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Predicting the Success of Invasive Species in the Great Bay Estuarine Researve

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PREDICTING THE SUCCESS OF INVASIVE SPECIES IN THE GREAT BAY ESTUARINE RESERVE

A Final Report to
The New Hampshire Estuaries Project

Submitted by

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EXECUTIVE SUMMARY

The University of New Hampshire Zoology Department reports on a study designed to continue monitoring the distribution of invasive species in the Great Bay Estuary and to carry out laboratory experiments designed to test the effects of salinity on ascidian mortality and determine predators of ascidian species. Researchers collected presence/absence and abundance data of invasive species at four sites within the Great Bay Estuarine System. The report gives a brief description of the results of the monitoring program to compare results obtained from 2006 to 2007 and to assess the response of ascidians to varying salinity and predators. This report specifically includes monitoring data from 2007 and results of laboratory and field experiments examining the effects of salinity and predators on ascidian distribution.

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INTRODUCTION

Estuarine systems are under increasing pressure from invasive species (Carlton 1996; Carlton 2003). Consequently, predicting under what conditions invasive species will successfully invade and alter estuarine biota is growing in importance. Invasions in marine and estuarine systems are one of the leading causes of biodiversity loss. Once established, invasive species may change the relationships among members of the community, thereby altering the integrity of the system. Despite a growing concern for invasive species, coastal managers find it difficult to predict which species will invade an estuary and impact local communities. Survival and growth of species depend on many factors including the physical make-up of the host environment and the identity of the invasive species. Therefore, understanding the biological and physical tolerances of an invader will enable estuarine managers to forecast which species will invade or fail to establish in estuarine systems and also the extent of the invasion. Two of the most important factors influencing the reproduction, settlement, growth and ultimate distribution of marine organisms in estuarine environments are predators and salinity (Osman and Whitlatch 1996; Leonard et al. 1999; Lohrer and Whitlatch 2002; Siddon and Witman 2004).

In the past 25 years many invasive species, including the sea moss: *Membranipora membranacea* and the sea squirts (ascidians): *Styela clava*, *Ascidiella aspersa*, *Botrylloides violaceus*, *Didemnum* sp. and *Diplosoma listerianum* have been observed in the New England area, particularly in the Great Bay Estuary. *M. membranancea* was first observed in 1987 at the Isles of Shoals and has since spread along the coast and into the Great Bay Estuary. Since its introduction, *M. membranacea* has negatively impacted kelp beds (Lambert et al. 1992), and has facilitated the spread of other invasive species (Levin et al. 2002). Ascidians have also recently become pests in estuaries, aquaculture sites and fishing grounds along the west and east coasts of the United States (Lambert and Lambert 1998; Lambert 2001; Lambert and Lambert 2003)**.** A particularly striking example is the colonial ascidian (*Didemnum* sp.) which presently covers an area of approximately 88 square miles on Georges Bank in the Gulf of Maine (Valentine et al. 2007b). Here, it is observed overgrowing mobile and sedentary invertebrates, including commercially valuable scallops. Currently, there are 6 species of exotic ascidians in the Great Bay Estuary. The two solitary ascidians, *Styela clava* (a major pest in aquaculture sites in Prince Edward Island, Canada) and *Ascidiella aspersa* (a common species south of New Hampshire) have small populations in Little Harbor (Dijkstra and Harris, pers. obs). The solitary ascidian *Ciona intestinalis* (a recent additional pest in PEI as well as New Zealand and Chile) has been common in (Berman 1992) the New Hampshire coastal zone for decades (Harris and Irons 1982). The three colonial ascidians, *Diplosoma listerianum*, *Didemnum* sp. and *Botrylloides violaceus* are found in large numbers at the mouth of the Great Bay Estuary (Dijkstra et al. 2007a). *B. violaceus* is also present in the Great Bay Reserve. It is the oldest of the invaders and it is largely a marine species that over time has crept into the Great Bay reserve (Berman 1992; Berman et al. 1992).

