An initial assessment of native and invasive tunicates in shellfish aquaculture of the North American east coast

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Summary

The objective of the study was to assess the distribution of native and invasive tunicates in the fouling community of shellfish aquaculture gear along the U.S. east coast of the Atlantic. Since the 1980s, several species of invasive tunicates have spread throughout the coastal waters of the North American east coast and have become dominant fouling organisms on docks, boat hulls, mooring lines, and in shellfish aquaculture. Invasive and native tunicates negatively impact shellfish aquaculture through increased maintenance costs and reduced shellfish growth. While the presence of alien tunicates has been well documented at piers, harbors, and marinas, there are few published reports of invasive tunicate impacts to aquaculture. We surveyed shellfish aquaculture operations at Martha's Vineyard, Massachusetts and shellfish aquaculturists in other areas along the North American east coast and report high levels of fouling caused by seven invasive, three native, and two cryptogenic species of tunicates. All study sites were fouled by one or more tunicate species. Biofouling control treatments varied among aquaculture sites and were effective in removing tunicates. Invasive and native tunicates should be considered when assessing the economic impacts of fouling organisms to the aquaculture industry.

Introduction

Following a series of alien tunicate introductions in the 1980s, the tunicate fauna of New England has become dominated by invasive colonial and solitary tunicates, including *Ascidiella aspersa* (D.F. Müller 1776), *Botrylloides violaceus* Okra 1927, *Didemnum vexillum* Kott 2002, *Diplosoma listerianum* (Milne-Edwards 1841), *Styela clava* Herdman 1881, *Styela plicata* (Lesueur 1823), and *Botryllus schlosseri* (Pallas 1774). *B. schlosseri* was introduced to New England in the early 1800s; *B. violaceus, D. vexillum, S. clava* in the 1970s; *D. listerianum* and *A. aspersa* in the 1980s; and *S. plicata* in 2000 (Pederson, 2005; J. Carlton, pers. comm.). Invasive and native tunicates are an economic concern for shellfish aquaculturists because they overgrow bivalves and foul gear, thereby adding weight and restricting water exchange and nutrients (Kluza et al., 2006; Howes et al., 2007; Locke et al., 2007; Rajbanshi and Pederson, 2007; Lutz-Collins et al., 2009).

Removal and control methods for biofouling on oysters and mussels include exposure to air (Katayama and Ikeda, 1987), plastic wrap (Sinner and Coutts, 2003; Coutts and Sinner, 2004), and applications of dilute bleach (Denny, 2008), vinegar (Carver et al., 2003), acetic acid, or calcium hydroxide (Locke et al., 2009). These practices can account for up to 30% of the operational expenses in bivalve farming (Claereboudt et al., 1994), although what proportion of these costs are attributable solely to tunicates is unknown. The objective of this study was to assess the distribution and prevalence of native and invasive tunicates associated with shellfish aquaculture in North American east coast waters and to document tunicate removal and control measures presently being employed in this region.

Materials and Methods

During summer 2008, we qualitatively surveyed U.S. east coast shellfish aquaculture operations (n=24) for tunicate prevalence and control measures by written communication (n=15) and by rapid assessment (n=19 around Martha's Vineyard, Massachusetts). A written questionnaire was sent by email to shellfish farmers requesting information on economic losses owing to the fouling of both native and non-native tunicates (sea squirts). Of particular interest were the costs associated with the following: 1) maintenance of fouled gear, 2) costs of antifoulant coatings (if used), 3) growth rate reductions of shellfish due to fouling of gear by tunicates, 4) shellfish mortality that may be attributed to tunicate fouling, and 5) any other costs.

Rapid assessment surveys were conducted by small boat and included examination of submerged substrate at each aquaculture site to assess the level of tunicate fouling. The amount, type, and age of substrate (cages, bags, ropes, floats, and cultured shellfish) varied at each site. Tunicate species presence and absence was determined and no distinction was made between juvenile or market size shellfish gear in this initial assessment. All tunicates were identified via collection of specimens or photographs. Recent literature references of tunicate prevalence at shellfish aquaculture sites in Massachusetts, Rhode Island, and Prince Edward Island, Canada, were also included in this assessment.

