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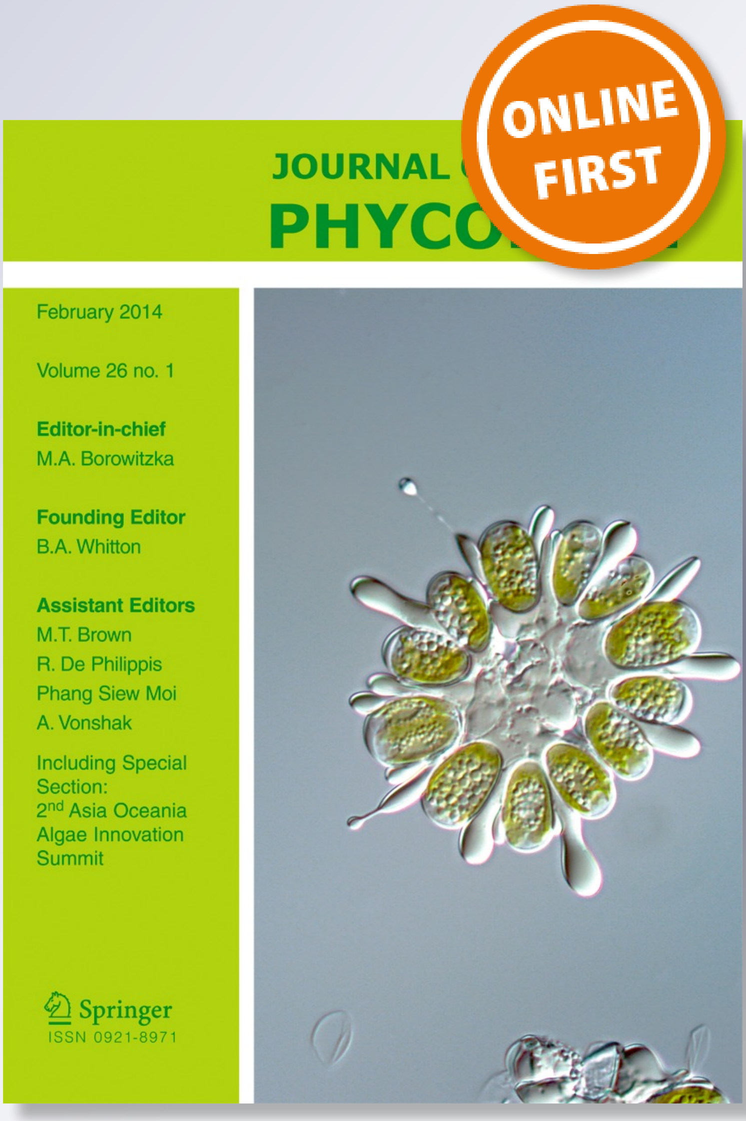

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IV LATIN AMERICAN CONGRESS OF ALGAE BIOTECHNOLOGY (CLABA) AND IV REDEALGAS WORKSHOP

Seaweed biotechnology in Brazil: six decades of studies on natural products and their antibiotic and other biological activities

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Abstract The Brazilian seaweed assemblage currently comprises 770 taxa, distributed along 7,367 km of coastline with highly diverse ecological conditions, suggesting a high biotechnological potential for these species. Studies on seaweed biotechnology in Brazil began in 1948 and have produced extensive published information that is presently scattered in many sources. This manuscript presents an overview of biotechnology studies on seaweeds that were carried out in Brazil, from the earliest through 2012, with the purpose of directing new studies in this field. The studies analyzed were retrieved from the curricula of Brazilian seaweed researchers, centralized in the public database *Currículo Lattes*, supported by the Brazilian National Council of Technological and Scientific Development (CNPq). Scientific papers dealing with biological activities of natural extracts from native and some non-native seaweeds were selected. The survey was complemented by a search for older references cited in the first group. Together, the studies extend over 64 years, totaling 364 scientific papers investigating the potential of 160 seaweed taxa, including tests for 6 antibiotic activities, 11 categories of other biological activities, and a wide range of natural products. In general, the studies focused on antiinflammatory, antinociceptive, and antiviral activities, and some characterized the effects of molecules, including sulfated polysaccharides, lectins, and terpenes.

Keywords Review · Seaweed resources · Seaweed utilization · Health and well-being

Introduction

Brazil is a country of continental dimensions, with 7,367 km of coastline (IBGE 2013), where approximately 770 species of seaweed have been recorded (Bicudo and Menezes 2010). Brazilian seaweeds occur over a gradient of salinity influenced by numerous rivers and over a wide depth range, from the intertidal zone of rocky shores to 100 m on the continental shelf (Horta 2000; Yoneshigue-Valentin et al. 2006). Most of Brazil is tropical; however, part of the southeastern and southern regions has a warm temperate climate, producing a wide variation in seawater temperatures (Horta 2000; IBGE 2013). The northeastern region is influenced by the South Equatorial Current and the North Brazil Current, resulting in seawater temperatures of 25–29 °C (Hazin et al. 2008). The southern region is influenced by cold waters from the South Atlantic Ocean, which cools the water temperature to below 20 °C (Provost et al. 1999). Moreover, upwelling from September to March off Rio de Janeiro state, caused by the rise of South Atlantic central waters, produces water temperatures of 11–18 °C (Valentin 1984; Stramma and England 1999). Intense solar irradiance and UV rays, principally in northeastern Brazil, also affect the seaweeds (Kirchhoff et al. 2000).

This wide range of ecological conditions is reflected in a pronounced diversification of the seaweed flora. This local species richness suggests a high biotechnological potential for Brazilian seaweeds. The first study applying the concept of biotechnology investigated the properties of agar extracted from *Hypnea musciformis* (and *Gracilaria cornea* in comparison to a commercial bacto-agar (Humm and Williams 1948). However, interest in the biotechnological applications of seaweeds really arose after a cycle of taxonomic and floristic

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studies in the 1950s and ecological studies between the 1970s and 1990s enhanced the knowledge of native species. Researchers benefited from government funding incentives after 2003 and following the creation of REDEALGAS (Brazilian Network for Algae Biotechnology) in 2005.

With a large body of research and data now available, it has become necessary to inventory all scientific publications dealing with seaweeds used in biotechnological studies in Brazil, in order to better direct future studies in this area. The present study comprises the first general review of the results of Brazilian seaweed biotechnology research. The review lists papers published between 1948 and 2012 that evaluated various biological activities of native species, but also included exotic cultured species (*Kappaphycus alvarezii*) and commercially obtained exotic samples. These studies provide an insight into the chemical compounds isolated from the species examined.

Methods

The curricula of Brazilian seaweed investigators were evaluated from the online database *Currículo Lattes* (http://www.lattes.cnpq.br), maintained by the Brazilian National Council of Technological and Scientific Development (CNPq). The curricula were selected from this database using "seaweed" as a keyword. Only curricula of researchers based in Brazilian educational and research institutions were used. Each curriculum was examined individually, selecting papers related to the use of extracts from seaweeds in questions regarding biological activities focused on human health and well-being, in addition to those that characterized natural products. Only papers published in scientific journals were selected. A complementary search was based on the references cited in the papers retrieved, in order to include articles that appeared prior to the period covered by the *Currículo Lattes* database.

