BRAZILIAN JOURNAL OF BIOLOGY®

ISSN 1519-6984 (Print)
ISSN 1678-4375 (Online)

Retraction

Retraction: Evaluating the secondary bioactive metabolites in Geodia corticostylifera

The editorial board of Brazilian Journal of Biology, announces the formal Retraction of the following article:

- Abdelbasset, W.K., Bokov, D.O., Jasim, S.A., Yasin, G., Abbas, H., Alkadir, O.K.A., Taifi, A., Jalil, A. T. and Aravindhan, S., 2024. Evaluating the secondary bioactive metabolites in *Geodia corticostylifera*. *Brazilian Journal of Biology*, vol. 84, e260090. https://doi.org/10.1590/1519-6984.260090.
  This decision was made based on the fact that:
- the article presents a corresponding author information that does not belong to the actual authorship of this article;
- the article presents data that was previously published by Clavico et al. (2006) and used without permission by the authors and without the proper citation.

Profa. Dra. Takako Matsumura Tundisi
Editor in chief

References

CLAVICO, E.E.G., MURICY, G., GAMA, B.A.P., BATISTA, D., VENTURA, C.R.R. and PEREIRA, R.C., 2006. Ecological roles of natural products from the marine sponge *Geodia corticostylifera*. *Marine Biology*, vol. 148, no. 3, pp. 479-488. http://dx.doi.org/10.1007/s00227-005-0097-z.

Brazilian Journal of Biology®

ISSN 1519-6984 (Print)
ISSN 1678-4375 (Online)

Original Article

Evaluating the secondary bioactive metabolites in *Geodia corticostylifera*

Avaliação dos metabólitos bioativos secundários em *Geodia corticostylifera*

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Abstract

Ophiactis savignyi could be discovered all over the world in tropical marine environments. People could have aided in the spread of *O. savignyi*, particularly in the western and eastern populations of Panama's Isthmus. The brittle star *Ophiactis savignyi*, often known as *savigny*'s brittle star coexists alongside the sponge *Geodia corticostylifera*. The focus of this research has been to assess the functional relevance of G. corticostylifera secondary metabolites as antifoulant against mussels, protection against generalist fish and chemical cues to affiliated brittle stars. Both in flow-through and static seawater laboratory studies, *O. savignyi* which has previously been connected with sponges, was given both treated and control mimics at the same time. The sponge extract was also tested for its ability to protect fish against predators and fouling. Deterrence test using chemicals indicated that the normal level of the sponge extract may also suppress generalist fish predation in the field as well as the mussel *Perna perna*'s normal attachment in clinical contexts. According to the findings, *G. corticostylifera* crude extract has many roles in the aquatic environments, apparently being accountable for this sponge's tighter relationship with *O. savignyi*, which protects the ophiuroid and inhibits epibionts on itself.

Keywords: marine sponges, symbiotic relationships, endobiotic bacteria, aquiferous system, *G. corticostylifera.*

Resumo

Ophiactis savignyi pode ser descoberta em todo o mundo em ambientes marinhos tropicais. A população pode ter contribuído para a propagação de *O. savignyi*, particularmente as populações ocidentais e orientais do istmo do Panamá. A estrela-quebradiça *O. savignyi*, muitas vezes conhecida como estrela-quebradiça de savigny, coexiste com a esponja *Geodia corticostylifera*. O foco desta pesquisa foi avaliar a relevância funcional dos metabólitos secundários de *G. corticostylifera* como anti-incrustante contra mexilhões, proteção contra peixes generalistas e sinais químicos para estrelas-quebradiças afiliadas. Em estudos de laboratório com fluxo contínuo e estático de água do mar, *O. savignyi*, que anteriormente havia se ligado a esponjas, recebeu mimetizadores tratados e controle ao mesmo tempo. O extrato de esponja também foi testado por sua capacidade de proteger os peixes contra predadores e incrustações. Testes de dissuasão usando produtos químicos indicaram que o nível normal de extrato de esponja também pode suprimir a predação de peixes generalistas no campo, bem como a fixação normal do mexilhão Perna perna em ambientes clínicos. De acordo com os achados, o extrato bruto de *G. corticostylifera* tem diversas funções em ambientes aquáticos, aparentemente responsáveis pela relação mais próxima dessa esponja com *O. savignyi*, protegendo o ofiuroide e inibindo os epibiontes.

Palavras-chave: esponjas marinhas, relações simbióticas, bactérias endobióticas, sistema aquífero, *G. corticostylifera.*

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Received: January 16, 2022 – **Accepted:** February 3, 2022

1. Introduction

One of the prominent constituents of the marine benthos is marine sponges, which are found all over the world in temperate and polar waters, as well as deep-sea and intertidal environments (Pereira et al., 2002; Bouzon and [illegible]eire, 2007; Lo Giudice and Rizzo, 2018; Ereskovsky et al., 20[illegible]; Lhullier et al., 2020; Strano et al., 2020). In coral reef habitats, where predation and herbivory are frequent, these benthic organisms, accompanied by alcyonarian and scleractinian coelenterate, play a key role (Paul, 2019; J[illegible]so[illegible] and [illegible]allock, 2020). Scleractinia, often known as hard or stony corals, are Cnidaria phylum aquatic creatures that produce a hard bone structure (Cairns, 2007; Cairns et al., 2009). Alcyonaria, which includes roughly three thousand water-based species made up of eight-fold symmetric colonial polyps, is an Anthozoa subgroup (Ivan[illegible], 20[illegible]). Soft corals make up the majority of the Alcyonaria subclass (Ghallab et al., 2020). Sponges are a crucial group for ecological research, and they are among the most diverse and common groups of sessile marine invertebrates in Caribbean coral reefs (Diaz and Rützler, 2001).

