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**Research Article**

# Potential of the invasive colonial ascidian, *Didemnum vexillum*, to limit escape response of the sea scallop, *Placopecten magellanicus*

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**Editor's note:**
This paper is a contribution to the proceedings of the 3rd International Invasive Sea Squirt Conference held in Woods Hole, Massachusetts, USA, on 26–28 April 2010. The conference provided a venue for the exchange of information on the biogeography, ecology, genetics, impacts, risk assessment and management of invasive tunicates worldwide.

## Abstract

*Didemnum vexillum* is a globally invasive species and a major pest to the aquaculture industry. Like other colonial ascidians, *D. vexillum* can readily overgrow aquaculture nets and cultured species. Recently, the species has been found in great abundance on seafloor habitats, where it is often associated with commercially important shellfish species such as sea scallops, *Placopecten magellanicus*. Despite the increasing abundance of *D. vexillum* in areas that are regularly fished for sea scallops, little work has been conducted on the ascidians impact on scallop behavior. This study examined the effect of overgrowth of the sea scallop by *D. vexillum* using four measures: time to initial exhaustion, swimming speed, horizontal and vertical displacement. Scallops covered by *D. vexillum* became exhausted more quickly, and were not able to swim as far in either the horizontal or vertical direction as the control sea scallops without *D. vexillum* encrustation. The expansion of *D. vexillum* into sea scallop habitat may increase the vulnerability of sea scallops to predation and limit their ability to access food rich habitats.

**Key words:** escape response, epibiont, *Didemnum vexillum*, *Placopecten magellanicus,* swimming behavior

## Introduction

The sea scallop, *Placopecten magellanicus* (Gmelin, 1791), is indigenous to the Northwest Atlantic, ranging from waters off Newfoundland and Labrador to Cape Hatteras, North Carolina at depths between 15 and 110 m (Posgay 1957). This fishery represents one of the largest fishing industries in the United States with a catch of 24,000 tonnes that is valued at over $400 million US and is one of the most valuable wild scallop fisheries in the world (NMFS 2007). Sea scallop habitat and fishery extend both offshore and inshore along the eastcoast of the USA within the federal 3-mile Exclusive Economic Zone. In recent years, scallop landings in the 3-mile zone have declined, particularly along the coast of Maine (NMFS 2007), and likely would have declined on Georges Bank but for area closures in the 1990s which resulted in a rebound in populations when fishing pressure was removed (Hart and Rago 2006). The preferred habitat of *P. magellanicus* is coarse sediment such as cobble, gravel, and clay (Hart and Chute 2004). In recent years, the sea scallop has been associated with and found to be encrusted by the colonial sea-squirt *Didemnum vexillum* Kott, 2002 (Valentine et al. 2007). While most non-native species occur in shallow waters on artificial and rocky substrate (Ruiz et al. 1997; Dijkstra et al. 2007; Neves et al. 2007), *D. vexillum* is often found in deeper waters in habitat preferred by sea scallops (Valentine et al. 2007; Mercer et al. 2009).

Scallops are bivalves and are often associated with encrusting epibionts including sponges, barnacles, polychaete worms, ascidians and bryozoans. However, the interactions between scallops and different epibionts vary depending upon the identity of the encrusting species. For example, some sponges have a mutualistic relationship with scallops, by serving as protection against predation by sea stars either through camouflage or by interfering with the adhesion of the sea star's tubefeet (Forester 1979). Sponges also benefit by greater food intake (e.g., phytoplankton and/or bacteria) resulting from increased current generated by the scallop siphons (Forester 1979), or by being cleared of sediment when the scallop swims or claps its valves (Burns and Bingham 2002). In contrast, barnacles limit the ability of the scallop to swim long distances by decreasing the speed of the scallop and the swimming height it can attain, but confer no apparent benefit on the scallop (Donovan et al. 2003).

Swimming is an important escape response, particularly in sea scallops that are < 80 mm shell height (Baird 1954), allowing scallops to avoid predation and to disperse. Inhibiting the swimming behavior of scallops may increase the likelihood of predation (Stephens and Boyle 1978; Peterson et al. 1982). They also swim to migrate and to access habitats richer in food (Moore and Marshall 1967; Morton 1980; Hamilton and Koch 1996); thus, detrimental shell encrustation may limit their dispersal ability.

