Responses of Common Fouling Organisms in the Indian River, Florida, to Various Predation and Disturbance Intensities

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ABSTRACT: The response of some common fouling organisms to increased predation by scraping and decreased predation by caging is described. Substrate coverage by many colonial forms such as *Perophora viridis* and *Diplosoma macdonaldi* was not affected by changes in predation intensity whereas coverage by many solitary forms such as *Spirorbis* sp. and *Styela plicata* increased when predation was reduced. These differences in responses of colonial and solitary species may be because solitary species reproduce sexually and resettle newly opened space whereas colonial species can rapidly expand adjacent colonies into newly cleared space.

Introduction

Many studies have shown that predation can affect the structure of biological communities (Connell 1961; Paine 1966; Menge and Sutherland 1976; Menge 1978; Mook 1981; Ayling 1981; and others). However, relatively few studies have addressed the responses of individual species to predation. Jackson (1977) suggested that predation may affect colonial species differently than it affects solitary species because solitary forms are generally killed by the action of predators whereas colonial species could regenerate from remaining fragments of their colonies.

Mook (1981) described the effects of increasing and decreasing predation pressure on fouling communities. The study was done strictly on the community level with little reference to individual species. This paper describes the responses of common species in the fouling community to increasing and decreasing predation pressures.

Methods

Studies were conducted in the Link Port canal at Harbor Branch Foundation, located on the west bank of the Indian River Lagoon, about 6 km north of Ft. Pierce, Florida (27°32.0′N, 80°21.0′W). Settlement surfaces were 15 × 15 cm ceramic Italian quarry tiles suspended 1 m deep in random positions from a 2.5 × 3.5 m float. Tiles were about 30 cm apart.

Coverage of all sessile fouling species on all treatments was estimated each month from November 1976 to January 1978, except for December and February 1977 and January 1978 when water temperatures were so low that little growth occurred in the fouling communities. A random point sampling method (80 points) was used to estimate percent cover of all fouling organisms (Mook 1980). Both canopy space and overgrown living animals were counted. This often resulted in total percent coverage exceeding 100%. New sets of random points were used for each replicate tile censused.

Treatments (five replicates each) consisted of a control treatment to simulate natural predation, a caged treatment to simulate reduced predation and three scraped treatments (50% a month, 25% a month and 50% every other month) to simulate varying nonselective predation pressures. Caged tiles were surround with a 3-cm mesh fish net to keep out large fish predators. The cage was large enough so there was 15–20 cm between the net and the tiles to prevent the net from interfering with the tiles. The net

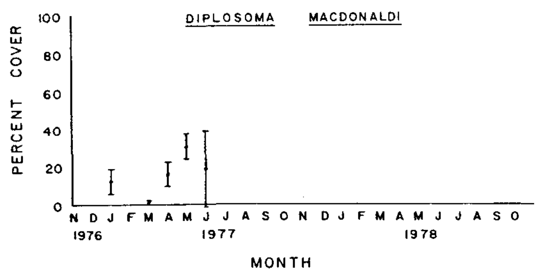

Fig. 1. Coverage of *Diplosoma macdonaldi* on control tiles. Vertical lines indicate + and − 1 standard deviation(s).

