12-31-2007

Seasonal Appearance and Monitoring of Invasive Species in the Great Bay Estuarine System

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SEASONAL APPEARANCE AND MONITORING OF INVASIVE SPECIES IN THE GREAT BAY ESTUARINE SYSTEM

A Final Report to
The New Hampshire Estuaries Project

Submitted by

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December 31st, 2007

This project was funded in part by a grant from the New Hampshire Estuaries Project as authorized by the U.S. Environmental Protection Agency's National Estuary Program.

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EXECUTIVE SUMMARY

The University of New Hampshire Zoology Department reports on a study designed to synthesize existing data on invasive species in the estuary and the surrounding area, compare succession between two panel studies (1979 to 1982 and 2003 to 2006), seasonally monitor invasive species in the Great Bay Estuary, and identify predators of invasive species. Researchers identified species most likely to invade the Great Bay Estuary, analyzed succession between two long-term panel studies separated by approximately 25 years, collected presence/absence and abundance data of invasive species at four sites within the Great Bay Estuarine System and identified potential predators of invasive species. This report gives a brief description of the results of the long-term comparative study and specifically includes monitoring data from 2006 on invasive species and predator distribution patterns in the Great Bay Estuary.

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INTRODUCTION

Estuarine systems are particularly susceptible to invasion due to the abundance and variety of species transported to them (Cohen and Carlton 1998). Despite a growing concern for the affect these invasive species have on ecosystems, few studies have been able to assess their long and short-term impacts on local estuarine communities. Therefore, estuarine managers find it difficult to predict and monitor the invasion of an estuary by invasive species.

In the past 25 years many invasive species, including the asian shore crab: *Hemigrapsus sanguineus*, 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. *H. sanguineus* has displaced other crab species and is commonly found in most intertidal zones south of New Hampshire. At present this species is increasing in abundance along the coast of New Hampshire and in the Great Bay Estuary (Tyrrell 1999). *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, 2003). A particularly striking example is the colonial ascidian (*Didemnum* sp.) which presently covers an area of approximately 200 km^2 at Georges Bank in the Gulf of Maine (U.S. Geological Survey 2008). Here, it is observed overgrowing sedentary invertebrates and preventing juvenile benthic fish from finding suitable habitat (Valentine et al. 2007).

Currently, there are 5 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, pers. obs). 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.

Many of the exotic species present in the Great Bay Estuary are salt water species that are now found in areas experiencing highly fluctuating temperatures and salinities (Dijkstra et al. 2007b). If these species expand into the Great Bay Reserve system, they can substantially alter habitats making them less desirable to commercial juvenile fish or lobster (Tyrrell and Harris 2000, Lohrer and Whitlatch 2002). While it is clear exotic species are established in the estuarine system, little is known of their temporal and spatial abundance, the distribution and identity of potential predators and the extent to which invasive species have altered marine fouling communities.

PROJECT GOALS AND OBJECTIVES

The purpose of this research was to 1) synthesize pre-existing information on invasive species and identify species that are likely future threats. 2) examine the seasonal distributional patterns of exotic species in the Great Bay Estuarine System, NH; 3) identify predators of invasive species and monitor their seasonal abundance and 4) continue a long-term study investigating changes in fouling community composition and structure e.g., dominance and diversity patterns in the Great Bay Estuarine System. 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 research can be summarized as follows:

1. Synthesize pre-existing information on invasive species and identify species that are likely future threats.
2. Identify predators of invasive species and monitor their seasonal distribution.
3. Continue a long-term study investigating changes in fouling community composition and structure
4. Seasonal monitoring of invasive species in the Great Bay Estuarine Reserve

OBJECTIVE 1: SYNTHESIZSE PRE-EXISTING INFORMATION ON INVASIVE SPECIES AND IDENTIFY SPECIES THAT ARE LIKELY FUTURE THREATS

Most of the information on invasive species is scattered in reports, dissertations and published papers. Our goal was to synthesize data on invasive species in the area and make a list of likely future invaders.