Results

The utilization of seaweeds was previously confined to fishing villages, particularly in the northeast region of Brazil, where certain edible species such as *Gracilaria* spp. and *Hypnea* spp. were used for food (Câmara-Neto and Chaves-Câmara 2012). The possibilities for use of this resource expanded with the advance of scientific research, which began over 60 years ago and has resulted in the production of 364 original scientific papers.

Fewer than ten publications in the field appeared in each decade between 1948 and 1989. In the 1990s, about 50 papers were published. Interest in seaweed biotechnology increased with the new millennium. Scientific production between 2000 and 2005 reached 82 papers, and from 2006 through 2010, around 120 papers appeared. The most recent 2 years of the survey equaled 78 % of the output between 2006 and 2010.

In total, the articles examined 160 taxa of seaweed, of which 16 % were Chlorophyta, 17 % Heterokontophyta, and 67 % Rhodophyta. The most frequently studied taxa were *Caulerpa* spp., *Codium* spp., *Ulva* spp., *Dictyota* spp., *Canistrocarpus cervicornis*, *Sargassum* spp., *Spatoglossum schroederi*, *Bryothamnion* spp., *Hypnea* spp. *Gracilaria* spp., and *Osmundaria obtusiloba*. Most samples used in these investigations were collected from their natural habitats (95 %); only 3.5 % of the seaweeds were reared from in vitro cultures, and 1.5 % were found adrift on the beach or were a commercial product.

Antibiotic and other biological activities

The biological activities of the seaweeds were divided into (i) antibiotic activities and (ii) other biological activities (Table 1). Antibiotic activities were subdivided into antibacterial, antifungal, antihelminthic, antiprotozoal, antiviral, and insecticidal. Other biological activities were subdivided into antifouling, antiophidic, antiinflammatory, cytotoxicity, antitumoral, antioxidant, immunostimulatory, antinociceptive, effects on coagulation, photoprotective activity, and healing. The studies assessed 20 species of Chlorophyta, 19 Heterokontophyta, and 64 Rhodophyta, including the species *Caulerpa cupressoides*, *Caulerpa racemosa*, *C. cervicornis*, *Lobophora variegata*, *S. schroederi*, *Bryothamnion seaforthii*, and *Bryothamnion triquetrum*, which showed the most types of biological activities (Table 1).

Antibiotic activities

The studies of antibiotic activities focused on antiviral (36 papers), antiprotozoal (7 papers), and antibacterial activities (6 papers). Some human pathogenic viruses (HIV-1; HTLV-1; HSV-1 and HSV-2; Dengue virus types 1, 2, 3, 4; human metapneumovirus; and bovine viral diarrhea virus), protozoans (*Trypanosoma cruzi* and *Leishmania amazonensis*), and bacteria (*Escherichia coli*, *Proteus vulgaris*, *Staphylococcus* spp., *Enterobacter aerogenes*, *Klebsiella pneumoniae*, *Morganella morganii*, *Pseudomonas aeruginosa*, *Salmonella* spp., and *Vibrio cholerae*) were analyzed in these investigations. Extracts from *Dictyota* spp., *C. cervicornis*, *Laminaria abyssalis*, *O. obtusiloba*, and *H. musciformis* show antiviral effects, extracts of *Laurencia dendroidea* and *C. cervicornis* show antiprotozoal effects, and extracts of *Caulerpa* spp. and *Bryothamnion* spp. show antibacterial effects (Table 1).

A few studies also tested activities against yeasts (*Candida albicans*, *Candida parapsilosis*, and *Cryptococcus neoformans*), a helminth (*Nippostrongylus brasiliensis* Travassos), and arthropods (the beetle *Callosobruchus*

Table 1 Brazilian species of seaweed extracts and compounds tested for antibiotic and other biological activities