Sponge species abound throughout the Brazilian coast, much as they do in the Caribbean ([illegible]andall and H[illegible]tman, 1968; Ferreira et al., 2004), yet the greater part of the species found along this southwestern Atlantic region's large coastline are undiscovered. The major contributors of marine organisms' unique secondary metabolites are sponges (Amsler et al., 2001; Rinehart, 2008; Li[illegible] a[illegible], 2020). Such primitive multicellular aquatic organisms are considered to have a wide range of biological effects, including antibacterial, antiviral, antifungal and antitumoral properties. Regarding this, ecological investigations conducted lately have shed some insight on the real ecological significance of marine sponges' secondary metabolites (He et al., 2020; Lee et al., 2021).

Earlier research employed feeding trends of organisms and proper methods to assess the efficacy of pure chemicals or crude extracts from sponges as predator-defense mechanisms, mostly in the temperate and tropical Caribbean, Mediterranean, Pacific, and Southwestern Atlantic (McGrath et al., 2018; Gökalp, 2021; Maslin et al., 2021).

It was found that reef fish *Thalassoma bifasciatum* (blue-headed wrasse) were put off by the crude extracts that were generated by a lot of the 71 Caribbean sponge species (69%), but that deterrence varied greatly across and within species (Pawlik et al., 1995). While chemical resistance was thought to be a useful tactic among many Caribbean sponges, certain dominant organisms in the Caribbean and the Red Sea seem to employ alternative strategies such as spicules (Burns and Ilan, 2003). Even though defenses against predation appears to be the most prevalent ecological activity linked to sponge secondary metabolites, additional functions have been identified. On Guam, for instance the sponge Cacospongia sp. is outgrown by the sponge Dysidea sp. as a result of necrosis.

A groundbreaking field research has revealed that sponge secondary metabolites could operate as kairomones, promoting overgrowth by others, or as allomones, suppressing overgrowth (Engel and Pawlik, 2000). Furthermore, several investigations also demonstrated that marine sponges' secondary metabolites could reduce fouling in the research lab or even in field experiments, indicating that sponges produce allelochemicals to keep themselves free of epibionts (Adnan et al., 2018; Paul, 2019; Puglisi et al., 2019; Angulo-Preckler et al., 2020; Bryan et al., 2020; Levert et al., 2021). Many sponges, on the other hand, have symbiotic partnerships with a variety of invertebrates, microalgae, protozoa, autotrophic and heterotrophic bacteria, and this interconnectedness grow to the stage where the symbionts provide more biomass than the sponge for certain individuals (Haygood et al., 1999; Pochon et al., 2001; Totti et al., 2010). Sponges have such a large and varied affiliated fauna on their inner tissues, canals, and surfaces that they are regarded as one of the wealthiest benthic biotopes and living lodges in the ocean (Ribeiro et al., 2003). Different sponge properties, including geographic distribution, anatomy, morphology, and size, as well as seasonality, and depth, may influence the makeup of the sponge-associated fauna (Poore et al., 2000; Amsler et al., 2009). Few extensive studies on sponges' generation of chemical cues which could lure or deter certain species of animals have been conducted (Poore et al., 2000; Ribeiro et al., 2003; Amsler et al., 2009; Totti et al., 2010). Amphipods can detect antibiotic compounds from the *Halichondria panicea* sponge. *Halichondria panicea* is a shallow-subtidal or intertidal sponge exhibiting distinctive volcanoe-shaped oscular chimneys (Poore et al., 2000). It is occasionally branched, huge, or heavily encrusting. It can take many different forms, making identification challenging. The common name comes from the fact that certain forms have a grainy surface, but others have smooth, uniform glassy surfaces.

In laboratory experiments, *H. panicea* attracted the related amphipods *Jassa falcata* and *Caprella linearis* (Pugli[illegible] al., [illegible]019). Females' ability to swim of *Tritaeta gibb[illegible]* was inhibited when the same sponge species was present ([illegible]av[illegible]o et al., 2006). Hymeniacidon perleve and Halichondria panicea attracted the amphipods *Corophiu[illegible]*, *Microdeutopus anomalus*, *Microdeutopus damno[illegible]ensis*, and the crab *Carcinus maenas* (Gerovasileiou and Vo[illegible]ltsiado[illegible], [illegible]; Strano et al., 2020). Such instances suggest that the host sponges might release chemical pheromone which serve as signals to the fauna around them. It was recently proposed that brittle stars that live in sponge environments have developed a way for identifying sponges (Henke[illegible] and Paw[illegible]k, 2005; Dahihande and Thakur, 2017). Given the overwhelming body of work on the ecological significance of sponge compounds in the Caribbean, Bermuda, Mediterranean, and tropical Pacific sea (Pawlik et al., 1995; Cl[illegible]ico et al., 2006; Ribeiro et al., 2010; Gerovasileiou and Vou[illegible]tsia[illegible], 2012; de Goeij et al., 2017; Schönberg et al., 2017; Avila et al., 2018; Pomponi et al., 2019; Bo et al., 2020; Mauro et [illegible] 2020), such studies are scarce in the South Atlantic. With a variety of pharmacological effects, including antimicrobial, neurotoxic, cytotoxic, and hemolytic activities, *Geodia corticostylifera* has uncharacterized secondary metabolites (Lee et al., 2021). Including *Ophiactis savignyi*, this sponge is home to a variety of brittle star species, which in densities of more than two-hundred individuals per sponge, or four individuals per cm^3 of sponge tissue, are located inside the sponge's aquiferous canals (Figure 1) (Ereskovsky et al., 2019; Wulff, 2021).

According to our hypothesis, chemical cues may attract *O. savignyi* to *G. corticostylifera*, which may also prevent epibionts and predators (Pochon et al., 2001; Gökalp, 2021). The focus of this research has been to assess the functional [illegible] of *G. corticostylifera* secondary metabolites as antifouling against mussels, protection against generalist fish and chemical cues to affiliated brittle stars.