TABLE 1: SUMMARY OF INTRODOCUED SPECIES DOCUMENTED IN THE BENTHIC COMMUNITY STUDIES ASSOCIATED WITH THE NH ESTUARIES PROGRAM. PRESENCE AT THE FOUR STUDY STIES AND COMMENTS ON ECOLOGY AND DISTRIBUTION (WM = Wentworth Marina; CML = Coastal Marine Lab; GBM = Great Bay Marina; JEL = Jackson Estuarine Laboratory).

SPECIES	WM	CML	GBM	JEL	COMMENTS
Chlorophyta					
Codium fragile ssp. tomentosoides					Common on the open coast and in tide pools at Fort Stark.
Rhodophyta					
Neosiphonia harveyi	X	X	X		Abundant in fouling and benthic communities along the coast.
Bonnemaisonia hamifera					Abundant in benthic communities in both life history stages.
PORIFERA					
Halichondria bowerbankia	X	X			Present in fouling communities, but often confused with *H. panicea.*
Microciona prolifera				X	Present in benthic communities within the estuary.
CNIDARIA					
Cordylophora caspia					Common in the tidal portions of rivers entering the estuary.
Diadumene lineata		X	X		Ephemeral populations appear in protected areas of the coast and within the estuary.
MOLLUSCA					
Littorina littorea	X	X	X	X	Common intertidal and subtidal throughout NH coastal zone.
Ostrea edulis					Established in the estuary and in Gosport Habor, Isles of Shoals.
ARTHROPODA					
Praunus flexuosus	X	X	X		Common mysid in NH coastal zone.

Caprella mutica					Dominant caprellid on fish cages off Isles of Shoals.
Carcinus maenas	X	X	X	X	Most common crab in intertidal and estuary, but also common in protected shallow subtidal bays and estuary.
Hemigrapsus sanguineus	X	X	X		Increasingly common in intertidal habitats and occasionally on floats.
BRYOZOA					
Alcyonidium sp.					Present on offshore fish cages and estuaries farther north.
Membranipora membranacea	X	X	X		Very abundant on algae in NH coastal zone.
UROCHORDATA					
Ascidiella aspersa	X				Small population present at Wentworth, but common to south and north to Casco Bay.
Ciona intestinalis	X	X			May be cryptogenic, but can be very common in fouling communities.
Styela clava	X				Small population on floats at Wenthworth Marina, but common south of NH and into Casco Bay.
Styela canopus					Recorded from Hampton Estuary.
Botryllus schlosseri	X	X	X	X	Common in a wide diversity of benthic and fouling communities.
Botrylloides violaceus	X	X	X	X	Most common colonial tunicate in estuary, intertidal and shallow subtidal communities.
Diplosoma listerianum	X	X			Ephemeral species that can be very abundant after mild winters.
Didemnum sp.	X	X			Very aggressive competitor for space in subtidal coastal habitats, but appears to be sensitive to extremes in salinity, which inhibits its spread into the estuary.

TABLE 2: SPECIES OF CONCERN FOR INTRODUCTION INTO THE NEW HAMPSHIRE ESTUARINE RESERVE

SPECIES	COMMENTS
RHODOPHYTA	
Grateloupia turuturu	This large red alga has been found in Boston Harbor and is likely to move north into NH waters.
CNIDARIA	
Sagartia elegans	Present in Salem Harbor, but may be too cold sensitive to survive in NH estuaries.
ARTHROPODA	
Synidotea laevidorsalis	Large isopod now present in Long Island Sound. Impact not known.
Eriocheir sinensis	The Chinese mitten crab appears to have established populations as far north as the Hudson River and is also present in the St. Lawrence Seaway. While it breeds in estuarine or marine environments, it spends most of its life in freshwater rivers and streams where it digs into the banks, causing erosion. This crabs numbers and size make it particularly likely to have a significant impact on riverine communities. Monitoring and planning for managing this species is strongly suggested.
BRYOZOA	
Bugula neritina	Common as far north as Salem Harbor, MA and likely to colonize NH estuaries as temperature continues to climb. Its purple coloration makes it easy to identify.

