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Andrea Locke and Mary Carman (Guest Editors)

Research article

Impact of the invasive colonial tunicate *Didemnum vexillum* on the recruitment of the bay scallop (*Argopecten irradians irradians*) and implications for recruitment of the sea scallop (*Placopecten magellanicus*) on Georges Bank

James A. Morris, Jr.[1*], Mary R. Carman[2], K. Elaine Hoagland[3], Emma R.M. Green-Beach[4] and Richard C. Karney[4]

[1]*National Oceanic and Atmospheric Administration, National Ocean Service, National Centers for Coastal Ocean Science, 101 Pivers Island Road, Beaufort, North Carolina, 28516, USA, E-mail: james.morris@noaa.gov*
[2]*Geology and Geophysics, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, 02543, USA, E-mail: mcarman@whoi.edu*
[3]*National Oceanic and Atmospheric Administration, National Ocean Service, National Centers for Coastal Ocean Science 1315 East-West Highway, Silver Spring, Maryland, 20910, USA, E-mail: elaine_hoagland25@hotmail.com*
[4]*Martha's Vineyard Shellfish Group, Inc., PO Box 1552, Oak Bluffs, Massachusetts, 02557, USA, E-mail: mvsg@comcast.net*
* *Corresponding author*

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Abstract

The invasive colonial tunicate *Didemnum vexillum* has become widespread in New England waters, colonizing large areas of shell-gravel bottom on Georges Bank including commercial sea scallop (*Placopecten magellanicus*) grounds. *Didemnum vexillum* colonies are also fouling coastal shellfish aquaculture gear which increases maintenance costs and may affect shellfish growth rates. We hypothesized that *D. vexillum* will continue to spread and may affect shellfish larval settlement and survival. We conducted a laboratory experiment to assess interactions between larval bay scallops (*Argopectin irradians irradians*) and *D. vexillum*. We found that larval bay scallops avoid settling on *D. vexillum* colonies, possibly deterred by the low pH of the tunicate's surface tissue. The results of this study suggest that widespread colonization of substrata by *D. vexillum* could affect scallop recruitment by reducing the area of quality habitats available for settlement. We propose that the bay scallop can serve as a surrogate for the sea scallop in estimating the negative impact *D. vexillum* could have on the recruitment of sea scallops on Georges Bank.

Key words: *Didemnum vexillum*, invasive species, tunicates, scallops

Introduction

Since 1988, sightings of the non-native colonial tunicate *Didemnum vexillum* Kott, 2002 (Figure 1) have increased substantially at locations on Georges Bank and in tidal lagoons and estuaries of New England, U.S. (Carman and Roscoe 2003; Pederson 2005; Bullard et al. 2006; Bullard et al. 2007; Dijkstra et al. 2007; Osman and Whitlach 2007; Valentine et al. 2007a). The specific vector of the *D. vexillum* introduction is uncertain, although international shipping, local boat traffic, and/or shellfish imports are among the likely sources (Wonham and Carlton 2005). Didemnids are colonial ascidians and are capable of both sexual and asexual reproduction. Didemnids also possess chemical defenses as evidenced by their highly acidic tunics (Pisut and Pawlik 2002). *Didemnum vexillum* exhibits a wide thermal tolerance of -2 to 24ºC (Valentine et al. 2007a) and resides in a variety of habitat types (Osman and Whitlatch 2007). In addition, didemnids possess other traits including multiple dispersal mechanisms, few known predators, and fast growth rates that enable them to invade, outcompete, and dominate new habitats around the world (Bullard et al. 2007; Lambert 2007; Osman and Whitlatch 2007).

Didemnid colonization occurs on hard substrata and in areas of high anthropogenic disturbance such as docks, aquaculture gear, and mooring gear (Tyrrell and Byers 2007). Recent surveys in Long Island Sound and on Georges Bank revealed a benthos with up to 75%

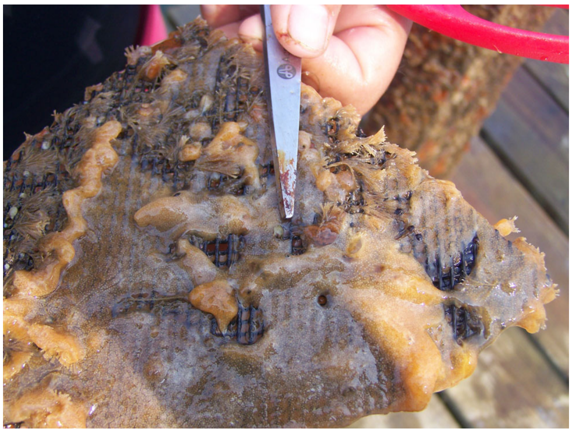

Figure 1. Photograph showing *Didemnum vexillum* used during this study attached to Vexar® mesh.

coverage by didemnid colonies at some sites (Lengyel et al. 2009; Whitlatch and Osman 2009). The direct impact of this coverage on benthic faunal communities is uncertain. However, there are several impact hypotheses including: 1) smothering of bivalves (Valentine et al. 2007b); 2) reduction of structural complexity; and 3) reduction in available benthic prey (infaunal organisms) for finfish (Lengyel et al. 2009; Mercer et al. 2009).