2. Materials and Methods

In our search for bioactive compounds from marine organisms, we came upon *G. corticostylifera*, whose extracts showed antifungal and antibacterial activities. Chemical defense systems are indicated by its orange color and the apparent lack of adjacent predators and fouling species. On the upwelling coast of Arraial do Cabo, *G. corticostylifera* is a sponge [illegible] could be discovered in depths of 3-39 meters. However, it [illegible] even be observed in Venezuela, as well as along the whole southeastern Brazilian coast (Almeida et al., 20[illegible]1). It is beige on the inside and orange on the outside, [illegible] a cerebriform, massive-globose shape and a hard consistency with deep grooves at the surface (Calcinai et al., 2017). In both sides of the Atlantic, eastern Pacific, Indo-Pacific, and subtropical and tropical areas, the ophiuroid *O. savignyi* may be found in Brazil, the Gulf of Mexico, the Caribbean, Bermuda, and South Carolina are all located in the Western Atlantic. It may be observed down to a depth of 518 meters, but it prefers shallow waters (Stöhr et al., 2012; Hendler and Brugneaux, 2013; Granja-Fernández et al., 2017).

The tropical peninsula of Arraial do Cabo protrudes from Brazil's southeast coast. The predominant eastern and northeastern winds produce a coastal upwelling in this region. *O. savignyi* and *G. corticostylifera* specimens were obtained manually by SCUBA diving from 5-8 meters depth at Saco dos Cardeiros and Forno beach. The upwelling phenomenon has no bearing on any collecting location. Throughout collecting, samples were encased in polyethylene bags to avoid the destruction of accompanying fauna, which was later isolated from the sponges in the lab. The density of related *O. savigny* was assessed in the lab after a number of sympatric sponge species were collected (based on each species' natural abundance, n=1-12) and entangled in polyethylene bags. *Briefly after collection, G. corticostylifera samples were washed thoroughly in saltwater* to eliminate any attached animals that could tamper with the sponge's endobiotic bacteria or secondary metabolites. Sponge tissues have been sliced into little bits, and organic solvents were used to remove them one after the other. To improve the efficacy of the initial extraction, sponge pieces were homogenized in methanol before being exposed to ultrasonic waves for about fifteen minutes. Utilizing pieces of dry spongin skeleton (commercial marine sponges), treatment and control sponge mimics were created, and then a solvent-only gel (controls) or an extract-containing gel (treatments) were added. The extract's natural volumetric content was determined by employing a recently made crude organic extract to create 20 ml of gel (consistent with 20 ml of G. corticostylifera). In advance of heating to the boiling point, an amount of 1.01 g phytagel was dissolved in deionized water of 20 ml and vigorously stirred. The extract aliquot was added after cooling to around 60°C and was then poured onto treatment (one spongin piece). With dichloromethane (DCM) added simply as solvent control, control mimics were generated in the very same way.

In a way analogous to that which is thought to occur naturally, phytagel was employed to facilitate the regulated organic extract diffusion to saltwater from the sponge mimic. Flow-through and static experiments were utilized.

With one *O. savignyi* specimen, a plastic container with a rectangle shape in the initial experimental trials was used to store the treatment [illegible] control mimics. Without water flow, with a [illegible] m water depth, all recipients were put in

Figure 1. A variety of brittle star species live in Ophiactis savignyi.

a 2-m circular pool made of fiberglass. In each container, one brittle star was put evenly between treatment and control mimics (Figure 2).

A new group of tests was conducted using a seawater flow-through configuration to imitate more realistic dilution and flow of chemical cues since static seawater tests are implausible. With a seawater input and output, mimics of treatment and control were set in a rectangular plastic tray at opposite angles during an analogous test. Allowing the water to pass to the ophiuroid, the water input was placed on both sides of the treated and control mimics (Figure 2).

Experiments in the field and the preparation of artificial food were carried out (Burns et al., 2003; Helber et al., 2017; Wulff, 2021). To replicate the normal amount of chemical present in *G. corticostylifera*, 0.4 g of water, tuna fish, and alginic acid was mixed with an extract corresponding to 60 ml of fresh *G. corticostylifera* tissue. Before being placed into a rectangular mold, the mixture was vigorously stirred to form pellets. The same procedure was used to make control pellets but without the inclusion of extract.

Individuals demonstrating substrate-exploring activity were chosen for trials after the mussels were collected. A variation of the process initially employed by Ina et al. (1989) and Goto et al. (1992), which was the method described by Da Gama et al. (2003), was used to measure antifouling activity. The results obtained in the field have been highly correlated with those acquired from this lab experiment. Filter paper with a water-resistant coating has been immersed insolvent after being sliced into 3-cm radius circles. With a 3-cm radius, one more set of filter papers has been immersed in *G. corticostylifera* crude extract at a natural concentration after being sliced into a chess board design.

Each assay's experimental design dictated the statistical analysis. The number of attached byssal threads in antifouling tests was studied, and the pellet quantity devoured (not as % as illustrated in graphs) in field predation was evaluated. Yates' correction for continuity (or Yates' chi-square test) (χ^2) was employed to assess chemotaxis findings. The Yates' Correction is a modification to the Pearson's Chi-Squared test that is used to determine if two categorical variables are related. Because the variables did not follow the assumption of normality, the Wilcoxon signed ranks test was used to assess the predation and antifouling outcomes.

3. Results and Discussion

Sponge species were sampled out of a total of 27 specimens: *Paraleucilla magna*, *G. corticostylifera*, *Dysidea robusta*, *Aplysina fulva*, *Amphimedon viridis*. Per 100 ml^{-1} sponge *O. savigny* density varied from 0 to 385 ind. (Figure 3).