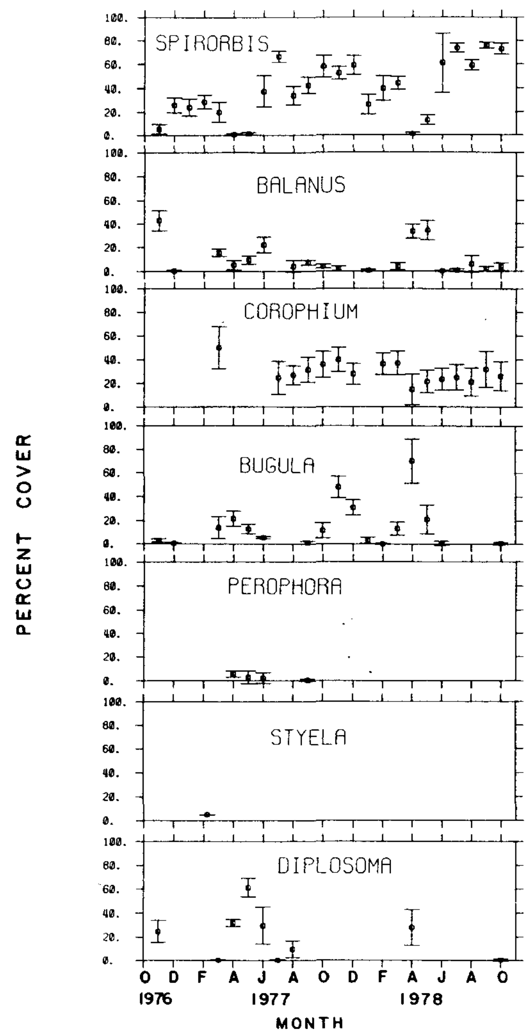

Fig. 2. Percent cover of *Spirorbis*, *Balanus*, *Corophium lacustre*, *Bugula neritina*, *Perophora viridis*, *Styela plicata* and *Diplosoma macdonaldi* on monthly tiles. Vertical lines indicate + and − 1 standard deviation(s).

was changed monthly to minimize any effects of fouling organisms settling on the mesh. To simulate varying nonselective predation, scraping was done in the following way. Random squares from a 6 × 6 grid (36 2.5 × 2.5 cm squares) of the community were scraped off with a chisel until the desired amount of cover was removed. For example, to simulate 50% removal, 18 2.5 × 2.5 cm squares were removed at random, to simulate 25% removal, 9 squares were removed. Randomization was done using a random number generator. A Kruskal-Wallis test ($\alpha = 0.05$) showed no statistical differences between the three scraped treatments so only the treatment with 50% of the cover on the tiles removed monthly was used in this analysis. Recruitment was monitored by submerging five clean tiles each month during the study and examining them after 1 month of submergence.

All species of the genus *Balanus* were pooled for the analysis. This is justified because only one species of *Balanus* was abundant and all *Balanus* species found in this study appeared to have similar feeding mechanisms, growth rates and settlement times.

Percent coverage of common species found on tiles in various treatments was compared using a Kruskal-Wallis test ($\alpha = 0.05$).

Results

The encrusting colonial ascidian *Diplosoma macdonaldi* was present during the first several months of submergence on the tiles of all treatments. After an initial peak in coverage in the spring of 1977, *Diplosoma* coverage declined and *Diplosoma* was not found again on test tiles during the study (Fig. 1). *Diplosoma* settlement occurred in November 1976, April–August 1977 and in April and October 1978 (Fig. 2). No significant differences were noted in *Diplosoma* coverage among the caged, scraped and control tiles.

The stoloniferous colonial ascidian, *Perophora viridis* was present on all tiles after

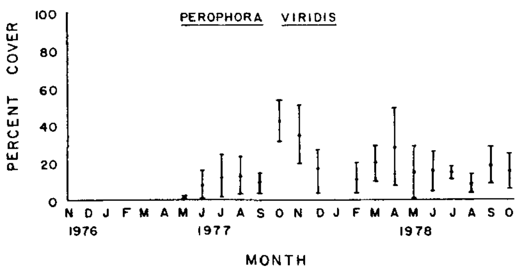

Fig. 3. Percent cover of *Perophora viridis* on control tiles. Vertical lines indicate + and − 1 standard deviation(s).

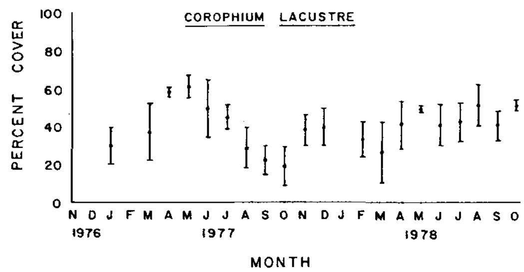

Fig. 4. Percent cover of *Corophium lacustre* on control tiles. Vertical lines indicate + and − 1 standard deviation(s).

its initial settlement in April–May 1977 (Fig. 3). Settlement was generally sparse, only settling for a few months in the spring (April–June) and fall (Septenber–October) in small amounts ($<1\%$ coverage) (Fig. 2). However, once established, it spread its stolons throughout the communities on all tiles, often achieving greater than 40% coverage on some replicates. It appeared well adapted for occupying both freshly cleared primary space on scraped tiles and secondary space such as the surfaces of *Styela plicata* and the branches of *Bugula* spp. No significant difference in coverage was noted among scraped, caged or control tiles.

