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From: Vincent Guida - NOAA Federal [mailto:vincent.guida@noaa.gov]
Sent: Tuesday, March 12, 2013 10:06 AM
To: David Preble
Cc: David Stevenson - NOAA Federal; Michelle S. Bachman
Subject: Northern Closed Area Two

Dear Mr. Preble,

I understand that the New England Council's Habitat PDT and Committee are considering possible modifications to the existing habitat closed area at the northern end of Closed Area Two (CA II), including the elimination of the habitat closure and the creation of a habitat research area. In that context, I wanted to express interest in continuing NEFSC research in this area. The Ecosystems Processes Division, Coastal Ecology Branch, based at the NEFSC J.J. Howard Laboratory (Sandy Hook, NJ) has been conducting fisheries ecology research there in collaboration with our Woods Hole Laboratory, the University of Rhode Island and the US Geological Survey since 2004. We plan to continue that work into 2015, by which time we anticipate developing a detailed map to accurately represent the distribution, extent, and nature of habitats there and how they are utilized by fisheries resource species, e.g. cod, haddock, sea scallops. I use "habitat" here in the sense of a physical-biological environment of relatively uniform character, e.g. "gravel bottom habitat" rather than as the domicile of a particular species, e.g. "juvenile cod habitat". This area is of particular interest, as it appears to harbor a patchwork of habitats of varying bottom types and hydrographic regimes within a small area. Among these is rare band of boulders and gravel with an exceptionally diverse fauna that appears to be virtually undisturbed by mobile bottom fishing gear. Observations suggest that this may function as a refuge for juvenile cod and other fishes. To my knowledge there is no other known patch of habitat like this on the U.S. portion of the Bank.

Attached please find files, including cruise reports and published papers, chronicling the work we have done in and around the HAPC since 2004, and proposals and requests for ship time in 2013-2015.

Thank you for your interest in Georges Bank.

Sincerely,

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Recolonization of gravel habitats on Georges Bank (northwest Atlantic)

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ABSTRACT

Gravel habitats on continental shelves around the world support productive fisheries but are also vulnerable to disturbance from bottom fishing. We conducted a 2-year *in situ* experiment to measure the rate of colonization of a gravel habitat on northern Georges Bank in an area closed to fishing (Closed Area II) since December 1994. Three large (0.25 m^2) sediment trays containing defaunated pebble gravel were deployed at a study site (47 m water depth) in July 1997 and recovered in June 1999. The undersides of the tray lids positioned 56 cm above the trays served as settlement panels over the same time period. We observed rapid colonization of the gravel substrate (56 species) and the settlement panels (35 species), indicating that colonization of gravel in this region is not limited by the supply of colonists. The species composition of the taxa found in the trays was broadly similar to that we collected over a 10-year period (1994–2004) in dredge samples from gravel sediments at the same site.

The increase in abundance of animals in the gravel colonization trays was rapid and reached a level in 2 years that took 4.5 years to achieve in the surrounding gravel sediments once fishing had stopped, based on data from dredge sampling at this site. The increase in biomass of animals found in the sediment trays paralleled the trend of biomass increase observed in dredge samples over the same period (1997–1999) but was lower in value. These data suggest that after rapid initial increase in abundance of organisms, succession proceeded by increasing individual body size.

A comparison of settlement panel and tray faunas revealed that the mean biomass of structure-forming epifauna (sponges, bryozoans, anemones, hydroids, colonial tube worms) on the panels was 8 times that found on the trays. Structure-forming taxa constituted 29% of the mean biomass of the panel fauna but only 5.5% of the tray fauna. By contrast, the mean biomass of scavengers (crabs, echinoderms, nudibranchs, gastropods) in the trays was 32 times that on the panels. Colonization of the tray gravel was more rapid for free-living species (many of which are prey for fish) than for structure-forming epifauna, though colonists of the latter species were present. The reduced success of structure-forming species in colonizing the tray gravel possibly is related to factors such as intermittent burial of the gravel by migrating sand and low survival of new recruits due to the presence of high numbers of scavengers on the gravel. These two factors might explain, to varying degree, the slow recolonization of gravel habitats by structure-forming species in Closed Area II of the northern part of Georges Bank.

1. Introduction

Continental shelves support high levels of biological production, including the bulk of world fisheries. These important ecosystems are subject to natural and human disturbances. Natural disturbance to continental shelf habitats and communities is caused chiefly by tidal currents and storm-induced wave action, which attenuates below 60 m water depth on Georges Bank, our study area (Twitchell et al., 1987). Human disturbances include bottom fishing, hydrocarbon exploration and production, and other infrastructure activities. Mobile bottom-fishing gear is widely used on continental shelves around the world (Kaiser et al., 2002); the spatial distribution of bottom fishing is patchy, but where it occurs, it is considered the most pervasive threat to marine biodiversity (NRC, 1995). To regulate and mitigate human activities on continental shelves requires that we can (1) distinguish human from natural disturbance, (2) understand how human disturbance affects ecosystem function, and (3) measure the recovery rates of continental shelf communities. Depending on the substrate, recovery rates can range from one year to more than a decade (Collie et al., 2000a), but there have been few direct measurements.

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Georges Bank is a shallow submarine plateau off the east coast of North America with an area of approximately 43,000 km^2 within the 200-m isobath (Fig. 1). It has been an important fishing ground since the 18th century (Backus and Bourne, 1987). A gravel lag deposit is present on the northern edge of the bank, covering an area of approximately 3000 km^2 (Valentine and Lough, 1991). In this area, strong semi-diurnal currents have winnowed the seabed sediments, leaving a veneer of gravel pavement overlying sand. The gravel is ecologically important because it is substrate for the attachment of juvenile sea scallops (*Placopecten magellanicus*) and also for attachment of colonial epifauna, including hydroids, bryozoans, and tube worms (Collie et al., 1997). This biologically rich habitat provides an abundant food source for demersal fish and is especially important as a nursery ground for juvenile cod and haddock (Lough et al., 1989).

Disturbance to the gravel pavement from mobile fishing gear, especially scallop dredges, is apparent in side-scan sonar images (Valentine and Lough, 1991). In December 1994, a large area of Georges Bank in US waters abutting the US/Canada boundary was closed to bottom fishing to reduce fishing mortality on the principal groundfish species (Fig. 1). Since that time, we have conducted studies of the benthic fauna in Closed Area II, in adjacent areas of gravel open to fishing, and in fished and unfished gravel habitats on the Canadian part of the bank. Spatial comparisons between heavily fished and lightly fished areas have indicated significant differences in abundance, biomass, and species composition of the benthic communities (Collie et al., 1997).

The closed area, in offering protection from bottom fishing disturbance, has provided a rare opportunity to measure the long-term recovery of benthic communities on gravel habitats (Collie et al., 2005). To supplement our dredge sampling of the gravel inside and outside of Closed Area II, we conducted a 2-year recolonization experiment with gravel-filled trays and polycarbonate settlement panels from July 1997 to June 1999. The objective of this experiment was to measure the rate of colonization on substrates we could collect relatively intact from the seabed for complete enumeration. The purpose of this report is to analyze the colonization of sediment trays and panels as measured by the abundance and biomass of species, and to compare these results with similar data we have collected over a 10-year period (1994–2004) based on dredge sampling at the same and adjacent sites on the gravel habitat.

2. Methods

Six sediment aggregating modules (SAM) were designed and constructed at the Equipment Development Laboratory of the Graduate School of Oceanography (Fig. 2). The design was patterned after "New Free Vehicles" intended for deployment in the deep sea (Snelgrove et al., 1995). Tested in laboratory flume studies, the low-profile, sloping base of these vehicles was found to minimally disturb the boundary layer flow at horizontal current velocities comparable to the deep sea (10–15 cm s^{-1}). Each SAM has a poured concrete base (weight 300 kg in water) to anchor the tray to the sea floor. The base is a spherical section with a bottom diameter of 142 cm and height of 25 cm, designed to allow a smooth flow of water over the gravel in the tray. A depression was molded into the top of the base to accommodate the stainless-steel tray (inner dimensions $50 \times 50 \times 11$ cm; surface area 0.25 m^2). The SAM bases have a larger slope angle than the "New Free Vehicles" and bottom-current velocities are higher on Georges Bank (~50 cm s^{-1}) than the horizontal velocities used in the flume tank experiments (Snelgrove et al., 1995). Therefore we expected the SAM tray bases to reduce, but not eliminate, flow artifacts on the sediment trays.

Four galvanized steel posts supported a superstructure consisting of a tray lid, coiled lines, and deployment bail (Fig. 2). The lid was a polycarbonate square (56 cm × 56 cm; 0.31 m^2) reinforced with aluminum plate and attached to an aluminum guide bar fitted through a slot in the steel superstructure. A 40-cm

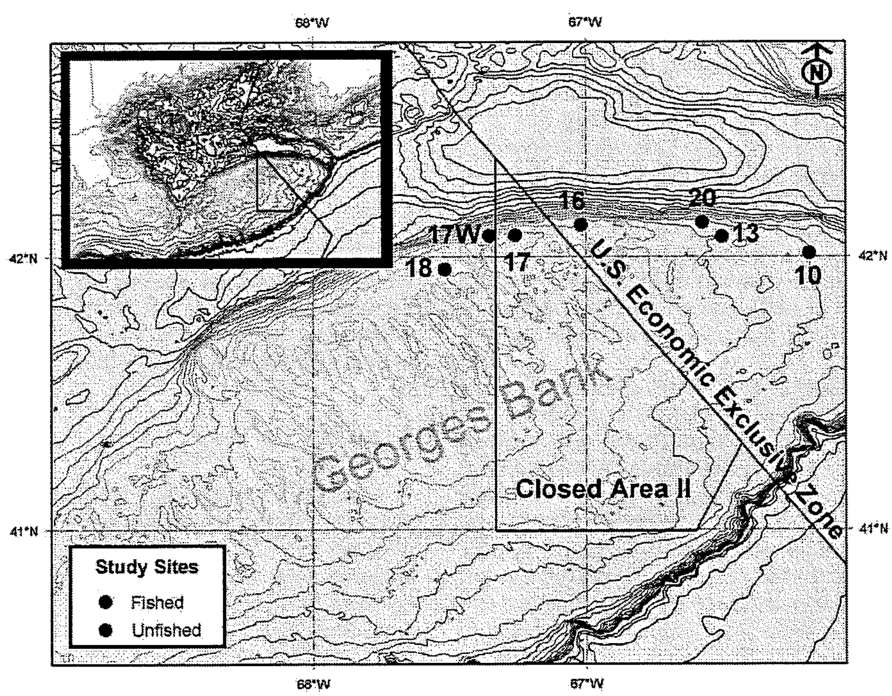

Fig. 1. Map of Georges Bank showing the location of the area closed to fishing in December 1994 (Closed Area II) and the fished and unfished gravel habitat study sites surveyed between 1994 and 2004. The sediment recolonization (SAM) trays and settlement panels were deployed at Sites 17 and 20 (modified from Asch and Collie, 2005).

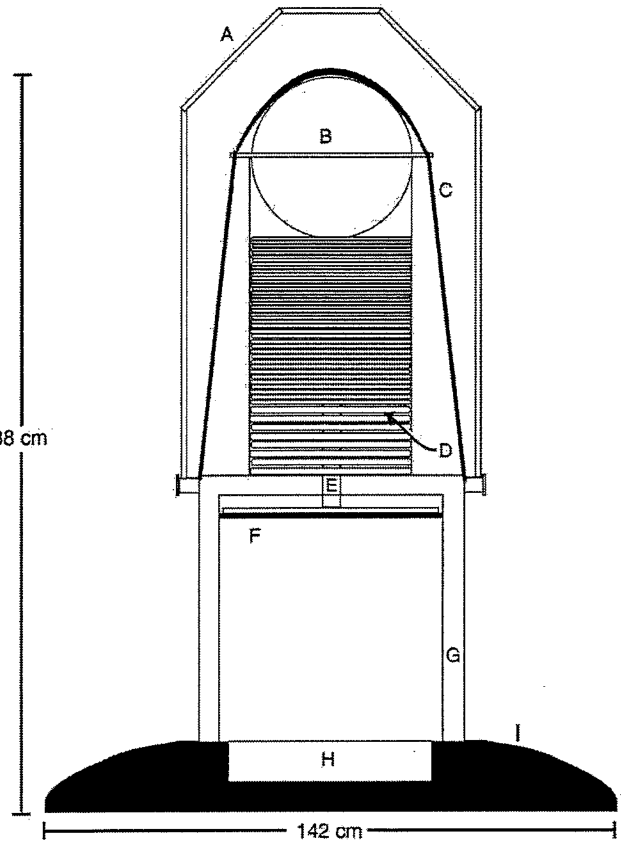

Fig. 2. Diagram of the sediment aggregating module or SAM tray: (A) deployment bail, (B) glass float, (C) Spectra line to be cut for retrieval, (D) polypropylene recovery line coiled in PVC tube, (E) tray lid guide bar, (F) tray lid, (G) one of four legs, (H) sediment tray, and (I) concrete base.

diameter polyvinylchloride (PVC) tube contained a coil of floating polypropylene recovery line. The floating line was tapered, starting with 33 m of 20-mm line at the bottom that could support the full weight of the SAM, 100 m of 10-mm line, and 200 m of 5-mm line attached to a 43-cm diameter glass float and protective "hard hat." A PVC disc inserted below the float prevented the polypropylene recovery line from uncoiling inside the container. A length of Spectra line passed around the glass float and tray lid, keeping the float secured to the PVC tube and the lid raised above the tray. This line was designed to be cut by an ROV or submersible, allowing the lid to drop onto the tray and the glass float to rise to the surface with the recovery line. Finally, a deployment bail was hinged and counter weighted so that it would rest on one side of the SAM when not in use and not impede the recovery line.

Since 1994, our sampling of the gravel habitat has been clustered in two areas: between 80 and 90 m depth on the Canadian part of Georges Bank (Fig. 1, Sites 13, 20); and between 45 and 50 m on the US part, inside and outside of Closed Area II (Sites 17, 17W, and 18). Following this strategy, the SAMs were deployed in two clusters of three in areas with little or no bottom fishing activity and in which the background benthic community had been characterized. Three SAMs were deployed at Site 20 (42° 4.75′N, 66° 34.50′W, depth 86 m), an undisturbed site with biogenic substrate. The other three SAMs were deployed at Site 17 (42° 4.75′N, 67° 15.25′W, depth 47 m) inside Closed Area II. This site (the one reported on here) is located on the gravel pavement on the northern edge of Georges Bank (Fig. 1) in an area that was heavily fished until December 1994 when it was closed to all bottom fishing. This gravel habitat has been well characterized with video and still photography, Naturalist dredge samples, and baited traps (Collie et al., 1997, 2000b; Hermsen, 2002).

The SAMs were deployed from the R.V. *Abel J* in July 1997. Defaunated pebble-size gravel (40–60 mm diameter) from Georges Bank was frozen into the sediment trays in seawater to kill any organisms on the gravel and to keep it in place during deployment. The SAMs were gently lowered to the seabed on a line looped from the vessel's bow to stern through the deployment bail. The location of each SAM was recorded with two independent GPS measurements.

Initial recovery and redeployment of a subset of the SAMs was planned for 1998 on the R.V. *Edwin Link*. However, due to problems with the ship's DGPS navigation system and the sector-scanning sonar on the submersible *Clelia*, we were unable to find and release any of the SAMs. A second recovery attempt was made a year later in June 1999 on the R.V. *Abel J* with the NURP Max ROVER MKI ROV. One of the three SAMs in Area 20 was located, but none were recovered. The three SAMs at Site 17 were located readily with the ROV's sector-scanning sonar. Despite initial problems with the recovery lines, all three SAMs were recovered by the R.V. *Connecticut*. Due to biogenic fouling, the tray lids failed to drop completely onto the trays, which means there was some possibility of sample loss during recovery.

The colonization trays were photographed before all living animals were picked out of the gravel, which was sieved on a 5-mm screen. Sand that had accumulated in the trays was further sieved on a 0.5-mm screen and all the animals were preserved in 5% buffered formalin. The undersides of the tray lids acted as settlement panels and were treated as separate sample types for comparison with the tray samples. Each panel was photographed before all the animals were scraped off and preserved separately in buffered formalin. In the laboratory, the tray and panel samples were sorted, all animals were identified to species (or the lowest taxon possible) and counted, and individuals of each species were weighed together.

Data from the trays were analyzed with univariate and multivariate methods and compared with data collected annually with a 1-m wide Naturalist dredge at sites inside (Site 17) and outside (Sites 17W, 18) of the closed area during a period that included the 2-year period of SAM deployment. A complete description of these dredge data is provided by Collie et al. (2005); the data are available from Asch and Collie (2005). Non-metric multidimensional scaling (MDS) was used to ordinate the species composition data. The ordination was based on the Bray–Curtis similarity between samples, calculated from root-transformed data. The similarity of percentages (SIMPER) routine was used to identify a subset of species accounting for the dissimilarity between the SAM trays and dredge samples (Clarke and Warwick, 2001). Rank dominance curves were calculated for abundance and biomass summed over replicates.

3. Results

Three SAM trays were recovered from Site 17 in 1999 after 2 years of deployment. On recovery, the trays were between 75% and 90% full of gravel, indicating that some loss of gravel had occurred, most likely during lifting of the SAMs from the seabed to the ship. Sand had filled the interstices between the pebbles and covered the bottoms of the trays, such that the substrate in the trays mimicked the ambient seabed, a gravel pavement overlying sand.

A combined total of 56 taxa were found in the three trays, of which 46 were identified to species. The species were divided into two groups to facilitate comparison with Naturalist dredge samples collected in the same area. Group 1 includes 22 taxa, most of which are colonial or small species that are not consistently retained in our dredge (Table 1). Group 1 is numerically dominated by caprellid and gammarid amphipods, especially *Pontogeneia inermis* and *Ischyrocerus anguipes*. Together, the amphipods constituted 90% of the total number of individuals but only 2.6% of biomass. Group 1 also included colonial epifauna that were weighed but not counted (Bryozoa, Hydrozoa, Porifera, and the tube worm, *Filograna implexa*). Sponges dominated the epifaunal biomass. Group 1 faunal data were standardized by the surface area of the trays (Table 1).

Group 2 contains 34 larger species that are consistently retained on the 5-mm sieves we use to process the dredge samples (Table 2). This group is numerically dominated by the amphipod, *Melita dentata*, the shrimp, *Eualus pusiolus*, and the brittle star, *Ophiopholis aculeata*. Biomass of the SAM trays was dominated by crabs (*Cancer borealis*, *Cancer irroratus*, *Hyas coarctatus*) and echinoderms (*Strongylocentrotus droebachiensis* and *Ophiopholis aculeata*), and the waved whelk (*Buccinum undatum*).

Group 2 faunal data were standardized by the surface area of the trays and also by the volume of sediment in the trays so as to be comparable to the Naturalist dredge samples. Because the dredge is towed for short distances over the sea floor (30–50 m), more consistent results are obtained by normalizing the data to the volume of gravel collected instead of the area dredged (Collie et al., 1997). The study area was heavily fished prior to the area closure in December 1994, such that the abundance trend at Site 17 inside the closed area essentially corresponds to the recolonization of bare gravel (Fig. 3a). Colonization of the tray sediments during the experiment was very rapid, and reached the level of numerical abundance in 2 years that took 5 years in the surrounding sediment at Site 17 (Fig. 3a). The number of organisms collected by the SAM trays exceeded the highest number observed in dredge samples at Site 17 area during a 10-year period. Accumulation of biomass in the colonization trays was lower between 1997 and 1999 than that observed on surrounding gravel at Site 17 between 1996 and 1999 but showed a parallel trend (Fig. 3b). Taken together, both the dredge sample and sediment tray results indicate a rapid colonization of the gravel by small individuals, after which succession was dominated by the accumulation of biomass, not by further increases in numbers of individuals.

Group 2 species composition was similar among the SAM trays, but somewhat dissimilar from that in the surrounding gravel sediment at Site 17 (Fig. 4). The species composition of dredge samples had a serial pattern from 1994 on the left-hand side of the MDS plot to 2004 on the right, which we interpret as a recolonization gradient. The SAM tray species composition was least similar to the species in the 1994 dredge samples collected prior to the area closure, and most similar to the dredge sample species from 1997, 1998, and 1999, the same years that the trays were deployed. Even so, the SAM tray samples form a distinct cluster in the MDS plot (Fig. 4). A SIMPER test identified a subset of species that contributed most to the dissimilarity between the SAM and dredge samples. The SAM trays were characterized by higher abundances of *Eualus pusiolus*, *Cancer borealis*, *Margarites*

Table 1
Colonial, attached, and small, free-living taxa collected in three colonization trays and on three settlement panels on northern Georges Bank between 1997 and 1999 (Group 1).

Scientific name	Common name	Trays		Panels	
		Abundance	Biomass	Abundance	Biomass
Ampharetidae unident.	Polychaete worm			1.59	0.062
Amphipoda unident.	Amphipod	25.82	0.011	5248.72	4.503
Amphitrite johnstoni	Polychaete worm	4.08	0.188		
Anomia simplex	Smooth jingle shell	66.58	3.662	1016.16	87.374
Anomia squamula	Prickly jingle shell	40.76	1.620	1313.78	66.197
Anomia spp.	Mixed jingle shells[a]				84.394
Balanus balanus	Barnacle	4.08	2.484	177.51	89.514
Balanus crenatus	Barnacle			29.76	28.482
Bryozoa bushy	Bryozoan[b]		0.117		41.593
Bryozoa coralline	Bryozoan[b]				5.402
Bryozoan encrusting	Bryozoan				20.721
Buccinum undatum egg case	Waved whelk eggs[a]		1.978		9.831
Caprellidae unident.	Skeleton shrimp	1232.39	3.557	17,495.75	31.180
Chirona hameri	Barnacle	2.72	8.359	668.58	664.631
Filograna implexa	Lacy tube worm[b]		0.063		36.104
Hydrozoa unident.	Hydroids[b]		0.645		96.047
Ischyrocerus anguipes	Amphipod	2078.90	1.938		
Leptocheirus pinguis	Amphipod	6.79	0.171		
Lumbrineris fragilis	Polychaete worm	6.79	3.920		
Molgula sp.	Sea grape	1.36	0.012	230.65	47.618
Nemertinea unident.	Ribbon worm	8.15	1.333		
Nudibranchia unident. eggs	Nudibranch eggs[a]				2.764
Paramphithoe pulchella	Amphipod	1.36	0.046		
Phoxocephalus holbolli	Amphipod	1.36	0.003		
Pleusymtes glaber	Amphipod	1133.20	0.860		
Polynoidae unident.	Scale worm	33.97	0.743		
Pontogeneia inermis	Amphipod	3782.78	17.301		
Porifera unident.	Sponge[b]		41.143		13.552
Stenothoidae unident.	Seed amphipod	195.66	0.080		
Sums		8626.75	90.23	26182.50	1329.97

Mean abundance (m^{-2}) and biomass ($g\,m^{-2}$) was measured in the gravel sediment and on the tray lids (panels).

[a] Not counted as a distinct taxon.

[b] Structure-forming species.

Table 2
Free-living species collected in three colonization trays and on three settlement panels on northern Georges Bank between 1997 and 1999 (Group 2).

Scientific name	Common name	Trays		Panels	
		Abundance	Biomass	Abundance	Biomass
Achelia spinosa	Sea spider	1.36	0.001		
Aeolidia papillosa	Nudibranch[b]	2.72	7.672		
Amphipholis squamata	Brittle star[b]	4.08	0.046		
Astarte borealis	Boreal astarte	61.14	7.479		
Asterias vulgaris	Boreal asterias[b]	16.31	88.421	5.31	14.634
Boltenia echinata	Cactus sea squirt			3.19	6.212
Buccinum undatum	Waved whelk[b]	107.34	68.559	2.13	0.002
Cancer irroratus	Rock crab[b]	25.82	115.679		
Cancer borealis	Jonah crab[b]	14.95	579.628	1.06	2.917
Cerastoderma pinnulatum	Northern dwarf cockle	5.44	0.401		
Crenella glandula	Gladular bean mussel	40.76	6.282		
Crenella faba	Little bean mussel	28.53	1.836	22.32	0.019
Cyclocardia borealis	Northern cardita	1.36	0.053		
Dendrodoa carnea	Blood drop sea squirt	1.36	0.019		
Eualus pusiolus	Shrimp	241.86	5.026	3.19	0.058
Flabellina spp.	Nudibranch[b]	8.15	0.985	1.06	−0.001
Hiatella arctica	Arctic saxicave	17.66	1.387	206.21	6.124
Hiatella striata	Rock borer	1.36	0.001	2.13	0.091
Hyas coarctatus	Toad crab[b]	29.89	36.746	4.25	1.293
Margarites costalis	Northern rosy margarite	9.51	0.058	1.06	0.002
Melita dentata	Amphipod	612.80	5.734		
Modiolus modiolus	Horse mussel	2.72	0.520	10.63	0.569
Musculus discors	Discordant mussel	16.31	0.008	1.06	0.164
Myoxocephalus aeneus	Grubby sculpin	4.08	10.998		
Mytilus edulis	Blue mussel			23.38	42.839
Nephtys incisa	Painted worm	6.79	0.538		
Nereis pelagica	Clam worm			89.29	2.535
Nereis zonata	Clam worm	42.12	5.461		
Ophiopholis aculeata	Daisy brittle star[b]	116.85	27.197	90.35	12.266
Pagurus acadianus	Acadian hermit crab[b]	5.44	2.314		
Pagurus pubescens	Hermit crab[b]	2.72	0.457		
Pandora gouldiana	Gould's pandora shell	10.87	1.855		
Phyllodoce maculata	Paddleworm	4.08	0.024		
Placopecten magellanicus	Atlantic sea scallop			3.19	0.010
Potamilla neglecta	Feather-duster worm	1.36	0.152		
Pycnogonum littorale	Sea spider			3.19	0.057
Strongylocentrotus droebachiensis	Green sea urchin[b]	2.72	74.334		
Tautogolabrus adspersus	Cunner	1.36	2.023		
Urticina felina	Northern anemone[a]	6.79	21.785	212.59	305.919
Sums		1456.59	1073.68	685.59	395.71

Mean abundance (m^{-2}) and biomass ($g\,m^{-2}$) was measured in the gravel sediment and on the tray lids (panels).

[a] Structure-forming species.
[b] Scavenging species.

costalis, *Melita dentata*, and *B. undatum*. In contrast, the dredge samples from 1997 to 1999 had higher densities of *Placopecten magellanicus*, *Strongylocentrotus droebachiensis*, *Crepidula plana*, *Asterias vulgaris*, and *Crangon septemspinosa*.

The rank dominance curves for abundance and biomass from the SAM tray samples (1997–1999) lie close together (Fig. 5a), typical of a moderately disturbed community in which species are represented by many small individuals (Clarke and Warwick, 2001). In contrast, the biomass-dominance curves from the Naturalist dredge samples (1995, 1997, 1999) lie appreciably above the abundance–dominance curves, as expected in a less-disturbed community in which biomass is dominated by one or several species of large individuals (Figs. 5b–d). The number of Group 2 species found in the SAM trays (34 after 2 years) reflects the colonization period. The SAM trays had more species than the dredge samples in 1995 (25 after <1 yr) but fewer than the dredge samples in 1997 (55 after 2.5 yr) or 1999 (48 after 4.5 yr). These dominance curves reinforce the finding that the numerical colonization of the SAM trays was rapid but that accumulation of biomass through individual growth took longer to develop.

The undersides of the SAM tray lids acted as settlement panels, which were 100% colonized after 2 years (e.g. Fig. 6). A total of 35 taxa were collected on the panels, of which 24 were identified to species (Tables 1 and 2). Biomass was concentrated in attached epifauna, including barnacles, the bivalve *Anomia* spp., and structure-forming taxa including anemones, bryozoans, hydroids, and a tube worm. Abundance was dominated by small taxa including caprellid and gammarid amphipods. The fact that these free-living animals were found on the settlement panels indicates a close association with the colonial epifauna, which they use for habitat and to increase feeding opportunities (Collie et al., 1997). The panel fauna had approximately $2\frac{1}{2}$ times more individuals and $1\frac{1}{2}$ times more biomass per square meter than the tray fauna. Colonies of *F. implexa* up to 10 cm in diameter were found on the panels, from which we can infer colony growth rates of up to 5 cm per year. Taking the mean number of *F. implexa* colonies per panel (5) and a growth rate of 5 cm in diameter per year, this colonial tube worm could reach 100% coverage in 5 years in the absence of other competitors.

A comparison of settlement panel and tray faunas at Site 17 (Tables 1 and 2) reveals that mean biomass of structure-forming

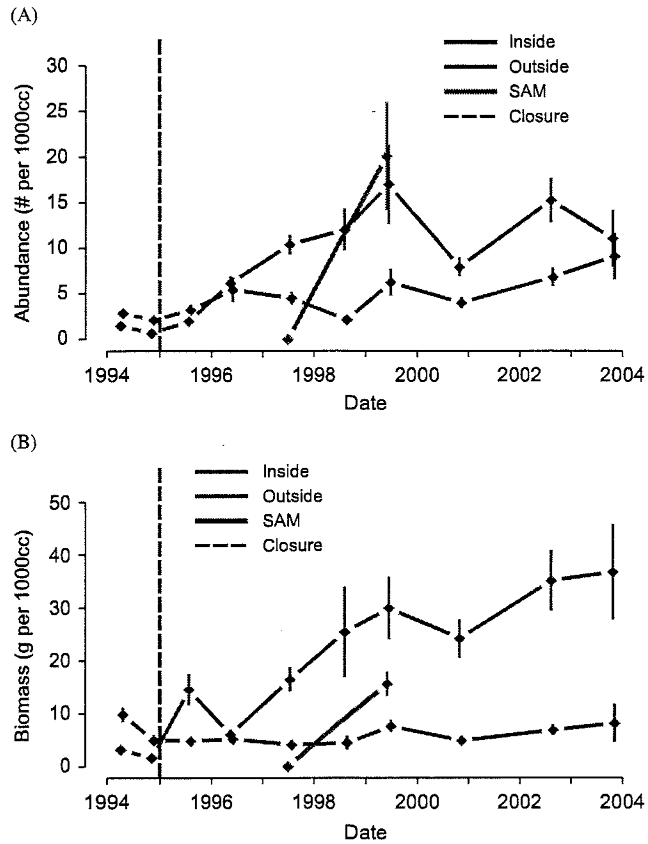

Fig. 3. Abundance (A) and biomass (B) of Group 2 organisms collected in the SAM trays at Site 17 inside the closed area compared with dredge samples from Site 17 and with dredge samples from sites 17W and 18 outside the closed area (Fig. 1). Each data point is the mean of three or more replicates; vertical lines are the 95% confidence intervals of the means. The dashed vertical line indicates the initiation of Closed Area II in December 1994.

