Aquatic Invasions (2011) Volume 6, Issue 4: 507–510
doi: 10.3391/ai.2011.6.4.15
© 2011 The Author(s). Journal compilation © 2011 REABIC

Open Access

Proceedings of the 3rd International Invasive Sea Squirt Conference, Woods Hole, USA, 26–28 April 2010

Short Communication

The effect of high-pressure spraying for tunicate control on byssal thread characteristics in the cultured blue mussel (*Mytilus edulis* Linnaeus, 1758)

Collin J. Arens*, S. Christine Paetzold and Jeff Davidson

Atlantic Veterinary College, University of Prince Edward Island, 550 University Ave., Charlottetown, PEI, C1A 4P3, Canada
E-mail: carens@upei.ca *(CJA)*, paetzold_christine@yahoo.co.uk *(SCP)*, davidson@upei.ca *(JD)*
**Corresponding author*

Received: 2 December 2011 / Accepted: 8 June 2011 / Published online: 28 July 2011

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

Mussel growers in Prince Edward Island (PEI), Canada, currently use high-pressure water spraying (~700 psi) to mortally injure or dislodge invasive tunicates from mussel product and gear. An added benefit of this process may be the stimulation of byssal thread production, leading to improved mussel attachment. This study measured byssal thread abundance and thickness in cultured blue mussel *Mytilus edulis* exposed to high-pressure spraying either once, five times (every three weeks), or not at all (control). No significant differences were observed in number or width of byssal threads between treatments indicating routine high-pressure spraying does not affect mussel attachment strength.

Key words: aquaculture, aquatic invasive species, mitigation strategies, tenacity

Introduction

The blue mussel (*Mytilus edulis* Linnaeus, 1758) aquaculture industry in Prince Edward Island (PEI), Canada, currently uses high-pressure water to mortally injure or dislodge several invasive tunicate species from mussel lines and aquaculture gear (Locke et al. 2009; Paetzold and Davidson 2010). A potential added benefit of this treatment is stimulation of byssal thread production of the mussels through regular agitation of the mussel socks. Since mussels can be dislodged from the socks by excessive biomass (of mussels or fouling organisms such as attached tunicates) when mussel lines are lifted out of the water, an increase in attachment strength could reduce the likelihood of crop loss during maintenance and harvesting.

Attachment strength, or tenacity, in the blue mussel is determined largely by byssal thread count, width and quality (Côté 1995; Carrington 2002; Moeser and Carrington 2006). Byssal thread production can be influenced by several factors, including turbulence caused by wave action or current velocity (Young 1985; Carrington 2002; Moeser et al. 2006; Lachance et al. 2008), temperature (Young 1985; Lachance et al. 2008), predators (Côté 1995; Leonard et al. 1999) and seasonal changes in resource allocation as energy is redirected into reproduction (Carrington 2002; Lachance et al. 2008). However the effects of intermittent disturbances, such as treatment using high-pressure spraying, have not been assessed. The objective of this study was to determine if high-pressure spraying, at a pressure and frequency consistent with mussel crop maintenance, affects byssal thread count and width in *M. edulis*.

Methods

Experimental design and treatment

On 28 May 2009, 27 mussel socks were seeded and deployed along longlines in an active