Results

Twelve species of tunicates were found at shellfish aquaculture sites along the North American east coast (Table 1). This list included seven invasive species: *A. aspersa, B. violaceus, B. schlosseri, D. vexillum, D. listerianum, S. clava, S. plicata;* two cryptogenic species: *C.*

intestinalis and *Molgula citrina* (Alder and Hancock 1848); and three native species: *Aplidium constellatum* (Verrill 1871), *Didemnum albidum* (Verrill 1871), and *Molgula manhattensis* (Dekay 1843). The most common fouling tunicate was the invasive *B. violaceus*. Invasive and native tunicates were found to be common fouling organisms in shellfish aquaculture, comprising in some cases nearly 100% of the biofouling community (Fig. 1). The amount and type of gear (cages, boxes, bags, ropes, and buoys) and number of bivalves examined varied at surveyed sites. *Aplidium constellatum* and *C. intestinalis* were attached only to aquaculture gear, whereas *A. aspersa, B. violaceus, B. schlosseri, D. albidum, D. vexillum, D. listerianum, M. manhattensis, S. clava* were attached to gear and shellfish (Table 2). Tunicates fouled cultured bay scallops *Argopecten irradians irradians* (Lamarck 1819), oysters *Crassostrea virginica* (Gmelin 1791), and blue mussels *Mytilus edulis* Linnaeus 1758 at several locations. Quahogs *Mercenaria mercenaria* (Linnaeus 1758) and steamer clams *Mya arenaria* Linnaeus 1758 contained in treated boxes and benthic cages were partially within bottom sediments so that the shellfish were infaunal or epifaunal and were thus tunicate free. Up to seven species of tunicates occurred in a single embayment at Martha's Vineyard (Fig. 2). Salinity at locations containing tunicates ranged from 28 to 33.5 (Table 2).

Tunicates were absent on treated shellfish or aquaculture gear. Observed strategies for fouling control on aquaculture gear include peroxide and anti-fouling paint applied to boxes, freshwater sprays with a garden hose for five minutes, and air-drying on land for three days. Treatments applied directly to oysters included five-minute freshwater sprays, exposure to air for 24 hours, tumbling for ten minutes, and salt brine dips for 10 minutes followed by air exposure for two hours. Floating bags of oysters were flipped over every two weeks during spring, summer, and fall. All treatments were effective in removing attached tunicates. Bay scallops cannot tolerate these treatments and were routinely removed from fouled bags and placed in clean bags every two to three months during spring, summer, and fall.

Discussion

This is the first descriptive assessment of invasive tunicate fouling and removal techniques in shellfish aquaculture along the U.S. east coast. It is likely that other species of tunicates are present at aquaculture sites in New Jersey, New York, North Carolina and Virginia (Table 1). Our preliminary results suggest that site visits in these states would be warranted and will likely add to the knowledge of the geographic distribution of tunicate species negatively impacting shellfish aquaculture operations. Because the materials used at the farms are of different types and age, studies where panels are exposed for a known exposure time to explore tunicate settling behavior and panels of the identical material used at farms but of different ages (first time use, second time use, or longer term use) to see whether settling characteristics are changing are warranted.

Tunicates likely foul cultured shellfish and aquaculture gear because of the available hard substrate they provide in the water column. It appears that the conditions suitable for shellfish aquaculture are also highly conducive to tunicate growth. Antifouling procedures will likely be different for each shellfish species and age of the shellfish. Tunicate removal requires additional labor by aquaculturists, although cost estimates for this maintenance have not been calculated. Future research is needed to determine the most efficient procedures for preventing and removing fouling tunicates. The results of such studies could lead to recommendations that would help environmental agencies and farm managers to optimize mitigation strategies when trying to cope with tunicate fouling problems.

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Fig. 1. Cage fouling by *Molgula manhattensis* in Virginia (photo credit, Tom Leggett)

Fig. 2. Geographical distribution of tunicate species on Martha's Vineyard, Massachusetts, 2008

Table 1. Geographical distribution of tunicates at shellfish aquaculture sites along the North American east coast, 2005-2008. Abbreviations: *Ac=Aplidium constellatum; Aa=Ascidiella aspersa; Bv=Botrylloides violaceus; Bs=Botryllus schlosseri; Ci=Ciona intestinalis; Da=Didemnum albidum; Dv=Didemnum vexillum; Dl=Diplosoma listerianum; Mc=Molgula citrina; Mm=Molgula manhattensis; M*sp=*Molgula* sp.*; Sc=Styela clava; Sp=Styela plicata*. The tunicate species at Maine (J. Dijkstra, pers. comm.), other sites in Massachusetts (Valentine et al., 2007), Rhode Island (Carman et al., 2009), and PEI, Canada (A. Locke, pers. comm.) were identified from live specimens and tunicate species at Maryland, New Jersey, New York, North Carolina, and Virginia were identified from photographs.