Many of the exotic species present in the Great Bay Estuary are marine water species that are now found in areas experiencing highly fluctuating temperatures and salinities (Harris and Dijkstra, pers. obs) and therefore have the potential to establish in the reserve. If these species greatly increase in number or expand into the Great Bay reserve system, they can substantially alter habitats making them less desirable to commercial juvenile fish, scallops or lobster (Carman et al. 2007, Valentine et al. 2007a). In addition, the sea squirts can smother sessile economically important species such as the eastern oyster, *Crassostrea virginica*. Our own data examining long-term impacts of exotic species, specifically *M. membranacea*, *Didemnum* sp., *D. listerianum* and *B. violaceus*, in Portsmouth Harbor indicate that they are seasonally abundant (Dijkstra et al. 2007a). In addition, our studies as well as others reveal during times of peak abundance ascidians can substantially alter diversity (Blum et al. 2007; Dijkstra et al. 2007b) and species composition (Blum et al. 2007; Dijkstra 2007). While it is clear exotic species are established in the estuarine system, little is known of the affects of predators and salinity on the distribution of invasive species within the Great Bay Estuarine System.

PROJECT GOALS AND OBJECTIVES

The purpose of the project was to 1) Examine the affects of salinity on invasive species; 2) Continue a seasonal monitoring study of exotic species that was implemented last year in the Great Bay Estuarine System, NH; 3) Examine the affects of predators on invasive species. This research is relevant to existing New Hampshire Estuaries Project Action Plan RST-7 to 1) support research and monitoring efforts of marine exotic species in order to predict the success of invasions in the Great Bay Estuary.

Objectives of the proposed work can be summarized as follows:

1) Perform laboratory experiments on survival and physiological tolerance of invasive species to low salinities
2) Run laboratory predator-prey preference experiments to examine predation upon invasive species.

3) Continue characterizing the seasonal distribution of invasive species at four sites in the Great Bay Estuarine Reserve.

OBJECTIVE 1) EXAMINED THE AFFECTS OF SALINITY ON INVASIVE SPECIES.

The unprecedented flooding in May 2006 and its impact on community structure illustrate the importance of salinity as a linking factor for the presence/absence of invasive species in estuarine environments (Dijkstra and Harris, unpublished data). The objective of this study was to determine the effects of salinity, particularly low salinity on invasive colonial and solitary ascidians.

We developed a novel technique to assess survivability and osmotic stress of ascidians to salinity. Heart rate was used as a proxy for health to assess the condition of individual colonies of *Botrylloides violaceus*, *Botryllus schlosseri*. Results revealed that both species experienced 100% mortality after 1 day at 5 psu; mortality of colonies held at 10 psu increased with number of days (Figure 1 and 2). Heart rates declined with decreasing salinity. Heart rates of *B. schlosseri* remained consistent between 15 psu and 30 psu and slowed at 10 psu (Dijkstra et al. in press). Heart rates of *B. violaceus* remained constant between 20 psu and 30 psu, but slowed at 15 psu.

