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C:N Ratio in Some Marine Macrophytes and Its Possible Ecological Significance

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Carbon and nitrogen levels have been determined for 24 species of intertidal benthic algae from the northwest coast of Spain, by means of an automatic C, H, N, combustion analyzer. These are presented here as a carbon to nitrogen ratio. Brown algae showed the highest mean values among the non-calcified algae. The rate of production of a given alga and its C:N ratio shows an inverse relationship. There was no evident relationship between the level at which a given alga was growing in the intertidal, and the C:N ratio. Older thallus parts showed a greater C:N ratio than did younger parts.

Introduction

The hydrographical significance of C:N ratios has been considered by a number of authors (Parsons and Strickland 1962, Provasoli 1963, Menzel and Ryther 1964, Trevaillon 1967, Flemmer and Biggs 1971, Quazim and Sankaranarayanan 1972, Banse 1974, and Fraga, in press), who have been concerned with the relationship between the levels of these elements in organisms and their recycling in aquatic habitats. Parsons *et al.* (1961) studied the organic composition of eleven planktonic algae cultured in the laboratory, and Mann (1972) has considered the C:N ratio as related to phenological observations.

Materials and Methods

Twenty-four species of benthic algae were collected from intertidal rocks in Vigo Bay, N.W. Spain (Tab. 1). All collections were made during the last week of January, and were processed for analysis on the same day as they were collected. The plants were dried at 80 °C for 3 hours, then ground manually to a homogeneous fine powder, and ultimately dried further at 100 °C. The dried and powdered samples were then introduced for combustion in a C, N, H, Perkin-Elmer 240 autoanalyzer. The accuracy of the analysis was verified by running known samples of glutamic acid and other amino acids (Fraga, in Press). The combustion temperature used was 840 °C.

Multiple samples of the most important species (sense from Whittaker 1965) from the intertidal communities sampled were studied, so that an evaluation of statistical variation could be obtained.

Results

The percentages of dry matter separated into carbon (1), nitrogen (2), and hydrogen (3) along with the C:N ratio (4) are presented in Figure 1. It will be seen that the amounts of carbon and nitrogen show a low positive correlation value (r equals 0.48). A graphic presentation of a regression analysis (according to the methods used by Fraga, in press) is shown in Figure 2. The formula derived from Figure 2 is that in the following equation:

$$(1) \quad C = 5.39 N + 12.43$$

There were significant differences found between the C:N ratio in the brown algae studied and other groups (Chlorophyta and Rhodophyta). The brown algae appear to have a lower nitrogen content than red and green algae (Fig. 1 and 2).

Discussion

Low C:N ratios are characteristic of those phases in algal growth cycles when there is a rapid increase in biomass, while higher values pertain when there is low productivity. Mann (1972) found these same trends for *Laminaria digitata* and *L. longicruris* during favorable and unfavorable growth seasons.

It seems logical to infer that the position in which an intertidal alga is growing would influence the C:N ratio because those at high intertidal sites would have thicker cell walls than those at lower less exposed levels. This seems to be the case for *Pelvetia canaliculata*, *Fucus spiralis* and *Himanthalia elongata*; however, greater C:N ratios were found in species below or near the mean tide

