9

# MARINE MACROALGAL DIVERSITY IN ADMIRALTY BAY, KING GEORGE ISLAND, SOUTH SHETLANDS ISLANDS, ANTARCTICA

http://dx.doi.org/10.4322/apa.2014.112

Yocie Yoneshigue-Valentin[1,*], Ingrid Balesteros Silva[2], Mutue Toyota Fujii[2], Nair Sumie Yokoya[2], Diclá Pupo[2], Silvia Maria Pita de Beauclair Guimarães[2], Aline Paternostro Martins[3], Paola Frazan Sanches[4], Dinaelza Castelo Pereira[3], Adriana Galindo Dalto[1] Jonatas Martinez Canuto de Souza[2], Cláudio Martin Pereira de Pereira[5], Franciane Maria Pellizzari[6] & Pio Colepicolo[3]

[1]Universidade Federal do Rio de Janeiro, Instituto de Biologia, Av. Carlos Chagas Filho, 373, Ilha do Fundão, Rio de Janeiro, CEP 21941-902, Brazil
[2]Instituto de Botânica, Núcleo de Pesquisa em Ficologia, Av. Miguel Estéfano, 3867, Água Funda, CEP 04301-902, São Paulo, SP, Brazil
[3]Universidade de São Paulo, Instituto de Química, Av. Prof. Lineu Prestes, 748, Cidade Universitária, CEP 05508-000, São Paulo, SP, Brazil
[4]Universidade Federal de Santa Catarina, Centro de Ciências Biológicas, Campus Universitário, CEP 88040-970, Florianópolis, SC, Brazil
[5]Universidade Federal de Pelotas, Capão do Leão S/N,Campus Universitário, CEP 96010-900, Brazil
[6]Universidade Estadual do Paraná, campus FAFIPAR, Rua Comendador Correia Júnior - 117, Centro, CEP 82203-280, Paranaguá, Paraná, Brazil

*e-mail: yocie@biologia.ufrj.br

**Abstract:** *The Antarctic Continent is undergoing environmental alterations due to global climate changes and anthropic activities. The knowledge of the biodiversity and of the ecophysiology of the organisms in this region is of essential importance to delineate strategies of protection and for the management of such a fragile region of the planet. Among the organisms to be monitored, the macroalgae are an important natural resource. Admiralty Bay, including the Martel inlet, is an Antarctica Special Management Area (ASMA), which undergoes changes during the year due to the coverage of ice creating perturbed climatic conditions, negatively affecting the macroalgae. Previous studies suggest that Admiralty Bay is an ecotone between the Sub-Antarctic Islands and the coastal zone of Continental Antarctica. This research has the purpose of contributing to the knowledge of the macroalgae clarifying the transitory character of the macroalgal community and its distribution in the bay. From the analysis of the samples of macroalgae collected in the period of December 2010 to February 2011 and from December 2011 to January 2012, it was possible to identify 60 species of algae, of which, 29 Rhodophyta, 14 Chlorophyta and 17 Heterokontophyta. The Ceramiales order (10 species) was the most representative among the Rhodophyta, in that 80% consisted of Delesseriaceae. The presence of Heterokontophyta of large size, such as Himantothallus grandifolius, Phaeurus antarcticus, Ascoseira mirabilis and Cystophaera jacquinotii, and the Rhodophyta, Pyropia endiviifolia and Georgiella confluens confirm the endemic character of these species in Maritime Antarctica and in the Antarctic Peninsula. The Chlorophyta, Blidingia minima, Ulva compressa, U. intestinalis and the Heterokontophyta, Petalonia fascia encountered in Admiralty Bay have wide geographical distribution in both hemispheres. In the southern hemisphere, in the Cabo Frio region, of the State of Rio de Janeiro, these species appear fully developed during the summer, a period marked by the occurrence of phenomenon of upwelling, which confirms the connectivity of the Sub-Antarctic waters with the tropical region of the South Atlantic.*

**Keywords:** Admiralty Bay, Antarctica, Macroalgae, Taxonomy

## Introduction

Antarctica could be considered the most preserved region in the planet and the most vulnerable to global environmental changes, and it has been defined as the Science Continent. Although submitted to geographical isolation, this region has been undergoing environmental alterations due to global climate changes and anthropic activities (Reich, 1980). Many of the global climatic alterations observed today may be related with those that occur in Polar Regions, especially in Antarctica, with repercussions even as far as the North of Brazil. To understand them it is necessary to study their ecosystemic aspects, as much terrestrial as marine. Thus, in the marine ecosystem, the organisms, including the algae, are well adapted to extreme climatic conditions with very low temperatures (Bischoff-Bäsmann & Wiencke, 1996), effects of ice, prolonged freezing of seawater and variations in the periods of solar radiation between winter and summer (Wiencke *et al*., 2007).