OBJECTIVE 2: IDENTIFY PREDATORS OF INVASIVE SPECIES AND MONITOR THEIR SEASONAL ABUNDANCE

Monitoring objective

The objective of discovery and documentation of native predators of invasive species is to report the distribution of predators in the Great Bay Estuarine System and whether native or invasive predators prey upon sessile invasive species. Predators can 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* (Harris and Mathieson 1999), the snail *Mitrella lunata* on *B. violaceus, Botryllus schlosseri* and *Diplosoma listerianum* (Osman and Whitlatch 1995) and the sea star *Henricia sanguinolenta* on *D. listerianum* (Harris pers. obs.).

SCUBA was used to identify predators at three sites in the Great Bay Estuarine System (Table 3: Wentworth Marina, Coastal Marine Laboratory, Great Bay Marina, and Jackson Estuarine Laboratory). Higher numbers of predators were found at the mouth of the estuary in Portsmouth Harbor than inside the estuarine reserve (Figs. 2 through 7). We often witnessed and photographed the starfish *H. sanguinolenta* feeding with extended stomachs on *Diplosoma listerianum* (Dijkstra et al. 2007a), *Botryllus schosseri*, and *Botrylloides violaceus* and *Didemnum* sp. (Dijkstra and Harris, in prep.). We've also witnessed, along with others (Pratt and Grason 2007), the nudibranch *Onchidoris muricata* feeding on the invasive species *Membranipora membranacea*. Further studies are required to examine the extent of predation on invasive species.

TABLE 3: SUMMARY OF PREDATORS ON INTRODUCED ALGAE AND INVERTEBRATES

SPECIES	COMMENTS
MOLLUSCA	
Littorina littorea	This introduced snail feeds on the juvenile and necrotic portions of the green alga *Codium fragile ssp. tomentosoides* and also will graze on the tunicate *Botrylloides violaceus*.
Velutina velutina	Feeds on solitary tunicates and also on *Didemnum albidum*. May feed on *Didemnum* sp.
Buccinum undatum	Observed feeding on *Ciona intestinalis* and possibly *Ascidiella aspersa* and *Styela clava*.
Astyris (=Mitrella) lunata	Feeds on juvenile colonial tunicates, the bryozoan *Membranipora membranacea* and egg masses of gastropods. Densities of this tunicate predator have increased in coastal benthic communities since the appearance of *D. listerianum and M. membranacea*.
Nucella lapillus	Preys on young *Ostrea edulis* where they overlap in distribution. Populations of *Urosalpinx cinera* in Great Bay may limit *Ostrea edulis* in the upper estuary.
Elysia viridis	Estuarine predator on siphonaceus green algae and may feed on *Codium*.
Elysia chlorotica	Estuarine and salt marsh predator on siphonaceus green algae and may feed on *Codium*.
Placida dendritica	Major predator on *Codium* in protected coastal locations and may control populations.
Aeolidia papillosa	Specialist on sea anemones and eats *Diadumene lineata* and *Sagartia elegans*.
Tenellia adspersa	Hydroid predator in estuaries and controls distribution of *Cordylophora caspia*.
Onchidoris muricata	Has become a major predator on *Membranipora membranacea*. Wentworth Marina, Coastal Marine Laboratory and Great Bay Marina.
Doridella obscura	Moving into NH waters from south and feeds on *Membranipora membranacea*. Not present in the Great Bay
Acanthodoris pilosa	Feeds on *Alcyonidium* sp.