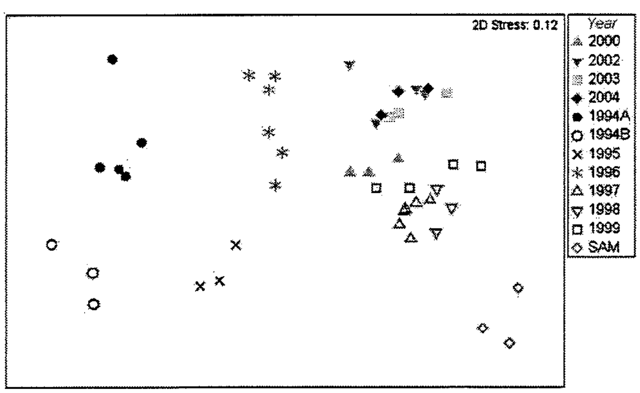

Fig. 4. Ordination of community samples from SAM trays (Group 2 species) and dredge samples collected at Site 17 on northern Georges Bank. Non-metric multidimensional scaling was performed on the Bray–Curtis similarity calculated from the root-transformed abundances of 103 macrofaunal species. The change in species composition with time from the left (1994) to the right (2004) of the plot represents a recolonization gradient. There were two cruises in 1994 before initiation of Closed Area II in December of that year: April (A) and November (B).

epifauna (bryozoans, hydrozoans, tube-building worms, sponges, anemones) on the panels (6 species) was 8 times that on the trays (5 species). Structure-forming species constituted 29% of the total mean biomass of the panel fauna but only 5.5% of the tray fauna. By contrast, the mean biomass of scavengers (nudibranchs, gastropods, echinoderms, crabs) on the trays (12 species) was 32 times that on the panels (6 species). Scavengers constituted 86% of the total mean biomass of the tray fauna but only 2% of the panel fauna. An analysis of the ambient gravel at Site 17 shows that from the 1994 closure to 2004, colonization was more rapid for many free-living species (including scavengers) than for structure-forming epifauna (Asch and Collie, 2008), even though colonists of the latter species were present as documented by our settlement panel data.

4. Discussion

Operation of the SAM trays was generally successful in measuring the recolonization of gravel sediments on the outer continental shelf. Data collected from the settlement panels (tray lids) provide an informative contrast in that they measured colonization on a hard substrate, with elevated current velocities, and lower densities of scavengers. The fact that the panels were 100% colonized after 2 years suggests that larval settlement was not impeded by flow artifacts related to the design of the SAM trays.

The location of our experiment on Georges Bank is relatively shallow compared with colonization experiments conducted in the deep sea. Therefore, our results resemble shallow-water colonization experiments, in which the initial species composition was determined by larval habitat selection and juvenile colonization from the surrounding community (Snelgrove et al., 2001). In contrast, recolonization of deep-sea sediments generally occurs more slowly because reproductive rates of deep-sea animals are low, weaker currents limit dispersal, and food supply is low (Grassle, 1977).

The SAM trays were deployed $2\frac{1}{2}$ years after the initiation of Closed Area II on Georges Bank because of the time required to design, build, and deploy the trays. Thus recolonization in the closed area had already begun, providing a local source of colonists for this experiment. For this reason, the colonization of the trays may have proceeded more quickly than if the experiment were begun shortly after closure (Fig. 3). The colonization tray fauna was numerically dominated by small, free-living amphipods that live in the gravel interstices and by caprellid amphipods that live attached to other epifauna. However, there were no functional or life-history differences between the species assemblage colonizing the trays and the assemblage colonizing the surrounding gravel substrate.

This part of Georges Bank has a mean current of $20\,cm\,s^{-1}$ (Twitchell et al., 1987), which translates to a possible displacement of larvae up to 500 km in 30 days. Of the 56 taxa found in the SAM trays, 29 are sessile bivalves, polychaetes, or attached species that (based on their reproductive strategies) are assumed to have settled as larvae. Of the 35 taxa found on settlement panels (tray lids), 22 are attached species, polychaetes, and bivalves that also are assumed to have settled as larvae; many of these species also occurred in the trays. Thus there is ample opportunity for passive dispersal of larvae and epibenthic ampipods throughout the closed area, and there is evidence that the initial colonization of the SAM trays and panels was not limited by the supply of colonists. The remaining 13 species from the settlement panels are mobile nudibranchs, gastropods, echinoderms, and crustaceans that may have arrived as settled larvae or crawled up the SAM structure to the panels.

Sponges were the dominant emergent colonial epifaunal taxon in the SAM trays, followed by anemones, hydroids, and bryozoans, and the colonial tube worm *F. implexa* (Table 1). This result is consistent with quantitative analysis of bottom photographs from

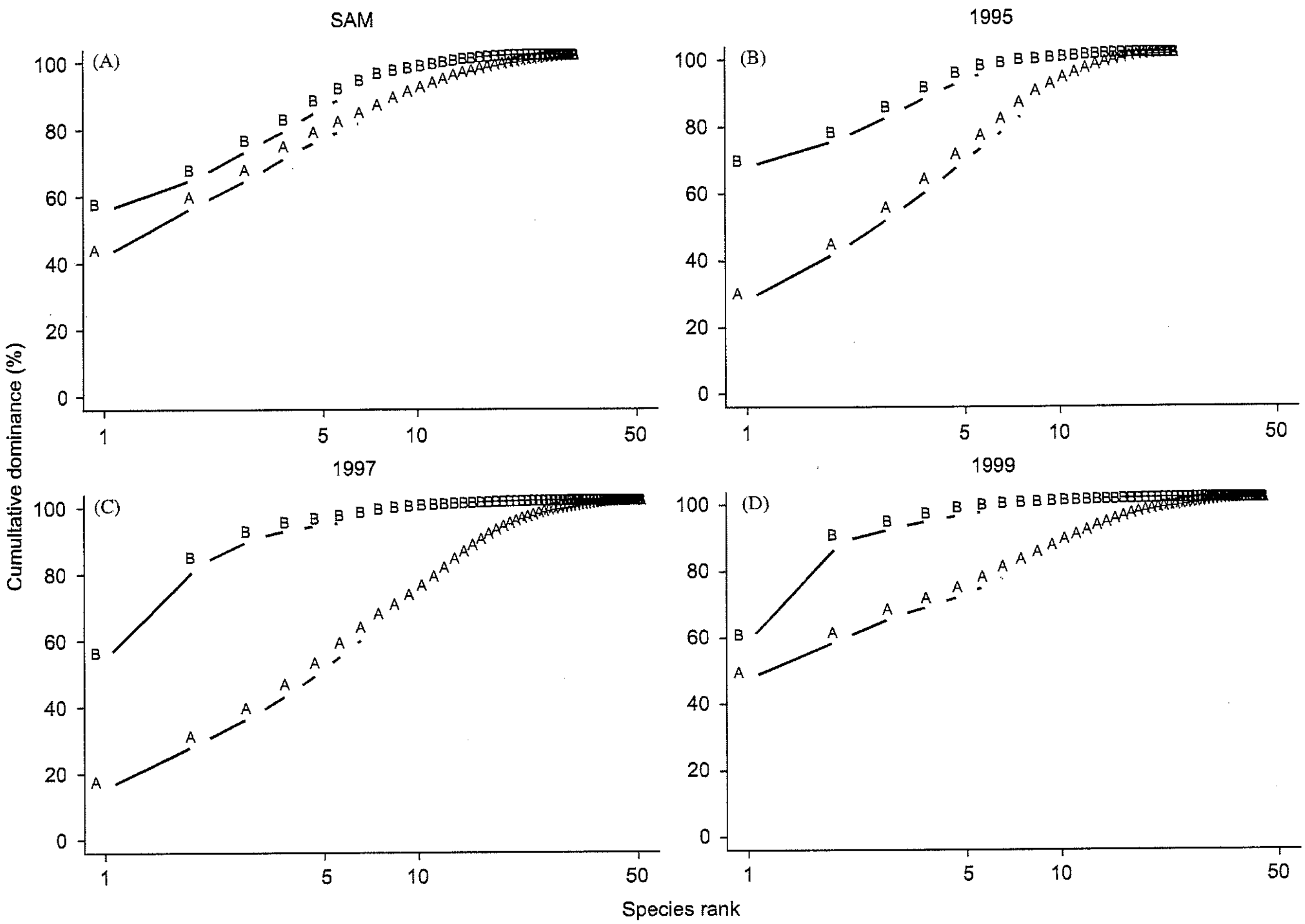

Fig. 5. Cumulative dominance curves for the SAM tray samples (Group 2 species) compared with dominance curves from dredge samples collected at Site 17 in 1995, 1997, and 1999. The species were ranked by biomass (B) and by abundance (A).

the same site, which showed a significant increase in percent cover of sponges in 1997, 1998, and 1999 following the closure of Area II (Asch and Collie, 2008). The settlement panels were densely covered with anemones, hydroids, bryozoans, and colonies of the tube worm *F. implexa*, totaling eight times more biomass than the same taxa in the trays. This shelter-giving fauna on the panels supported a higher density of non-attached animals than the gravel substrate in the trays. The community on the panels was similar to that observed in photographs of scattered boulders at our study site.

We were surprised by the low density of colonial epifauna on the tray gravel after 2 years of colonization. This lower density cannot be explained by limited larval supply given the abundant growth of epifauna on the panels. We also observed relatively little attached epifauna (apart from sponges) in bottom photographs at Site 17 in the years following the closure of Area II in late 1994 (Asch and Collie, 2008), which indicates that the lack of epifauna on the tray gravel is not an artifact of the configuration of the SAM trays. The differential success of colonization by structure-forming species on the panels and trays possibly is related to factors such as (1) possible intermittent burial of the gravel in the trays by migrating sand that inhibits survival there but not on the panels and (2) the higher success of new recruits on the panels where scavengers were much less numerous than on the gravel. The second explanation is supported by settling-panel experiments, which demonstrated that predation on post-settlement life stages impacts the recruitment of benthic species and the eventual species composition of epifaunal communities, even though predators had little effect on the adults of prey species (Osman and Whitlatch, 2004).

5. Conclusions

The SAM trays provided direct before–after evidence for recolonization of gravel habitat over a 2-year period on the outer continental shelf off New England. This experiment recorded a rapid colonization of the gravel by small animals. After the initial colonization, succession was dominated by accumulation of biomass, not by further increases in numbers of individuals. The results are broadly consistent with increases in abundance and biomass observed in dredge samples collected over a 10-year period at the same site. The tray results confirm the value of dredge samples collected over very short distances for comparative studies of benthic fauna.

The life histories of most species on the settlement panels and many species in the sediment trays suggest that recolonization of the gravel seabed is not limited by the lack of colonizing larvae. The panels and the tray gravel exhibited different proportions of some species groups. Settlement panels were rich in structure-forming species (anemones, bryozoans, hydroids, colonial tube worm) and trays were rich in scavenger species

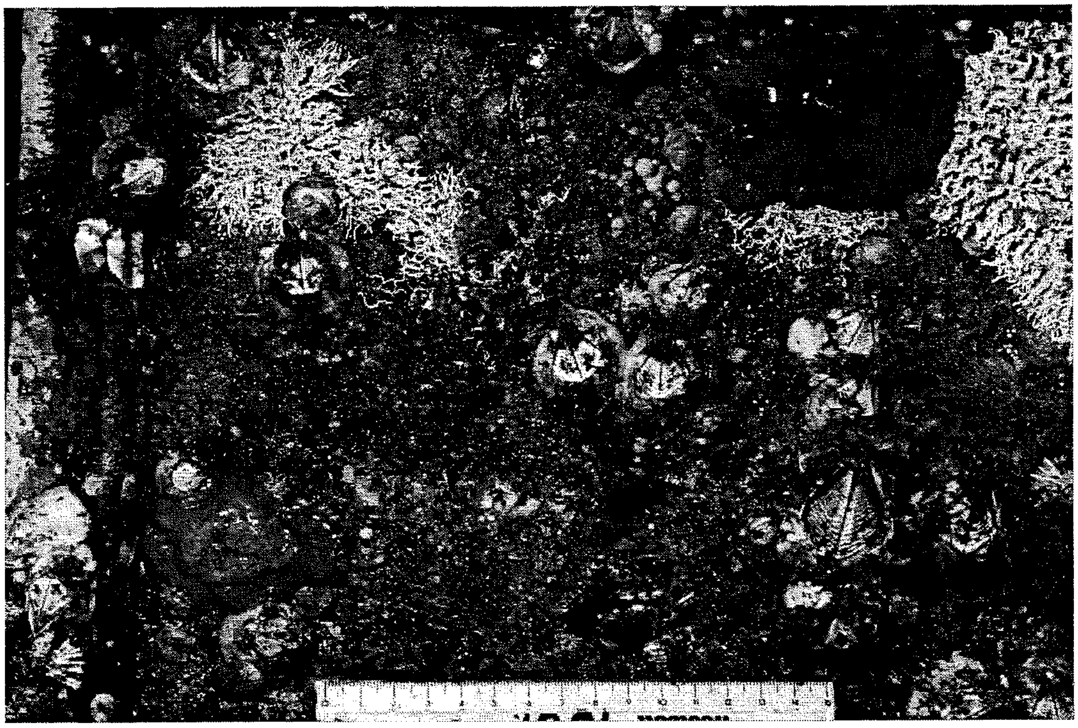

Fig. 6. Close-up of epifauna collected on the underside of one of the SAM settlement panels (tray lids) on northern Georges Bank in June 1999 after 2 years of deployment. Visible are the northern anemone, *Urticina felina*, barnacles, *Balanus* spp., hydroids, bryozoans, and the lacy tube worm, *Filograna implexa*. Scale bar is 15 cm; full dimensions of the lid are 56 cm × 56 cm. Photo credit: Dann Blackwood, USGS.

(crabs, echinoderms, gastropods, nudibranchs), suggesting that the tray environment was less favorable to structure-forming species because of the presence of scavengers and/or movement of sand over the gravel.

The closure of disturbed gravel habitats to bottom fishing can result in measurable increases in some elements of the benthic fauna. Many of these colonizing species, especially amphipods, shrimps, and crabs are important in the diets of demersal fish (Bowman et al., 2000). Protection of these habitats therefore promotes the production of prey species for fish (Hermsen et al., 2003). However, structure-forming taxa (bryozoans, sponges, hydroids, tube worms), which also play an important role in habitat function, have been less successful in colonizing the closed area, even though colonizers for this group are present in the environment.

Acknowledgements

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Semidiurnal Temperature Changes Caused by Tidal Front Movements in the Warm Season in Seabed Habitats on the Georges Bank Northern Margin and Their Ecological Implications

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Abstract

Georges Bank is a large, shallow feature separating the Gulf of Maine from the Atlantic Ocean. Previous studies demonstrated a strong tidal-mixing front during the warm season on the northern bank margin between thermally stratified water in the Gulf of Maine and mixed water on the bank. Tides transport warm water off the bank during flood tide and cool gulf water onto the bank during ebb tide. During 10 days in August 2009, we mapped frontal temperatures in five study areas along ~100 km of the bank margin. The seabed "frontal zone", where temperature changed with frontal movment, experienced semidiurnal temperature maxima and minima. The tidal excursion of the frontal boundary between stratified and mixed water ranged 6 to 10 km. This "frontal boundary zone" was narrower than the frontal zone. Along transects perpendicular to the bank margin, seabed temperature change at individual sites ranged from 7.0°C in the frontal zone to 0.0°C in mixed bank water. At time series in frontal zone stations, changes during tidal cycles ranged from 1.2 to 6.1°C. The greatest rate of change ($-2.48°C\ hr^{-1}$) occurred at mid-ebb. Geographic plots of seabed temperature change allowed the mapping of up to 8 subareas in each study area. The magnitude of temperature change in a subarea depended on its location in the frontal zone. Frontal movement had the greatest effect on seabed temperature in the 40 to 80 m depth interval. Subareas experiencing maximum temperature change in the frontal zone were not in the frontal boundary zone, but rather several km gulfward (off-bank) of the frontal boundary zone. These results provide a new ecological framework for examining the effect of tidally-driven temperature variability on the distribution, food resources, and reproductive success of benthic invertebrate and demersal fish species living in tidal front habitats.

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Introduction

Georges Bank is a large, relatively shallow offshore continental shelf feature that extends eastward from the southeastern Massachusetts coast toward the southern tip of Nova Scotia and forms the southern boundary of the much deeper Gulf of Maine (Fig. 1). It is one of the world's most productive marine ecosystems [1]. The character and function of Georges Bank benthic habitats are influenced by spatial factors of hydrographic, geologic, climatic, and anthropogenic origin [2–4], producing a patchwork of distinct habitats that contribute to overall benthic, and ultimately, fisheries production [5].

The hydrographic setting for the benthic habitats of Georges Bank results from the interaction of water masses, tides, topography, and atmospheric warming and cooling. In the warm season, shallow tidally-mixed Georges Bank Water (GBW) is bounded on the north by a 3-layer system of water masses in the Gulf of Maine that includes Maine Surface Water (MSW), Maine Intermediate Water (MIW), and Maine Bottom Water (MBW); in the cool season, MSW and MIW coalesce and form the upper layer of a 2-layer system with MBW [6]. A clockwise gyre, driven by strong semidiurnal tidal currents, and influenced by wind and neighboring water masses, surrounds well-mixed water on the top of the bank [7], [8]. High primary productivity on the bank results when nutrient-rich water from the Gulf of Maine is transported up the steep northern slope of the bank and pumped into the euphotic zone on the bank's northern margin [9–11] where it enters the gyre.

Hydrographic fronts, as detected from surface temperature gradients between water masses [visible in satellite imagery, are pervasive features of northwestern Atlantic continental margins [12], [13]. The front located along the northern margin of Georges Bank is typical of a class of tidal-mixing fronts that form at the edges of shallow banks. Turbulence generated by tidal

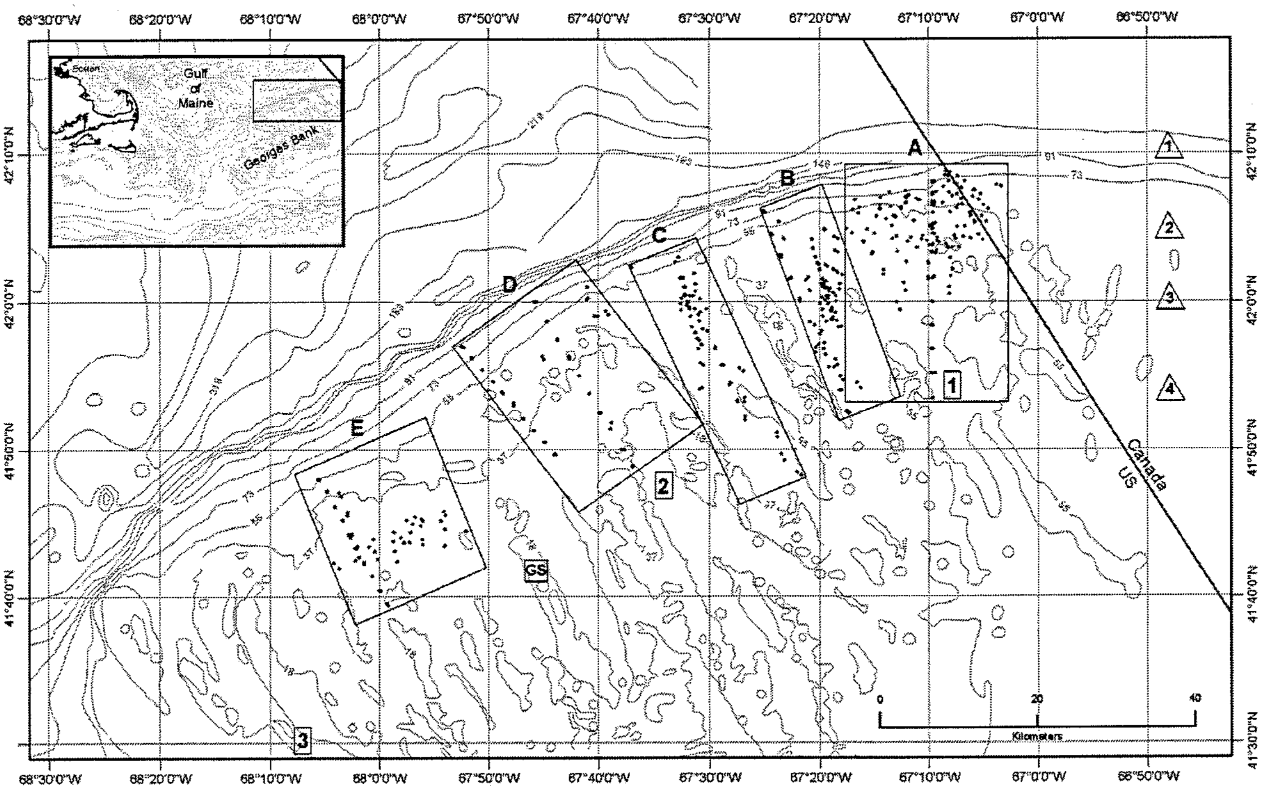

Figure 1. Map showing the location of Georges Bank (inset) and study areas. The locations of study areas A-E (boxes) and 464 seabed temperature stations (dots) occupied in the August 4–13, 2009 time period are indicated. Numbers 1–3 in rectangles mark tidal current prediction sites shown on NOAA Chart 13200 [43]. Numbers 1–4 in triangles mark locations of moored instruments of Loder et al. [18] in July 1988. GS marks location of tidal height predictions on Georges Shoal [42]. Isobaths from NOAA Chart 13200 [43] are labeled in meters.
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currents at the seabed on the bank causes mixing of the water column, enabling a front to develop between mixed and stratified water masses and guaranteeing the front impinges directly on the seabed [14–16].

The boundary between the Georges Bank and Gulf of Maine water masses is a complex frontal system, best developed in the warm season, that is continually in motion within a narrow zone along the northern topographic edge of the bank in response to semidiurnal tidal forcing [17–19]. During flood tide (into the Gulf of Maine), the front moves northward in an off-bank direction, and during ebb tide, it moves southward in an on-bank direction. The semidiurnal tide causes 2 high and 2 low tides per tidal day of 24.83 hr [20], which result in marked changes in seabed water temperature four times a day in the study region. In this study, the term "frontal zone" describes the area of the seabed where the water temperature is changed by tidal movement of the front. The term "frontal boundary zone" describes the area swept by tidal movement of the transitional boundary between stratified and mixed water. The area of the frontal zone is larger than that of the frontal boundary zone. The front is particularly well developed during the summer and early fall when temperature gradients are largest between warm, well-mixed Georges Bank Water and cold, stratified Maine Intermediate Water [18], and when the bank's gyre circulation is most rapid [21]. The intensity, persistence, and extent of this summer front are evident in satellite thermal imagery [12].

There is a substantial history of effort to understand circulation over the entirety of Georges Bank through hydrographic modeling [22], [23]. The most recently published *in situ* measurements and analyses of tidal front temperature phenomena on the northern margin of the bank have been made in Canadian waters [18], [19], [24], [25], where the bathymetry is somewhat deeper than in U.S. waters (see Figure 1 for locations of study sites of Loder et al., [18]). On the shallower and larger U.S. portion of the bank margin, published hydrographic data that describe the front's temperature structure apparently are limited to one time-series station from October 1978 [26].

Tidal hydrology and circulation patterns influence the ecology of the bank and play a role in nutrient supply and primary production [27–29] and in the distribution of holozooplankton and larvae [26], [30–34]. In the area of the northern bank margin affected by the movement of the front, seabed temperature at an individual seabed site was reported to change 6 to 7°C from high to low tide and temperature rates of change were as large as 4°C hr^{-1} [26]. The influence of rapid cyclic temperature changes on benthic communities of the bank and on the demersal fishes they support is unknown.

Several tidal fronts located in the coastal seas of northern Europe are similar to the northern Georges Bank front and have been studied extensively [35], [36]. These fronts have been shown to coincide with changes in the distributions of bivalve species [37], epibenthic invertebrates and fish [38], and sediment texture and sedimentary processes [39]. Elements of the benthic and

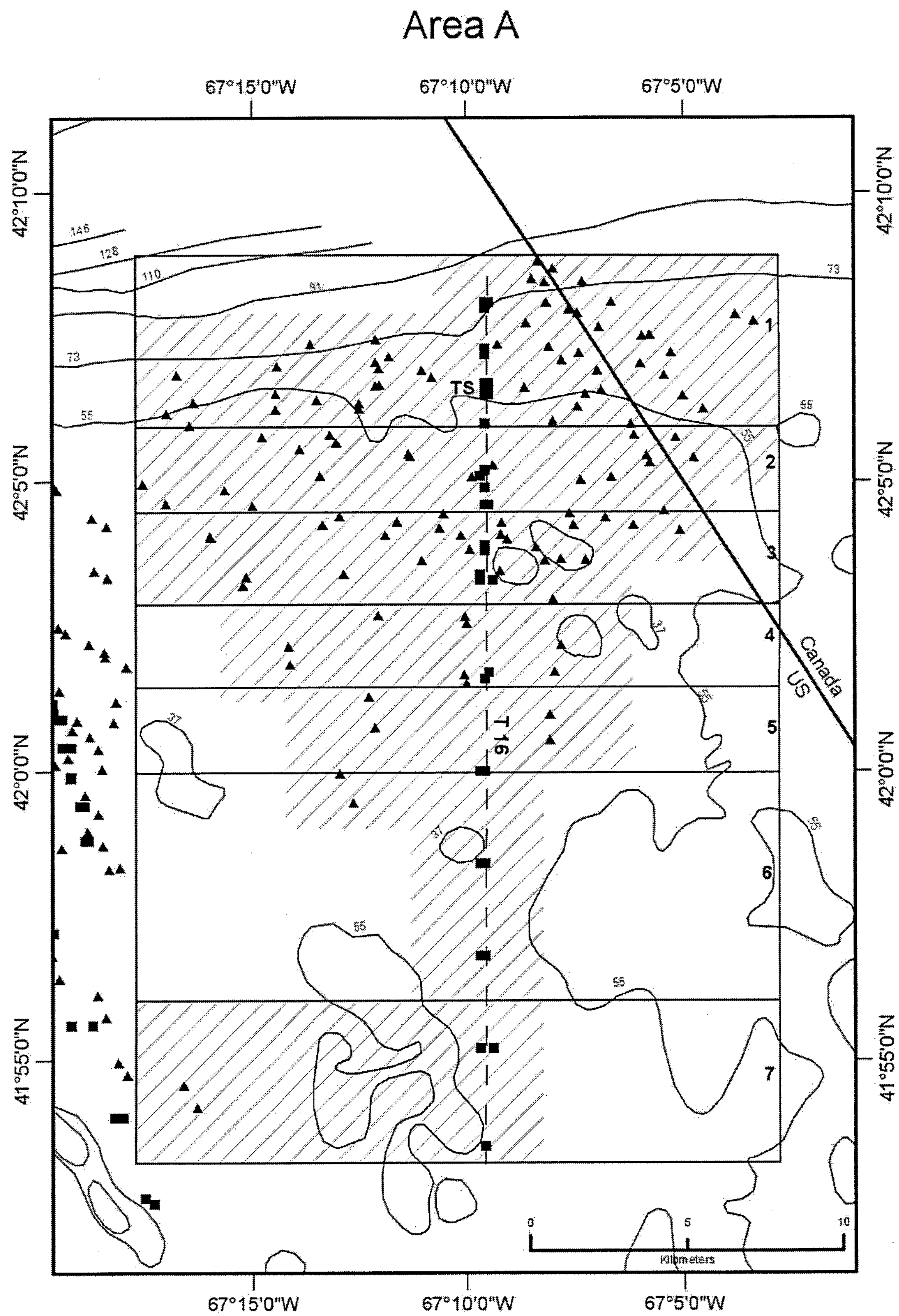
Area A
67°15'0"W
67°10'0"W
67°5'0"W
42°10'0"N
42°5'0"N
42°0'0"N
41°55'0"N
TS
T16
Canada
US
1
2
3
4
5
6
7
146
128
110
91
73
55
37
0
5
10
Kilometers

Figure 2. Detail map of study area A showing subareas and seabed temperature stations. Data was obtained from the northern margin of Georges Bank in August 2009. Subareas 1–7 of are shown as boxes subdividing the larger area A box, labeled just inside their right (eastern) margin. Dashed line is path of CTD transect 16 that was sampled around high and low tides (Fig. 7A, Table 1). TS is the site of time-series station (Fig. 8, Tables 3, 4). Hachures show distribution of temperature data used to characterize the effect of frontal movement in each subarea (Fig. 11, Table 5). Black squares are hydrocast temperature observations on transects and at time-series stations. Black triangles are temperature observations at the starts and ends of video drift stations. Isobaths from NOAA Chart 13200 [43] are labeled in meters.
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demersal faunas have been shown to be enriched in the immediate vicinity of the fronts [38], [40]. However, the tidal-mixing fronts in northern Europe have been treated as quasi-fixed features, and there has been little documentation of their semidiurnal tidal motions [41] or of the biological consequences of such movements. In contrast, the semidiurnal dynamism of the Georges Bank front has been a focus of previous studies but restricted to a small area only ([18]: Fig. 1). Here we expand on those studies to document frontal movement and attendant temperature changes along ~100 km of the bank's northern margin habitats.

The purposes of the present study are to quantify and map temperature changes at the seabed in U.S. waters on the northern margin of Georges Bank caused by movement of a strong semidiurnal tidal front in the warm season; to discuss the potential for applying these results to the study and management of the productive fisheries species and habitats located there; and to provide *in situ* temperature data that can be used to calibrate models of hydrodynamic processes in the frontal zone.

Methods

1. Ethics Statement

The field work reported herein and the use of ship time to perform it were authorized by Dr. Nancy B. Thompson, Science and Research Director of the National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service, Northeast Fisheries Science Center (NEFSC) and Captain Emily Christman, Commanding Officer, NOAA Marine Operations Center-Atlantic through written approval of a detailed cruise plan prior to departure. The work was also undertaken with the knowledge of Dr. William Schwab, Chief Scientist, U.S. Geological Survey Woods Hole Science Center. All sampling was performed within the U.S. and Canadian Exclusive Economic Zones (EEZs), but outside the waters of all States, Provinces and marine sanctuaries. Entry into and sampling within the Canadian EEZ was authorized specifically for this cruise by the government of Canada via an application process through the U.S. Department of State. Shipboard operations were conducted in accordance with NOAA and NEFSC protocols, which incorporate the U.S. Government's Code of Environmental Management Principles (CEMP) for pollution prevention. Protocols to limit impacts from sampling, ship's acoustic emissions, and unintentional encounters with protected species were reported to and reviewed by U.S. Environmental Protection Agency (EPA) under an Environmental Assessment (EA) process for the larger NEFSC shipboard sampling program. The work reported upon here involved no intentional take of organisms and minimal disturbance of physical habitats. All raw hydrographic data collected during in the course of this work is available at this address: http://www.nefsc.noaa.gov/epd/ocean/MainPage/ioos.html. To access the data, select "Water Column Properties"/"By Cruise ID"/"DEL0908-05-AUG-2009".

2. Study Sites

All field data presented here were collected from August 4 to 13, 2009 during cruise DE09-08 aboard NOAA Fisheries Vessel *Delaware II*. Sites were located along the northern margin of the U.S. sector of Georges Bank in areas where studies of fisheries habitats are in progress (Fig. 1). Substrates in the study region are dominated by sand and gravel, with extensive gravel pavements separated by sand ridges which are oriented northwest-southeast, parallel to the strongest tidal flow. At present, habitat research is focused in study areas A, B, and C in the east, and more temperature data were collected there than in areas D and E where study is just commencing. Hydrographic transects were positioned in each study area so as to lie parallel to the movement (on-bank and off-bank) of the major semidiurnal tidal current and transverse to the orientation (along-bank) of the associated semidiurnal tidal front. Sites of additional temperature observations were selected based on the need to image and sample the seabed for habitat studies. Sample sites lie in water depths of 27 to 94 m, and the 5 study areas are located along approximately 100 km of the bank margin which trends northeast-southwest in the study region. Ship and station positions for all data collected on the cruise were recorded using Global Positioning System (GPS) with an accuracy of approximately 12 m.

Meteorological observations taken during the cruise indicated that weather was not a major influence on hydrographic conditions. No storms occurred on Georges Bank, and based on 10-minute averages of true wind velocities, mean wind velocity was $4.77\ ms^{-1}$ ($SD = 1.92\ ms^{-1}$), with a maximum value of $10.06\ ms^{-1}$ (moderate breeze on the Beaufort scale). Wind direction showed no dominant heading. Tidal height predictions for Georges Shoal ([42]: Fig. 1) suggested relatively uniform tidal forcing with an amplitude of approximately 1.2 (±0.1) m over the period of this study. That period (August 4–13, 2009) missed spring and neap variations in tidal amplitudes (up to ±0.5 m) predicted for later in the month.

