frontiers in
MARINE SCIENCE

ORIGINAL RESEARCH ARTICLE
published: 22 July 2014
doi: 10.3389/fmars.2014.00024

Anti-inflammatory activity in selected Antarctic benthic organisms

Juan Moles[1]*, Anna Torrent[2], M. José Alcaraz[3], Ramon Ruhí[2] and Conxita Avila[1]

[1] *Department of Animal Biology (Invertebrates), Biodiversity Research Institute (IrBIO), Universitat de Barcelona, Barcelona, Catalonia, Spain*
[2] *R&D Department, Bioibérica, Barcelona, Catalonia, Spain*
[3] *Department of Pharmacology and Pharmacodynamics, University of Valencia, Valencia, Spain*

Edited by:
Donatella De Pascale, National Research Council- CNR, Italy

Reviewed by:
Maria Rosaria Coscia, National Research Council of Italy, Italy
Giovanna Romano, Stazione Zoologica Anton Dohrn, Italy

****Correspondence:***
Juan Moles, Department of Animal Biology (Invertebrates), Biodiversity Research Institute (IrBIO), Universitat de Barcelona, Av. Diagonal 643, 08028 Barcelona, Catalonia, Spain
e-mail: moles.sanchez@gmail.com

Antarctic benthos was prospected in search for anti-inflammatory activity in polar benthic invertebrates, in two different geographical areas: deep-bottoms of the Eastern Weddell Sea and shallow-waters of the South Shetland Islands. A total of 36 benthic algae and invertebrate species were selected to perform solubility tests in order to obtain extracts that were soluble at an innocuous ethanol concentration (0.2%) for cell culture, and further test them for anti-inflammatory activity. From these, ethanol extracts of ten species from five different phyla resulted suitable to be studied in cell macrophage cultures (RAW 264.7). Cytotoxicity (MTT method) and production of inflammatory mediators (prostaglandin E_2, leukotriene B_4, interleukin-1β) were determined at three extract concentrations (50, 125, 250 μg/mL). Bioassays resulted in four different species showing anti-inflammatory activity corresponding to three sponges: *Mycale* (*Oxymycale*) *acerata*, *Isodictya erinacea*, and *I. toxophila*; and one hemichordate: *Cephalodiscus* sp. These results show that Antarctic sessile invertebrates may have great value as a source of lead compounds with potential pharmaceutical applications.

Keywords: inflammatory inhibitor, Antarctic benthic invertebrates, sponge, hemichordate, marine natural products

INTRODUCTION

The Ocean harbors a rich source of both biological and chemical diversity. Although this diversity is the source of unique chemical compounds, its potential for pharmaceutical applications remains still underexplored (Kijjoa and Sawangwong, 2004; Albericio et al., 2010). Some marine natural products show useful pharmacological activities and are being developed either as analgesics or to treat inflammation (Jha and Zi-rong, 2004; Mayer et al., 2011). Many sessile and soft bodied benthic organisms possess defensive mechanisms based on the use of chemical compounds, which often display high biological activity (Faulkner, 1995). Recent studies on marine organisms are in fact providing many bioactive natural products, in larger percentages than terrestrial organisms (König et al., 2006; Newman and Cragg, 2012). In particular, organisms from temperate and tropical areas have been the most studied so far, while polar organisms remain almost unknown (Lebar et al., 2007; Avila et al., 2008; Blunt et al., 2013). During several cruises in the Southern Ocean we collected samples of benthic sessile and sluggish organisms in order to evaluate their potential for pharmacological applications. Thus, the aim of this study was to determine the potential anti-inflammatory and pain-killer applications of some Antarctic samples collected in the Eastern Weddell Sea and the South Shetland Islands. In order to do this, we tested the possible inhibition of the production of some important mediators of inflammation and pain. We tested ethanol (EtOH) extracts at different concentrations as a source of natural products from marine organisms. Since inflammation is caused by the release of chemicals from tissues and migrating cells (Korbut and Guzik, 2011), we decided to test the release of some of the most strongly implicated compounds in the inflammation reaction: the prostaglandins (PGs), leukotrienes (LTs), and interleukin-1 (IL-1).