Okenia aspersa	Predator on solitary tunicates, particularly *Molgula* spp., and may also feed on introduced solitary species. Rare in the Great Bay.
ARTHROPODA	
Cancer borealis	Feeds on juvenile solitary tunicates, including *Ciona intestinalis, Ascidiella aspersa* and *Styela clava*. Present at Wentworth Marina and the Coastal Marine Laboratory
Cancer irroratus	Will eat juvenile solitary tunicates. Present at Wentworth Marina and the Coastal Marine Laboratory
Carcinus maenas	Preys on juvenile *Ostrea edulis* and *Littorina littorea*. May also eat juvenile tunicates. Present in the intertidal and subtidal zones at all 4 sites.
Hemigrapsus sanguineus	Eat juvenile *Littorina littorea* and may feed on introduced red algae. Found in the rocky intertidal zone near the Coastal Marine Laboratory and Wentworth Marina.
ECHINODERMATA	
Henricia sanguinolenta	Actively preys on *Diplosoma listerianum* and will consume *Botrylloides violaceus* and possibly *Didemnum* sp. Observed at Wentworth Marina and the Coastal Marine Laboratory
Strongylocentrotus droebachiensis	Omnivorous and will feed on all introduced algae and most sessile invertebrates, particularly *Diplosoma listerianum* and *Membranipora membranacea*. Has been observed grazing on *Didemnum* sp., but not having an impact on its spread. Found at Wentworth Marina and the Coastal Marine Laboratory
CHORDATA	
Tautogolabrus adspersus	Active predator on small solitary tunicates and large males feed on small *Carcinus* and *Hemigrapsus* where they overlap. Observed at Wentworth Marina and the Coastal Marine Laboratory
Pseudopleuronectes americanus	Large (30+ cm in length) individuals feed on *Botryllus schlosseri* and on larger individuals of *Littorina littorea*. Observed at all 4 sites in the Great Bay Estuary.

OBJECTIVE 3: CONTINUE A LONG-TERM STUDY INVESTIGATING CHANGES IN FOULING COMMUNITY COMPOSITION AND STRUCTURE.

Monitoring objective

The objective of documenting long-term changes in fouling communities is to determine the impact of invasive species on community composition, structure and succession. Long-term studies are rare and due to infrequent sampling are often uncertain of the underlying mechanisms of species turnover and community change.

We analyzed two experiments of fouling community succession that took place between 1979 to 1982 and 2003 to 2006. The 2003 to 2006 study was a follow-up of an earlier study conducted by Harris and Irons (1982) which documented the development of a marine fouling community on $0.1m^2$ Plexiglas® panels beneath a cement pier in Portsmouth Harbor. Photographs and observations of the 1979 to 1982 community on the pier indicated that the fouling community was dominated by sponges, hydroids, anemones and large barnacles. Soft corals, ascidians, encrusting and erect bryozoans, and mussels were interspersed throughout these assemblages. Succession was seasonal leading towards increased homogeneity and diversity was maintained as secondary substrate provided by the dominant bivalve *Mytilus edulis*.

Since the 1979 to 1982 study summer and autumn temperatures have risen, facilitating the dominance of warmer water native and invasive species. The combined effect of rising temperature and invading species has created a novel community that is 33% different (Figs. 8 and 9, Appendix I) than the historical community and driven by invasive colonial ascidians (Dijkstra 2007). Invasive species observed on panels in the 2003 to 2006 experiment were the encrusting bryozoan *Membranipora membranacea*, and the colonial ascidians *Botrylloides*

violaceus, *Diplosoma listerianum* and *Didemnum* sp. Unlike the 1979 to 1982 community succession was directional in the first two years only, leading towards increased heterogeneity. Diversity was not maintained by secondary substrate but by primary substrate due to the seasonal life-history characteristics of the invasive species (Dijkstra and Harris, in review).

OBJECTIVE 4: SEASONAL MONITORING OF INVASIVE SPECIES IN THE GREAT BAY ESTUARINE RESERVE

The objective of monitoring the seasonal abundance of exotic species in the Great Bay Estuary was to determine the extent of invasions in the Great Bay and to provide baseline data for future studies. We deployed horizontal and vertical $0.1m^2$ Plexiglas panels off floating docks (at one site panels will be suspended in the water column), at each of four sites in the Great Bay Estuarine System (Figure 1; Jackson Lab, Great Bay Marina, Coastal Marine Laboratory and Wentworth Marina). We monitored panels at 3 month intervals throughout the year (Figs. 10 through 13).

