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Sea Squirts as Potential Vectors of Harmful Algal Introductions

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Introduction

Harmful algal blooms (HAB) form when naturally occurring algal cells multiply as a result of favorable environmental conditions. Some HAB species produce toxins that can harm aquaculture organisms, while others produce toxins that can bioaccumulate in the food chain and can be harmful to humans that consume cultured shellfish. These HAB can also impair water quality resulting in anoxic or hypoxic conditions that stress or kill other organisms, including cultured fish and shellfish.

The geographical extent and duration of HAB have been increasing, attributed in part to human activities (Hallegraeff, 1993; Heisler et al., 2008) including aquaculture. The economic impact of harmful algal blooms worldwide has been estimated to be in the range of $50M annually (Anderson et al., 2000). These blooms are particularly costly to the shellfish aquaculture industry and resource management agencies (Shumway et al., 1988; Adams et al., 2011; Matsuyama and Shumway, 2009; Watson et al., 2009). Area closures can delay harvest, result in lost income, and there are also significant costs associated with monitoring and managing for blooms.

Figure 1. Sea squirts have colonized almost every surface of this aquaculture cage. Photo by Tessa Getchis.

Researchers have been examining potential pathways of HAB introductions and methods to reduce the spread of these toxic blooms. While the movement of aquaculture species is strictly regulated by state, federal and international governing bodies, other husbandry activities and non-target organisms associated with aquaculture may have the potential to cause the unintentional spread of HAB.

The accumulation of biofouling organisms on aquaculture gear is a significant and costly problem for aquaculture producers (Adams et al., 2011). The predominant types of biofouling organisms are ascidians, or sea squirts, as they are commonly known. Both native and non-native ascidian species readily colonize aquaculture gear and other hard surfaces (Arsenault et al., 2009). These filter-feeding tunicate species, which exist in both solitary and colonial forms, compete for space and resources and rapidly overgrow and restrict water flow to the cultured species (Daigle and Herbinger, 2009; Kripa et al., 2012) (Figure 1).

Numerous measures have been attempted, with varying degrees of success, to prevent or control biofouling organisms; however, the most common practice used by industry is to remove the biofouling material by manually scrubbing or powerwashing aquaculture gear (Braithwaite et al., 2007). In most cases, it is cost-prohibitive to transport this material to shore for disposal, and as such, it is often dumped overboard. Past research has indicated that many fouling organisms remain alive and can reestablish themselves on other surfaces at the dump site (Bullard et al., 2007a). In New England and Long Island Sound, for example, five invasive species of tunicates (*Styela clava, Ascidiella adspersa, Botrylloides violaceus, Diplosoma listerianum,* and *Didemnum vexillum*) have successfully invaded in the last 30 years (Steneck and Carlton, 2001; Bullard et al., 2007b; Dijkstra et al., 2007).

Research has already demonstrated that transplanted shellfish can be vectors for the transport of harmful algae, and that blooms can in fact form following transport (Hégaret et al., 2008). As such, the transport and disposal of ascidians presents a very real risk that harmful algae associated with them may be introduced into receiving waters. The research team set out to determine if the removal, transport, or transfer of these organisms by aquaculturists has the potential to concentrate and further distribute harmful algal cells to new areas.

The Study

To establish the potential for transfer of harmful algal blooms via ascidians, wild-caught sea squirts were exposed to various species of harmful algae. Specifically, six common (both native and non-native) species of fouling ascidians (see Figure 2) were exposed to six species of harmful algae (Table 1). Following exposure, researchers collected and analyzed the biodeposits to determine if any harmful algal cells remained. Fecal pellets were examined for chlorophyll fluorescence which indicates the presence of potentially viable algal cells. The biodeposits were then cultured for several weeks to determine if any of the ingested cells remained viable and were able to form a bloom.

Cells of all harmful algal bloom (HAB) species were found to pass intact after being ingested by the ascidians and remained viable (Figure 3). Ascidians survived exposure to all HAB species, however, there was a consistently high mortality rate associated with exposure to *Alexandrium monilatum*. The most concerning result was the clear demonstration that in many cases the cells were capable of re-establishing HAB populations.

Table 1. List of harmful algal species used in exposure trials.