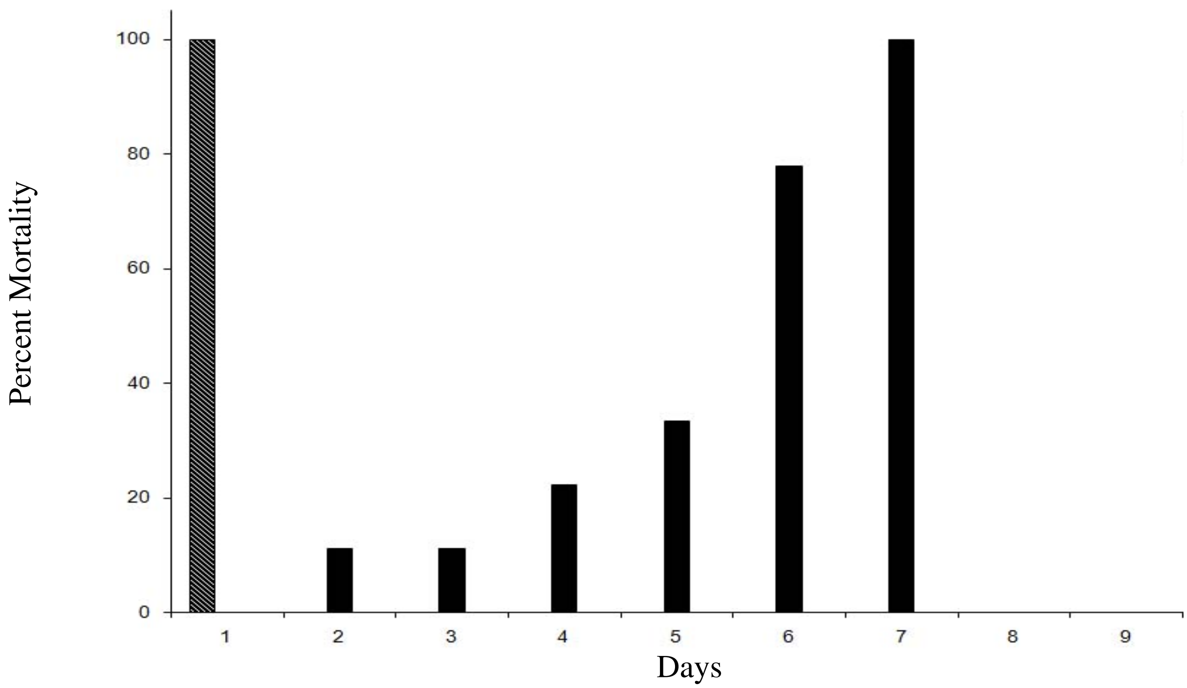

Figure 1 (from Dijkstra et al., in press): Percent mortality of *Botryllus schlosseri* colonies exposed to salinities between 5 psu and 10 psu Mortality of colonies held between 15 psu and 30 psu was 0% and are not shown on the graph.

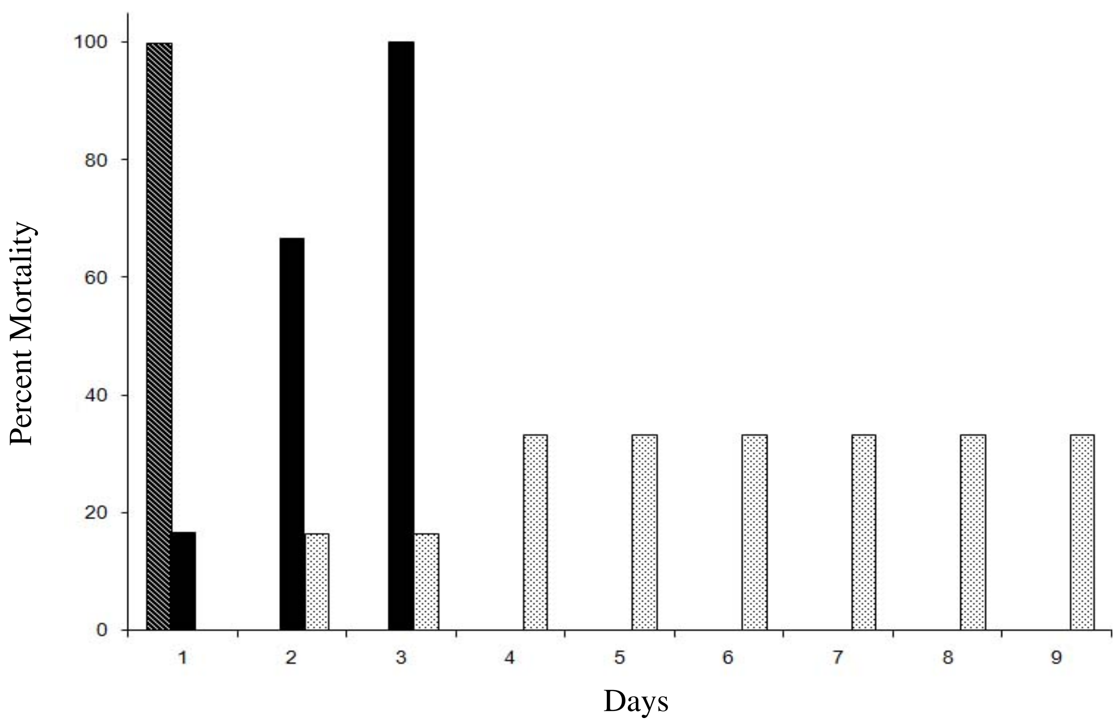

Figure 2 (from Dijkstra et al., in press): Percent mortality of *Botrylloides violaceus* colonies exposed to salinities between 5 psu and 15 psu Mortality of colonies held between 20 psu and 30 psu was 0% and are not shown on the graph.

