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DIDEMNID ASCIDIANS: RAPID COLONIZERS OF ARTIFICIAL REEFS IN EILAT (RED SEA)

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ABSTRACT

Ascidians frequently occur on man-made surfaces submerged in marine waters and constitute a major technical and economic problem worldwide. In Eilat (Red Sea), artificial reefs constructed for attractive diving are frequently fouled by ascidians. In this study we examined aspects of temporal and spatial fouling of two common ascidians, *Didemnum granulatum* and *Didemnum* sp., on two modular experimental artificial reefs. Habitat partitioning, growth rate and survivorship of the two species were monitored along these artificial reefs for 1 yr. *D. granulatum* was the first ascidian to appear, and the most prominent species on both artificial reefs. Its initial recruitment was on the lower sides of the deepest horizontal plates of both artificial reefs, and it gradually recruited towards the lower sides of the shallower horizontal plates. *Didemnum* sp. colonies recruited at different depths along the artificial reef, while following a similar pattern of gradual recruitment towards the shallower plates. Both species successfully foul on the artificial reefs prior to the appearance of long lived organisms such as corals. Transplantation experiments further confirmed the depth and position required by *D. granulatum* along the artificial reefs. We suggest that the initial recruitment of *D. granulatum* on the lower sides of the deepest horizontal plates is an outcome of its negatively phototactic and geotropic bottom swimming larvae, which are able to delay settlement in order to locate a suitable settlement site.

Fouling organisms such as ascidians frequently occur on man-made surfaces submerged in marine waters (Holmstrom and Kjelleberg, 1994). It is accepted that the dispersal of ascidians is dependent on their pelagic larval phase, and the availability of a suitable habitat (Svane and Young, 1989). The larvae of compound ascidians are lecithotrophic and tend to swim for only a few minutes prior to settling (Svane and Young, 1989). However, Olson (1985) found that in the absence of suitable substrate some larvae of the ascidian *Didemnum molle* swim for as long as 20 min prior to settlement. The settling site of the larvae is crucial for their continuing development and largely determines the environmental conditions experienced by the juvenile and adult stages (Keough and Downes, 1982; Svane and Young, 1989). Settlement of ascidian larvae is strongly influenced by light (Davis and Butler, 1989), current regime (Olson, 1985; Butman, 1989) and active behavior (Young and Chia, 1987; Svane and Young, 1989).

A study conducted at the northern Gulf of Eilat (Red Sea) showed that ascidians constitute a minor benthic component on exposed surfaces on the natural reefs (Goren, 1992). However, colonies of *Didemnum* are seasonally found on the underwater constructions of the oil jetties at Eilat (Goren, 1992), and also successfully foul there on other various randomly deployed man-made substrata (Oren and Benayahu, 1997). As part of a comprehensive study on colonization of artificial reefs at Eilat we followed the initial recruitment of two common ascidians, *Didemnum granulatum* and *Didemnum* sp., on two modular experimental artificial reefs at Eilat. We monitored their habitat partitioning, percent coverage over time, and their effect on recruitment and survivorship of other sessile organisms, particularly corals. In addition, we conducted transplantation experiments in order to further understand the habitat preferences of the ascidians on the artificial reefs.

Materials And Methods

In December 1990 and late August 1991, two modular experimental artificial reefs were deployed at 31 and 18 m depths, respectively, in front of the Marine Biology Laboratory (MBL) at Eilat (Red Sea). The reefs were composed of a set of smooth white PVC plates attached to stainless steel wire anchored to the bottom, and vertically floated by buoys up to 2–3 m below sea level (Fig. 1A,B). The 50 × 50 cm plates in both artificial reefs were attached in vertical and horizontal positions along the wires for examination of recruitment preference. Both artificial reefs were placed on sandy bottoms covered with scattered knolls.

Recruitment and growth of *D. granulatum* and *Didemnum* sp. on the artificial reefs were recorded every 2 mo throughout 1991–1992. A 50 × 50 cm measuring frame, divided into 10 × 10 cm squares, was placed on both sides of the plates, and used to determine the percent coverage of the ascidians.

