Boll. Mus. Ist. Biol. Univ. Genova, **68**: 253-261, 2003 (2004)

SPONGE INTERACTIONS WITH SPATIAL COMPETITORS IN THE SPERMONDE ARCHIPELAGO

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ABSTRACT

This study describes the *in situ* effects of four bioactive sponges on their neighbours at three different locations and two depths in the Spermonde Archipelago, SW Sulawesi, Indonesia. The natural rates of interaction between the sponge species and eight possible competitive invertebrate groups were defined and quantified in circular subplots, this was repeated 25x for each of the four species and for each location and depth. Most interactions occurred with other sponges and with corals. Coral overgrowth by the four target species caused necrosis in more than 85 % of these interactions, whereas this was less than 25 % in sponge overgrowths. These results suggest that the toxins are used in spatial competition and that the concentrations of the bioactive compounds of the target species differ both intra-individually and intra-specifically.

KEY WORDS

Spatial competition, allelopathy, sponge culture, Indonesia.

INTRODUCTION

A growing interest in pharmaceuticals from the sea has expanded in the last decades. Sponges produce a large amount of secondary metabolites with biological activity. Many of these bioactive compounds show antimitotic, cytotoxic, antibacterial, antifungal and antiviral properties, and may have a potential to be processed in pharmaceuticals. Currently, more than 3500 different compounds have been isolated from appromixately 475 species of marine sponges (BLUNT & MUNRO, 1998; VAN SOEST & BRAEKMAN, 1999) and more natural products continue to be isolated at a very fast pace. Since the supply-matter of these potential drugs is a major problem, a need for alternative ways to obtain these compounds has arisen. In most cases it is not feasible to harvest wild sponges on a commercial scale, as sponge populations are often small and have a patchy distribution. In New Zealand, aquaculture of several sponge species has appeared to be a viable and reliable option for providing the toxic compound for initial preclinical trials (MUNRO *et al.,* 1999).

Different species of sponges thrive under different ecological circumstances; consequently the bioactivity may also differ per habitat. The sponge bioactivity is thought to be enhanced in tropical environments such as coral reefs (BECERRO *et al.*, 2003). Thus, the species-rich Indonesian reefs (VAN SOEST, 1990; MORA *et al.,* 2003) may harbour the highest diversity in sponge chemical compounds of the world. Therefore an attempt has been made to set up a sponge aquaculture in the Spermonde Archipelago, SW Sulawesi, which is presently one of the best marine explored regions in Indonesia (MOLL, 1983; HOEKSEMA, 1990; VERHEIJ, 1993; DE VOOGD *et al.,* 1999). However, with the wide array of compounds being isolated from a myriad of sponge species (SUPRIYONO *et al.,* 1995; ROY *et al.,* 2000), the life history and growth rates of sponges have to be better understood first. The ecological functions of such bioactive compounds have occasionally been tested in the field in recent years (SCHULTE & BAKUS, 1992; PAWLIK *et al.,* 1995; AERTS & VAN SOEST, 1997), but the answers have remained ambiquous. Some of the compounds may be used for anti-fouling, UV-protection (BECERRO *et al.,* 1995; ZEA *et al.,* 1999), antipredator (WULFF, 1994; PAWLIK *et al.,* 1995; DUNLAP & PAWLIK, 1996), and in competition for space (*e.g.,* SULLIVAN *et al.,* 1983, PORTER & TARGETT, 1988; AERTS & VAN SOEST, 1997). The bioactivity may differ intra-specifically and even intra-individually in relation to the ecological conditions. This depends on the function of the compound which may differ per situation, such as with variation in illumination (BECERRO *et al.,* 1995; ZEA *et al.,* 1999), lifeform (SWEARINGEN & PAWLIK, 1998; SCHUPP *et al.,* 1999), and the amount of possible competitors (AERTS, 2000). Space is a highly limited resource for sessile organisms living on hard substratum (DAYTON, 1971), this is especially the case in tropical coral reefs. Consequently, for sessile invertebrates to be able to gain and maintain space depends mostly on their competitive abilities (AERTS & VAN SOEST, 1997). Sponges are important spatial competitors, not only by means of overgrowing competitors but also by producing toxic anti-settlement or fouling compounds (PORTER & TARGETT, 1988). Spatial competition can be visibly determined as overgrowth, necrosis, and bleaching of the interacting neighbour (AERTS, 2000).