Species	Antibiotic activities	Biological activities	Chemical compounds
Chlorophyta			
Avrainvillea elliotti A. Gepp & E.S. Gepp	Vir[6]	–	Cex[6]
Caulerpa cupressoides (Vahl) C. Agardh	Bact[1, 2]	Infl[41], Tumo[60], Nocic[41], Oxi[68], Coag[68, 80]	Cex[2], Poly[41, 60, 68], Hem[80]
Caulerpa mexicana Sonder ex Kützing	Bact[2]	Infl[38], Nocic[38], Oxi[67], Coag[79]	Cex[2, 38, 67, 79], Phe[67]
Caulerpa prolifera (Forsskål) J.V. Lamouroux	Bact[1, 2]	Tumo[60], Coag[79]	Cex[2, 79], Poly[60]
Caulerpa racemosa (Forsskål) J. Agardh	Vir[6, 7, 8]	Infl[39, 60], Tumo[56, 60], Nocic[39], Oxi[60], Coag[79, 83]	Cex[6, 39, 56, 79], Glyc[7], Alk[8, 56], Poly[60, 83]
Caulerpa sertularioides (S.G. Gmelin) M.A. Howe	–	Infl[38], Tumo[60], Nocic[38], Coag[79]	Poly[60] Cex[2, 38, 79]
Chaetomorpha antennina (Bory de Saint-Vincent) Kützing	Vir[6]	Cyto[54]	Cex[6, 54]
Cladophora prolifera (Roth) Kützing	Vir[6]	–	Cex[6]
Codium decorticatum (Woodward) M.A. Howe	Vir[6, 10]	Foul[28], Cyto[54], Oxi[67]	Cex[6, 10, 28, 54, 67], Phe[67]
Codium isthmocladum Vickers	Bact[2]	Cyto[54], Tumo[60], Oxi[60], Coag[79]	Cex[2, 54, 79], Poly[60]
Codium spongiosum Harvey	Vir[6]	–	Cex[6]
Codium taylorii P.C. Silva	–	Oxi[67]	Cex[67], Phe[67]
Dictyosphaeria cavernosa (Forsskål) Børgesen	–	Coag[79]	Cex[79]
Enteromorpha linza (Linnaeus) J. Agardh	Bact[2]	–	Cex[2]
Gayralia oxysperma (Kützing) K.L. Vinogradova ex Scagel	Vir[6, 11]	–	Cex[6], Shet[11]
Halimeda tuna (J. Ellis & Solander) J.V. Lamouroux	Vir[6]	–	Cex[6]
Penicillus capitatus Lamarck	Vir[6]	–	Cex[6]
Udotea flabellum (J. Ellis & Solander) M.A. Howe	Vir[6]	–	Cex[6]
Ulva intestinalis Linnaeus (=*Enteromorpha intestinalis*)	–	Cyto[54]	Cex[54]
Ulva lactuca Linnaeus (=*Ulva fasciata*)	Bact[1, 2], Vir[7, 10]	Cyto[54], Oxi[67], Coag[83]	Cex[1, 2, 10, 54, 67], Glyc[7], Phe[67], Poly[83]
Ulva linza Linnaeus	–	Coag[79]	Cex[79]
Valonia aegagropila C. Agardh	Bact[2]	–	Cex[2]
Heterokontophyta			
Canistrocarpus cervicornis (Kützing) De Paula & De Clerck (=*Dictyota cervicornis*)	Proto[23], Vir[7, 9]	Foul[31], Ophi[33], Oxi[60, 69], Cyto[54], Tumo[60], Coag[60, 69]	Cex[54], Glyc[7], Terp[9, 23, 31, 33], Poly [60], Fuc[69]
Colpomenia sinuosa (Mertens ex Roth) Derbès & Solier	–	Oxi[67], Cyto[54]	Phe[67], Cex[54, 67]
Dictyopteris delicatula J.V. Lamouroux	Bact[2], Vir[6],	Tumo[58], Oxi[58, 60], Coag[58, 60] Foul[30]	Cex[2, 6, 30], Poly[60], Fuc[58]
Dictyopteris polypodioides (A.P.De Candolle) J.V. Lamouroux (=*Dictyopteris justii*)	–	Coag[76]	Poly[76]
Dictyota menstrualis (Hoyt) Schnetter, Hörning & Weber-Peukert	Vir[6, 7, 8]	Tumo[60], Oxi[60], Coag[60]	Cex[6], Terp[8], Glyc[7], Poly[60]
Dictyota mertensii (Martius) Kützing	Vir[17]	Tumo[60], Oxi[60], Coag[60]	Fuc[17], Poly [60]
Dictyota friabilis Setchell (=*Dictyota pfaffii*)	Proto[24], Vir[8, 25]	Cyto[50]	Terp[8, 24, 25, 50]
Ectocarpus breviarticulatus J. Agardh	–	Cyto[54]	Cex[54]
Fucus vesiculosus[a] L.	Vir[17]	Infl[48], Cyto[53], Oxi[70], Coag[78]	Fuc[17, 48, 53, 70, 78]
Laminaria abyssalis A.B.. Joly & E.C. Oliveira (=*Laminaria brasiliensis*)	Vir[10]	Cyto[52]	Cex[10], Alg[52]
Lobophora variegata (Lamouroux) Womersley	Vir[6, 17]	Infl[35, 71, 86], Cyto[53], Tumo[56], Oxi[71], Coag[79, 86]	Cex[6, 56, 79], Fuc[17, 35, 53, 71, 86]
Padina gymnospora (Kützing) Sonder	Bact[2], Vir[6, 10]	Infl[45], Cyto[54], Oxi[67, 70], Coag[44, 79]	Cex[2, 6, 10, 54, 67, 79], Phe[67], Fuc[44, 45, 70]
Sargassum cymosum C. Agardh	Vir[6]		Cex[6]
Sargassum filipendula C. Agardh	–	Tumo[59], Oxi[59, 60], Coag[60]	Poly[60], Fuc[59]
Sargassum polyceratium Montagne	Vir[6]	–	Cex[6]
Sargassum stenophyllum Martius	–	Cyto[52, 54]	Cex[54], Alg[52], Fuc[52]
Sargassum vulgare C. Agardh	Bact[2], Vir[6, 10]	Foul[27, 28], Cyto[54], Oxi[67]	Cex[2, 6, 10, 28, 54, 67], Phe[27, 67]
Spatoglossum schroederi (C. Agardh) Kützing	Bact[90], Vir[17]	Ophi[32], Tumo[56, 60], Nocic[65], Oxi[60], Coag[74, 79]	Cex[56, 79], Fuc[17, 65, 74, 90], Poly[60], Cho[56], Terp[32]
Stypopodium zonale (J.V. Lamouroux) Papenfuss	Vir[6]	Foul[26, 28], Tumo[56]	Cex[6, 28, 56], Terp[26, 56]
Rhodophyta			
Acanthophora muscoides (Linnaeus) Bory de Saint-Vincent	–	Coag[79]	Cex[79]
Acanthophora spicifera (Vahl) Børgesen	Bact[2], Vir[15]	Cyto[54], Oxi[67], Coag[79]	Cex[2, 54, 67, 79], Aga[15], Phe[67]

Table 1 (continued)

Species	Antibiotic activities	Biological activities	Chemical compounds
Agardhiella subulata (C. Agardh) Kraft & M.J. Wynne (=*Agardhiella tenera*)	Bact[2]	–	Cex[2]
Amansia multifida J.V. Lamouroux	Bact[1]	Infl[47], Immu[72], Coag[47, 79]	Cex[1, 79], Gal[4], Lec[72]
Bostrychia montagnei Harvey	Vir[16]	Cyto[52]	Aga[16], Gal[52]
Bostrychia radicans (Montagne) Montagne	Vir[6]	–	Cex[6]
Bostrychia tenella (J.V. Lamouroux) J. Agardh	Proto[22], Fung[22]	Oxi[67]	Cex[22, 67], Phe[67]
Botryocladia occidentalis (Børgesen) Kylin	Bact[2]	Ophi[34], Coag[75]	Cex[2], Gal[34, 75]
Bryothamnion seaforthii (Turner) Kützing	Bact[3]	Foul[30], Tumo[57], Nocic[64], Coag[85], Heal[91]	Lec[3, 57, 91], Cex[30], Carb[64], Hem[85]
Bryothamnion triquetrum (S.G. Gmelin) M.A. Howe	Bact[3]	Infl[37], Cyto[55], Tumo[57], Nocic[37], Coag[79, 85]	Lec[3, 55, 57], Cex[37], Hem[79, 85]
Callophyllis microdonta (Greville) Falkenberg	–	Oxi[67]	Cex[67], Phe[67]
Centroceras clavulatum (C. Agardh) Montagne	Proto[21], Vir[6]	Cyto[54]	Cex[6, 21, 54]
Champia feldmannii Díaz-Piferrer	–	Cyto[61], Tumo[61], Immu [61], Nocic[62], Coag[62], Infl[62]	Poly[61, 62]
Chondracanthus acicularis (Roth) Fredericq (=*Gigartina acicularis*)	Bact[2], Vir[6]	Cyto[54], Oxi[70]	Cex[2, 6, 54], Crg[70]
Chondria sedifolia Harvey	Bact[2]	–	Cex[2]
Corallina panizzoi R. Schnetter & U. Richte	Vir[6]	–	Cex[6]
Cryptonemia crenulata (J. Agardh) J. Agardh	Vir[12, 14]	–	Gal[12, 14], Crg[14]
Cryptonemia luxurians (C. Agardh) J. Agardh	Bact[2]	–	Cex[2]
Cryptonemia seminervis (C. Agardh) J. Agardh	Vir[6]	Oxi[67]	Cex[6, 67], Phe[67]
Dichotomaria marginata (J. Ellis & Solander) Lamarck (=*Galaxaura marginata*)	–	Oxi[67], Cyto[54]	Cex[54, 67], Phe[67]
Dictyurus occidentalis J. Agardh	–	Coag[79]	Cex[79]
Enantiocladia duperreyi (C. Agardh) Falkenberg	–	Coag[79, 80]	Cex[79], Hem[80]
Eucheuma cottonii[a] Weber-van Bosse	–	Oxi[70]	Crg[70]
Eucheuma spinosum[a] J. Agardh	–	Oxi[70]	Crg[70]
Ganonema farinosum (J.V. Lamouroux) K.C. Fan & Yung C. Wang	–	Oxi[67]	Cex[67], Phe[67]
Gelidiella acerosa (Forsskål) Feldmann & G. Hamel	–	Coag[79]	Cex[79]
Gelidium crinale (Hare ex Turner) Gaillon	–	Coag[73]	Gal[73]
Gelidium coarctatum Kützing	–	Coag[79]	Cex[79]
Gelidium pusillum (Stackhouse) Le Jolis	–	Coag[84]	Hem[84]
Gigartina pistillata[a] (S.G. Gmelin) Stackhouse	–	Oxi[70]	Crg[70]
Gracilaria birdiae E.M. Plastino & E.C. Oliveira	–	Infl[43], Oxi[66], Coag[83], Photo[87]	Poly[43, 83], Ctn[66], Maa[87]
Gracilaria cearensis (A.B.. Joly & Pinheiro) A.B.. Joly & Pinheiro	Vir[6]	Oxi[67]	Cex[6, 67], Phe[67]
Gracilaria cervicornis Turner. (J. Agardh) (=*Gracilaria ferox*)	–	Oxi[67], Coag[80]	Hem[80], Cex[67], Phe[67]
Gracilaria debilis (Forsskål) Børgesen	Bact[2]	–	Cex[2]
Gracilaria domingensis (Kützing) Sonder ex Dickie	Bact[1]	Cyto[54], Oxi[66, 67], Coag[84], Photo[87]	Cex[1, 54, 67], Phe[67], Ctn[66], Hem[84], Maa[87]
Gracilaria foliifera (Forsskål) Børgesen	Bact[2]	–	Cex[2]
Gracilaria ornata Areschoug	Bact[4], Inse[88]	–	Poly[4], Lec[88]
Gracilariopsis andersonii (Grunow) E.Y. Dawson (=*Gracilariopsis sjoestedtii*)	Bact[2]	–	Cex[2]
Grateloupia doryphora (Montagne) M.A. Howe	–	Cyto[54]	Cex[54]
Gymnogongrus griffithsiae (Turner) Martius	Vir[14]	–	Gal[14], Carr[14]
Haloplegma duperreyi Montagne	–	Coag[79]	Cex[79]
Halymenia floresii (Clemente) C. Agardh	–	Coag[82]	Poly[82]
Hydropuntia caudata (J. Agardh) Gurgel & Fredericq (=*Gracilaria caudata*)	–	Tumo[60], Oxi[60]	Poly[60]
Hydropuntia cornea (J. Agardh) M.J. Wynne (=*Gracilaria cornea*)	Inse[89]	Infl[40], Nocic[40], Coag[83]	Lec[89], Poly[40, 83]
Hypnea musciformis (Wulfen) J.V. Lamouroux	Bact[2], Vir[7, 10]	Cyto[49,54], Oxi[49, 67], Coag[49, 80], Tumo[49]	Cex[2, 10, 54, 67], Glyc[7], Gal[49], Hem[80], Phe[67]
Hypnea spinella (C. Agardh) Kützing (=*Hypnea cervicornis*)	Vir[6]	Infl[36, 63], Nocic[63]	Cex[6], Lec[36], Agg[63]
Jania adhaerens J.V. Lamouroux	Vir[6]	–	Cex[6]