3. Choice of Biologically Relevant Data

Our goal has been to identify patterns of ecological data that are relevant to the management of demersal fisheries on Georges Bank. The entire range of salinity measured via vertical CTD casts in our study areas was 31.66 to 33.06 psu (n = 22,356 measurements). The small variations within these limits are not likely to have appreciable influence on distribution and behavior of demersal species. By contrast, seabed temperature values within the same dataset ranged from 5.1° to 16.4°C, a very large span in physiological terms. We have chosen to evaluate patterns in the distribution and dynamics of seabed temperature exclusively in the current work. Temperature data recorded at sites along near-synoptic CTD transects across the tidal front and at time-series stations in the frontal zone are sufficient for mapping the broad areal patterns of tidally-influenced seabed water temperature changes in which we are interested. They do not allow the mapping of the very high-frequency temperature fluctuations known to characterize the water column of the frontal system [18].

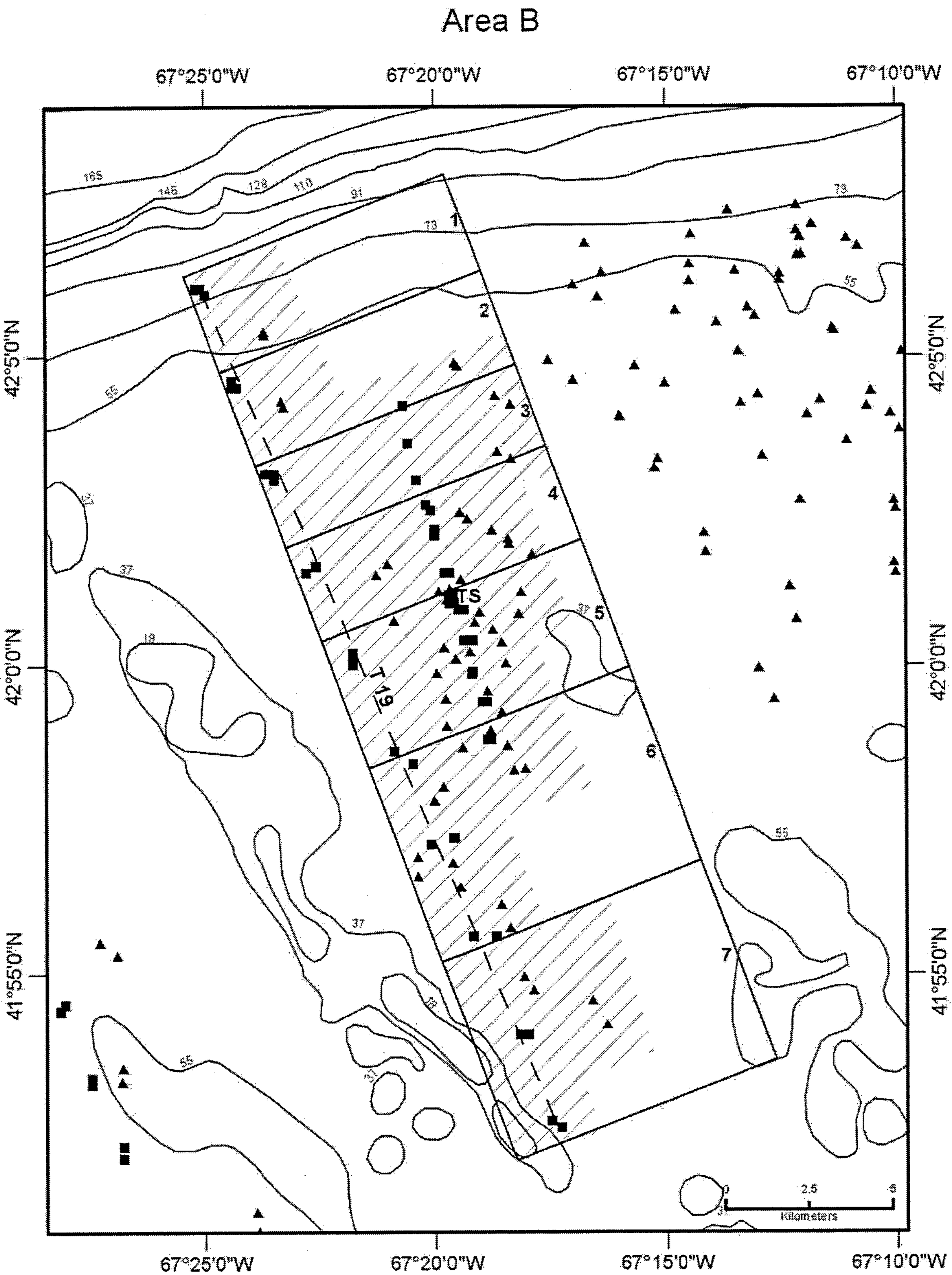

Figure 3. Detail map of study area B showing subareas and seabed temperature stations. Data were obtained from the northern margin of Georges Bank in August 2009. Subareas 1–7 are shown as boxes subdividing the larger area B box, labeled just inside their right (northeastern) margin. Dashed line is path of CTD transect 19 that was sampled around high and low tides (Fig. 7B, Table 1). TS is the site of time-series station (Fig. 8, Table 3). Other symbols and depth contours are as in Fig. 2.
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Area C

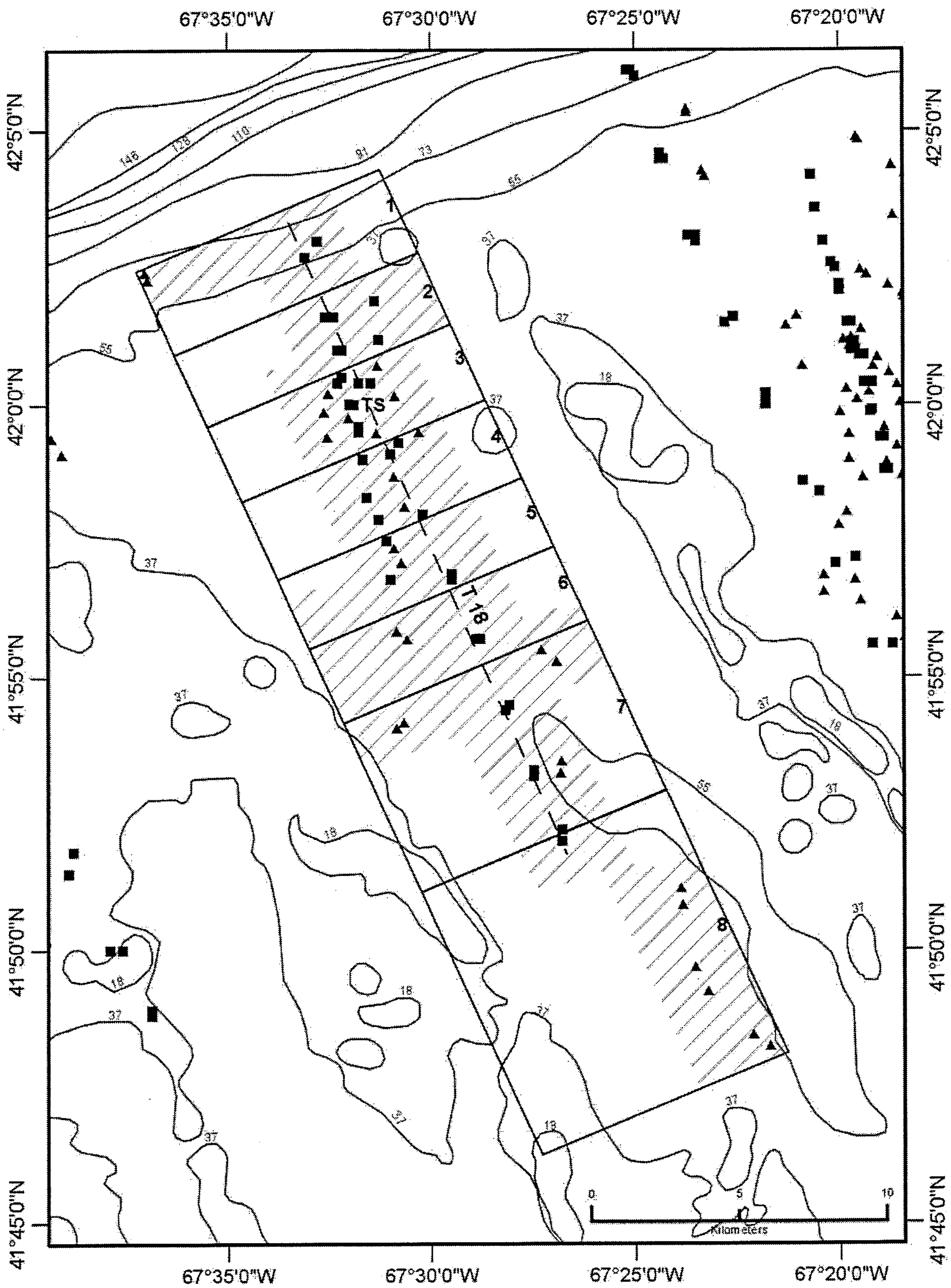
67°35'0"W
67°30'0"W
67°25'0"W
67°20'0"W
42°5'0"N
42°0'0"N
41°55'0"N
41°50'0"N
41°45'0"N
146
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Figure 4. Detail map of study area C showing subareas and seabed temperature stations. Data were obtained from the northern margin of Georges Bank in August 2009. Subareas 1–8 of are shown as boxes subdividing the larger area C box, labeled just inside their right (northeastern) margin. Dashed line is path of CTD transect 18 that was sampled around high and low tides (Fig. 7C, Table 1). TS is the site of time-series station (Fig. 8, Table 3). Other symbols and depth contours are as in Fig. 2.
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4. The Timing of High and Low Tides in the Study Areas

Investigation of the internal temperature structure and movement of the tidal front on the northern margin of Georges Bank requires knowledge of the timing of high and low tides in the study areas in order to determine when to sample the water column. At three locations in the study region, NOAA Chart 13200 displays a diagram showing 12 vectors that represent the direction and velocity of tidal currents at hourly intervals ([43], Fig. 1). The predicted times of high and low tides (slack water) are represented by the shortest tidal current velocity vectors on these diagrams. The actual time of each hourly vector shown in the diagrams is related to the time of maximum flood tide at Pollock Rip Channel (east end) near Cape Cod [44]. For example, on a given day at location 1 (Fig. 1), high tide and low tide occur 5.0 and 11.0 hours, respectively, after the time of maximum flood tide at Pollock Rip Channel. At location 2, the equivalent high and low tide times relative to Pollock Rip Channel are 4.5 and 10.5 hours and at location 3, 4.0 and 10.0 hours. This information was used to construct tables of high and low tide times for use in the field and later for determining the time before or after high tide of each temperature observation.

5. Vertical Temperature Profiles Collected Along Transects Across the Tidal Front

Water column properties were collected across the front in 5 study areas on the northern margin of the bank (Fig. 1) using a Seabird Electronics® SBE Model 19+ profiling CTD deployed vertically from the ship by a conducting hydrographic wire. The instrument was lowered to approximately 1 to 5 m above the seabed and retrieved at a rate of approximately 0.8 m s^{-1} second while recording the water conductivity, temperature, and depth (CTD). Data were collected at a rate of 2 observations per second during retrieval (upcast) of the profiler. The sensors in the profiler recorded temperature to an accuracy of 0.0001°C and depth to an accuracy of 0.001 m. The maximum water depth at a station was recorded by the ship's Simrad® EK60-120 kHz echo sounder to an accuracy of 0.01 m.

CTD profile stations were located along transects oriented normal (north-south or northwest-southeast) to the trend of the shelf edge so as to obtain data for constructing temperature sections across the front (Figs. 2,3,4,5,6). Individual casts were made at spatial intervals ranging from 2 to 3 km, depending upon transect length, and timed around predicted times of local high and low tides (Fig. 7). Along each transect, two casts (paired stations) were completed at each site during a 12-hour period to document the frontal temperature structure around the predicted times of high and low tides. Additionally, in each of the 5 study areas, during the interval between flood and ebb tide passes, a time series of CTD casts was performed on an hourly or half-hourly basis (Fig. 8) at a station located on or near transects T16, T18, T19, T23, and T24 to record the temperature structure of the front as it moved past the location (Figs. 2,3,4,5,6).

CTD stations on a transect could not be performed simultaneously at the time of the predicted high or low tide. Transects were completed as rapidly as possible, and with the exception of 1 station on transect 16 in study area A and 5 stations on transect 19 in study area B, all CTD casts associated with flood and ebb tide passes were made within 100 minutes of the predicted times of slack tidal currents. Flood tide passes along transects were begun at their northernmost (off-bank) ends, starting 90 min prior to predicted slack high water. Sampling proceeded southward from there as the front completed its northward (off-bank) movement. Ebb tide passes were begun at the southernmost (on-bank) ends of transects, starting 90 min prior to predicted slack low water, and sampling proceeded northward as the front completed its southward (on-bank) movement. Six transects that included both a flood and ebb tide pass were completed in study areas A (T16), B (T19), C (T18), D (T22, T23), and E (T24). In all, 216 CTD stations were completed in the 5 study areas (A-E) along the northern margin of the bank in water depths ranging from 32 to 94 m during a 9-day period from August 5 to 13, 2009.

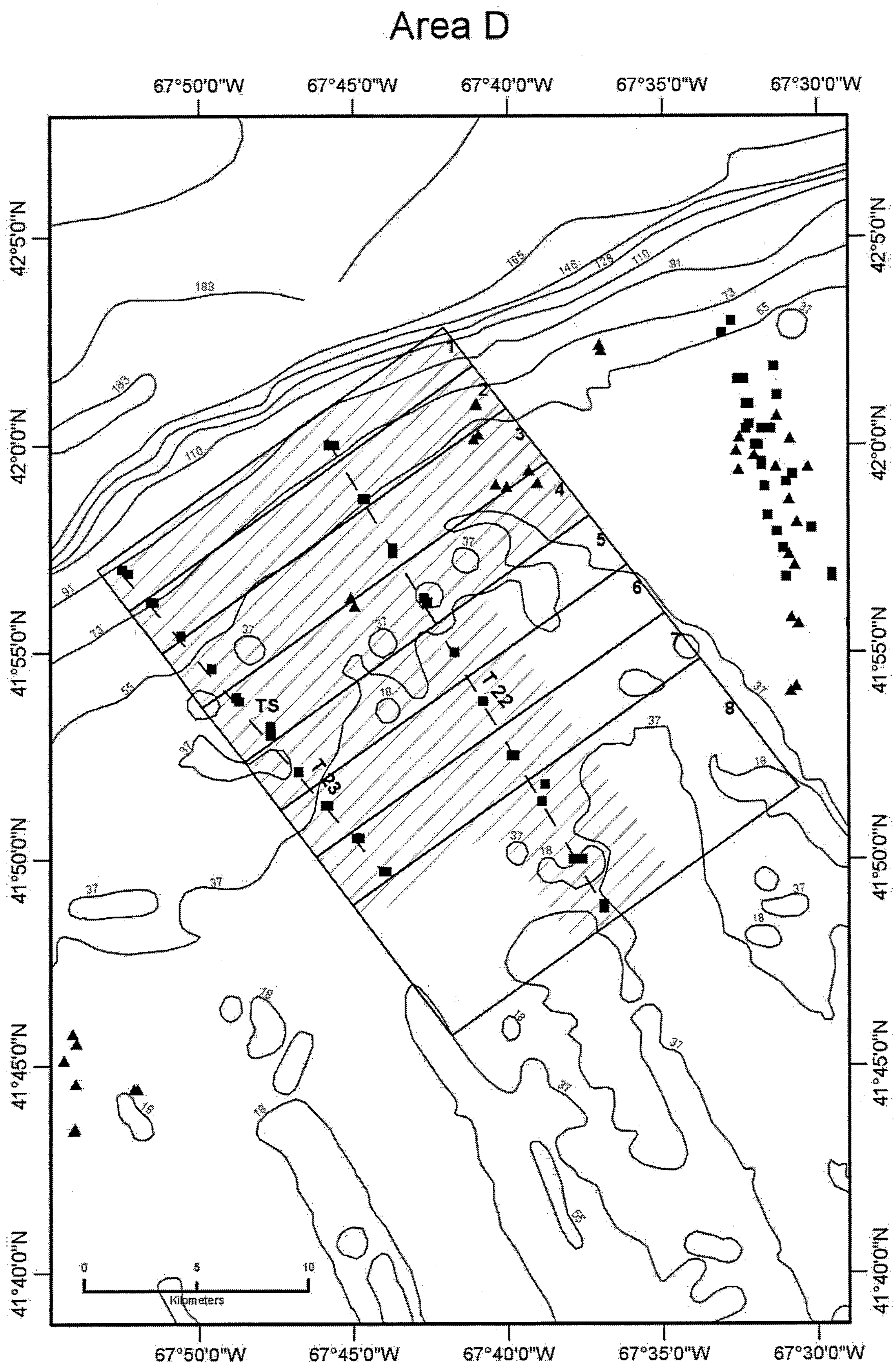
6. Analysis of the Temperature Structure and Movement of the Tidal Front

At each CTD station, temperature data were collected from the maximum depth of the instrument (1–5 m above the seabed) to the sea surface. After inspection, data from shallower than 1 m below the sea surface were considered to be unreliable and discarded. The temperature structure of the tidal front along each transect at approximately flood and ebb tides was mapped by using Surfer® software (Golden Software, Inc.) to contour temperature data collected at individual stations by water depth and distance between stations (Fig. 7A-F). Movement of the front during sampling along a transect caused unavoidable minor distortion in the contoured temperature data. The changing temperature structure of the front with time at a single location during ebb and flood tides was mapped by contouring temperature data collected multiple times from that location by water depth and time (Fig. 8). These temperature contour plots show water column structure (stratified or mixed), frontal movement on and off the bank, and variation in seabed temperature at individual locations in the frontal zone.

7. Temperature Data Collected on Seabed Video Transects

Seabed water temperature data were collected using a Seabird Electronics SBE Model 19 profiling CTD attached to the USGS' Seaboss (seabed observation and sampling system [45], which was used to collect photographs and video imagery while drifting over the seabed in the study areas. The Seaboss and CTD were lowered from the ship to a depth approximately 1 m above the seabed, and water conductivity, temperature, and depth (CTD) data were collected during the entire track of each video drift, which ranged in length from 117 to 2664 m. Data were collected at a rate of 2 observations per second and were downloaded from the profiler after recovery. The sensors in the profiler aboard Seaboss were the same as those for the CTD used for vertical casts (Results section 4.). The maximum water depth at a station was recorded by the ship's Simrad EK60-120 kHz echo sounder to an accuracy of 0.01 m.

Temperature observations were collected in five study areas (A-E) along the northern margin of the bank in water depths ranging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41°45'0"N
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Figure 5. Detail map of study area D showing subareas and seabed temperature stations. Data were obtained from the northern margin of Georges Bank in August 2009. Subareas 1–8 are shown as boxes subdividing the larger area D box, labeled just inside their right (northeastern) margin. Dashed lines are paths of CTD transects 22 and 23 that were sampled around high and low tides (Figs. 7b D and E, Table 1). TS is the site of time-series station (Fig. 8, Table 3). Other symbols and depth contours are as in Fig. 2.
doi:10.1371/journal.pone.0055273.g005

from 27 to 87 m during a 10-day period from August 4 to 13, 2009 (Figs. 2,3,4,5,6). Seabed temperature observations (248 in all) collected at the end of the descent and the beginning of the ascent of the Seaboss supplemented those collected by 216 CTD casts. Temperature data collected at the seabed along Seaboss drift tracks were plotted by temperature and drift time to determine if high-frequency temperature changes were present that would suggest the presence of turbulent mixing in the frontal zone (Figs. 9, 10).

8. Analysis of Seabed Temperatures in Subareas of the Tidal Front Region

We hypothesized that the magnitude of temperature change at the seabed caused by tidally-driven frontal movement would vary with location in the frontal zone. For purposes of identifying this cross-frontal pattern, we initially divided each study area (A-E) into subareas of equal length (2.8 km) along the axis perpendicular to the front. An inspection of the distribution of our sampling points (Fig. 1), the temperatures observed at sites within each subarea, and subsequent plotting of these temperatures relative to their time of occurrence during flood and ebb tides (Fig. S1A-E), enabled us to identify and map geographic subareas within study areas A-E (Figs. 2,3,4,5,6) that experienced differing ranges of temperature change during movement of the front.

Results

1. Water Column Temperature Structure of the Tidal Front at High and Low Tides

Contoured water column temperature data, collected at 2- to 3-km intervals along 6 transects across the northern bank edge, revealed the complex stratified structure of the tidal front (Fig. 7A-F). Stratification along transects was most pronounced at low tide when the front was at its maximum on-bank location. In the frontal zone, isotherms were primarily horizontal near the surface and more nearly vertical at depth. Near the off-bank end of most transects, upward-arching isotherms represented the advance and retreat of relatively cold stratified water from the Gulf of Maine onto the bank; and isolated patches of cold water were bounded on both sides by slightly warmer water at the seabed. The temperature of the water column varied as much as 12°C (6–18°C) from seabed to surface (Fig. 7A). At the on-bank ends of transects, the front was undetectable, the water column was well mixed, and widely-spaced near-vertical isotherms ranged from 14 to 16°C. The leading edge of the front, the frontal boundary, was represented by the location of near-vertical isotherms that separated stratified off-bank water from mixed on-bank water. Individual isotherms that intersected the seabed within the frontal boundary zone moved 6 (Fig. 7A, B) to 10 km (Fig. 7D) between high and low tides.

Some transect stations were located in the frontal zone, and others were located at all times in mixed bank water and were minimally affected by changes in temperature between tides (Fig. 7A-F). We differentiated seabed stations that were thermally affected by movement of the front from those that were not by comparing changes in temperature at paired stations at high and low tides along each transect. As we are interested in the potential effects of temperature and temperature variability on the biota, for the purpose of this study we classified those stations having a flood- vs. ebb-tide temperature difference of >1°C as being affected by the front (Table 1, S1). Other observers may select different criteria for classifying the stations, depending on their research goals. Using our definition, 5 of the 6 transects (T16, T18, T19, T22, T24) collected samples across the frontal boundary at high and low tides (Figs 7a A-C, 7b D, F). Transect T23 sampled only within the frontal zone, as the most bankward station pair (172 and 177) had a flood- vs. ebb-tide temperature change of 1.1°C (Figs. 5, 7b E, Table 1). The high- vs. low-tide temperature change at the most-affected pair of sites on each transect ranged from 3.7°C in area E to 7.0°C in area D (Table 1).

Seabed temperature change with distance (C km^{-1}) along the parts of transects affected by the front in areas A-E averaged 0.22 to 0.50°C km^{-1} at high tide and 0.37 to 0.55°C km^{-1} at low tide (Tables 2, S2). Along parts of transects in mixed water not affected by the front, temperature change averaged 0.00 to 0.07°C km^{-1} at high tide and 0.07 to 0.12°C km^{-1} at low tide). The rate of temperature change (°C km^{-1}) in each area was consistently greater at low tide than at high tide.

2. Water Column Temperature Structure at Single Sites during Tidal Flow

Time series temperature data were recorded at 5 sites in study areas A-E, each located in the frontal zone on or close to a CTD transect that crossed the tidal front (Figs. 2,3,4,5,6). Water column temperature data collected periodically at each site were used to determine: a) the minimum and maximum seabed temperatures observed; b) the temperature change with time (°C hr^{-1}) at that location; and c) the residence time on the bank of cold off-bank water. The 5 time series included observations collected over periods of 8.8 to 12.2 hr (Fig. 8, Table 3). The longest time series is in study area A, and it best represents the temperature effect caused by frontal movement over the seabed.

Temperature values at the seabed were closely correlated with tidal movement. At all 5 sites, minimum and maximum temperatures occurred at low and high tide, respectively, coincident with on-bank flow of cold gulf water during ebb tide and the off-bank flow of warm bank water during flood tide. Temperature change at the sites during the observation period ranged from 1.2 to 6.1°C and was determined by the site's location in the frontal zone (Figs. 2,3,4,5,6). Time-series sites in study areas A, C, and D were most affected and recorded temperature changes of 5.1, 4.8, and 6.1°C, respectively; sites in study areas B and E were least affected and recorded temperature changes of 2.1 and 1.2°C, respectively (Table 3).

As expected, seabed temperature did not change uniformly with time (°C hr^{-1}) as the tidal front moved across a site. In general, the most rapid rates of temperature change occurred in the middle part of ebb and flood flow when tidal current speeds were predicted to be highest [43]; and the slowest rates of temperature change occurred at high and low tides (slack water) when frontal movement was minimal. At the time-series site in study area A, seabed temperature rate of change (a decrease) was greatest

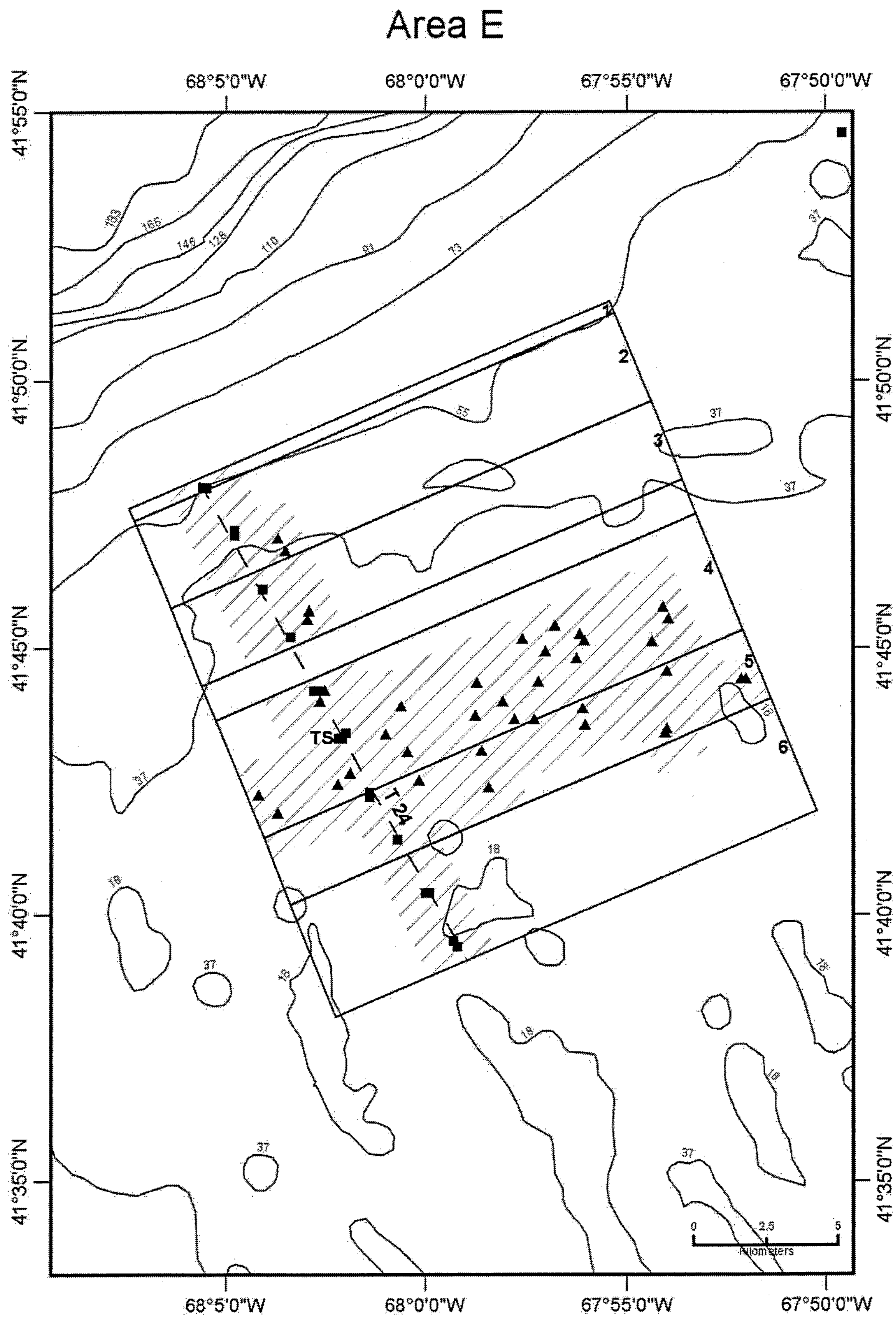
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Figure 6. Detail map of study area E showing subareas and seabed temperature stations. Data were obtained from the northern margin of Georges Bank in August 2009. Subareas 1–6 are shown as boxes subdividing the larger area E box, labeled just inside their right (northeastern) margin. Dashed line is the path of CTD transect 24 that was sampled around high and low tides (Fig. 7F, Table 1). TS is the site of time-series station (Fig. 8, Table 3). Other symbols and depth contours are as in Fig. 2. Data was insufficient to characterize the un-numbered subarea between subareas 3 and 4.
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(-2.48°C hr^{-1}) approaching mid-ebb flow and then decreased to almost nil (-0.03°C hr^{-1}) at low tide (Fig. 8, Table 4). During the subsequent flood tide, the maximum rate of temperature change (an increase) approaching mid flood was much lower (1.14°C hr^{-1}). At this site, within a period of approximately 3 hours that included low tide, seabed temperature varied only 0.8°C (6.1 to 6.9°C). Inspection of the time-series temperature-contour plots (Fig. 8) indicates that seabed temperature on the bank changed <1°C in areas A-C during the 3-hour period that bracketed low tide when cold off-bank water was present.

3. Short-term High-frequency Temperature Fluctuations

The CTD data collected between the starts and ends of Seaboss video drifts were not used in mapping the broad-scale effects of frontal movement on seabed temperature in the study region, our interest here. However, these data include phenomena that cannot be observed in CTD profiles of the water column, and examples of them are shown here to illustrate some of the fine-scale hydrographic complexity of the frontal structure. The video drift data need to be viewed with some caution as they represent records collected from a moving vehicle (25–100 cm s^{-1}).