In this paper, we describe the *in situ* effects of four bioactive sponges on their neighbours at different locations and depths. The target species, *Aaptos suberitoides* (Brønsted, 1934), *Amphimedon paraviridis* (Fromont, 1993), *Niphates olemda* (de Laubenfels, 1954), and *Callyspongia* (*Callyspongia*) sp., were carefully chosen on the basis of their known bioactivity, natural abundance and potential use in aquaculture. We wanted to relate field observations to the possible ecological functions of the bioactive compounds and make a prediction on how intra-specific and intra-individual bioactivity differ.

MATERIAL AND METHODS

The research area is located in the Spermonde Archipelago just off the coast of Makssar, SW Sulawesi, Indonesia. This study is part of an ongoing project for a sustainable exploitation of bioactive sponges and an exploratory study has been done for the toxic sponges in the area. Around 43 species were collected of which 26 has been chemically analysed and tested in various bioassays. The bioactivity in order of magnitude for the crude extracts is; *Callyspongia (Callyspongia)* sp. > *Amphimedon paraviridis* > *Niphates olemda* > *Aaptos suberitoides* (unpublished Symbiosponge data accessible through www-zma.bio.uva.nl/departments/coel/ symbiosponge/).

The microhabitat of the four sponge target species was described by defining and quantifying the natural rates of interactions between the target sponge and its neighbours. A circular frame constructed of a rubber garden hose with a diameter of 25 cm was randomly put over 25 sequential individuals per target species along a 100 m transectline at two depth intervals (6 and 12 m) at the Northwest (NW) (05º07.326' S 119º20.410' E) and Southeast (SE) (05º07.597' S 119º20.686' E), side of Samalona Island, and the NW-side (05º06.195' S 119º17.082' E) of Kudingareng Keke Island (KKW). Neighbours of eight possible competitive groups were identified: Porifera, Scleractinia, Octocorallia, Milleporidae, Ascidiacea, Actinaria, Antipatharia, and large fleshy algae. A neighbour is considered a competitor for space when it reached a mimal size of 9 cm^2. Five types of interactions were defined (after AERTS & VAN SOEST, 1997):

A Overgrowth of neighbour by the target species

B Peripheral tissue contact of the sponge and the neighbour along and parallel to eachother for a distance of more than 3 cm

C Tissue contact of less than 3 cm of the sponge and the neighbour

D Non contact; the neighbour lives within a distance of 5 cm of the sponge boundary

E Overgrowth by neighbour of the target species.

In addition, the state of the neighbour with which the target sponge interacted was noted, whether it was necrotic/bleaching or whether it appeared healthy.

RESULTS

A total of 1909 interactions were recorded for 550 sponge individuals. *N. olemda* was not found at the Southeast side of Samalona, therefore only 100 individuals were investigated for this species. The total number of interactions for the different targets species were; *A. suberitoides* (509), *A. paraviridis* (482), *Callyspongia* (*C.*) sp. (566) and *N. olemda* (352). Non-contact situations were the most observed interactions for all species, and this was the highest for *A. suberitoides* (258). Most interactions were observed with Scleractinia and other Porifera, however, the number of overgrowth interactions with those neighbours differed greatly between locations and depth for the different species (Fig. 1).

A. paraviridis and *Callyspongia* (*C.*) sp. had a significantly higher number of overgrowth interactions with Scleractians at KKW than at SE (Kruskal Wallis respectively $P = 0.023$; $P = 0.007$) and SW (Kruskal-Wallis respectively $P = 0.000$; $P = 0.007$). Both species also had a significant higher incidence of overgrowth interaction with sponges at SE (respectively $P = 0.003$; $P = 0.005$) and SW (respectively $P = 0.000$; $P = 0.000$) than at Kudingareng Keke. Scleractinian overgrowth by the four target species caused more than 80% necrosis (Fig. 2). Poriferan overgrowth by *A. paraviridis* and *Callyspongia* (*C.*) sp. was less than 8 %, whereas this was higher than 15 % for *A. suberitoides* and *N. olemda* (Fig. 2).