Table 2. Shellfish aquaculture sites visited, 2008. Approximately one hour was spent looking for tunicates at each of the 26 sites. Abbreviations (shellfish): *Aii=Argopecten irradians irradians; Cv=Crassostrea virginica; Ma=Mya arenaria; Meme=Mercenaria mercenaria*. Abbreviations (tunicates): *Ac=Aplidium constellatum; Aa=Ascidiella aspersa; Bv=Botrylloides violaceus; Bs=Botryllus schlosseri; Ci=Ciona intestinalis; Da=Didemnum albidum; Dv=Didemnum vexillum; Dl=Diplosoma listerianum; Mm=Molgula manhattensis; Sc=Styela clava*.

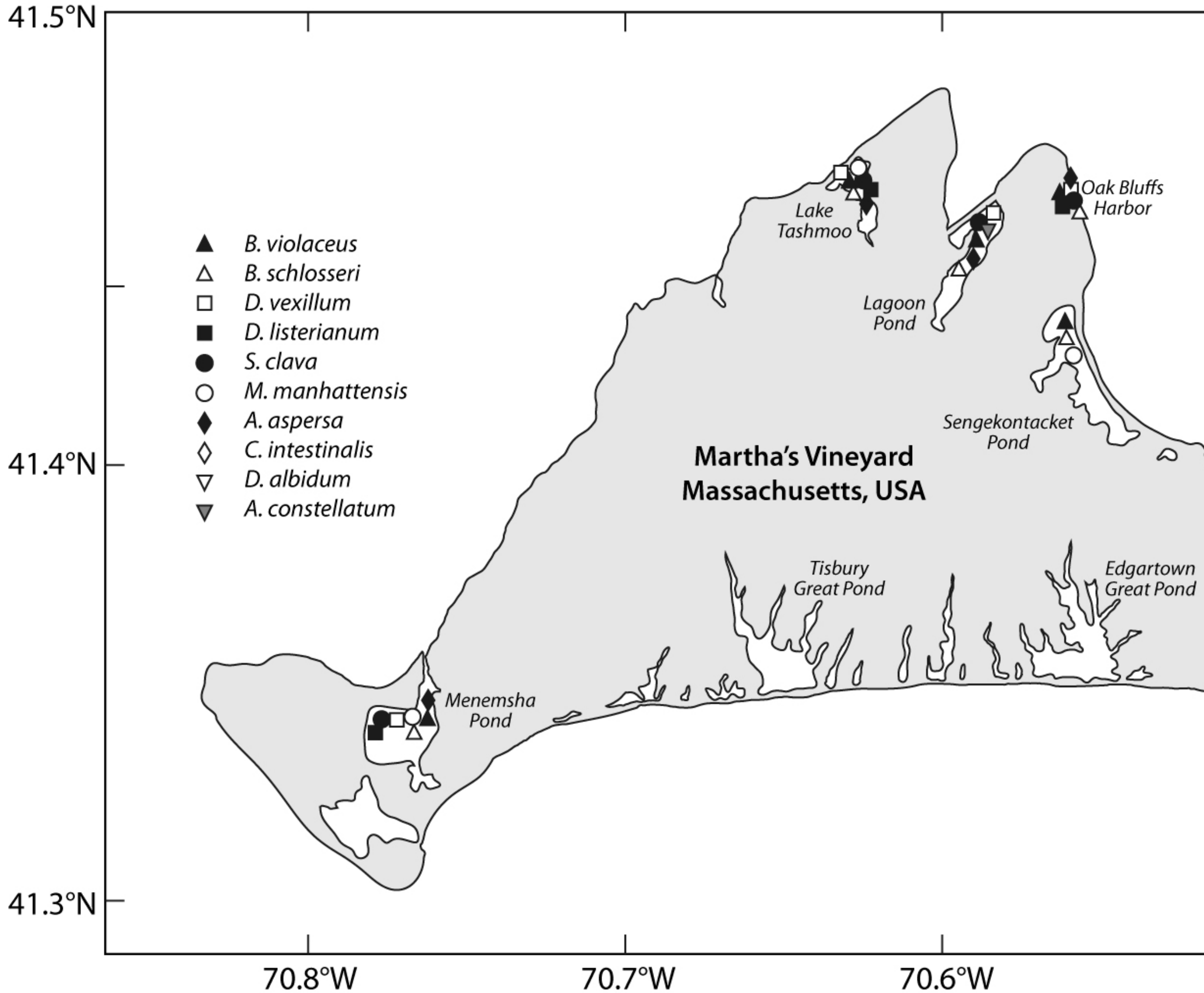
Figure 1

	Ac	*Aa*	*Bv*	*Bs*	*Ci*	*Da*	*Dv*	*Dl*	*Mc*	*Mm*	*M*sp	*Sc*	*Sp*
Maine			X				X	X	X				
Maryland										X			
Massachusetts	X	X	X	X		X	X			X		X	
New Jersey										X			
New York			X	X							X	X	
North Carolina					X						X		X
Rhode Island			X		X		X				X	X	
Virginia										X			
PEI, Canada			X	X	X				X	X		X	