G. corticostylifera had the largest densities, whereas *A. fulva* had the lowest. In static seawater experiments, *O. savignyi* had a strong inclination to migrate near *G. corticostylifera* than the control, but the difference was not statistically noticeable (Figure 4a; χ^2, p<0.37).

However, in flowing seawater experiments, considerably more *O. savignyi* were drawn to sponge mimics with *G. corticostylifera* crude extract (χ^2, p<0.03). This finding suggests that compounds capable of causing positive taxis conduct in *G. corticostylifera*'s linked ophiuroid *O. savignyi*.

The artificial food comprising the *G. corticostylifera* crude extract was substantially less eaten than the control in the experiments for a chemical protective effect against predation by generalist fish (Figure 4b; Wilcoxon, p<0.001). This finding showed that this sponge species crude extract may protect against a wide range of generalist fish, including *Kyphosus sectatrix*, *H. steindacneri*, *Haemulon aurolineatum*, and *Abudefduf saxatilis*, the area's most frequent species.

Indicating a considerable antifouling effect in comparison to the control (Wilcoxon, p<0.01), the *G. corticostylifera* crude extract strongly prevented byssal thread attachment in juvenile mussels of the *genus Perna* (Figure 4c). The mussels earlier introduced

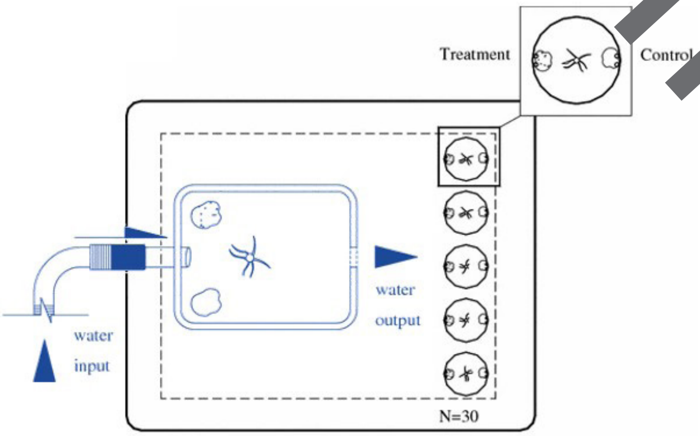
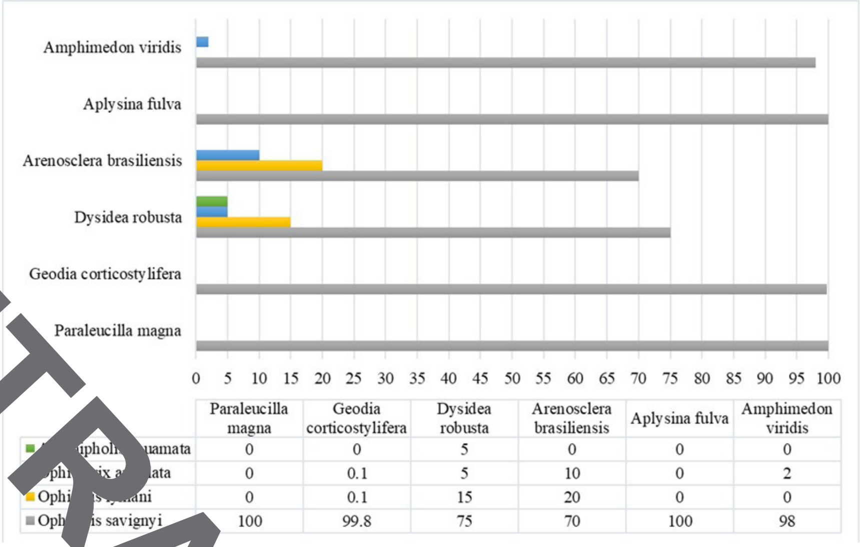
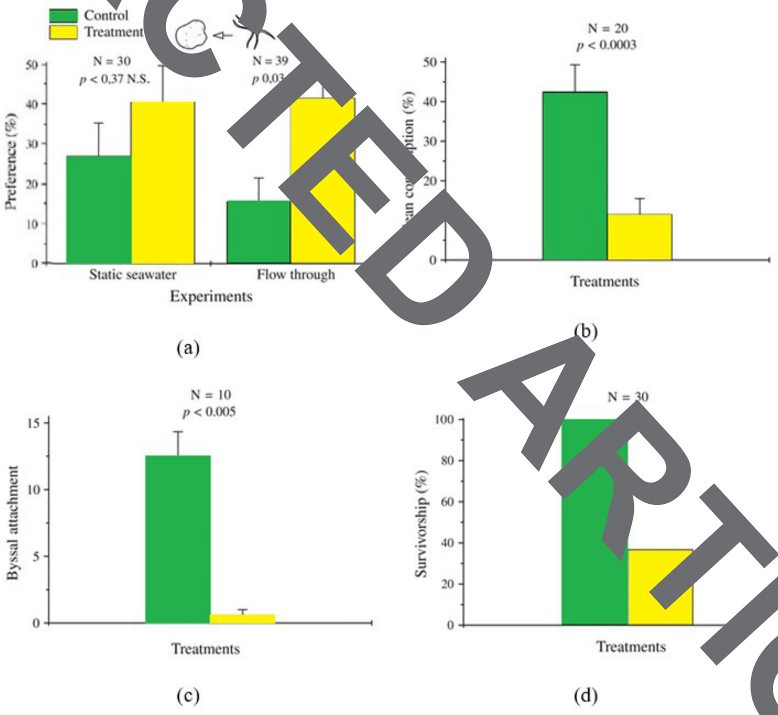


Figure 2. The static seawater test's experimental unit schematic. The brittle star receives seawater from the mimics as is demonstrated in this schematic of chemotaxis experiment.