In June 1992, round cuttings of *D. granulatum*, 3 cm^2 each, were removed from a large colony that had previously recruited on the lower side of the 17 m horizontal plate of the 18 m artificial reef (Fig. 1B). These cuttings were immediately fastened by thin wires to rigid plastic nets and reattached to the same plate (17 m) for 24 h, in order to enable their injured edges to heal (see also Stoner, 1989). A day later, three cuttings were transplanted to each side of the horizontal plates, at depths of 5, 11 and 15 m, and to the vertical plates at 6 and 14 m (Fig. 1B). Growth of these transplants was monitored by underwater close-up photography, using a Nikonos III camera. The photographs were taken on days 0, 10, 30 and 45 after transplantation. Accurate measurements of the transplants' surface area on each date were made by a computerized image analyzer (Olympus, CUE-3) of the color slides. Similar efforts to carry out transplantation experiments with *Didemnum* sp. failed, due to the softness and thin texture of this species.

Results

D. granulatum was the first ascidian to appear and the most prominent fouling organism on both artificial reefs. This species recruited only on the lower sides of the horizontal plates and was never found on the upper sides of the horizontal or vertical ones. On June 1991, 6 mo after placement of the 31 m artificial reef, we observed several small and separate colonies of *D. granulatum* on the lower side of the deepest horizontal plate at 30 m (Fig. 1A). During the following months, through November 1991, its coverage gradually increased to approximately 90% of the lower plate area. In September 1991, we found colonies of *D. granulatum* on the 27 m plate, and 2 mo later colonies of this species were observed on the lower side of the 24 m plate. This artificial reef was unfortunately lost in December 1991 during a strong southern storm, and therefore the results represent a limited period of time only. Recruitment of *D. granulatum* on the 18 m artificial reef (Fig. 1B) followed a similar pattern as previously recorded on the deep artificial reef. The initial settlement occurred on the lower side of the deepest horizontal plate at 17 m and only subsequently on the lower sides of the 15 and 13 m plates. The fused colony at 17 m gradually grew to cover approximately 90% of the lower side of this plate. In the following months we recorded a sharp decrease in colony size, and in August 1992 only 10% of the lower side of 17 m plate was covered. Colonies of *D. granulatum* appeared on the 15 m plate in April 1992. Similarly, these colonies fused into one colony which obtained its

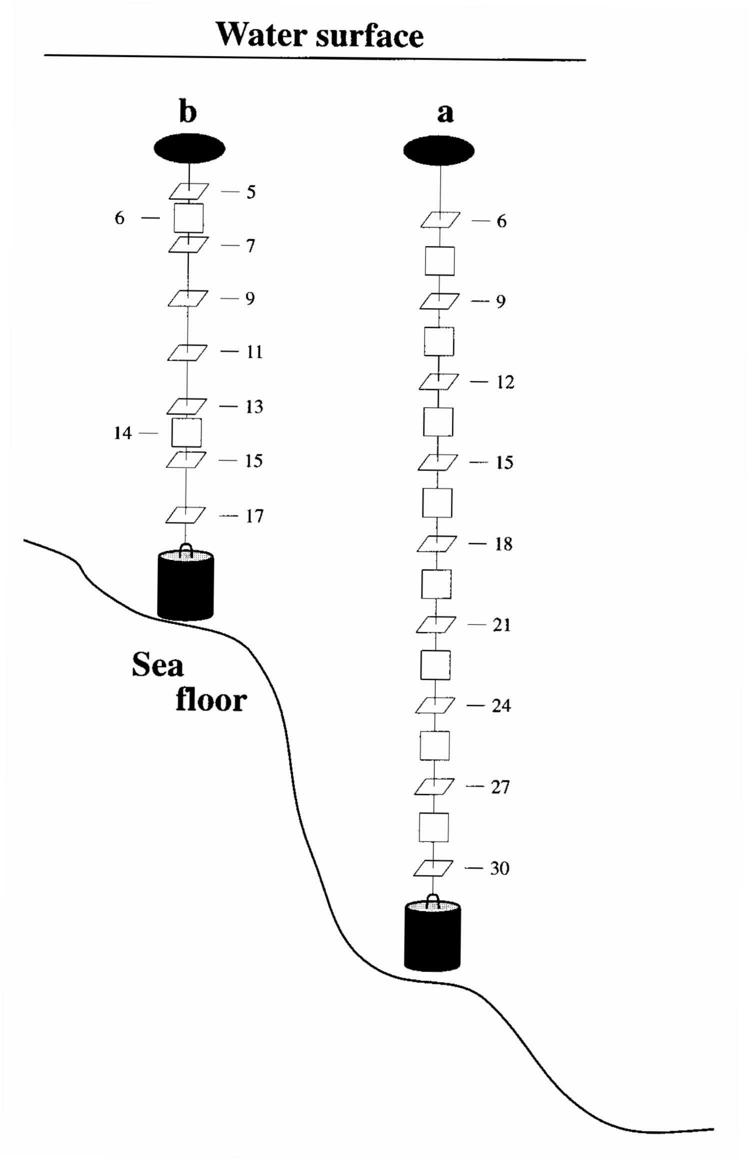

Figure 1. The experimental artificial reef constructions: a. 31 m reef, b. 18 m reef. Numbers indicate depths (in meters) of the horizontal and vertical plates.