MATERIALS AND METHODS

SAMPLE COLLECTION

Marine benthic invertebrate samples were collected in the Eastern Weddell Sea (Antarctica) during the ANT XXI/2 cruise (November 2003–January 2004) on board the R/V "Polarstern" (AWI, Bremerhaven, Germany). Our samples were obtained from 7 stations at depths ranging from 230 to 600 m sampled with Agassiz and bottom trawls. During ACTIQUIM-I campaigns (2007–2008 and 2008–2009), algae and invertebrate samples from Deception, Livingston, and Snow Islands were sampled by SCUBA at 7 stations (*ca.* 0–15 m depth) (**Table 1**). Organisms were photographed alive and immediately frozen (−20°C) for chemical investigations. Organisms were selected according to potential interest based on ecological observations and/or previous ecological assays (Taboada et al., 2012). Voucher specimens or a portion of each sample was fixed in 10% formalin or 70% EtOH for taxonomical identification. These vouchers are deposited at the Dept. of Animal Biology (Invertebrates), University of Barcelona, Spain.

CHEMICAL EXTRACTION AND SOLUBILITY SCREENING

When necessary, several conspecific specimens from the same station were extracted together in order to obtain enough extract

Table 1 | Data of the benthic algae and invertebrates used in this study, collected in the Weddell Sea and the vicinities of the South Shetland Islands (Deception, Livingston, and Snow Islands) during ANT XXI/2, ACTIQUIM-1, and ACTIQUIM-2 cruises.

Taxonomic group (phylum, class) and species name	Location	Latitude (S)	Longitude (W)	Gear	Depth (m)
ACHROPHYTA, PHAEOPHYCEAE					
Adenocystis utricularis (Bory de Saint-Vincent) Skottsberg, 1907	Snow I.	62° 44.01′	61° 12.2′	SD	1.3
Ascoseira mirabilis Skottsberg 1907 (1)	Livingston I.	62° 45′	60° 20′	SD	0.7
Ascoseira mirabilis Skottsberg 1907 (2)	Deception I.	62° 58′ 12″	60° 29′ 52″	SD	15
**Desmarestia anceps* Montagne, 1842 (1)	Deception I.	62° 59′ 29″	60° 33′ 43″	SD	15
Desmarestia anceps Montagne, 1842 (2)	Livingston I.	62° 45′	60° 20′	SD	0.7
**Desmarestia menziesii* J. Agardh, 1848	Deception I.	62° 58.59′	60° 40.58′	SD	0.4
Phaeurus antarcticus Skottsberg, 1907	Deception I.	62° 58′ 12″	60° 29′ 53″	SD	15
RHODOPHYTA, FLORIDEOPHYCEAE					
Neuroglossum delesseriae (Reinsch) M. J. Wynne, 1997	Deception I.	62° 58.59′	60° 40.58′	SD	0.4
Palmaria decipiens (Reinsch) Ricker, 1987	Deception I.	62° 58.59′	60° 40.58′	SD	0.4
Rhodymenia coccocarpa (Montagne) M. J. Wynne, 2007	Deception I.	62° 58.59′	60° 40.58′	SD	0.4
PORIFERA, DEMOSPONGIAE					
Calyx arcuarius (Topsent, 1913)	Weddell Sea	70° 52.16′	10° 43.69′	BT	290.4
Cinachyra antarctica (Carter, 1872)	Weddell Sea	71° 07.15′	11° 26.23′	AGT	228.4
Dendrilla antarctica Topsent, 1905	Deception I.	62° 59′ 29″	60° 33′ 43″	SD	15
**Homaxinella* cf. *balfourensis* (Ridley and Dendy, 1886)	Deception I.	62° 59′ 29″	60° 33′ 43″	SD	15
**Isodictya erinacea* (Topsent, 1916)	Weddell Sea	70° 52.75′	10° 51.24′	BT	294.8
Isodictya kerguelenensis (Ridley and Dendy, 1886)	Deception I.	62° 58′ 12″	60° 29′ 52″	SD	15
**Isodictya toxophila* Burton, 1932	Weddell Sea	72° 51.43′	19° 38.62′	BT	597.6
**Mycale* (*Oxymycale*) *acerata* Kirkpatrick, 1907	Weddell Sea	70° 52.75′	10° 51.24′	BT	294.8
*Pyloderma latruncul*ioides (Ridley and Dendy, 1886)	Weddell Sea	70° 56.42′	10° 31.61′	BT	284.4
HEXACTINELLIDA					
Anoxycalyx (*Scolymastra*) *joubini* (Topsent, 1916)	Weddell Sea	70° 57.00′	10° 33.02′	BT	332.8
Rossella villosa Burton, 1929	Weddell Sea	70° 55.92′	10° 32.37′	AGT	288
Rossella sp.1	Weddell Sea	70° 55.92′	10° 32.37′	AGT	288
CNIDARIA, ANTHOZOA					
Alcyonium haddoni Wright and Studer, 1889	Deception I.	62° 59′ 29″	60° 33′ 43″	SD	15
Isotealia antarctica Carlgren, 1899	Deception I.	62° 59′ 29″	60° 33′ 43″	SD	15
MOLLUSCA, BIVALVIA					
Laternula elliptica (King, 1832)	Deception I.	62° 58′ 12″	60° 29′ 53″	SD	15
GASTROPODA					
Doris kerguelenensis (Bergh, 1884)	Weddell Sea	70° 52.75″	10° 51.24″	BT	294.8
Nacella polaris (Hombron and Jacquinot, 1841)	Deception I.	62° 59′ 29″	60° 33′ 43″	SD	15
CHORDATA, ASCIDIACEA					
Aplidium falklandicum Millar, 1960	Weddell Sea	70° 55.92′	10° 32.37″	AGT	288
Cnemidocarpa verrucosa (Lesson, 1830)	Weddell Sea	70° 57′	10° 33.02″	BT	332.8
Molgula pedunculata Herdman, 1881	Weddell Sea	70° 52.16′	10° 43.69′	BT	290.4
**Synoicum adareanum* (Herdman, 1902)	Weddell Sea	70° 57′	10° 33.02′	BT	332.8
THALIACEA					
**Salpa* cf. *thompsoni* Foxton, 1961	Deception I.	62°59′	60°37′	SD	15
ECHINODERMATA, ASTEROIDEA					
**Odontaster validus* Koehler, 1906	Deception I.	62° 59′ 29″	60° 33′ 43″	SD	15
ECHINOIDEA					
Sterechinus neumayeri (Meissner, 1900)	Deception I.	62° 59′ 29″	60° 33′ 43″	SD	15
OPHIUROIDEA					
Ophionotus victoriae Bell, 1902	Deception I.	62° 59′	60° 37′	SD	15
NEMERTEA, ANOPLA					
Parborlasia corrugatus (McIntosh, 1876)	Deception I.	62° 59′	60° 37′	SD	15
ANNELIDA, POLYCHAETA					
Aglaophamus trissophyllus (Grube, 1877)	Deception I.	62° 47′	60° 41′ 21″	SD	15
HEMICHORDATA, GRAPTOLITHOIDEA					
**Cephalodiscus* sp.	Weddell Sea	70° 52.16″	10° 43.69′	BT	290.4

