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ORIGINAL PAPERS

Antipredator Defenses in Soft Corals of the Genus *Sarcophyton* (Octocorallia; Alcyoniidae) from Coastal Waters of Central Vietnam[1]

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Abstract—As sessile marine organisms, soft corals may use chemical or/and physical factors of defense against fish predators for their survival and growth. In Vietnam, corals of the speciose genus *Sarcophyton* are abundant on reefs. However, little is known about their defensive traits and strategies. In the study of feeding deterrence, experiments in the field and in an aquarium were conducted using only crude extract, only sclerites, and a mixture of both from *Sarcophyton cinereum*, *S. glaucum*, *S. serenei*, *S. trocheliophorum* and *Sarcophyton* sp. For all species, pellets containing a mixture of crude extract and sclerites were consumed by reef fishes from 0.8 to 14.6% (in the field, F) and from 0.3 to 13.3% (in aquarium, A); crude extract was consumed from 5.2 to 42.6% (F) and from 7.4 to 64.0% (A); and sclerites were consumed from 34.6 to 100% (F) and from 30 to 83.3% (A). The consumption of pellets containing *S. serenei* sclerites was significantly reduced both in the field assays with reef fishes and in the aquarium assays with the moon wrasse *Thalassoma lunare* ($P < 0.05$), which showed sclerites as a dominant physical factor in the *S. serenei* feeding deterrence. Overall, in *Sarcophyton* soft corals, the effect of fish predation prevention was most pronounced in the combination of both chemical and physical defense factors, followed by the chemical and then the physical factor alone. Hence, both chemical and physical factors of defense against predation may contribute to the *Sarcophyton* abundance on reefs.

Keywords: predator deterrence, crude extract, sclerites, Sarcophyton, *Thalassoma lunare*, Vietnam

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INTRODUCTION

In coral reef assemblages, soft corals (Octocorallia, Alcyonacea) influence productivity and also provide a food supply and habitat for other organisms [12]. They represent major components of the sessile benthos contributing to the diversity of tropical reef communities [11, 13, 39] including those inhabiting the South China Sea [5, 9, 17]. Like many other sessile marine organisms including sponges, zooanthids, and hard corals, soft corals often produce numerous bioactive substances for their protection that provide deterrence of predators and parasites, inhibition of pathogenic microorganisms' growth [21], anti-fouling action [8, 23], or advantage in space competition [1, 32, 33]. Some soft corals such as *Sinularia polydactyla, Sarcophyton ehrenbergi, Rhytisma fulvum fulvum, Heteroxenia ghadarqensis*, and *Xenia crenata* have been found to use secondary metabolites to defend themselves against carnivorous fish predators [3, 4, 16, 19, 36, 37, 39]. Other species, including *Sinularia compressa, S. kavarattiensis*, and *S. candidula*, may utilize their bioactive compounds to prevent fouling on their surfaces or to protect their organisms from viral infections [2, 6, 23]. Therefore, the conspicuous richness of chemical defense factors in soft corals may contribute to their invasive potential and ability to occupy space on reefs [13, 22, 29].

In contrast to the strong structural skeleton in hard corals, tissues of most soft corals contain small sclerites embedded in the coenenchyme. Some studies suggest that the density, shape, and size of sclerites in soft corals may contribute to the deterrence of predators [28, 31, 37]. On the other hand, predatory reef fish were not found to be deterred from feeding on the soft coral *Rhytisma fulvum fulvum* although its sclerites make up about 80% of tissue dry weight [19]. Also, another study showed that the predation of reef fish was not affected even by a double natural concentra-

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tion of sclerites in *Ovabunda crenata* [16]. Therefore, the role of sclerites as a factor of defense against predators is still not clear and remains controversial.

In Vietnam, soft corals are represented by approximately 200 species from 45 genera and 14 families [17]. The highest their biodiversity is distributed in the Nha Trang Marine Protected Area (MPA) (142 species), the Ly Son MPA (60 species), and the Cu Lao Cham (CLC) MPA (45 species). Nevertheless, the highest coverage values of soft corals with a major contribution of the genus *Sarcophyton* were recorded from the CLC MPA [18]. It is possible that an efficient defense against fish predation could contribute to this success. However, there is a lack of experimental data to confirm or reject this role.

This paper presents the results of the predation deterrence experiments in the field and in an aquarium using feed pellets containing crude extracts and/or sclerites from five *Sarcophyton* species common in Vietnam.

