Coverage and Recruitment of the Edible Green Macroalga *Gayralia* sp. (Monostromataceae) in Paranaguá Bay, Southern Brazil

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**ABSTRACT**


We assessed seasonal variation in coverage and recruitment of the edible green alga *Gayralia* (*Ulvophyceae*) in Paranaguá Bay, a large subtropical estuarine system. Randomly selected rocks from Mangue Seco Beach were sampled monthly during 2002. Quadrat’s percentual coverage (1 m²) was estimated from photographs and analyzed using Adobe PhotoShop software. Frond size was measured directly in situ, aiming at recruitment data. These data were correlated to temperature, salinity and nutrients. During the sampling period, algal coverage showed no clear pattern of seasonal variation and could not be related to the environmental variables studied. Although no statistically significant variation was found, we observed lower percent cover during the summer. During the winter and early spring, there is a trend toward increased coverage and mean frond size, which is probably related to lower temperatures. The results show that the target alga is present in the bay throughout the year. Peak of recruitment occurs during the winter, which seems to be the most suitable period for net placement. Conditions in the bay favor the cultivation and management of this seaweed mariculture is a mean of coping with the fisherie's depletion stocks and the impoverishment of local inhabitants.

**ADDITIONAL INDEX WORDS:** Brazil, mariculture, Chlorophyta, seaweed

**INTRODUCTION**

Estuaries are well known to exhibit broad variation in environmental parameters, thereby reducing species diversity. Among the benthic algae, Chlorophyceae are usually dominant on estuaries in the Northern Hemisphere (MATTHEWSON and PENNMAN, 1986). However, in tropical and subtropical areas, where estuarine regions are dominated by mangrove, an association of red algae, (named "Bostrychietum") becomes the dominant algal vegetation (OLIVEIRA, 1984).

*Monostroma oxspernum* (Kützing) Doty and *Gayralia oxsperma* (Kützing) KL Vinogradova ex Scagel et al. are edible green algae that may substitute for the popular "nori" (*Porphyra* spp) in many of its culinary applications (ARASAKI and ARASAKI, 1983). *Monostroma* spp. and *Gayralia* spp. are known as "Aonori" in Japan and as "green layers" in the UK. It is used in soups, to produce "nori jam" and, when powdered, as a general seasoning (ARASAKI and ARASAKI, 1983). Annual production of Monostomataceae in Japan is 2,500 t dry wt (OHINO and TRIET, 1997), sold at US$ 20-30/kg (OHINO and LARGO, 1998).

Although this alga has been commercially grown in Japan and in some other countries (cf. OHINO and CRITCHLEY, 1998), it is not well known in tropical and subtropical areas. In Brazil, it has been identified at several points along the coast (OLIVEIRA, 1977; cf. also www.ib.usp.br/algamare-br), but little is known about its phenology. CORDEIRO-MARINO et al. (1993) and BRAGA et al. (1997) have published detailed studies on the reproduction and ontogeny of nonomostromatic green algae in Brazil, with implications for the correct identification of species. In addition, BRAGA (1997) studied recruitment on artificial substrates. However, field observation data are scarce.

This work is part of a larger project that aims to develop commercial mariculture of *Gayralia* sp. in Paranaguá Bay. There is a market for the species in oriental restaurants and shops in the states of São Paulo and Paraná. It has been harvested by fishermen and sold locally at about US$ 7/dry kg (OLIVEIRA, E., unpublished). Here we provide the first data on the phenology of *Gayralia* sp. comprising recruitment and percentage cover in a population from Paranaguá Bay.

**The Study Site**

The region known as Paranaguá Bay is located on the coast of the state of Paraná (25°16'/25°34'S and 48°17'/48°42'W). It is a complex subtropical estuarine system encompassing an area of more than 600 km². It comprises a system of large lagoons connected to the sea by three channels, the largest being the Galheta channel. The Galheta channel allows access to Paranaguá Harbor, from which more grain is exported than from any other port in South America.