*AGT, Agassiz trawl; BT, bottom trawl; SD, scuba diving. *Species selected for the anti-inflammatory assays according to their solubility in ethanol.*

for the experiments. Frozen selected samples were weighted and immediately lyophilized for 24–48 h. Subsequently, dehydrated samples were re-weighted, pounded, and exhaustively extracted with absolute ethanol (1:10 w/v) helping with ultrasonic baths of 10 min. After filtering, the ethanol of the remaining extracts was evaporated *in vacuo*. The solid ethanol extracts were sequentially solubilized at different EtOH/H_2O concentrations: 125 μg/μL EtOH 100%, 5 μg/μL EtOH 4%, and 0.25 μg/μL EtOH 0.2% and freeze-dried immediately. Cell culture was performed only with ethanol extracts that remained soluble at EtOH 0.2%, as it is the highest ethanol concentration innocuous to cells. Ten species with soluble extracts at 0.2% EtOH were chosen to perform anti-inflammatory assays according to the solubility tests. We similarly extracted more individuals and/or the rest of the frozen samples selected in order to obtain enough extract for the anti-inflammatory assays. Infrared spectra of samples and replicates were performed for all the species in order to discard contamination due to extraction methods of the ten species. Wet, dry, and extract's weight of the species selected and those rejected are shown in Supplementary Tables S1, S2, respectively.