In warm well-mixed water in on-bank subareas (Fig. 9A), temperature patterns showed <0.1°C overall temperature change, and included high frequency fluctuations of <0.01°C with periods of <2 s. Within an hour of low tide (slack water), in both off-bank and on-bank subareas (Fig. 9B), small temperature changes were observed that ranged up to 0.02°C with periods up to 10 s. Within the 2- to 5-hour period bracketing high tide, large variations in temperature were recorded in off-bank subareas (Fig. 9C). Temperature fluctuations had amplitudes of up to 0.1°C and periods of up to 10 s, and overall temperature changes ranged up to 0.5°C, with rates of up to 2°C hr^{-1}. In off-bank subareas,

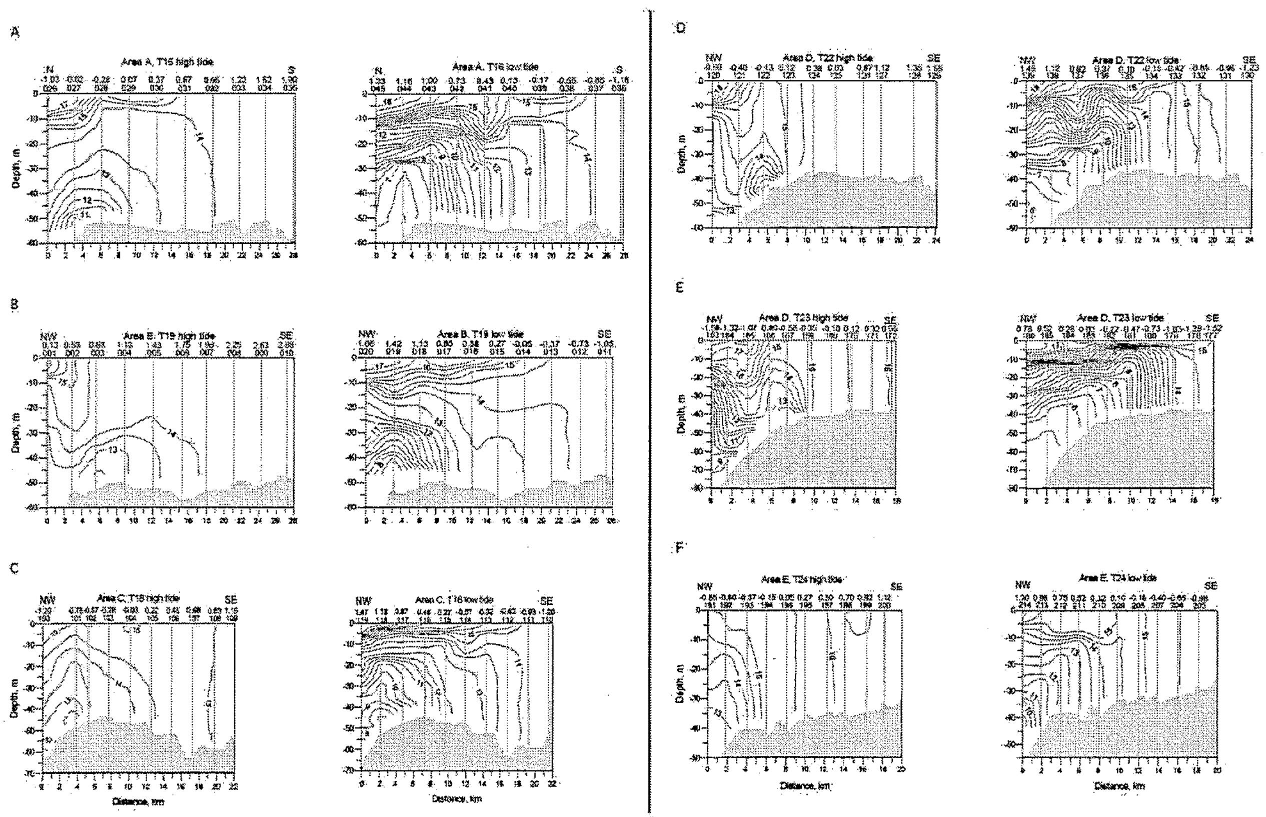

Figure 7. Water-column cross sections along CTD transects in study areas A-F. Data were obtained from the northern margin of Georges Bank in August 2009 (Figs. 2,3,4,5,6). Stations were occupied in numerical order, from off-bank to on-bank around high tide and from on-bank to off-bank around low tide. Temperature contour interval is 0.5°C. All sections are oriented from N or NW (left, off bank) toward S or SE (right, on bank). Numbered vertical lines represent CTD temperature profile stations. Depth of deepest station is not shown when results of contouring were unreliable due to a large change in depth of seabed between some off-bank stations. See Table S1 for station depths. Numbers above station numbers indicate times of temperature observations in hours before (-) and after (+) high tide or low tide, depending on which tide is represented.
doi:10.1371/journal.pone.0055273.g007

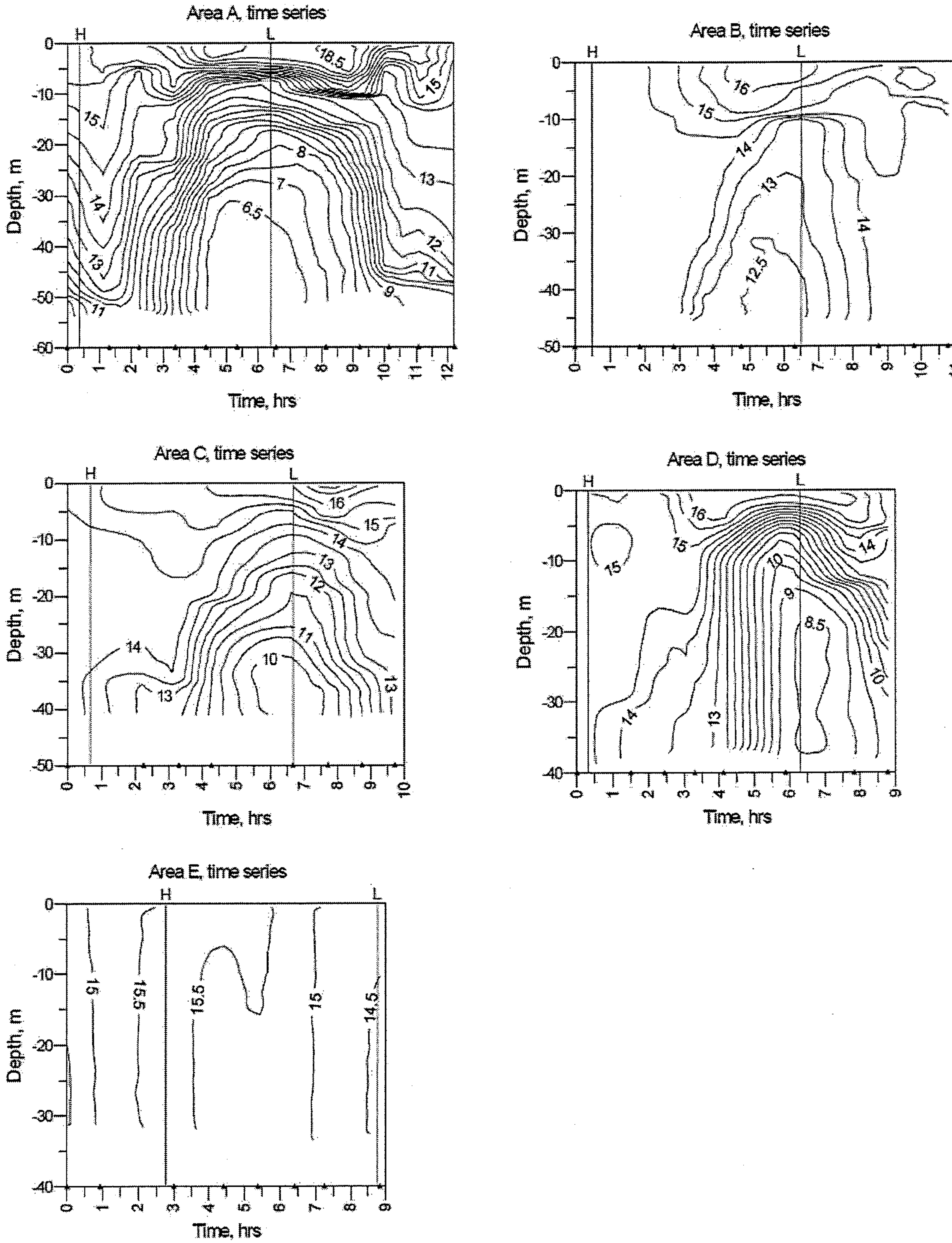

Figure 8. Water-column cross sections at CTD time-series sites in study areas A-E. Data were obtained from the northern margin of Georges Bank in August 2009 (Figs. 2,3,4,5,6). Observations were made over time periods of 8.8 to 12. 2 hr (Tables 3, 4). Temperature contour interval is 0.5°C. Vertical lines represent time of high (H) and low (L) tide. Black triangles on the x-axis indicate times of temperature observations after start of time series.
doi:10.1371/journal.pone.0055273.g008

Table 1. Water depth, seabed temperature, and temperature change along transects across the tidal front.

Location	Stations		Seabed temperature °C			Frontal influence
Area, Transect	Pair groups	Depth range, m	H Temp Range	L Temp range	H-L ΔT	(Y/N)
A, T16	1–6	51–81	9.8–13.6	5.8–12.4	1.2–4.3	Y
	7–10	52–59	14.0–14.2	13.4–14.1	0.0–0.6	N
B, T19	1–3	51–82	9.5–13.2	6.1–9.5	2.9–6.1	Y
	4–10	47–57	12.8–14.3	12.3–14.2	0.1–0.7	N
C, T18	1–8	43–68	11.2–15.0	7.2–13.8	1.2–4.4	Y
	9–10	52–60	15.0	14.1–14.4	0.6–0.9	N
D, T22	1–7	37–88	11.2–15.0	7.2–13.8	1.2–4.4	Y
	8–10	37–45	15.7	15.1–15.7	0.0–0.6	N
D, T23	1–10	37–94	7.2–16.0	5.1–14.9	1.1–6.3	Y
E, T24	1–6	37–60	12.1–15.6	8.4–14.4	1.2–3.7	Y
	7–10	32–35	15.8–16.4	14.8–15.7	0.6–1.0	N

Temperature change from high to low tide is shown for the parts of transects where seabed temperature is influenced (Y) or not influenced (N) by frontal movement. Station pair groups (column 2) are numbered in each area from north to south (1–10; i.e. off-bank to on-bank). Each pair group contains up to 8 pairs of CTD stations, at which temperature was recorded at high or low tide. H Temp and L Temp are the ranges of seabed temperatures within the pair group measured at high and low tide, respectively. H-L ΔT is the range of temperature differences between high and low tides at stations within the pair group. This value is the criterion on which frontal influence is based. If the minimum value for H-L ΔT is >1.0°C, the pair group is considered influenced by frontal movement. Note that all station pairs in area D, Transect 23 were influenced. Area names (A-E) are as in Figure 1; names of transects (TXX) across the tidal front are as in Figures 2,3,4,5,6. See Figure 7 for locations of individual stations along CTD transects. Table S1 includes data for all 60 station pairs.

doi:10.1371/journal.pone.0055273.t001

several patterns of rapid temperature fluctuations occurred, including single rapid changes, up to 0.6°C in 0.2 min (Fig. 10A); and multiple saw tooth fluctuations of temperature in rapid succession, some up to 0.3°C in 4 to 5 min (Fig. 10B), and some up to 2–3°C in 6 min (Fig. 10C).

4. Areal and Temporal Distribution of Seabed Temperatures Below the Tidal Front

Variation in seabed temperatures in study areas was chiefly in on- and off-bank directions (parallel to tidal flow and frontal movement). Temperature data collected at sites along transects, at time-series sites, and from the starts and ends of Seaboss video drift deployments were not evenly distributed within the study areas (Fig. 1). Nevertheless, plotting of temperature data collected during flood and ebb tides at sites within each study area revealed the presence of geographic subareas (6 to 8 in each study area; Figs. 2,3,4,5,6) with distinctive temperature-change characteristics (Fig. S1A-E, Tables 5, S3). Data from study area E are not discussed in detail here because its off-bank part extended only to 60 m water depth and was sparsely sampled. Its on-bank part (subareas 4–6; Fig. S1E) showed seabed temperature characteristics similar to on-bank subareas of study areas A-D described below.

Seabed temperatures in off-bank subareas followed the tidal pattern and tended, with few exceptions (Fig. S1A, subarea 2), to reach their maxima and minima within an hour of high and low tide, respectively. In those on-bank subareas where the water column was mixed, temperatures were nearly isothermal (Fig. S1 C, subarea 8). In off-bank subareas, the most northerly (subareas 1 in study areas A-D) displayed low minimum temperatures due to the strong influence of cold off-bank water that moved onto the bank during ebb tide, and relatively low maximum temperatures due to the weak influence of warm on-bank water that moved off the bank during flood tide (Fig. S1A-D). In other subareas (2 and higher) of the study areas, both temperature minima and maxima increased in the on-bank direction in response to the increasing influence of warm on-bank water during flood tide and the decreasing influence of cold off-bank water during ebb tide.

The geographic movement and associated temperature effect of the tidal front were approximated by determining the magnitude of temperature change occurring in a subarea, based on all temperature observations from that subarea. In many of the more northerly subareas, seabed temperatures changed more than 3°C as a result of tidal movement (Table 5). In study area A (subareas 1–4), temperature change ranged from 4.0 to 6.9°C; in study area B (subareas 1–4), temperature change was 3.9 to 6.9°C; in C (subareas 1–4), 4.0 to 6.8°C; and in D (subareas 2–5), 4.4 to 8.0°C (Fig. S1A-D). In some subareas, these data were collected over a 12-hour period during both flood and ebb tides, while in others data were collected only during flood or ebb tides. The overall pattern of temperature variation indicates that frontal movement caused significant temperature changes in small geographic areas during a 6-hour flood or ebb tide. By contrast, in the more southerly on-bank subareas, where warm mixed on-bank water dominated, minima and maxima showed little difference and the temperature change was <1°C (Fig. S1A-D).

Subareas experiencing maximum temperature change occurred in the frontal zone but not in the frontal boundary zone (Fig. 11). Rather they were located several km seaward (off-bank) of the frontal boundary zone in areas A, B, and C; and partially overlapped the frontal boundary zone in area D.

Temperature dynamics along the bank margin were very similar in study areas A-D. The subareas most affected by temperature change (3.9 to 8.0°C) during frontal movement extended approximately from 40 m on the bank to 80 m on the

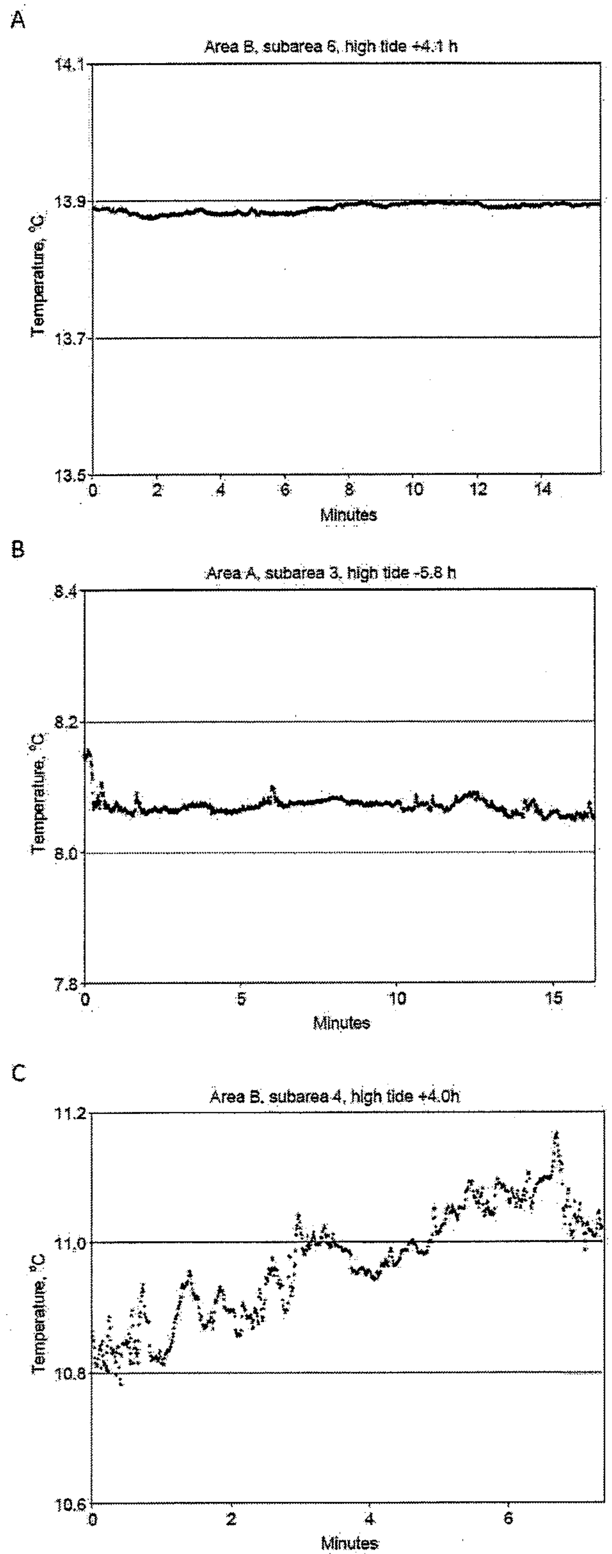

Figure 9. Hydrological complexity in CTD temperature data collected along Seaboss video drift tracks. A. Well-mixed, warm on-bank water showing little overall temperature change (<0.1°C); sta. 908007, 775 m drift. B. Within an hour of low tide in on- and off-bank areas, small high-frequency temperature changes (up to 0.02°C); sta. 908026, 259 m drift. C. Within 2 to 5 hours of high tide in off-bank areas, moderate high-frequency temperature changes (up to 0.1°C); sta. 908023, 304 m drift.
doi:10.1371/journal.pone.0055273.g009

bank edge (Fig. 11, Table 5). With increasing distance off the bank and increasing water depth in area D, the front had reduced effect on seabed temperatures. The deepest part of area D (subarea 1, 86–94 m) exhibited a much-reduced temperature change of 2.8°C compared with the next shallower interval (subarea 2, 60–76 m) where the temperature change was 7.9°C. We assume if study areas A-C were extended northward off the bank, they also would show this trend of declining temperature change with increasing water depth. Individual subareas showing the greatest temperature change at the seabed were located at depths of 40 to 56 m and included: study area A (subarea 2), 6.9°C, depth 49–56 m; area B (subarea 3), 6.9°C, 51–52 m; area C (subarea 2), 6.8°C, 48–51 m; and area D (subarea 4), 8.0°C, 40–47 m (Table 5). In area E, sampling along transect T24 (Fig. 6) did not extend below 60 m and temperature change in its most affected subarea was 3.7°C.

Summary and Discussion

1 Tidal Front Movement and Seabed Temperature

In summer on the northern margin of Georges Bank, a tidal-mixing front forms between the thermally stratified off-bank water of the Gulf of Maine to the north and mixed on-bank water to the south. At the seabed, cool water from the gulf and warm water from the bank move back and forth in the frontal zone in response to movements of the semidiurnal tide. During our study in August 2009, gulf water was warm (~18°C) at the surface and cold (~6°C) at the seabed at water depths of 80 to 90 m. In contrast, bank water displayed a relatively uniform temperature that varied <1°C in the range of 14 to 16°C from the surface to the seabed at depths of 40 to 60 m. The semidiurnal movement of the tidal-mixing front that formed where these very different water masses interacted affected the entire length (~100 km) of our study region. Our analyses, and those of previous studies ([18]: Fig. 7A-F), show that the movement of the tidal-mixing front in summer subjects seabed habitats beneath it to changes in temperature four times a day.

Water column temperature data collected along 6 transects across the bank margin in 5 study areas showed that the frontal boundary moved 6 to 10 km between high and low tides in August 2009 (Fig. 7A-F), in line with observations in July 1988 by Loder et al. ([18]: Fig. 7A-F). Observations of seabed temperature along our transects showed that temperature change at sites with paired stations (high and low tide) ranged from 0.0 to 7.0°C. Along the parts of transects affected by the front, temperatures changed with distance on average 0.21 to 0.55°C km^{-1} in the on- and off-bank directions (Table 2,S2). The spacing of isotherms at the seabed indicated that variations in temperature were not uniform across the frontal zone (Fig. 7A-F). Most cross sections of the frontal structure displayed localized depressions in isotherms of 10 to 40 m in depth (Fig. 7A-E), suggesting the presence of internal wave-like phenomena in the water column as described by Loder, et al. ([18]: Figs. 9, 10). These appeared at both high and low tide, presumably reflecting their development during both flood and ebb tide intervals, as reported by these authors.

Water column time-series temperature data collected at individual sites showed that the magnitude of seabed temperature

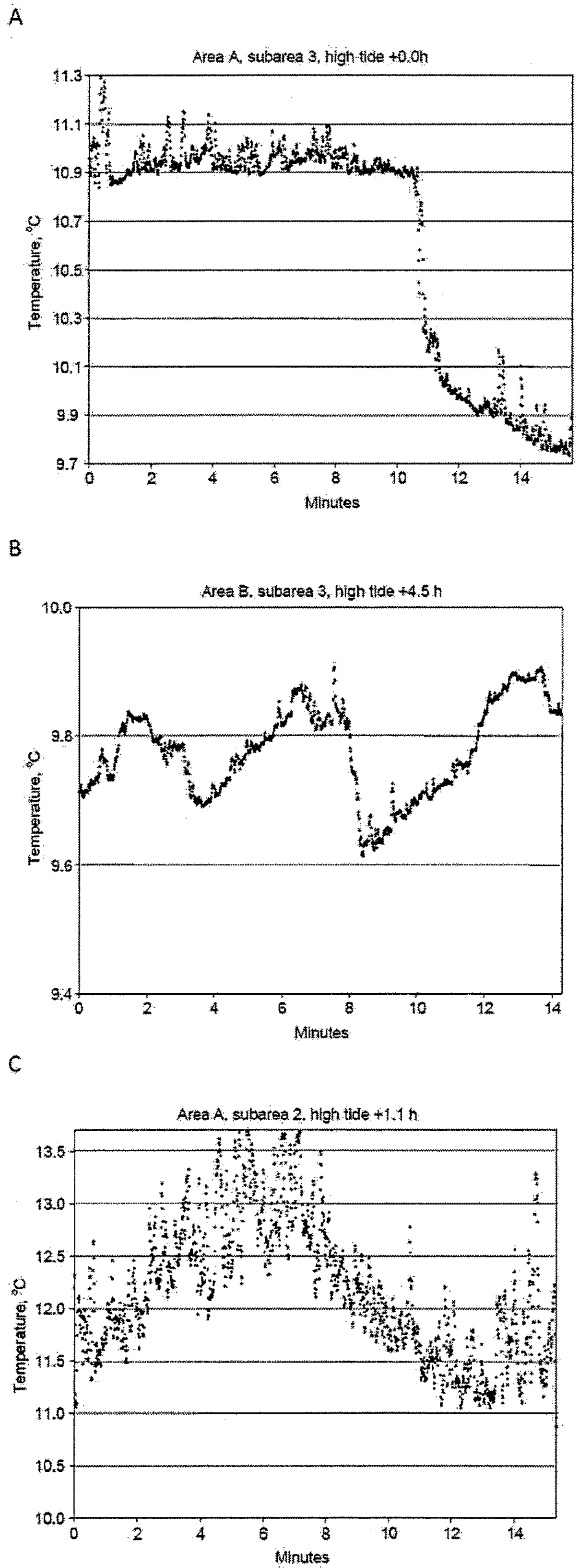

Figure 10. Rapid temperature changes in CTD temperature data collected along Seaboss video drift tracks. Examples of rapid temperature changes within the tidal front in off-bank subareas. A. Single rapid temperature changes (up to 0.6°C); sta. 908047, 801 m drift. B. Multiple rapid (4–5 min duration) saw tooth fluctuations (up to 0.3°C); sta. 908024, 498 m drift. C. Multiple rapid (6 min duration) saw tooth temperature fluctuations (up to 2–3°C); sta. 908034, 812 m drift.
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change caused by tidal movement was variable in the frontal zone. Maximum temperature change at the seabed ranged from 1.2 to 6.1°C at the 5 sites and was influenced by geographic location. The magnitude of change was greatest in the 40 to 80 m depth interval, and seabed temperatures changed with time as much as 2.48°C hr^{-1} (Table 3). The rate of change was greatest at mid-ebb and mid-flood tide, when tidal currents were predicted to be strongest, with little change in temperature in the 3 hours bracketing slack water (Fig. 8).

CTD data collected along Seaboss video drift tracks in the frontal zone provided evidence for short-term temperature instability at the seabed. High frequency fluctuations (period ≤20 seconds) occurred to a varying degree in subareas affected by frontal movement (Fig. 9C) but not in subareas with a mixed water column (Fig. 9A). The video drift data also exhibited sharp temperature fluctuations and cyclic variations (2 to 3°C) that strongly suggest the passage of internal waves (Fig. 10A-C).

Analyses of seabed CTD temperature data from transect and time-series stations, and the starts and ends of video drift stations, revealed that the geographic extent of the frontal effect on the seabed in 5 study areas can be mapped as subareas with distinctive temperature-change characteristics (Fig. 11). Within each subarea, the tidally-induced temperature change at the seabed was approximated by basing it on the aggregation of all temperature observations from the subarea. This approach revealed geographic areas of the bank margin that were characterized by temperature stability or instability depending on location and tidal dynamics. Subareas within each of the 5 study areas experienced temperature changes in the range of 0.2 to 8.0°C between high and low tides (Table 5, S3). Temperature changes caused by frontal movement decreased with both increasing water depth in the off-bank direction and decreasing depth in the on-bank direction. In the deepest subarea (area D, subarea 1; 86–94 m), temperatures at the seabed remained relatively cold (5.1–7.9°C) from high to low tide. Similarly, at relatively shallow depths on the bank (area D, subarea 8; 37–45 m) temperatures remained relatively warm (15.1–15.7°C) during a like period (Table 5, S3). The largest temperature changes attributed to frontal movement ranged from 3.9 to 8.0°C in subareas of study areas A-D and occurred along the bank margin in a 15- to 18 km-wide band in the 40 to 80 m depth interval (Fig. 11). In area E, the effect of frontal movement on seabed temperature is not well documented, but existing data suggest temperature change was largest in water depths of 60 m and deeper.

2 Ecological Implications for the Fishery

The large tidally-driven temperature changes within the frontal zone on the northern margin of Georges Bank in August likely have ecological implications for fish and invertebrate species that inhabit the region. The northern margin exhibits the highest benthic production on an otherwise highly productive bank [5], much of it attributable to sea scallops (*Placopecten magellanicus*) [4]. Yet this productivity may come with a high physiological and/or ecological price. Benthic invertebrates must endure rapid and

Table 2. Comparison of parts of seabed transects along which temperature is affected or not affected by the tidal front at high and low tide.

Location		Part of transect AFFECTED by front				Part of transect NOT AFFECTED by front			
		Temperature, °C				Temperature, °C			
Area, transect	Tide	Dist., km	Min/Max	ΔT	°C km^{-1}	Dist., km	Min/Max	ΔT	°C km^{-1}
A, T16	Hi	17.1	9.8/13.6	3.8	0.22	10.8	14.0/14.1	0.1	0.01
A, T16	Lo	17.1	5.8/12.4	6.6	0.39	10.8	13.4/14.1	0.7	0.07
B, T19	Hi	7.2	9.5/12.4	2.9	0.40	19.9	12.9/14.3	1.4	0.07
B, T19	Lo	7.7	6.1/9.5	3.4	0.44	19.6	12.3/14.2	1.9	0.10
C, T18	Hi	18.5	11.2/15.0	3.8	0.21	2.6	15.0/15.0	0.0	0.00
C, T18	Lo	18.0	7.2/13.8	6.6	0.37	3.5	14.1/14.4	0.3	0.09
D, T22	Hi	17.1	7.9/15.7	7.8	0.46	7.0	15.7/15.7	0.0	0.00
D, T22	Lo	17.2	5.8/14.6	8.8	0.51	6.8	15.1/15.7	0.6	0.09
D, T23	Hi	17.5	7.2/16.0	8.8	0.50	–	–	–	–
D, T23	Lo	17.8	5.1/14.9	9.8	0.55	–	–	–	–
E, T24	Hi	11.2	12.1/15.6	3.5	0.31	7.1	15.8/16.3	0.5	0.07
E, T24	Lo	10.9	8.4/14.4	6.0	0.55	7.3	14.8/15.7	0.9	0.12

Seabed temperature change per kilometer is given for parts of transects where individual sites are affected or not affected by the tidal front. By our definition, a site is affected by frontal movement if the temperature change between high and low tides is >1°C (Table S1, H-L ΔT). For example, in study area A at high tide, the part of transect T16 affected by the front extended over a distance of 17.1 km. Temperature changed from a minimum of 9.8°C (in the deep part) to a maximum of 13.6°C (in the shallow part) over that distance. Thus at high tide, temperature changed 3.8°C over 17.1 km and the rate of change was 0.22°C km^{-1}. In area D, all stations along transect 23 were affected by frontal movement. See Figure 7 for locations of stations along CTD transects. Table S2 contains additional data.
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substantial temperature changes during each flood and ebb tide. In some locations, temperatures vary as much as 7.0°C (Table 1) over a 6-hour period at short-term rates of up to 2.5°C hr^{-1}. They may also experience very short-term temperature instabilities associated with turbulent mixing. Fish conceivably can respond directly to temperature changes by moving horizontally and/or vertically to remain within their zone of acclimation. There is evidence from the scientific literature (see below) that cyclic temperature changes have an effect on the behavior and distribution of invertebrate and fish species, although no such studies have been conducted in a region of the continental shelf where temperatures are driven by movements of a tidal-mixing front.

Large, rapid, cyclical swings in temperature are uncommon in most shelf environments, but they are typical of intertidal and shallow subtidal settings where it is well documented that tidally-driven temperature changes result in zonation of resident species [46–48]. On the northern margin of Georges Bank one might expect to find that cyclical temperature changes similarly affect the distribution of resident species and result in a zonation of benthic communities. Such zonation patterns have not been reported from the frontal zone, possibly because their detection has been confounded by the heterogeneity of surficial sediments there [49], by the effects of disturbance by bottom fishing [50], and by the lack of directed study.

Cyclic temperatures have been shown in laboratory experiments to affect the growth, and development of larval and adult

Table 3. Rates of seabed temperature change at time-series sites in study areas A-E.

	Date	Stations		Time-series description			Temperature, °C		Max ΔT, °C hr^{-1}	
Area	2009	No. CTDs	Depths, m	Start, hr	End, hr	Duration, hr	Min/Max	Range	Flood	Ebb
A	Aug 7	12	54–57	−0.43	−0.50	12.22	6.1/11.2	5.1	+1.14	−2.48
B	Aug 8	9	47–50	−0.50	−2.00	10.77	12.3/14.4	2.1	+0.78	−1.62
C	Aug 11	8	44–46	−0.63	−3.23	9.72	9.5/14.3	4.8	+1.65	−1.38
D	Aug 12	8	42–43	−0.35	−3.92	8.77	8.7/14.8	6.1	+0.81	−2.29
E	Aug 13	8	35–37	−2.73	6.10	8.83	14.4/15.6	1.2	+0.73	−0.32

Data at sites were collected during tidal cycles, including at both high and low tide, over periods of 8 to 12 hr. Time-series start and end times are hours before (−) or after (+) high tide. Minimum temperature occurred at low tide (on-bank frontal movement) and maximum temperature occurred at high tide (off-bank frontal movement). Maximum rates (°C hr^{-1}) of temperature change (ΔT) were recorded between sequential CTD observations during flood and ebb tidal phases within each time series. See Figures 2,3,4,5,6 for locations of time-series sites (TS) and Figure 8 for temperature cross sections at sites. See Table 4 for temperature data and timing (relative to tidal movement) of the 12 stations at the time-series site in study area A.
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Table 4. Hourly rates of seabed temperature change at the time-series site in study area A.

	Timing of observations, hr					Temperature, °C		
CTD sta	Start	Time elapsed	Before Hi	After Hi	Tide stage	T	ΔT	°C hr^{-1}
052	0.00	–	−0.43		F	9.7	–	–
057	1.32	1.32		0.88	E	11.2	+1.4	+1.09
058	2.25	0.93		1.82	E	11.1	−0.1	−0.10
059	3.38	1.13		2.95	mid ebb	8.3	−2.8	**−2.48**
060	4.37	0.98		3.93	E	6.5	−1.8	−1.83
061	5.33	0.97		4.90	E	6.1	−0.4	−0.36
066	6.55	1.22		6.12	low tide	6.1	0.0	−0.03
069	8.13	1.58	−4.58		F	6.9	+0.8	+0.53
070	9.2	1.07	−3.52		F	8.1	+1.2	**+1.14**
071	10.13	0.93	−2.58		F	8.8	+0.7	+0.71
072	11.07	0.93	−1.65		F	9.1	+0.3	+0.36
073	12.22	1.15	−0.50		F	9.1	0.0	−0.01

Observations were made at intervals ranging from 0.93 to 1.32 hr over a 12.22-hr period. They extended from 0.43 hr before (−) high tide (Hi) to 0.50 hr before (−) high tide and encompassed both flood (F) and ebb (E) stages. Rates of temperature change (°C hr^{-1}) were calculated using differences in seabed temperature (ΔT) and the time elapsed from the previous observation. Rates were highest at or just after mid-ebb tide (CTD sta 059, −2.48°C hr^{-1}; CTD sta 060, −1.83°C hr^{-1}) and just before mid-flood tide (CTD sta 070, 1.14°C hr^{-1}). Maximum flood and ebb rates of temperature change used for Area A in Table 3 are shown in bold type here. No data were collected at the exact times of high or mid-flood tides, although both were bracketed. Low rates of temperature change bracketed low tide (slack water; CTD sta 061, 066, 069). Temperature decreased during ebb tide (CTD sta 057-061) and increased during flood tide (CTD sta 069-073). See Figure 8 for temperature cross-section at the site.