The margins of the bay are lined by mangrove forests of *Laguncularia, Avicennia* and *Rhizophora*, interspersed with *Spartina* salt marshes and occasional rocky outcrops. The rainy period extends from the beginning of the spring until late summer and the driest period is from the end of autumn through the end of winter, with dominant winds from the east and southeast. The tidal system is semi-diurnal with a spring tidal range of 2.2 m. The bottom is soft and composed of a mixture of terrigenous clay, silt, sand and bioclastic materials from the mangal and salt marshes. On lower mangrove branches and pneumatophores, the algal flora is dominated by *Bostrychietum*. At the higher level and on the scattered rocky substrate, *Bostrychietium* is usually accompanied by green algae (*Enteromorpha* spp. and *Gayralia* sp.). On shallow bottoms, the latter two are also commonly found attached to pebbles or empty shells partially buried in the sediment.

**METHODS**

Coverage was assessed by non-destructive sampling based on photographs taken from six rocks randomly selected from the Mangue Seco beach, in the city of Pontal do Sul (PR). We chose three rocks from the east side and three from the west side, the latter being near the mouth of the Rio Vermelho river on the Galheta channel.

During 2002, monthly photographs were taken. In order to cover an area of 1 m², photos were taken from same distance...
with a Samsung camera equipped with a 38-140 mm lens. Images were treated with Adobe PhotoShop software, and percent cover was evaluated by pixel calculation from scanned photographs.

In each photographed area, recruitment was assessed in situ and specimens measuring 1 cm or less in their largest dimension were considered recent recruits. The largest fronds were also measured. Other algae species related to Gayralia sp. were registered as well.

Environmental variables measured were: temperature (digital thermometer), salinity (refractometer, precision +/- 1 psu), dissolved NO$_3$, NO$_2$, NH$_4$ and PO$_4$ were measured according to GRASSHOFF et al. (1983). Results were analyzed using ANOVA and t-test.

RESULTS

Temperature, salinity and the nutrients data are given in Table 1, and on Figure 1. Temperature varied from 21°C (August) to 29°C (January). Salinity varied from 28 psu (December) to 34 psu (September), which is a remarkably small variance for an estuary.

Variations in nutrient concentrations were a bit erratic. However, there was a trend toward higher NO$_3$ and PO$_4$ concentrations in September and October and higher NH$_4$ concentrations in November and December.

The concentration of dissolved inorganic nitrogen and the ratio of nitrogen to phosphorous increased during the year, reaching their highest values in November and December (Figure 1).

Gayralia sp. was present in the studied region throughout the year. Maximum coverage occurred during the winter and early spring, with zero cover in some of the sampled areas, especially during the summer (Table 2). However, as shown in Figure 2, the differences observed were not statistically significant (p = 0.69). Percent cover varied considerably with time and space (sampled rocks) and maximum coverage (70%) for rock 3W was attained in September (Table 2). The largest frond sizes were also observed in late winter and early spring (Table 2).

Recruitment was seen throughout the year. Supposedly young fronds (less than 1 cm) were found at all times of year, indicating potential reproduction over time in the region. Fronds reached their largest size (7 cm) in September on the studied rocks. However, on shallow bottoms uncovered during low water spring tides, specimens found attached to pebbles and to fragments of shells or roots buried in the sediments reached 11 cm. In the intertidal, specimens of M. oxyspermum were found attached to all sorts of available solid substrate, including blocks of cement, fishing nets, plastic, wood and ceramic.

The more conspicuous species accompanying M. oxyspermum were Bostrychia calyptra Montagne, Herposiphonia secunda (C. Agardh) Ambronn, Enteromorpha linea (Linnaeus) J. Agardh and E. compressa (Linnaeus) Nees. All were in the mid-intertidal belt, although Gayralia sp. was more common at the higher levels.

Concentration of nitrogen, especially in the form of ammonium, has been considered a limiting factor for algal growth (e. g., LAPOINTE TENORE, 1981). However, this does not seem to be the case in the studied region because we did not find a significant variation in the percent cover and size of the thalli over the year (Fig. 2). In the studied area, the concentration of phosphate, relatively high in comparison to nitrite and nitrate, also occurred in the period during which the highest concentrations of nitrate and phosphate were found (September/October).

CONCLUSIONS

Our data give an indirect assessment of seasonal biomass variation in Gayralia sp within an area of Paranaguá Bay. The data were based on a non-destructive methodology, which has not been used in previous studies of this economically important species.