In this context, the knowledge of biodiversity and ecophysiology is of essential importance for delineating the strategies of protection and handling of such a fragile region of the planet. Among the organisms that are being monitored, the macroalgae constitute an important natural resource. Such organisms, formed by a thallus (no roots, stalk, leaves, flowers and fruit), possess great diversity of forms. Colours and dimensions play a fundamental ecological role, in the form of food, shelter, refuge plus spawning ground, which significantly reinforces their role in the ecosystem, as well as in the conservation and preservation of the natural renewable marine resources (Lee, 2008).

Up to the moment 119 species of macroalgae have been registered for the Antarctica region (Wiencke & Clayton, 2002). According to a revision of the bibliography by Pedrini (1992), it was estimated that the Antarctic Peninsula and The South Shetland islands present approximately 82 species. The diversity in the surroundings of the Polish Station Henry Arctowski (Admiralty Bay) was estimated in 36 taxons (Zielinski, 1981; Rakusa-Suszczewski & Zielinski, 1993). However, Oliveira *et al*. (2009) identified 42 species (21 Rhodophyta, 14 Heterokontophyta and 7 Chlorophyta) only in the vicinity of Brazilian Antarctic Station-Comandante Ferraz (Admiralty Bay), corresponding to approximately 31% of the total estimated biodiversity of the whole archipelago of South Shetlands, showing that possibly the macroalgae marine diversity was underestimated for a number of years, especially because all these studies were concentrated in intertidal zones and not shallow infralittoral zones.

It is known that the benthic macroalgae of Antarctica present a high degree endemism in approximately 90% of the Heterokontophyta, 70% of the Rhodophyta and 40% of the Chlorophyta with the majority of species occurring in the peninsula area and there are only a few species registered in existence further south, for example, in the Ross Sea (Wiencke *et al.,* 2007), suggesting that Admiralty Bay is an ecotone between the Sub-Antarctic Islands and the coastal zone of the Antarctic Continent (Rakusa-Suszczewski & Zielinski, 1993).

The recent phycological studies in Antarctica and the South Atlantic were principally concentrated in the areas of biochemistry and physiology (Amsler *et al.,* 2009; Hoyers *et al.,* 2002; Peters *et al.,* 2002), including those developed by researchers linked to the Brazilian Antarctic Programme, there being few surveys of flora (Pedrini, 1992; Oliveira *et al.,* 2009), however, many gaps related to taxonomy and the life history of some species, especially from the infralittoral areas, still exist (Wiencke *et al*., 2007; Hommersand *et al*., 2009).

Admiralty Bay, including Martel inlet, is an Antarctic Specially Managed Area (ASMA), which undergoes changes during the year due to ice coverage creating perturbed climatic conditions, negatively affecting the macroalgae. Thus, the present work has the purpose of contributing to the knowledge of macroalgae, making evident the transitory nature of the macroalgal community and its distribution in the bay.

## Materials and Methods

Admiralty Bay (62°04'14,5"-62°10'03,5"S and 58°20'15"-58°27'60"W) is the biggest bay of King George Island, as well as all the other islands of the archipelago of the South Shetlands. This bay is an area of great scientific and environmental interest and is divided in three sectors covered or not by permanent glaciers, which drain their glacial melt water into the bay. The water of the bay occupy 138 km$^2$ and communicate to the south by means of the Bransfield Strait and to the North is divided in three fjords forming the inlets of Ezcurra, Mackelar and Martel with depths varying from shallow water of up to 550 metres, with on average 176.3 metres (Rakusa-Suszcewski, 2002). The ice-free areas located along the beach zone and some rock prominences, such as Keller Peninsula, Hennequin Point, Demay Point, and the region of Thomas Point complete Admiralty Bay. In these regions of the intertidal zone and infralittoral shallows predominate rock substrates in the form of pebble stones that can represent an area of development and concentration of biomass for benthic macroalgae flora (Figures 1-2), which covers 30% of the bottom of the bay (Nedzarek & Rakusa-Suszcewski, 2004) and contributes as a source of organic material for organisms that inhabit this environment.