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crustaceans from freshwater and coastal environments including mud crab larvae [51], shrimp [52] and juvenile crayfish [53]. These results are suggestive of the effects that may be imposed on early life history stages of seabed animals by cyclic temperature regimes, but are not directly applicable to our study area because they were not conducted on species or in temperature and salinity conditions typical of the Georges Bank frontal zone. In a study of summer flounder larvae (*Paralichthys dentatus*), a species that occurs on Georges Bank, Johns et al. [54] measured their development rates in a variety of constant and cyclic temperature regimes and found that larvae raised in cyclic temperatures developed faster than those raised at a constant temperature of 5°C, but slower than those raised at 21°C. Larvae reared at the coldest constant temperature (5°C) and those reared in the coldest cyclic temperature regime (5–11°C) did not survive. Summer flounder eggs, larvae, and adults are present on Georges Bank but are sparse in the frontal zone [55].

A study of the American lobster (*Homarus americanus*), a resident of Georges Bank and the frontal zone, showed that for individuals acclimated to temperatures of 2, 5, 10, 15, 20, or 25°C, walking activity was lowest at 2 and 5°C and generally increased as acclimation temperatures increased [56]. When lobsters from these acclimation groups were tested after being subjected to a rapid change in temperature for at least 1 hour, those acclimated to 2 and 5°C were most active at 5–10°C, those acclimated to 10°C were most active at 15°C, and those acclimated to 15, 20, or 25°C were most active at the acclimation temperature. In addition, lobsters acclimated to 15°C were inactive at 2°C, those acclimated to 20°C were inactive at 5°C, and those acclimated to 25°C were inactive at 10°C. These results suggest that tidally-driven, cyclic temperature changes possibly regulate lobster activity by slowing it during ebb tide when cool water moves southward onto the bank and increasing it during flood tide when flow is reversed and warm bank water moves northward across the bank margin.

Claireaux et al. [57] conducted a study of the behavioral response of Atlantic cod (*Gadus morhua*) acclimated at 5°C to temperatures in the range of 4 to 11°C. They reported that in a mixed water column in a test tank, voluntary swimming activity was doubled by a rise in temperature of 2°C (to 7°C). In a stratified water column, cod avoided cold (4°C) water introduced at the base of the tank; and the fish preferred deeper, colder water during the day and shallow, warmer water at night. These observations suggest that Atlantic cod, a major fishery species of the bank, possibly exhibit a behavioral response to the temperature changes caused by movement of the tidal-mixing front.

Lough [58] has shown that survival of recently-settled (July) juvenile Atlantic cod is enhanced in the gravel habitat of northern Georges Bank, part of which lies in our study region. He suggested that complex gravel habitat serves the cod both as a source of prey and as a refuge from predators. The distribution of juvenile cod can now also be examined to determine if the tidally-induced seabed temperature changes described herein affect their behavior and habitat preferences.

We speculate that the response of fish and invertebrates to tidally-induced, cyclic temperature changes in the frontal zone depends on how species are affected by the temperature change between high and low tide, by the rate of temperature change with time, and by the duration of temperature stability at high and low tide. A number of questions are raised by our analysis of temperature cycles in the frontal zone. 1. Do demersal fish species follow the front during flood and ebb tides to maintain their acclimated temperature and/or to gain access to feeding grounds at temperatures favorable to them; or do they remain within an area and alter their physiology and behavior in response to *in situ* temperature changes? 2. How is the activity level of mobile invertebrates affected by cyclic temperature changes at the seabed?

Table 5. Summary of seabed water depths and the frontal effect on temperature change in subareas of study areas A–E.

			Depth, m		Temperature, °C	
Area, subarea	Width, km	CTD sta	Min/Max	Range	Min/Max	Range
A,1	5.5	74	52/87	35	5.7/12.2	6.5
A,2	2.7	28	49/56	7	6.7/13.6	6.9
A,3	3.0	33	46/58	12	7.9/13.9	6.0
A,4	2.7	11	48/56	8	9.8/13.8	4.0
A,5	2.7	6	53/56	3	12.4/13.8	1.4
A,6	7.3	6	52/56	4	13.4/14.2	0.8
A,7	5.2	6	51/59	8	14.0/14.2	0.2
B,1	3.1	5	62/82	20	6.1/10.0	3.9
B,2	3.0	8	50/54	4	6.9/13.2	6.3
B,3	2.6	9	51/52	1	6.7/13.6	6.9
B,4	3.0	20	46/55	9	8.7/14.6	5.9
B,5	4.1	37	46/55	9	12.3/14.7	2.4
B,6	6.2	20	48/58	10	13.5/14.3	0.8
B,7	6.4	8	47/51	4	14.1/14.3	0.2
C,1	3.1	4	64/81	17	5.5/11.2	5.7
C,2	2.7	6	48/51	3	7.4/14.2	6.8
C,3	2.8	21	43/47	4	9.1/14.3	5.2
C,4	2.9	11	43/46	3	10.4/14.4	4.0
C,5	2.6	6	46/50	4	12.8/14.4	1.6
C,6	2.8	4	50/53	3	13.1/14.7	1.6
C,7	6.3	11	46/67	11	13.8/15.0	1.2
C,8	9.8	7	54/59	5	14.8/15.1	0.3
D,1	2.2	4	86/94	8	5.1/7.9	2.8
D,2	2.4	8	60/76	16	5.3/13.2	7.9
D,3	3.0	10	42/59	17	5.8/12.5	6.7
D,4	3.0	14	40/47	7	7.1/15.1	8.0
D,5	2.8	4	37/42	5	11.3/15.7	4.4
D,6	2.7	4	37/39	2	13.8/15.7	1.9
D,7	2.6	6	38/39	1	14.3/16.0	1.7
D,8	7.3	6	37/45	8	15.1/15.7	0.6
E,1	0.5	5	59/60	1	8.4/12.1	3.7
E,2	3.3	4	40/47	7	11.1/12.9	1.8
E,3	2.9	6	37/41	4	12.1/15.3	3.2
E,4	4.4	34	27/38	11	13.4/15.7	2.3
E,5	2.6	14	30/35	5	14.8/16.3	1.5
E,6	4.2	4	32/34	2	15.5/16.4	0.9

Temperature data was collected at CTD stations located along transects, at time-series stations, and at the starts and ends of video-drift stations. Subareas in each study area are numbered in an off-bank to on-bank direction (Figs. 2,3,4,5,6). Subarea widths are measured normal to the tidal front. The range of seabed temperatures experienced by each subarea is shown and indicates which subareas are affected by frontal movement. The largest temperature changes between high and low tide (ranging from 3.9 to 8.0°C) occurred in subareas that lie in a 11–14 km wide band that extends ~100 km along the bank margin above 80 m water depth (Fig. 11). Table S3 expands this data by showing the frontal effect on temperature change in the subareas during flood and ebb tides.

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3. Do temperature fluctuations in the frontal zone affect the survival and/or reproduction of benthic invertebrate species and prevent some species from living there; thus influencing community composition in parts of a large region of gravel substrate? 4. Does alternating occupation of the frontal zone by water masses from Georges Bank and the Gulf of Maine provide, over periods of hours, different kinds and quantities of food for filter-feeding invertebrate species, thus affecting local benthic productivity?

We anticipate that the observations reported here will provide a framework for ecological studies to determine the effects of short-term temperature variability on the distribution, behavior, and food and shelter resources of both invertebrate and fish species that inhabit the northern margin of Georges Bank in summer when the front is well developed. Additionally, these results should be helpful in calibrating hydrographic models for predicting

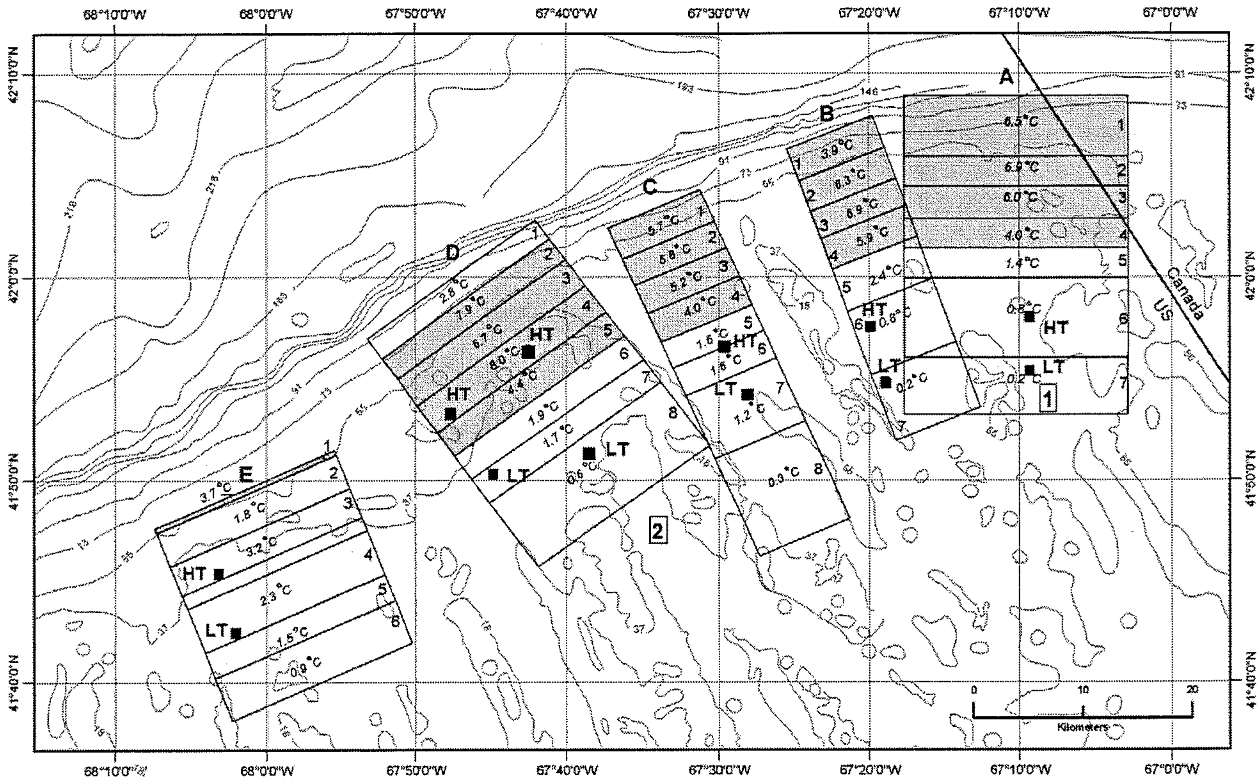

Figure 11. Map of study areas A-E and numbered subareas with tidal temperature changes. Values in each subarea are changes in seabed temperature (°C) during tidal front movement off bank (flood tide) and on bank (ebb tide) during the August 4–13, 2009 time period. Shaded subareas represent regions of greatest effect on seabed temperature (40 to 80 m depth interval). Unshaded subareas represent regions of lesser tidal effect on temperatures (see Tables 5, S3 for details). The frontal zone is the area where seabed temperature is changed >1°C by tidal movement of the front. Square black markers indicate the approximate positions of the frontal boundary (i.e. the transition from a stratified to a mixed water column) along each of the linear transects during high tide (HT) and low tide (LT). The area between HT and LT is the frontal boundary zone. Numbers in rectangles and bathymetry are as in Fig. 1.
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seabed temperature patterns in areas of the bank affected by the tidal-mixing front.

Supporting Information

Figure S1 Seabed temperature versus tidal phase. Seabed temperature is plotted against time before (−) and after (+) high tide in the subareas of study areas A-E on the northern margin of Georges Bank in August 2009. Subareas are numbered as in Figs. 2–6. A pattern of larger changes in the deeper subareas within each area is evident, as summarized in Fig. 11.
(PDF)

Table S1 Water depth, seabed temperature, and temperature change along transects across the tidal front. Temperature change from high to low tide is shown for paired CTD stations at observation sites along transects in study areas A-E. Station pairs are grouped in Table 1. In each study area, station pairs (column 1) are numbered from north to south (i.e. off bank to on bank). Individual stations (columns 2–3) are numbered 001-214. The change in temperature between high and low tides at the paired stations is Hi-Lo ΔT. By our definition, a site is affected (Y) by frontal movement if Hi-Lo ΔT is >1.0°C. See Figure 1 for locations of study areas; Figures 2,3,4,5,6 for locations of CTD transects; and Figure 7 for locations of individual CTD stations.
(DOC)

Table S2 Comparison of parts of seabed transects along which temperature is affected or not affected by the tidal front at high and low tide. Stations along each transect are arranged across the tidal front from deep to shallow (off bank to on bank). Seabed temperature change per kilometer is given for parts of transects where individual sites are affected or not affected by the tidal front. By our definition, a site is affected by frontal movement if the temperature change between high and low tides is >1°C (Table S1, Hi-Lo ΔT). For example, in study area A at high tide, the part of transect T16 affected by the front extended from station 026 to station 031 over a distance of 17.1 km. Water depths at 026 and 031 were 79 and 54 m, respectively. Temperature changed from a minimum of 9.8°C at station 026 (in the deep part) to a maximum of 13.6°C at station 031 (in the shallow part). Thus at high tide, temperature changed 3.8°C over 17.1 km and the rate of change was 0.22°C km^{-1}. In area D, all stations along transect 23 were affected by frontal movement. See Table S1 for depth and temperature data for all stations. See Figure 7 for locations of stations along CTD transects.
(DOC)

Table S3 Summary of seabed water depths and the frontal effect on temperature change in subareas of study areas A-E. Temperature data was collected at numerous CTD stations located along transects, at time-series stations, and at the starts and ends of video-drift stations. Subareas in each study area are

numbered in an off-bank to on-bank direction (Figs. 2,3,4,5,6). Subarea widths are measured normal to the tidal front. Temperature data collected during flood or ebb tides are plotted in Figure S1. The largest temperature changes between high and low tide (ranging from 3.9 to 8.0°C) occurred in subareas that lie in a 11–14 km wide band that extends ~100 km along the bank margin above 80 m water depth (Fig. 11). Abbreviations: nd – no data; ndef - data not definitive to determine range.
(DOC)

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Author Contributions

Conceived and designed the experiments: VGG PCV. Performed the experiments: VGG PCV. Analyzed the data: VGG PCV LBG. Contributed reagents/materials/analysis tools: VGG PCV LBG. Wrote the paper: VGG PCV LBG.

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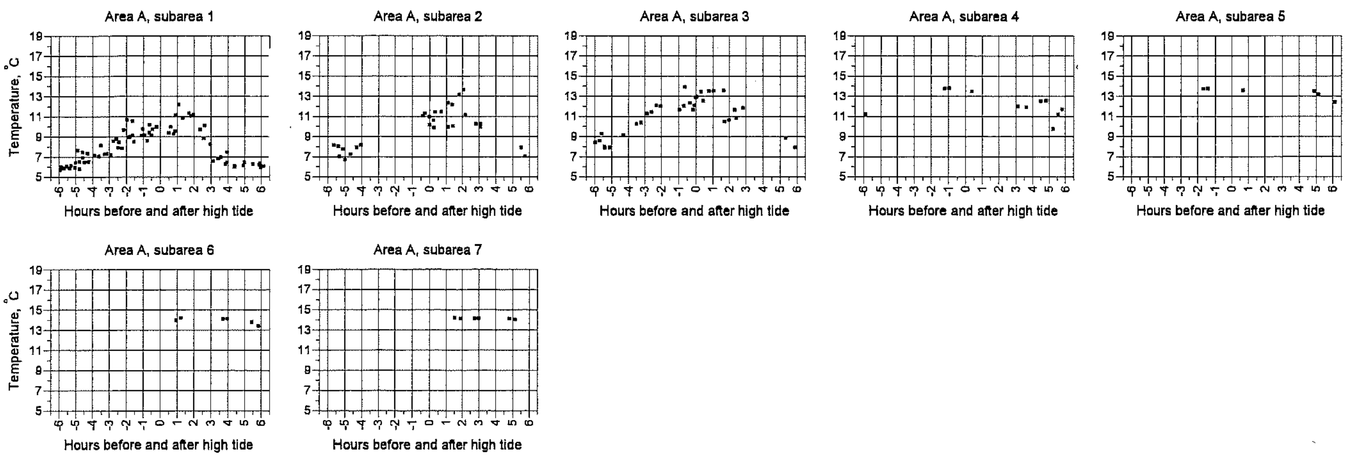
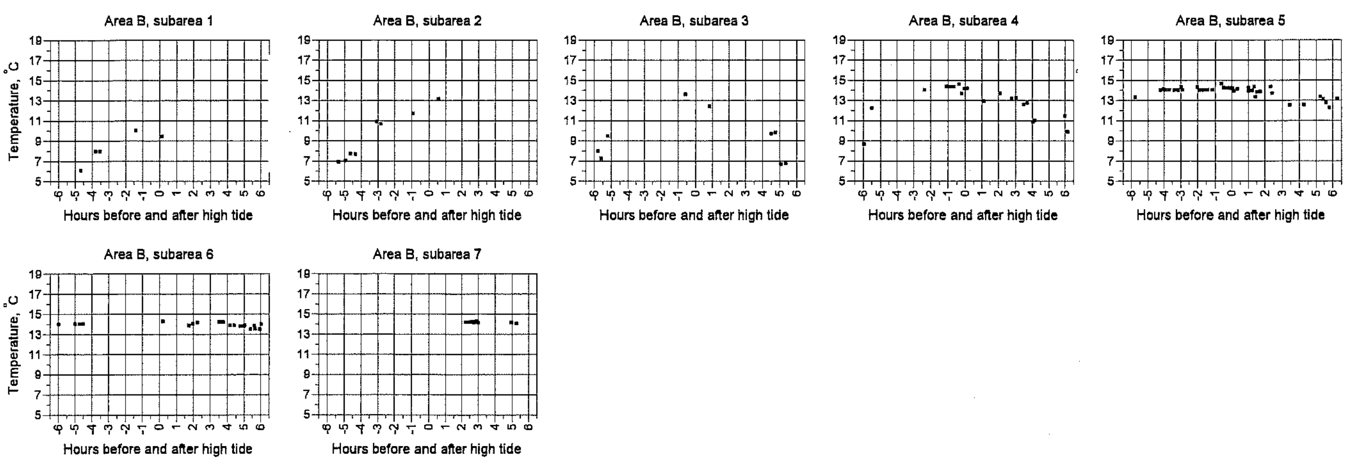
Figure S1. Seabed temperature versus tidal phase. Seabed temperature is plotted against time before (−) and after (+) high tide in the subareas of study areas A-E on the northern margin of Georges Bank in August 2009. Subareas are numbered as in Figs. 2–6. A pattern of larger changes in the deeper subareas within each area is evident, as summarized in Fig. 11.

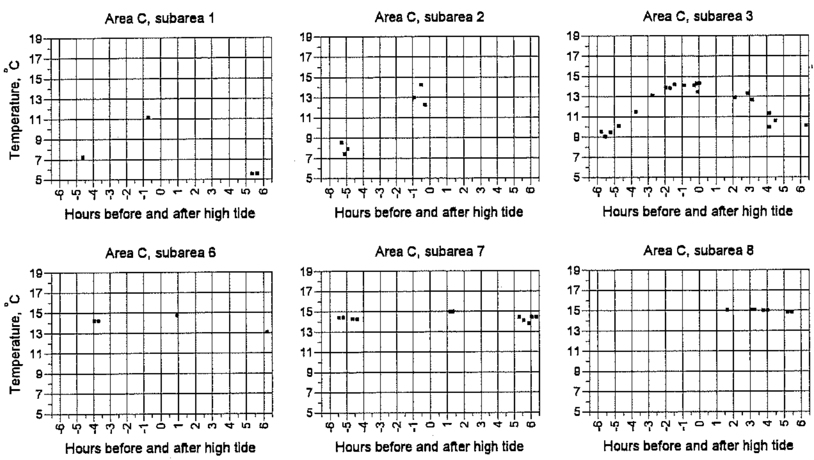
A


Area A, subarea 1
Area A, subarea 2
Area A, subarea 3
Area A, subarea 4
Area A, subarea 5
Area A, subarea 6
Area A, subarea 7
Temperature, °C
Hours before and after high tide

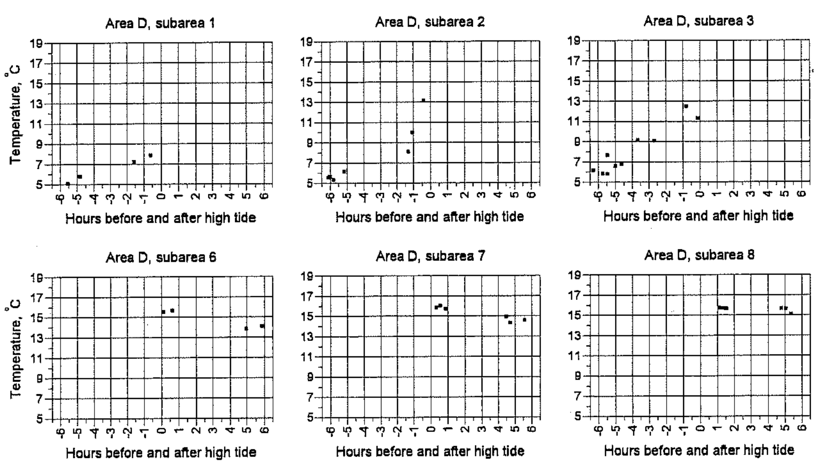
B


Area B, subarea 1
Area B, subarea 2
Area B, subarea 3
Area B, subarea 4
Area B, subarea 5
Area B, subarea 6
Area B, subarea 7
Temperature, °C
Hours before and after high tide

C

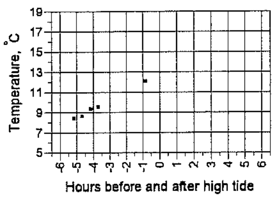

Area C, subarea 1
Area C, subarea 2
Area C, subarea 3
Area C, subarea 4
Area C, subarea 5
Area C, subarea 6
Area C, subarea 7
Area C, subarea 8
Temperature, °C
Hours before and after high tide

D

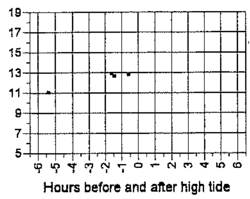

Area D, subarea 1
Area D, subarea 2
Area D, subarea 3
Area D, subarea 4
Area D, subarea 5
Area D, subarea 6
Area D, subarea 7
Area D, subarea 8
Temperature, °C
Hours before and after high tide

E

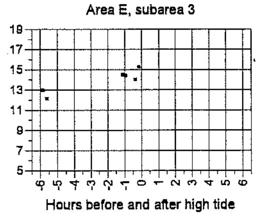
Area E, subarea 1



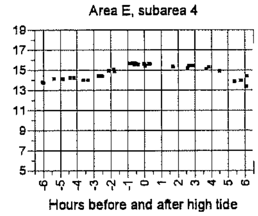
Area E, subarea 2



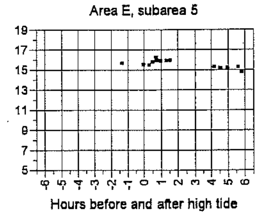
Area E, subarea 3



Area E, subarea 4



Area E, subarea 5



Area E, subarea 6

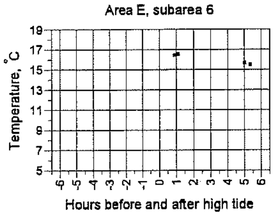


Table S2. Comparison of parts of seabed transects along which temperature is affected or not affected by the tidal front at high and low tide.

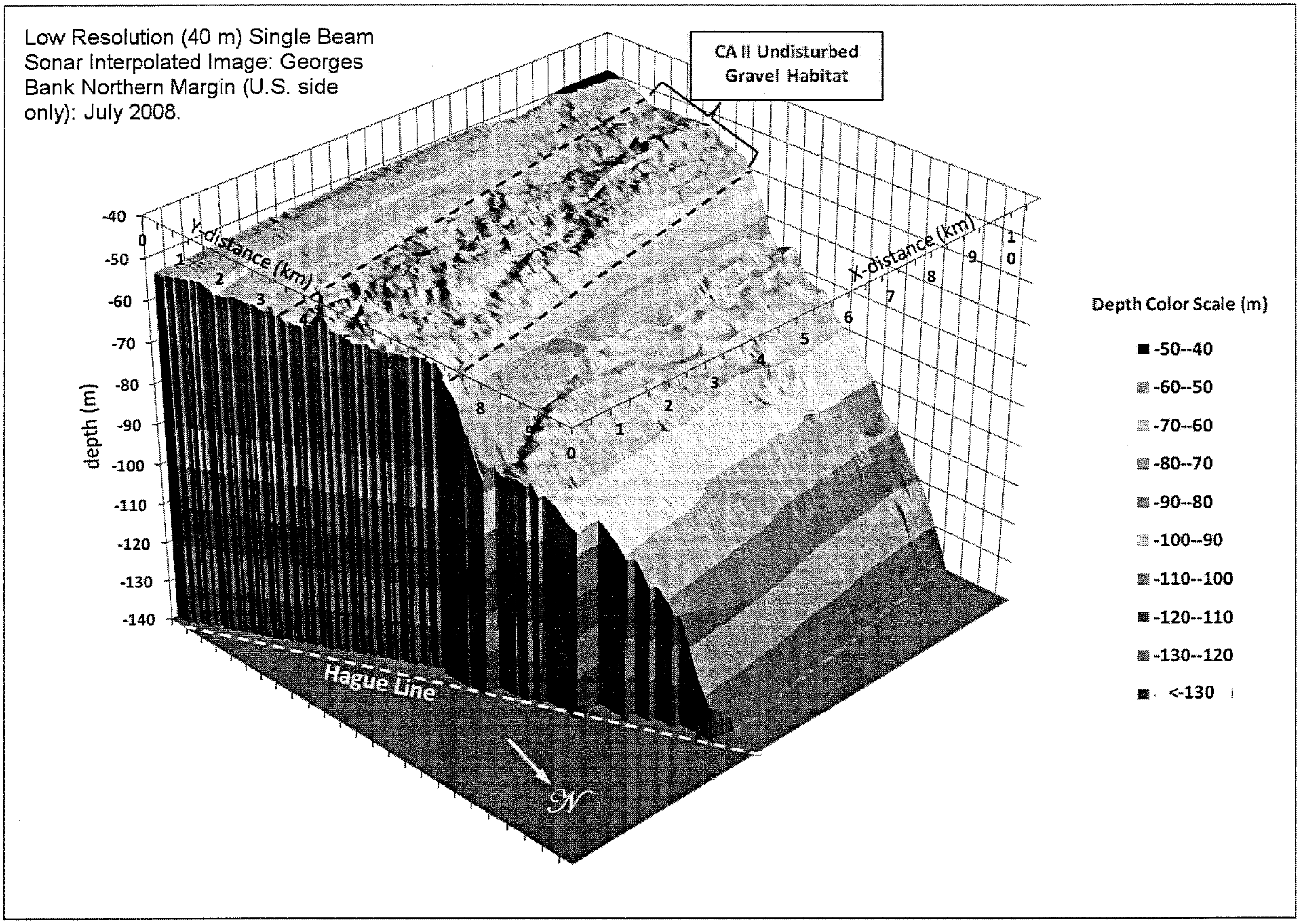
Location			Part of CTD transect AFFECTED by tidal front						Part of CTD transect NOT AFFECTED by tidal front					
						Temperature, °C						Temperature, °C		
Area, transect	Tide	Transect, km	Stations	Dist., km	Depth, m	Min/Max	ΔT	°C km^{-1}	Stations	Dist., km	Depth, m	Min/Max	ΔT	°C km^{-1}
A, T16	Hi	27.9	026-031	17.1	79-54	9.8/13.6	3.8	0.22	032-035	10.8	53-59	14.0/14.1	0.1	0.01
A, T16	Lo	27.8	045-040	17.1	81-53	5.8/12.4	6.6	0.39	039-036	10.8	54-57	13.4/14.1	0.7	0.07
B, T19	Hi	27.1	001-003	7.2	82-51	9.5/12.4	2.9	0.40	004-010	19.9	50-48	12.9/14.3	1.4	0.07
B, T19	Lo	27.2	020-018	7.7	82-51	6.1/9.5	3.4	0.44	017-011	19.6	49-47	12.3/14.2	1.9	0.10
C, T18	Hi	21.1	100-107	18.5	68-64	11.2/15.0	3.8	0.21	108-109	2.6	60-54	15.0/15.0	0.0	0.00
C, T18	Lo	21.5	119-112	18.0	64-63	7.2/13.8	6.6	0.37	111-110	3.5	59-52	14.1/14.4	0.3	0.09
D, T22	Hi	24.0	120-126	17.1	88-39	7.9/15.7	7.8	0.46	127-129	7.0	39-45	15.7/15.7	0.0	0.00
D, T22	Lo	23.9	139-133	17.2	86-38	5.8/14.6	8.8	0.51	132-130	6.8	38-45	15.1/15.7	0.6	0.09
D, T23	Hi	17.5	163-172	17.5	92-39	7.2/16.0	8.8	0.50	-	-	-	-	-	-
D, T23	Lo	17.8	186-177	17.8	94-38	5.1/14.9	9.8	0.55	-	-	-	-	-	-
E, T24	Hi	18.2	191-196	11.2	60-37	12.1/15.6	3.5	0.31	197-200	7.1	35-33	15.8/16.3	0.5	0.07
E, T24	Lo	18.2	214-209	10.9	59-36	8.4/14.4	6.0	0.55	208-205	7.3	34-32	14.8-15.7	0.9	0.12

Table S1. Water depth, seabed temperature, and temperature change along transects across the tidal front.

