolia*** *J. Agardh were analysed from samples collected in Iligan Bay (Initao, Misamis Oriental, Northern Mindanao, Philippines) over a 20-month period.*

The samples were oven-dried (24 h at 70 °C) and ground to fine powder for nitrogen analysis employing a Carlo Erba C/H/N Elemental Analyser. Tissue phosphorus content was measured photometrically as phosphate following digestion in a concentrated HCl of combusted materials (5 h at 550 °C).

Tissue nitrogen-and phosphorus-content (0.7 to 2.76 % g dw and 0.03 to 0.26 % g dw, respectively) varied throughout the collecting period without showing distinct seasonal trends.

The results may show that nutrient acquisition and primary productivity of seaweeds are not solely a function of the external nutrient concentration, but are influenced by time dependent processes such as nutrient accumulation and internal nutrient levels, adaptation and physiological state of the seaweeds.

Introduction

At present much of the Philippine seaweed production for export and processing for phycocolloid are derived from the cultivation of *Eucheuma,* the leading economically important seaweed. However, other genera are identified of importance for their chemical constituents and potential for culture such as *Gracilaria* (Trono & Ganzon-Fortes, 1981, 1988; Legasto, 1988).

Although. technology for pond culture of *Gracilaria* is available from Taiwan (Shang 1976, Yang & Wang 1983), this has not been widely practised in the Philippines (e.g. Hurtado-Ponce, 1990). Thus much of the seaweeds utilized for production are derived from the natural stock from the wild.

PATRIA ROSALES-APAO, the senior author is connected with the Department of Biological Sciences, MSU-Iligan Institute of Technology. WINFRID SCHRAMM is with the Institute of Marine Sciences, Kiel, Germany.

Despite continuous commercial utilization and increasing demand for phycocolloid, in the Philippines little basic information is available on the role of environmental conditions, as for example nutrient availability, which affect productivity and chemical quality of *Gracilaria.*

Among the environmental factors affecting algal growth and productivity, nutrients play an important role (e.g. Ryther & Dunstan 1971, 1981, Rosenberg *et al.*, 1984). This may apply especially in the tropics where the nutrients in offshore waters are said to be low, therefore limiting phytoplankton production (DeBoer 1981, Smith & Atkinson, 1984; Dawes, 1987).

It has been demonstrated that seaweeds in temperate waters take up nutrients proportional to the seawater concentrations as documented by seasonal changes in internal tissue nitrogen- and phosphorus- content of seaweeds (Chapman & Craigie, 1977, Hanisak 1979, Asare & Harlin 1983, Kornfeldt 1982, Asare & Harlin, 1983).

In the Philippines, no studies had been done on the internal nutrient concentration in relation to the external nutrient concentration, therefore this study. In addition to characterization of the internal nutrient concentration, the productivity of the macrophyte is described..

This paper provides background data on nutrient condition in the natural habitat and on variation of internal nitrogen- and phosphorus-content of *Gracilaria coronopifolia* J. Agardh from Iligan Bay. In addition the importance of internal nitrogen and phosphorus to the productivity of the species is discussed.