MATERIALS AND METHODS

Study Area

The CLC MPA is located in the coastal waters of central Vietnam (15°55′ N, 108°28′ E). The CLC MPA was established in 2005 and then became the core zone of the UNESCO Hoi An-Cu Lao Cham Biosphere Reserve in 2009. According to Hoang and Thai [18], coral reefs there support 45 taxa of soft corals in 13 genera and 7 families. The coverage of soft coral ranges from 7.7 ± 3.4 to 40.3 ± 7.7% with an average of 21.2 ± 7.0% [18]. The genus *Sarcophyton* is a major contributor, with its coverage on reefs reaching 30%.

Sample Collection

Three replicate samples of five *Sarcophyton* species–*Sarcophyton cinereum*, *S. glaucum*, *S. serenei*, *S. trocheliophorum*, and *Sarcophyton* sp. were collected by SCUBA diving from a depth of 3–10 m in the CLC MPA. Each sample was 0.5–1.4 kg wet weight. After collection, the samples were transported to the laboratory, where the volume was calculated using water displacement. A subsample of each sample was fixed in 70% ethanol for morphological identification.

Extraction

At the first step, a fresh sample (whole colony) was immersed in 1000 mL ethyl acetate at room temperature for 24 h [22]. The obtained crude extract was filtered through a paper filter, and the solvent was removed on a rotary evaporator. The extracted coral tissue was stored in a freezer at –20°C until further processing. After being extracted in the first step, the sample was cut into small cubic pieces (about 0.5 cm^3), then immersed into a mixture of dichloromethane (DCM) and methanol (MeOH) (1 : 1 v/v), and left for 24 h at room temperature [39]. This second crude extract was also filtered through filter paper, and the solvent was evaporated until drying out. The crude extract after the 1st and 2nd steps was combined, weighed, and kept at –20°C for the preparation of feed pellets. The natural concentration of the crude extract was estimated on the basis of the volumes of the coral samples, which were 20, 27, 23, 16, and 23 mg/mL for *S. cinereum*, *S. glaucum*, *S. serenei, S. trocheliophorum*, and *Sarcophyton* sp., respectively. These were used as a reference for making the feed pellets.

Sclerites Preparation

Each colony of the *Sarcophyton* soft corals was cut into several small pieces and immersed in 12% sodium hypochlorite for 12 h two or three times to remove soft tissue. Collected sclerites were rinsed 3 times with distilled water, dried at 80°C until complete drying out, and weighted. The natural concentration of sclerites was estimated by dividing the dry weight of sclerites by the volume of the colony: 180, 70, 420, 70, and 10 mg/mL, respectively, for *S. cinereum*, *S. glaucum*, *S. serenei*, *S. trocheliophorum*, and *Sarcophyton* sp.

Food Preparation

Feed pellets for the field assay were prepared according to Pawlik and Fenical [27] and Hoang et al. [16] with some modifications. A mixture of 30 mL distilled water, 1.30 g Phytagel (Sigma-Aldrich), and 1.38 g squid powder (cuttlefish *Sepia aculeata*, cleaned, freeze-dried, and ground into powder) were stirred up well and boiled for 5 min, then cooled to 40°C or lower. The crude extract of soft corals dissolved in ethanol and/or soft coral sclerites was added at the natural concentration and mixed well (0.7 mL of *S. cinereum*; 1.0 mL of *S. glaucum*, 1.9 mL of *S. serenei*, 0.6 mL of *S. trocheliophorum*, and 0.8 mL of *Sarcophyton* sp.). The viscous material was poured into a plastic mold with a 1 mm^2 mesh mosquito net. After the matrix cooled to room temperature, the solidified gel was removed from the mold, cut into small pieces of the same size, and weighed. Feed pellets for the aquarium experiment were prepared according to Pawlik et al. [26]. The ethanolic crude extract was mixed well with 0.3 g alginic acid (Sigma-Aldrich), 0.5 g powdered squid, and distilled water to reach the final volume of 10 mL. The mixture was loaded into a 10 mL-syringe and expelled slowly into a 0.25 M $CaCl_2$ solution to form a "noodle" food material. After rinsing with seawater, the "noodle" was cut into pieces of about 3 mm in length and 1 mm in diameter for the feeding experiment. The feed pellets containing the original concentration of sclerites and the diluted extracts (50 and 25% of the natural extract concentration) were prepared for testing the antipredator effec-

tiveness of sclerites. The control pellets were prepared in the same way as the treatment pellets, but without the crude extract and/or sclerites and with the same amount of ethanol.