Prorocentrum minimum
Heterosigma akashiwo
Alexandrium monilatum
Alexandrium fundyense
Aureococcus anophagefferens
Karenia brevis

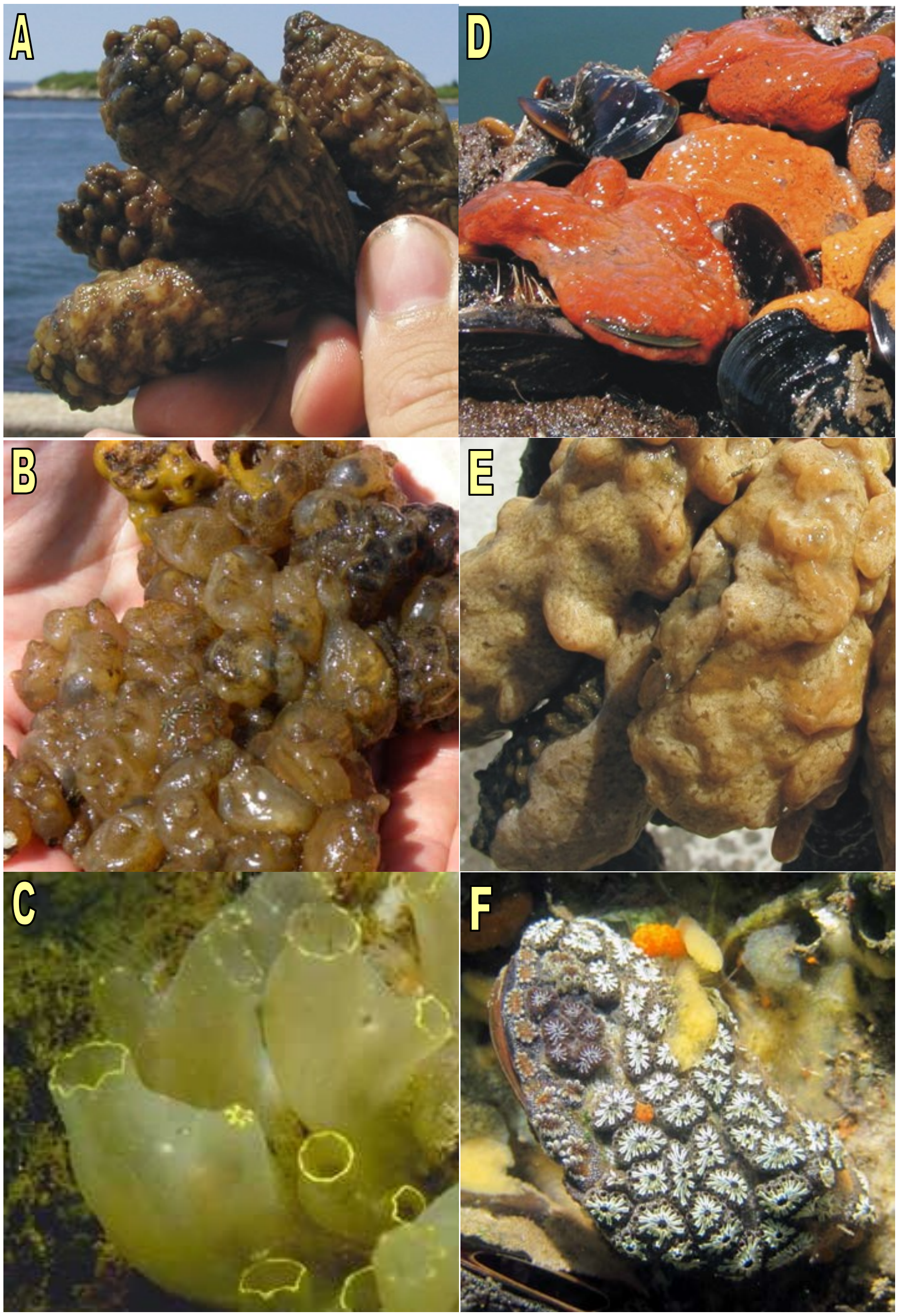

Figure 2. Ascidians used in HAB exposure trials include solitary tunicates: A. *Styela clava* B. *Molgula manhattensis* C. *Ciona intestinalis* and colonial tunicates: D. *Botrylloides violaceus* E. *Didemnum vexillum* F. *Botryllus schlosseri*. Photos by Stephan Bullard (A, D-F); Nancy Balcom, (B) and Patrick van Moer (C).