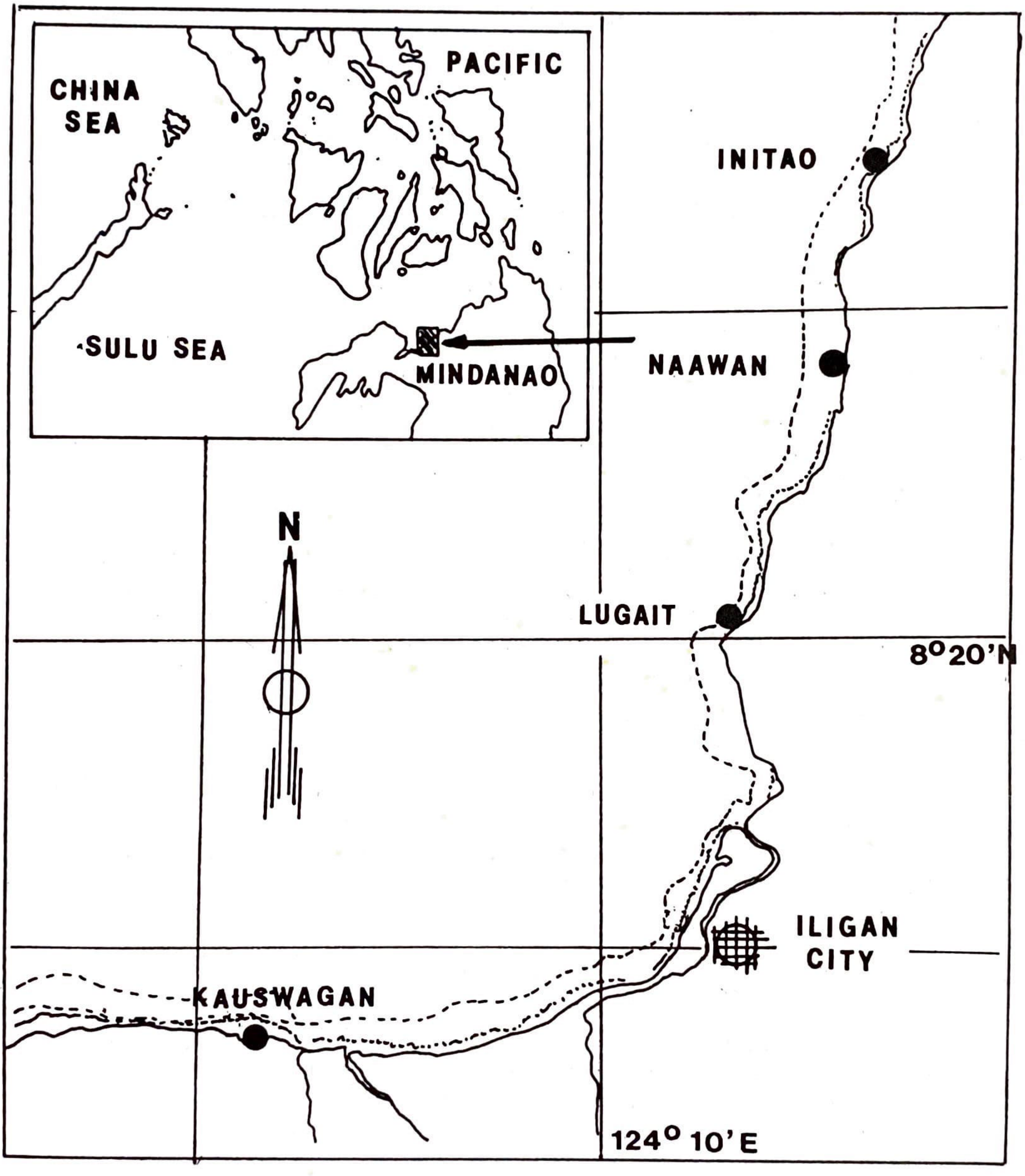
Materials and Methods

The algae were collected from the wild at about 2 m in Initao, Misamis Oriental, Northern Mindanao, Philippines (Figure. 1) during a 20-month period from April 1987 to November 1988.

Samples from different individuals were combined and after removal of other attached algae and debris, weighed, oven-dried (24 h at 65 - 70^0 Centigrade) and finally ground to fine powder with a mortar and pestle. The ground material were kept in polypropylene vials in dessicator until further analysis.

Tissue nitrogen content was measured employing a Carlo Erba C/H/N Elemental Analyzer at the Institute for Marine Sciences, Kiel, Germany. Total phosphorus in the tissue was determined as phosphate after digestion with concentrated HCl of combusted material (5 hours at 550^0 Centigrade) and subsequent dilution with distilled water (Schramm & Booth, 1981). Aliquots were taken for spectrophotometric analysis according to Grasshoff

Figure 1. Location of sampling station (Initao) in Iligan Bay, Mindanao, Philippines.



et al. (1983). Two to three replicate analyses were made from the combined samples.