A long-term study monitoring community development has revealed a marked decline in the spatial dominance of some colonial ascidian species during and after the May 2006 flooding (Dijkstra and Harris, unpublished data). The flooding event lowered abundances of *Didemnum* sp. A to such an extent that they had not recovered by November, 2006, disrupting the seasonal abundance cycle of the species (Figure 3). Abundance of *Botrylloides violaceus* also declined during and after the flooding event while abundance of *Botryllus schlosseri* did not decline.

Solitary ascidians were more affected by the flooding than colonial ascidians. Laboratory studies revealed low salinities (0 ppt. and 13 ppt.) negatively affect morphological characteristics and survival of solitary ascidians (*S. clava* and *A. aspersa;* McKillop et al., 2003)**.** At low salinities both species were no longer able to regulate their water content and absorbed water, resulting in mortality. Seasonal monitoring in the Great Bay Estuarine System revealed high abundance of *Ciona intestinalis* before the flooding, but not after (Figure 4).

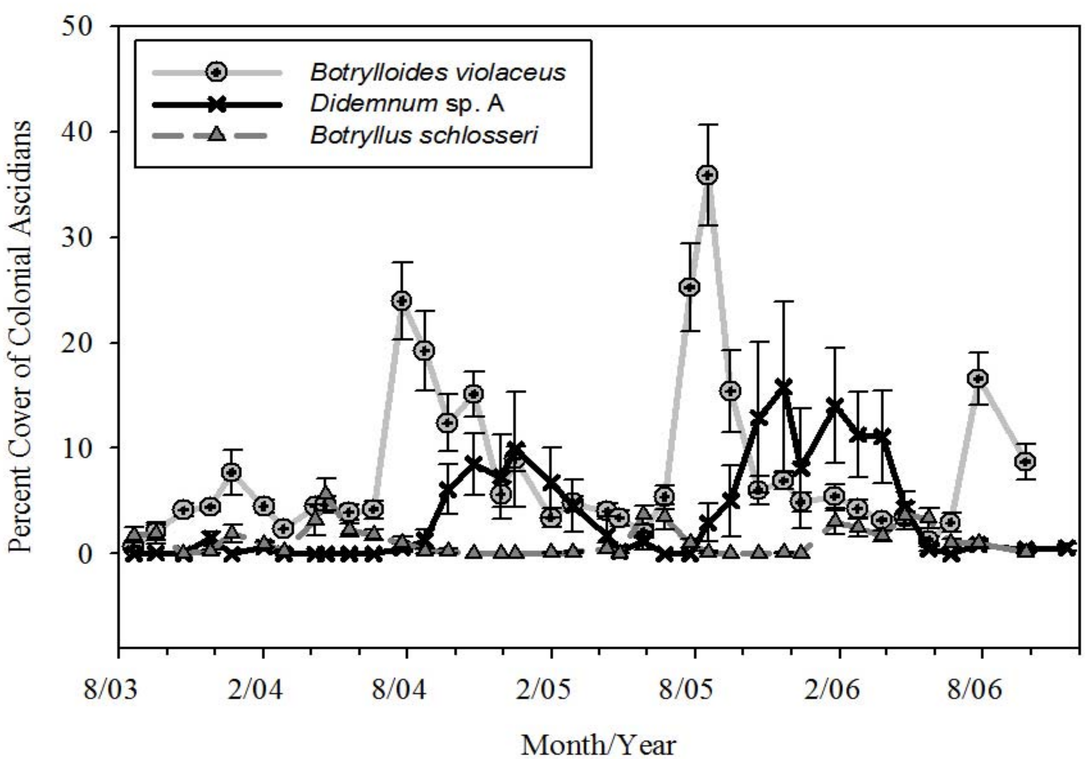

Figure 3 (from Dijkstra, 2007): Three year (2003 to 2006) seasonal cycle of three colonial ascidians *Didemnum* sp. A, *Botrylloides violaceus* and *Botryllus schlosseri*. Data were collected underneath the cement pier at the Coastal Marine Laboratory.