Monitoring in the Great Bay revealed a higher number of invasive species at the mouth of the estuary (Portsmouth Harbor) than in the estuarine reserve (Table 4). This was an expected result as species distribution patterns are determined by environmental variables and the four sites represent a gradation in environmental factors (Short 1992).

Figure 1: Monitoring sites in the Great Bay Estuary

TABLE 4: SEASONAL DISTRIBUTION OF INVASIVE SPECIES ON HORIZONTAL AND VERTICAL PANELS

Horizontal panels	*B. schlosseri*	*B. violaceus*	*D. listerianum*	*Didemnum* sp. A	*M. membranaceau*
JEL Apr. 06	0.00	0.00	0.00	0.00	0.00
GBM Apr. 06	0.00	0.00	0.00	0.00	0.00
CML Apr. 06	0.00	0.00	0.00	0.00	0.00
WM Apr. 06	0.00	0.00	0.00	0.00	0.00
JEL Jul. 06	0.00	0.00	0.00	0.00	0.00
GBM Jul. 06	0.00	0.00	0.00	0.00	8.00
CML Jul. 06	1.67	0.00	0.00	0.00	0.00
WM Jul. 06	9.33	1.33	0.00	0.00	2.33
JEL Oct. 06	4.33	0.00	0.00	0.00	0.00
GBM Oct. 06	1.00	0.33	0.00	0.00	22.33
CML Oct. 06	18.33	8.00	0.67	1.67	0.00
WM Oct. 06	24.67	52.33	1.33	0.33	0.67
JEL Dec. 06	4.00	0.00	0.00	0.00	0.00
GBM Dec. 06	1.33	0.00	0.00	0.00	0.00
CML Dec. 06	2.50	2.00	0.00	1.33	0.00
WM Dec. 06	3.00	5.00	0.00	0.00	0.00

Vertical panels	*B. schlosseri*	*B. violaceus*	*D. listerianum*	*Didemnum* sp. A	*M. membranaceau*
JEL Apr. 06	0.00	0.00	0.00	0.00	0.00
GBM Apr. 06	0.00	0.00	0.00	0.00	0.00
CML Apr. 06	0.00	0.00	0.00	0.00	0.00
WM Apr. 06	0.00	0.00	0.00	0.00	0.00
JEL Jul. 06	0.00	0.00	0.00	0.00	0.00
GBM Jul. 06	0.00	0.00	0.00	0.00	4.33
CML Jul. 06	0.67	0.00	0.00	0.00	1.67
WM Jul. 06	5.67	1.00	0.00	0.00	4.00
GBM Oct. 06	0.67	0.00	0.00	0.00	19.33
CML Oct. 06	12.00	4.00	0.33	0.67	5.67
WM Oct. 06	13.33	29.33	0.00	0.33	0.33
GBM Dec. 06	1.00	0.00	0.00	0.00	0.00
CML Dec. 06	2.50	3.50	0.00	0.00	0.00
WM Dec. 06	3.67	2.33	0.00	0.00	0.00

Publications resulting from this grant:

Dijkstra, J., *H. Sherman, L. Harris. (2007) The role of colonial ascidians in altering biodiversity in marine fouling communities. Journal of Experimental Marine Biology and Ecology. 342: 168-171.

Dijkstra J., L. Harris and E. Westerman. (2007) The long-term distribution and ecology of four invasive colonial ascidians in the Gulf of Maine. Journal of Experimental Marine Biology and Ecology. 342: 61-68.