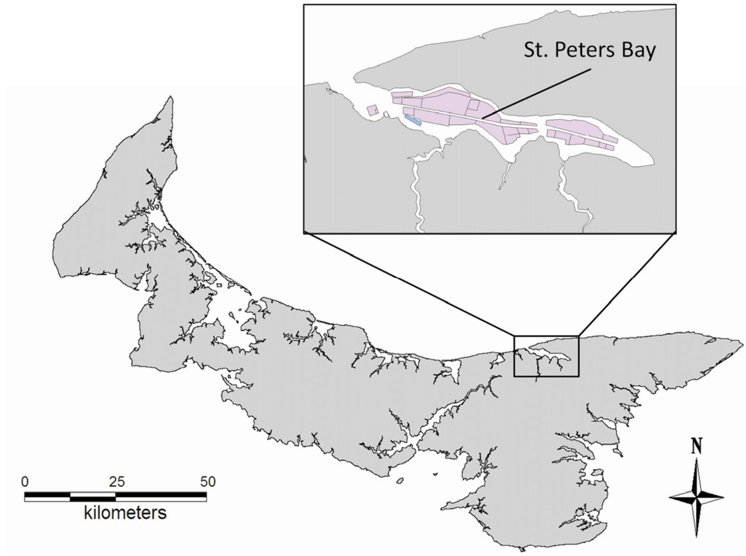

Figure 1. Study site in St. Peters Bay (enlarged inset), Prince Edward Island, Canada. Mussel culture leases are indicated by shaded regions within the bay.

mussel lease in St. Peters Bay, PEI (46° 25.005′N, 62°41.247′W; Figure 1). Three groups of nine socks were randomly allocated to one of two high-pressure spraying treatment groups and a control group. Treated socks were sprayed using a single rotary nozzle at ~700 psi for ~10 s/sock. The first group received a single treatment on 15 October 2009. The second group received five treatments at three-week intervals from 16 July 2009 to 15 October 2009. In the control group, mussel socks were lifted and handled in a manner consistent with the treatment groups but were not sprayed.

Processing and data analysis

On 16 November 2009, one month after the final treatment, 30 cm sections were removed from the base of each of the 27 mussel socks, excluding the bottom 5 cm. Twenty mussels were randomly selected from each sock section and removed by severing the byssal threads between the byssal stem and the byssal plaques (Figure 2). Mussels were frozen until further processing.

Byssal thread count and width were assessed microscopically after removing the byssus from thawed mussels and trimming the byssal threads to within 3 to 5 mm of the byssal stem to improve ease of counting. Only operative threads (translucent, whitish) were counted using a Zeiss Stemi 2000-C dissecting microscope, while inoperative threads (darkened) were ignored.

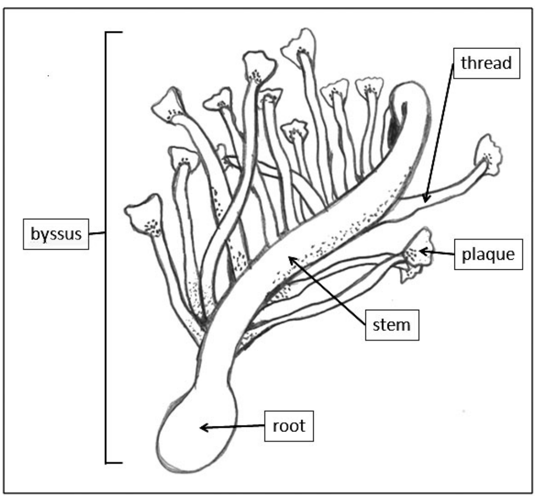

Figure 2. Illustration of a detached *Mytilus edulis* byssus. Byssal root, stem, threads and plaques indicated. Not drawn to scale.

Mean byssal thread abundance per mussel was calculated from triplicate counts. The width of five byssal threads per mussel were measured approximately 0.5 mm from the byssal stem using AxioVision 4.7.2.0 image analysis software. Differences in thread count and width were evaluated using nested ANOVA with mussels from each sock nested within treatments.

Results

Byssal thread count decreased as treatment frequency increased, 57.3±13.4 SD for untreated mussels, 54.5±11.7 SD for those which received a single treatment, and 46.4±11.6 SD for mussels which received multiple treatments, but this difference was not statistically significant ($F_{2,24}$ = 1.81, p = 0.185).

No significant difference was observed for byssal thread width ($F_{2,24}$ = 0.29, p = 0.749), with mean width of 159.5±9.3 µm SD for untreated mussels, 162.0±4.4 µm SD for those which received a single treatment, and 158.5 ± 8.8 µm SD for mussels which received multiple treatments.