Clearly, the potential for negative ecological and economical impacts on commercially important finfish and shellfish is apparent. One fishery that could be affected is the sea scallop (*Placopecten magellanicus* (Gmelin, 1791)) fishery of New England. According to the NOAA National Marine Fisheries Service (NMFS), approximately 24,000 metric tons of sea scallops, valued at nearly $400 million USD, were landed in 2006 (NMFS 2007) representing one of the largest valued commercial fisheries in the U.S. Sea scallops are mollusks with pelagic larvae that settle to the benthos and attach to the substrata using byssal threads (Langton and Robinson 1990). We hypothesize that an additional impact of didemnid colonization may be a substantial loss of habitat for settling sea scallops. If this hypothesis is true, the continued spread of didemnids may impact sea scallop recruitment by reducing settlement substrate. For this reason, we designed a laboratory study to investigate the interactions between settling bay scallop (*Argopecten irradians irradians,* (Lamarck, 1819)) larvae (a surrogate for the sea scallop) and *D. vexillum*. Furthermore, the impact of *D. vexillum* colonies on the bay scallop fishery is itself of scientific and practical economic interest. The specific objective of this study was to determine if settlement of larval bay scallops is negatively affected by the presence of *D. vexillum*.

Methods

To determine if larval scallop settlement is reduced by *D. vexillum*, we conducted a laboratory experiment at the Chappaquiddick Island shellfish nursery of the Martha's Vineyard Shellfish Group, Inc., Edgartown, Massachusetts. Due to the unavailability of larval sea scallops for this experiment, we used larval bay scallops as surrogates for sea scallops. The setting behavior of larval bay scallops and sea scallops are similar enough that this experiment's results likely mimic sea scallop setting under the same circumstances.

We constructed two separate 500 L seawater systems representing an experimental and a control system with each system equipped with ten replicate settlement containers. Both systems were constructed of identical materials and received a seawater exchange rate of 1.2 ± .5 L/min. Each settlement container consisted of a 10 cm high × 30 cm diameter PVC ring with 118 µm Nitex® nylon mesh glued to one side, creating a sieve-like container capable of receiving flow-through seawater and retaining larval bay scallops and *D. vexillum* colonies within the container (Figure 2). The benthic substratum in the experimental system containers was comprised of a colony of *D. vexillum* (25% of the bottom) and silicone (25% of the bottom) attached to pieces of Vexar® plastic mesh that rested on the nylon mesh (50% of the bottom of the container) (Figure 2). The *D. vexillum* fragments were gardened onto the Vexar® mesh from naturally occurring *D. vexillum* colonies found in nearby waters. In the control containers, the substrate was comprised of silicone on Vexar® mesh (50% of the bottom) that rested on the nylon mesh (50% of the bottom) of the container (Figure 2). In both container types, the silicone was applied in a fashion that simulated the lumpy texture and relief of the surface of a *D. vexillum* colony. This design allowed comparisons of impacts of the tunicate on bay scallop settlement at both the system level (i.e., between seawater systems containing *D. vexillum*) and at the individual container level (i.e., between the two substrate types).

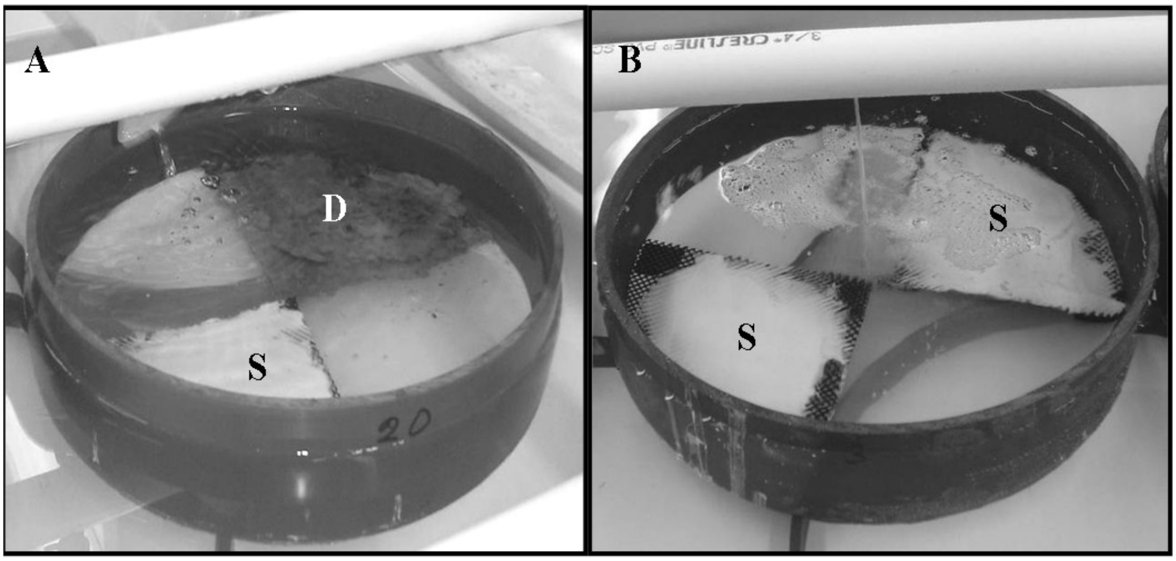

Figure 2. Pictures depicting one replicate sieve from the experimental (A) and control (B) tanks. D = *Didemnum vexillum* colony, S = silicone.

