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Cultivation of the edible green seaweed *Gayralia* (Chlorophyta) in southern Brazil

Franciane Maria Pellizzari · Theresinha Absher · Nair S. Yokoya · Eurico C. Oliveira

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Abstract During the last two decades, the monostromatic green seaweed *Gayralia* sp. has been harvested sporadically by local fishermen on the Paraná coast of southern Brazil and sold to Japanese restaurants. However, the production is erratic and its economic impact very small. This paper provides basic information about a technique to cultivate this seaweed on suspended nets in Paranaguá Bay, southern Brazil, aiming to develop a more reliable and sustainable source of income for impoverished coastal dwellers. *Gayralia* sp. occurs year round in the region, usually growing on mangrove stems and roots. Polypropylene nets (10 m long × 1 m wide with 16 cm mesh) were placed close to the mangrove fringe. Recruitment occurred year round reaching a peak of 500 recruits m^{-2} during early spring. Higher recruitment occurred at periods of low temperature (21–23°C) and high salinity (30–33 psu). Growth rates of *Gayralia* sp. ranged from 5.75 ± 0.56% to 6.50 ± 0.43% day^{-1} during the winter and from 1.43 ± 1.65% to 4.65 ± 2.17% day^{-1}, during the summer. Production ranged from 22 ± 6 g m^{-2} DW in June to 58 ± 21 g m^{-2} DW in September 2004 in 45 days after zooid settlement. The simplicity of the cultivation method, reasonable growth rates and extensive favorable area for cultivation suggest that mariculture of *Gayralia* sp. may become a good alternative of income for the local inhabitants.

Key words biomass production · edible algae · mariculture · monostromatic green algae · recruitment

F. M. Pellizzari (✉) · E. C. Oliveira
Instituto de Biociências, Universidade de São Paulo,
Cx. Postal 11461, 05422-970 São Paulo, Brazil
e-mail: francianep@yahoo.com

T. Absher
Centro de Estudos do Mar,
Universidade Federal do Paraná,
Caixa Postal: 246-Matinhos,
Cep: 83260-000 Paraná, Brazil

N. S. Yokoya
Instituto de Botânica, Seção de Ficologia,
C. Postal 4005, 01061-970 São Paulo, Brazil

Introduction

Gayralia is a monostromatic green alga (Ulvales, Gayraliaceae; Guiry et al. 2006) that has been equivocally identified as *Ulvaria* or *Monostroma* on the Brazilian coast (Pellizzari 2005). Those genera have economic applicability and the most important utilization is in food as substitute for "nori" (*Porphyra* spp), as well as in seasonings, jams, nutraceuticals and the cosmetic industry. In Brazil, *Gayralia* occurs in the intertidal zones of estuaries and mangroves, being more abundant in southeastern Brazil (Oliveira Filho 1977). Information about monostromatic green seaweeds in Brazil is scarce. Braga et al. (1997) reported on the reproduction of two species of monostromatic green algae, Cordeiro-Marino et al.