	Paraleucilla magna	Geodia corticostylifera	Dysidea robusta	Arenosclera brasiliensis	Aplysina fulva	Amphimedon viridis
🟩 Amphipholis squamata	0	0	5	0	0	0
🟦 Ophiothrix angulata	0	0.1	5	10	0	2
🟨 Ophiactis lymani	0	0.1	15	20	0	0
⬜ Ophiactis savignyi	100	99.8	75	70	100	98

Figure 3. Ophiuroid species [illegible] each sponge species has a different dominance (%).



(a) (b)

(c) (d)

Figure 4. In static seawater, *O. savignyi* the brittle star approaches a treatment or control sponge mimic and pass-through chemotaxis experiments, (a). After the field experiment, generalist fish ate a certain percentage of the treatment and control pellets (b). *P. perna* mussel attachment after 12 hours in treatment and control, (c). Percentage of *P. perna* mussels that survived 24 hours after the experiments ended, (d).

to the sponge extract had a significant rate of death following the 24-hour recovery period, but none of the controls perished (Figure 4d). As a result, the toxicity of the *G. corticostylifera* crude extract to mussels is most likely connected to the nature of attachment inhibition in antifouling experiments.

4. Conclusion

Living organisms such as sponges, polychaete mats, and algae are common habitats for the brittle star *O. savignyi*. *Ophiothrix fragilis*, which were already common in several sponge species, showed a similar pattern, and clearance trials demonstrated that these brittle stars might pick their environment after settling. According to our results, the ophiuroid O. savignyi is attracted to secondary metabolites produced by G. corticostylifera. Chemical cues are likely to initiate the relationship between *O. savignyi* and *G. corticostylifera* in nature, confirming prior data that ophiuroids' behavior is predominantly governed by chemoreception. *O. savignyi* is likely looking for a relationship with G. corticostylifera for defense, feeding, or both causes. Because the *G. corticostylifera* crude extract reportedly deters generalist fish in the environment, the sponge may help protect *O. savignyi* from predation. A quick and cost-effective screening procedure for antifouling activity is the mussel test, with findings that are usually replicated by field experiments. Our findings revealed that *G. corticostylifera* crude extract serves a variety of ecological functions.

References

ADNAN, M., ALSHAMMARI, E., PATE[illegible] M., AMIR ASHRAF, S., KHAN, S. and HADI, S., 2018. Significance and potential of marine microbial natural bioactive compounds against biofilms/biofouling: necessity for green chemistry. *PeerJ*, vol. 6, pp. e5049. http://dx.doi.org/10.7717/peerj.[illegible]. PMid:29[illegible]730.

ALMEIDA, D.S., SANDES, J., GUIMARES, C.R.P. and MUR[illegible], G., 2021. Taxonomy of Geodia and Rhabdastrella from the Brazilian coast: a new species, new synonyms and redescription of Geodia tylastra (Demospongiae: Astrophorina: Geodiidae and Ancorinidae). *Zootaxa*, vol. 4995, no. 2, pp. 281-302. http://dx.doi.org/10.11646/zootaxa.4995.2.4. PMid:34810570.

AMSLER, C.D., MCCLINTOCK, J.B. and BAKER, B.J., 2001. Secondary metabolites as mediators of trophic interactions among Antarctic marine organisms. *American Zoologist*, vol. 41, no. 1, pp. 17-26. http://dx.doi.org/10.1093/icb/41.1.17.

AMSLER, M.O., MCCLINTOCK, J.B., AMSLER, C.D., ANGUS, R.A. and BAKER, B.J., 2009. An evaluation of sponge-associated amphipods from the Antarctic Peninsula. *Antarctic Science*, vol. 21, no. 6, pp. 579-589. http://dx.doi.org/10.1017/S0954102009990356.

ANGULO-PRECKLER, C., GARCÍA-LOPEZ, E., FIGUEROLA, B., AVILA, C. and CID, C., 2020. Natural chemical control of marine associated microbial communities by sessile Antarctic invertebrates. *Aquatic Microbial Ecology*, vol. 85, pp. 197-210. http://dx.doi.org/10.3354/ame01948.

AVILA, C., NÚÑEZ-PONS, L. and MOLES, J., 2018. From the Tropics to the Poles: chemical defense strategies in sea slugs (Mollusca: Heterobranchia). In: M. P.PUGLISI and M. A.BECERRO, eds. *Chemical ecology: the ecological impacts of marine natural products*. Boca Raton: CRC Press, pp. 71-163.

BO, M., COPPARI, M., BETTI, F., MASSA, F., GAY, G., CATTANEO-VIETTI, R. and BAVESTRELLO, G., 2020. Unveiling the deep biodiversity of the Janua Seamount (Ligurian Sea): first Mediterranean sighting of the rare Atlantic bamboo coral Chelidonisis aurantiaca Studer, 1890. *Deep-sea Research. Part I, Oceanographic Research Papers*, vol. 156, pp. 103186. http://dx.doi.org/10.1016/j.dsr.2019.103186.

BOUZON, J.L. and FREIRE, A.S., 2007. The Brachyura and Anomura fauna (Decapoda; Crustacea) in the Arvoredo Marine Biological Reserve on the southern brazilian coast. *Brazilian Journal of Biology = Revista Brasileira de Biologia*, vol. 67, no. 2, pp. 321-325. http://dx.doi.org/10.1590/S1519-69842007000200018. PMid:17876443.

BRYAN, P.J., MCCLINTOCK, J.B., WATTS, S.A., MARION, K.R. and HOPKINS, T.S., 2020. Antimicrobial activity of ethanolic body-wall extracts of echinoderms from the northern Gulf of Mexico. In: P.J.BRYAN, J.B.MCCLINTOCK, S.A.WATTS, K.R.MARION and T.S.HOPKINS, eds. *Echinoderms through time*. Boca Raton: CRC Press, pp. 17-23.