Seaweed specimens were collected during Austral Summer season from December/2010 to February/2011 and from December/2011 to January/2012 from a total of 30 sites at Martel, Marckelar and Ezcurra inlet, which are shown in the Figure 3. The marine macroalgae were

**Figure 1.** General view of the consolidated substrate formed by pebbles at Baleia beach, adjacent to Brazilian Antarctic Station Comandante Ferraz (EACF). (Photo: M.T. Fujii, January/2012).

**Figure 2.** Detail of the seaweeds attached to the pebbles, during low tide in Botany Point (Photo: M.T. Fujii, January/2012).

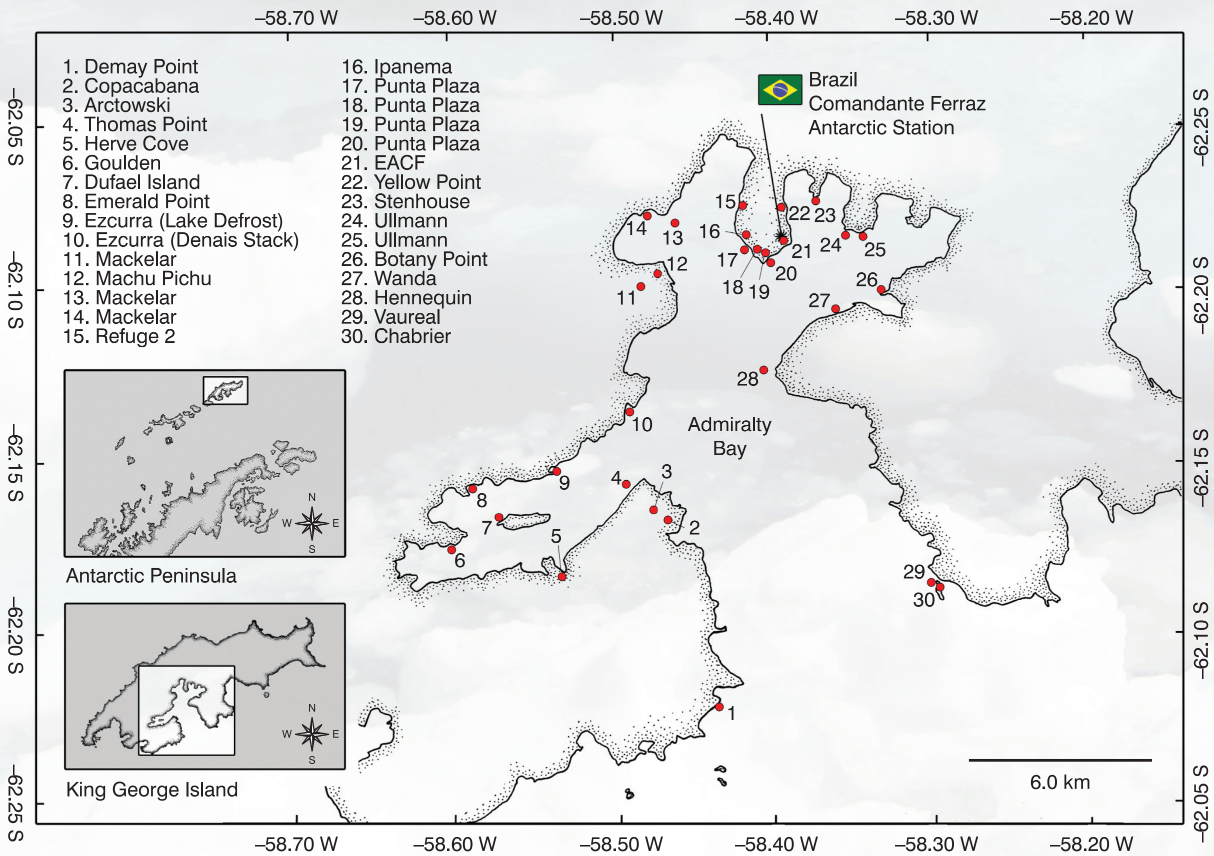


**Figure 3.** Seaweed sampling sites at Martel, Marckelar and Ezcurra inlets at Admiralty Bay, King George Island, South Shetlands, Antarctic.

collected fixed to consolidated substrate during low tides, as well as by dredging at depths of up to 30 metres, but also washed up on the beaches (Figure 4). Although the presence of calcarian algae encrusted on the consolidated substrate is conspicuous (Figure 5) these were not included in the present study due to the need of a specific methodology to identify this group of algae. The material collected was preserved in a solution of formaldehyde with 4% of sea water for morphological studies and preparation of *vouchers*. For the identification of taxonomy of the macroalgae the standard methodology was followed in Phycology, using longitudinal and transversal sections stained with blue aniline at 0.5% acidity with HC1 1N, whenever necessary, for the better visualization of the diagnostic structures. The exsiccates were included in the Phycological Herbary of the Botanic Institute in São Paulo (SP).