CELL CULTURE

The mouse macrophage RAW 264.7 cell line (American Type Culture Collection, Manassas, VA, U.S.A.) was cultured in DMEM medium supplemented with 5% fetal bovine serum. Cells were incubated with marine organisms' extracts at concentrations of 50, 125, and 250 μg/mL (dissolved in 0.2% ethanol). The cells were stimulated with lipopolysaccharide (LPS; 1 μg/ml) and incubated for 24 h, in the presence or absence of extracts. Dexamethasone (1 μM) was used as a reference anti-inflammatory drug. Each test was performed in quadruplicate. Toxicity of the extracts at the concentrations tested was assessed by the mitochondrial-dependent reduction of 3-(4,5-dimethylthiazol-2-yl)-2,5 diphenyltetrazolium bromide to colored formazan (MTT method). The production of inflammatory mediators was determined in cell supernatants by measuring: prostaglandin E_2 (PGE_2) and leukotriene B_4 (LTB_4) by radioimmunoassay and interleukin-1β (IL-1β) by ELISA. Statistical significance was established by ANOVA followed by Dunnett's test. Results indicate mean ± SE (at least $n = 8$ for each group). $^*P < 0.05$, $^{**}P < 0.01$ with respect to LPS control.

RESULTS

SOLUBILITY TESTS

A total of 36 ethanol extracts from benthic algae and invertebrates were dissolved at decreasing ethanol concentrations, down to 0.2% EtOH, to perform the bioactivity assays at an innocuous ethanol concentration (**Table 1**). Ethanol extracts of ten species from five different phyla: Achrophyta (2), Porifera (4), Chordata (2), Echinodermata (1), and Hemichordata (1), resulted suitable, i.e., soluble at EtOH 0.2%, to cell culture (asterisks in **Table 1**).

CYTOTOXICITY

EtOH extracts of the alga *Desmarestia menziesii*, the sponge *Mycale* (*Oxymycale*) *acerata,* and the seastar *Odontaster validus* exhibit cytotoxicity at the two higher concentrations (125 and 250 μg/mL; **Figure 1**). Certain cytotoxicity, only at the highest concentration, was found in the alga *Desmarestia anceps*, the sponge *Isodictya toxophila*, and the hemichordate *Cephalodiscus* sp. Finally, the sponges *Isodictya erinacea* and *Homaxinella* cf. *balfourensis*, the ascidiacean *Synoicum adareanum*, and the thaliacean *Salpa* cf. *thompsoni* were not cytotoxic at the concentrations tested.

RELEASE OF INFLAMMATORY MEDIATORS

Desmarestia menziesii extracts decreased the release of IL-1β and PGE_2 at cytotoxic concentrations (Supplementary Figure S1). Similarly, the extract of *Odontaster validus* reduced the release of IL-1β at the highest concentration, which had cytotoxic effects. The EtOH extract of the brown alga *D. anceps* inhibited PGE_2 release at non-cytotoxic concentrations (50 and 125 μg/mL), while showing no action on the other mediators. The extract of the salpid *Salpa* cf. *thompsoni* reduced significantly and dose-dependently the release of IL-1β and PGE_2. However, at the highest concentration (250 μg/mL) increased the release of LTB_4. The EtOH extract of the demosponge *Homaxinella* cf. *balfourensis* reduced significantly the release of IL-1β and PGE_2 only at the highest, but not cytotoxic, concentration (250 μg/mL). Finally, the extract of the colonial ascidiacean, *Synoicum adareanum*, increased the release of PGE_2 and LTB_4 at the highest concentration, having no effect at lower concentrations (Supplementary Figure S1).

The extract of *Isodictya erinacea* inhibited significantly and dose-dependently the release of IL-1β and PGE_2, although not affecting LTB_4 (**Figure 1**). The extracts of both the sponge *Isodictya toxophila* and the hemichordate *Cephalodiscus* sp. decreased the release of IL-1β and LTB_4 at two non-cytotoxic concentrations (50 and 125 μg/mL) and also diminished PGE_2 release at the intermediate concentration (125 μg/mL) (**Figure 1**). *Mycale* (*Oxymycale*) *acerata*'s extract decreased the release of IL-1β, PGE_2, and LTB_4 at the lower concentration of 50 μg/mL, which was not cytotoxic (**Figure 1**).

DISCUSSION

Cytotoxicity was determined in order to evaluate the possible further applications as anti-inflammatory activity. Among the three species which exhibit more cytotoxic activity two were previously investigated. The brown macroalgae *Desmarestia menziesii* is known to produce plastoquinones, which have been suggested to present cytotoxic activity against leukemia cells, toxicity to fish, and inhibit mitosis of fertilized sea urchin eggs (Rivera, 1996). Also *Mycale* (*Oxymycale*) *acerata* is a chemically bioactive species displaying cytotoxicity to sea urchin gametes (McClintock et al., 1990). However, the sea star *Odontaster validus* is here reported as a cytotoxic species for the first time.