In order to relate the internal nutrient content with the external source, seawater samples were collected from the same site. A 100-ml plastic syringe was used to collect bottom water or water in the algal bed. Three replicate samples were collected each time. Water samples were transferred into separate polypropylene containers and were brought in a cooling box to the laboratory for analysis within six hours. Water samples were analysed for inorganic nitrate, nitrite, ammonium, phosphate and urea following standard methods (Grasshoff *et al.* 1983). Absorbance readings were made with a double beam spectrophotometer (SHIMADZU 150).

Results

Concentrations of inorganic nitrate, nitrite, ammonium and phosphate-ion as well as urea in the seawater varied, however, did not show a seasonal trend throughout the sampling period (Figure 2,3;Table 1). Although ammonium and urea were not determined during the first 8 months of the study period, we may therefore assume that the concentrations of these nitrogen sources have been similar to those of the succeeding months.

Tissue N- and P-content of *Gracilaria coronopifolia* varied considerably, however, without showing seasonal trends during the 20-month sampling period (Figure 4, Table 2). Tissue N- content values ranged from 0.7 to 2.67 % g dry weight, with the lowest and the highest values observed in the months of March and November 1988, respectively. On average, tissue N-content was 1.35 % g dry weight. Tissue P-content, on the other hand, varied from 0.03 to 0.26 % g dry weight with the highest values observed in December.

Tissue N has a low correlation (0.389, $P>0.05$) with nitrate concentration in the water whereas tissue P-content and phosphate concentration is negatively correlated (-0.86, $P> 0.05$).

Tissue content (nitrogen and phosphorus) does not show a good correlation with nutrient concentration in the seawater in contrast to temperate algal species.

Discussion

Tropical marine waters are usually considered as poor in nutrients. Particularly in offshore areas, nitrogen as well as phosphorus are very often the limiting factors for primary production.

On the other hand, it is well known from temperate areas that nutrient conditions in the offshore pelagic systems may considerably differ from benthic systems, particularly from phytobenthic communities, where as a result of rapid regeneration of nutrients in the sediment system and through the activity of the associated epifauna and microorganisms (e.g. Nowicki & Nixon, 1985), seawater nutrient concentration in the plant canopy are significantly higher compared to the surface water.

In the Baltic Sea, for example, in *Fucus* or red-algal communities nutrient levels are mostly beyond growth saturating levels, even in early summer, when in the water column of the offshore areas nutrient concentrations usually become limiting for primary production (Schramm *et al.* 1988). Similar observations were made in subtropical *Cladophora* beds (Schramm & Booth 1981) and tropical coral reef flats or seagrass communities (Schramm,

Figure 2. Nutrient concentration (umol/l) in the algal bed in Initao, Misamis Oriental from April 1987 to November 1988 (n=3).