**Figure 4.** Drift macroalgae biomass during Summer season of 2011, in front of EACF (Photo: Rafael Bendayan de Moura).

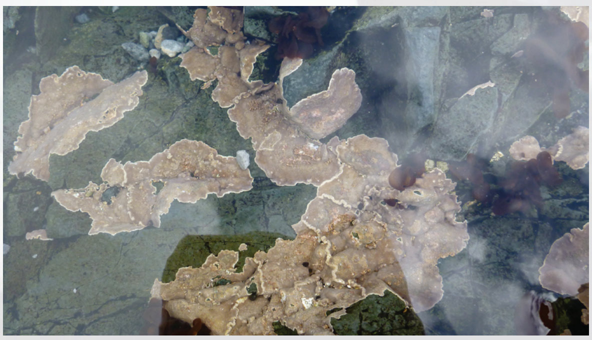

**Figure 5.** Calcareous seaweeds on the consolidated substrate during low tide at Punta Plaza, Admiralty Bay (Photo: M.T. Fujii, January/2012).

## Results

60 taxonomic samples were identified, 29 Rhodophyta, 14 Chlorophyta and 17 Heterokontophyta (Table 1).

Figure 6 shows that the Ceramiales order, with 10 species, is the most representative among the Rhodophyta, in that 80% of the order consists of Delesseriaceae (Table 1).

## Discussion and Conclusion

Chlorophyta *Endophyton atroviride* (Figure. 7) develops in the form of small green markings on the thallus of *Iridaea chordata,* showing its affinity, which almost specifies it as host, showing geographical distribution in the regions of Sub-Antarctica and Antarctica (Ricker, 1987).

Green filamentous tufts formed by *Ulothrix flacca*, *U. australis* and *Urospora peniciliformis* were very conspicuous in the higher levels of the intertidal region during the collection of samples, characterising the ambiences of the calm waters of Admiralty Bay (Figure 8). In the northern hemisphere, the heteromorphic life cycle of these species, whose sporophyte corresponds to the *Codiolum* (Druehl, 2000) variety, suggesting a strategy of survival for a period of freezing and absence of light during winter. However, in Admiralty Bay this phase has still not been identified, suggesting that the abiotic conditions can take place in a form and intensity differently from the northern hemisphere.

*Prasiola crispa* is a green nitrophyla algae which grows forming extensive carpets in the region of penguin rookeries, benefitting from the nitrogen composts originating from the excrements of birds (Figures 9-10). On the other hand, *Prasiola* sp. was found forming extensive carpets in the supralittoral zone, in localities not related to the penguin rookeries. The molecular analyses showed that the latter species is close to *P. stipitata,* however more studies will be necessary to definitively identify the specie (A. Medeiros *et al.* data unpublished). It is also noteworthy, the first indications of *Callophyllis pinnata* (Figure 11) in Admiralty Bay, broadening in this way its area of geographic distribution further south, after recordings by Hoffmann & Santelices (1997) who informed the species in Concepción, Chiloé island and Valdívia on the Chilean coast which is also mentioned in the North American Atlantic Ocean (Abbott & Norris, 1965; Abbott & Hollenberg, 1976; Ramírez & Rojas, 1988; Ramírez & Santelices, 1991).

**Table 1.** Species of marine algae collected in Admiralty Bay, King George Island, South Shetlands Archipelago, Antarctic, during summer season from December/2010 to February/2011 and from December/2011 to January/2012.