The species with intermediate cytotoxicity, i.e., only at the highest concentration, have been reported previously with similar cytotoxic activity. *Desmarestia anceps* possess antibacterial and diatom's antifouling activity (Laturnus et al., 1996; Huang et al., 2006). Cytotoxicity against cells of human colon adenocarcinoma was recently proved in the deep-sea sponge *Isodictya toxophila* (Turk et al., 2013). Several studies in equatorial waters showed that isolates from *Cephalodiscus gilchristi*, the cephalostatins,

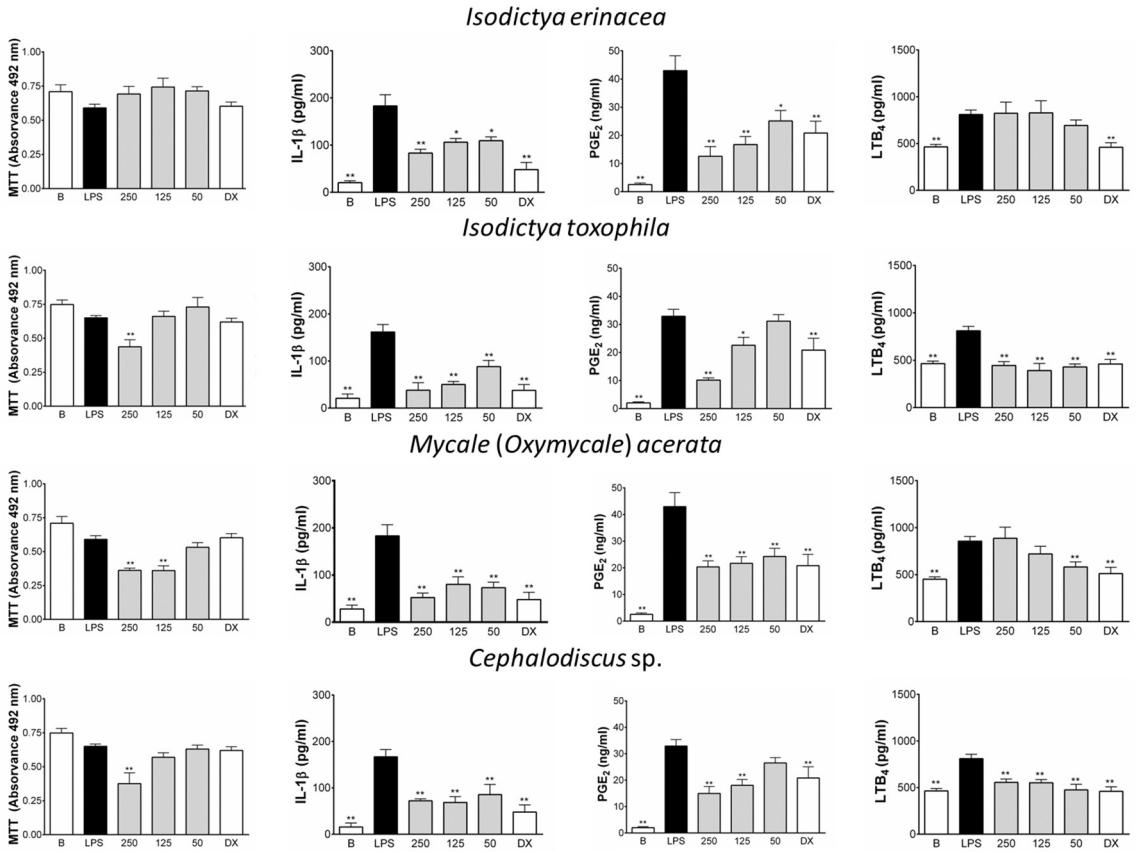

FIGURE 1 | Toxicity and anti-inflammatory effects of the extracts of *Isodictya erinacea, I. toxophila, Mycale* (*Oxymycale*) *acerata,* and *Cephalodiscus* sp. in the mouse macrophage cell line RAW 264.7. Cytotoxicity (MTT method) and amount of inflammatory mediators released: PGE_2, LTB_4, and IL-1β, for each concentration tested (250, 125, 50 μg/mL), LPS control, and the reference anti-inflammatory drug dexamethasone (DX). B indicates the non-stimulated cell control. Statistical significance (ANOVA followed by Dunnett's test): $^{*}P < 0.05$, $^{**}P < 0.01$, with respect to LPS control.