The expansion of *Didemnum vexillum* into valuable sea scallop fishing grounds in New England has led to concern about the impact of this tunicate on economically important sea scallop habitat (Valentine et al. 2007). One study by Morris et al. (2009) found that *D. vexillum* inhibits the settlement of the bay scallop (*Argopecten irradians irradians*), and therefore, will likely prevent the settlement of sea scallop spat. However, it is unclear whether *D. vexillum* affects the swimming behavior of sea scallops and if so to what degree. Therefore, we experimentally examined the effects of epibiosis by *D. vexillum* on the swimming behavior of *Placopecten magellenicus*. Given the importance of commercial shellfisheries, it is imperative to understand further ecological interactions between *D. vexillum* and juvenile and adult sea scallops.

## Materials and methods

Our experiments were carried out in a flow-through sea-water clear Plexiglas tank (3.0 m × 0.85 m × 1.4 m) at the Shoals Marine Laboratory on Appledore Island, ME in May and June, 2008. To quantify swimming behavior of *Placopecten magellanicus*, a plastic sheet spanning the length of the tank and marked with vertical lines 2 cm apart was attached to the wall of the tank. Another sheet of plastic (0.24 m × 1.4 m), also marked by 2 cm increments, was placed vertically in the tank. Swimming behavior of sea scallops was recorded using a video recorder mounted on a tripod and was placed ~1 meter in front of the tank. Videos were later analyzed for vertical and horizontal distance swum, initial time to exhaustion, and swimming speed.

To examine the effects of overgrowth by *Didemnum vexillum* on the escape response of *Placopecten magellanicus*, two treatments [no epibionts (control) and epibionts] and four response variables (time to exhaustion, swimming speed, horizontal distance, and vertical distance) were measured. A total of 38 scallops with shell heights ranging from 30 mm to 70 mm were used for the experiment. In each of three trials, each scallop was tested with (treatment) and without (control) *D. vexillum* as an epibiont. Our epibiont treatment consisted of 100% overgrowth by *D. vexillum*. To attain this level of cover, we glued, using superglue, *D. vexillum* to the top of the scallops shell, leaving enough space at the edge of the shell that cover by *D. vexillum* would not physically inhibit swimming. Shell valves were not covered. To ensure our treatment only reflected movement limited by *D. vexillum*, a similar amount of superglue was also applied to the top shell of control scallops.

To elicit an escape response, scallops were induced to swim using a seastar (*Asterias rubens*) attached, using nylon filament, to the end of a stick. At the beginning of each trial, the tubefeet of the seastar touched the scallop, thereby inducing an escape response (swimming). To examine time to initial exhaustion, the seastar continued to touch the scallop (and hence the scallop continued to swim) until it rested and further clapping was not observed, at which time the trial came to an end.

Time to initial exhaustion, swimming speed, horizontal and vertical distances swum were collected after each trial from the video footage. Initial time to exhaustion was measured as the total amount of time the scallop spent swimming. Horizontal distance was the total distance traveled while swimming. Vertical distance was measured as the greatest height in the water column reached by each scallop. Speed was

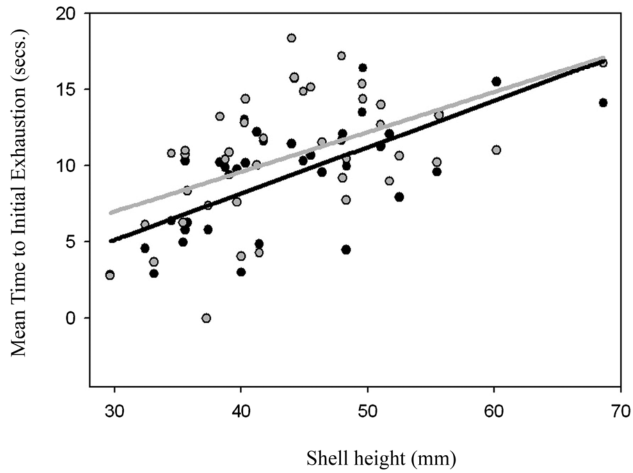


**Figure 1.** Individual mean measurements of total time swimming (seconds) until exhaustion as a function of shell height of sea scallop, *Placopecten magellanicus*. Gray (control) and black (treatment) dots indicate individual mean values for control (gray; no epibiosis) and treatment (black; *Didemnum vexillum* epibiosis) trials, respectively. Gray and black lines indicate regressions fitted for each of the control and treatment data sets.