BURNS, E. and ILAN, M., 2003. Comparison of anti-predatory defenses of Red Sea and Caribbean sponges. II. Physical defense. *Marine Ecology Progress Series*, vol. 252, pp. 115-123. http://dx.doi.org/10.3354/meps252115.

BURNS, E., IFRACH, I., CARMELI, S., PAWLIK, J.R. and ILAN, M., 2003. Comparison of anti-predatory defenses of Red Sea and Caribbean sponges. I. Chemical defense. *Marine Ecology Progress Series*, vol. 252, pp. 105-114. http://dx.doi.org/10.3354/meps252105.

CAIRNS, S.D., 2007. Deep-water corals: an overview with special reference to diversity and distribution of deep-water scleractinian corals. *Bulletin of Marine Science*, vol. 81, no. 3, pp. 311-322.

CAIRNS, S.D., JAAP, W.C., and LANG, J.C., 2009. Scleractinia (Cnidaria) of the Gulf of Mexico. In D.L.FELDER and D.K.CAMP, eds. *Gulf of Mexico origin, waters, and biota*. Texas: Texas A&M University Press, College Station, vol. 1, pp. 333-348.

CALCINAI, B., BASTARI, A., BAVESTRELLO, G., BERTOLINO, M., HORCAJADAS, S.B., PANSINI, M., MAKAPEDUA, D.M. and CERRANO, C., 2017. Demosponge diversity from North Sulawesi, with the description of six new species. *ZooKeys*, vol. 680, pp. 105-150. http://dx.doi.org/10.3897/zookeys.680.12135. PMid:28769718.

CLAVICO, E.E.G., MURICY, G., DA GAMA, B.A.P., BATISTA, D., VENTURA, C.R.R. and PEREIRA, R.C., 2006. Ecological roles of natural products from the marine sponge Geodia corticostylifera. *Marine Biology*, vol. 148, no. 3, pp. 479-488. http://dx.doi.org/10.1007/s00[illegible]7-005-0097-z.

DA GAM[illegible], B.A., PEREIRA, R.C., SOARES, A.R., TEIXEIRA, V.L. and Y[illegible]ESHIGUE-VALENTIN, Y., 2003. Is the mussel test a good indicator of antifouling activity? A comparison between laboratory and field assays. *Biofouling*, vol. 19, no. S1, (suppl.), pp. 161-[illegible]. http://dx.doi.org/10.1080/0892701031000089534. PMid:[illegible]24.

DAHIHANDE, A[illegible] and T[illegible]R, N.L., 2017. Differential growth forms of the sponge [illegible]emna [illegible]rtis govern the abundance of its associated brittle star [illegible] modesta. *Journal of Sea Research*, vol. 126, pp. 1-11. http://dx.doi.org/10.1016/j.seares.2017.06.007.

DE GOEIJ, J.M., LESSER, M[illegible] and PAW[illegible], 2017. Nutrient fluxes and ecological functions of coral reef sponges in a changing ocean. In: J.CARBALLO and [illegible]BELL, eds. *[illegible]ate change, ocean acidification and sponges*. Cham: Springer, pp. 373-410. https://doi.org/10.1007/978-3-319-5900[illegible]_8.

DIAZ, M.C. and RÜTZLER, K., 2001. Sponges: an essential component of Caribbean coral reefs. *Bulletin of Marine Science*, vol. [illegible], no. 2, pp. 535-546.

ENGEL, S. and PAWLIK, J.R., 2000. Allelopathic activities of sponge extracts. *Marine Ecology Progress Series*, vol. 20[illegible], pp. 273-281. http://dx.doi.org/10.3354/meps207273.

ERESKOVSKY, A., OZEROV, D.A., PANTYULIN, A.N. and TZETL[illegible].B., 2019. Mass mortality event of White Sea sponges as the result of high temperature in summer 2018. *Polar Biology*, vol. 42, no. [illegible], pp. 2313-2318. http://dx.doi.org/10.1007/s00300-019-02606-0.

FERREIRA, C.E.L., FLOETER, S.R., GASPARINI, J.L., FERREIRA, B.P. and JOYEUX, J.C., 2004. Trophic structure patterns of Brazilian reef fishes: a latitudinal comparison. *Journal of Biogeography*, vol. 31, no. 7, pp. 1093-1106. http://dx.doi.org/10.1111/j.1365-2699.2004.01044.x.

GEROVASILEIOU, V. and VOULTSIADOU, E., 2012. Marine caves of the Mediterranean Sea: a sponge biodiversity reservoir within a biodiversity hotspot.*PLoS One*, vol. 7, no. 7, pp. e39873. http://dx.doi.org/10.1371/journal.pone.0039873. PMid:22808070.

GHALLAB, A., MAHDY, A., MADKOUR, H. and OSMAN, A., 2020. Distribution and Diversity of Living Natural Resources from the Most Northern Red Sea Islands, Egypt: I-Hard and Soft Corals. *Egyptian Journal of Aquatic Biology and Fisheries*, vol. 24, no. 5, [illegible] 125-145. http://dx.doi.org/10.21608/ejabf.2020.103627.

GOKALP, M., 2021. *The multifunctional role of marine sponges in multi-trophic mariculture systems: towards sustainable use of sponges in polluted marine waters*. Wageningen, the Netherlands: Wageningen University, 183 p. PhD Thesis.

GOTO, R., KADO, R[illegible]RAMOTO, K. and KAMIYA, H., 1992. Fatty acids as antifoulants in a marine sponge.*Biofouling*, vol. 6, no. 1, pp. 61[illegible]. http://dx.doi.org/10.1080/08927019209386210.