Table 1 (continued)

Species	Antibiotic activities	Biological activities	Chemical compounds
Jania verrucosa J.V. Lamouroux (=*Jania crassa*)	Vir[6]	–	Cex[6]
Jania rubens (Linnaeus) J.V. Lamouroux	–	Foul[30]	Cex[30]
Laurencia aldingensis Saito & Womersley	Fung[18]	Cyto[51]	Cex[18, 51]
Laurencia caduciramulosa Masuda & Kawaguchi	–	Foul[29]	Terp[29]
Laurencia catarinensis Cordeiro-Marino & Fujii	Fung[18]	Cyto[51, 77]	Cex[18, 51], Halo[77]
Laurencia dendroidea J. Agardh	Fung[18], Proto[20], Vir[6]	Cyto7[51]	Cex[6, 18, 51], Terp[20]
Laurencia dichotoma Cordeiro-Marino, Toyota et Pinheiro-Joventino	–	Coag[79]	Cex[79]
Laurencia intricata J.V. Lamouroux	Fung[18]	Cyto[51]	Cex[18, 51]
Laurencia microcladia Kützing	–	Coag[79]	Cex[79]
Laurencia obtusa (Hudson) J.V. Lamouroux	Bact[2]	–	Cex[2]
Laurencia scoparia J. Agardh	Helm[19]	–	Terp[19], Ald[19]
Laurencia translucida Fujii & Cordeiro-Marino	Fung[18]	Cyto[51]	Cex[18, 51]
Meristotheca gelidium (J. Agardh) E.J. Faye & M. Masuda (=*Meristiella gelidium*)	Vir[10, 13]	Coag[79]	Cex[10, 79], Crg[13]
Osmundaria obtusiloba (C. Agardh) R.E. Norris (=*Vidalia obtusiloba*)	Bact[2], Vir[7, 10]	Foul[28], Oxi[67], Coag[79]	Cex[2, 10, 28, 67, 79], Glyc[7], Phe[67]
Osmundaria volubilis (Linnaeus) R.E. Norris (=*Vidalia volubilis*)	–	Coag[79]	Cex[79]
Palisada flagellifera (J. Agardh) K.W. Nam	–	Cyto[51]	Cex[51]
Palisada perforata (Bory de Saint-Vincent) K.W. Nam (=*Laurencia papillosa*)	Bact[2]	Coag[79]	Cex[2, 79]
Plocamium brasiliense (Greville) M.A. Howe & W.R. Taylor	Vir[6]	Oxi[67]	Cex[6, 67], Phe[67]
Neosiphonia ferulacea (Suhr ex J. Agardh) S.M. Guimarães & M.T. Fujii (=*Polysiphonia ferulacea*)	Bact[2]	–	Cex[2]
Pyropia acanthophora (E.C. Oliveira & Coll) M.C. Oliveira, D. Milstein & E.C. Oliveira (=*Porphyra acanthophora*)	Vir[7]	–	Glyc[7]
Pyropia columbina (Montagne) W.A. Nelson (=*Porphyra columbina*)	–	Cyto[52]	Aga[52]
Pterocladiella capillacea (S.G. Gmelin) Santelices & Hommersand	Vir[6, 7, 10]	Foul[28], Infl[46], Cyto[54], Nocic[46], Oxi[67], Coag[83]	Cex[6, 10, 28, 54, 67], Glyc[7], Phe[67], Poly[83], Lec[46]
Solieria filiformis (Kützing) P.W. Gabrielson	Bact[5]	Infl[42, 81], Coag[81, 83], Nocic[42]	Lec[5], Poly[42, 83], Crg[81]
Spyridia clavata Kützing	Vir[6]	Oxi[67]	Cex[6, 67], Phe[67]
Tricleocarpa cylindrica (Ellis & Solander) Huisman & Borowitzka	Vir[6]	–	Cex[6]

Abbreviations for types of activity: *Bact* antibacterial, *Fung* antifungal, *Inse* insecticidal, *Hel* antihelminthic, *Proto* antiprotozoal, *Vir* antiviral, *Coag* effects on coagulation, *Cyto* cytotoxicity, *Foul* antifouling, *Heal* healing, *Immu* immunostimulatory, *Infl* antiinflammatory, *Ophi* antiophidic, *Oxi* antioxidant activity, *Nocic* antinociceptive, *Photo* photoprotective, *Tumo* antitumor; Abbreviations for types of chemical compounds: *Aga* Agaran, *Agg* agglutinin, *Ald* aldehyde, *Alg* alginate, *Alk* alkaloid, *Carb* carbohydrate fraction, *Cex* crude extract, *Cho* cholesterol, *Crg* carrageenan, *Ctn* carotenoids, *Fuc* fucan, *Gal* galactan, *Glyc* glycolipids, *Halo* halogenated compounds, *Hem* hemagglutinin, *Lec* lectin, *Maa* mycosporine-like amino acids, *Phe* total phenolic, *Poly* total polysaccharides, *Shet* sulfated heterorhamnan, *Terp* terpene