Location	Station	Stations		Depth, m		Temperature, °C			Frontal
Area, transect	pair	Hi tide	Lo tide	Hi tide	Lo tide	Hi tide	Lo tide	Hi-Lo ΔT	effect
A, T16	1	026	045	79	81	9.8	5.8	4.0	Y
	2	027	044	57	56	10.2	5.9	4.3	Y
	3	028	043	52	51	11.3	7.0	4.3	Y
	4	029	042	53	52	13.0	9.3	3.7	Y
	5	030	041	55	54	13.5	11.2	2.3	Y
	6	031	040	54	53	13.6	12.4	1.2	Y
	7	032	039	53	54	14.0	13.4	0.6	N
	8	033	038	56	55	14.2	13.8	0.4	N
	9	034	037	52	53	14.2	14.0	0.2	N
	10	035	036	59	57	14.1	14.1	0.0	N
B, T19	1	001	020	82	82	9.5	6.1	3.4	Y
	2	002	019	53	52	13.2	7.1	6.1	Y
	3	003	018	51	51	12.4	9.5	2.9	Y
	4	004	017	50	49	12.9	12.3	0.6	N
	5	005	016	53	52	13.4	13.3	0.1	N
	6	006	015	57	55	13.9	13.2	0.7	N
	7	007	014	53	54	14.0	13.5	0.5	N
	8	008	013	50	48	14.2	13.9	0.3	N
	9	009	012	50	50	14.2	14.1	0.1	N
	10	010	011	48	47	14.3	14.2	0.1	N
C, T18	1	100	119	68	64	11.2	7.2	4.0	Y
	2	101	118	49	51	12.3	7.9	4.4	Y
	3	102	117	46	45	13.4	9.5	3.9	Y
	4	103	116	44	43	13.7	10.9	2.8	Y
	5	104	115	46	45	13.9	12.3	1.6	Y
	6	105	114	47	46	14.4	12.8	1.6	Y
	7	106	113	52	50	14.7	13.1	1.6	Y
	8	107	112	64	63	15.0	13.8	1.2	Y
	9	108	111	60	59	15.0	14.1	0.9	N
	10	109	110	54	52	15.0	14.4	0.6	N
D, T22	1	120	139	88	86	7.9	5.8	2.1	Y
	2	121	138	60	60	13.2	6.2	7.0	Y
	3	122	137	50	42	11.3	7.7	3.6	Y
	4	123	136	43	42	15.1	9.3	5.8	Y
	5	124	135	39	37	15.7	12.2	3.5	Y
	6	125	134	39	37	15.7	14.1	1.6	Y
	7	126	133	39	38	15.7	14.6	1.1	Y
	8	127	132	39	38	15.7	15.1	0.6	N
	9	128	131	43	37	15.7	15.6	0.1	N
	10	129	130	45	45	15.7	15.7	0.0	N
D, T23	1	163	186	92	94	7.2	5.1	2.1	Y
	2	164	185	76	75	8.1	5.3	2.8	Y
	3	165	184	61	61	10.0	5.7	4.3	Y
	4	166	183	50	52	12.5	6.2	6.3	Y
	5	167	182	45	40	11.9	7.1	4.8	Y
	6	168	181	43	42	14.8	8.7	6.1	Y
	7	169	180	42	41	15.3	11.3	4.0	Y
	8	170	179	38	37	15.5	13.8	1.7	Y
	9	171	178	39	38	15.8	14.3	1.5	Y
	10	172	177	39	38	16.0	14.9	1.1	Y
E, T24	1	191	214	60	59	12.1	8.4	3.7	Y
	2	192	213	47	46	12.8	11.1	1.7	Y
	3	193	212	40	38	14.0	12.1	1.9	Y
	4	194	211	41	40	15.3	13.0	2.3	Y
	5	195	210	38	36	15.4	13.8	1.6	Y
	6	196	209	37	36	15.6	14.4	1.2	Y
	7	197	208	35	34	15.8	14.8	1.0	N
	8	198	207	35	34	16.3	15.3	1.0	N
	9	199	206	34	32	16.4	15.5	0.9	N
	10	200	205	33	32	16.3	15.7	0.6	N

Table S3. Summary of seabed water depths and the frontal effect on temperature change in subareas of study areas A-E.

					Seabed temperature, °C						
			Depth, m		Subarea		Flood tide		Ebb tide		Date
Area, sub	Width, km	CTD sta	Min/Max	Range	Min/Max	Range	Min/Max	Range	Min/Max	Range	Aug. 2009
A,1	5.5	74	52/87	35	5.7/12.2	6.5	5.7/10.7	5.0	5.9/12.2	6.3	5,6,7,8,10
A,2	2.7	28	49/56	7	6.7/13.6	6.9	6.7/11.3	4.6	7.0/13.6	6.6	5,6,7,8
A,3	3.0	33	46/58	12	7.9/13.9	6.0	7.9/13.9	6.0	7.9/13.6	5.7	6,7,8,9,10
A,4	2.7	11	48/56	8	9.8/13.8	4.0	11.2/13.8	2.6	9.8/13.5	3.7	6,8,9
A,5	2.7	6	53/56	3	12.4/13.8	1.4	nd	nd	12.4/13.6	1.2	6,8,9
A,6	7.3	6	52/56	4	13.4/14.2	0.8	nd	nd	13.4/14.2	0.8	6,8
A,7	5.2	6	51/59	8	14.0/14.2	0.2	nd	nd	14.0/14.2	0.2	4,6
B,1	3.1	5	62/82	20	6.1/10.0	3.9	6.1/10.0	3.9	9.5/9.5	ndef	5,9
B,2	3.0	8	50/54	4	6.9/13.2	6.3	6.9/13.2	6.3	13.2/13.2	ndef	5,8,9
B,3	2.6	9	51/52	1	6.7/13.6	6.9	7.3/13.6	6.3	6.7/12.4	5.7	5,8
B,4	3.0	20	46/55	9	8.7/14.6	5.9	8.7/14.6	5.9	9.9/14.2	4.3	5,8,10
B,5	4.1	37	46/55	9	12.3/14.7	2.4	13.3/14.7	1.4	12.3/14.4	1.1	4,5,8,10
B,6	6.2	20	48/58	10	13.5/14.3	0.8	14.0/14.0	0.0	13.5/14.3	0.8	4,5,8
B,7	6.4	8	47/51	4	14.1/14.3	0.2	nd	nd	14.1/14.3	0.2	4,5
C,1	3.1	4	64/81	17	5.5/11.2	5.7	7.2/11.2	4.0	5.6/5.6	ndef	9,11
C,2	2.7	6	48/51	3	7.4/14.2	6.8	7.4/14.2	6.8	nd	nd	9,11
C,3	2.8	21	43/47	4	9.1/14.3	5.2	9.1/14.3	5.2	10.0/14.3	4.3	9,11
C,4	2.9	11	43/46	3	10.4/14.4	4.0	10.9/14.0	3.1	10.4/14.4	4.0	9,11
C,5	2.6	6	46/50	4	12.8/14.4	1.6	14.0/14.0	ndef	12.8/14.4	1.6	9,11
C,6	2.8	4	50/53	3	13.1/14.7	1.6	14.2/14.2	ndef	13.1/14.7	1.6	9,11
C,7	6.3	11	46/67	11	13.8/15.0	1.2	14.3/14.4	ndef	13.8/15.0	1.2	9,10,11
C,8	9.8	7	54/59	5	14.8/15.1	0.3	nd	nd	14.8/15.1	0.3	9,10
D,1	2.2	4	86/94	8	5.1/7.9	2.8	5.1/7.9	2.8	nd	nd	10,12
D,2	2.4	8	60/76	16	5.3/13.2	7.9	5.3/13.2	7.9	nd	nd	10,12
D,3	3.0	10	42/59	17	5.8/12.5	6.7	5.8/12.5	6.7	nd	nd	10,12
D,4	3.0	14	40/47	7	7.1/15.1	8.0	8.9/14.8	5.9	7.1/15.1	8.0	10,12
D,5	2.8	4	37/42	5	11.3/15.7	4.4	15.3/15.3	ndef	11.3/15.7	4.4	10,12
D,6	2.7	4	37/39	2	13.8/15.7	1.9	nd	nd	13.8/15.7	1.9	10,12
D,7	2.6	6	38/39	1	14.3/16.0	1.7	nd	nd	14.3/16.0	1.7	10,12
D,8	7.3	6	37/45	8	15.1/15.7	0.6	nd	nd	15.1/15.7	0.6	10,12
E,1	0.5	5	59/60	1	8.4/12.1	3.7	8.4/12.1	3.7	nd	nd	13
E,2	3.3	4	40/47	7	11.1/12.9	1.8	11.1/12.9	1.8	nd	nd	12,13
E,3	2.9	6	37/41	4	12.1/15.3	3.2	12.1/15.3	3.2	nd	nd	12,13
E,4	4.4	34	27/38	11	13.4/15.7	2.3	13.7/15.7	2.0	13.4/15.6	2.2	12,13
E,5	2.6	14	30/35	5	14.8/16.3	1.5	15.5/15.7	ndef	14.8/16.3	1.5	12,13
E,6	4.2	4	32/34	2	15.5/16.4	0.9	nd	nd	15.5/16.4	0.9	13



Low Resolution (40 m) Single Beam Sonar Interpolated Image: Georges Bank Northern Margin (U.S. side only): July 2008.
CA II Undisturbed Gravel Habitat
Y-distance (km)
X-distance (km)
depth (m)
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
Hague Line
N
Depth Color Scale (m)
-50--40
-60--50
-70--60
-80--70
-90--80
-100--90
-110--100
-120--110
-130--120
<-130

Cruise reports

CRUISE RESULTS
NOAA SHIP DELAWARE II
DE04-15 Benthic Habitat Study

Cruise Period and Area of Operations

The cruise period was November 1-12, 2004 (due to weather, the ship returned to port at 1400h on November 2, and resumed operations at 1000h on November 8). The area surveyed included selected stations on northern Georges Bank (in US waters only), and in and near the northeast corner of Nantucket Lightship Closed Area (NLCA).

Objectives

The objectives of the cruise were to use otter trawls, beam trawls, Naturalist◆s Dredge, the USGS Seabed Observation and Sampling System (SEABOSS) photography/bottom grab equipment, and CTDs to conduct the following operations: 1) determine present distribution of the invasive colonial tunicate, *Didemnum lahillei,* on northern Georges Bank gravel habitat. Document relationships to other ecosystem components and substrates. Collect specimens for further study including DNA analysis. Survey several known sites near the tunicate area to determine if the "macaroni" organisms reported by fishermen in their nets are really tunicates; 2) continue monitoring recovery and productivity of untrawled gravel habitats in the Habitat Area of Particular Concern (HAPC) on northeastern Georges Bank, as compared to nearby trawled habitats; 3) in Great South Channel area, a) groundtruth existing multibeam imagery to create habitat maps, b) continue sampling inside/outside the western boundary of Closed Area I (CAI), and c) reoccupy 3 stations inside CAI to continue monitoring dredging effects/recovery; and 4) in the northeast corner of the NLCA, a) use ship◆s fathometer to map east-west trending sand ridges, b) reoccupy existing stations, and sample new stations on a transect from the northeast corner of NLCA to outside the eastern boundary of NLCA, c) use SEABOSS to survey a north-south transect just outside NLCA◆s eastern border, and d) monitor recovery of a sponge community from past trawling, and response to new experimental trawling.

Due to weather-related loss of sampling time, only objectives 1, 2 and 4 could be addressed. We did not have time to sample for the "macaroni" organisms noted in objective 1. We also could not sample in Canadian waters as intended. Objective 4 was modified to concentrate on reoccupying stations sampled in and outside the northeast corner of NLCA in 2003.

Operations

<u>*Areas and Parameters Sampled (see also Fig. 1)*</u>
Northern Georges Bank - In Project Area 17 (within the HAPC), 3 video/photo transects were conducted, and 2 beam trawl and 6 Naturalist◆s Dredge samples were collected. In Project Area 17W (gravel habitat just west of HAPC), 1 video/photo transect was conducted, and 2 beam trawl samples were taken. In Project Area 18, further west of HAPC, sampling included 36 video/photo transects, 3 otter trawl and 3 Naturalist◆s Dredge tows.

NLCA - In the sand and gravelly sand habitat in the northeast part of the NLCA, and in an area open to fishing just east of NLCA, 10 video/photo transects were conducted, and 6 grab samples were taken for sediment analysis, and 8 beam trawl tows were made.

Sampling Methods

The scientific party was divided into two operational teams. One team (staffing the 2400-1200 watch) was responsible for deploying SEABOSS and obtaining sediment samples from its grab sampler. The other team (1200-2400 watch) used Naturalist■s dredge, beam trawl and otter trawl to sample fish, benthic megafauna and epifauna.

At each site, several habitat monitoring and sampling instruments were deployed. The SEABOSS, provided and operated by the US Geological Survey, Woods Hole Field Station, was deployed to conduct video and still picture transects. The SEABOSS has two video cameras (forward and downlooking), a downlooking 35 mm camera, and a modified Van Veen grab sampler. Quartz halogen lights provide illumination for the video and an electronic flash unit provides lighting for still photographs. The system was tethered and essentially ■flown■ over the seafloor while the support vessel was drifting. Video was viewed in real time allowing collection of representative images and sediment samples. Each transect collected 20 minutes of continuous video, 20 still photographs (at approximately one minute intervals throughout the transect), and a sediment sample (except in the gravelly habitats of northern Georges Bank, where grab sampling is difficult). Video will be used to quantify microhabitat distributions, the distribution and microhabitat relationships of fishes, and the distribution of seabed sand ripples and dunes. Still photographs will be used to generate percent cover estimates for common habitat types. The top 2 cm of sediment was collected from samples obtained with the Van Veen sampler. These samples will be used to determine grain-size characteristics of surficial sediments.

To sample the fish component of the habitat, a 15 minute otter trawl haul was made at selected sites at a towing speed of 3.8 knots. The gear used was a #36 Yankee otter trawl rigged with 41 cm diameter rollers, 9 meter bridles and 450 kilogram polyvalent trawl doors rigged with chain backstraps. Also, a 2-meter-wide beam trawl was towed for 5 minutes at selected sites.

Catches were sorted to species and all fish and invertebrates caught were weighed and enumerated. Biological samples, including length frequency data, were collected from selected species for feeding ecology, age and growth, and other special studies. Stomach samples were either examined at sea (volumetrically) or individually preserved in 10% formalin for later analysis. Both station and biological data were recorded on standard NEFSC trawl logs. A CTD (Conductivity-Temperature-Depth) profiler was deployed twice a day, to determine subsurface temperature and salinity profiles. Salinity samples were also collected for CTD calibration.

The Naturalist■s dredge used had a 1 m wide frame, and was towed for 1 minute at 2-3 knots. The overall volume of material sampled was measured, and either the entire sample or a subsample was examined for fauna. Fauna collected were preserved in 10% formalin.

Results

Trawl and Dredge Sampling:

Summary of Samples Collected

Date	Area	Type	Number of samples
11/02/04	NLCA	Beam Trawl	8
11/09/04	18	Dredge	3
11/09/04	18	Otter Trawl	3
11/10/04	17	Dredge	3
11/10/04	17	Beam Trawl	2
11/10/04	17W	Beam Trawl	2
11/11/04	17	Dredge	3

Findings and Impressions

Nantucket Lightship Closed Area (NLCA)

Four pairs of beam trawl stations were made inside and outside of the northeast corner of the NLCA. The depths ranged from 66 to 82 m. The habitat is sand ridges with gravel in the troughs. This sampling repeated the same stations that were sampled in 2003. Preliminary analysis of the 2003 samples indicated significantly higher biomass, number of individuals, and number of species inside the NLCA compared with paired stations just outside. The 2004 samples seem to confirm these differences. Samples inside the NLCA were characterized by *Suberites* sponge, sea stars, scallops and other mollusks, red hake and other fishes. Stations outsides the NLCA had smaller numbers of the same species, with sand dollars being the only abundant species.

Didemnum Infestation

Area 18 is the site colonized by the invasive colonial tunicate, *Didemnum lahillei*. Three replicate dredge samples were made to characterize the benthic community composition. *Didemnum* colonies were abundant on the gravel collected at this site. The fauna collected from the gravel were preserved for laboratory analysis. These samples will be added to our time series at this site, which started in 1994. Based on the samples collected in 2003, we have begun to see changes in the community composition at this site that may be attributable to colonization by *Didemnum*. Samples of *Didemnum* were preserved for future analyses, including DNA extraction. Three otter trawl tows were made to characterize the fish community and the food habits of benthic-feeding fish. One tow was made in an area without tunicates and two tows were made in the area colonized by *Didemnum*. The catches were dominated by small haddock, longhorn sculpin, and assorted demersal fish. Cancer crabs dominated the diet of several species. In the area colonized by *Didemnum*, tunicate fragments were found in the stomachs of haddock, winter flounder, and longhorn sculpin. None of the fragments appeared to be digested, even those in the lower intestine of longhorn sculpin.

Habitat Area of Particular Concern (HAPC)

Samples were collected inside and outside of the HAPC to continue monitoring the effect of the area closure on the benthic fauna. These samples included three replicate dredge samples inside, three outside, and two beam-trawl samples inside, two outside. Inside the HAPC there is higher abundance of scallops, sea stars, red hake, sea urchins, waved whelks, and hermit crabs. Based on the videos and gravel collected in the dredge samples, there was less attached epifauna (sponges, bryozoans) in the HAPC than was observed in priors years after the closure.

SEABOSS Photography and Sediment Sampling:

Findings and Impressions

Didemnum infestation

In the fall of 2003, the same research team first spotted the infestation of the colonial tunicate *Didemnum lahillei* over roughly 6 square miles of ocean bottom during a scientific cruise to study habitats in Area 18 on eastern Georges Bank. This year, a major objective of the cruise was to map the area of tunicate coverage. A larger area was surveyed with the SEABOSS, and the area of infestation was found to be larger than 40 square miles (statute) of gravel seabed that is highly productive for fish and sea scallops. Video and photo transects documented the distribution of the tunicate colonies in water depths of 42 to 65 meters (138 to 213 feet). In large parts of the affected area, the sea squirts cover 50 percent or more of the seabed. There was not adequate time to survey the entire area. The Georges Bank infestation is unique, the only known occurrence of this magnitude in a major offshore fishing ground.

Scientists will analyze data collected on the cruise to determine if the tunicate invasion has the potential to alter seabed communities that sustain commercial fish species. Tunicate fragments were also found in the stomachs of haddock and winter flounder collected in the area, but did not appear to be digested. Samples of the tunicate will be evaluated to determine its nutritional value to predators, and to confirm the species through DNA analysis.

Data Management and Disposition of Data

Video, still photographs, and VanVeen grab samples for grain size analysis from the SEABOSS were forwarded to the USGS, Woods Hole Field Center, Woods Hole, MA for analysis. Preserved (10% formalin) Naturalists• dredge collections were taken to University of Rhode Island for analysis. Samples taken for feeding ecology studies were preserved in 10% formalin solution and stored at the NMFS Woods Hole Laboratory for analysis. Feeding ecology data will be processed and analyzed at the Woods Hole Laboratory.

Scientific Personnel

National Marine Fisheries Service, NEFSC, Highlands, NJ

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National Marine Fisheries Service, Northeast Regional Office, Gloucester MA

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Page Valentine	Geologist
Dann Blackwood	Photographer
Erin Heffron	Geological Technician

University of Rhode Island, Narragansett, RI

Jeremy Collie	Professor of Oceanography
Rebecca Asch	Graduate Student
Tony Wood	Graduate Student

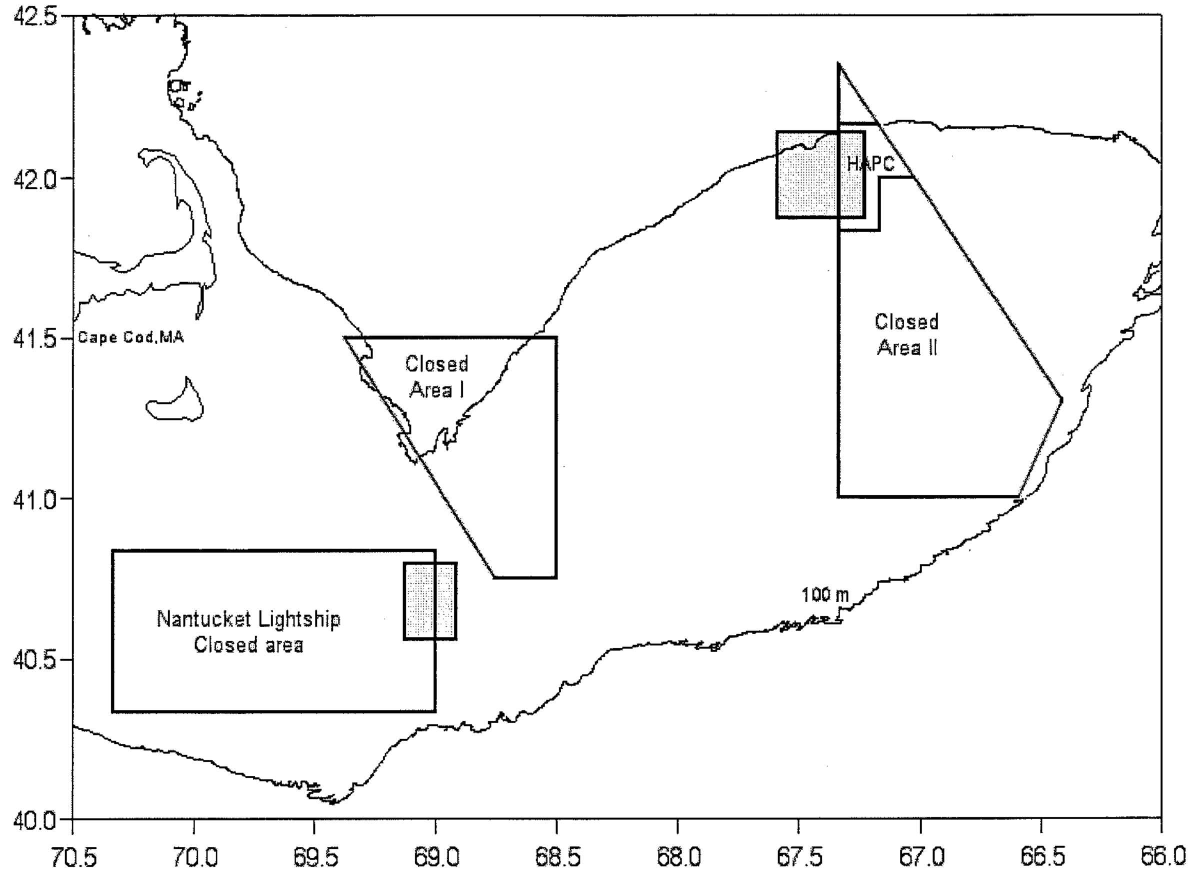

Figure 1. Areas sampled (shaded) on NOAA FRV DELAWARE II Cruise DE04-15 (Benthic Habitat Study)

CRUISE RESULTS
NOAA SHIP DELAWARE II
DE05-11 Benthic Habitat Study

Cruise Period and Area of Operations

The cruise period was August 22- September 1, 2005 (due to weather, the ship returned to port one day before the scheduled return date, September 2). The area surveyed included selected stations on northern Georges Bank in both US and Canadian waters.

Objectives

The objectives of the cruise were to use otter trawls, beam trawls, Naturalist•s Dredge, the USGS Seabed Observation and Sampling System (SEABOSS) photography/bottom grab equipment, and CTDs to conduct the following operations: 1) determine present distribution of the invasive colonial tunicate, *Didemnum* sp., on northern Georges Bank gravel habitat. Document relationships to other ecosystem components and substrates. Collect specimens for further study including DNA analysis. Survey several known sites near the tunicate area to determine if the "macaroni" organisms reported by fishermen in their nets are really tunicates. Sample for tunicates and other biota in a large mussel bed, an important habitat feature on the Canadian part of Georges Bank; 2) continue monitoring recovery and productivity of untrawled gravel habitats in the Habitat Area of Particular Concern (HAPC) on northeastern Georges Bank, as compared to nearby trawled habitats; 3) in Great South Channel area, groundtruth existing multibeam imagery to create habitat maps, and sample for tunicates; and 4) time permitting, reoccupy existing stations and sample new stations on a transect from the northeast corner of Nantucket Lightship Closed Area (NLCA) to outside the eastern boundary of NLCA.

Due to the time required to thoroughly address objectives 1 and 2, the lower priority objectives were not met.

Operations

<u>*Areas and Parameters Sampled (see also Fig. 1)*</u>
Northern Georges Bank - In Project Area 17 (within the HAPC), 7 video/photo transects were conducted, and 3 beam trawl and 3 Naturalist•s Dredge samples were collected. In Project Area 17W (gravel habitat just west of HAPC), 1 video/photo transect were conducted, and 5 beam trawl and 4 dredge samples were taken. In Project Area 18, farther west of HAPC, sampling included 39 video/photo transects, 4 otter trawl and 3 dredge tows. In area "HAPC South", 50 video/photo transects, 2 otter trawl and 3 dredge tows were made. In a large mussel patch in Canadian waters on northeastern Georges, 19 video/photo transects, 3 beam trawl and 4 dredge samples were taken. At area 20 just east of the mussel patch, 11 video/photo transects and 2 dredge samples were taken. At area 13 (south of 20), 5 video/photo transects and 2 beam trawl samples were taken. One site where "macaroni" has been reported by fishermen was sampled with 1 video/photo transect. A total of 133 video/photo transects were completed with SEABOSS.

Sampling Methods

The scientific party was divided into two operational teams. One team (staffing the 1200-2400 watch) was responsible for deploying SEABOSS and obtaining occasional samples of tunicates with its grab sampler. The other team (2400-1200 watch) used Naturalist•s dredge, beam trawl and otter trawl to sample fish, benthic megafauna and epifauna.

At each site, several habitat monitoring and sampling instruments were deployed. The SEABOSS, provided and operated by the US Geological Survey, Woods Hole Field Station, was deployed to conduct video and still picture transects. The SEABOSS has two video cameras (forward and downlooking), a downlooking 35 mm camera, and a modified Van Veen grab sampler. Quartz halogen lights provide illumination for the video and an electronic flash unit provides lighting for still photographs. The system was tethered and essentially ▪flown• over the seafloor while the support vessel was drifting. Video was viewed in real time allowing collection of representative images and sediment samples. Each transect collected 20 minutes of continuous video, 20 still photographs (at approximately one minute intervals throughout the transect), and a sediment sample (except in the gravelly habitats of northern Georges Bank, where grab sampling is difficult). Video will be used to quantify microhabitat distributions, the distribution and microhabitat relationships of fishes, and the distribution of seabed sand ripples and dunes. Still photographs will be used to generate percent cover estimates for common habitat types. The top 2 cm of sediment was collected from samples obtained with the Van Veen sampler. These samples will be used to determine grain-size characteristics of surficial sediments.

To sample the fish component of the habitat, a 15 minute otter trawl haul was made at selected sites at a towing speed of 3.8 knots. The gear used was a #36 Yankee otter trawl rigged with 41 cm diameter rollers, 9 meter bridles and 450 kilogram polyvalent trawl doors rigged with chain backstraps. Also, a 2-meter-wide beam trawl was towed for 5 minutes at selected sites.

Catches were sorted to species and all fish and invertebrates caught were weighed and enumerated. Biological samples, including length frequency data, were collected from selected species for feeding ecology, age and growth, and other special studies. Stomach samples were either examined at sea (volumetrically) or individually preserved in 10% formalin for later analysis. Both station and biological data were recorded on standard NEFSC trawl logs. A CTD (Conductivity-Temperature-Depth) profiler was deployed twice a day, to determine subsurface temperature and salinity profiles. Salinity samples were also collected for CTD calibration.

The Naturalist•s dredge used had a 1 m wide frame, and was towed for 1 minute at 2-3 knots. The overall volume of material sampled was measured, and either the entire sample or a subsample was examined for fauna. Fauna collected were preserved in 10% formalin.

Results

Trawl and Dredge Sampling:

Summary of Samples Collected

Date	Area	Type	Number of samples
08/24/05-08/24/05	18	Otter trawl	4
08/24/05	18	Dredge	3
08/25/05	17	Dredge	3
08/25/05, 08/28/05	17	Beam trawl	3
08/26/05, 08/28/05	17W	Beam trawl	5
8/26/05	17W	Dredge	4
8/27/05	Mussel Patch	Beam trawl	3
8/27/05	Mussel Patch	Dredge	4
8/27/05	13	Beam trawl	2
8/27/05	20	Dredge	2
8/28/05	HAPC South	Otter trawl	2
8/29/05	HAPC South	Dredge	3

Findings and Impressions

Didemnum Infestation

Area 18 was the site of dense tunicate colonies in 2004. The tunicate is still present at this site, but at much reduced percent cover. There were no obvious changes to the benthic fauna, except a reduction of the polychaete species that have been associated with *Didemnum*. A new dredge site was established in the southern quadrant of the Habitat Area of Particular Concern (HAPC) in an area of dense tunicate colonies (10-25% cover). This site is also a horse mussel bed. The third dredge sample contained seven live mussels with associated fauna. The association between *Didemnum* and the polychaetes, *Nereis* and *Harmothoe* was confirmed at this site. These polychaete worms were commonly found burrowing between the tunicate and the pebble and shell substrate.

Paired otter trawl tows inside and outside of the tunicate patch were made to determine whether the tunicate affects the diet of benthic feeding fish. No tunicate fragments were observed in any of the stomachs that were visually examined. Samples of *Didemnum* were preserved (formalin, alcohol, freezing) for taxonomic, genomic, and chemical analyses. The invasive tunicate was not seen at any of the dredge stations on the Canadian side of Georges Bank. Small tunicate colonies were found in the dredge samples that did not appear to be the invasive species. Based on morphological appearance, there may be three other types. These samples were preserved in ethanol for subsequent DNA analysis.

Effects of Bottom Fishing

Sites were resampled to monitor the effect of area closures on benthic megafauna. The visual appearance of these sites is similar to prior years (2003, 2004). The sites outside the closed area (18 and 17W) appear heavily disturbed. The sites inside the closed area contain high abundances of taxa that are sensitive to bottom fishing disturbance, including sea urchins (Site 17) and horse mussels (HAPC South). However, there is less attached epifauna (bryozoans, sponges) than was observed in the years immediately following the closure.

The mussel patch is an example of the 'biogenic bottom' described by Thouzeau et al. Inside the patch the sediment is almost completely covered with horse mussels and attached hydroids. The hydroids provide habitat for toad crabs, brittle stars, and several shrimp species. Orange-footed sea cucumbers were prevalent at this site; large sea stars were grazing on the mussels. In contrast, the sediment at a site about two miles outside the mussel patch consisted of gravel mixed with sand. Benthic epifauna were scarce at this site compared with inside the mussel patch. Fishing boats were in evidence in the general area. The mussel patch appears to be unfished because of the presence of scattered boulders. Comparison of our sampling location with maps of fishing effort will help to determine their fishing history.

Sites 13 and 20 were resampled to determine their status since we last sampled here in 2002. Site 13 appears similar to previous cruises, with continued low abundance of benthic fauna. Site 20 appears more highly disturbed with much less attached epifauna, especially the small, calcareous tube-dwelling polychaete, *Filograna implexa*. Our impression is that the undisturbed area at Site 20 is shrinking due to fishing activity as evidenced by trawl marks observed in the videos.

Juvenile cod were caught with the beam trawl in small numbers, confirming their occurrence in the HAPC. However, the beam trawl is not optimally configured for catching juvenile cod. The heavy trawl cable rides on the bottom in front of the trawl opening, likely causing juvenile cod to avoid the net. The gravel bottom was very rough on the beam trawl, causing numerous net tears and finally destroying the trawl.

Video and Photo Transects:

Findings and Impressions

<u>*Didemnum* infestation</u>

In the fall of 2003, the same research team first spotted the infestation of the colonial tunicate *Didemnum lahillei* over roughly 6 square miles of ocean bottom during a scientific cruise to study habitats in Area 18 on eastern Georges Bank. In the fall of 2004, a major objective of the cruise was to map the area of tunicate coverage. A larger area was surveyed with the SEABOSS, and the area of infestation was found to be larger than 40 square miles (statute) of gravel seabed that is highly productive for fish and sea scallops. Video and photo transects documented the distribution of the tunicate colonies in water depths of 42 to 65 meters (138 to 213 feet). In large parts of the affected area, the sea squirts covered 50 percent or more of the seabed. There was not adequate time to survey the entire area. This year (August 2005) the video/photo survey of the gravel habitat was conducted over a much larger area than in 2004. A survey of the previously reported area of infestation (Area 18) and the contiguous area to the south of it revealed the presence of the tunicate in 67 sq mi (statute) of seabed. The very large colonies observed in 2004 were absent, except in a few locations around large boulders, but many small colonies were present. We hypothesize that disturbance by trawling and dredging has fragmented the large colonies during the past year. An area inside Closed Area 2 (several miles to the east of the known area of infestation) was surveyed and found to contain tunicate colonies in 21 sq mi (statute) of gravel habitat. The Georges Bank infestation is now known to affect 88 sq mi (statute) of gravel habitat in two areas in US waters near the US/Canada boundary. It is the only known occurrence of this magnitude in a major offshore fishing ground.