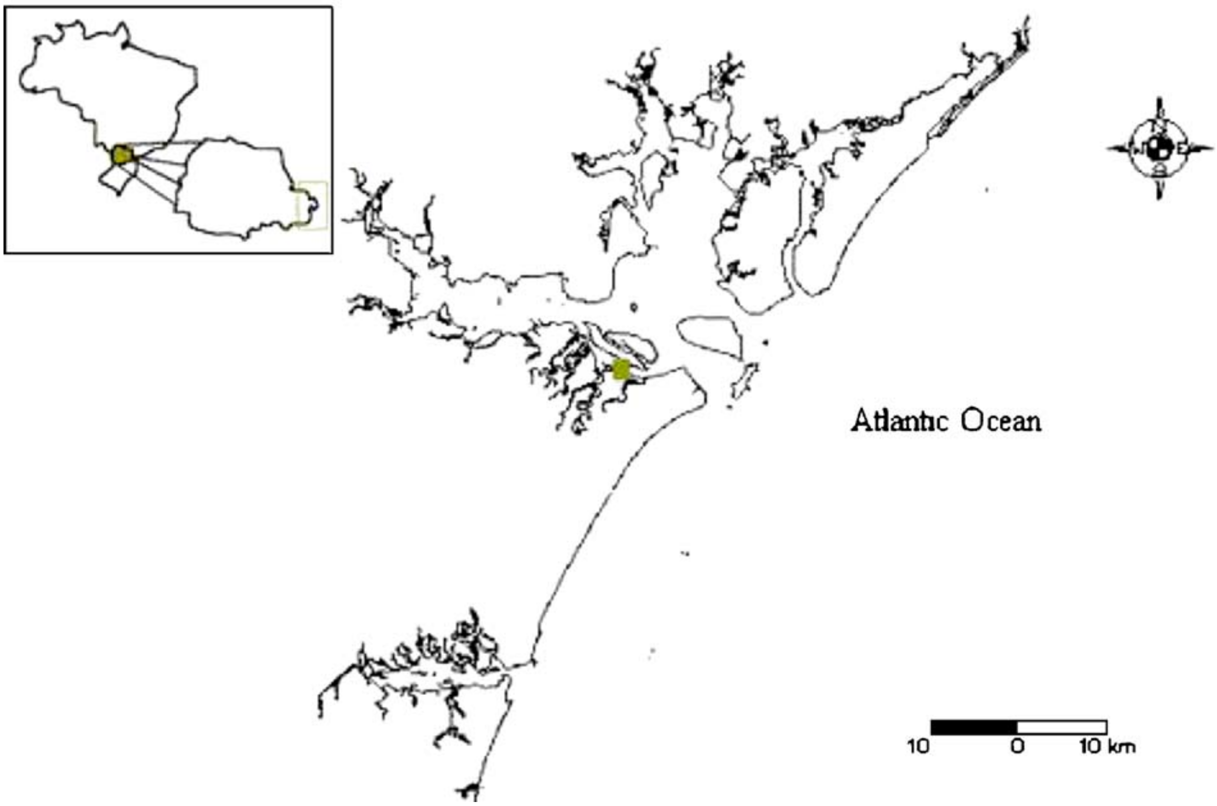

Figure 1 Estuarine complex of Paranaguá Bay showing the area selected for the pilot cultivation of *Gayralia* sp. in the Paraná coast, southern Brazil.

(1993) cultured *Monostroma* sp. in the laboratory, and Braga (1997) studied the colonization of two species of *Monostroma*-like algae on various substrates in the southern coast of São Paulo state. The most detailed study aiming to define the biological basis for the cultivation of monostromatic chlorophytes in Brazil was by Pellizzari (2005) on the coast of Paraná state. This author showed, in controlled experiments, that temperature and salinity conditions of coastal lagoons in Paraná are within the range of optimum values for the local species of *Gayralia*.

The coast of Paraná state, in southern Brazil, is characterized by the presence of a large estuarine complex bordered by mangroves, and the presence of an important harbor. The region is a traditional place for fishing and stocking oyster seeds (*Crassostrea rhizophorae* and *C. brasiliana*) in net cages, until they reach commercial size. Those activities have been gradually declining in the last decade due to overexploitation of the seeds (Andriguetto-Filho 1998).

The demand of seaweed is repressed in the Brazilian market due to the high cost of imported material. But even so, Brazil imports ca. U.S. $ 2 million of edible seaweeds per year (FAOSTATS 2005) and this was an additional motivation to develop this study.

Local communities from São Paulo and Paraná coasts traditionally harvest monostromatic green blades from mangrove stems and roots, dry it in the sun and sell it as “hitoegusa or aonori” at ca. U.S. $ 10 kg^{-1} dry weight (equivalent to imported product, which is sold as seasoning in São Paulo specialized shops for about U.S. $ 150 kg^{-1} DW). Recently this autochthonous activity was discontinued due to several factors, including the decrease of natural stock, lack of knowledge of both the biology of the species and of technology for cultivation.

This paper reports on a pilot cultivation of *Gayralia* sp. in the Paranaguá Bay, aiming to establish a simple mariculture procedure that could become an alternative income for coastal dwellers.