exhibit potent cytotoxicity toward murine P388 lymphocytic leukemia cell line (Rudy et al., 2008). In fact, cephalostatin 1 proved to be one of the most powerful cancer cell growth inhibitors (Moser, 2008). However, no *Cephalodiscus* species from the Southern Ocean had been tested for cytotoxic properties before our study and there are no molecules isolated so far (Avila et al., 2008).

Four species were not cytotoxic at the concentrations tested. The sponges *Isodictya erinacea* and *Homaxinella* cf. *balfourensis* have been previously tested and no cytotoxic activity was found (McClintock et al., 1990; Turk et al., 2013). Similarly, to the polyketide isolated from *Synoicum adareanum*, palmerolide A, which presented no cytotoxicity against several cell lines, in our study the macrophages RAW 264.7 were not affected by the different concentrations of the extracts tested (Diyabalanage et al., 2006). Likewise, several polyunsaturated acids with hemolytic activity have been isolated from individuals of *Salpa thompsoni* (Mimura et al., 1986).

The species providing the best results for avoiding the release of inflammatory mediators at non-cytotoxic concentrations were the hemichordate *Cephalodiscus* sp., and the sponges *Isodictya erinacea*, *I. toxophila*, and *Mycale* (*Oxymycale*) *acerata*. Since inflammation is caused by the release of chemicals from tissues and migrating cells, as mentioned above, we may conclude that the active extracts could be useful in avoiding inflammation and pain. Thus, these extracts possess promising molecules with anti-inflammatory activity, potentially useful in pharmacology. Finally, our study shows that Antarctic benthic invertebrates may have a great value as a source of lead compounds with potential pharmaceutical applications, such as painkillers. For this reason, it will be very interesting to isolate and to test the isolated molecules responsible of the release-avoidance of inflammatory mediators, which might provide future anti-inflammatory drugs.

ACKNOWLEDGMENTS

The authors wish to thank J. Vázquez, J. Cristobo, L. Núñez-Pons, and S. Taboada for field and laboratory support. Thanks are due to Prof. W. Arntz and the crew of the R/V of Polarstern for allowing our participation in the Antarctic cruise ANT XXI/2 (AWI, Bremerhaven, Germany). Funding was provided by the Spanish government through the ACTIQUIM Projects (CGL2004-03356/ANT, CGL 2007-65453/ANT, and CTM2010-17415/ANT) and by the pharmaceutical company Bioibérica.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: http://www.frontiersin.org/journal/10.3389/fmars.2014.00024/abstract

REFERENCES

Albericio, F., Álvarez, M., Cuevas, C., Francesch, A., Pla, D., and Tulla-Puche, J. (2010). "The sea as a source of new drugs Fernando," in *Molecular Imaging for Integrated Medical Therapy and Drug Development*, eds N. Tamaki and Y. Kuge (Tokyo: Springer Japan), 237–249.

Avila, C., Taboada, S., and Núñez-Pons, L. (2008). Antarctic marine chemical ecology: what is next? *Mar. Ecol.* 29, 1–71. doi: 10.1111/j.1439-0485.2007.00215.x

Blunt, J. W., Copp, B. R., Keyzers, R. A., Munro, M. H. G., and Prinsep, M. R. (2013). Marine natural products. *Nat. Prod. Rep.* 30, 237–323. doi: 10.1039/c2np20112g

Diyabalanage, T., Amsler, C. D., McClintock, J. B., and Baker, B. J. (2006). Palmerolide A, a cytotoxic macrolide from the antarctic tunicate *Synoicum adareanum*. *J. Am. Chem. Soc.* 128, 5630–5631. doi: 10.1021/ja0588508

Faulkner, D. J. (1995). Chemical riches from the ocean. *Chem. Br.* 31, 680–684.