GRANJA-FERNÁNDEZ, [illegible] RODRÍGUEZ-TRONCOSO, A.P., HERRERO-PÉREZRUL, M.D., SOT[illegible]O-C[illegible]AS, R.C., FLORES-ORTEGA, J.R., GODÍNEZ-DOMÍNGUEZ, E., SALAZAR-SILVA, P., ALARCÓN-ORTEGA, L.C., CAZAR[illegible]SALAZAR, [illegible]d CUPUL-MAGAÑA, A.L., 2017. Ophiuroidea (Echinodermata) from the Central Mexican Pacific: an updated checklist including new distribution records. *Marine Biodiversity*, vol. 47, no[illegible] pp. 167-177. http://dx.doi.org/10.1007/s12526-016-0459[illegible].

HAYGOOD, M.G., SCHMIDT, E.W., DAVIDSON, S.K. and FAULKNER, D.J., 1999. Microbial symbionts of marine invertebrates: opportunities for microbial biotechnology.*Journal of Molecular Microbiology and Biotechnology*, vol. 1, no. 1, [illegible] 33-[illegible]3. PMid:10941782.

HE, Q., MIAO, S., NI, N., MAN, Y. and GONG, K., 2020. A review of the secondary metabolites from the marine sponges of the genus Aaptos.*Natural Product Communications*, vol. 1[illegible] no. 9, p. 1-12. https://doi.org/10.1177/1934578X20951439.

HELBER, S.B., DE VOOGD, N.J., MUHANDO, C.A., ROHDE, S. and SCHUPP, P.J., 2017. Anti-predatory effects of organic extracts of 10 common reef sponges from Zanzibar.*Hydrobiologia*, vol. 790, no. 1, pp. 247-258. http://dx.doi.org/10.1007/s10750-016-3036-8.

HENDLER, G. and BRUGNEAUX, S.J., 2013. New records of brittle stars from French Guiana: Ophiactis savignyi and the alien species Ophiothela mirabilis (Echinodermata: Ophiuroidea).*Marine Biodiversity Records*, vol. 6, pp. e113. https://doi.org/10.1017/S1755267213000845.

HENKEL, T.P. and PAWLIK, J.R., 2005. Habitat use by sponge-dwelling brittlestars.*Marine Biology*, vol. 146, no. 2, pp. 301-313. http://dx.doi.org/10.1007/s00227-004-1448-x.

INA, K., TAKASAWA, R., YAGI, A., ETOH, H. and SAKATA, K., 1989. Isothiocyanates as an attaching repellent against the blue mussel Mytilus edulis.*Agricultural and Biological Chemistry*, vol. 53, no. 12, pp. 3323-3325. http://dx.doi.org/10.1271/bbb1961.53.3323.

IVANOVA, N.Y., 2020. Classification and evolution of the burrowing sea anemones (Anthozoa: Actiniaria: Athenaria): a review of the past and current views.*Zoosystematica Rossica*, vol. 29, no. 2, pp. 213-237. http://dx.doi.org/10.31610/zsr/2020.29.2.213.

JOHNSON, S.K. and HALLOCK, P., 2020. A review of symbiotic gorgonian research in the western Atlantic and Caribbean with recommendations for future work.*Coral Reefs*, vol. 39, no. 2, pp. 239-258. http://dx.doi.org/10.1007/s00338-020-01891-0.

LEE, Y.-J., CHO, Y. and TRAN, H.N.K., 2021. Secondary metabolites from the marine sponges of the genus Petrosia: A literature review of 43 years of research.*Marine Drugs*, vol. 19, no. 3, pp. 122. http://dx.doi.org/10.3390/md19030122. PMid:33668842.

LEVERT, A., FOULON, V., FAUCHON, M., TAPISSIER-BONTEMPS, N., BANAIGS, B. and HELLIO, C., 2021. Antifouling activity of meroterpenes isolated from the ascidian Aplidium aff. densum.*Marine Biotechnology (New York, N.Y.)*, vol. 23, no. 1, pp. 51-61. http://dx.doi.org/10.1007/s10126-020-10000-9. PMid:33094389.

LHULLIER, C., MORITZ, M.I.G., TABALIPA, E.O., SARDÁ, F.N., SCHNEIDER, N.F.Z., MORAES, M.H., CONSTANTINO, L., REGINATTO, F.H., STEINDEL, M., PINHEIRO, U.S., SIMÕES, C.M.O., PÉREZ, C.D. and SCHENKEL, E.P., 2020. Biological activities of marine invertebrates extracts from the northeast brazilian coast.*Brazilian Journal of Biology = Revista Brasileira de Biologia*, vol. 80, no. 2, pp. 393-404. http://dx.doi.org/10.1590/1519-6984.213678. PMid:31389485.

LIU, Z., FRANK, M., YU, X., YU, H., TRAN-CONG, N.M., GAO, Y. and PROKSCH, P., 2020. Secondary metabolites from marine-derived fungi from China.*Progress in the Chemistry of Organic Natural Products*, vol. 111, pp. 81-153. http://dx.doi.org/10.1007/978-3-030-37865-3_2. PMid:32114663.

LO GIUDICE, A. and RIZZO, C., 2018. Bacteria associated with marine benthic invertebrates from polar environments: unexplored frontiers for biodiscovery?*Diversity (Basel)*, vol. 10, no. 3, pp. 80. http://dx.doi.org/10.3390/d10030080.

MASLIN, M., GAERTNER-MAZOUNI, N., DEBITUS, C., JOY, N. and HO, R., 2021. Marine sponge aquaculture towards drug development: an ongoing history of technical, ecological, chemical considerations and challenges.*Aquaculture Reports*, vol. 21, pp. 100813. http://dx.doi.org/10.1016/j.aqrep.2021.100813.