[a] Non-native species (commercial resource)

Numbers indicate references: [1] Lima-Filho et al. 2002, [2] Vieira and Caland-Noronha 1971, [3] Teixeira et al. 2007, [4] Amorim et al. 2012, [5] Holanda et al. 2005, [6] Soares et al. 2012a, [7] Mattos et al. 2011, [8] Pinto et al. 2012, [9] Vallim et al. 2010, [10] Santos et al. 1999, [11] Cassolato et al. 2008, [12] Talarico et al. 2007, [13] Faria et al. 2006b, [14] Talarico et al. 2005, [15] Duarte et al. 2004, [16] Duarte et al. 2001b, [17] Queiroz et al. 2008, [18] Stein et al. 2011b, [19] Davyt et al. 2001, [20] Machado et al. 2011, [21] Rocha et al. 2011, [22] Felício et al. 2010, [23] Santos et al. 2011, [24] Soares et al. 2012b, [25] Cirne-Santos et al. 2006, [26] Soares et al. 2008, [27] Plouguerné et al. 2012, [28] Appelhans et al. 2010, [29] Cassano et al. 2008, [30] Medeiros et al. 2007, [31] Bianco et al. 2009, [32] Domingos et al. 2012, [33] Moura et al. 2011, [34] Toyama et al. 2010, [35] Siqueira et al. 2011, [36] Figueiredo et al. 2010, [37] Cavalcante-Silva et al. 2012, [38] Matta et al. 2011, [39] Souza et al. 2009, [40] Coura et al. 2012, [41] Rodrigues et al. 2012, [42] Araújo et al. 2011, [43] Vanderlei et al. 2011, [44] Silva et al. 2005, [45] Marques et al. 2012, [46] Silva et al. 2010, [47] Souza et al. 2012, [48] Cardoso et al. 2010, [49] Alves et al. 2012, [50] Garrido et al. 2011, [51] Stein et al. 2011a, [52] Stevan et al. 2001, [53] Queiroz et al. 2006, [54] Lhullier et al. 2006, [55] Oliveira et al. 2008, [56] Rocha et al. 2007, [57] Pinto et al. 2009, [58] Magalhães et al. 2011, [59] Costa et al. 2011, [60] Costa et al. 2010, [61] Lins et al. 2009, [62] Assreuy et al. 2008, [63] Bitencourt et al. 2008, [64] Vieira et al. 2004, [65] Farias et al. 2011, [66] Guarantini et al. 2012, [67] Martins et al. 2012a, [68] Costa et al. 2012, [69] Camara et al. 2011, [70] Souza et al. 2007b, [71] Paiva et al. 2011, [72] Lima et al. 1998, [73] Pereira et al. 2005, [74] Rocha et al. 2005, [75] Farias et al. 2000, [76] Melo et al. 2012, [77] Lhullier et al. 2010, [78] Azevedo et al. 2009, [79] Ainouz et al. 1992, [80] Ainouz and Sampaio 1991, [81] Araújo et al. 2012, [82] Amorim et al. 2011, [83] Rodrigues et al. 2010, [84] Benevides et al. 1999, [85] Freitas et al. 1995, [86] Medeiros et al. 2008, [87] Cardozo et al. 2011, [88] Leite et al. 2005, [89] Lima et al. 2005, [90] Leite et al. 2004, [91] Nascimento-Neto et al. 2012 *maculatus* (F.) and the cattle tick *Boophilus microplus* Canestrini), although with few seaweed species (Table 1, Online Resource 1).

Other biological activities

Eleven biological activities were cataloged, and a large number of species were tested for three of them. Thirty-six species were tested for antioxidant activity; *Caulerpa* spp. and *Solieria filiformis* were the most studied. Thirty species of seaweeds were evaluated for cytotoxicity, mostly *Codium* spp., *H. musciformis*, and the *Laurencia* complex. The coagulation effects of 46 species were investigated for anticoagulant, hemagglutinating, and antithrombotic activities, mainly by applying extracts of *Caulerpa* spp., *S. schroederi*, *Dictyota* spp., *H. musciformis*, *B. seaforthii*, and *B. triquetrum* (Table 1, Online Resource 1).

Antiinflammatory activity was most frequently studied (27 papers) followed by antinociceptive activity (15 papers) (Online Resource 1). The effects of 15 species of seaweeds were observed on inflammatory reactions, including antiinflammatory responses as well as edema and inflammation induction. The activities of *Caulerpa* spp., *L. variegata*, *Padina gymnospora*, and *S. filiformis* were the most studied. Antinociceptive activity was primarily tested by applying extracts of *Caulerpa* spp., *Hypnea cervicornis* J. Agardh, *B. seaforthii*, and *B. triquetrum*.

In addition to these biological activities, studies assessed the neutralizing effects of seaweed extracts on venom from the snakes *Crotalus durissus cascavella* L. and *Lachesis muta* L. and the applicability of extracts as antifouling agents against the microalgae *Cylindrotheca closterium* (Ehrenberg) Reimann & J.C. Lewin, *Chlorarachnion globosum* K. Ishida & Y. Hara, *Pleurochrysis roscoffensis* (P.A. Dangeard) J. Fresnel & C. Billard, *Rhodella cyanea* C. Billard & J. Fresnel, *Scenedesmus armatus* (R. Chodat) R. Chodat; a mollusk (*Perna perna* L.); and biofilm (*Vibrio aestuarianus* and *Pseudoalteromonas elyakovii*). Some studies also tested the antitumoral activity against tumoral ovarian cells in mice, human melanoma, and sarcoma, and the antiproliferative effect on HeLa cells (derived from cervical cancer linked to HPV). *Bryothamnion seaforthii* and *B. triquetrum* were applied as markers of human colon carcinoma cells; *B. seaforthii* acted as a marker of central nervous system primary tumors.

Natural products from seaweeds

Classes of substances extracted and isolated from species of seaweeds were also cataloged (Table 2). These chemical compounds were analyzed from 19 species of Chlorophyta, 21 Heterokontophyta, and 80 Rhodophyta. For some of these species, a wide range of natural products is described: *C. racemosa*, *S. schroederi*, and *Cryptonemia crenulata* (Table 2). The most characterized natural products of seaweeds (Table 2) were sulfated polysaccharides (75 papers), lectins, a family of proteins (30 papers), and terpenes (22 papers). Other chemical compounds were less investigated, including phenolic compounds and carotenoids as antioxidants and caulerpin, an alkaloid, from *Caulerpa* spp. as an antinociceptive and antiinflammatory agent.