The photographic method utilized to assess seaweed coverage of substrate seems reliable and reduced fieldwork time considerably. This is a significant advantage in this type of muddy environment, which is frequently subjected to rain and high winds and provides an ideal habitat for mosquitoes. The use of a larger quadrant (1 m$^2$) compensates for a reduced number of samples (LITTLE and LITTLE, 1985). This may also be an advantage in this kind of sampling. We tested other methods of coverage analysis, such as paper plots and software that assess coverage through color. However, these methods were unsatisfactory for Chlorophytes (which appear as non-discriminated shades) and for Gayralia sp., since it can be confused with Enteromorpha spp or other green alga present on the area.

BRAGA et al. (1997), studying the ontogeny of samples of monostromatic green alga in a nearby area, found two different algal groups growing together in that region: Monostroma spp and Ulvaria oxyperma (Kützing) Bliding. However, that was not the case with the alga we studied because the ontogeny pattern and morphology results fit well with Gayralia sp. (PELLIZZARI, F., unpublished).

The relatively higher minimum temperatures observed in 2002 should be considered with care, since they could have been affected by the fact that 2002 was an ENSO year. However, this should have little effect on cultivation of this species in the region. BRAGA et al. (1977) have shown that the species grows and reproduces at temperatures as low as 10°C, although it does not tolerate temperatures exceeding 30°C. Our own data show that Gayralia sp. in the studied region grows best between 18-22°C (PELLIZZARI, F., unpublished).

The presence of Gayralia sp. observed over a complete year cycle in Paranaguá Bay is in agreement with data from BRAGA (1997), who made her observations on a nearby area. The author also found that recruitment occurred throughout the year and on the three substrates tested, which were ceramic tiles, mollusk shells and pebbles. In September, greatest coverage coincided with lowest temperature and highest salinity values, although the values are not statistically significant. Although possibly coincidental, the largest frond sizes and highest percent cover also occurred in the period during which the highest concentrations of nitrate and phosphate were found (September/October).

Concentration of nitrogen, especially in the form of ammonium, has been considered a limiting factor for algal growth (e. g., LAPOINTE and TENORE, 1981). However, this does not seem to be the case in the studied region because we did not find a significant variation in the percent cover and size of the thalli over the year (Fig. 2). In the studied area, the concentration of phosphate, relatively high in comparison to nitrite and nitrate, may result from a process of denitrification in the surface sediment (MACHADO, E., pers. comm.). On the other hand, the high concentration of ammonium in the bay (Fig. 1) corroborates data from MACHADO et al. (1997) and BRANDINI et al. (2001). It seems that this high ammonium concentration is associated with the heavy rainfall during the summer months,
the runoff from which brings organic matter from surrounding vegetation and domestic sewage into the bay. Nonetheless, the eventual effect of high NH4 concentrations was not seen in our analysis, indicating that there is no shortage of nutrients for Gayralia sp. growth in the bay throughout the year.

CONCLUSIONS

In conclusion, our data indicates that conditions in Paranaguá Bay seem suitable for supporting a mariculture project to grow Gayralia sp. The area is easily accessible and temperature, salinity and nutrients are well within the limits for optimum growth (data not shown here). In addition, the species is common, is present in the area the year round, and production of recruits also occurs throughout the year. Moreover, the area available for cultivation is very large and there seem to be no conflicts with other potential uses, such as tourism. Experiments under way (not shown here) indicate that the species grows well when seeded on artificial collectors, such as polypropylene nets, and placed within the bay. Therefore, we have indications that this species is adaptable to management and cultivation in the bay. This is relevant because fishery production in the bay is declining and algal cultivation and management could provide an alternative livelihood for impoverished fishermen in the region. In addition, as a byproduct of commercial seaweed production in the bay, the eutrophication level would be reduced (e.g. Mata and Santos, 2003).

ACKNOWLEDGMENTS

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LITERATURE CITED


Table 2. Seasonal variation of Gayralia sp coverage (%) on rocks from Paranaguá Bay. Six rocks were sampled monthly from the east (E) and west (W) side of Mangue Seco beach during 2002. The values at the bottom are the minimum and maximum frond sizes (centimeters). Fronds of minimum size were designated recruits.

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Figure 2. Seasonal variation in Gayralia sp. coverage on rocks from Paranaguá Bay. Mean, standard deviation and error were calculated from six rocks sampled monthly during 2002.