Field Assay

The field assay was conducted at the same sampling place of the reef in the CLC MPA. Feed pellets were suspended on a vertical fishing line with a buoy at one end and weight at the nother end in the reef. The feed pellets were distributed as a pair of one pellet containing crude extract and/or sclerites and the other control (containing ethanol only) in each hanging position of the line. For each experiment ($n = 3$), three pellets were made, resulting in a total of nine pellets (replicate and sub-replicate) for each species. Reef fishes feeding on the feed pellets were observed by SCUBA divers from a distance of 4 m. The line was collected if either control or treatment pellets were eaten, or after 3 h. After each field bioassay, the remaining feed pellets were weighted to determine the amount consumed. Unused treatment pellets were re-extracted to determine whether they retained the natural concentration of crude extracts or if the concentration of crude extract decreased due to degradation or leaching. The results showed that the natural concentration of crude extract in the feed pellets was not lost after the field bioassay.

Aquarium Experiment

The feeding choice assay was conducted in the Department of Aquaculture Technology, Institute of Oceanography, Vietnam Academy of Science and Technology. The moon wrasse *Thalassoma lunare* was selected for the aquarium assay because it is a common species in the region and a well-known generalist feeder preying on benthic invertebrates such as soft coral [30]. Each fish ($n = 10$, with 12–15 cm in total length, collected from the CLC MPA) was placed in a tank filled with 40 L of seawater at 25°C and exposed to a 12 h light : 12 h dark cycle. The fish were fed artificial fish feed every day at 9:00 a.m. After two weeks of acclimatization to the new tank, the fish were adapted to feeding on control feed pellets for one week.

In each test, moon wrasse were offered a control pellet and then, if they ate, one treatment pellet (containing crude extract, sclerites, or both). The feed test was conducted by feeding the fish alternately control and treatment pellets. In case the fish ignored the treatment pellet, another control pellet was offered in order to discriminate between the deterrence of the treatment pellet and satiation. A pellet was considered "rejected" when it was ignored, spit out, or the fish swam away from it and consumed a control pellet thereafter. The feed trials were repeated with each *Sarcophyton* species ($n = 3$) by using 10 control and 10 treatment pellets, resulting in a total of 60 pellets, and the number of consumed or rejected pellets was counted.

Experiments were conducted from 9:00 to 11:00 AM for eight weeks. Different treatment pellets were tested on different days and repeated for each fish, with a 3- to 5-day rest between each test. In all, over 660 trials were conducted.

Data Analysis

The feeding deterrence in the field and aquarium assay was assessed by pairwise comparison of the consumption rates for control and treated pellets using the paired *t*-test. The discrimination between control and treated pellets was tested by the Fisher's exact test for each soft coral species independently. Since fish may have learning ability, the statistical evaluation of the extract deterrence was based solely on the acceptance or rejection of the first treated pellet according to Hoang et al. [16].

RESULTS

In the field, food pellets were observed to be eaten mostly by wrasses (Labridae), damselfishes (Pomacentridae), triggerfishes (Balistidae), and groupers (Serranidae), which are common reef fishes in the area. The proportion of pellets consumed varied depending on the tretment pellets and the soft coral species.

As shown in Fig. 1, the proportion of consumed pellets containing only crude extracts at a natural concentration varied among five *Sarcophyton* species (5.2–42.6%). Except for *S. serenei*, those from four species showed a significant difference ($p < 0.05$) vs. control.

While almost all pellets containing a natural concentration of sclerites from the four soft coral species (*S. cinereum, S. glaucum*, *S. trocheliophorum*, and *Sarcophyton* sp.) were consumed by the reef fishes (Fig. 2), only $34.6 \pm 9.2\%$ (mean $\pm$ *SE*) of pellets containing *S. serenei* sclerites was eaten ($p < 0.05$).

Pellets containing a mixture of crude extract and sclerites at a natural concentration (0.8–14.6%) were consumed to a significantly lesser extent by reef fishes (Fig. 3) ($p < 0.05$).