Callyspongia (*C.*) sp. was significantly smaller in size and had a different morphology, encrusting vs branching, in high coral cover environments (KKW) in comparison with low ones SE (Kruskal-Wallis, $P = 0.000$) & SW (Kruskal-Wallis, $P = 0.000$). For all species, one individual could at the same cause necrosis to one type of neighbour and not visually being harmful to another type of neighbour in its overgrowth interaction.

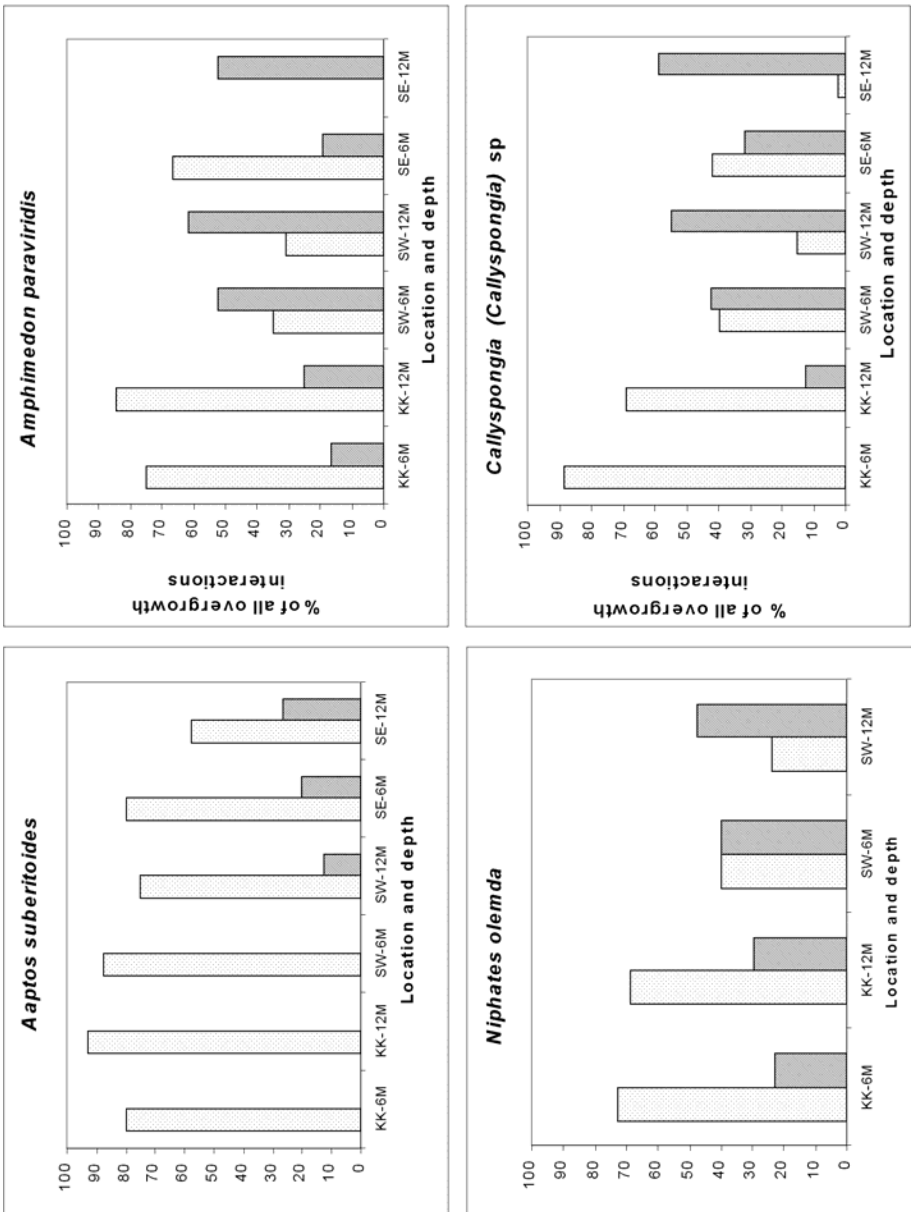

Fig. 1. Average percentage of Scleractinia (SCL, spotted bars) and Porifera (POR, striped bars) overgrowth interactions per target species. Abbreviations (SW = Samalona West; SE = Samalona East; KK = Kudingareng Keke; 6 m and 12 m of depth).