**RHODOPHYTA**

**Bangiales**
Bangiaceae
- *Porphyra plocamiestris* R.W. Ricker
- *Pyropia endiviifolia* (A.Gepp & E.Gepp) H.G. Choi & M.S. Hwang

**Hildenbrandiales**
Hildenbrandiaceae
- *Hildenbrandia lecannellieri* Hariot

**Bonnemaisoniales**
Bonnemaisoniaceae
- *Delisea pulchra* (Greville) Montagne

**Palmariales**
Palmariaceae
- *Palmaria decipiens* (Reinsch) R.W. Ricker
- *Palmaria georgica* (Reinsch) R.W. Ricker

**Ceramiales**
Wrangeliaceae
- *Georgiella confluens* (Reinsch) Kylin

Delesseriaceae
- *Delesseria lancifolia* J. Agardh
- *Delesseria salicifolia* Reisch
- *Microrhinus carnosus* (Reinsch) Skottsberg
- *Myriogramme manginii* (Gain) Skottsberg
- *Neuroglossum delesseriae* (Reinsch) M.J. Wynne
- *Phycodrys antartica* (Skottsberg) Skottsberg
- *Phycodrys austrogeorgica* Skottsberg
- *Phycodrys quercifolia* (Bory) Skottsberg

Rhodomelaceae
- *Picconiella plumosa* (Kylin) J. De Toni

**Gigartinales**
Cystocloniaceae
- *Acanthococcus antarcticus* J.D. Hooker et Harvey

Gigartinaceae
- *Gigartina skottsbergii* Setchell & N.L. Gardner
- *Iridaea cordata* (Turner) Bory de Saint-Vincent
- *Sarcothalia papillosa* (Bory) Leister

Kallymeniaceae
- *Callophyllis atrosanguinea* (J.D.Hooker & Harvey) Hario
- *Callophylis pinnata* Setchell & Swezy

Phyllophoraceae
- *Gymnogongrus antarcticus* Skottsberg
- *Gymnogongrus turquetii* Hariot

**Gracilariales**
Gracilariaceae
- *Curdiea racovitzae* Hariot

**Halymeniales**
Halymeniaceae
- *Pachymenia orbicularis* (Zanardini) Setchell & N.L. Gardner

**Plocamiales**
Plocamiaceae
- *Plocamium cartilagineum* (L) P.S. Dixon
- *Plocamium hookeri* Harvey

**Rhodymeniales**
Rhodymeniaceae
- *Rhodymenia coccocarpa* (Montagne) M.J.Wynne

**CHLOROPHYTA**

**Chaetophorales**
Chaetophoraceae
- *Endophyton atroviride* O´Kelly

**Ulotrichales**
Gomontiaceae
- *Monostroma hariotii* Gain

Ulotrichaceae
- *Protomonostroma undulatum* (Wittrock) K.L.Vinogradova
- *Ulothrix australis* Gain
- *Ulothrix flacca* (Dillwyn) Thuret

**Ulvales**
Kornmanniaceae
- *Blidingia minima* (Nägeli ex Kützing) Kylin

Ulvaceae
- *Ulva bulbosa* (Suhr) Hariot
- *Ulva compressa* Linnaeus
- *Ulva intestinalis* Linnaeus

**Prasiolales**
Prasiolaceae
- *Prasiola crispa* (Lightfoot) Kützing
- *Prasiola* sp.

**Acrosiphoniales**
Acrosiphoniaceae
- *Acrosiphonia arcta* (Dillwyn) J. Agardh
- *Urospora penicilliformis* (Roth) Areschoug

**Cladophorales**
Cladophoraceae
- *Chaetomorpha* sp.

**HETEROKONTOPHYTA**

**Syringodermatales**
Syringodermataceae
- *Syringoderma australe* Levring

**Fucales**
Seirococcaceae
- *Cystosphaera jacquinotii* (Montagne) Skottsberg

**Ectocarpales**
Chordariaceae
- *Haplogloia moniliformis* Ricker
- *Haplogloia andersonii* (Farlow) Levring
- *Elachista antarctica* Skottsberg

Acinetosporaceae
- *Geminocarpus austrogeorgiae* Skottsberg
- *Geminocarpus geminatus* (Hooker & Harvey) Skottsberg
- *Pylaiella littoralis* (L.) Kjellman

Adenocystaceae
- *Adenocystis utricularis* (Bory) Skottsberg

Scytosiphonaceae
- *Petalonia fascia* (O. F. Müller) Kuntze

**Desmarestiales**
Desmarestiaceae
- *Desmarestia anceps* Montagne
- *Desmarestia antarctica* R.L. Moe & P.C. Silva
- *Desmarestia confervoides* (Bory) M.E. Ramírez & A.F. Peters
- *Desmarestia menziesii* J Agardh
- *Himantothallus grandifolius* (A and E Gepp) Zinova
- *Phaeurus antarcticus* Skottsberg