Similarly, the ratio of pellets consumed by moon wrasse in the aquarium experiment also varied depending on the treatment pellets and the soft coral species (Fig. 4). The pellets containing crude extracts were consumed in a range of 7.4–64.1%, showing a significant difference vs. control for all the *Sarcophyton* species (Fisher's exact test, $p < 0.05$), except *S. serenei* ($p > 0.05$). On the other hand, the pellets containing only sclerites were consumed at 30–83.3% as compared to the controls, but this effect was only significant for *S. serenei* ($p < 0.05$). However, the pellets containing a mixture of crude extract and sclerites

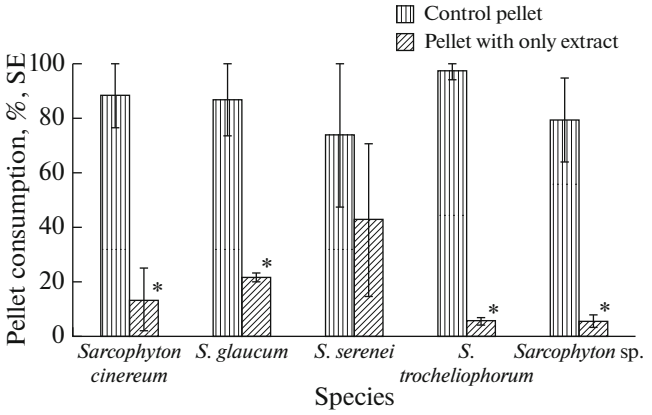

Fig. 1. Proportion (%) of pellets containing only the crude extract from five soft coral species consumed by reef fishes compared to that of control pellets in the field experiment; * significant difference ($p < 0.05$) vs. control.

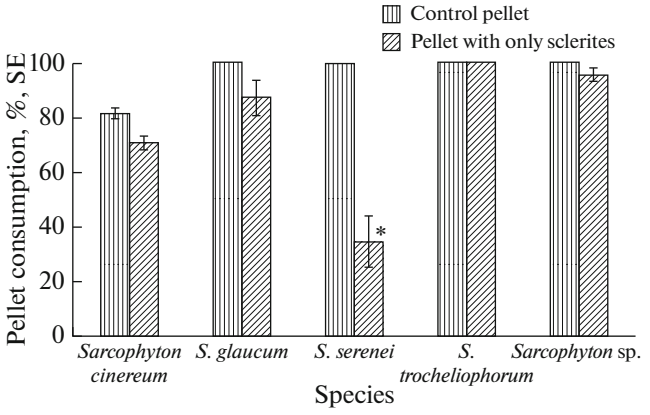

Fig. 2. Proportion (%) of pellets containing only sclerites from five soft coral species consumed by reef fishes compared to that of control pellets in the field experiment; * significant difference ($p < 0.05$) vs. control.

were consumed to a significantly lesser extent than the control ones for all five *Sarcophyton* species ($p < 0.05$). The result indicated that a mixture of crude extract and sclerites of *Sarcophyton* soft coral showed the strongest antipredator effect, at least at natural concentration, in both the field and aquarium experiments.

Further, the deterrent effect decreased with decreasing crude extract concentration and at the same natural concentration of sclerites for all five *Sarcophyton* species (Fig. 5). The proportion of these treatment pellets consumed by moon wrasse was significantly different vs. control ($p < 0.05$) for the five species.

DISCUSSION

In the present study, the crude extract from four (out of five) *Sarcophyton* species showed the feeding deterrence effect in both the field assays with reef fishes and the aquarium assays with moon wrasse, *T. lunare*. Several studies have found that the crude extract from Octocorallia plays an important role in the defense factors against fish predators in tropical Pacific waters [14, 15, 35], in the Red Sea [16, 19], the Caribbean [13], and other regions [1, 24]. The result of the experiments with pellets containing a mixture of crude extract and sclerites at a natural concentration has clearly indicated that in the *Sarcophyton* species this combination of factors protected the corals from reef fishes more effectively than the crude extract or sclerites alone. This may explain why *Sarcophyton*, a potential food supply for reef fishes, is rarely consumed by them [3], although fish predators are abundant in Cu Lao Cham [25].

The lack of the antipredator effect of sclerites from four out of five studied *Sarcophyton* species suggest that sclerites alone may play only a minor role in soft corals' defense against predatory fish. According to studies, the feeding deterrence of sclerites may be effective only in some parts of the colony, where their concentration is particularly high, e.g., in tips of the gorgonian *Annella reticulata* [28] or at the base of a *Sinularia* colony [37]. Other studies emphasize the influence of the size, shape, and density of sclerites of soft corals and sponges on the deterrence effect against predatory fish [7, 20, 37]. For the *S. serenei* species, the coenenchymal sclerites in a disc colony (with a length of 0.9 mm) and in the stalk colony (1.5–1.7 mm in length) were often found to be larger than in other species [8; This study]. *S. serenei* sclerites showed the feeding deterrence effect against tropical fish at a natural concentration (0.42 g/mL), which was much higher than for the other species tested. Thus, a combination of sclerite size, shape, and high concentration could be responsible for the significant antipredator