Conclusions

The results of this study are limited with respect to the specific geographic area and number of potential interactions between ascidians and HAB species, yet they clearly demonstrate the potential risk associated with the transport of biofouling ascidians on a global scale. While prior research (Hégaret et al., 2008) indicated that one HAB species, the brown tide alga, *Aureococcus anophagefferens*, did not form blooms after ingestion by five different species of bivalve molluscs, the current research determined that *A. anophagefferens* could pass intact through the digestive system of ascidians. Because ascidians filter at a much higher rate and often more efficiently than bivalve molluscs, they may present an even greater threat to the potential spread of HAB species.

Industry and managers should recognize this potential threat and the ecological impact of spreading biofouling ascidians and employ the following best management practices (BMP) to mitigate adverse impacts:

1. Transport fouling material to a landfill for disposal.

2. Compost the removed fouling material for a minimum of five days.

3. Allow gear to dry and fouling organic material to flake off, rotating with new gear during this time period.

While these measures may represent an increase in production duties and costs, the potential environmental consequences associated with dumping biofouling material are high and should not be ignored. In recognition of the financial burden that these BMP have on aquaculture operations, Extension specialists have been working with the USDA Natural Resources Conservation Service to create a cost-share program to help defray the costs associated with implementing such conservation measures. The implementation of these BMP should help to mitigate the risks associated with moving fouled aquaculture gear.

To learn more about the impacts of Aquatic Nuisance Species (ANS), visit the ANS Task Force home page at: http://anstaskforce.gov/ans.php. The ANS Task Force is an intergovernmental organization dedicated to preventing and controlling aquatic nuisance species, and implementing the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990.

To report a non-native aquatic species, contact your local resource management agency or visit: http://nas.er.usgs.gov/SightingReport.aspx.

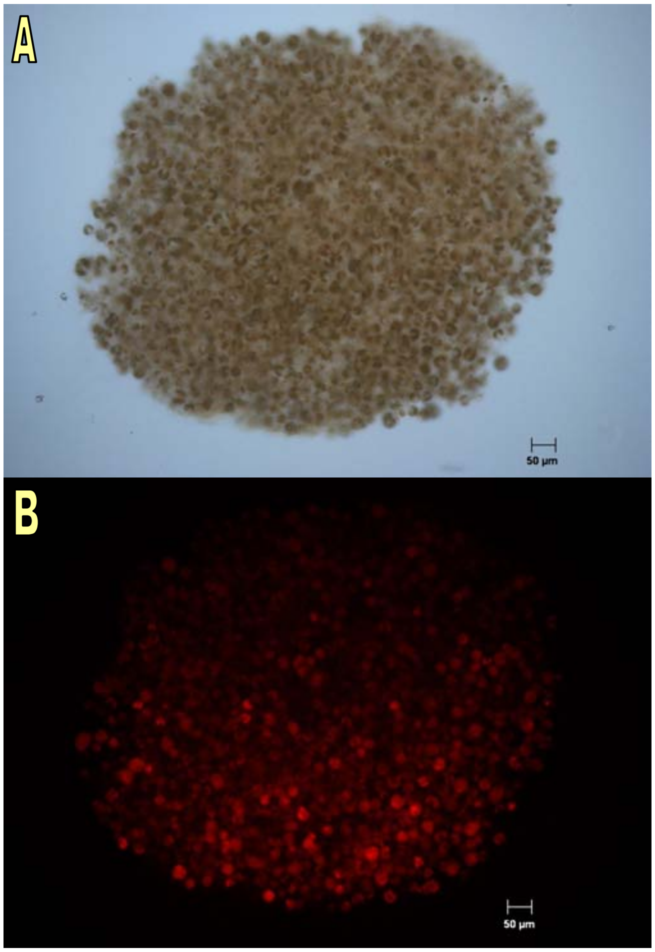

Figure 3. A) Fecal pellet from *Ciona intestinalis* after exposure to the harmful alga *Alexandrium fundyense*. Under a light microscope, packed algal cells are visible. B) The red fluorescence filter of the same image shows that the cells still have chlorophyll after being ingested and passing through the digestive system, suggesting that cells are potentially viable. Photos by Maria Rosa.

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Learn more about invasive species and aquaculture:

Padilla, D.K., McCann, M.J., Shumway, S.E., 2011. Marine invaders and bivalve aquaculture: sources, impacts and consequences. In: Shumway, S.E. (Ed.), *Shellfish Aquaculture and the Environment*, Wiley-Blackwell, Ames, IA, pp. 395-416.

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