The new area of infestation is inside Closed Area 2 and will be protected from disturbance by fishing gear. This area will be the basis for future studies on the growth and spreading rate of tunicate colonies and on the effects of the colonies on the ecology of the gravel habitat and the benthic species that inhabit it.

Data Management and Disposition of Data

Video, still photographs, and VanVeen grab samples for grain size analysis from the SEABOSS were forwarded to the USGS, Woods Hole Field Center, Woods Hole, MA for analysis. Preserved (10% formalin) Naturalists♠ dredge collections were taken to University of Rhode Island for analysis. Samples taken for feeding ecology studies were preserved in 10% formalin solution and stored at the NMFS Woods Hole Laboratory for analysis. Feeding ecology data will be processed and analyzed at the Woods Hole Laboratory.

Scientific Personnel

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National Marine Fisheries Service, NEFSC, Woods Hole, MA

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Dann Blackwood	Photographer
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University of Rhode Island, Narragansett, RI

Jeremy Collie	Professor of Oceanography
Rebecca Asch	Graduate Research Assistant
Richard Bell	Graduate Research Assistant
Nicole Lengyel	Undergraduate Research Assistant

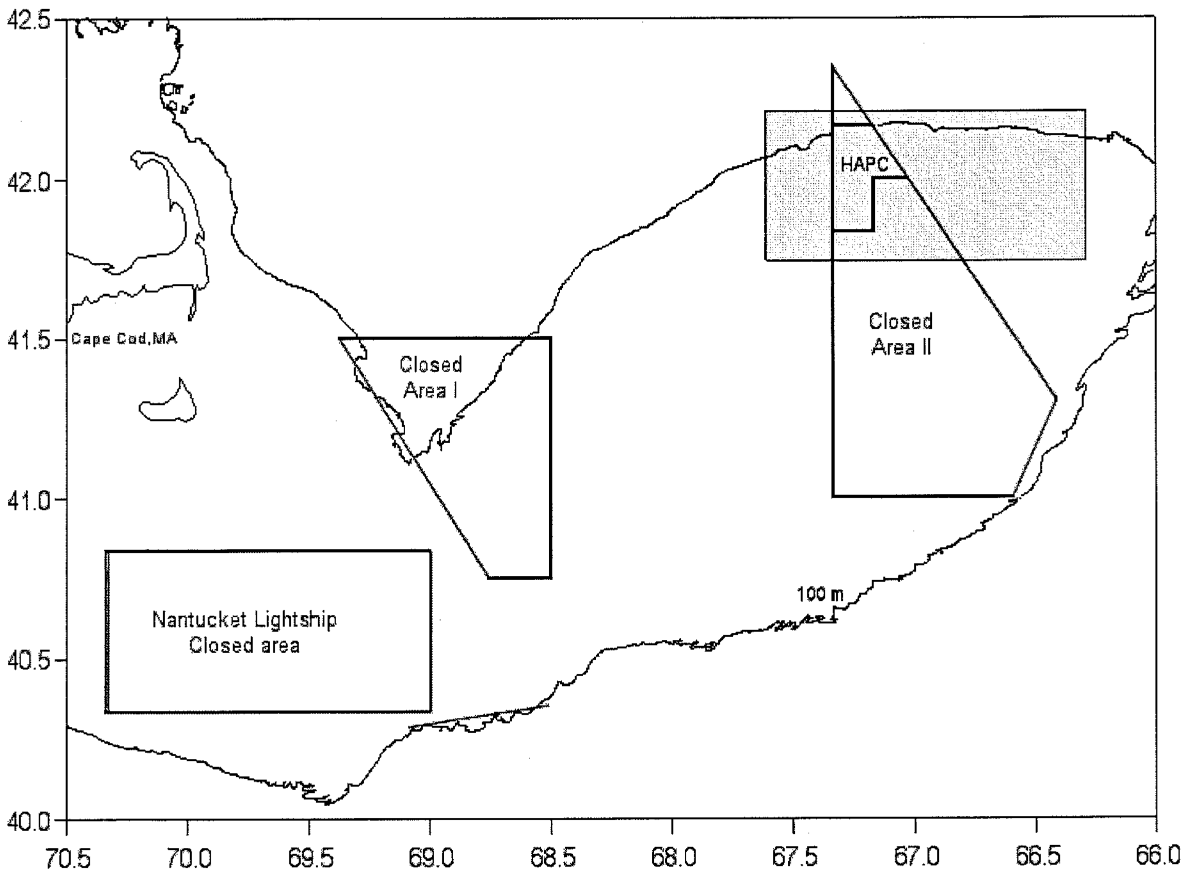

Figure 1. Areas sampled (shaded) on NOAA FRV DELAWARE II Cruise DE04-15 (Benthic Habitat Study)

CRUISE RESULTS
NOAA SHIP DELAWARE II
DE06-14 Benthic Habitat Study

Cruise Period and Area of Operations

The cruise period was August 22- September 1, 2006). The area surveyed included selected stations on northern Georges Bank in both US and Canadian waters.

Objectives

The objectives of the cruise were to use otter trawls, beam trawls, Naturalist•s Dredge, the USGS Seabed Observation and Sampling System (SEABOSS) photography/bottom grab equipment, and 30-liter Niskin bottles to conduct the following operations: 1) determine present distribution of the invasive colonial tunicate, *Didemnum* sp., on northern Georges Bank gravel habitat; 2) document relationships to other ecosystem components and substrates; 3) collect specimens for further study including DNA analysis and biochemical analysis of nutritional value; 4) filter bottom waters to determine fatty acid signatures of particulate matter, for comparison with signatures of the tunicate and potential predators; 5) survey several known sites near the tunicate area to determine if the "macaroni" organisms reported by fishermen in their nets are really tunicates; 6) sample for tunicates and other biota in a large mussel bed, an important habitat feature on the Canadian part of Georges Bank, and also sample in the Canadian waters closest to the Hague Line; 7) continue monitoring recovery and productivity of untrawled gravel habitats in the Habitat Area of Particular Concern (HAPC) on northeastern Georges Bank, as compared to nearby trawled habitats; 8) in Great South Channel area, groundtruth existing multibeam imagery to create habitat maps, and sample for tunicates; and 9) time permitting, reoccupy existing stations and sample new stations on a transect from the northeast corner of Nantucket Lightship Closed Area (NLCA) to outside the eastern boundary of NLCA.

Due to the time required to thoroughly address objectives 1-4 and 6-7, the other objectives were not met.

Operations

<u>*Areas and Parameters Sampled (see also Fig. 1)*</u>
Northern Georges Bank - In Project Area 17 (within the HAPC), 4 video/photo transects were conducted, and 2 otter trawl and 3 Naturalist•s Dredge samples were collected. In Project Area 17W (gravel habitat just west of HAPC), 1 video/photo transect was conducted, and 3 dredge samples were taken. In Project Area 18, farther west of HAPC, sampling included 17 video/photo transects (with 8 tunicate samples), 2 otter trawl and 3 dredge tows. In area 19 (= "HAPC South"), 35 video/photo transects (16 tunicate samples), 3 otter trawl and 4 dredge samples were taken. In a large mussel bed in Canadian waters on northeastern Georges, 12 video/photo transects, 3 otter trawl and 4 dredge samples were taken. At area 20 just east of the mussel bed, 7 video/photo transects, 1 otter trawl and 4 dredge samples were taken. At area 13 (south of 20), 6 video/photo transects and 3 dredge samples were taken. At area 16, adjacent to

the U.S./Canada boundary, 7 video/photo transects were taken. A total of 90 video/photo transects were completed with SEABOSS.

Sampling Methods

The scientific party was divided into two operational teams. One team (staffing the 2400-1200 watch) was responsible for deploying SEABOSS and obtaining occasional samples of tunicates with its grab sampler. The other team (1200-2400 watch) used Naturalist▴s dredge, beam trawl and otter trawl to sample fish, benthic megafauna and epifauna.

At each site, several habitat monitoring and sampling instruments were deployed. The SEABOSS, provided and operated by the US Geological Survey, Woods Hole Science Center, was deployed to conduct video and still picture transects. The SEABOSS has two video cameras (forward and downlooking), a downlooking 35 mm camera, and a modified Van Veen grab sampler. Quartz halogen lights provide illumination for the video and an electronic flash unit provides lighting for still photographs. The system was tethered and essentially ■flown• over the seafloor while the support vessel was drifting. Video was viewed in real time allowing collection of representative images and sediment samples. Each transect collected 15 to 20 minutes of continuous video, still photographs (at approximately one minute intervals throughout the transect), and a tunicate sample where possible. Video will be used to quantify microhabitat distributions, the distribution and microhabitat relationships of fishes, and the distribution of seabed sand ripples and dunes. Still photographs will be used to generate percent cover estimates for common habitat types. The top 2 cm of sediment was collected from samples obtained with the Van Veen sampler. These samples will be used to determine grain-size characteristics of surficial sediments.

To sample the fish component of the habitat, a 15 minute otter trawl haul was made at selected sites at a towing speed of 3.8 knots. The gear used was a #36 Yankee otter trawl rigged with 41 cm diameter rollers, 9 meter bridles and 450 kilogram polyvalent trawl doors rigged with chain backstraps. Also, a 2-meter-wide beam trawl was towed for 5 minutes at selected sites.

Catches were sorted to species and all fish and invertebrates caught were weighed and enumerated. Biological samples, including length frequency data, were collected from selected species for feeding ecology, age and growth, and other special studies. Stomach samples were either examined at sea (volumetrically) or individually preserved in 10% formalin for later analysis. Both station and biological data were recorded on standard NEFSC trawl logs.

The Naturalist▴s dredge used had a 1 m wide frame, and was towed for 1 minute at 2-3 knots. The overall volume of material sampled was measured, and either the entire sample or a subsample was examined for fauna. Fauna collected were preserved in 10% formalin.

The 30-liter Niskin bottle was deployed from the oceanographic winch, and was held 1-2 meters off bottom for 5 minutes in areas of dense tunicates before being tripped. The water samples were filtered in the lab, and material retained on the filters was held on dry ice for return to

Howard Laboratory.

Results

Trawl and Dredge Sampling:

Summary of Samples Collected

Date	Area	Type	Number of samples
08/23/06	18	Dredge	3
08/23/06	18	Otter trawl	2
08/24/06	19	Dredge	4
08/2406	19	Otter trawl	2
08/2506	17	Dredge	3
08/26/06	17	Otter trawl	2
08/26/06-08/27/06	Mussel Bed	Dredge	4
08/26/06-08/27/06	Mussel Bed	Otter trawl	3
08/28/06	20	Dredge	4
08/28/06	20	Otter trawl	1
08/29/06	13	Dredge	3
08/31/06	17W	Dredge	3

Findings and Impressions

Didemnum Infestation

Two of the dredge sites in U.S. waters had dense tunicate colonies: Area 18, outside the HAPC, and Area 19 inside the HAPC. The association between *Didemnum* and the polychaetes *Nereis* and *Harmothoe* was confirmed at these sites. These polychaete worms were commonly found burrowing between the tunicate and the pebble and shell substrate. The only other species common at these sites was the rock crab, *Cancer irroratus*. Live horse mussels, *Modiolus modiolus* were recovered at Area 19.

The otter trawl catches inside the tunicate areas were dominated by winter skate. No tunicate fragments were observed in any of the stomachs that were visually examined. Samples of *Didemnum* were preserved (formalin, alcohol, freezing) for taxonomic, genomic, and chemical analyses. The invasive tunicate was not seen at any of the dredge stations on the Canadian side of Georges Bank. Small tunicate colonies were found in the dredge samples that did not appear to be the invasive species. Based on morphological appearance, there may be three other tunicate species. These samples were preserved in ethanol for subsequent DNA analysis.

Effects of Bottom Fishing

Sites were resampled to monitor the effect of area closures on benthic megafauna. The visual appearance of these sites is similar to prior years (2003, 2004, 2005). The sites outside the closed area (18 and 17W) appear heavily disturbed, as indicated by the VMS fishing location data. The sites inside the closed area contain higher abundances of taxa that are sensitive to bottom fishing disturbance, including sea urchins (Site 17) and horse mussels (Site 19). However, there is less attached epifauna (bryozoans, sponges) than was observed in the years immediately following the closure. The sediment in Area 17 is much sandier than in previous years; this sand may prevent the growth of attached epifauna.

The mussel bed is a good example of the 'biogenic bottom' described by Thouzeau et al. (1991). Inside the bed the sediment is almost completely covered with horse mussels and attached hydroids. The hydroids provide habitat for toad crabs, brittle stars, and several shrimp species. Orange-footed sea cucumbers were prevalent at this site; large sea stars graze on the mussels. In contrast, the sediment at a heavily fished site about four miles southeast of the mussel bed consisted of clean gravel with very little attached epifauna. Fishing boats were in evidence around, but not in, the mussel bed. Maps of fishing effort confirm the lack of scallop fishing in the mussel bed, which appears to be unfished because of the presence of scattered boulders and lack of scallops. Large haddock catches were made at stations just outside the mussel bed. The haddock and other demersal fish were feeding on many of the benthic invertebrates that are more abundant in the mussel bed (shrimps, polychaetes, and mollusks).

Sites 13 and 20 were resampled to continue a time series started in 1994. Site 13 appears similar to previous cruises, with smooth gravel and lower abundance of benthic fauna, but somewhat more attached epifauna than in previous years, perhaps due to decreased scallop fishing effort in recent years. Site 20 has higher abundance of benthic fauna, sponges, and hydroids but less *Filograna implexa* than in previous years. The area around Site 20 has some trawling effort but almost no scallop fishing effort. The otter trawl in Area 20 had numerous shrimp.

Juvenile cod were caught with the otter trawl in small but consistent numbers, confirming their occurrence in the HAPC and on the Canadian side of northern Georges Bank. However, the otter trawl is not optimally configured for catching juvenile cod, which may escape under the roller gear.

Video and Photo Transects:

Didemnum infestation

In the fall of 2003, the same research team first spotted the infestation of the colonial tunicate *Didemnum* sp. over roughly 6 square miles of ocean bottom during a scientific cruise to study habitats in Area 18 on eastern Georges Bank. In the fall of 2004, a major objective of the cruise was to map the area of tunicate coverage. A larger area was surveyed with the SEABOSS, and the area of infestation was found to be larger than 40 square miles (statute) of gravel seabed that is highly productive for fish and sea scallops. Video and photo transects documented the distribution of the tunicate colonies in water depths of 42 to 65 meters (138 to 213 feet). In large parts of the affected area, the sea squirts covered 50 percent or more of the seabed. There was not adequate time to survey the entire area.

In August 2005 the video/photo survey of the gravel habitat was conducted over a much larger area than in 2004. A survey of the previously reported area of infestation (Area 18) and the contiguous area to the south of it revealed the presence of the tunicate in 67 sq mi (statute) of seabed. The very large colonies observed in 2004 were absent, except in a few locations around large boulders, but many small colonies were present. We hypothesize that disturbance by trawling and dredging has fragmented the large colonies during the past year. Area 19 inside Closed Area 2 (several miles to the east of the known area of infestation) was surveyed and found to contain tunicate colonies in 21 sq mi (statute) of gravel habitat. The Georges Bank infestation is now known to affect 88 sq mi (statute) of gravel habitat in two areas in US waters near the US/Canada boundary. It is the only known occurrence of this magnitude in a major offshore fishing ground.

In August 2006 (this cruise), both Areas 18 and 19 were resurveyed to examine the presence and condition of the tunicate colonies. In both areas, the colonies had increased in number and size since 2005. At some sites, tunicate colonies covered more than 75 percent of the seabed. Many samples (24) of tunicate colonies were collected for taxonomic and chemical analyses.

Area 19 is inside Closed Area 2 and is protected from disturbance by fishing gear. This area will be the basis for future studies on the growth and spreading rate of tunicate colonies and on the effects of the colonies on the ecology of the gravel habitat and the benthic species that inhabit it.

Tunicate colonies were not observed in the other areas of gravel habitat surveyed in both U.S. and Canadian waters, including an area adjacent to the international boundary where the tunicate is most likely to occur first.

Data Management and Disposition of Data

Video, still photographs, and VanVeen grab samples of tunicates from the SEABOSS were forwarded to the USGS, Woods Hole Field Center, Woods Hole, MA for analysis. Tunicate samples were preserved in ethanol and in 10% formalin. Naturalists' dredge collections preserved in 10% formalin were taken to University of Rhode Island for analysis. Samples taken for feeding ecology studies were preserved in 10% formalin solution and stored at the NMFS Woods Hole Laboratory for analysis. Feeding ecology data will be processed and analyzed at the Woods Hole Laboratory. Samples of bottom water particulate matter were taken to the NMFS Howard Laboratory for analysis.

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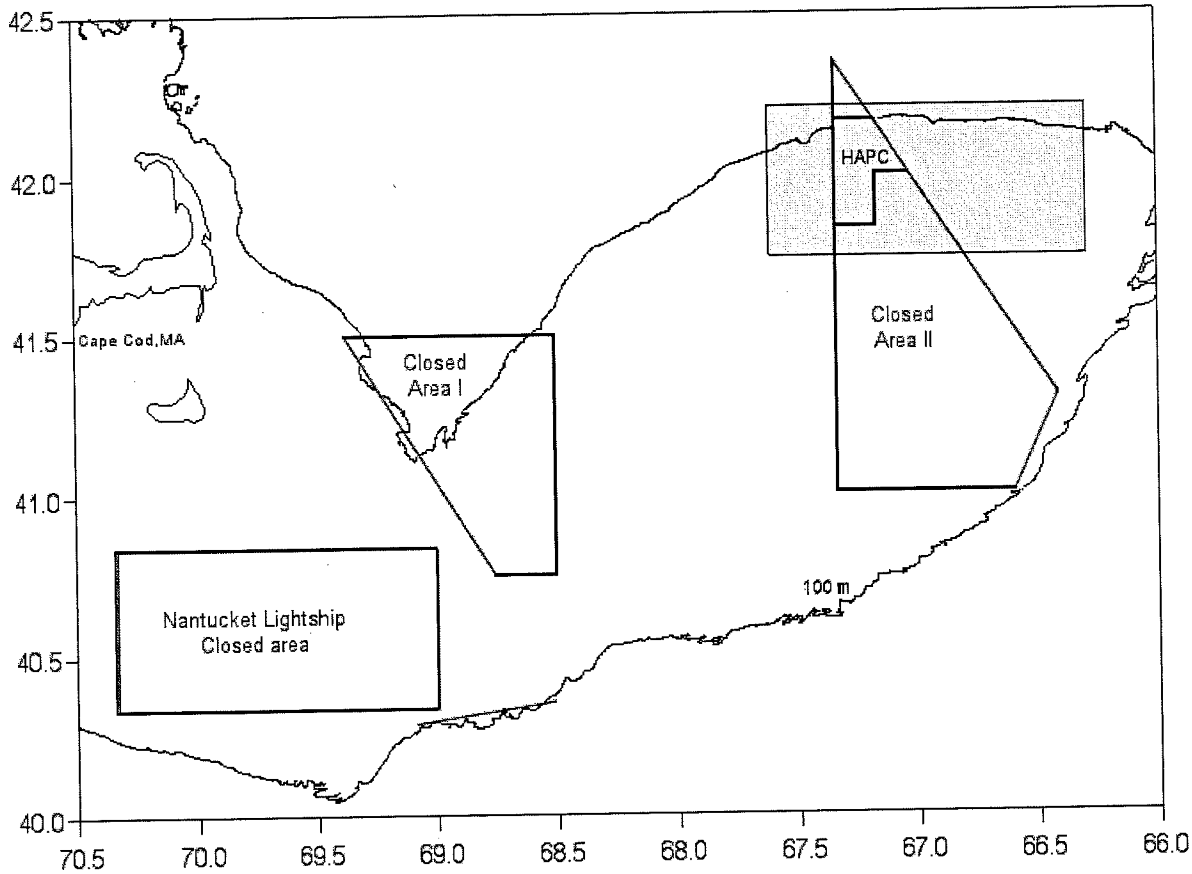

Figure 1. Areas sampled (shaded) on NOAA FRV DELAWARE II Cruise DE06-14 (Benthic Habitat Study)

CRUISE RESULTS
NOAA SHIP DELAWARE II
DE07-07 Benthic Habitat Study

Cruise Period and Area of Operations

The cruise period was July 2-13, 2007). The area surveyed included selected stations on western and northern Georges Bank. Stations were occupied in both US and Canadian waters.

Objectives

The objectives of the cruise were to use otter trawls, beam trawls, Naturalist Dredge, SEABOSS photography/bottom grab equipment, CTDs, and large (30 liter) Niskin water bottles to conduct the following operations: 1) determine distribution of invasive colonial tunicate *Didemnum* sp. on northern Georges Bank gravel habitat, and also northeast of Great South Channel (where the species had recently been reported); 2) document relationships to other ecosystem components and substrates; 3) collect tunicate specimens for further study including DNA analysis, and collect near-bottom water samples in tunicate areas; 4) continue monitoring recovery and productivity of untrawled gravel habitats in HAPC on northeastern Georges Bank, as compared to nearby trawled habitats; also, time permitting, 5) groundtruth existing multibeam imagery in Great South Channel area, to create habitat maps, and sample for tunicates; and 6) re-occupy existing stations and sample new stations on a transect from the northeast corner of NLCA to outside the eastern boundary of NLCA.

Due to the time required to thoroughly address objectives 1-4, and to add hydrographic profiling and examination of a newly-found "unfished" area, objectives 5 and 6 were not met.

Operations

<u>*Areas and Parameters Sampled (see also Fig. 1)*</u>
Northern Georges Bank - In Project Area 17 (within the HAPC), 6 video/photo transects were conducted, and 3 otter trawl and 4 Naturalist's Dredge samples were collected. In Project Area 17W (gravel habitat just west of HAPC), 3 video/photo transects were conducted, and 3 dredge and 3 otter trawl tows were made. In Project Area 18, farther west of HAPC, sampling included 16 video/photo transects, 2 otter trawl and 3 dredge tows. In area 19 (= "HAPC South"), 17 video/photo transects, 2 otter trawl and 3 dredge samples were taken. In a large mussel bed in Canadian waters on northeastern Georges, 14 video/photo transects, 1 otter trawl and 3 dredge samples were taken. At "Mussel Bed Control" (= Area 20) just east of the mussel bed, 1 video/photo transect, 1 otter trawl and 3 dredge samples were taken. At area 16 on the Canadian side of the U.S./Canada boundary, 6 video/photo transects were taken. At area 16 on the U.S. side of the boundary, 15 video/photo transects were taken, 13 of them in a newly-discovered undisturbed gravel habitat. On the northern edge of the bank, 17 video/photo transects were completed with a Seabird CTD to delineate the water temperature structure of the region. Another 4 video/photo transects were taken near the eastern boundary of Closed Area I. See

Results for more specific data on sampling.

Sampling Methods

The scientific party was divided into two operational teams. One team (staffing the 1200-2400 watch) was responsible for deploying SEABOSS and obtaining occasional samples of tunicates with its grab sampler, and water samples from just above abundant tunicate colonies. The other team (2400-1200 watch) used Naturalist•s dredge and otter trawl to sample fish, benthic megafauna and epifauna.

At each site, several habitat monitoring and sampling instruments were deployed. The SEABOSS, provided and operated by the US Geological Survey, Woods Hole Science Center, was deployed to conduct video and still picture transects. The SEABOSS has two video cameras (forward and downlooking), a downlooking 35 mm camera, and a modified Van Veen grab sampler. Quartz halogen lights provide illumination for the video and an electronic flash unit provides lighting for still photographs. The system was tethered and essentially ■flown• over the seafloor while the support vessel was drifting. Video was viewed in real time allowing collection of representative images and sediment samples. Each transect collected 15 to 20 minutes of continuous video, still photographs (at approximately one minute intervals throughout the transect), and a tunicate sample where possible. Video will be used to quantify microhabitat distributions, the distribution and microhabitat relationships of fishes, and the distribution of seabed sand ripples and dunes. Still photographs will be used to generate percent cover estimates for common habitat types.

To sample the fish component of the habitat, a 30 minute otter trawl haul was made at selected sites at a towing speed of 3.8 knots. The gear used was a #36 Yankee otter trawl rigged with 41 cm diameter rollers, 9 meter bridles and 450 kilogram polyvalent trawl doors rigged with chain backstraps.

Catches were sorted to species and all fish and invertebrates caught were weighed and enumerated. Biological samples, including length frequency data, were collected from selected species for feeding ecology, age and growth, and other special studies. Stomach samples were either examined at sea (volumetrically) or individually preserved in 10% formalin for later analysis. Both station and biological data were recorded on standard NEFSC trawl logs.

The Naturalist•s dredge used had a 1 m wide frame, and was towed for 1 minute at 2-3 knots. The overall volume of material sampled was measured, and either the entire sample or a subsample was examined for fauna. Fauna collected were preserved in 10% formalin.

The 30-liter Niskin bottle was deployed from the oceanographic winch, and was held 1-2 meters off bottom for 5 minutes in areas of dense tunicates before being tripped. The water samples were filtered in the lab, and material retained on the filters was held on dry ice for return to Howard Laboratory.

Results

Trawl and Dredge Sampling - Jeremy Collie (University of Rhode Island) and Brian Smith (NEFSC):

Summary of Samples Collected

Date	Area	Type	Number of samples
07/04/07	18	Otter trawl	2
07/04/07	18	Naturalist dredge	3
07/05/07	19	Otter trawl	2
07/05/07	19	Naturalist dredge	3
07/08/07	17	Naturalist dredge	4
07/12/07	17	Otter trawl	3
07/09/07-07/10/07	Mussel Bed	Naturalist dredge	3
07/10/07	Mussel Bed	Otter trawl	1
07/10/07	Mussel Bed Control	Otter trawl	1
07/09/07-07/10/07	Mussel Bed Control	Naturalist dredge	3
07/11/07	17W	Naturalist dredge	3
07/11/07-07/12/07	17W	Otter trawl	3

Findings and Impressions

Didemnum Infestation

Area 18 has been the site of dense tunicate colonies since 2003. Intense bottom fishing in this area appears to fragment but not kill the tunicate colonies. The tunicate is still present at this site, but the percent cover appears to be reduced compared with 2006, possibly in response to bottom fishing. Area 19, in the HAPC, had a higher percent cover of *Didemnum*; numerous tunicate colonies occurred in the dredge and otter trawl samples. The positive association between *Didemnum* and the polychaetes, *Nereis* and *Harmothoe* continues at this area. These polychaete worms were commonly found burrowing between the tunicate colonies and the pebble and shell substrate.

Paired otter trawl tows were made inside the tunicate patches at Areas 18 and 19 to determine whether the tunicate affects the diet of benthic feeding fish. Trawl catches within these two areas were dominated by haddock and longhorn sculpin respectively. Tunicate fragments were observed in stomachs of haddock and winter flounder that were visually examined. Tunicate fragments were also found in the stomachs of four winter flounder collected in Area 17W, but no tunicate colonies were observed in this area. It is likely that the winter flounder fed in an area infested with *Didemnum* and swam to area 17W, where they were caught. Samples of *Didemnum* were preserved (formalin, alcohol, freezing) for taxonomic, genomic, and chemical analyses. The invasive tunicate was not seen at any of the dredge stations on the Canadian side of Georges Bank. Small colonies of *Didemnum albidum* were found in the dredge samples at the Mussel Bed. These samples were preserved in ethanol for subsequent DNA analysis and in formalin for morphological identification.

Effects of Bottom Fishing

Sites were resampled to monitor the effect of area closures on benthic megafauna and fish diets. The visual appearance of these sites is generally similar to prior years (2003-2006). The sites outside the closed area (18 and 17W) appear heavily disturbed, with relatively little epifauna. The dredge site at Area 17, had a more gravelly substrate than in 2006, when sand covered the gravel. Probably as a result of the sand, there is less attached epifauna (bryozoans, sponges) than was observed in the years immediately following the closure (1997-1999). A new undisturbed area was found in the HAPC, just west of the Canadian border. With the SEABOSS, this area was seen to have a high cover of emergent epifauna (hydroids, bryozoans, and sponges). A voucher sample was collected with the grab sampler, but no other biological sampling was conducted.

The mussel patch is an example of the 'biogenic bottom' described by Thouzeau et al. (1991). Inside the patch the sediment is almost completely covered with horse mussels and attached hydroids. The hydroids provide habitat for toad crabs, brittle stars, and several shrimp species. This area is not closed to bottom fishing. As in 2006, many fishing boats were observed in this general area. The mussel bed has virtually no sea scallops and scattered boulders have discouraged bottom trawling. However, some bottom trawling does occur in this area. Lines made by trawl doors were evident in the video; in one transect trawl warps could be seen caught on a boulder. These observations suggest that the mussel bed is vulnerable to bottom trawling disturbance. A control site about 5 miles southeast of the Mussel Bed was resampled. This site was chosen because it has had high densities of scallop dredging effort in past years. The dredge samples at this control site consisted mainly of clean gravel; however, one of the replicates had more hydroids than in 2006. Benthic epifauna were scarce at this site compared with inside the Mussel Bed.

Juvenile cod were caught with otter trawl in small numbers, particularly at the Mussel Bed area. However, the otter trawl is not optimally configured for catching juvenile cod, which may escape under the roller gear.

Video and Photo Transects – Page Valentine (US Geological Survey):

Introduction:
During the cruise, seabed habitats were mapped and sampled using the USGS' Seaboss video/photo system. Study areas are on the northern edge of Georges Bank in U.S. and Canadian waters. Seaboss also collected bottom temperature data using HOBO Tidbit loggers and a Seabird CTD. In addition, 30 liter water bottles were used to sample seawater near the seabed in areas infested by the invasive colonial tunicate *Didemnum* sp. Over 7 working days at sea, we collected data from 99 stations (see table below).

Results:
On the transit from Woods Hole to our study areas, we made 4 Seaboss video/photo drifts at a location in Closed Area I (near its eastern boundary) where *Didemnum* sp. was observed in 2006 by WHOI researchers. We confirmed that the tunicate persists there, living on a mixed sand and pebble gravel habitat.

Our long-term study areas 18 and 19 continue to be infested by *Didemnum* sp. The affected areas, totaling 230 sq km of gravel habitat, have not increased appreciably since our survey in 2006 because they are bounded by mobile sand which smothers the tunicate and because cold bottom water temperatures prevent the tunicate's expansion into adjacent gravel habitats. We surveyed our other long-term study areas in both U.S. and Canadian waters and did not observe *Didemnum* sp. It is likely that the species has not spread to these areas because the bottom water temperatures are too cold for sexual reproduction to occur.

We made a significant discovery of gravel habitat in U.S. waters that is virtually undisturbed by bottom fishing gear. Surveys with the Seaboss in the HAPC of Closed Area II (Area 16 U.S.) adjacent to the Hague Line discovered a large area of gravel seabed (primarily cobbles and boulders) that may represent a habitat type that was typical of the northern edge of Georges Bank prior to the use of bottom trawling and dredging gear. Glacial deposits of pebble and cobble gravel and scattered boulders constitute the hard substrate; loose sand lies between the cobbles and boulders. The cobbles and boulders are completely covered by attached epifauna that include bryozoa, hydrozoa, sponges, *Filograna* colonial worms, and solitary tunicates. Bryozoa and hydrozoa dominate by far. Altogether, the attached epifauna covers 50 percent or more of the seabed. Unusually large numbers of haddock and cod were present in this area. Trawling and dredging has removed the epifauna in some places, but to a minor extent overall. Trawl/dredge scars can be recognized as open places where attached epifauna has been removed. Trawl wire was observed on the seabed wrapped around boulders. Presumably, the boulders in the area and its closure to fishing have prevented the destruction of the habitat to date, and the scars may have been made prior to the closing of the Closed Area II region in 1994.