Tab. 1. Species collected for C, H, N analysis

Code	Species	Part of thallus used in the analysis	Number of samp.	Phenological stage in time of collection ¹	Level of collection ³
Chlorophyta:					
1	<i>Enteromorpha ramulosa</i> (Smith) Hooker	Whole thallus	2	Growth-pause	Low eulittoral
2	<i>Ulva gigantea</i> (Kütz.) Bliding	Non reproductive part	2	Active growth	Low eulittoral
3	<i>Enteromorpha compressa</i> (L.) Greville	Whole thallus	2	Active growth	Low eulittoral
Phaeophyta:					
4	<i>Pelvetia canaliculata</i> (L.) Decaisne et Thuret	Vegetative	4	Reproductive growth-pause ²	High eulittoral
5	<i>Fucus spiralis</i> L.	Vegetative	3	Reproductive growth-pause ²	Middle eulittoral
6	<i>Himanthalia elongata</i> (L.) S.F. Gray	Ribbon-shaped receptacle	2	Active growth	Low eulittoral
6'	<i>Himanthalia elongata</i> (L.) S.F. Gray	Vegetative base	2	No growing part	Low eulittoral
7	<i>Laminaria saccharina</i> Lamouroux	Lamina	1	Active growth	Low eulittoral
8	<i>Cystoseira tamariscifolia</i> (Hudson) Papenfuss	Vegetative perennial part	1	No growing perennial part	Sublittoral
9	<i>Cystoseira baccata</i> (Gmelin) Silva	Vegetative perennial part	1	No growing perennial part	Sublittoral
10	<i>Laminaria ochroleuca</i> La Pylaie	Stipe	1	Growth-pause	Sublittoral
10	<i>Laminaria ochroleuca</i> La Pylaie	Lamina	1	Growth-pause	Sublittoral
11	<i>Saccorhiza polyschides</i> (Light.) Batters	Lamina	1	Growth-pause	Low eulittoral
Rhodophyta:					
12	<i>Gelidium attenuatum</i> (Turner) Thuret	Whole vegetative thallus	1	Growth-pause	Low eulittoral
13	<i>Gigartina acicularis</i> (Wulfen) Lamouroux	Whole vegetative thallus	2	Growth-pause	Low eulittoral
14	<i>Gelidium sesquipedale</i> (Turner) Thuret	Vegetative	1	Growth-pause	Low eulittoral
15	<i>Chondrus crispus</i> (L.) Lyngbye	Vegetative	3	Beginning growth period	Low eulittoral
16	<i>Laurencia obtusa</i> (Hudson) Lamouroux	Vegetative	2	Beginning growth period	Low eulittoral
17	<i>Gymnogongrus norvergicus</i> (Gunner) J. Ag.	Vegetative	2	Beginning growth period	Low eulittoral
18	<i>Plocamium coccineum</i> (Hudson) Lyngbye	Vegetative	1	Active growth	Low eulittoral
19	<i>Calliblepharis ciliata</i> (Hudson) Kützinger	Vegetative	1	Active growth	Low eulittoral
20	<i>Gracilaria confervoides</i> (Linne) Greville	Vegetative	1	Active growth	Low eulittoral
21	<i>Laurencia pinnatifida</i> Lamouroux	Vegetative	2	Active growth	Low eulittoral
22	<i>Gastroclonium ovatum</i> (Hudson) Papenfuss	Whole vegetative	1	Active growth	Low eulittoral
23	<i>Lithophyllum tortuosum</i> (Esper) Foslie	Vegetative	1	Calcareous	Low eulittoral
24	<i>Corallina mediterranea</i> Areschoug	Vegetative	3	Calcareous	Low eulittoral

¹ Unpublished data; ² Subrahmayan 1960 and 1961; ³ Lewis 1964

level such as *Laminaria ochroleuca*, *Sacchoriza polyschides*, *Cystoseira tamariscifolia* and *Cystoseira baccata*, so that while intertidal position may influence the composition of some algae, not all algae respond in this way.

Studies on the productivity and phenology of benthic algae in Vigo Bay (Niell, unpublished) seem to be related to the analysis presented in Figure 1. All species having a winter period of dormancy such as *Enteromorpha ramulosa*, *Sacchoriza polyschides*, *Laminaria ochroleuca*, *Cystoseira baccata*, *Cystoseira tamariscifolia*, *Fucus spiralis*, *Pelvetia canaliculata*, *Gelidium sesquipedale*, *Gelidium attenuatum*, and *Gigartina acicularis* have high C:N ratios compared with algae within the same Division not having this seasonal reproductive pattern. However, other species that were growing during the winter period

as *Enteromorpha intestinalis*, *Ulva rigida*, *Laminaria saccharina*, *Himanthalia elongata*, *Chondrus crispus*, *Gymnogongrus norvergicus*, *Gracilaria confervoides*, *Plocamium coccineum*, *Gastroclonium ovatum*, *Laurencia pinnatifida* and *Laurencia obtusa* showed lower values of C:N.

The carbon to nitrogen ratio is also an indicator in senescence in various tissues on the same algal thallus of *Himanthalia elongata*. Here old vegetative bases have significantly higher ratios than young ribboned thalli bearing reproductive cells (Tab. 1). The C:N ratio in algae encrusted with calcium carbonate, such as the crustose corallines, averages higher values because of their special composition.

Fig. 1. Values of C, N and H (down) in the species codified following Table 1. On top C:N values for the same species: G.P = growth pause period; A.G. = active growth period; B.G.P = beginning growth period; R.G.P = reproductive growth pause; C.C. = crustose calcareous; h.e. = brown algae collected in high eulittoral; m.e. = the same collected in low eulittoral; l.e. = the same collected in low eulittoral; s = the same collected in subtidal.

Fig. 2. Values of C versus N expressed as percents of dry matter. Symbols are crossed in the species growing actively.

Conclusions

1. Carbon: Nitrogen ratios are distinctive in the algal groups studied, with higher values in the brown algae than those found in either the Chlorophyta or Rhodophyta.
2. The growth and reproduction of the seaweeds belonging at the same phyla coincides with variations in the carbon to nitrogen ratios. This finding is in agreement with the observations of Mann (1972), who also correlated intense growth periods with high C:N ratios. Similarly, species in a dormant, or slow-growth period had lower C:N values.
3. The older parts of the algae having persistent and not persistent thalli (Hemiphanerophytes in the sense of Feldmann 1951) present higher values than young occasional ones.

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