Bay scallop pediveligers (9 days post spawning) were stocked simultaneously into all containers at a stocking density of approximately 32,500 larvae per container. Bay scallop settlement was observed regularly to determine when the larvae had begun to set. On the fifth day, when the pediveligers were beginning to form byssus attachments to the substratum, the locations of bay scallop larvae and their density per cm^2 were determined for each substratum type in each tank by visual observation using a dissecting microscope and transparent sampling grid. The total number of bay scallops per cm^2 was determined for each type of substratum in control and experimental tanks. These densities were compared using a Student's t-Test (SAS version 9.1.3, SAS Institute, Cary, NC) with an alpha of 0.05 considered significant.

To assess the tunic pH of the *D. vexillum* colonies during the trials, a pH probe was placed on the surface of the colonies of each container (n = 10) and allowed to press against the tunic along the entire length of the tip of the probe. To determine the pH at the interface of the tunic and seawater, a pH probe was placed at the surface of *D. vexillum* but was not allowed to sink into the tunic. The pH of the silicone and seawater were also measured.

Results

No bay scallop larvae were observed to settle on *D. vexillum* colonies during this experiment. In both experimental and control tanks, scallop larvae were observed to be predominately associated with the silicone substratum. When comparing total settlement of scallops on all types of substratum between systems, we observed a mean of 13.2 ± 6.0 scallops per cm^2 in the experimental system and a mean of 41.8 ± 9.5 scallops per cm^2 in the control system (Figure 3). This difference was found to be statistically significant ($t = 2.49$, $df = 18$, $P = 0.023$).

The pH of the *D. vexillum* lobe was 3.8 ± 0.2 and the pH of the seawater at the tunic surface was 5.9±0.2. The pH of the silicone and seawater was 7.5 ± 0.1.

Discussion

The results of this experiment suggest that *D. vexillum* is capable of deterring settlement of bay scallop larvae and by analogy sea scallop larvae. We suggest that benthic coverage by *D. vexillum* may reduce bay scallop settlement and subsequently limit population recruitment to the fishery in New England coastal areas.

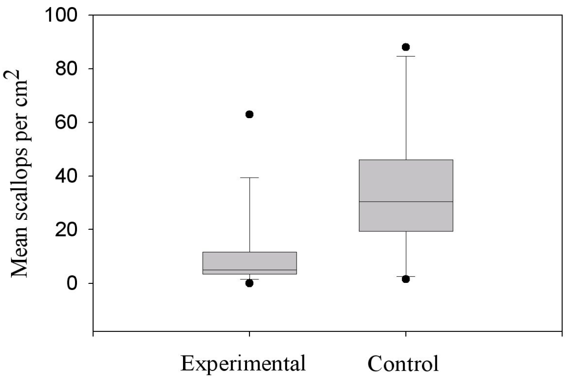

Figure 3. Boxplots depicting the mean number of scallops per cm^2 that settled in both the experimental (with *Didemnum vexillum*) and control (without *Didemnum vexillum*) systems. The boundary of the box closest to zero represents the 25th percentile with the line in the middle representing the median. The boundary of the box farthest from zero indicates the 75th percentile with the whiskers (error bars) indicating the 90th and 10th percentiles. Outliers are indicated by black circles.

Further, the expanding coverage of *D. vexillum* on the sea floor of Georges Bank may have the same effect on the sea scallop fishery.

The acidity of the tunic imparted by lower pH to the laminar surface waters of the *D. vexillum* colonies provided a zone that was acidic compared with ambient seawater. We hypothesize that the acidic property of the *D. vexillum* tunic is a deterrent to larval settlement. High mortality and abnormal development of molluscan larvae have been observed at pH values lower than 6.75 (Calabrese and Davis 1966). However, it is uncertain if larval scallop interaction (i.e., attempts to settle) with *D. vexillum* actually caused mortality of the scallop larvae. It is also unclear if the presence of *D. vexillum* colonies caused a delay in settlement, possibly having a negative effect on scallop nutrition or health, or causing crowding of scallops on the alternative silicone substrate.

While we did not observe larval bay scallops settling on *D. vexillum* during the course of the experiment, we did note a few juvenile scallops on a *D. vexillum* colony in our field observations. It is likely that adult and juvenile scallops (which are quite mobile) can temporarily survive the acidic environment of the tunic. It is yet unclear if *D. vexillum* is capable of causing direct mortality of shellfish by over-growth.

This study provides the first documentation of the interactions between larval shellfish and *D. vexillum*. Given the potential impact that the tunicate could have on commercial shellfisheries, attention should be given to better understanding the specific ways that it impacts scallops, mussels, and oysters, with particular emphasis on the role of lower pH substrate on the setting behavior of larval shellfish.

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