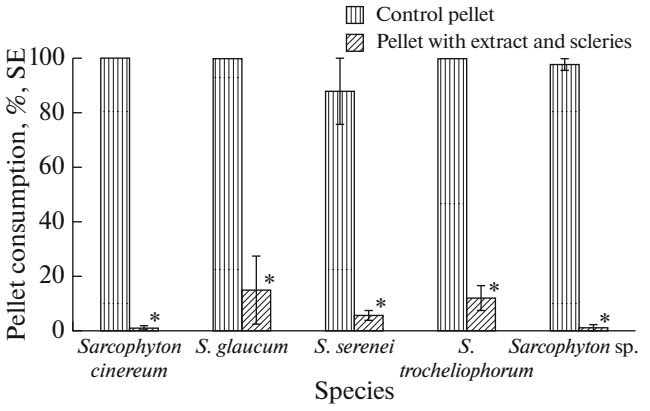

Fig. 3. Proportion (%) of pellets containing a mixture of crude extract and sclerites from five soft coral species consumed by reef fishes compared to that of control pellets in the field experiment; * significant difference ($p < 0.05$) vs. control.

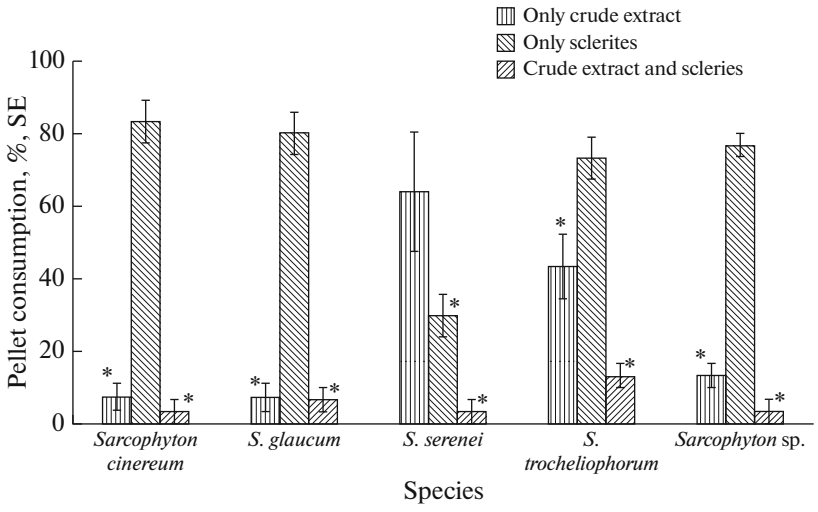

Fig. 4. Proportions (%) of pellets containing the crude extract, sclerites, and a mixture of both consumed by moon wrasse (*Thalassoma lunare*) in the aquarium experiment; * significant difference ($p < 0.05$) vs. control. (The control pellets were consumed completely in all tests, data not shown).

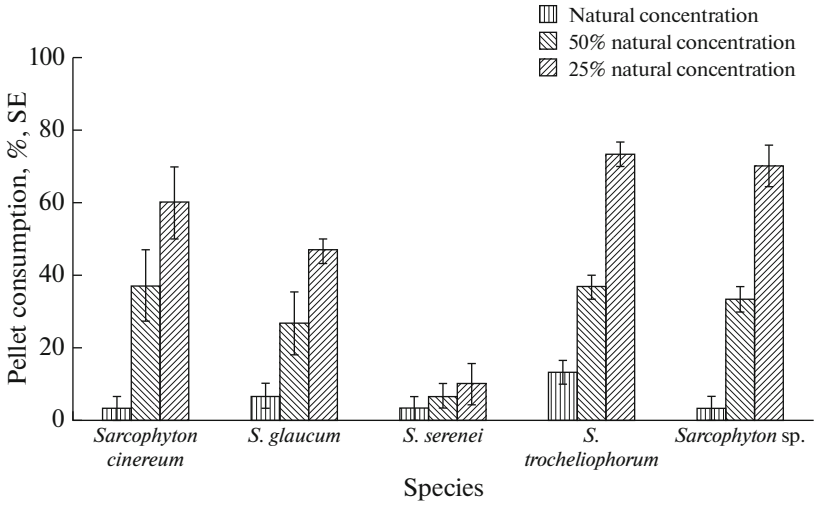

Fig. 5. Proportions (%) of consumed pellets containing a mixture of sclerites with a constant natural concentration and the crude extract at 100, 50, and 25% of natural concentration in the aquarium experiment. (The control pellets were consumed completely in all tests, data not shown).

effect shown by *S. serenei*. However, the feeding deterrence might also be explained by a lower quality of food for predators, since the treatment pellets containing sclerites were of a lower nutritional quality than the control pellets [11].