**Ascoseirales**
Ascoseiraceae
- *Ascoseira mirabilis* Skottsberg

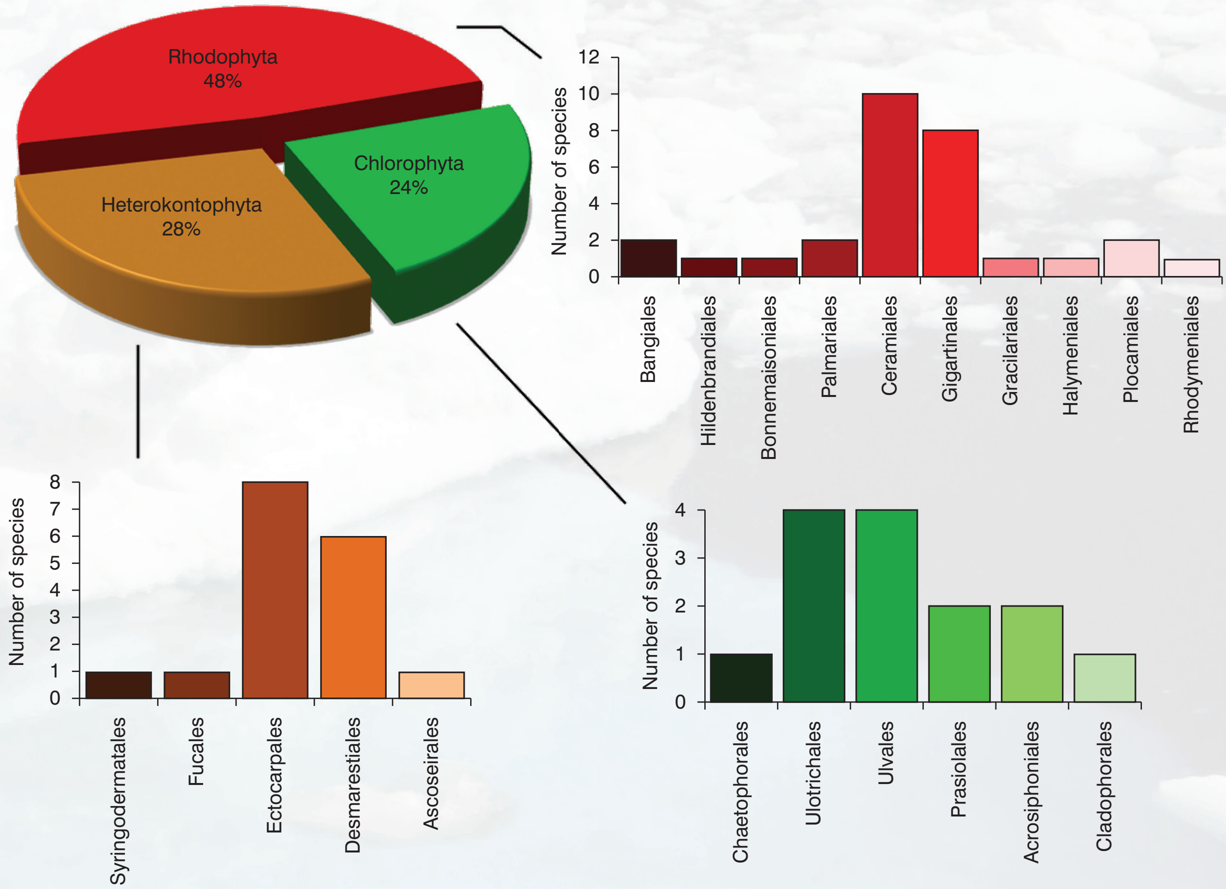


**Figure 6.** Diversity of marine macroalgae in admiralty bay.

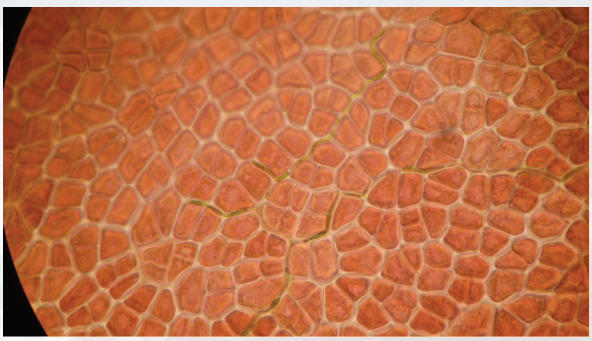

**Figure 7.** *Endophyton atroviride* growing in the thallus of rhodophycean *Iridaea chordata*.

**Figure 8.** Green filamentous algae formed by *Ulothrix flacca*, *U. australis* e *Urospora peniciliformis* are frequently observed growing on the upper portion of intertidal zone of Admiralty Bay.