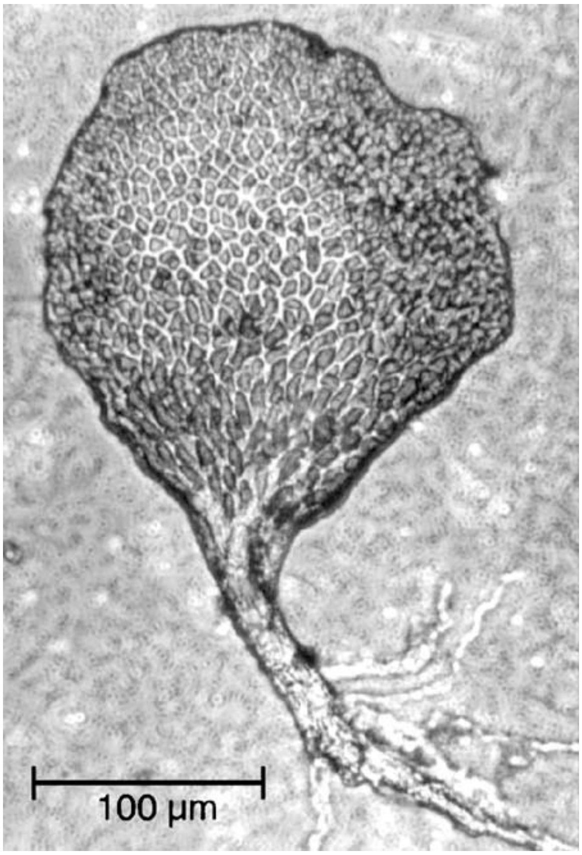

Figure 2 *Gayralia* sp.: Photomicrograph of plantlets after 20 days of development showing prominent rhizoids.

Material and methods

Studied area

The estuarine complex of Paranaguá Bay (48°25′W, 25°30′S), Paraná State, has an area of 612 km^2. Experiments were carried out near the mouth of the Emboguaçu and Maciel tidal creeks, at a place named "Maciel" (25°33′240″S, 48°24′117″W) near the city of Pontal do Sul (Figure 1). These channels drain a large mangrove area in the euryhaline outer sector of this subtropical estuary. Maximum tidal amplitude is 2.2 m (Marone and Camargo 1994). Average annual rainfall is 2,500 mm, with higher precipitation during the summer (Lana et al. 2001).

Sampling and cultivation

Experiments to evaluate recruitment rate and biomass production were conducted monthly from May 2003 to April 2004. Nets (10 m long × 1 m wide with 16 cm mesh) made with polypropylene thread (2.5 mm thick), were suspended horizontally from bamboo poles at 0.5 m above the sediment, close to the mangrove–water border in the intertidal zone. Position of the nets was based on the natural distribution of *Gayralia* sp. in the area. Recruitment of *Gayralia* sp. on nets was monitored monthly based on random sampling (n = 15) of net segments (±70 mm long), which were cut, taken to the laboratory in seawater and observed under a stereomicroscope to record the presence of plantlets. Values were expressed in number of recruits per square meter of net. Biomass production (BP) was recorded monthly through random sampling of 1 m^2 quadrats (n = 3) of net surface and fronds were collected, washed and weighed. The survival rate (SR) was calculated from the number of fronds higher than 1 cm per m^2 of net.

Concentrations of dissolved nitrite, nitrate, ammonium and phosphate were analyzed according to Grasshoff et al. (1983), while temperature, salinity,

Table 1 Averages of water temperature, salinity, nutrients, and rates of radiation and rainfall during the period of *Gayralia* sp. recruitment on nets in the Paranaguá Bay, southern Brazil

	2003								2004			
	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Temperature (°C)	24.4	23.1	21.2	20.4	21.3	22.5	23.9	25.5	26.7	27.8	27.3	25.2
Salinity (psu)	29	30	32	31	33	30	29	28	27	27	26	27
Radiation (MW m^{-2})	140	90	110	400	500	500	600	500	550	700	500	400
Rainfall (mm)	62	91	100	0	87	89	160	226	287	274	168	344
Nitrite (µM)	0.15	0.11	0.10	0.10	0.23	0.26	0.07	0.12	0.08	0.17	0.08	0.28
Nitrate (µM)	0.35	0.24	0.44	0.65	0.37	0.72	0.36	0.29	0.04	0.03	0.04	0.02
Ammonium (µM)	1.38	0.86	1.45	1.85	3.40	3.37	1.18	4.60	0.79	0.67	0.53	0.61
Phosphate (µM)	0.41	0.39	0.42	0.39	0.65	0.61	0.55	0.57	0.35	0.67	0.30	0.54