The feeding deterrence effect was still apparent when the concentration of crude extract in the pellets was reduced to 25% of the natural concentration found in *Sarcophyton* tissue, with the natural concentration of sclerites. This means that the studied *Sarcophyton* species may be consistently resistant to fish predation even when secondary metabolite concentrations vary under different environmental conditions, as described earlier [13, 35]. Although the chemical compounds in the crude extract from the species in our study are not yet identified, the findings have clearly demonstrated their feeding deterrence, as evidenced by their impressive effect not only towards certain species (e.g., *Thalassoma lunare*) but also towards other common reef fishes. Further study is needed to assess the composition of effective metabolites and elucidate whether they act additively or synergistically.

In this study, the prevention of fish predation has confirmed the chemical defense in *Sarcophyton* species, while the physical defense was pronounced in some species. Our results support the assumption that the use of chemical and physical factors by soft corals

against fish predation can be one of the explanations for their abundance on reefs in Vietnam.

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COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interests. The authors declare that they have no conflict of interest.

Statement on the welfare of animals. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

REFERENCES

1. Aceret, T.L., Sammarco, P.W., and Coll, J.C., Toxic effects of alcyonacean diterpenes on scleractinian corals, *J. Exp. Mar. Biol. Ecol.*, 1995, vol. 188, pp. 63–78. https://doi.org/10.1016/0022-0981(94)00186-H
2. Ahmed, S., Ibrahim, A., and Arafa, A.S., Anti-H5N1 virus metabolites from the Red Sea soft coral, *Sinularia candidula, Tetrahedron Lett*, 2013, vol. 54, pp. 2377–2381. https://doi.org/10.1016/j.tetlet.2013.02.088
3. Kasumyan, A., Isaeva, O., and Zvonareva, S., Coloration type of two allied cowries (Ovulidae:Gastropoda) tested through palatability evaluation in feeding experiments with fish, *J. Exp. Mar. Biol. Ecol.*,2021, vol. 538, pp. 1–7. https://doi.org/10.1016/j.jembe.2021.151529
4. Bakus, G.J., Chemical defense mechanisms on the Great Barrier Reef, Australia, *Science*, 1981, vol. 211, pp. 497–499.
5. Benayahu, Y., Jeng, M.-S., Perkol-Finkel, S., et al., Soft corals (Octocorallia: Alcyonacea) from Southern Taiwan: 2. Species diversity and distributional patterns, *Zool. Stud*, 2004, vol. 43, pp. 548–560.
6. Bhosale, S.H., Nagle, V.L., and Jagtap, T.G., Antifouling potential of some marine organisms from India against species of *Bacillus* and *Pseudomonas, Mar. Biotechnol*, 2002, vol. 4, pp. 111–118. https://doi.org/10.1007/s10126-001-0087-1
7. Burns, E. and Ilan, M., Comparison of anti-predatory defenses of Red Sea and Caribbean sponges: 2. Physical defense, *Mar. Ecol. Prog. Ser.*, 2003, vol. 252, pp. 115–123.