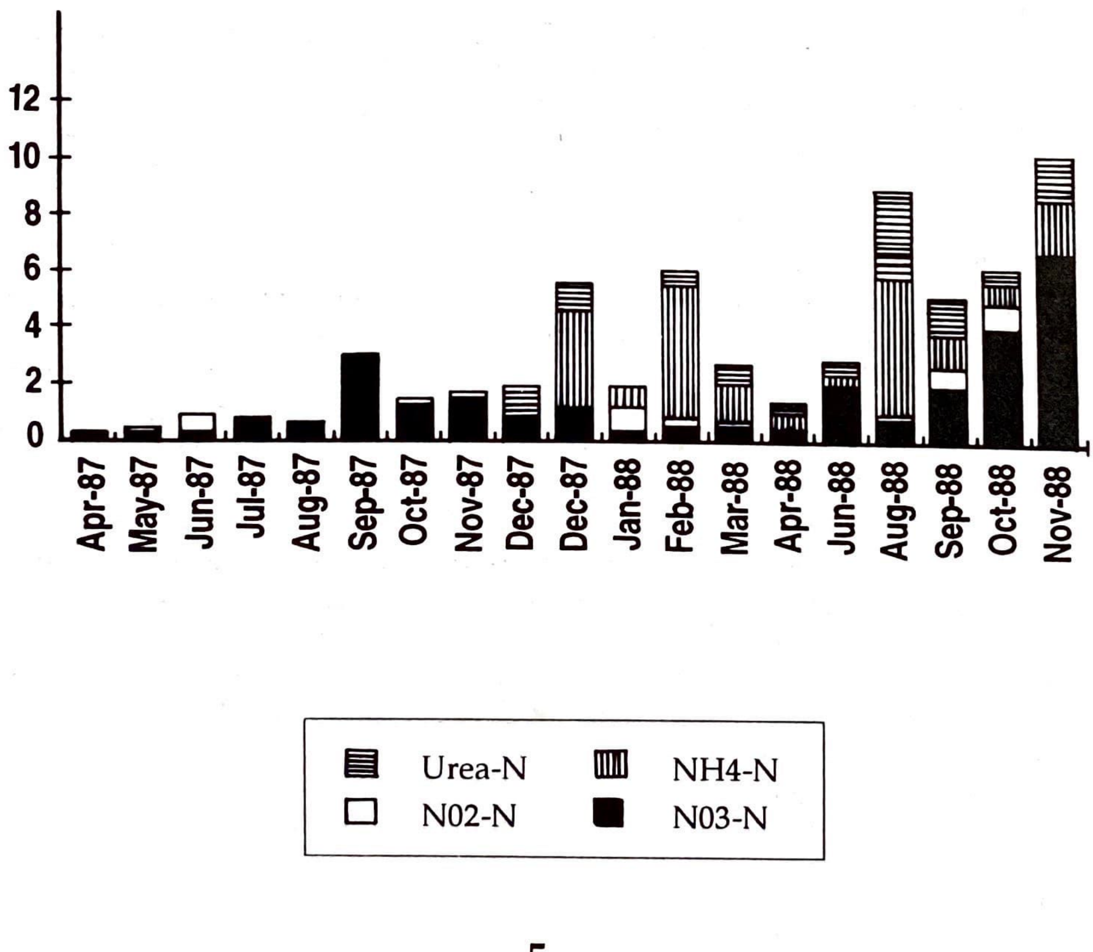
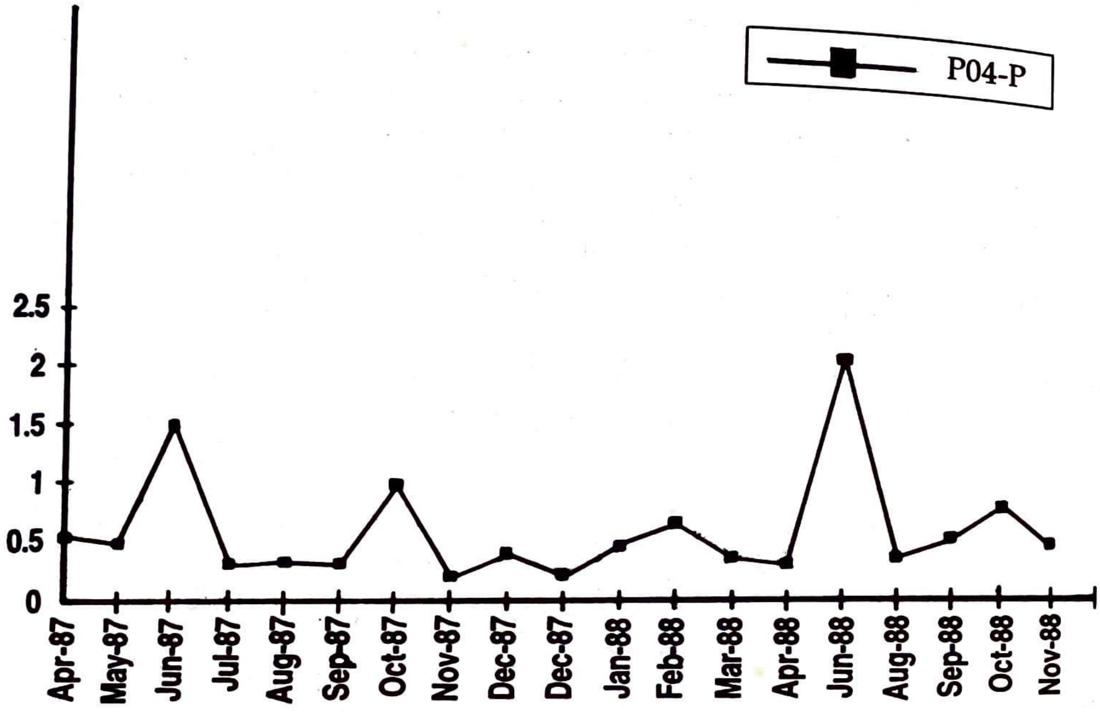


Figure 3. Phosphate concentration (umol/l) in the algal bed in Initao, Misamis Oriental from April 1987 to November 1988 (n=3).



unpublished data).