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APPENDIX I

Predators of the Great Bay Estuary

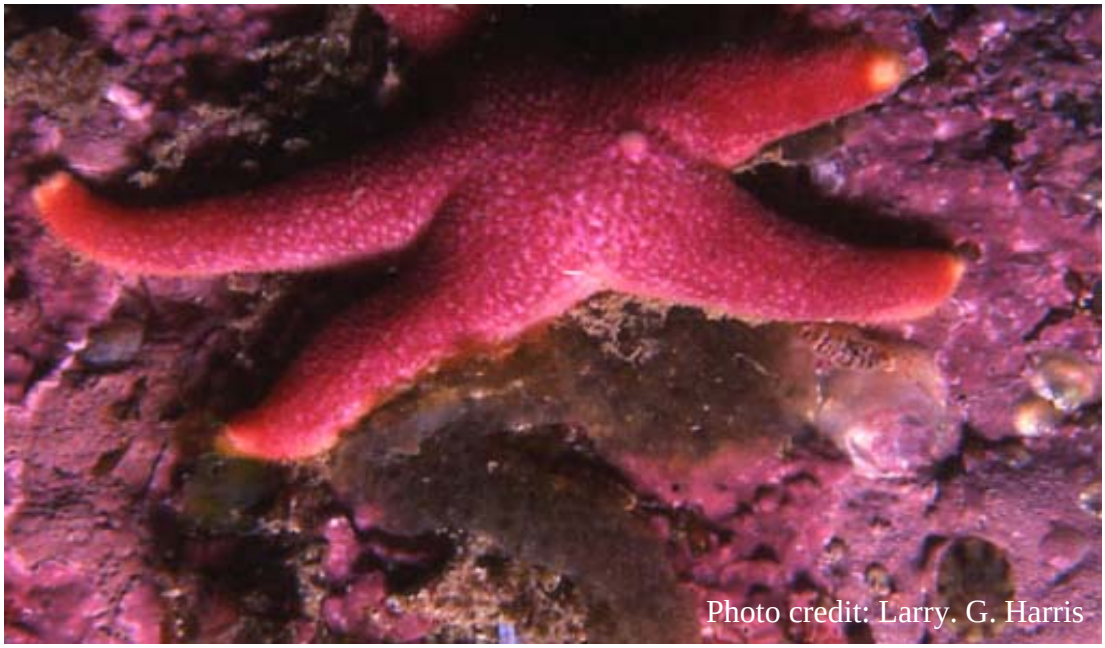

Figure 2: *Henricia sanguinolenta*: The blood star preying on the introduced tunicate, *Diplosoma listerianum*. Found on natural and artificial substrates in Portsmouth Harbor.

Figure 3: *Hemigrapsus sanguineus*: The asian shore crab. Intertidal crab that is common in Portsmouth Harbor, but also found in small numbers in the Great Bay Reserve.

Figure 4: *Strongelocentrotus drobachiensis* (the green sea urchin). Common in Portsmouth Harbor.