The tubes of the corophiid amphipod, *Corophium lacustre,* often occupied up to 50% of the surface area, especially in spring 1977 and summer 1978 on all tiles (Fig. 4). No significant differences were found among caged, scraped and control tiles. *Corophium* built their tubes on all types of space including bare tile (primary space), crevices between barnacles, the surfaces of other animals and among the branches of arborescent forms such as the bryozoan *Bugula* spp. (secondary space). *Corophium* was found on 1-month tiles in April 1977 and from August 1977 to the termination of the study in October 1978 (Fig. 2).

The serpulid polychaete *Spirorbis* spp. settled in large numbers throughout the year (Fig. 2) and was most abundant on monthly tiles. It occupied primary space on most tiles except the caged tiles where it settled mainly on the test of *Styela plicata.* Only after most of the *Styela* fell off in spring 1978, leaving open primary space on the tiles, was *Spirorbis* found on primary space on the caged tiles. *Spirorbis* was significantly ($p < 0.05$) more abundant on the caged tiles at certain times of the study (June 1977–February 1978, August–October 1978) than on the control or scraped tiles (Fig. 5).

The solitary ascidian *Styela plicata* was abundant only on the caged tiles where it dominated approximately one third of the primary space between September 1977 and April 1978 (Fig. 6). Its settlement on monthly tiles was sparse (Fig. 2) and it was only seen rarely on tiles of other treatments. By June 1977 *Styela* had overgrown all of the barnacles and serpulid worms that were on the caged tile surfaces. The exposed tests of *Styela* then became the main attachment site for many organisms such as the erect bryozoan, *Bugula* spp., the serpulid polychaete, *Spirorbis* sp. and the colonial ascidian, *Perophora viridis.* During the period that *Styela* dominated the caged tiles, the primary tile space was chiefly occupied by dead barnacle tests encrusted with *Corophium* tubes.

By April 1978, large individuals of *Styela* began sloughing off the caged tiles, leaving large areas of clean tile. A similar sequence was noted by Sutherland (1978) at Beaufort, North Carolina. By July 1978 most of the *Styela* had fallen off the caged tiles. Subsequent observation of the caged tiles after October 1978 indicated that the *Styela* was again settling and dominating the caged tiles.

Balanus eburneus was the most common barnacle species settling on tiles during the study. *Balanus trigonus* and *B. amphitrite* also settled in lesser abundance. Barnacle coverage increased for the first months of the study on control and scraped treatments

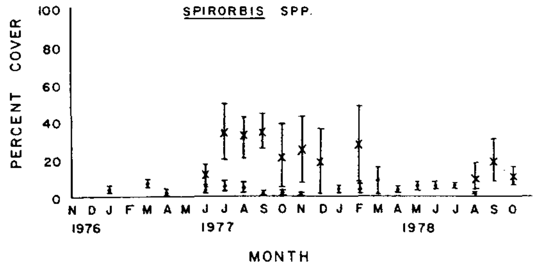

Fig. 5. Percent cover of *Spirorbis* spp. on control (indicated by dot) and caged (indicated by x) tiles. Coverage of *Spirorbis* spp. on caged tiles is shown only when it is significantly different than the control. Vertical lines indicate + and − 1 standard deviation(s).

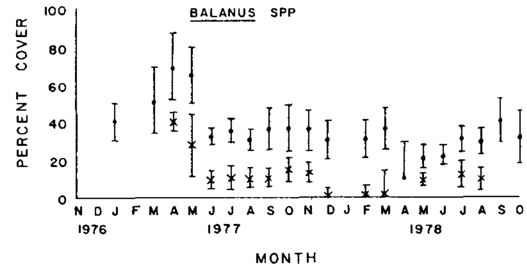

Fig. 7. Percent cover of *Balanus* on control (indicated by dot) and scraped (indicated by x) tiles. Coverage on scraped tiles is shown only when it is significantly different than the coverage of the control tile. Vertical lines indicate + and − 1 standard deviaion(s).

and then drecreased to a lower level which remained fairly constant throughout the remainder of the study (Fig. 7). For example, barnacle coverage in the control was about 30% after 1 month of submergence, increasing to nearly 70% after 6 months, and then decreasing again to about 35% for the remainder of the study. Barnacle coverage on scraped tiles was significantly less than on the control. The caged tiles also showed a high initial peak in barnacle coverage (70% coverage), but within 9 months, barnacles were completely overgrown by the solitary ascidian, *Styela plicata* and were not found in that community again for the remainder of the study (Fig. 6). Barnacle settlement occurred year round (Fig. 2).