Figure 4a: Photo of 20 X 20 cm Plexiglas panels taken April, 2006 at Wentworth Marina

Figure 4b: Photo of 20 X 20 cm Plexiglas panels taken May, 2006 at Wentworth Marina

Populations of *S. clava*, *Ciona intestinalis* and *A. aspersa* disappeared from Wentworth Marina and no specimens of *A. aspersa* have been observed as of December, 2007. Two individuals of *S. clava* were found during a rapid assessment survey at Wentworth Marina in August, 2007 while one individual of *C. intestinalis* was observed as early as October, 2006 at the Coastal Marine Laboratory and several more have been observed at the Coastal Marine Laboratory in the spring and summer of 2007 and the Jackson Estuarine Laboratory in October 2007. It is likely small populations living in the center of the channel survived the flooding event and are now re-colonizing hard substrata on the outer edges of the channel.

OBJECTIVE 2) EXAMINED PREDATION UPON INVASIVE SPECIES IN LABORATORY AND FIELD TRIALS.

Predators play a role in mitigating the impact of certain introduced species. For example, native predators on invasive species include the sea slug *Placida dentritica* on *Codium fragile* spp. *tomotosoides* (Harris and Mathieson 1999), the nudibranch *Onchidoris muricata* on *M.*

membranacea (Pratt and Grason 2007), the snail *Mitrella lunata* on *B. violaceus* and *Botryllus schlosseri* (Osman and Whitlatch 1998) and the sea star *Henricia sanguinolenta* on *D. listerianum* (Dijkstra et al. 2007a).

We tested predation by the wrasse *Tautologlobrus adspersus* (cunner) on ascidians by placing individuals from eight species of ascidians (*Botrylloides violaceus*, *Didemnum* sp. A, *Ascidiella aspersa*, *Styela clava*, *Botryllus schlosseri*, *Diplosoma listerianum*, *Molgula* sp. and *Ciona intestinalis*) on a section of the cement pier underneath the Coastal Marine Laboratory that had a high population of cunner. Adults of *A. aspersa*, *S. clava* and *C. intestinalis* are large; consequently they were cut into smaller pieces, representing smaller animals. Preliminary results of this experiment revealed cunner preyed preferentially upon the solitary ascidians *Molgula* sp., *Ciona intestinalis* and *Ascidiella aspersa*, but not *Styela clava* (Table 1). Cunner did not prey on *Diplosoma listerianum* or *Didemnum* sp. A. These results coincide with others showing predation by cunner on solitary ascidians (Osman and Whitlatch 1996; Osman and Whitlatch 1998). We've documented predation by the seastar *Henricia sanguinolenta* on the the four colonial ascidians (*Botrylloides violaceus*, *Diplosoma listerianum*, *Didemnum* sp. A and *Botryllus schlosseri*). Results indicate *H. sanguinolenta* prey on all four species, though *Didemnum* sp. A was only preyed if it were damaged or dying. *D. listerianum* is the preferred prey item (Dijkstra et al., in prep.).

Predation by crabs (*Carcinus maenus*, *Cancer irrotus*, *Cancer borealis*) on ascidians was tested in a 10 °C room at the University of New Hampshire. Crab species were placed in an aquarium, one crab species per aquarium, and given individual ascidian species. Preliminary results revealed all three crab species preyed on solitary ascidians, but not on colonial ascidians

(Table 1). These results coincide with those of others showing *Carcinus maenus* preys upon solitary ascidians (Osman and Whitlatch 2004).