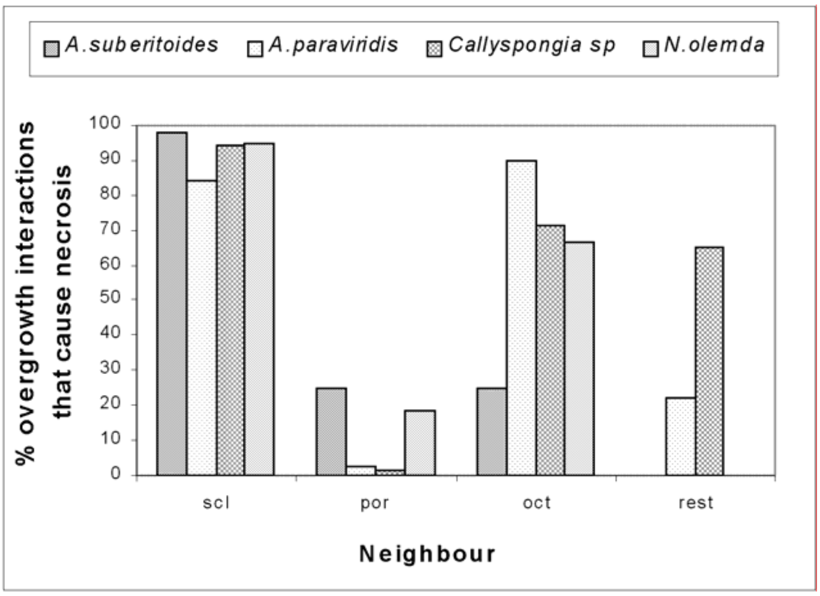

Fig. 2. Overgrowth interactions that cause necrosis with Scleractinia (SCL), Porifera (POR), Octocorallia (OCT), and Rest group (includes: Milleporidae, Ascidiacea, Actinaria, Antipatharia, and large fleshy algae).

DISCUSSION AND CONCLUSIONS

A. paraviridis and *Callyspongia* (*C.*) sp. both have a variable growth form; from encrusting, repent to large branching specimens. The encrusting growth form of *Callyspongia* sp. caused a significantly higher percentage of dead tissues / necrosis of scleractinian corals than its branching growth form, although this was less apparent with *A. paraviridis*. The necessity for sponges to compete with corals in order to gain space likely depends on their growth form in combination with other growth characteristics (BECERRO *et al.,* 1995; AERTS, 2000). Consequently, morphological strategies are important to sessile benthic invertebrates in their struggle for substrate (JACKSON, 1979; HOPPE, 1988). Encrusting and massive sponges will be more effective than branching species in gaining space by means of overgrowth, because branching invertebrate species can avoid competition by 'escaping in height' (MEESTERS *et al.,* 1996). *Iotrochota* sp. from the Great Barrier Reef forms thins crusts, but occasionally forms thick, fleshy vertical projections. It was suggested that this species utilises both confrontational and non-confrontational strategies in competition for space, whereby vertical growth may be a form of avoiding confrontation with space competitors (EVANS-ILLIDGE *et al.,* 1999).

Callyspongia (*C.*) sp. was practically never overgrown by other organisms and in the instances it occurred it did not appear visibly harmed. Individuals of this sponge species were found predominantly in the encrusting growth form and were smaller in size in high coral environments at Kudingareng Keke; *Callyspongia* (*C.*) sp. is most likely allocating its energy towards the production of secondary metabolites in order to maintain space in a reef, whereas in lower competitive environments it is directing its energy to spatially expand in the reef.

N. olemda always forms erect tubes, and escapes confrontation by growing in height. Although 95 % of all overgrowth interactions of *N. olemda* with corals resulted in necrosis, most of these contact points formed at the same time the substrate of the sponge. This mode of interactions indicates that *N. olemda* does not gain space, but rather obtains or holds space by either smothering/overshadowing its live substrate or exuding chemicals. *A. suberitoides* forms masses of globular lobes, and of all target species this species had the least number of overgrowth interactions. Although growth rates for all species are not yet evident, fast horizontal growth by *A. suberitoides* may smother the adjacent organism rather than that they release bioactive compounds.