8. Changyun, W., Haiyan, L., Changlun, S., et al., Chemical defensive substances of soft corals and gorgonians, *Acta Ecol. Sin.*, 2008, vol. 28, pp. 2320–2328. https://doi.org/10.1016/S1872-2032(08)60048-7
9. Dautova, T.N. and Savinkin, O.V., *Octocorallia: Alcyonacea. Benthic Fauna of Bay of Nhatrang, Southern Vietnam*, Moscow: KMK, 2013.
10. Dinesen, Z.D., Patterns in the distribution of soft corals across the central Great Barrier Reef, *Coral Reefs*, 1983, vol. 1, pp. 229–236. https://doi.org/10.1007/BF00304420
11. Duffy, J.E. and Paul, V.J., Prey nutritional quality and the effectiveness of chemical defenses against tropical reef fishes, *Oecologia*, 1992, vol. 90, pp. 333–339. https://doi.org/10.1007/BF00317689
12. Fabricius, K.E. and Alderslade, P., *Soft Corals and sea Fans: A Comprehensive Guide to the Tropical Shallow Water Genera of the Central-West Pacific, the Indian Ocean and the Red Sea*, Queensland, Australia, Australian Institute of Marine Science, 2001.
13. Fleury, B.G., Lages, B.G., Barbosa, J.P., et al., New hemiketal steroid from the introduced soft coral *Chromonephthea braziliensis* is a chemical defense against predatory fishes, *J. Chem. Ecol.*, 2008, vol. 34, pp. 987–993. https://doi.org/10.1007/s10886-008-9499-y
14. Goh, B.P.L., Tan, G.E., and Tan, L.T., Diversity, distribution and biological activity of soft corals (Octocorallia, Alcyonacea) in Singapore, *J. Coastal Dev.*, 2009, vol. 12, pp. 89–98.
15. Goh, N.K.C. and Chou, L.M., Toxicity and palatability of gorgonian (Octocorallia: Gorgonacea) extracts to goldfish *Carassius auratus* (Linnaeus, 1758), in *Asian Marine Biology,* Aberdeen, Hong Kong: Hong Kong Univ. Press, 1998, pp. 199–210.
16. Hoang, B.X., Sawall, Y., Al-Sofyani, A., et al., Chemical versus structural defense against fish predation in two dominant soft coral species (Xeniidae) in the Red Sea, *Aquat. Biol.*, 2015, vol. 23, pp. 129–137. https://doi.org/10.3354/ab00614
17. Hoang, X.B. and Dautova, T.N., Diversity of soft corals (Alcyonacea) in Vietnam, in *Marine Biodiversity of East Asian Sea: Status, Challenges and Sustainable Development, Proc. Int. Conf.,* Dautova, T.N. and Lutaenko, K.A., Eds., Nha Trang, Vietnam, 2010, pp. 82–87.
18. Hoang, X.B. and Thai, M.Q., Biodiversity and characteristic of octocoral communities (Octocorallia: Alcyonacea and Gorgonacea) in Cu Lao Cham Marine Protected Area, Quang Nam province, *Vietnam J. Mar. Sci. Technol.*, 2019, vol. 19, pp. 589–599. https://doi.org/10.15625/1859-3097/19/4/12661
19. Kelman, D., Benayahu, Y., and Kashman, Y., Chemical defence of the soft coral *Parerythropodium fulvum fulvum* (Forskål) in the Red Sea against generalist reef fish, *J. Exp. Mar. Biol. Ecol.*, 1999, vol. 238, pp. 127–137. https://doi.org/10.1016/S0022-0981(99)00016-7
20. Koh, L.L., Goh, N.K.C., Chou, L.M., et al., Chemical and physical defenses of Singapore gorgonians (Octocorallia: Gorgonacea), *J. Exp. Mar. Biol. Ecol.*, 2000,