Also in our study area at Initao, the nutrient concentrations were in the range determined in other locations in the Philippines (e.g. Horstman, 1980, Dy, 1984, Bodungen *et al.* 1985) and slightly higher than in the offshore water, although considerably lower than those known for coastal waters of higher latitudes (e.g. Wheeler & North, 1980; Asare & Harlin, 1983, Schramm *et al.*, 1988, Lyngby 1990).

Seasonal variation in nutrient concentration in the seawater in the tropics are usually small in comparison to temperate waters, where seasonality is triggered by key environmental factors such as light and temperature. The observed distinct, but irregular nutrient fluctuations in the seawater of Iligan Bay may have been influenced by wind regimes (monsoons), but also the influence of land run-off, precipitation, nutrient remineralization and seasonal changes in biological activity in the area could not be disregarded.

Tissue N - and P - content of the seaweed in the field varied throughout

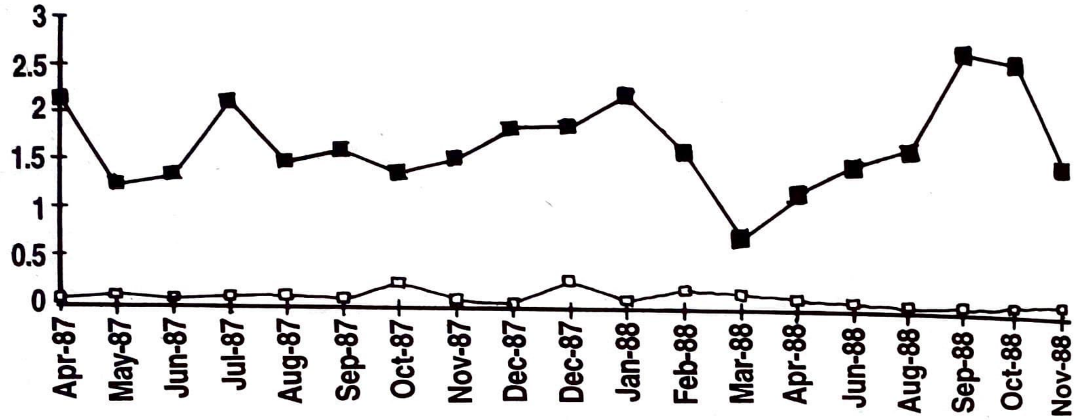
Table 1. Mean nutrient concentration (umol.dm^{-3}+/-SD; n=3) in seawater from the algal bed.

Date	NO_3-N	NO_2-	NH_4-N		Urea-N	PO_4-P	
1987							
April	0:09	0.07					0.53
May	0.08	0.20					0.47
June	0.10	0.73					1.48
July	0.61	0.03					0.30
Aug	0.34	0.15					0.31
Sept	2.77	0.17					0.3
Oct	1.11	0.22					0.96
Nov	1.36	0.17					0.18
Dec	0.60	0.09			0.20	0.87	0.38
Dec	0.89	0.07			3.68	0.84	0.20
1988							
Jan	0.18	0.94	0.61	0.07	0.46		
Feb	0.41	0.28	4.78	0.50	0.63		
Mar	0.34	0.28	1.34	0.67	0.35		
Apr	0.14	0.13	0.67	0.31	0.29		
Jun	1.84	0.06	0.35	0.54	2.05		
Aug	0.68	0.20	4.86	3.13	0.35		
Sep	1.81	0.72	1.36	1.16	0.51		
Oct	4.28	0.45	0.86	0.53	0.76		
Nov	6.56	0.17	1.84	1.51	0.46		
Total	24.19	5.13	20.55	10.13	11.0		
Mean	1.27	0.27	1.87	0.92	0.57		

the sampling period without showing any seasonal trend. This is in contrast to other observations, especially for seaweeds from temperate zones, which usually show distinct changes in the tissue N-and P-content (Topinka & Robbins, 1976; Chapman & Craigie, 1977; Hoyle, 1978; Kornfeldt, 1982; Rosell & Srivastava, 1985; Schramm *et al.* 1988).