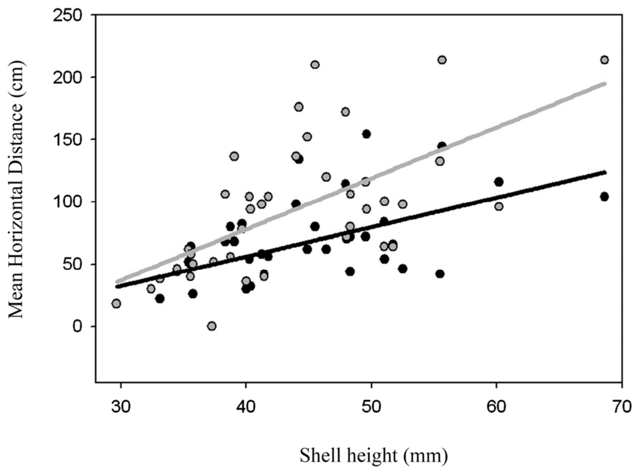


**Figure 2.** Horizontal distance traveled by sea scallops (*Placopecten magellanicus*) as a function of shell height. Gray (control) and black (treatment) dots indicate individual mean values for control (no epibiosis) and treatment (*Didemnum vexillum* epibiosis) trials, respectively. Gray and black lines indicate regressions fitted for each of the control and treatment data sets.

calculated as the sum of the horizontal and vertical distance divided by total time swimming. This gave an average speed for that trial. Scallops (control and treatment) were made to swim to exhaustion once a day and then allowed to rest 11–14 hours, a suitable period of rest for scallops (Donovan et al. 2002). A paired-t test was used to test for differences between treatments for mean response variables.

## Results

Overall there was a significant negative effect of epibiosis on the escape response of *Placopecten magellanicus* (Table 1). Sea scallops encrusted by *Didemnum vexillum* reached exhaustion more rapidly than unencrusted sea scallops (Figure 1). They did not swim as far or as high as unencrusted *P. magellanicus* (Figures 2 and 3). Finally, encrusted sea scallops did not swim as fast as individuals free of encrustation (Figure 4).

A difference in swimming behavior was observed between encrusted and unencrusted sea scallops, however the magnitude of the difference for time to initial exhaustion and horizontal distance traveled appeared to be dependent on size (Figures 1 and 2). For time to initial exhaustion, difference between control and treatments decreased with increasing shell height (Figure 1). Smaller scallops were quicker to fatigue than larger scallops. In contrast, the divergence in distance traveled between encrusted and unencrusted sea scallops was greater for larger scallops (Figure 2).

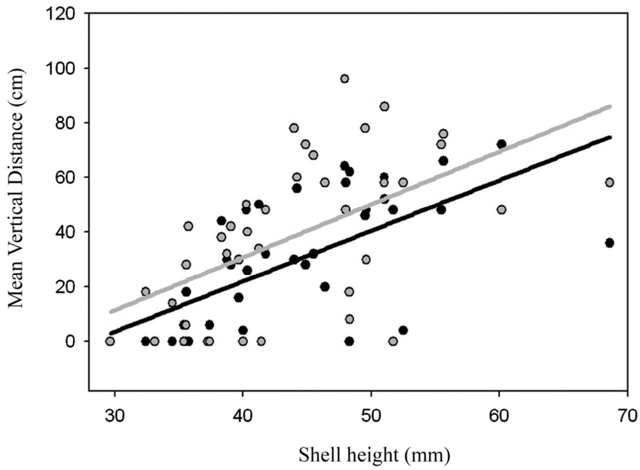


**Figure 3.** Vertical distance traveled by scallops as a function of shell height. Gray (control) and black (treatment) dots indicate individual mean values for control (no epibiosis) and treatment (*Didemnum vexillum* epibiosis) trials, respectively. Gray and black lines indicate regressions fitted for each of the control and treatment data sets.