Two species of arborescent bryozoan, *Bugula neritina* and *Bugula stolonifera*, were noted in this study. Since *B. stolonifera* coverage was minimal, only attaining maximum coverages of less than 5% at times when *B. neritina* is shown in Figs. 2 and 8. Greatest settlement for both species of *Bugula* occurred from November through June during both years of the study (Fig. 2).

In the warmer months *Bugula* spp. was significantly more abundant on the caged treatment than on the scraped or control treatments (Fig. 8). From December to April *Bugula* was abundant on all treatments and no significant differences were found among the treatments.

The encrusting bryozoans *Hippodiplosia* sp., *Hippoporina verrilli, Conopeum tenuissimum, Conopeum seurati* and *Schizoporella floridana* were occasionally found throughout the study. Of these species, only *Schizoporella floridana* occupied any major space (>5% of any tiles). A *Schizoporella* colony covered about 10% on one of the replicate tiles of a scraped treatment for a period of about 18 months from May 1977

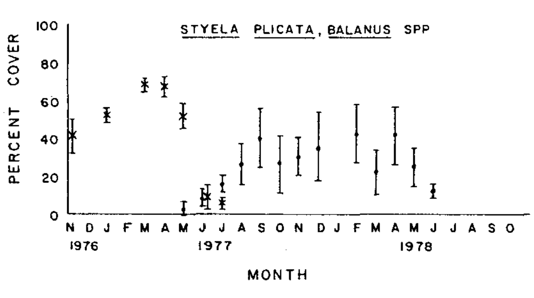

Fig. 6. Percent coverage of *Styela plicata* (indicated by dot) and *Balanus* (indicated by x) caged tiles. Vertical lines indicate + and − 1 standard deviation(s).

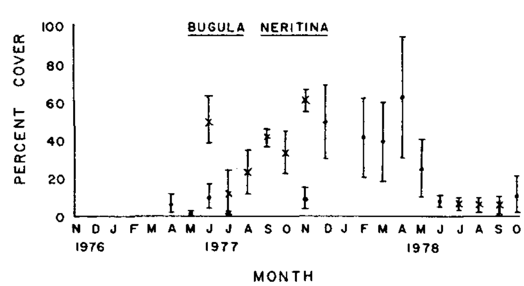

Fig. 8. Percent coverage on *Bugula neritina* on control (indicated by dot) and caged (indicated by x) tiles. Coverage on caged tiles is only shown when it is significantly different than on the control tiles. Vertical lines indicate + and − 1 standard deviation(s).

to the end of the study. It overgrew all organisms on a portion of the tiles in about a month and was successful in preventing settlement by other organisms until August 1978 when the colony appeared to start breaking up and decreasing in size. When sections of the colony were removed by scraping, the colony grew back over the cleared space within a month, overgrowing other organisms that had settled there. The filamentous bryozoan *Zoobotryon verticillatum* was on the caged tiles in September 1978, but did not appear to have any effect on those communities. *Hippodiplosia* sp. was observed on a few tiles that were submerged in October 1976 but were not noted subsequently.

Sponges were observed only during the warmer months on the control and scraped treatments but were found year round on the caged tiles. The most common sponge was *Halichondria* sp. (up to 5% coverage), but *Haliclonia* sp. and the boring sponge, *Cliona* sp. were occasionally seen in small amounts (<1% coverage).

Hydroids noted throughout the study were *Plumularia* spp., dominating from April to June and *Obelia* spp. dominating from July to October. Hydroid settlement occurred in the warmer months both years of the study but hydroids never occupied much space (<5%) on monthly settlement tiles suggesting that several months of submergence may be necessary for hydroids to occupy large areas of fouling communities. They largely occupied primary space which was made available by scraping and by natural predation.