**Figure 9.** Penguin colony in the Polish Station Arctowski.

**Figure 10.** Population of *Prasiola crispa* growing in a wetland under the influence of penguin droppings.

The presence of Heterokontophyta of large size such as, *Himantothallus grandifolius*, *Phaeurus antarcticus*, *Ascoseira mirabilise Cystophaera jacquinotii*, and linked to the Rhodophyta *Pyropia endiviifolia*e and *Georgiella confluens* confirm the endemic characteristic of this species in Maritime Antarctica and in the Antarctica Peninsula (Clayton, 1994; Wiencke & Clayton, 2002). In Admiralty Bay, Oliveira *et al.* (2009) 42 species distributed as follows were found: 21 Rhodophyta, 14 Heterokontophyta and 7 Chlorophyta. Of the species informed by these authors *Porphyra woolhouseae* Agardh *Notophycus fimbriatus* R.L. Moe, *Plocamium* aff. *secundatum*, *Ballia callitrichia* (C. Agardh) Kützing and *Desmarestia chordalis* J.D. Hooker & Harveynão were found in the course of the present study. On the other hand, in the collecting that took place in 2010-2011 and 2011-2012, the diversity was greater in comparison with that obtained by Oliveira *et al.* (2009), through the register of a further eighteen species (*Palmaria georgica*, *Callophyllis pinnata*, *Acanthococcus antarcticus*, *Sarcothalia papillosa*, *Plocamium hookerii*, *Rhodymenia coccocarpa*, *Delesseria salicifolia*, *Myriogramme mangini*, *Phycodrys antarctica*, *P. austrogeorgica*, *Desmarestia confervoides*, *Syringoderma australis*, *Endophyton atroviride*, *Ulothrix flacca*, *Blidingia mínima*, *Ulva compressa*, *U. intestinalis* and *Chaetomorpha* sp).

The Chlorophyta *Blidingia minima*, *Ulva compressa*, *U. intestinalis* and the Heterokontophyta *Petalonia fascia* found in Admiralty Bay have wide geographic distribution in both hemispheres. In the southern hemisphere, in the region of Cabo Frio, State of Rio de Janeiro, these species appear fully developed during the summer, a period marked by the occurrence of a resurgence phenomenon (Yoneshigue, 1985; Yoneshigue-Valentin & Valentin, 1992; Reis & Yoneshigue-Valentin, 1996), which confirms the connectivity of the Sub-Antarctic waters with the tropical region of the South Atlantic.

**Figure 11.** *Callophyllis pinnata* identified from macroalgae collected in Admiralty Bay.

## Acknowledgments

We thank the National Council for Scientific and Technological Development, (CNPq, Portuguese acronym) process: 574018/2008-5 and process: 557030/2009-9, and Carlos Chagas Foundation for Support of Research in the State of Rio de Janeiro (FAPERJ, Portuguese acronym), process n° E-26/170.023/2008) for the financial support and FAPERJ´s Grant E.26/102.757/2011 for the first author.

## References


Abbott, I.A. & Norris, R.E. (1965). Studies on *Callophyllis* (Rhodophyceae) from the Pacific coast of North America. Nova Hedwigia, 10: 67-84.

Abbott, I.A. & Hollenberg, G.J. (1976). Marine algae of California. Stanford, California: Stanford University Press. 827p.

Amsler, C.D.; Iken, K.; McClintock, J.B. & Baker, B. (2009).Defenses of polar macroalgae against herbivores and biofoulers. Botanica Marina, 52: 535-545.

Bischoff-Bäsmann, B. & Wiencke, C. (1996).Temperature requirements for growth and survival of Antarctic Rhodophyta. Journal of Phycology, 32: 525-535.

Clayton, M.N. (1994). Evolution of the Antarctic marine benthic algal flora. Journal of Phycology, 30: 897-904.

Druehl, L. (2000). Pacific Seaweeds: A guide to common seaweeds of the west coast. 1st ed. British Columbia, Harbour Publishing, 190 p.

Hoffmann, A. & Santelices, B. (1997). Marine flora of central Chile. Santiago: Ediciones Universidad Católica de Chile. 434pp.