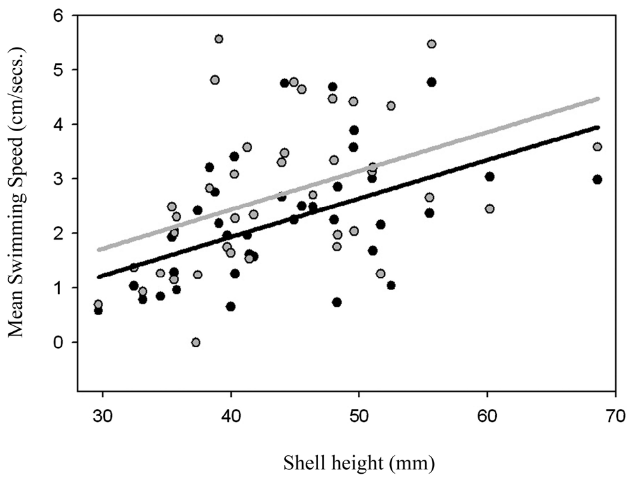


**Figure 4.** Swimming speed of sea scallops as a function of shell height. Gray (control) and black (treatment) dots indicate individual mean values for control (no epibiosis) and treatment (*Didemnum vexillum* epibiosis) trials, respectively. Gray and black lines indicate regressions fitted for each of the control and treatment data sets.

**Table 1.** Paired t-test on mean response variables (time swimming, horizontal and vertical distance) before and after treatment.

| | T-statistic | Degrees of Freedom | P-value |
|---|---|---|---|
| Time to exhaustion | 3.13 | 38 | <0.003 |
| Horizontal distance | 4.51 | 38 | <0.001 |
| Vertical distance | 2.40 | 38 | <0.022 |
| Swimming speed | 2.72 | 38 | <0.001 |

## Discussion

*Didemnum vexillum* was first noted in Damariscotta, ME, before 1982 by oyster farmers (R. Clime, pers. comm.) and has since been observed in sea scallop habitat along the coast of Maine, NH and the Isles of Shoals (Dijkstra and L.G. Harris, pers. obs.). The sea scallop uses swimming to access a habitat with more resources (e.g., food) and to avoid predators. Our study demonstrates that encrustation by the invasive colonial ascidian *D. vexillum* negatively affects the escape response of sea scallops. Encrusted sea scallops swam less and reached exhaustion sooner than unencrusted sea scallops, specifically for scallops with shell heights of less than 40 mm.

The metabolism of smaller individuals is faster than larger individuals and likely exacerbated the time to initial exhaustion observed between control and treatment scallops.

Distance and height traveled was substantially different between encrusted and unencrusted sea scallops. Unencrusted scallops traveled farther (horizontally and vertically) than encrusted scallops. Controls swam on average 20 cm farther during each trial than treatment scallops, and the difference was greater for scallops > 40 mm. Weight of the ascidian may be proportionately greater for larger scallops than for smaller scallops. Therefore, larger scallops with heavier fouling loads may suffer greater reductions in swimming ability than smaller scallops. Reduction in the ability of encrusted *P. magellanicus* to swim as fast, as high or as far as unencrusted individuals likely increases their vulnerability to predation and reduces their ability to disperse.

It remains unclear whether scallops gain benefits from *D. vexillum* encrustation. In similar studies examining epibiosis by sponges on scallops, it was found that scallops benefited from the presence of the sponge because it was harder for seastar tubefeet to grip overgrown scallop shells (Burns and Bingham 2002). *D. vexillum* may provide a similar defense. In addition, the tunic of *D. vexillum* contains acids (Bullard et al. 2007), which could further deter predation by seastars and fishes (Pisut and Pawlik 2002).

In New England, the sea scallop fishery is worth about $431 million annually (Athearn 2005). This fishery, however, may be threatened by the continuing spread of *Didemnum vexillum* into sea scallop habitat. Unlike most invasive colonial ascidians, *D. vexillum* grows well in deep water (~49 m) and cooler habitats (Valentine et al. 2007; Valentine et al. 2009). In the Gulf of Maine, the species was found associated with scallop beds around the Isles of Shoals, ME and NH, Portsmouth Harbor, NH, Damariscotta River, ME, Georges Bank and Eastport, ME (Valentine et al. 2007; Dijkstra et al. 2007; Dijkstra and Harris, unpub. data). While the presence of *D. vexillum* is likely to inhibit recruitment of scallops in these habitats (Morris et al. 2009), growth or reproduction may also be affected by the overgrowth of *D. vexillum*, by preventing dispersal into food rich habitats. Further research on the effects of overgrowth by *D. vexillum* is needed to assess the full ecological impact of this species on sea scallops.

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