Both the serpulid polychaete *Hydroides* spp. and the sabellid polychaete *Branchiomma nigromaculata* were occasionally found on all tiles. *Hydroides* generally occupied primary (>1%) coverage space but was usually overgrown by other species before it reached large size. *Branchiomma nigromaculata* settled during the warm months on all tiles but was slightly more abundant on the caged tiles (never occupying >5% of the space) where it occupied crevices between barnacles or was found at the bases of *Styela*.

Discussion

Diplosoma did not persist on any of the long term tiles (Fig. 1) after it ceased settlement in the summer of 1977 (Fig. 2), or become reestablished on long term tiles in the spring of 1978 when it was again noted on monthly tiles. This pattern in *Diplosoma* suggests that *Diplosoma* may be unable to maintain itself or establish itself in an established community. The mechanism that keeps *Diplosoma* from persisting at Link Port was not determined. It is doubtful that it is spatial competition because artificial predation removed much of the community monthly on scraped tiles. This scraping would have removed some of the competition for *Diplosoma*, allowing it to persist on those tiles. The fact that this did not occur suggests that some other mechanism, possibly some kind of inhibitive interaction (Karlson and Jackson 1981), prevented *Diplosoma* from maintaining or reestablishing itself. Both *Perophora viridis* and *Bugula* spp. settled on tiles about the same time *Diplosoma* disappeared suggesting that one of these forms may be the agent responsible. Since *Bugula* and *Diplosoma* were found together on monthly tiles in the spring of 1978, *Perophora* is the more likely organism of the two to inhibit *Diplosoma*. More studies would be necessary to confirm this.

In other studies done in tropical (Day 1977) and temperate (Russ 1980) waters, colonial ascidians tended to dominate communities that were protected from predators.

Since colonial organisms are generally better competitors than solitary forms (Jackson 1977), one would expect that colonial ascidians such as *Diplosoma* and *Perophora* would dominate the caged tiles at Link Port. The highly variable physical parameters at Link Port may preclude many colonial forms from dominating (Mook 1980) because these forms tend to be less tolerant to physical stress than solitary forms (Jackson 1977).

Since *Corophium* does not have free swimming larvae (Bousfield 1973), its colonization must be done by mobile adults. Because of this adult mobility, once adults reached the float where the fouling studies were being done (probably in January 1977), *Corophium* was able to move freely from tile to tile and rapidly move into areas cleared by scraping resulting in no differences between control, caged and scraped tiles. *Corophium* coverage was generally less on monthly tiles than on long term tiles. This difference may be either because *Corophium* has a preference for older tiles or there was higher predation pressure on the monthly tiles. Only after 9 months was *Corophium* found at all on monthly tiles (except April 1977). The presence of *Corophium* on monthly tiles after 9 months may be a result of possibly higher *Corophium* populations on the float itself which may have forced more individuals to the less favored monthly tiles.

The significantly higher coverage of *Spirorbis* on the caged tiles is probably a result of *Styela* offering additional surface area for *Spirorbis* to settle. The greater coverage of *Spirorbis* on the monthly tiles than on long term tiles may be due to: (1) less competition for new arrivals on the cleaner monthly plates, or (2) *Spirorbis* preferring cleaner surfaces. If competition is a factor for *Spirorbis* coverage, one would expect more *Spirorbis* on the scraped tiles. This was not the case in this study, suggesting factors other than competition are also important.

Styela was found in abundance only on the caged tiles (Fig. 6), suggesting predation may keep it from establishing itself on uncaged surfaces. Sutherland (1974) and Marshall et al. (1980) also noted increases in *Styela* coverage when encrusting communities were protected from predators. Whether *Styela* is vulnerable to predation only when it is small (Sutherland 1974) or at all sizes at Link Port cannot be determined. Large individuals are seen growing in areas around Link Port suggesting that *Styela*'s larger size may provide an escape from predation after the animal reaches maturity.

The barnacle-*Styela* interaction noted in this study is very similar to the barnacle-mussel interaction described by Menge and Sutherland (1976). In both cases, barnacles persisted when their competitors were removed by predators but were overgrown by their competitors when predators were kept out. Other studies (Marshall et al. 1980; Sutherland 1978) have shown that *Styela* can outcompete barnacles. The results of this and the above studies indicate that predators may be necessary for barnacle survival in many places, because without predators, barnacles are outcompeted for space by other species.