Table 1: Predators that preyed upon invasive species. A. a (*Ascidiella aspersa*), C.i. (*Ciona intestinalis*), S.c. (*Styela clava*), B.s. (*Botryllus schlosseri*), B.v. (*Botrylloides violaceus*), D.l. (*Diplosoma listerianum*), D sp. A (*Didemnum* sp. A), M.m. (*Membranipora membranacea*)

Predators	***Molgula* sp.**	***A.a.***	***C.i.***	***S.c.***	***B.s.***	***B.v.***	***D.l.***	***D sp.A***	***M.m.***
Tautologlabrus adspersus	X	X	X						
Cancer borealis	X	X	X	X					
Cancer irrotus	X	X	X	X					
Carcinus maenus	X	X	X	X					
Onchidoris muricatus									X
Henricia sanguinolenta					X	X	X	X	

OBJECDTIVE 3) CONTINUED CHARACTERIZITION OF THE SEASONAL DISTRIBUTION OF INVASIVE SPECIES AT FOUR SITES IN THE GREAT BAY ESTUARINE RESERVE.

We have continued to monitor the spread of invasive species at four sites in the Great Bay Estuarine System (Figure 5).

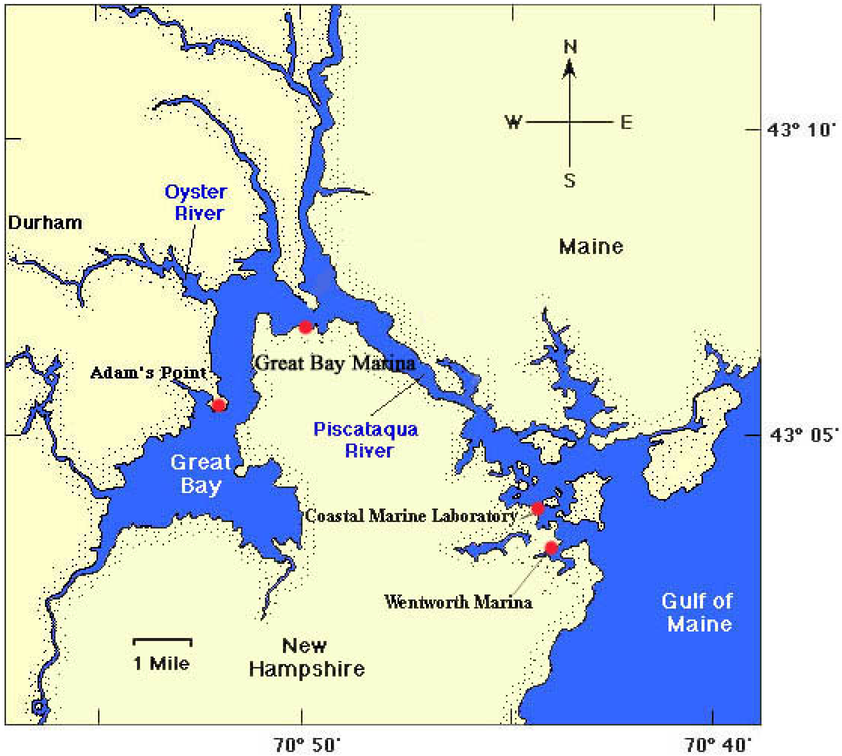

Figure 5: Monitoring sites in the Great Bay Estuarine System. Dots indicate study sites.

The May, 2006 flooding event eradicated many species from the upper estuary e.g. Jackson Laboratory, with the exception of *Botryllus schlosseri*. However, in 2007 many marine species had returned to the Jackson Estuarine Laboratory, including *Botrylloides violaceus*, *Ciona intestinalis*, and the sponge *Halichondria panicea*. Large colonies of *B. violaceus* were observed on the Jackson laboratory floating dock in October, suggesting colonies had settled in late August or early September (Table 2).

Table 2: Invasive species observed during 2006 and 2007 at each of four monitoring sites in the Great Bay Estuary. Higher number of invasive species were found inside the reserve in 2007 vs. 2006.