Hommersand, M. H.; Moe, R.L.; Amsler, C.D. & Fredericq, S. (2009). Notes on the systematics and biogeographical relationships of Antarctic and sub-Antarctic Rhodophyta with descriptions of four new genera and five new species. Botanica Marina, 52: 509-534.

Hoyers, K.; Karsten, U.& Wiencke, C. (2002). Induction of sunscreen compounds in Antarctic macroalgae by different radiation conditions. Marine Biology, 141(4): 619-627.

Lee, R. E. (2008). Phycology. 4th ed Cambridge. University Press. Cambridge, 547 p.

Nedzarek, A.& Rakusa-Suszczewski, S. (2004). Decomposition of macroalgae and the release of nutrients in Admiralty Bay, King George Island, Antarctica.Polar Bioscience, 17: 16-35.

Oliveira, E. C.; Absher, T.; Pellizzari, F.M. & Oliveira, M.C. (2009). The seaweed flora of Admiralty Bay, King George Island, Antarctic.Polar Biology, 32: 1639-1647.

Pedrini, A.G. (1992). Catálogo de espécies, ocorrência geográfica e bibliografia de algas marinhas bentônicas das Ilhas Shetlands do Sul, Antártica. Arquivos do Jardim Botânico do Rio de Janeiro, 31: 87-102.

Peters, K.J.; Amsler, C.D.; Amsler, M.O.; McClintock, J.B.; Iken, K.B.& Baker, W.J. (2002). The effects of thallus toughness and nutritive quality on palatability of Antarctic macroalgae.Jounal of Phycology, 38: 29-30.

Ramírez, M.E. & Rojas, G.(1988). Nuevos registros de algas marinas para la costa de Chile, I. Boletín Museo Nacional de Historia Natural Chile (Chile), 41: 17-43.

Ramírez, M.E. & Santelices, B. (1991). Catálogo de las algas marinas bentónicas de la costa temperada del Pacífico de Sudamérica. Monografías Biológicas, 5: 1-437.

Rakusa-Suszczewski, S. & Zielinski, K. (1993). Macrophytobenthos. In: Rakusa-Suszczewski, S. (ed) The maritime Antarctic coastal ecosystem of Admiralty Bay. Polish Academy of Sciences, Warsaw, 57-60p.

Rakusa-Suszczewski, S. (2002).King George Island – South Shetlands Islands, Maritime Antarctic. In.: I. Beyer & M. Bölter (eds.) Geoecology of Antarctic ice-free coastal landscape ecological studies.Springer-Verlag, Berlin, Heidelberg. 23-40p.

Reich, R.J, (1980). The development of Antarctic tourism.Polar Record, 20: 203-214.

Reis, R. P. & Yoneshigue-Valentin, Y. (1996). Distribuição das macroalgas na Lagoa de Araruama, estado do Rio de Janeiro, Brasil. Revista Brasileira de Botânica, 19(1): 77-85.

Ricker, R.W. (1987).Taxonomy and Biogeography of Macquarie Island Seaweeds. London: British Museum (Natural History). 344p.

Wiencke C. & Clayton, M.N. (2002). Antarctic seaweeds. In: J.W. Wägele &J. Sieg (eds.) Synopses of the Antarctic Benthos, vol 9. Gantner, Ruggell. 239p.

Wiencke, C.; Clayton, M.N.; Gómez, I.; Iken, K.; Lüder, U.H.; Amsler, C.D.; Karsten, U.; Hanelt, D.; Bischoff, K. & Dunton, K.(2007). Life strategy, ecophysiology and ecology of seaweeds in polar waters.Reviews in Environmental Science and Biotecnology, 6: 95-126.

Yoneshigue, Y. (1985). Taxonomie et ecologie des algues marines dans la region de Cabo Frio (Rio de Janeiro, Brésil). Thèse Docteur d'État-Sciences.Université d'Aix Marseille II, 466p.

Yoneshigue-Valentin, Y. & Valentin, J. L. (1992).Macroalgae of the Cabo Frio. Upwelling region, Brazil: ordination of communities. Seeliger, U. (ed.). In: Coastal plant communities of Latin America.Academic Press, San Diego. 31-50p.

Zielinski, K. (1981). Benthic macroalgae of Admiralty Bay (King George Island, South Shetland Islands) circulation of algal matter between the water and the shore. Polish Polar Research, 2: 71-94.