Poriferan overgrowth by *A. paraviridis* and *Callyspongia* (*C.*) sp. appeared more frequent in low coral cover environments and rarely cause dead tissue to the overgrown sponge. RÜTZLER (1970) found that overgrown sponges remain unharmed, they have ways of adapting which allows them to be overgrown and survive. Most of the poriferan overgrowth interactions were with sponges with a similar branching or repent growth form. In numerous cases individuals of *Callyspongia* (*C.*) sp. were intimately intertwined with one or more other sponge species. These associations were always with the same sponge species. WULFF (1997) described an intimate association of three common Caribbean species which were mutually beneficial. Heterospecific sponges increased their growth rates when they were tightly adhered to each other. To increase survival against a variety of hazards, a symbiosis with sponge species that differs in chemistry, tissue density and skeletal architecture would be favourable. When the interacting organisms are very similar, competition for the same resources may outweigh the benefits of such a close association. Thus, intimate associations between heterospecific sponges with similar resource requirements would be less likely to be mutually beneficial.

In the present study, one individual of all target species could at the same time cause necrosis to one type of neighbour and was not visually harmful to another type of neighbour in its overgrowth interaction. Thus, it is unlikely, that an individual is invariably bioactive to any neighbour it encounters.

Our observations as well as those of previous authors (THOMPSON, 1985; PORTER & TARGETT, 1988; TURON *et al.,* 1996; NISHIYAMA & BAKUS, 1999) suggest that water borne allelochemicals may deter particular substrate competitors from growing in direct contact with sponges. TURON *et al.* (1996) suggested that *Crambe crambe* from the Mediterranean Sea releases waterborne chemicals and causes dead tissue in an adjacent organism at a small scale. Certain tolerant coral species may grow adjacent to sponges, whereas others may rarely or never be found in close proximity to any sponge. Close encounters with scleractinian corals often causes necrosis in the corals and suggests allelopathy of sponge toxins. How the toxin is triggered to be released or how an organism can recognize a beneficial association (*e.g.* with another sponge) remains unclear. Possibly the organisms which are involved in these intimate associations may produce similar chemicals or may not be negatively affected by sponge toxins.

Not many studies have been done on the intraspecific and intraspecimen variation of the distribution of chemicals in sponge organism. SCHUPP *et al.* (1999)

suggested that biologically important parts of the Pacific sponge *Oceanapia* sp., the reproductive parts of the organism and the exposed parts show higher concentrations of secondary metabolites. In this case, the parts which interact with a aggressive neighbour are likely to have higher amounts of the toxins. In our study, the parts of the sponge which interact with an aggressive neighbour likely have higher amounts of the toxins The fact that both inter- and intra-specific differences seem possible in the bioactive compound composition points to the ability of *A. paraviridis* and *Callyspongia* (*C.*) sp. to synthesize the bioactive substances *de novo*. Sponge individuals that grow for prolonged periods away from scleractinian corals as a consequence may have a lower general toxicity than individuals in proximity of a coral competitor. However, the present observations were not made over time, thus the possible dynamics of these interactions were not recorded. Nevertheless, it may not be so straightforward, due to the multiple ecological roles a single secondary metabolite may have. For example, THACKER *et al.* (1998) did not find that the production of secondary metabolites was induced by the presence of a spatial competitor on which it inflicted necrosis.

It is important to have a good understanding of the ecological functions of the secondary metabolites before a sponge culture may be initiated. These results imply that toxins produced by *A. paraviridis*, *Callyspongia* (*C.*) sp., and *N. olemda* are used in spatial competition and that the concentration of the bioactive compounds of the target species differs both intra-individually and intra-specifically. It is likely, that other ecological factors besides spatial competition regulate the production of bioactive compounds of the described target sponges. Thus, when sponge individuals are grown on artificial substrata without further manipulation, the gross yield of the target toxins may be lower than those of individuals which grow in their naturally highly competitive environment. Future quantification of the toxins, and of the growth rates of the cultured specimen of these target species may give more conclusive evidence.

ACKNOWLEDGEMENTS

The research of the first author was funded through NWO-WOTRO W84-474. The second author received funding from the UvA STUNT grant and the Faculty of Science UvA Fund. The project was sponsored through the Indonesian Foundation of Science (LIPI). Prof. Dr Braekman (Université Libre de Bruxelles) provided the data on the bioactivity of the target sponge species. I thank the anonymous reviewers for their valuable comments on improving this article.

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