Discussion

High-pressure spraying did not have an observable effect on byssal thread count or width in our trial. This result was likely due to the limited duration of exposure (~10 s per sock, < 1 s per mussel), infrequent treatment interval (every three weeks), and/or the time interval between treatment and sampling.

Variation in mussel tenacity typically corresponds to changes in environmental cues such as temperature, salinity, wave height and current velocity (Young 1985; Carrington 2002; Moeser et al. 2006; Lachance et al. 2008), as well as predator-prey interactions (Côté 1995; Leonard et al. 1999) and seasonal changes in reproductive condition (Carrington 2002). These cues exert a continuous and dynamic influence on mussel tenacity as mussels attempt to accommodate changing conditions while minimizing energetic investment in thread production. Mussels do not appear to respond immediately to changes in their environment and even exposure to consistent cues results in lag times ranging from hours to weeks before a change in mussel tenacity is observed (Carrington 2002). Whether this delayed response is an adaptation to prevent unneeded investment in tenacity based on short-term changes in environmental conditions, or represents poor reaction of mussels to environmental changes as suggested by Carrington (2002) remains unclear; however, it seems likely that acute intermittent impacts, like those exerted during high-pressure spraying, may not be sufficient to incite a biological response.

High-pressure spraying also has the potential to negatively impact mussel tenacity. Price (1981) determined that forces in excess of 30 N to 42 N applied to a mussel may impair future byssal thread production by damaging or tearing the root from the byssal gland. Although we did not observe a significant decrease in byssal thread count on treated mussels in our trial, a general trend of declining byssal thread count with increasing treatment frequency was observed.

High variability in the abundance of byssal threads is common among mussels, though individual variation tends to be small (Young 1985). Additional variability in this study may have been introduced by the random selection of mussels from the socking material during processing, as some of these mussels would have been located within the sock and protected by their peers. In natural mussel beds, sheltered mussels produce fewer byssal threads and attach more weakly than exposed mussels in the same population (Witman and Suchanek 1984; Denney 1987; Bell and Gosline 1997). Variation in our study might have been reduced by classifying and then analyzing sheltered and exposed mussels separately. Our study also did not consider treatment-induced variation in byssal thread quality, such as chemical structure and tensile strength. Moeser and Carrington (2006) demonstrated that seasonal variation in byssal thread quality can significantly influence tenacity. Although our samples were taken and frozen over a four day period, and seasonal variation would not have played a role, the impact of high-pressure spraying on thread quality remains unknown.

As the high-pressure treatment schedule examined during this study was comparable to that used by PEI mussel growers in tunicate mitigation, an increase in byssal thread count or width would not be expected during regular crop maintenance by the industry. Variation in mussel tenacity observed by growers more likely relates to intra-annual variation in byssal thread quantity and quality related to changes in storm activity, temperature, and resource allocation (Carrington 2002; Moeser and Carrington 2006; Lachance et al 2008), rather than treatment effects. Seasonal changes in mussel tenacity have been well documented and vary two-fold annually with the greatest tenacity occurring in the late winter and early spring, while lowest tenacity occurs during the late summer and early fall (Carrington 2002; Lachance et al. 2008). Unfortunately, this period of declining tenacity coincides with the greatest level of tunicate fouling in PEI, where *Ciona intestinalis* has been reported to add in excess of 10 $kg \cdot m^{-1}$ to mussel socks. This additional weight coupled with reduced mussel tenacity creates conditions in which attachment failures occur, and crop losses of 50–60% are common under these circumstances (Ramsay et al. 2008). As hydrodynamic stress is among the most influential and potentially manipulative factors influencing mussel attachment, growers may be able to stimulate byssal thread production and reduce subsequent fall-off using large surface buoys attached along the mussel longline. This would improve the transfer of wind energy into sock agitation creating a more turbulent environment and potentially encouraging byssal thread production. However, measures to ensure limited or dampened energy transfer during periods of heavy storm activity would be necessary.