Huang, Y. M., McClintock, J. B., Amsler, C. D., Peters, K. J., and Baker, B. J. (2006). Feeding rates of common Antarctic gammarid amphipods on ecologically important sympatric macroalgae. *J. Exp. Mar. Biol. Ecol.* 329, 55–65. doi: 10.1016/j.jembe.2005.08.013

Jha, R. K., and Zi-rong, X. (2004). Biomedical compounds from marine organisms. *Mar. Drugs* 2, 123–146. doi: 10.3390/md203123

Kijjoa, A., and Sawangwong, P. (2004). Drugs and cosmetics from the sea. *Mar. Drugs* 2, 73–82. doi: 10.3390/md202073

König, G. M., Kehraus, S., Seibert, S. F., Abdel-Lateff, A., and Müller, D. (2006). Natural products from marine organisms and their associated microbes. *Chembiochem* 7, 229–238. doi: 10.1002/cbic.200500087

Korbut, R., and Guzik, T. J. (2011). "Inflammatory Mediators and Intracellular Signalling," in *Principles of Immunopharmacology*, *3rd Edn.*, eds F. P. Nijkamp and M. J. Parnham (Basel: Birkhäuser). doi: 10.1007/978-3-0346-0136-8_7

Laturnus, F., Wiencke, C., and Klöser, H. (1996). Antarctic macroalgae - sources of volatile halogenated organic compounds. *Mar. Environ. Res.* 41, 169–181. doi: 10.1016/0141-1136(95)00017-8

Lebar, M. D., Heimbegner, J. L., and Baker, B. J. (2007). Cold-water marine natural products. *Nat. Prod. Rep.* 24, 774–797. doi: 10.1039/b516240h

Mayer, A. M. S., Rodríguez, A. D., Berlinck, R. G. S., and Fusetani, N. (2011). Marine pharmacology in 2007-8: marine compounds with antibacterial, anticoagulant, antifungal, anti-inflammatory, antimalarial, antiprotozoal, antituberculosis, and antiviral activities; affecting the immune and nervous system, and other miscellaneous mec. *Comp. Biochem. Physiol. C Toxicol. Pharmacol.* 153, 191–222. doi: 10.1016/j.cbpc.2010.08.008

McClintock, J. B., Heine, J., Slattery, M., and Weston, J. (1990). Chemical bioactivity in common shallow-water Antarctic marine invertebrates. *Antarct. J. U. S.* 25, 204–206.

Mimura, T., Okade, M., Satake, M., Nakanishi, T., Inada, A., Fujimoto, Y., et al. (1986). Fatty acids and sterols of the tunicate, *Salpa thompsoni*, from the Antarctic Ocean: chemical composition and hemolytic activity. *Chem. Pharm. Bull.* 34, 4562–4568. doi: 10.1248/cpb.34.4562

Moser, B. R. (2008). Review of cytotoxic cephalostatins and ritterazines: isolation and synthesis. *J. Nat. Prod.* 71, 487–491. doi: 10.1021/np070536z

Newman, D. J., and Cragg, G. M. (2012). Natural products as sources of new drugs over the 30 years from 1981 to 2010. *J. Nat. Prod.* 75, 311–335. doi: 10.1021/np200906s

Rivera, P. (1996). Plastoquinones and a chromene isolated from the Antarctic brown alga *Desmarestia menziesii*. *Bol. Soc. Chil. Quim.* 41, 103–105.

Rudy, A., López-antón, N., Dirsch, V. M., and Vollmar, A. M. (2008). The cephalostatin way of apoptosis. *J. Nat. Prod.* 71, 482–486. doi: 10.1021/np070534e

Taboada, S., Núñez-Pons, L., and Avila, C. (2012). Feeding repellence of Antarctic and sub-Antarctic benthic invertebrates against the omnivorous sea star *Odontaster validus*. *Polar Biol.* 36, 13–25. doi: 10.1007/s00300-012-1234-z

Turk, T., Ambrožič Avguštin, J., Batista, U., Strugar, G., Kosmina, R., Čivović, S., et al. (2013). Biological activities of ethanolic extracts from deep-sea Antarctic marine sponges. *Mar. Drugs* 11, 1126–1139. doi: 10.3390/md11041126

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Received: 21 May 2014; accepted: 30 June 2014; published online: 22 July 2014.
*Citation: Moles J, Torrent A, Alcaraz MJ, Ruhí R, and Avila C (2014) Anti-inflammatory activity in selected Antarctic benthic organisms. Front. Mar. Sci. **1**:24. doi: 10.3389/fmars.2014.00024*
This article was submitted to Marine Biotechnology, a section of the journal Frontiers in Marine Science.