highest coverage of 90% 2 mo later. During June–October 1992 this colony followed a gradual decrease in size. On the 13 m plate *D. granulatum* was first observed only in June 1992, and a similar coverage increase was noted with time. During November 1992 all colonies of *D. granulatum* disintegrated and eventually completely disappeared. Colonies of *D. granulatum* were never found on the shallower plates of this artificial reef.

Didemnum sp. appeared only on the 18 m artificial reef (Fig. 1B). This species fouled only on the lower surfaces of the horizontal plates at 11, 9 and 7 m, and never on the

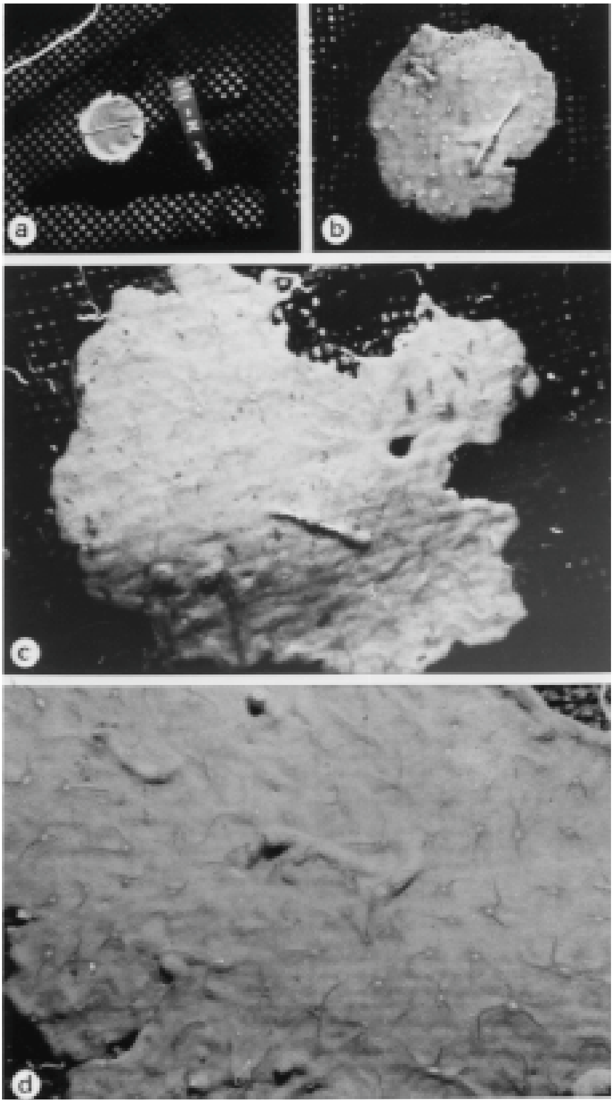

Figure 2. Growth of *Didemnum granulatum* transplants attached to nets: a. initial size of transplant, b. size on day 10, c. on day 30, d. on day 45. All figures at 50% actual size.

deeper or shallower ones. On the 11 m plate these small separate colonies fused into a single colony which grew progressively until it covered 80% of the surface. On April 1992 and June 1992 colonies of *Didemnum* sp. were observed on the 9 and 7 m plates, respectively. From early September, all the colonies disintegrated and finally disappeared. *Didemnum* sp. appeared also on the vertical plates, at 6 and 14 m depths, and was the only ascidian to foul on these plates.