Polysaccharides

The sulfated polysaccharides that were characterized and isolated from seaweeds show a vast range of activities. A sulfated fucan from *S. schroederi* has antibacterial activity (Leite et al. 2004). Iota-carrageenan from *Cryptonemia crenulata* has activity against the Dengue virus (Talarico et al. 2005), a sulfated heterorhamnan from *Gayralia oxysperma* acts against *Herpes simplex* (Cassolato et al. 2008), a fucan isolated from *Laminaria abyssalis* inhibited HTLV-1 (Romanos et al. 2002), and a sulfated galactan extracted from *Botryocladia occidentalis* Kylin shows antiophidic activity (Toyama et al. 2010). Several polysaccharides from *Caulerpa* spp., *C. cervicornis*, *Dictyota* spp., *S. schroederi*, *B. occidentalis*, *B. seaforthii* and *B. triquetrum*, *Champia feldmannii*, *Gracilaria birdiae*, *Hypnea* spp., and *S. filiformis* also show antiproliferative, antioxidant, and anticoagulant activities (Alves et al. 2012; Ainouz and Sampaio 1991; Costa et al. 2010). In addition, these extracts have antinociceptive, immunostimulant (Viana et al. 2002; Assreuy et al. 2008; Farias et al. 2011), and antiinflammatory (Araújo et al. 2011, 2012; Vanderlei et al. 2011) activities.

Lectins

Lectins were characterized in Brazil from species of Chlorophyta, Heterokontophyta, and Rhodophyta (Ainouz et al. 1992; Sampaio et al. 1998a, b; Nagano et al. 2005). This family of compounds shows potential biological applications. Lectins from *B. seaforthii*, *B. triquetrum*, and *S. filiformis* act as antibacterials (Teixeira et al. 2007; Holanda et al. 2005). Insecticidal activity against two arthropods was found in lectins from *Gracilaria cornea* and *Gracilaria ornata* (Lima et al. 2005; Leite et al. 2005). Lectins can also act as an immunostimulator (Lima et al. 1998) and can help to heal skin sores (Nascimento-Neto et al. 2012). However, the most studied activities of lectin were antiinflammatory, antinociceptive, anticoagulant, and antitumor, principally from *Pterocladia capillacea* (Silva et al. 2010; Oliveira et al. 2002), *H. cervicornis* (Figueiredo et al. 2010), *B. seaforthii*, and *B. triquetrum* (Pinto et al. 2009).

Table 2 Natural products extracted from selected seaweeds

Species	Sulfated polysaccharides	Protein	Other natural products
Chlorophyta			
Acetabularia calyculus J.V. Lamouroux	–	Lec[9]	–
Anadyomene stellata (Wulfen) C. Agardh	–	Lec[9]	–
Caulerpa cupressoides (Vahl) C. Agardh	Poly[73]	Hem[9], Lec[9, 16]	Amn[14], Ctn[19], Toco[19], Ret[19]
Caulerpa fastigiata Montagne	–	AA[30], Ptn[30]	–
Caulerpa mexicana Sonder ex Kützing	–	–	Amn[14], Ctn[19], Toco[19], Ret[19]
Caulerpa prolifera (Forsskål) J.V. Lamouroux	–	–	Ctn[19], Toco[19], Ret[19]
Caulerpa racemosa (Forsskål) J. Agardh	Poly[70], Carb[70]	AA[30], Ptn[30]	Amn[14], Ctn[19], Toco[19], Ret[19],
Caulerpa sertularioides (S.G. Gmelin) M.A. Howe	–	–	Amn[14]
Caulerpa verticillata J. Agardh	–	–	Fat[20], Inc[40]
Cladophora prolifera (Roth) Kützing	–	–	Amn[14], Ctn[19], Toco[19], Ret[19]
Codium decorticatum (Woodward) M.A. Howe	–	AA[30], Ptn[30]	Ctn[19], Toco[19], Ret[19]
Codium isthmocladum Vickers	–	–	–
Codium spongiosum Harvey	–	AA[30], Ptn[30]	–
Codium taylorii P.C. Silva	–	AA[30], Ptn[30]	–
Gayralia oxysperma (Kützing) K.L. Vinogradova ex Scagel	–	Lec[9]	–
Ulva lactuca Linnaeus (=*Ulva fasciata*)	Poly[71]	AA[30], Ptn[30], Lec[8]	Amn[14], Ctn[19], Toco[19], Ret[19], Fat[75]
Ulva laetevirens Areschoug	–	Lec[10]	–
Heterokontophyta			
Canistrocarpus cervicornis (Kützing) De Paula & De Clerck (=*Dictyota cervicornis*)	–	–	Fat[20], Terp[29, 31, 37] Phen[37], Ste[38], Inc[40]
Canistrocarpus crispatus (J.V. Lamouroux) De Paula & De Clerck (=*Dictyota crispata*)	–	–	Terp[29]
Chnoospora minima (K. Hering) Papenfuss	–	AA[30], Ptn[30]	–
Dictyopteris delicatula J.V. Lamouroux	–	Lec[9]	Ctn[19], Toco[19], Ret[19], Amn[14], Ste[38]
Dictyopteris plagiogramma (Montagne) Vickers	–	–	Fat[20], Inc[40]
Dictyopteris polypodioides (A.P.De Candolle) J.V. Lamouroux (=*Dictyopteris justii*)	–	Lec[9]	Fat[20], Inc[40]
Dictyota crenulata J. Agardh	–	–	Terp[27]
Dictyota dichotoma (Hudson) J.V. Lamouroux (=*Dictyota pardalis*)	–		Terp[31], Ste[38], Ctn[19], Toco[19], Ret[19], Amn[14]
Dictyota guineensis (Kützing) P.L. Crouan & H.M. Crouan	–	–	Terp[23]
Dictyota menstrualis (Hoyt) Schnetter, Hörning & Weber-Peukert	–	AA[30], Ptn[30]	Terp[25]
Dictyota mertensii (Martius) Kützing	Fuc[69], Ala[69]	Lec[9]	Terp[26, 37], Phen[37], Ste[38]
Dictyota friabilis Setchell (=*Dictyota pfaffii*)	–	–	Terp[36],
Laminaria abyssalis A.B.. Joly & E.C. Oliveira (=*Laminaria brasiliensis*)	Alg[52], Oli[58]	–	–
Lobophora variegata (Lamouroux) Womersley	–	–	Amn[14], Ctn[19], Toco[19], Ret[19]
Padina gymnospora (Kützing) Sonder	Ala[49, 69], Fuc[49, 69]	AA[30], Ptn[30]	Ctn[19], Toco[19], Ret[19], Fat[20], Inc[40]
Sargassum cymosum C. Agardh	–	–	Ctn[19], Toco[19], Ret[19], Fat[75]
Sargassum filipendula C. Agardh	–	–	Ste[38]
Sargassum furcatum Kützing	–	–	Terp[37], Phen[37], Ste[38]
Sargassum stenophyllum Martius	Fuc[41], Oli[41]	–	–
Sargassum vulgare C. Agardh	Fuc[69], Ala[69] Alg[63]	AA[30], Ptn[30]	–
Spatoglossum schroederi (C. Agardh) Kützing	Alg[39], Fuc [68]	–	Terp[17, 25]
Stypopodium zonale (J.V. Lamouroux) Papenfuss	–	–	Terp[17, 74]
Rhodophyta			
Acanthophora spicifera (Vahl) Børgesen	–	AA[30], Ptn[30]	Ctn[19], Ret[19]
Agardhiella ramosissima (Harvey) Kylin	–	Lec[9]	–
Aglaothamnion uruguayense (W.R. Taylor) N.E. Aponte, D.L. Ballantine & J.N. Norris	–	AA[30], Ptn[30]	–
Amansia multifida J.V. Lamouroux	Gal[59]	Lec[4]	Ctn[19], Toco[19], Ret[19]
Asparagopsis taxiformis (Delile) Trevisan de Saint-Léon	–	–	Fat[20], Inc[40]
Bostrychia calliptera (Montagne) Montagne	–	–	Vlt[22]

