Seasonal water temperature cycles and the recruitment of larvae of the colonial ascidian *Didemnum* sp. in New England coastal and offshore waters

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Objectives

A. Identify seasonal water temperature cycles in New England coastal and offshore waters

B. Determine the water temperatures marking the appearance of *Didemnum* sp. recruits

C. Use results in future studies to predict the potential geographic spread of the species

Approach

New England coast- use direct observations of water temperatures and settlement of recruits at infested sites

Georges Bank- use 30-year historical water temperature data to characterize areas where *Didemnum* is present or absent based on surveys from 1994 to 2007

Study Sites & Methods

Woods Hole, MA-

Dock in harbor south of Cape Cod

- Temperature loggers hung at 1, 2, 4, 5, 6, 8, and 10 m; 10 min records
- Pvc settlement plates (12 x 12 cm) hung at 50 cm and at 30-cm intervals from 1 to 5 m; inspected ~6-day intervals from April 2007 to present

Isles of Shoals, ME-

Submerged pier on offshore island

- Temperature loggers attached to pier at 1.5 to 3.5 m; hourly records
- Plexiglas settlement plates (10 x 10 cm) collected at 14-day intervals from June 7 to July 30, 2007

Damariscotta River, ME-

Floating dock in marine estuary

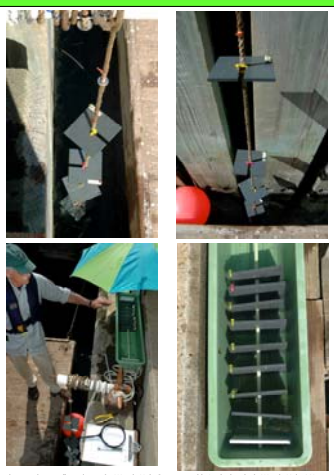
- Temperature loggers hung at 0.75 to 1.0 m; hourly records
- Plexiglas settlement plates (10 x 10 cm) collected at 14-day intervals from May to Dec 2006

Georges Bank-

Offshore fishing ground

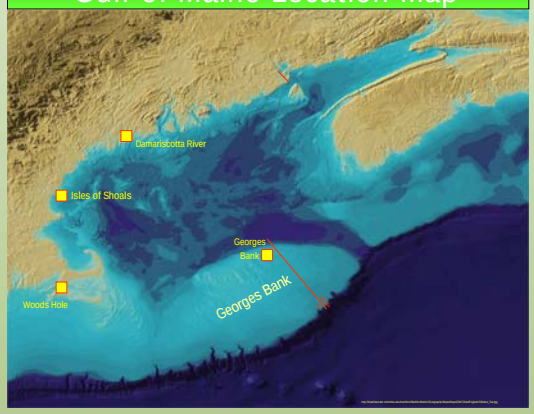
- Temperature data from NOAA ctd casts (1977-2007); also temperature data collected during tunicate surveys (2004-2007)
- Video/photo imagery and sampling to map *Didemnum* sp. presence and absence (1994-2007)

Settlement Plates at Woods Hole



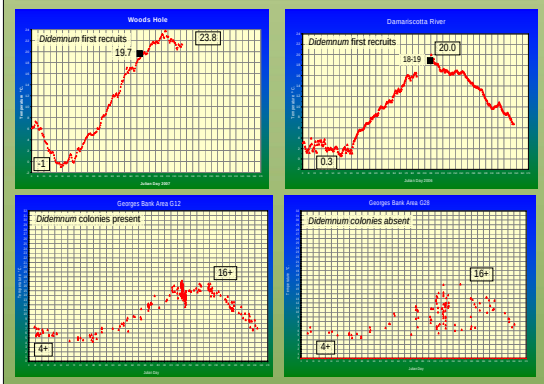
Settlement plate configuration at the Woods Hole Oceanographic Institution dock, Woods Hole, MA. Plates are 12 x 12 cm and are removable for inspection and photography. After inspection, plates are cleaned and redeployed.

Gulf of Maine Location Map



Map showing locations of sites where water temperatures were determined for *Didemnum* sp. first recruits (Woods Hole, Isles of Shoals, Damariscotta River) and for *Didemnum* sp. reproductive colonies (Georges Bank). Seasonal bottom temperature profiles from these sites are shown below.

Temperature Profiles at Study Sites



Seasonal water temperature trends are similar at Woods Hole, Damariscotta River, and Georges Bank where *Didemnum* sp. reproduces sexually. At all three sites the temperature trends in the warm season are well-defined and show little variability. On Georges Bank, stations showing variability at ~jd 240 are located in the northern part of G12 where fronts cause temperature variability and *Didemnum* is rare. By contrast, at G28 on the bank, where *Didemnum* sp. does not occur, the temperature trend is highly variable in the warm season. The maximum at G28 is 16+ °C, but the temperature varies from 5+ to 16+ °C. This trend is typical of the bank margin where the movements of strong fronts cause temperature variability. High variability in water temperatures in the warm season at a site may be an important factor in preventing sexual reproduction in *Didemnum* sp.