	2006				2007			
Species	WM	CML	GB	JEL	WM	CML	GB	JEL
Molgula sp.	X	X	X	X	X	X	X	X
Ascidiella aspersa								
Ciona Intestinalis		X				X		X
Styela clava					X			
Botrylloides violaceus	X	X	X		X	X	X	X
Didemnum sp. A		X			X	X		
Botryllus schlosseri	X	X	X	X	X	X	X	X
Diplosoma listerianum	X	X			X	X		
Membranipora membranacea	X	X	X		X	X	X	

Berman (1992) found *B. violaceus* colonies settled in late August. In Portsmouth Harbor, we found large colonies of *Diplosoma listerianum* on the “new” cement pier close to the Coastal Marine Laboratory; many colonies of *Didemnum* sp. A were also observed. For the first time, we found many large colonies of *Didemnum* sp. A at Wentworth Marina. Unfortunately, we were not successful in obtaining seasonal data for both Wentworth Marina and the Great Bay Marina. Our eyehooks and plates were removed from the Wentworth Marina docks while the current at the Great Bay Marina ripped our plates from the dock.

CONCLUSIONS

Based on our field and laboratory studies variation in salinity can affect the distribution of ascidians in the Great Bay Estuary. Invasive colonial ascidians (*Botrylloides violaceus*, *Didemnum* sp. A and *Diplosoma listerianum*) were found to have a higher tolerance to low salinity than solitary ascidians (*Ascidiella aspersa*, *Styela clava* and *Ciona intestinalis*). Colonial ascidians had a quicker recovery period and were the first to appear in areas that were eradicated during the May, 2006 flooding.

Predation by native species was observed and may be an important regulator for juvenile invasive ascidians (Osman and Whitlatch, 1998). Crabs (*Carcinus maenus*, *Cancer irrotus*, *Cancer borealis*) and cunner (*Tautologlobrus adspersus*) preyed upon solitary ascidians, while the seastar *Henricia sanguinolenta* preyed on the colonial ascidians (*Botrylloides violaceus*, *Botryllus schlosseri*, and *Diplosoma listerianum*; predation on *Didemnum* sp. A occurred, but on colonies that appeared damaged or unhealthy). Continued monitoring of sites in the Great Bay Estuary revealed a more extensive distribution of *Botrylloides violaceus*, *Ciona intestinalis* and *Didemnum* sp. A in 2007 than 2006.

RECOMMENDATIONS

During years of prolonged depressed salinities, colonial and solitary ascidians are unable to colonize substrate in the upper estuary. However, the salt wedge in the center of the tidal channel facilitates persistence of marine species. Since the Great Bay Estuarine System has a range of salinities and temperatures, it is recommended studies be performed on the effects of salinity on physiology of solitary ascidians and on the combined effects of temperature and salinity on the physiology of both solitary and colonial ascidians.

It is recommended to continue to monitor for invasive species in the Great Bay Estuary as early detection and eradication can prevent the establishment of other invasive species (Carlton, 1996). We used settling plates ($0.1m^2$) and SCUBA to monitor the distribution of invasive species in the Great Bay and found this to be adequate, though the current at the Great Bay Marina ripped off our settling plates and boaters at Wentworth Marina removed our plates. We suggest using artificial substrates already present e.g. floating docks in combination with SCUBA to monitor for sessile exotics. Most sessile invasive species were identified on floating docks and on subtidal natural hard substrata. Predators are generally not observed on floating docks; thus we recommend using SCUBA to identify exotic mobile species or their expansion into the Great Bay System.

PUBLICATIONS RESULTING FROM THIS GRANT:

Dijkstra J., *A. Dutton, E. Westerman and L. G. Harris. (in press) Response of two introduced colonial ascidians *Botryllus schlosseri* and *Botrylloides violaceus* to low salinities: heart rate reflects osmotic stress level. Marine Biology

Dijkstra, J. (2007) Climate change and invasive species interact to impact succession and diversity in Gulf of Maine marine fouling communities. University of New Hampshire. PhD Dissertation.

Dijkstra J., L. G. Harris, R. B. Whitlatch and S. G. Bullard. (in review) Facilitation in the seasonal development of a marine subtidal community by long-term climate change. Marine Ecology Progress Series.

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