Table 2 (continued)

Species	Sulfated polysaccharides	Protein	Other natural products
Bostrychia montagnei Harvey	Gal[56], Oli[57]	–	–
Bostrychia radicans (Montagne) Montagne	–	–	Amd[21], Phe[21]
Bostrychia scorpioides (Hudson) Montagne ex Kützing (=*Bostrychia binderi*)	Gly[12]	Lec[9]	–
Bostrychia tenella (J.V. Lamouroux) J. Agardh	–	–	Vlt[22]
Botryocladia occidentalis (Børgesen) Kylin	Poly[44]	–	Amn[14], Ctn[19], Ret[19]
Bryothamnion seaforthii (Turner) Kützing	Carb[72]	Lec[11, 13]	Amn[14], Ctn[19], Toco[19], Ret[19]
Bryothamnion triquetrum (S.G. Gmelin) M.A. Howe	Carb[72]	Lec[11]	Amn[14], Ctn[19], Toco[19], Ret[19]
Calliblepharis occidentalis Joly & Yamaguishi-Tomita	–	Lec[9]	–
Champia feldmannii Díaz-Piferrer	Poly[67]	–	–
Chondracanthus teedei (Mertens ex Roth) Kützing (=*Gigartina teedii*)	Crg[48]	–	–
Chrysymenia halymenioides Harvey	–	Lec[9]	–
Corallina officinalis Linnaeus	–	–	Ctn[19], Ret[19]
Cryptonemia crenulata (J. Agardh) J. Agardh	Crg[48]		Amn[14], Ctn[19], Toco[19], Ret[19]
Cryptonemia seminervis (C. Agardh) J. Agardh	Gal[54]	AA[30], Ptn[30]	–
Dichotomaria marginata (J. Ellis & Solander) Lamarck (=*Galaxaura marginata*)	Xyl[35]	–	–
Dichotomaria obtusata (J. Ellis & Solander) Lamarck (=*Galaxaura obtusata*)	Xyl[35]	Lec[9, 35]	–
Enantiocladia duperreyi (C. Agardh) Falkenberg	–	Lec[7]	Ctn[19], Toco[19], Ret[19]
Galaxaura rugosa (J. Ellis & Solander) J.V. Lamouroux	–	–	Fat[20], Inc[40]
Gelidium americanum (W.R. Taylor) Santelices (=*Pterocladia americana*)	–	–	Ctn[19], Toco[19], Ret[19]
Gelidium pusillum (Stackhouse) Le Jolis	–	Lec[5]	–
Gracilaria birdiae E.M. Plastino & E.C. Oliveira	Oli[61]	Maa[64]	Ctn[19], Toco[19], Ret[19]
Gracilaria cervicornis Turner (J. Agardh) (=*Gracilaria ferox*)	Aga[66]	–	Ctn[19], Toco[19], Ret[19]
Gracilaria chilensis C.J. Bird, McLachlan & E.C. Oliveira	Aga[46]	–	–
Gracilaria curtissiae J. Agardh	–	Hem[9], Lec[9]	–
Gracilaria cylindrica Børgesen	–	Lec[9]	–
Gracilaria domingensis(Kützing) Sonder ex Dickie	Poly[45], Oli[45]	AA[30], Ptn[30], Lec[5], Maa[64]	Ctn[19], Toco[19], Ret[19]
Gracilaria dura[b] (C. Agardh) J. Agardh	Aga[65]	–	–
Gracilaria foliifera (Forsskål) Børgesen	–	Hem[9], Lec[9]	–
Gracilaria gracilis (Stackhouse) M. Steentoft, L.M. Irvine & W.F. Farnham	Aga[46]	–	–
Gracilaria tenuistipitata C.F. Chang & B.M. Xia	Aga[46]	Maa[64]	–
Gracilaria venezuelensis W.R. Taylor	–	Lec[9]	–
Gracilariopsis longissima (S.G. Gmelin) M. Steentoft, L.M. Irvine & W.F. Farnham (=*Gracilaria verrucosa*)	–	Lec[9]	–
Gracilariopsis tenuifrons (C.J. Bird & E.C. Oliveira) Fredericq & Hommersand	–	AA[30], Ptn[30]	–
Gymnogongrus griffithsiae (Turner) Martius	Crg[48]	–	–
Halymenia floridana J. Agardh (=*Halymenia gelinaria*)	–	Lec[9]	–
Halymenia pseudofloresii F.S. Collins & M.A. Howe	–	Lec[9]	–
Heterodasya mucronata (Harvey) M.J. Wynne (=*Heterodasya sertularioides*)	–	Hem[9], Lec[9]	–
Hydropuntia caudata (J. Agardh) Gurgel & Fredericq (=*Gracilaria caudata*)	Aga[46,] Poly[71]	–	Ctn[19], Ret[19]
Hydropuntia cornea (J. Agardh) M.J. Wynne (=*Gracilaria cornea*)	Gal[62], Aga[66]	–	–
Hydropuntia edulis (S.G. Gmelin) Gurgel et Fredericq (=*Gracilaria edulis*)	Aga[60]	–	–
Hypnea musciformis (Wulfen) J.V. Lamouroux	Crg[48]	Lec[2]	Ctn[19], Ret[19], Fat[75]
Hypnea spinella (C. Agardh) Kützing (=*Hypnea cervicornis*)	–	Agg[1], Lec[2]	Ctn[19], Ret[19]
Kallymenia westii Ganesan	–	Lec[9]	–
Kappaphycus alvarezii[b](Doty) Doty ex P.C. Silva	Aga[53], Crg[51, 53], Oli[53]	–	–
Laurencia aldingensis Saito & Womersley	–	–	Terp[32]
Laurencia caduciramulosa Masuda & Kawaguchi	–	–	Terp[28]
Laurencia dendroidea J. Agardh	–	–	Vlt[18]

Table 2 (continued)