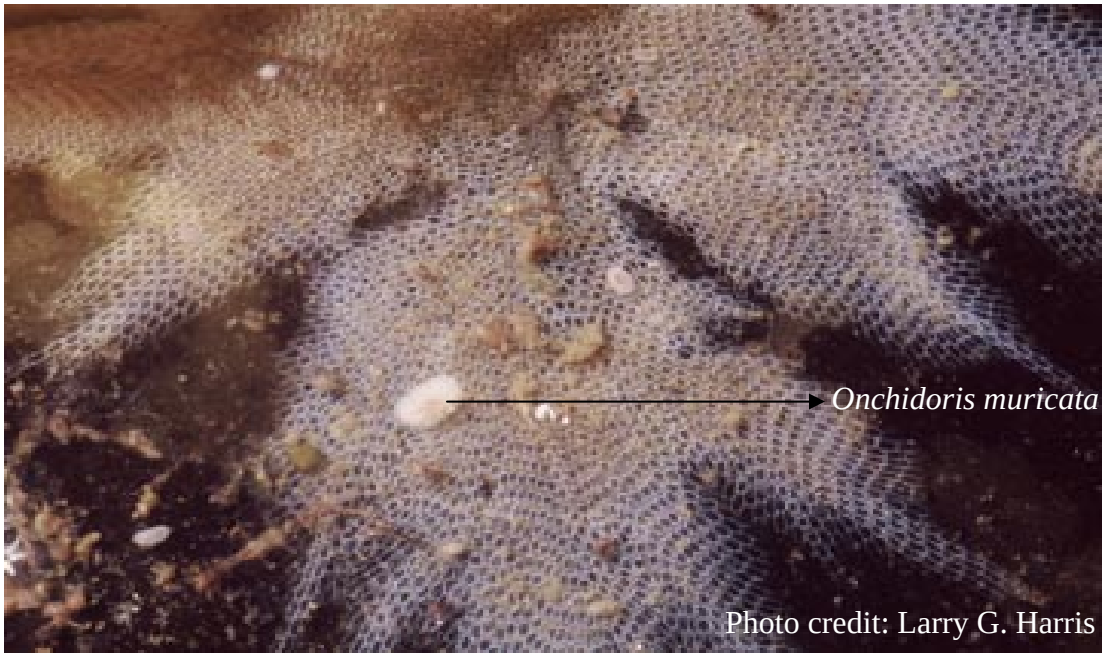

Figure 5: *Onchidoris muricata* preying on the encrusting bryozoans, *Electra pilosa*.

Figure 6: The wrasse, *Tautologlobrus adspersus*, feeding on solitary tunicates.

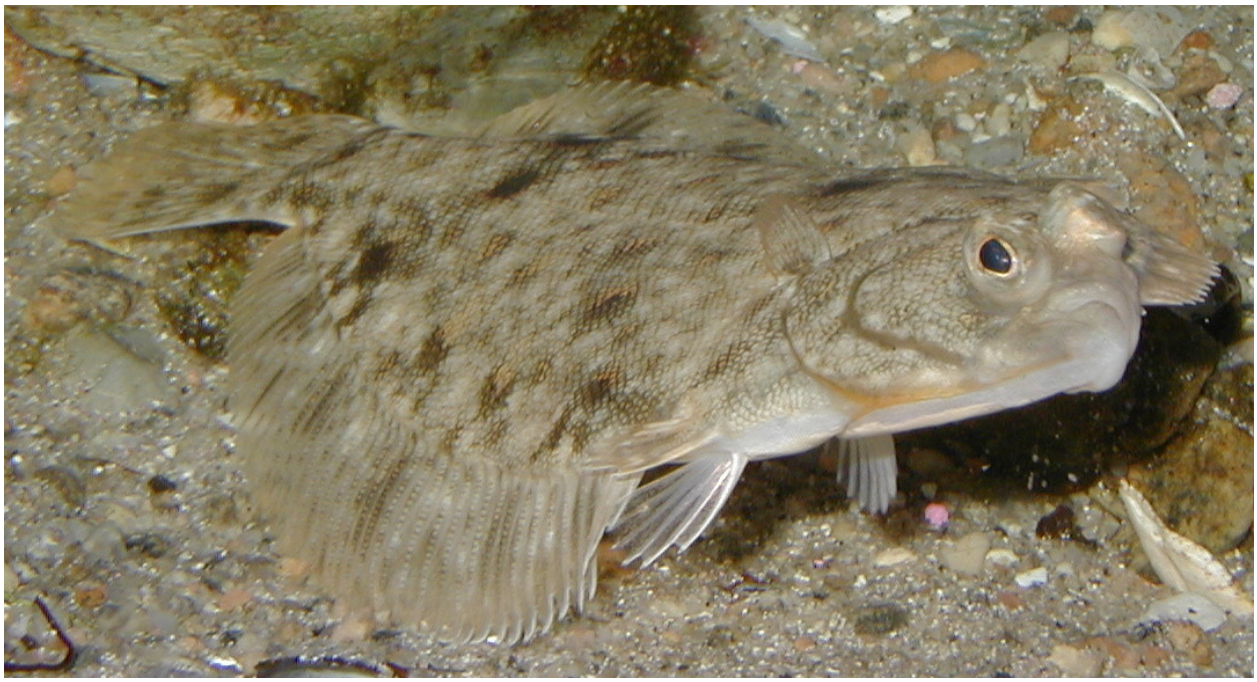

Figure 7: Winter flounder, *Pleuronectes americanus* consumes *Botryllus schlosseri*.