Seasonal Temperatures & First Recruits at Study Sites

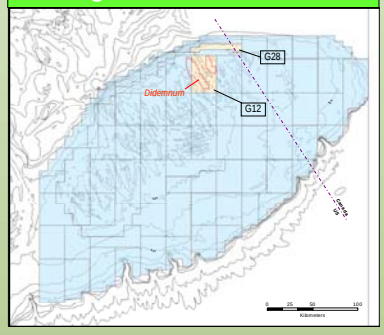
Location	Min temp °C date (jd)	Max temp °C date (jd)	First recruits date (jd)	First recruits temp °C
Woods Hole 2007 *adt*	-1.0 Feb 16 (047)	23.8 Aug 4 (216)	Jun 27-29 (178-180)	19.7 3 day avg
Isles of Shoals 2007 *adt, sst*	4+ Feb 18-25 (049-056)	19-20+ Jul 28-Aug 4 (209-216)	Jul 13-17 (194-198)	15.0 5 day avg
Damariscotta R. 2006 *adt*	0.3 Mar 3 (062)	20.0 Jul 30 (211)	Jul 14-28 (195-209)	18-19+ estimated
Georges Bank 12 1977-2007 *ctd*	4+ Mar-Apr (90-120)	16+ Aug-Sep-Oct (213-304)	unknown *Didemnum* present	unknown *Didemnum* present
Georges Bank 28 1977-2007 *ctd*	4+ Mar-Apr (90-120)	16+ Aug-Sep-Oct (Nov) (213-319)	none *Didemnum* absent	none *Didemnum* absent

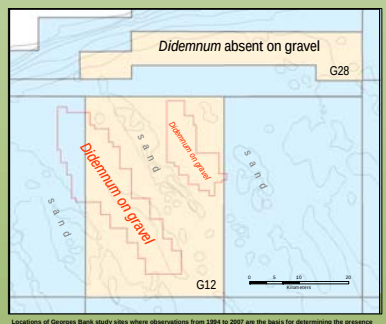
adt, average daily temp in situ *sst*, satellite surface temp *ctd*, bottom temp from ctd casts
Date in red is first day of recruit observation at end of plate deployment interval.

Summary of Study Site Characteristics

Location	Min temp °C	Temperature variability in warm season	Max temp °C	First recruits temp °C
Woods Hole 2007	<1	low	23+	19-20
Damariscotta R. 2006	<1	low	20+	18-19
Isles of Shoals 2007	4+	low	19-20+	15
Georges Bank 12 1977-2007	4+	low	17+	*Didemnum* present
Georges Bank 28 1977-2007	4+	high	up to >16+	*Didemnum* absent

Georges Bank Locations





Locations of Georges Bank study sites where observations from 1994 to 2007 are the basis for determining the presence and absence of *Didemnum* sp. (first reported in 2002). *Didemnum*-affected areas encompass 230 sq km. The species has not spread from G12 to G28. Seasonal bottom temperature profiles are shown at left.

Conclusions

A. Recruits of *Didemnum* sp. do not first appear at the same water temperature at all locations.

1. Woods Hole, MA-harbor south of Cape Cod 19-20 °C
2. Damariscotta River, ME- marine estuary 18-19 °C
3. Isles of Shoals, ME- offshore island 15 °C

B. The first appearance of larvae may be related to:

1. minimum water temperature at a site in the cold season
2. sustained temperature at a site in the warm season
3. temperature variability at a site in the warm season
4. temperature controls on sexual reproduction
5. length of larval brooding period

Didemnum Recruits at Woods Hole

Fig. 1. Many first recruits of *Didemnum* sp. (0.3 to 1 mm long) and two of *Botryloides violaceus* (4 mm long), June 29, 2007, 1.6 m water depth. *D. sp.* recruits display crescent-shaped white areas (lateral organs of the thorax) where spicules are produced; dorsal cloacal opening is visible in some recruits. Photo 9237

Fig. 2. Recruit of *Didemnum* sp., Aug. 22, 2007, 3.3 m water depth. Crescent-shaped white areas (lateral organs of the thorax) produce spicules; black spots are the ocellus and statolith. Photo 0684

Fig. 3. Three recruits of *Didemnum* sp., Aug. 22, 2007, 2.0 m water depth. Crescent-shaped white areas (lateral organs of the thorax) produce spicules. Newly-produced spicules give whitish cast to these recruits. In recruit on left, dorsal cloacal opening is visible. Photo 0737

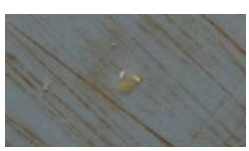


Fig. 4. Recruit of *Didemnum* sp. (0.3 mm long), Aug. 22, 2007, 4.3 m water depth. Crescent-shaped white areas (lateral organs of the thorax) produce spicules; black spots are the ocellus and statolith. Photo 0669

Fig. 5. Five recruits of *Didemnum* sp. (0.6 to 0.9 mm long) and one *B. violaceus* (2.7 mm long), Aug. 22, 2007, 2.0 m water depth. Crescent-shaped white areas (lateral organs of the thorax) produce spicules. In two large recruits on right, dorsal cloacal opening is visible. Photo 0739

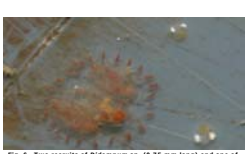


Fig. 6. Two recruits of *Didemnum* sp. (0.75 mm long) and one of *Botryloides violaceus* (3.4 mm long), Aug. 22, 2007, 1.6 m water depth. Crescent-shaped white areas (lateral organs of the thorax) produce spicules. In recruit on lower left, dorsal cloacal opening and black ocellus or statolith are visible. Photo 0706