vol. 251, pp. 103–115.
https://doi.org/10.1016/S0022-0981(00)00207-0

21. La Barre, S.C., Coll, J.C., and Sammarco, P.W., Defensive strategies of soft corals (Coelenterata: Octocorallia) of the Great Barrier Reef: 2. The relationship between toxicity and feeding deterrence, *Biol. Bull.*, 1986, vol. 171, pp. 565–576.
https://doi.org/10.2307/1541624
22. Lages, B.G., Fleury, B.G., Ferreira, C.E.L., et al., Chemical defense of an exotic coral as invasion strategy, *J. Exp. Mar. Biol. Ecol.*, 2006, vol. 328, pp. 127–135.
https://doi.org/10.1016/j.jembe.2005.07.011
23. Limna Mol, V.P., Raveendrana, T.V., Parameswaran, P.S., et al., Antifouling sesquiterpene from the Indian soft coral Sinularia kavarattiensis Alderslade and Prita, *Indian J. Mar. Sci.*, 2010, vol. 39, pp. 270–273.
24. Martín, D. and Uriz, M.J., Chemical bioactivity of Mediterranean benthic organisms against embryos and larvae of marine invertebrates, *J. Exp. Mar. Biol. Ecol.*, 1993, vol. 173, pp. 11–27.
https://doi.org/10.1016/0022-0981(93)90205-3
25. Nguyen, V.L. and Mai, X.D., Characteristics of fish fauna in marine ecosystems in the World Biosphere Reserve of Cu Lao Cham-Hoi An, *Vietnam J. Mar. Sci. Technol.*, 2020, vol. 20, pp. 105–120.
https://doi.org/10.15625/1859-3097/20/1/13553
26. Pawlik, J.R., Chanas, B., Toonen, R.J., et al., Defenses of Caribbean sponges against predatory reef fish: 1. Chemical deterrency, *Mar. Ecol. Prog. Ser.*, 1995, vol. 127, pp. 183–194.
27. Pawlik, J.R. and Fenical, W., Chemical defense of *Pterogorgia anceps*, a Caribbean gorgonian coral, *Mar. Ecol. Prog. Ser.*, 1992, vol. 87, pp. 183–188.
28. Puglisi, M.P., Paul, V.J., and Slattery, M., Biogeographic comparisons of chemical and structural defenses of the Pacific gorgonians *Annella mollis* and *A. reticulata, Mar. Ecol. Prog. Ser.*, 2000, vol. 207, pp. 263–272.
29. Rocha, J., Peixe, L., Gomes, N.C.M., et al., Cnidarians as a source of new marine bioactive compounds: An overview of the last decade and future steps for bioprospecting, *Marine Drugs*, 2011, vol. 9, pp. 1860–1886.
30. Rotjan, R.D. and Lewis, S.M., Impact of coral predators on tropical reefs, *Mar. Ecol. Prog. Ser.*, 2008, vol. 367, pp. 73–91.
31. Sammarco, P.W., Barre, S.L., and Coll, J.C., Defensive strategies of soft corals (Coelenterata: Octocorallia) of the Great Barrier Reef: 3. The relationship between ichthyotoxicity and morphology, *Oecologia*, 1987, vol. 74, pp. 93–101.
32. Sammarco, P.W., Coll, J.C., and La Barre, S., Competitive strategies of soft corals (Coelenterata: Octocorallia): 2. Variable defensive responses and susceptibility to scleractinian corals, *J. Exp. Mar. Biol. Ecol.*, 1985, vol. 91, pp. 199–215.
https://doi.org/10.1016/0022-0981(85)90176-5
33. Sammarco, P.W., Coll, J.C., La Barre, S., et al., Competitive strategies of soft corals (Coelenterata: Octocorallia): Allelopathic effects on selected scleractinian corals, *Coral Reefs*, 1983, vol. 1, pp. 173–178.
https://doi.org/10.1007/BF00571194
34. Slattery, M., Hines, G.A., Starmer, J., et al., Chemical signals in gametogenesis, spawning, and larval settlement and defense of the soft coral *Sinularia polydactyla, Coral Reefs*, 1999, vol. 18, pp. 75–84.
https://doi.org/10.1007/s003380050158
35. Slattery, M., Starmer, J., and Paul, V., Temporal and spatial variation in defensive metabolites of the tropical Pacific soft corals *Sinularia maxima* and *S. polydactyla, Mar. Biol.*, 2001, vol. 138, pp. 1183–1193.
https://doi.org/10.1007/s002270100540
36. Van Alstyne, K.L., Wylie, C.R., and Paul, V.J., Antipredator defenses in tropical Pacific soft corals (Coelenterata: Alcyonacea) II. The relative importance of chemical and structural defenses in three species of *Sinularia, J. Exp. Mar. Biol. Ecol.*, 1994, vol. 178, pp. 17–34.
https://doi.org/10.1016/0022-0981(94)90222-4
37. Van Alstyne, K.L., Wylie, C.R., Paul, V.J., et al., Antipredator defenses in tropical pacific soft corals (Coelenterata: Alcyonacea): 1. Sclerites as defenses against generalist carnivorous fishes, *The Biological Bulletin*, 1992, vol. 182, pp. 231–240.
https://doi.org/10.2307/1542116
38. Van Ofwegen, L.P., Status of knowledge of the Indo-Pacific soft coral genus *Sinularia* May, 1898 (Anthozoa: Octocorallia), in Proc. 9th Int. Coral Reef Symp., Moosa, M.K., Soemodihardjo, S., Soegiarto, A. et al., Eds., Bali, Indonesia, 2000, vol. 1, pp. 23–27.
39. Wylie, C.R., Paul, V.J., Chemical defenses in three species of Sinularia (Coelenterata, Alcyonacea): Effects against generalist predators and the butterflyfish *Chaetodon unimaculatus* Bloch, *J. Exp. Mar. Biol. Ecol.*, 1989, vol. 129, pp. 141–160.
https://doi.org/10.1016/0022-0981(89)90053-1