During the first 10 d post-transplantation of *D. granulatum*, cuttings onto the vertical plates and the upper surfaces of the horizontal ones disintegrated and died. However, transplants attached to the lower sides of the horizontal plates, at 5, 11 and 15 m, survived

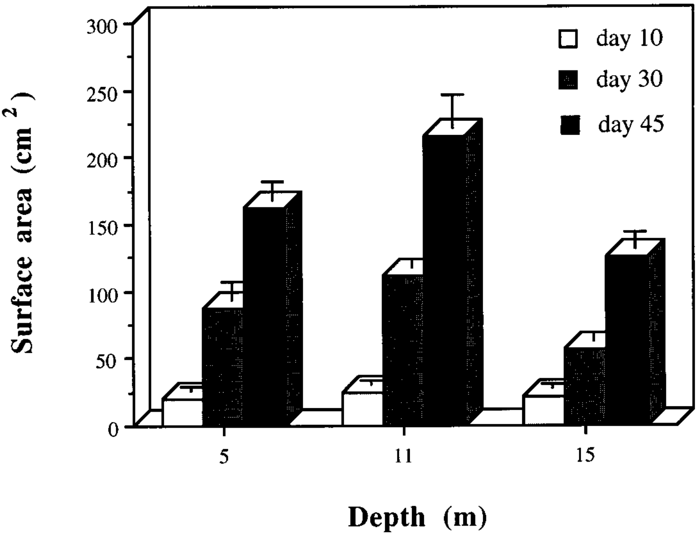

Figure 3. Average surface area (+ SD) of *Didemnum granulatum* transplants recorded at three time intervals on the lower side of the horizontal plates at 5, 11 and 15 m depth along the 18 m artificial reef (n=3 for each plate).

and gradually increased in size. The round transplants (Fig. 2A) maintained a circular shape for the first 10 d after transplantation (Fig. 2B), and then they grew asymmetrically (Fig. 2C). Later on they gradually fouled the entire net (Fig. 2D), and even expanded towards the horizontal PVC plates. Figure 3 presents the average surface area (+SD) of the cuttings through time in the different depths. On day 10 the colonies at all three depths were of similar size (1-way anova, $P > 0.05$). After 30 d, the colonies located at 5 and 11 m depth had identical surface areas (F-test, $P > 0.05$). However, the average size of these colonies was significantly larger than the average size of the colonies located at 15 m (F-test, $P < 0.05$). On day 45 the colonies located on the lower side of the 11 m horizontal plate attained the highest surface area (F-test, $P < 0.05$), implying that at this depth the transplants of *D. granulatum* had the highest growth rates.

During the study, we recorded various sessile organisms which have settled on the experimental surfaces. These organisms included serpulid polychaetes (Fig. 4A), colonies of hydroids (Fig. 4B), the stony coral *Porites* sp. (Fig. 4B) and several soft corals: *Dendronephthya hemprichi* (Fig. 4C), *D. sinaiensis*, *Heteroxenia fuscescens* and *Parerythropodium f. fulvum*. These organisms were rapidly overgrown by the ascidians and subsequently excluded.

Discussion

The results of the current study demonstrate that *D. granulatum* was the first and most predominant fouling organism on the experimental artificial reefs. It appeared 7 mo after deployment of the 31 m artificial reef, and 3 mo after deployment of the 18 m one. Both ascidian species recruited preferentially on the lower surfaces of the plates, and appeared first on the deepest horizontal ones (Fig. 1). The two *Didemnum* species are extremely