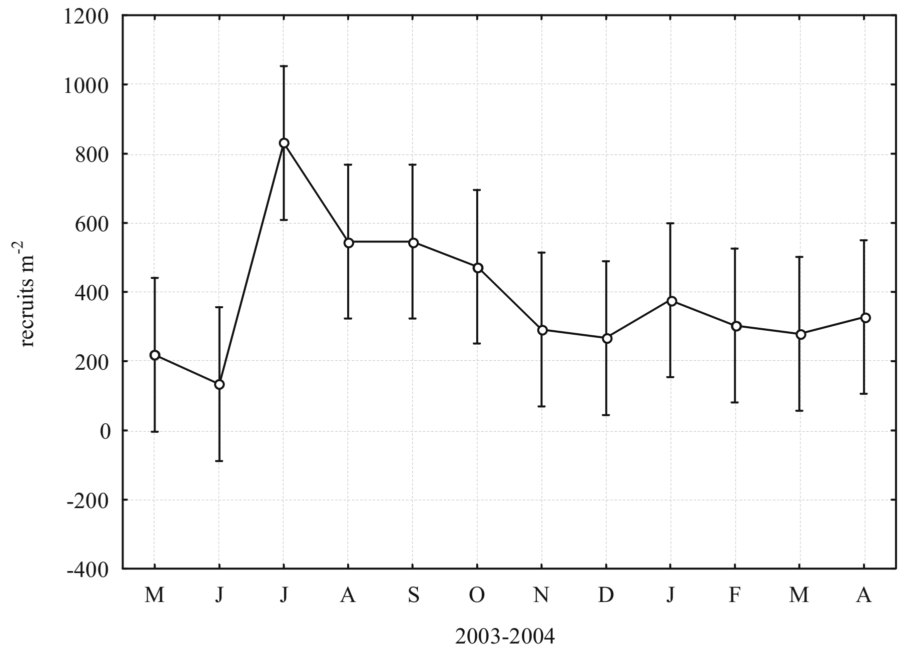

Figure 3 Seasonal variation on recruitment of *Gayralia* sp. starting from zooids on nets placed at Paranaguá Bay. Recruitment was assessed by averages of number of recruits per area (n = 15), and bars represent standard deviation.

rainfall and radiation were obtained from a meteorological and oceanographic station located at the Centro de Estudos do Mar (Universidade Federal do Paraná).

Growth experiments were conducted for 30 days during winter (from 15 June to 13 July) and summer (from 10 February to 10 March). Suspended cages (internal volume 600 cm^3) of nylon mesh (4 mm^2) were tied onto a 10 m-long line and placed parallel to the cultivation nets in the intertidal zone at intervals of 30 cm between cages. Plants with 0.15–0.30 g were collected from the Maciel tidal creek, weighed (t_0 = initial weight) and placed individually in the cages. Six cages were removed weekly and the fronds were weighed (t_f = final weight). Growth rates (GR) were calculated following Bird et al. (1976).

Data analysis of recruitment was carried out using unifactorial ANOVA (Statistica 6.0). Multiple regression analyses were carried used to detect the influence of physical and/or chemical variables on recruitment. Data of growth rates observed during the winter and summer were evaluated by ANOVA and Fisher LSD post-hoc test.

Results

Recruitment of *Gayralia* sp. on cultivation nets occurred year round in the region by zooid settlement. In approximately 20 days, plantlets reached 300 μm and rhizoids became evident (Figure 2). There was a trend of higher recruitment in late winter and early spring, periods with lower temperature (21–23°C), lower rainfall and higher salinity (30–33 psu); radiation varied from 400 to 600 mW m^{-2} (Table 1).

Density of *Gayralia* recruits varied significantly (p = 0.002) along the year (Figure 3), with mean values at around 500 individuals m^{-2} from August to

Table 2 Biomass production of *Gayralia* sp. on cultivated nets (g m^{-2}), starting from zooids after a period of 45 days in the Paranaguá Bay, from July to December 2003, and from June 2004 to January 2005 (n = 3)

	2003						2004							2005
	Jul	Aug	Sep	Oct	Nov	Dec	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
WW	173±70	198±54	252±131	345±123	290±87	189±63	128±43	165±15	381±104	438±157	395±21	274±183	182±76	58±18
DW	21±10	32±8	39±18	49±17	31±12	25±7	17±6	22±6	51±14	58±21	53±3	37±24	24±10	8±2

WW: wet weight; DW: dry weight

Figure 4 *Gayralia* sp. growing on cultivation net in a fixed system placed in the intertidal zone of Maciel Tidal Creek (Paranaguá Bay) during autumn 2003, showing fronds of commercial sizes.

October, with a peak of 800 individuals m^{-2} in July. The survival rate of recruited plantlets was 39 ± 14%. Biomass production during 2003 ranged from 21 ± 10 g m^{-2} DW in July to 49 ± 17 g m^{-2} DW in October, while in 2004 it varied from 17 ± 6 g m^{-2} DW in June to 58 ± 21 g m^{-2} DW in September, showing a small inter-annual variation (Table 2). Therefore, the peak of production occurred in the early spring reaching 458 ± 157 g m^{-2} wet weight (WW). From late summer to early autumn (February–May), production was insignificant using the fixed system of cultivation, and for this reason the results are not shown. The dry and wet weight ratio was approximately 1:7.5.