MAURO, M., LAZZARA, V., PUNGINELLI, D., ARIZZA, V. and VAZZANA, M., 2020. Antitumoral compounds from vertebrate sister group: A review of Mediterranean ascidians.*Developmental and Comparative Immunology*, vol. 108, pp. 103669. http://dx.doi.org/10.1016/j.dci.2020.103669. PMid:32192994.

MC[illegible]ATH, E.C., WOODS, L., JOMPA, J., HARIS, A. and BELL, J.J., 2018. Growth and longevity in giant barrel sponges: Redwoods of the [illegible]f or Pines in the Indo-Pacific?*Scientific Reports*, vol. 8, no[illegible] pp. 15317. http://dx.doi.org/10.1038/s41598-018-33294-1. PMid:30333574.

PAUL, V.J., 2019. *Ecological roles of marine natural products*. Ithaca, Nova Y[illegible] EUA: Cornell University Press, Chemical defenses of benthic marine invertebrates, pp. 164-188.

PAWLIK, J.R., C[illegible]NAS, [illegible]NEN, R.J. and FENICAL, W., 1995. Defenses of Caribbean sponges against predatory reef fish. I. Chemical deterrency.*Marine Ecology Progress Series*, vol. 127, pp. 183-194. http://dx.doi.org/10.3354/meps127183.

PEREIRA, R.C., CARVALH[illegible] A.G.V., GA[illegible]A.P. and COUTINHO, R., 2002. Field experimental evaluation of secondary metabolites from marine invertebrates [illegible] antifoulants.*Brazilian Journal of Biology = Revista Brasileira de Biologia*, vol. 62, no. 2, pp. 311-320. http://dx.doi.org/10.1590/S[illegible]19-69[illegible]200[illegible]00200015. PMid:12489403.

POCHON, X., PAWLOWSKI, J., ZANINET[illegible] L. and ROWA[illegible], R., 2001. High genetic diversity and relative specificity among Symbiodinium-like endosymbiotic dinoflagellates in soritid foraminiferans.*Marine Biology*, vol. 139, no. 6, pp. 1069-1078. http://dx.doi.org/10.1007/s002270100674.

POMPONI, S.A., DIAZ, M.C., VAN SOEST, R.W., BELL, L.J., BUS[illegible]IL, L., GOCHFELD, D.J., KELLY, M. and SLATTERY, M.2019. Sponges. Mesophotic Coral Ecosystems, pp. 563–588.

POORE, A.G., WATSON, M.J., DE NYS, R., LOWRY, J.K. and STEINBERG, P.D., 2000. Patterns of host use among alga-and sponge-associated amphipods.*Marine Ecology Progress Series*, vol. 208, pp. 183-196. http://dx.doi.org/10.3354/meps208183.

PUGLISI, M.P., SNEED, J.M., RITSON-WILLIAMS, R. and YOUNG, R., 2019. Marine chemical ecology in benthic environments.

Natural Product Reports, vol. 36, no. 3, pp. 410-429. http://dx.doi.org/10.1039/C8NP00061A. PMid:30264841.

RANDALL, J.E. and HARTMAN, W.D., 1968. Sponge-feeding fishes of the West Indies.*Marine Biology*, vol. 1, no. 3, pp. 216-225. http://dx.doi.org/10.1007/BF00347115.

RIBEIRO, S.M., BIANCO, É.M., ROGERS, R., TEIXEIRA, V.L. and PEREIRA, R.C., 2010. Chemical defense of Hymeniacidon heliophila (Porifera: Halichondrida) against tropical predators.*Brazilian Journal of Oceanography*, vol. 58, no. 4, pp. 315-321. http://dx.doi.org/10.1590/S1679-87592010000400006.

RIBEIRO, S.M., OMENA, E.P. and MURICY, G., 2003. Macrofauna associated to Mycale microsigmatosa (Porifera, Demospongiae) in rio de Janeiro state, SE Brazil.*Estuarine, Coastal and Shelf Science*, vol. 57, no. [illegible]-6, pp. 951-959. http://dx.doi.org/10.1016/S0272-7714[illegible]004[illegible]-0.

RINEHART, [illegible], 2008. Secondary metabolites from marine organisms.*Secondary Metabolites: Their Function and Evolution*, vol. 171, pp. 23[illegible]49, discussion 249-254. PMid:1302180.

SCHÖNBERG, C.H., FANG, [illegible]-H. and CARBALLO, J.L., 2017. Bioeroding sponges and the future of coral reefs. In: J.CARBALLO and J.BELL, eds. *Climate change, ocean acidification and sponges*. Cham: Springer, pp. 179-372. https://doi.org/10.1007/978-3-319-59008-0_7.

STÖHR, S., O'HARA, T.D. and THUY, B., 2012. Global diversity of brittle stars (Echinodermata: ophiuroidea).*PLoS One*, vol. 7, no. 3, pp. e31940. http://dx.doi.org/10.1371/journal.pone.0031940. PMid:22396744.

STRANO, F., MICARONI, V., COSTA, G., BERTOCCI, I. and BERTOLINO, M., 2020. Shallow-water sponge grounds along the Apulian coast (central Mediterranean Sea).*Marine Biodiversity*, vol. 50, no. 1, pp. 1-12. http://dx.doi.org/10.1007/s12526-019-01026-x.

TOTTI, C., ROMAGNOLI, T., DE STEFANO, M. and BAVESTRELLO, G., 2010. The diversity of epizoic diatoms. In: Z.DUBINSKY and J.SECKBACH, eds. *All flesh is grass. Cellular origin, life in extreme habitats and astrobiology*. Dordrecht: Springer, vol. 16, pp. 323-343.

WULFF, J.L., 2021. Targeted predator defenses of sponges shape community organization and tropical marine ecosystem function.*Ecological Monographs*, vol. 91, no. 2, pp. e01438. http://dx.doi.org/10.1002/ecm.1438.