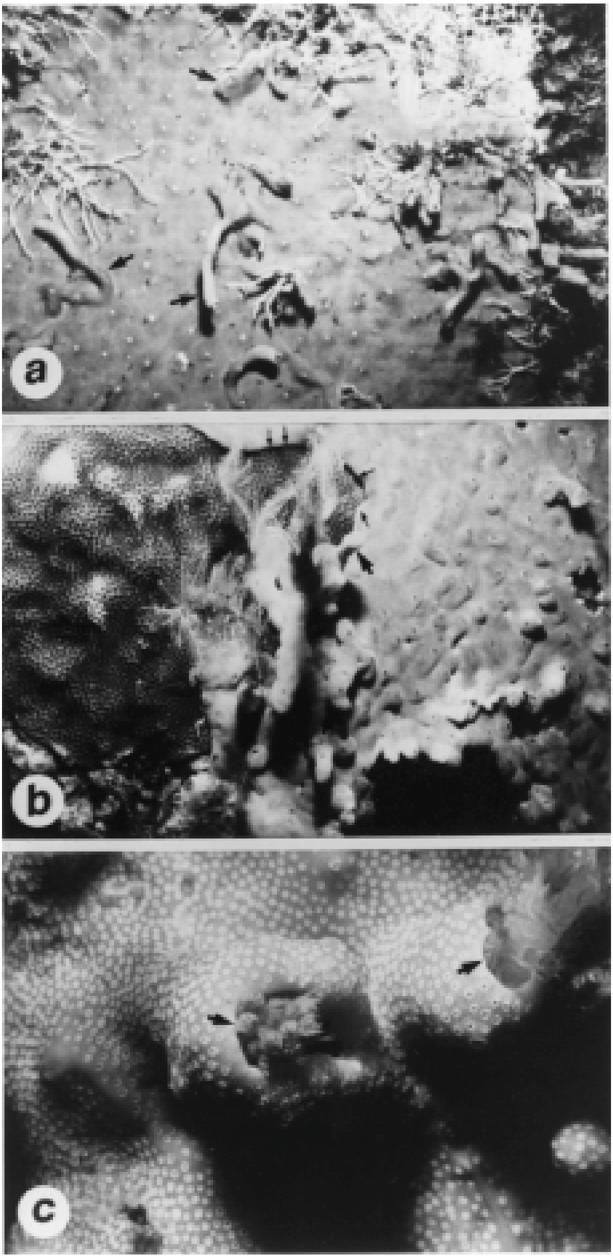

Figure 4. Surface colonization and overgrowth by *Didemnum granulatum*: a. a colony of *D. granulatum* covering the lower side of the horizontal plate at 17 m while overgrowing polychaetes (see arrows), b. *D. granulatum* overgrowing colonies of hydroids (large arrows) and a colony of a stony coral *Porites sp.* (small arrows), c. *D. granulatum* overgrowing two young colonies of the soft coral *Dendronephthya hemprichi* (see arrows), previously settled on the lower side of the 15 m horizontal plate. (Figs. a,b are at 50% actual size, Fig. c is 200% actual size).

rare in the vicinity of the artificial reefs and can hardly be found on natural reef overhangs at Eilat. Therefore, it is likely that the first recruitment was derived from larvae released by parents occupying more distant artificial habitats such as the oil jetties at Eilat, located 2 km north of the MBL. The recruitment of *D. granulatum* and *Didemnum* sp. on the remote artificial reefs is probably due to their ability to substantially delay their settlement (Olson, 1985). Several studies have shown that larvae of compound ascidians are photopositive upon release, and swim upwards in search of settling sites (Olson, 1983; Olson and McPherson, 1987). In addition, Hurlbut (1991) found that in the laboratory, larvae of *Didemnum candidum* are both photopositive and geonegative upon release. In the present study *D. granulatum* and *Didemnum* sp. fouled on undersides of the artificial surfaces, perhaps due to the preference of the larvae for sites with low illumination as previously suggested (see Svane and Young, 1989; Hurlbut, 1991). We propose that the initial settlement of *D. granulatum* on the nearest accessible undersurfaces of the plates is an outcome of its benthic swimming larvae.

The following colonization of the didemnids along the artificial reefs occurred within a relatively short time (see results). This colonization was probably achieved by larvae derived from already existing colonies on the artificial reefs and their settling preferences led to gradual utilization of the lower surfaces of the shallower plates. Both *D. granulatum* and *Didemnum* sp. exhibited in part a similar spatial recruitment pattern, in which their colonies gradually fouled towards the shallower horizontal plates, although each species preferd a different depth range. This partitioning of habitat by depth may function to prevent interspecific competition for space between the two species.

The survivorship of *D. granulatum* on the lower surfaces was further confirmed by the transplantation experiment (Fig. 3). It has already been shown that on exposed surfaces abiotic and biotic factors such as ultraviolet light (Olson, 1983), sedimentation and predation pressure (Svane and Young, 1989), competitive interactions with diatoms or filamentous algae and grazing (Young and Chia, 1984) can reduce the survivorship of compound ascidians. Thus, we similarly propose that the rapid and complete mortality of *D. granulatum* transplants on the upper horizontal and vertical plates may result from unfavorable conditions.

In both artificial reefs the recruitment of the didemnid ascidians occurred prior to the appearance of any other long-lived organisms. The presence of the ascidians excluded other benthic organisms (Fig. 4), and even inhibited further settlement on the artificial surfaces (see Oren and Benayahu, 1997). The percent increase of surface coverage of both didemnids through time strongly demonstrates their fouling potential on artificial reefs. The reduction of fouling by *D. granulatum* can be achieved by constructing artificial reefs without horizontal surfaces near the bottom or controlled by divers. Such manipulation, especially during the first 2 yrs after artificial reef deployment, could ensure diverse recruitment and high survivorship rates of other benthic organisms such as corals.

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