The largest fronds of *Gayralia* sp. (7.6 ± 1.8 cm long, ±0.2 g DW) developed in only 1 month after recruitment during winter (Figure 4). From late spring to early autumn, fronds reached a maximum size of about 4 cm (0.1 g DW). The peaks of recruitment and growth seem to be associated with lower temperatures as shown by multiple regression ($p = 0.019$ and $R^2 = 0.905$ for data of 2003, and $p = 0.005$ despite $R^2 = 0.309$ for data of 2004–2005) and low rainfall ($p = 0.033$), or a combination of those factors. Seasonal variations in nutrient concentrations or salinity were not significant to the recruitment and/or production.

Growth rates of *Gayralia* sp. ranged from 5.75 ± 0.56% day^{-1} to 6.5 ± 0.43% day^{-1} during the winter and from 1.43 ± 1.65% day^{-1} to 4.65 ± 2.17% day^{-1}, during the summer. The ANOVA showed significant differences ($p = 0.030$) between growth rates of *Gayralia* sp. observed in winter and summer (Table 3).

Discussion

Although we have studied the morphology, ontogeny and life history of *Gayralia* sp., we did not have

Table 3 Growth rates (% day^{-1}) of *Gayralia* sp. (minimum and maximum values, means and standard deviations) obtained *in situ* using fixed systems of cultivation during summer and winter in Paranaguá Bay, southern Brazil

2004/2005	Season	Minimum GR	Maximum GR	Mean ± SD
23 Jun	Winter 1	4.19	11.51	6.25 ± 2.76
29 Jun	Winter 2	5.16	6.49	5.75 ± 0.56
6 Jul	Winter 3	5.84	6.59	6.30 ± 0.45
13 Jul	Winter 4	5.77	6.80	6.50 ± 0.43
17 Feb	Summer 1	0.00	4.23	2.12 ± 1.94
24 Feb	Summer 2	3.00	6.23	4.65 ± 2.17
3 Mar	Summer 3	1.85	5.40	3.13 ± 0.88
10 Mar	Summer 4	0.00	4.50	1.43 ± 1.65

enough characteristics to identify the species. Preliminary molecular analyses (SSU rDNA) indicate that the Paranaguá population of *Gayralia* could be an as yet undescribed species.

Our data show that the introduction of polypropylene nets for recruitment may considerably increase the biomass production of *Gayralia* sp. in Paranaguá Bay. Similar observations were made by Kida (1990) in Japan for *Monostroma latissimum* Wittrock, a taxon recently transferred to *Gayralia oxysperma* (Kützing) K.L. Vinogradova ex Scagel et al. Water mass advection and turbulent diffusion prevailing in estuaries must be responsible for the distribution of reproductive cells of *Gayralia* sp. Fronds usually release zooids after periods of desiccation during low tides (data not shown) and, for this reason, the nets were placed near populations in the field for recruitment.

Gayralia sp. is an opportunistic species and apparently has no competitors in this environment. This species did not show selectivity for type of substratum, as observed by Braga (1997) and Eston et al. (1992), which is an advantage for aquacultural programs.

Recruitment of *Gayralia* sp. on cultivation nets occurred throughout the year, showing higher density of recruits during autumn and winter. Higher biomass, larger fronds (8 ± 1.8 cm) and higher growth rates occurred during the winter and spring. The growth of *Gayralia* sp. seems to be limited by temperature ($p < 0.05$). Variations of growth rates of *Gayralia* sp. also fit with the seasonal pattern observed for *M. nitidum* Wittrock from Shimanto River, Japan (Ohno and Rebello 1995). In Japan, Ohno (1993) also observed survival rates at around 50% of *M. nitidum* and a similar biomass production. However, in southern Brazil, production of *Gayralia* sp. occurs year round, while in Japan *Monostroma nitidum* disappears in the summer (Ohno 1993). *Gayralia oxysperma* (*M. latissimum*) also grows only during spring and winter in Mie Prefecture, Japan (Kida 1990). The occurrence and reproduction of *Gayralia* sp. throughout the year in Paranaguá Bay are certainly advantages when compared with other commercial species.