Field and laboratory studies have shown the influence of the seawater nutrient concentrations on internal nutrient levels and the dependence of growth on both external and internal nutrient levels (Dawes *et al.* 1974; DeBoer *et al.*, 1978, Gagne & Mann, 1981; Bird, 1984). During periods of excess nutrient supply, seaweeds are very often capable of luxury or surplus uptake of nitrogen and of phosphorus (Chapman & Craigie 1977, Gordon *et al.*, 1981, Rosenberg *et al.*, 1984; Fujita, 1985; Hurd & Dring, 1990).

Figure 4. Tissue N-and P-content (% g d w) of *G. coronopifilia* from Initao, Misamis Orientnal from April 1987 to November 1988.



Ammonium-nitrogen, for example, is rapidly assimilated (Rosenberg *et al.*, 1984, Thomas & Harrison, 1987). *Gracilaria tikvahiae* was able to double tissue N - content within hours when ammonium was supplied (Ryther *et al.*, 1981).

In Iligan Bay where the nutrients are low throughout the year, nutrient availability may neither be high enough for surplus uptake, nor even for saturated uptake. The tissue N - and P - contents of *Gracilaria coronopifolia* from Iligan Bay are considerably lower compared to *Gracilaria* species from temperate waters (e.g. Wallentinus, 1981, Penniman *et al.*, 1986).

Laboratory experiments on nitrogen and phosphorus uptake by *G. coronopifolia* have shown that the critical tissue N-content for saturated growth is approximately 2 % g dry weight (Rosales-Apao, 1991). On average *G. coronopifolia* from the field were below the critical tissue N - content for saturated growth. In some cases, the tissue N-content was even in the upper range of viable tissue N - content, i.e. the tissue N-level barely enough for algal maintenance, which was determined as 0.5-1.0 % dry

Table 2. Tissue N- and P-content (% g dw) of field samples collected from Initao (Iligan Bay, Philippines) from April 1987 to November 1988. For each analysis several dried samples were powdered and analysed together.

Date	Tissue N	Tissue P
1987		
Apr	2.13	0.05
May	1.23	0.09
June	1.32	0.05
July	2.07	0.07
Aug	1.45	0.08
Sept	1.57	0.05
Oct	1.35	0.22
Nov	1.50	0.05
Dec	1.81	0.03
1988		
Jan	2.16	0.07
Feb	1.59	0.17
March	0.72	0.14
April	1.17	0.09
June	1.47	0.05
Aug	1.65	0.03
Sept	2.67	0.03
Oct	2.61	0.05
Nov	1.57	0.10
Total	31.88	1.69
Mean	1.35	0.089

weight in the laboratory (Rosales-Apao, 1991).

Similarly, tissue P- content of our plant material from the wild was below the critical tissue P for saturated growth (ca. 0.3 % dry weight P), but were higher than the minimum viable tissue P levels (< 0.01 % dry weight P) as determined in laboratory experiments (Rosales-Apao, 1991).

The results suggest that average nutrient levels in Iligan Bay are not high enough to build up internal nutrient levels sufficient for continuous optimum or saturated growth of *Gracilaria coronopifolia*. However, external concentrations are sufficient to supply nutrient above the viable level for maintenance.

The results imply that for the purpose of farming or ranching of *Gracilaria coronopifolia*, as probably also for other seaweeds, information on the ranges and average levels of nutrient is advisable if not a prerequisite for the selection of a proper site. It should also be considered whether artificial fertilizing of the seaweeds, which is common in seaweed farming, could also be applied for *Gracilaria* .

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