Acknowledgements

This work was supported by the Atlantic Innovation Fund (ACOA), the PEI Atlantic Shrimp Corp. Inc, the PEI Department of Fisheries, Aquaculture and Rural Development, and the PEI Aquaculture Alliance. We thank mussel grower S. Fortune for suggesting this project, C. Picketts for assistance with sample collection and laboratory analysis, V. Robertson for illustrating Figure 2, as well as L. Comeau and J. Babarro for their advice during the development of this project.

References

Bell EC, Gosline JM (1997) Strategies for life in flow: tenacity, morphometry, and probability of dislodgment of two *Mytilus* species. *Marine Ecology Progress Series* 159: 197–208, http://dx.doi.org/10.3354/meps159197

Carrington E (2002) Seasonal variation in the attachment strength of blue mussels: causes and consequences. *Limnology and Oceanography* 47: 1723–1733, http://dx.doi.org/10.4319/lo.2002.47.6.1723

Côté IM (1995) Effects of predatory crab effluent on byssus production in mussels. *Journal of Experimental Maine Biology and Ecology* 188: 233–241, http://dx.doi.org/10.1016/0022-0981(94)00197-L

Denny MW (1987) Lift as a mechanism of patch initiation in mussel beds. *Journal of Experimental Marine Biology and Ecology* 113: 231–245, http://dx.doi.org/10.1016/0022-0981(87) 90103-1

Lachance AA, Myrand B, Tremblay R, Koutitonsky V, Carrington E (2008) Biotic and abiotic factors influencing attachment strength of blue mussels *Mytilus edulis* in suspended culture. *Aquatic Biology* 2: 119–129, http://dx.doi.org/10.3354/ab00041

Leonard GH, Bertness MD, Yund PO (1999) Crab predation, waterborne cues and inducible defences in the blue mussel, *Mytilus edulis*. *Ecology* 80: 1–14

Locke A, Doe KG, Fairchild WL, Jackman PM, Reese EJ (2009) Preliminary evaluation of effects of invasive tunicate management with acetic acid and calcium hydroxide on non-target marine organisms in Prince Edward Island, Canada. *Aquatic Invasions* 4: 221–236, http://dx.doi.org/10.3391/ai.2009.4.1.23

Moeser GM, Carrington E (2006) Seasonal variation in mussel byssal thread mechanics. *Journal of Experimental Biology* 209: 1996–2003, http://dx.doi.org/10.1242/jeb.02234

Moeser GM, Leba H, Carrington E (2006) Seasonal influence of wave action on thread production in *Mytilus edulis*. *Journal of Experimental Biology* 209: 881–890, http://dx.doi.org/10.1242/jeb.02050

Paetzold SC, Davidson J (2010) Viability of golden star tunicate fragments after high-pressure water treatment. *Aquaculture* 303: 105–107, http://dx.doi.org/10.1016/j.aquaculture.2010.03.004

Price HA (1981) Byssus thread strength in the mussel, *Mytilus edulis*. *Journal of Zoology* 194: 245–255, http://dx.doi.org/10.1111/j.1469-7998.1981.tb05771.x

Ramsay A, Davidson J, Landry T, Stryhn H (2008) The effect of mussel seed density on tunicate settlement and growth for the cultured mussel, *Mytilus edulis*. *Aquaculture* 275: 194–200, http://dx.doi.org/10.1016/j.aquaculture.2008.01.024

Young GA (1985) Byssus-thread formation by the mussel *Mytilus edulis*: effects of environmental factors. *Marine Ecology Progress Series* 24: 261–271, http://dx.doi.org/10.3354/meps024261

Witman JD, Suchanek TH (1984) Mussels in flow: drag and dislodgement by epizoans. *Marine Ecology Progress Series* 16: 259–268, http://dx.doi.org/10.3354/meps016259