Species	Sulfated polysaccharides	Protein	Other natural products
Laurencia filiformis (C. Agardh) Montagne	–	–	Terp[34]
Meristotheca gelidium (J. Agardh) E.J. Faye & M. Masuda (=*Meristiella echinocarpum*, *Meristiella gelidium*)	Crg[55]	–	–
Nemalion helminthoides[b] (Velley) Batters	Man[43], Oli[43], Xyl[43]	–	–
Neosiphonia ferulacea (Suhr ex J. Agardh) S.M. Guimarães & M.T. Fujii (=*Polysiphonia ferrulacea*)	–	Lec[9]	–
Osmundaria obtusiloba (C. Agardh) R.E. Norris (=*Vidalia obtusiloba*)	–	–	Ctn[19], Toco[19], Ret[19]
Palisada flagellifera (J. Agardh) K.W. Nam (=*Chondrophycus flagelliferus*, *Laurencia flagellifera*)	Aga[33], Man[50]	AA[30], Ptn[30]	–
Palisada perforata (Bory de Saint-Vincent) K.W. Nam (=*Chondrophycus papillosus*, *Laurencia papillosa*)	Man[50]	–	–
Palmaria palmata[a] (Linnaeus) Weber & Mohr	Xyl[35]	–	–
Plocamium brasiliense (Greville) M.A. Howe & W.R. Taylor	–	AA[30], Ptn[30]	Terp[24]
Pyropia acanthophora (E.C. Oliveira & Coll) M.C. Oliveira, D. Milstein & E.C. Oliveira (=*Porphyra acanthophora*)	Poly[71]	AA[30], Ptn[30]	–
Pyropia columbina (Montagne) W.A. Nelson (=*Porphyra columbina*)	Crg[42]	–	–
Pterocladiella capillacea (S.G. Gmelin) Santelices & Hommersan	Aga[47]	AA[30], Ptn[30], Lec[16]	–
Ptilota filicina J. Agardh	–	Lec[6]	–
Ptilota plumosa C. Agardh	–	Lec[3]	–
Ptilota serrata Kützing	–	Lec[15]	–
Scinaia halliae (Setchell) Huisman	Xyl[35]	–	–
Solieria filiformis (Kützing) P.W. Gabrielson	Crg[48]	Lec[16]	Ctn[19], Ret[19]
Spyridia clavata Kützing	–	Lec[9]	–
Tricleocarpa cylindrica (Ellis & Solander) Huisman & Borowitzka	Xyl[35]	–	–
Tricleocarpa fragilis (Linnaeus) Huisman & R.A. Townsend (=*Galaxaura oblongata*)	Xyl[35]	Lec[9]	–

AA amino acid composition, *Aga* Agaran, *Ala* alginic acid, *Alg* alginate, *Alk* alkaloid, *Amd* amides, *Amn* amines, *Carb* Carbohydrate fraction, *Crg* Carragenan, *Ctn* carotenoids, *Fat* fatty acids, *Fuc* fucan, *Gal* sulfated galactans, *Gly* glycoside, *Inc* inorganic elements content, *Maa* mycosporine-like amino acids, *Man* sulfated mannan, *Oli* oligosaccharide, *Phen* phenolic compounds, *Poly* total polysaccharides, *Ptn* total protein, *Ret* retinol, *Terp* terpene, *Toco* tocopherol, *Ste* Sterol, *Vlt* volatile compounds, *Xyl* xylans

[a] Non-native species (commercial resource)

[b] Exotic species

Numbers indicate references: [1] Nascimento et al. 2006, [2] Nagano et al. 2005, [3] Sampaio et al. 2002, [4] Costa et al. 1999, [5] Benevides et al. 1999, [6] Sampaio et al. 1998a, [7] Benevides et al. 1998, [8] Sampaio et al. 1998b, [9] Freitas et al. 1997, [10] Sampaio et al. 1996, [11] Ainouz et al. 1995, [12] Ascêncio et al. 2006, [13] Nascimento-Neto et al. 2012, [14] Alencar et al. 2011, [15] Sampaio et al. 1998c, [16] Abreu et al. 2012, [17] Soares et al. 2003, [18] Gressler et al. 2012, [19] Sousa et al. 2008, [20] Ferreira et al. 2012b, [21] Oliveira et al. 2012, [22] Oliveira et al. 2009, [23] de Paula et al. 2012, [24] Vasconcelos et al. 2010, [25] Cavalcanti et al. 2008, [26] Freitas et al. 2007, [27] de Paula et al. 2008, [28] Cassano et al. 2008, [29] de Paula et al. 2007, [30] Lourenço et al. 2002, [31] de Paula et al. 2001, [32] Carvalho et al. 2006, [33] Ferreira et al. 2012a, [34] Antunes et al. 2008, [35] Viana et al. 2011, [36] Barbosa et al. 2003, [37] Fleury et al. 1994a, [38] Fleury et al. 1994b, [39] Mandelli 1964, [40] Ferreira et al. 2012c, [41] Duarte et al. 2001a, [42] Noseda et al. 2000, [43] Recalde et al. 2008, [44] Barroso et al. 2007, [45] Guimarães et al. 2007,[46] Macchiavello et al. 1999, [47] Oliveira-Filho et al. 1996, [48] Oliveira-Filho and Saito 1990, [49] Andrade and Amado-Filho 2004, [50] Cardoso et al. 2007, [51] Reis et al. 2011, [52] Cosson et al. 1995, [53] Gonçalves et al. 2010,[54] Zibetti et al. 2009, [55] Faria et al. 2006a, b, [56] Duarte 2002, [57] Noseda et al. 1999, [58] Duarte et al. 1991, [59] Souza et al. 2007a, [60] Durairatnam 1987, [61] Maciel et al. 2008, [62] Melo et al. 2002, [63] Torres et al. 2007, [64] Cardozo et al. 2011, [65] Marinho-Soriano and Bourret 2004, [66] Marinho-Soriano et al. 2001,[67] Assreuy et al. 2008, [68] Leite et al. 1998, [69] Dietrich et al. 1995, [70] Rodrigues et al. 2009, [71] Araújo et al. 2009, [72] Viana et al. 2002, [73] Rodrigues et al. 2012, [74] Soares et al. 2012a, [75] Martins et al. 2012b

Terpenes

The main terpenes identified from *Dictyota* spp. and *C. cervicornis* were diterpenes such as dolabellanes and dolastanes. They show strong antiviral activity against herpes simplex and HIV (Soares et al. 2012a; Vallim et al. 2010; Santos et al. 2008; Teixeira et al. 2008) and also as antileishmanials (Santos et al. 2011; Soares et al. 2012b), antifouling agents (Bianco et al. 2009), and anticoagulants (Andrade Moura et al. 2011). Terpenes from *S. schroederi* neutralize the effect of snake venom (Domingos et al. 2012). Species of the *Laurencia* complex produce sesquiterpenes such as elatol, which have antifouling (Cassano et al. 2008) and antileishmanial (Machado et al. 2011) activities. In Brazil, this class of compounds has been found only in Heterokontophyta and Rhodophyta.

As seen in this overview, seaweed biotechnology in Brazil is expanding, and a wide range of studies using species of Chlorophyta, Heterokontophyta, and Rhodophyta have been published, testing for various biological activities. There has been a tendency to focus on antiinflammatory, antinociceptive, and antiviral activities and to characterize the effects of sulfated polysaccharides, protein compounds, and terpenes.

Future studies should determine the circumstances in which the well-characterized chemical compounds are produced. It is useful to learn how the many abiotic factors affect metabolic pathways and consequently influence the production of these substances with biological and antibiotic activities. These studies should compare populations in the natural environment and their thalli cultured in vitro. In parallel, screening studies should be done in other species, in view of the richness of species in Brazil.

The natural sources of species of interest must be determined, in order to analyze the sustainability of exploitation from an industrial and commercial perspective. It is useful to explore the biodiversity of the seaweed flora of Brazil for valuable bioactive compounds, but exploitation of this resource needs to be balanced with sustainability and environmental considerations.

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