TABLE 1. Effects of caging and scraping on coverage of common fouling organisms. 0 = no significant change, + = significant increase, − = significant decrease.

Species	Effect of Caging	Effect of Scraping
Perophora viridis (colonial)	0	0
Corophium spp. (solitary)	0	0
Diplosoma macdonaldi (colonial)	0	0
Spirorbis sp. (solitary)	+	0
Styela plicata (solitary)	+	0
Bugula spp. (colonial)*	+	0
Balanus spp. (solitary)	+	−

* Only difference from May to November significant.

The seasonal differences in responses of *Bugula* to caging may be because *Bugula*, generally a cool-season settler (Mook 1976), is grazed off the uncaged tiles in the warmer months and not rapidly replaced by new recruitment, whereas on the caged tiles, *Bugula* can persist. In the winter, predation pressure may be lower and *Bugula* settles in greater abundance, replacing colonies removed by artificial and natural predation on exposed tiles at a greater rate. This could result in greater coverage by *Bugula* on exposed tiles during the winter and spring months. On caged tiles, the increased *Bugula* settlement could result in increased competition with other *Bugula* on the tiles, thus preventing *Bugula* coverage on caged tiles from being significantly greater than on uncaged tiles in winter and spring.

Russ (1980) found a decrease in *Bugula* sp. abundance when predators were prevented from grazing on fouling communities. He attributed the decrease in *Bugula* abundance to increased competition from colonial ascidians on the protected tiles. Since competition from colonial ascidians was not a major factor at Link Port, *Bugula* became more abundant on caged tiles in summer, suggesting that locally, *Bugula* is limited by predation and seasonal low recruitment rather than competition from other species (Mook 1981).

Some colonial species did not appear to be affected by either increases (scraping) or decreases (caging) in predation while many solitary forms were (Table 1). The difference between solitary and colonial species response to predation may be because colonial animals may have a competitive edge over solitary forms in occupying newly opened space (Jackson 1977). Solitary forms have to replace their numbers by sexual reproduction and recruitment whereas established adjacent colonies (or parts of colonies) (Ayling 1981) can occupy cleared space by overgrowing or spreading stolons over the newly opened space. *Corophium* coverage acts the same as coverage by colonial species because individuals can easily move to the newly cleared space and build their tubes rather than have to wait for new larval recruits like other solitary forms.

Bugula, an arborescent form, appears to compete more like a solitary form rather than a colonial form. It does not spread over areas of substrate like many colonial forms but rather only occupies a small area of substrate and grows upward to avoid competition. This strategy, used by many solitary (Jackson 1977) and arborescent (Osman 1977) forms, does not allow occupation of newly cleared space in the same manner encrusting colonial forms can. Reoccupation of space can only occur by sexual reproduction and resettlement of larvae, a strategy which would cause arborescent forms such as *Bugula* to react to changes in predation pressure in the same manner as solitary forms.

Neither *Spirorbis, Bugula* or *Styela* showed any significant decreases on scraped tiles, suggesting that these species were already under very high predation pressure on the control tiles. Further scraping may have not added much additional predation pressure to these forms (Mook 1981). *Balanus* did show a decrease on scraped tiles indicating that artificial predation may have put additional predation pressure on it. Because of their solid attachment to the substrate and hard tests, barnacles may be immune to predation by some forms which attack other members of the community.

Since many natural predators are more selective than a nonselective chisel, random scraping with a chisel probably cannot accurately simulate the effect of increased natural predation by a single selective predator species. Because many different species of predators prey on the local fouling community, it is assumed that the nonselective chisel roughly simulates the combined actions of all the species of predators that prey on the fouling community at the Link Port canal. This assumption may not be applicable in regions where only a few types of predators exist unless the predators are relatively nonselective. There is much room for much more study on the effects of both selective and nonselective predators on fouling communities.

The effects of predators on many species can vary depending on many environmental factors (Menge 1978). Because of these varying effects, the observations in this study may not always be consistent with what other investigators may find in other areas. More work is needed in other areas in order to determine how predation effects on individual species can ultimately affect the structure of fouling communities.

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