Figure 8: Historical fouling community (1980)

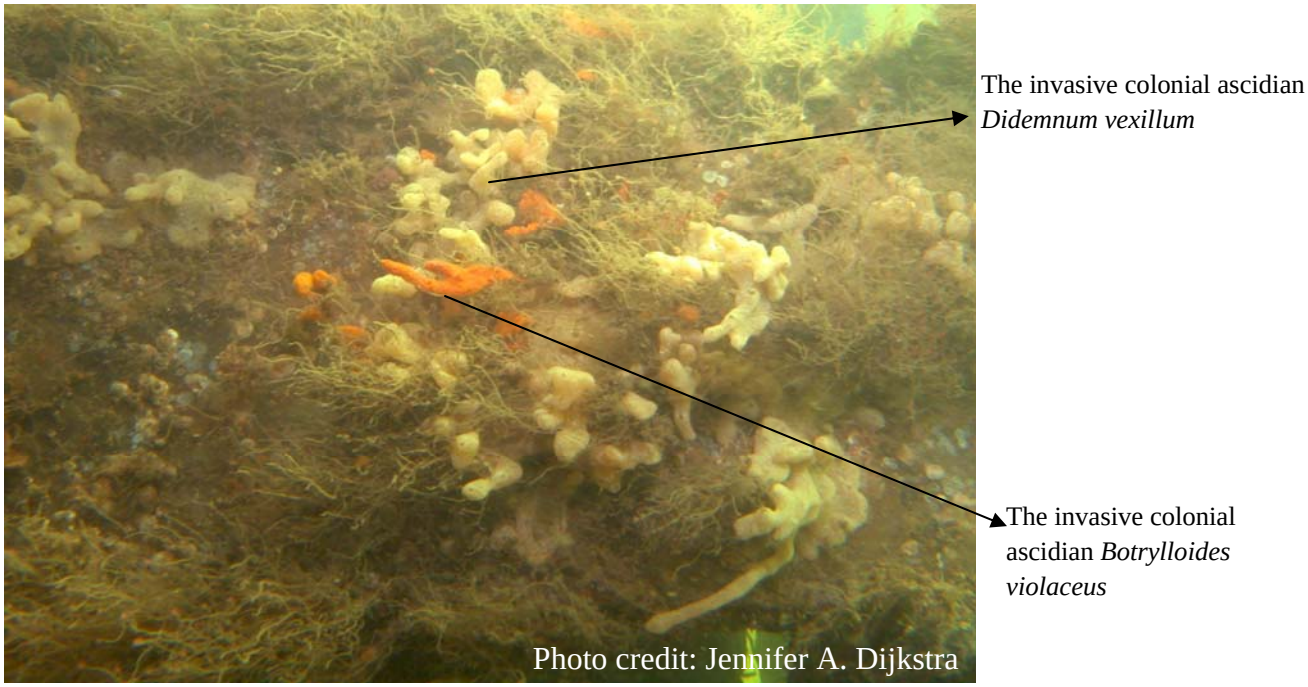

Figure 9: Present-day fouling community (2004)

Figure 10: Jackson Estuarine Laboratory (October, 2006); Barnacles, the solitary tunicate, *Molgula* sp., sponges and the colonial tunicate, Botryllus schlosseri were found on panels.

Figure 11: Great Bay Marina (October, 2006); Barnacles, the solitary tunica, *Molgula* sp., *Membranipora membranacea*, *Electra pilosa*, *Botryllus schlosseri* and *Botrylloides violaceus* were observed on panels.

Figure 12: Coastal Marine Laboratory (October, 2006); *Botrylloides violaceus*, *Botryllus schlosseri*, *Didemnum vexillum*, *Membranipora membranacea*, *Electra pilosa*, sponges and *Molgula* sp. were found on panels.

Figure 13: Wentworth Marina (October, 2006); Colonial tunicates, *Botrylloides violaceus*, *Botryllus schlosseri*, *Didemnum vexillum* and *Diplosoma listerianum* and solitary tunicates *Molgula* sp. were observed on panels.