Table 1

Site #	SITE VISITED	DATE	TUNICATES	TUNICATE SUBSTRATE	SALINITY
1	Sengekontacket Pond	24-Jul-08	*Bs,Bv,Mm*	gear	31
			Mm	cultured *Aii*	
			none	treated gear,cultured *Meme*	
2	Sengekontacket Pond	24-Jul-08	none	treated dock	
3	Lagoon Pond	29-Jul-08	*Aa,Bv,Bs,Dv,Sc*	cultured *Aii*	31
			Aa,Bv,Bs,Dv,Sc	dock,gear	
4	Katama Bay	30-Jul-08	*Bs,Bv,Ci,Dv,Sc*	gear	33.5
			Dv,Sc	cultured *Aii*	
5	Katama Bay	30-Jul-08	none	gear,cultured *Aii*	31
6	Caleb's Pond	30-Jul-08	*Bv,Dv*	gear	29.5
7	Katama Bay	30-Jul-08	*Dv,Sc*	dock	30
8	Katama Bay	30-Jul-08	*Bv,Dv,Sc*	gear	30
			none	wild *Meme*	
9	Pocha Pond	30-Jul-08	*Aa,Sc*	gear	28.5
			none	cultured *Aii*	
10	Pocha Pond	30-Jul-08	*Aa,Bv,Da,Sc*	gear	28.5
			Da	cultured *Aii*	
11	Pocha Pond	30-Jul-08	*Ci,Mm,Sc*	gear	28
			none	wild *Aii*	
12	Edgartown Great Pond	30-Jul-08	none	gear,cultured *Cv*	14.5
			none	wild *Ma*	
13	Edgartown Great Pond	30-Jul-08	none	gear	14
14	Menemsha Pond	14-Aug-08	*Aa,Bv,Bs,Dl,Dv,Mm,Sc*	gear	33.5
			none	gear	
15	Menemsha Pond	14-Aug-08	none	gear,cultured *Cv*	31
			Bv,Bs,Dv,Dl,Mm	gear	
16	Menemsha Pond	14-Aug-08	*Aa,Bv,Bs,Dv,Dl*	gear	31
			Aa,Bv,Dv	cultured *Aii*	
17	Menemsha Pond	14-Aug-08	none	crab trap	31
18	Lagoon Pond	14-Aug-08	none	wild *Aii*	31
19	Major's Cove	28-Aug-08	*Bv,Bs,Mm*	eelgrass	29.5
			none	wild *Aii*	
20	Major's Cove	2-Sep-08	*Bv,Bs*	eelgrass	30
			Bv	wild *Aii* on eelgrass	
21	Oak Bluffs Harbor	2-Sep-08	none	treated gear,cultuerd *Ma*	33
			Aa,Bv,Bs,Dv,Dl,Sc	dock	
22	Lagoon Pond	5-Sep-08	*Aa,Ac,Bv,Bs,Dv,Sc*	gear	31
23	Lake Tashmoo	5-Sep-08	*Bs,Bv,Dl,Mm*	gear	33
			Aa,Bv,Bs,Dl,Sc,Dv	gear	
24	Lake Tashmoo	5-Sep-08	none	wild *Meme*	31
25	Lake Tashmoo	5-Sep-08	*Aa,Bv,Bs,Dv,Dl,Sc*	gear	30
26	Lake Tashmoo	5-Sep-08	*Aa,Bs,Bv,Dl,Dv,Sc*	gear	30

Table 2


41.5°N
41.4°N
41.3°N
70.8°W
70.7°W
70.6°W
B. violaceus
B. schlosseri
D. vexillum
D. listerianum
S. clava
M. manhattensis
A. aspersa
C. intestinalis
D. albidum
A. constellatum
Martha's Vineyard
Massachusetts, USA
Lake Tashmoo
Lagoon Pond
Oak Bluffs Harbor
Sengekontacket Pond
Tisbury Great Pond
Edgartown Great Pond
Menemsha Pond