The growth rates of *Gayralia* sp. obtained during winter in the present study were similar to the values reported by Ohno (1993) for *M. nitidum* (5.9 ± 1.9% day^{-1}); and by Viaroli et al. (1996) for *Ulva rigida* C. Agardh (5.3 ± 3.9% day^{-1}).

Although we do not yet have data about the costs of cultivation of *Gayralia* sp. on the Paraná coast, our results show that the cultivation of this species is technically feasible, utilizing a very simple technology and preserving the natural beds, that would be kept as a source of seeding. Considering that the species seems to have a local market, although small, it seems worth trying to extend and improve this activity to supplement the income of littoral dwellers in the region. If this process is extended to the local inhabitants with success, besides contributing to their income it will at the same time decrease the exploitation pressures on other mangrove resources.

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References

Andriguetto-Filho JM (1998) Interações, fatores de mudança e sustentabilidade das práticas materiais e dinâmicas ambientais nos sistemas técnicos de pesca artesanal. In: Lima RE, Negrelle RR (eds) Meio ambiente e desenvolvimento no litoral do Paraná: Diagnóstico. Editora Universidade Federal do Paraná, Curitiba, pp 95–105

Bird N, Chen LCM, Mclachlan J (1976) Effects of temperature, light and salinity on growth in culture of *Chondrus crispus, Furcellaria lumbricalis, Gracilaria tikvahiae* (Gigartinales, Rhodophyta), and *Fucus serratus* (Fucales, Phaeophyta). Bot Mar 22:521–527

Braga MRA (1997) Recruitment of two species of monostromatic blade-like chlorophytes, *Monostroma* sp. and *Ulvaria oxysperma* (Ulvales), in São Paulo State, Brazil. Phycol Res 45:153–161

Braga MR, Fujii MT, Cordeiro-Marino M (1997) Monostromatic green algae (Ulvales, Chlorophyta) of São Paulo and Paraná states (Brazil): distribution, growth and reproduction. Rev Bras Bot 20:197–203

Cordeiro-Marino M, Braga MRA, Fujii MT, Guimarães SMPB, Mitsugui EM (1993) Monostromatic green algae from Espírito Santo state: life-history, growth and reproduction in culture. Rev Bras Biol 53:285–293

Eston V, Braga MRA, Cordeiro-Marino M, Fujii M, Yokoya NS (1992) Macroalgal colonization patterns on artificial substrates inside southeastern Brazilian mangroves. Aquat Bot 42:315–325

FAOSTATS (2005) Food and Agriculture Organizations of the United Nations. Statistical Databases. Retrieved from http://faostat.fao.org/faostat on 16 January 2006

Grasshoff FK, Ehrhardt M, Kremling K (1983) Methods of seawater analysis. Chemie, Weinheim, p 345

Guiry MD, Rindi F, Guiry GM (2006) *AlgaeBase version 4.0*. World-wide electronic publication, National University of

Ireland, Galway. Retrieved from http://www.algaebase.org on 07 February 2006
Kida W (1990) Culture of seaweeds *Monostroma*. Mar Behav Physiol 16:109–131
Lana PC, Marone E, Lopes RM, Machado EC (2001) The subtropical estuarine complex of Paranaguá Bay, Brazil. In: Ecological Studies, Coastal Marine Ecosystems of Latin America. Springer, Berlin 144:131–145
Marone E, Camargo R (1994) Marés meteorológicas no litoral do estado do Paraná: o evento de 18 de agosto de 1993. Nerítica 8:73–85
Ohno M (1993) Cultivation of *Monostroma nitidum* (Chlorophyta) in a river estuary, Southern Japan. J Appl Phycol 7:207–213
Ohno M, Rebello J (1995) Cultivo de *Monostroma*. In: Alveal K, Ferrari M, Oliveira EC, Sar E (eds) Manual de Métodos Ficológicos. Concepción, pp 521–528
Oliveira Filho EC (1977) Algas marinhas bentônicas do Brasil. PhD Thesis. São Paulo University, São Paulo, Brasil
Pellizzari FM (2005) Desenvolvimento das bases biológicas e de técnicas para o cultivo de algas verdes de talo monostromático (Chlorophyta) no litoral do Paraná-Brasil. PhD Thesis. São Paulo University. São Paulo, Brasil
Viaroli P, Naldi M, Bondavalli C, Benvicelli S (1996) Growth of the seaweed *Ulva rigida* in relation to biomass densities, internal nutrient pools and external nutrient supply in the Sacca di Goro Lagoon (Northern Italy). Hydrobiologia 329:93–103