A total of 15 Seaboss video/photo transects were conducted to delineate this habitat, with 13 within the undisturbed area. Transects were typically 0.25 to 0.5 nautical miles in length. We did not have enough time to delineate the boundaries of the habitat, but the survey indicates that it covers at least 7.4 sq nm (25 sq km; 10 sq statute mi). The undisturbed area extends westward from the U.S./Canada boundary approximately between the 40 and 50 fathom (55 and 73 m) isobaths, and possibly deeper, for at least 5 nm (9 km).

Table. Data collected during the Seaboss watch.

Date	Location on Georges Bank	Seaboss video/photo stations	Bottom temp stations	*Didemnum* sp. samples	Water sample, 30 liter	Seabird CTD stations
July 3, 2007	Closed Area I	4	4	1		0
"	Area 18	10	10	1	1	0
July 4	Area 18	5	5	2	1	0
"	Area 19, CA II	8	8	1	0	0

July 5	Area 19, CA II	0	0	0	0	1
July 8	Area 19, CA II	3	3	2	1	0
"	Northern Edge	17	0	0	0	17
"	Area 19, CA II	4	0	0	0	4
"	Area 18	1	0	0	0	1
July 9	Mussel Bed control, Canada	1	1			
"	Mussel Bed, Canada	14	14	0	0	0
July 10	Area 16, Canada	6	6	0	0	6
"	Area 16, US, CA II (undisturbed area)	4	4	0	0	4
"	Area 17, CA II	2	2	0	0	2
"	Area 17S, CA II	4	4	0	0	4
July 11	Area 17W	3	3	0	0	3
"	Area 19, CA II	2	2	1	1	2
"	Area 16, US, CA II (undisturbed area)	11	11	0	0	11
Totals		99	77	8	4	55

Data Management and Disposition of Data

Video, still photographs, and VanVeen grab samples of tunicates from the SEABOSS were forwarded to the USGS, Woods Hole Field Center, Woods Hole, MA for analysis. Tunicate samples were preserved in ethanol and in 10% formalin. Naturalists' dredge collections preserved in 10% formalin were taken to University of Rhode Island for analysis. Samples taken for feeding ecology studies were preserved in 10% formalin solution and stored at the NMFS Woods Hole Laboratory for analysis. Feeding ecology data will be processed and analyzed at the Woods Hole Laboratory. Samples of bottom water particulate matter were taken to the NMFS Howard Laboratory for analysis.

Scientific Personnel

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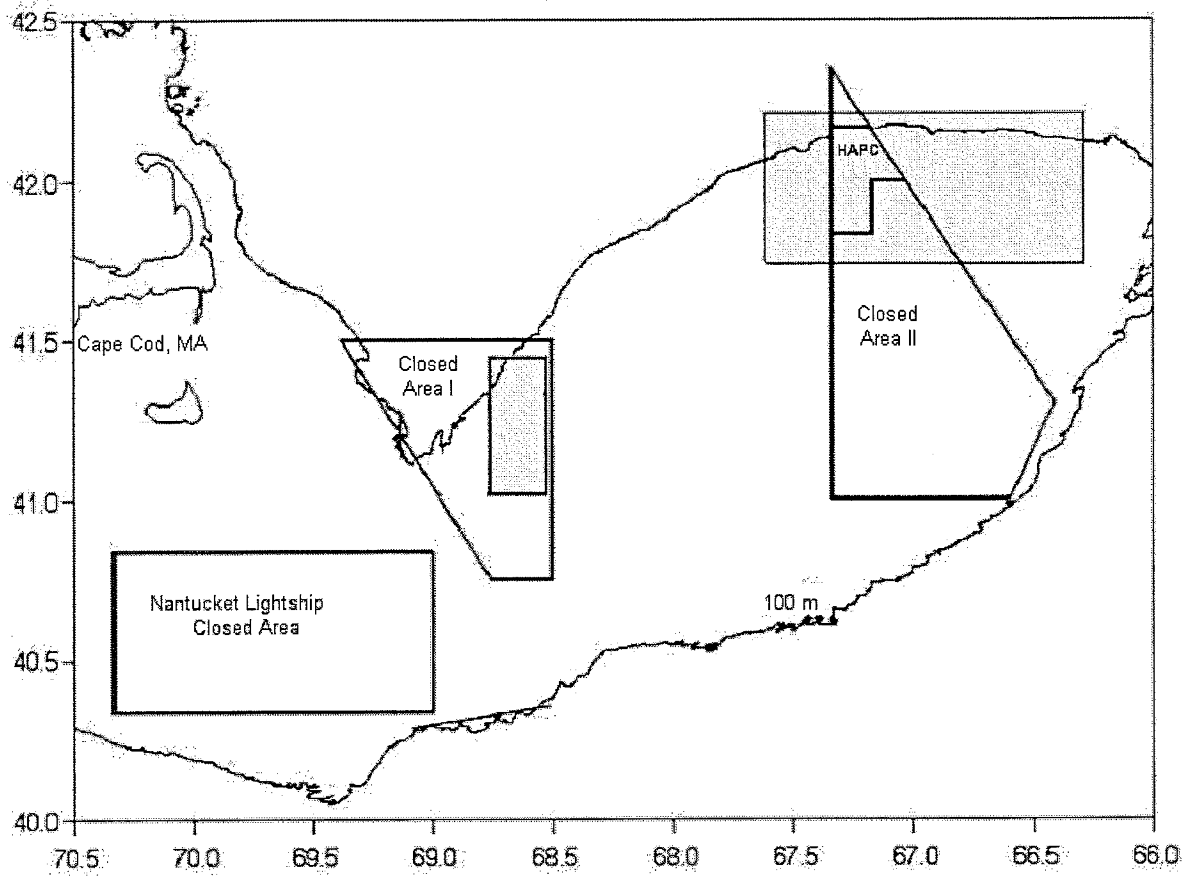

Figure 1. Areas sampled (shaded) on NOAA FRV DELAWARE II Cruise DE07-07 (Benthic Habitat Study)

29 September 2009

CRUISE RESULTS
NOAA Ship Delaware II
DE-09-08 Benthic Habitat Cruise

Executive Summary and Highlights

- This cruise was conducted along the northern edge of Georges Bank in order to explore the limits, extent and fisheries resource species associations of hard bottom habitats. Video and still photo images were gathered using the USGS Seaboss drift vehicle. A series of CTD hydrographic transects was also conducted in order to better understand the role of tidal hydrology in defining bottom habitats and fisheries resource associations. In addition to areas in an near Closed Area II (16-19) visited previously, habitats in new areas to the west (22-24) were investigated for the first time on this cruise.

- High-density, high-diversity "pristine" habitat supporting continuous cover with the bryozoan *Eucratia loricata*, was restricted to the northeast corner of Closed Area II. Small patches were found outside this area, including a newly-discovered area of concentration at the western end of Georges Bank (area 24).

- The invasive colonial tunicate *D. vexillum* was again confirmed in CA I and in areas 18 and 19 of CA II. No invasion of the more northerly areas of CA II (16, 16W, 17E, 17W) has been detected. There is no overlap between *D. vexillum* and *E. loricata* inside or immediately outside CA II. Overlap does occur, however in area 24 to the far west. Fishing activity appears to reduce tunicate dominance.

- This report of *D. vexillum* in area 24 is a first for the northwest corner of Georges Bank. Its dominance suggests it became established here several years ago.

- Sub-adult to adult cod and probably juvenile cod were repeatedly seen in the "pristine habitat" area. "Juvenile cod" also occurred immediately south (southern area 16W and area 17E). Haddock and silver hake were widespread in CA II, even where the bottom was dominated by *D. vexillum.* Gadoids were less often seen outside CA II than inside. Sea scallops occurred virtually everywhere at the eastern end of Georges Bank, inside and outside, with or without *D. vexillum*. No scallops and only a few silver hake were seen in area 24 in the west.

- Hydrographic transects revealed a strong tidal pattern of bottom water temperature fluctuation along the northern margin of Georges Bank: up to 6° C total change at rates reaching up to 4° C/hour between high and low tides. The change lessens with distance from the bank-slope break, gradually giving way to unvarying warm bottom temperatures within about 20 km south of the break. We believe that the strong fluctuations near the break play a role in discouraging *D. vexillum* colonization while encouraging an *E. loricata*-dominated epifaunal assemblage, cod and other fishery resource associates.

Cruise Period and Area of Operations

This cruise was conducted from August 3 to August 14, 2009 with designated stations (Fig. 1) located on Georges Bank, including stations in both the U.S. and Canadian EEZs.

Cruise Goals and Objectives

The objectives were to: 1) With USGS Seaboss camera/video vehicle, explore the limits, extent, and association of fishes in newly discovered "pristine" benthic cod-haddock habitats along the northern rim of Georges Bank, in both U.S. and Canadian waters, 2) Continue to monitor visually the presence and extent of the invasive colonial tunicate *Didemnum vexillum*, and 3) Conduct extensive hydrographic sampling (CTD and ADCP) in and around the northern edge of Georges Bank to characterize the influence of tidal hydrology on the distribution of epibenthic faunal assemblages and demersal fishes, particularly groundfish stocks.

Site Selection

Sites were selected from numbered zones on Georges Bank (Figs. 1,2) in order to achieve the objectives stated above. Area 16 is trans-boundary region at the northern edge of Georges. The "pristine habitat" are discovered two years ago is in 16W…the U.S. side of that area. Area 17 is block entirely within closed area 2 (CA II) that is know to harbor *D. vexillum*. Area 19 spans the CA II boundary and also harbors *D. vexillum*. Area 18 is outside CA II and contains the tunicate. Areas 17W, 22 and 24 are more westerly areas not previously explored with Sea Boss, but whose position and topography suggest they might contain more "pristine" habitat. In particular, block 24 is known to fishermen for "good tub trawling", i.e. longline fishing. The exact positions for Sea Boss deployments within the areas were chosen based on a variety of criteria that might bear on our knowledge of habitat type and condition, (e.g. visitation on a previous cruise, logical extension of previously surveyed site, unexplored area, bathymetry suggestive of habitat type, open or closed fishery status or trans-boundary position).

Hydrographic transects (Figs. 1,2) were positioned so as to span some of these same areas, oriented roughly perpendicular to contours of the bank sloping into the Gulf of Maine, and also to span most of the U.S. portion of the northern boundary of Georges Bank.

Procedures

Seaboss Operations

Video drifts were conducted using the USGS Sea bottom Observation and Sampling System (Seaboss) towed video vehicle. This vehicle has two video cameras (forward and downward looking), a downward looking 35 mm camera, and a modified Van Veen grab sampler. Quartz halogen lights provide illumination for the video and an electronic flash unit provides lighting for still photography. Dual lasers provide accurate photographic range and scale information. The system is tethered by a conducting cable and essentially "flown" over the seafloor at heights ranging from 0.5 – 3 m by a shipboard winch operator while the support vessel is drifting. Images from both video cameras were recorded digitally, but were also viewed in real time, allowing collection of representative still photographic images for analysis of topography, organisms and sediments. Each deployment of Seaboss consisted of drift transects of continuous video of variable duration. Still photos of features of biological and geological interest were taken manually at irregular intervals as they appeared on video, but the average rate was one photo per minute. A total of 128 Seaboss video/photo transects (120 in the U.S. EEZ, 8 in the Canadian EEZ) were conducted, generating a total of 38.6 h of digital video footage and nearly 2,000 still photos. Transects averaged 18 min. (≈ 1 km) in length. An NEFSC Seabird 19 CTD was mounted to Seaboss and recorded data internally during 127 of its 128 deployments. One 12-hour watch each day was devoted to Seaboss operations.

Hydrographic Transects

The other 12-hour watch each day was devoted to hydrographic operations using an SBE 19+ mounted to *DE II*'s hydrographic wire deployed from the aft starboard A-frame and controlled from a portable winch on the ship's fantail. These CTD casts were made along a series of transects approximately perpendicular to the depth contours along the Bank's northern margin (Figs. 1,2), a pattern based on one from a similar study on the Canadian portion of the Bank by Loder et al. 1992 (J. Geophys. Res. 97(C9):14,331-14,351). CTD casts were made within transects at equal spatial intervals (± 15%) ranging from 1-3 km, depending upon the transect, and timed around predicted times of local high and low tides. Those times were determined from the time of tidal current shift from N-S to E-W (i.e. slack tide) as calculated according to the method outlined on NOAA Chart 13200 (Georges Bank and Nantucket Shoal), using whichever current diagram on that chart that was closest to the transect. Timing prediction involves a temporal offset to predicted tides at Pollack Rip on Cape Cod. We felt that this would better represent local tide times than the more widely-used method of basing them on a prediction for the single Texas Tower location at Georges Shoal (temporally offset from Boston Harbor tidal predictions), roughly in the middle of Georges Bank. Offsets between temporal predictions by the two methods ranged 1-47 min. (mean ± 1 SD = 21 ± 13) for most predictions, but were up to 79 min. for transect T24.

Two passes along the same transect were performed during each 12 h watch. As all CTD stations in a transect could not be performed simultaneously exactly at the time of the predicted tide, transects were performed as rapidly as possible, timed to bracket each tidal prediction. The first was performed about 90 min. prior to the predicted high tide, usually ending within 90 min. after the prediction. That transect was begun at the northernmost (Gulf of Maine) end so as to follow any tidal front southward from the Gulf onto the Bank. The second pass along the transect was begun about 90 min. prior to the predicted low tide, starting at the southernmost station to follow any front off the Bank, also ending within 90 min. after the predicted time. During the interval between high and low tide transect passes, time permitting, a station in the center of the transect was chosen and CTDs were performed there on an hourly or half-hourly basis in hopes of seeing frontal phenomena move past that location. In some cases, a second high tide transect pass was begun before the end of the watch.

Results

<u>*Disclaimer:*</u> Results presented here represent a very preliminary overview of observations and data collection during cruise DE-08-01. Additional quality assurance examination needs to be applied to raw data and no attempt has been made to apply rigorous statistical tests to any existing quantitative data regarding any hypotheses. The following detailed presentation is meant only to provide the reader a general idea of the nature of the raw data available and its utility toward meeting the stated objectives of the cruise.

<u>***Objective Summaries:***</u>

Benthic Habitat and Biota Distributions

Comments herein on benthic habitat distribution are based upon preliminary notes made by Dr. Valentine during real-time monitoring of video image feed from the Seaboss vehicle. Complete analysis of video and still photo images will require considerably more time and effort.

Sediments:

Major sediment types at the chosen Seaboss transect sites were gravel, sand, or mixtures thereof (Fig. 3). Some boulders and cobbles were seen, but were not the major substrate type, and are therefore not represented here. All but one site in regions previously explored on Benthic Habitat cruises (i.e. east of longitude 67.6°W) contained gravel. Among sites in newly-explored regions (west of 67.6°W) all but one of those with sand only were rippled, indicating mobile as opposed to stable sand substrate. This is important because some fauna adaptable to sand substrates, sea scallops included, are not found on mobile sand.

Epifauna:

Conspicuous epifaunal types (Fig. 4) included the invasive colonial tunicate *Didemnum vexillum*, bushy arborescent byrozoan colonies *Eucratia loricata*, and a gregarious tube-building polychaete worm *Filograna implexa*. All three are associated with hard substrates. However it is clear that not all hard substrate is colonized by any of them.

On the transit from Woods Hole to our northern Georges Bank study areas, two Seaboss video/photo drifts were made at station HC1 within Closed Area I (Fig. 1), where *Didemnum vexillum* was observed in 2006 by WHOI researchers and confirmed by us in 2007. Doubt was cast upon the tunicate's persistence mixed sand and pebble gravel habitat there based on findings from a subsequent there by the same WHOI investigators.

Visits to HC1 by us during the Benthic Habitat cruise in 2008 and this 2009 cruise were made to confirm the presence of *D. vexillum* in this area. Indeed, we found it there in both years, though more abundantly in 2009.

Near-continuous coverage with *E. loricata* is the signature appearance for the pristine area and its diverse epifaunal community, as further described in results from previous Benthic Habitat cruises. On this cruise, however, some isolated patches of it were seen in adjacent areas with gravel bottoms. Within CA II, in particular, *E. loricata* dominated the "pristine habitat" in the northeast (area 16W), while the invasive tunicate, *D. vexillum*, dominated area 19 in the southwest, widely separated from the pristine habitat (Fig. 4). Most gravel areas in CA II other than these contained neither species. Indeed, most gravel observed was relatively barren. *F. implexa* was found in association with both *E. loricata* and *D. vexillum*, and rarely elsewhere, but most commonly in the "pristine habitat" with the bryozoan.

D. vexillum was also found in area 18, west of the closed area, where it had been seen on previous NEFSC Benthic Habitat cruises. However, it was noted that whereas coverage by *D. vexillum* colonies inside CA II (area 19) approached 50% of the bottom in many cases, coverage was far less extensive outside (area 18). Reduced coverage is thought to result from bottom fishing disturbance; trawling and/or dredging may disrupt extensive growth of tunicate colonies outside the closed area, leaving smaller, isolated colonies.

Promising topography just northwest of area 18 (area 22) turned out to be largely sandy (Fig. 3). Further to the southwest, centered around 67.9°W, a region of gravelly substrates in area 24 was found thanks to advice from a fisherman. Here, unlike within CA II, *E. loricata* and *D. vexillum* were found in close proximity. In the western portion of this region in particular, there was evidence of moving sand inundating the gravel and cobble substrate, resulting in isolated islands of hard substrate with avifauna separated by bare, rippled sand, rather than the continuous coverage seen in the pristine habitat. This entire area appeared to be largely free of trawl and dredge disturbance in recent years, probably due to a combination of lack of scallops and gadoids and rugged topography.

Benthic and demersal fisheries resource species:

Resource species observed included cod, haddock, silver hake, red hake, sea scallops, flatfish (not identified), skates (not identified), spiny dogfish, American lobster, and long fin squid. The distribution of major gadoids (cod, haddock, silver hake) and sea scallops is represented in Fig. 5. Included separately in this figure is the distribution of small (~10-15 cm total length) gadoids, tentatively identified as juvenile cod, also frequently seen in the video feed.

Sea scallops (*Placopecten magellanicus*) were found at all but one site in eastern area (areas 16-22 in Fig. 2) of the bank (Fig. 5). They occurred both inside and outside CA II on all sediment types, including rippled sand. It was noted that large scallops in some unfished areas often had their upper valves heavily fouled with bryozoans, hydrozoans, and sponges, whereas similarly-sized scallops in fished areas were largely free of such fouling. How this might relate to fishing effects and scallop production/survival is not yet clear.

Inside CA II cod (sub-adult to adult sizes) were often seen in the pristine habitat (northern half of area 16W) and area 19, and haddock were seen almost throughout CA II, but less frequently in the southern portion of areas 16W and 19 (Fig. 5). Putative juvenile cod were seen in the pristine habitat, the southern part of 16W (outside the pristine habitat), and further south in area 17E, and to the west in 17W. They were largely absent from tunicate-dominated area 19. Silver hake occurred nearly everywhere except in the pristine habitat (Fig. 5).

Outside CA II gadoids other than silver hake were less frequently encountered, particularly in the southern portion of area 18 (Fig. 5). Occasional silver hake were the only gadoids seen in area 24.

Tidal Hydrography

Results of CTD transits along transects normal to the slope of the bank's northern edge (Figs. 1,2) around the predicted times of high and low tides are typified by those recorded for T19 (Fig. 6). Surface temperatures were warmer and near-bottom temperatures colder at low tide than they were at high, most dramatically so at the northernmost stations (those with the lowest station numbers, closest to the Gulf of Maine) in the transect. In this case, surface water temperature rose about 2° C and near-bottom temperature fell about 6° C in the interval of approximately six hours between high and low tides. In addition to subjecting the bottom to a large temperature change over a relatively short period of time, this resulted in a very large change in surface-to-bottom temperature gradient (Fig. 6). The most southerly station (furthest onto the Bank) experienced the least tidal variation in surface and bottom temperatures values and surface-to-bottom gradient; the northernmost station experienced the largest changes. Salinities during tidal cycles ranged between approximately 31.5 to 32.5 psu, with the higher values and largest gradient also evident during low tide at the northern end of the transect. While both temperature and salinity changes of these magnitudes are important in terms of hydrography, the temperature fluctuations are far more important in terms of animal physiology.

The extent and distribution of bottom temperature changes along the same transect are demonstrated in Fig. 7. Clearly any bottom fauna near the bank-slope break, where the slope of the bottom changes rapidly (station 2), are subject to the largest tidal changes in bottom temperatures. Similar patters were evident in other long transects (Fig. 8), with the warmest and least variable temperatures at the southern (bank crest) ends, and decreasing and more variable temperatures proceeding northward (gulfward), with the largest variations at or near the bank-slope break.

The rate of bottom temperature change was assessed at single stations in the middle stations of each of five transects (TP, T19A, T18A, T23, and T24) performed during the cruise. Data from transect TP is presented as an example in Fig. 9. Among all these transects, maximum rates of temperature change ranged from 2° to 4° C per hour (2.9° C per hour for TP station 3: Fig. 9), suggesting considerable physiological influence.

Data from CTD casts made aboard Seaboss have yet to be fully analyzed, but preliminary observation suggests that they contain spatial anomalies, sudden changes across horizontal boundaries, that can further define the hydrodynamics of bottom water along the northern edge of Georges Bank.

Data Management and Disposition of Data and Samples

Data from the Ship's Computer System (SCS), including navigational, weather, and EK60 single beam sonar data, and raw CTD data are retained by the Chief Scientist at J.J. Howard Lab. Copies of this data will be provided to the U.S. State Department in accordance with the form 11081 issued by the Chief Scientist on 8/19/09. DVD digital copies of videotapes created during the cruise, still photographs, USGS navigational data, and logbooks from the Seaboss are retained by USGS, Woods Hole Science Center (WHSC), Woods Hole, MA for analysis. These will be passed by Dr. Valentine directly to Dr. Brian Todd of the Geological Survey of Canada according to prior agreement.

Scientific Personnel

Dr. Vincent Guida	Chief Scientist	NEFSC, J.J. Howard Lab
Dr. Page C. Valentine	Research Geologist	USGS, Woods Hole Center
Dann Blackwood	Photographer	USGS, Woods Hole Center

*watch chiefs

For further information, contact:

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Figure 1. Georges Bank. Red circles - Sea Boss sites; Blue dotted lines with blue font labels - CTD transects; CA I, CA II – closed areas 1 and 2. HC1 – station HC1. All depths (black font) are in meters based on NGDC contours.

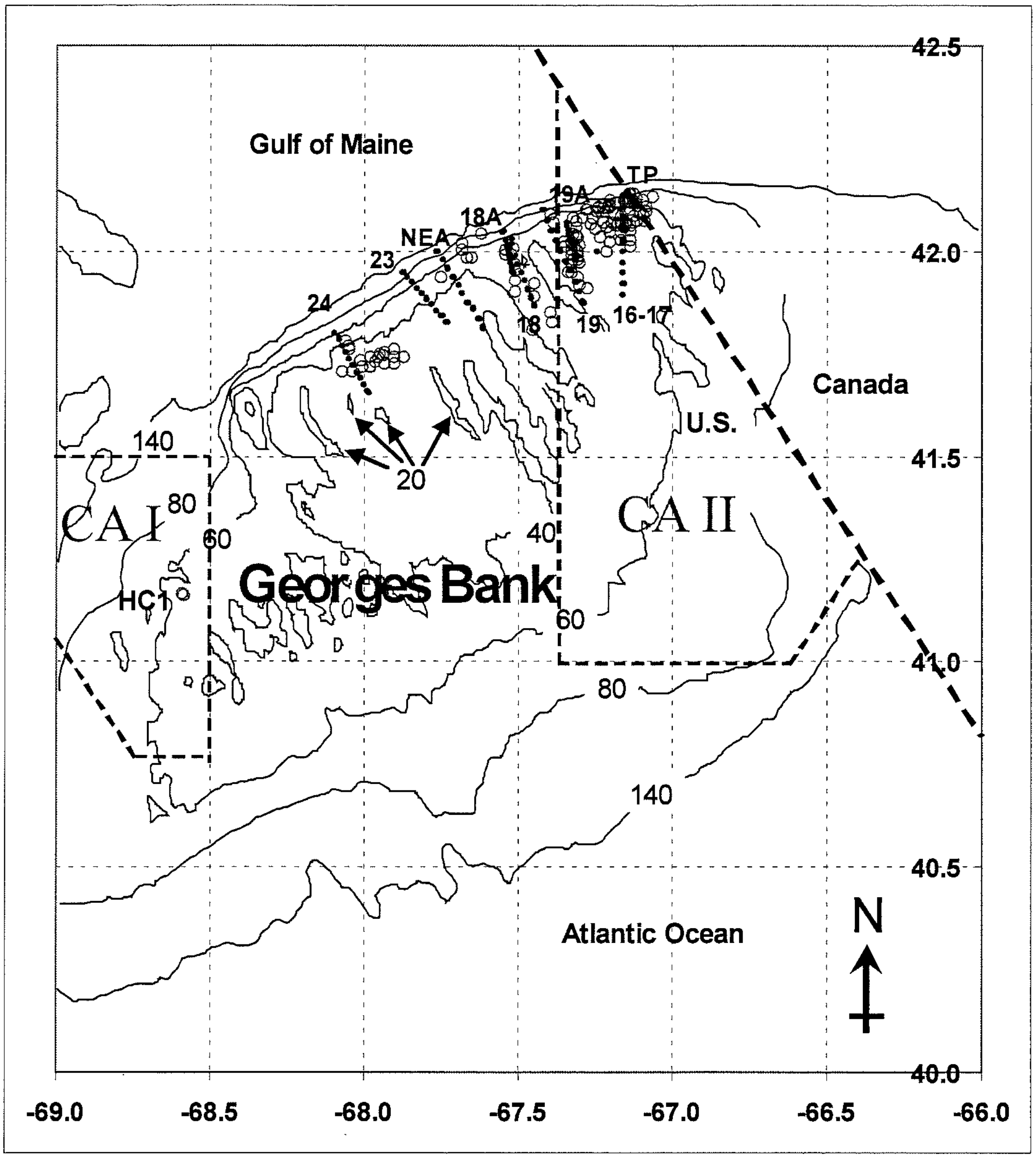


Figure 2. Detail of eastern portion of sampling area showing Sea Boss transect median positions in various numbered sampling areas (variously colored symbols), long CTD transects (dashed blue lines and blue font labels) and short CTD transects (solid red lines and red font labels). Area 16 stations are in the Canadian EEZ; all others are in the U.S. EEZ. CA II is closed area 2. All depths are in meters: NGDC contours.

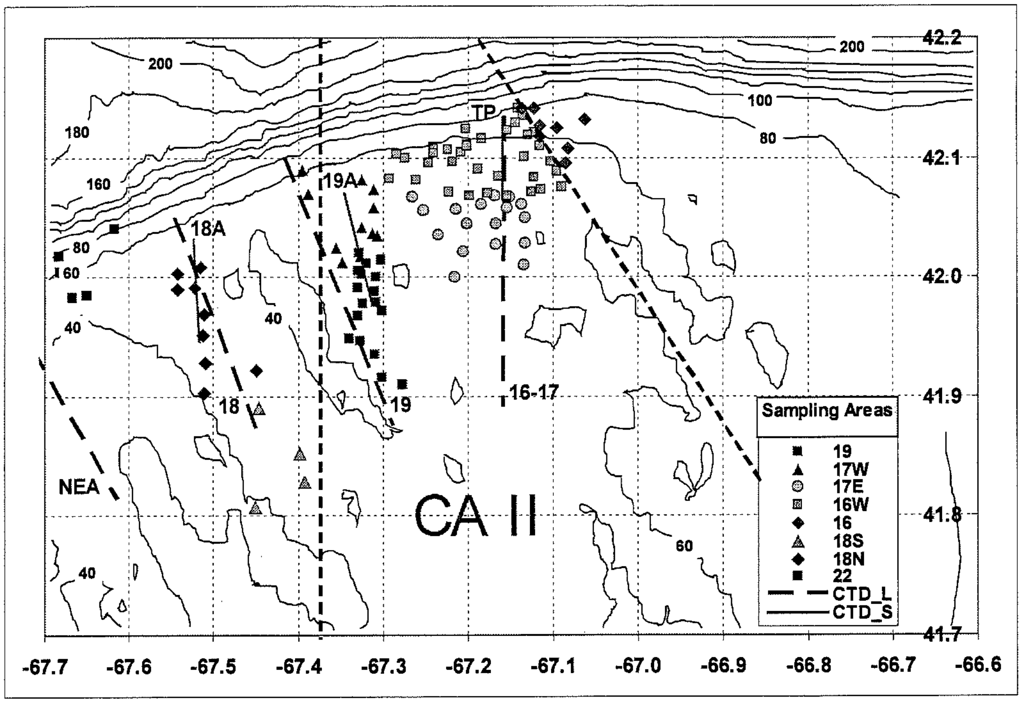


Figure 3. Dominant sediment type distribution based on Seaboss observations. Abbreviations: rip sand = rippled sand, grav&sand = gravel and sand, grav&rsand = gravel and rippled sand.

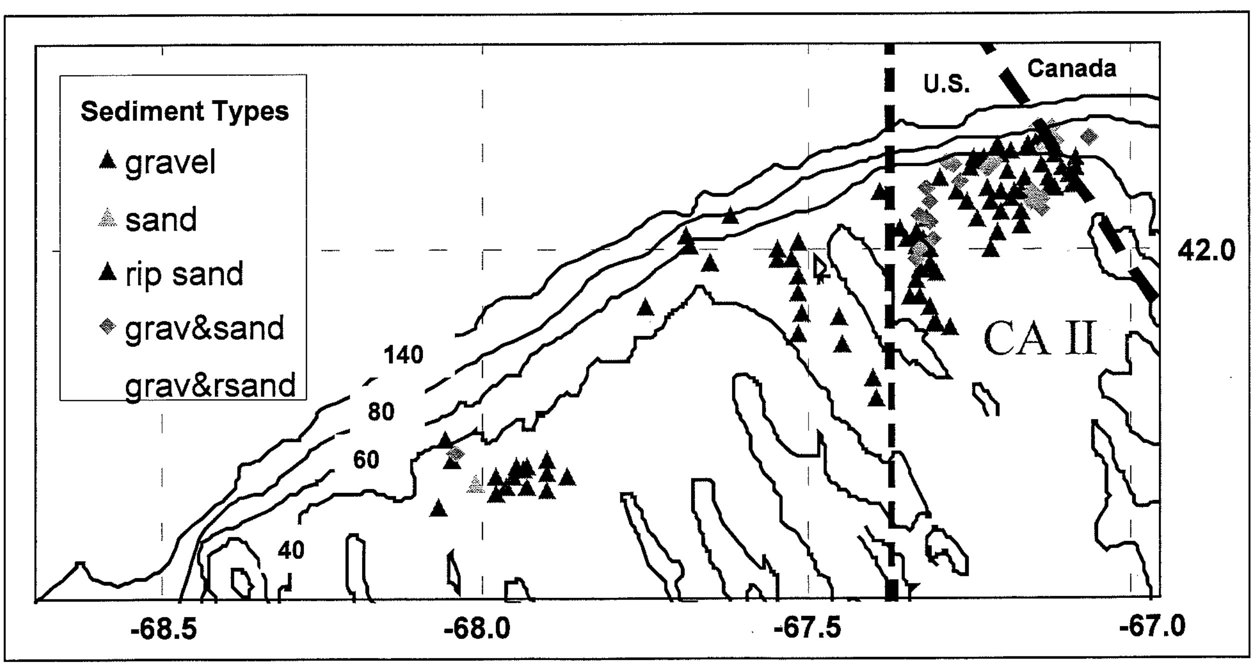


Figure 4. Dominant epifaunal type distribution based on Seaboss observations. *Didemnum* = *D. vexillum* (invasive colonial tunicate), *Eucratia* = *E. loricata* (bushy arborescent bryozoan), *Filograna* = *F. implexa* (gregarious tube-dwelling polychaete).

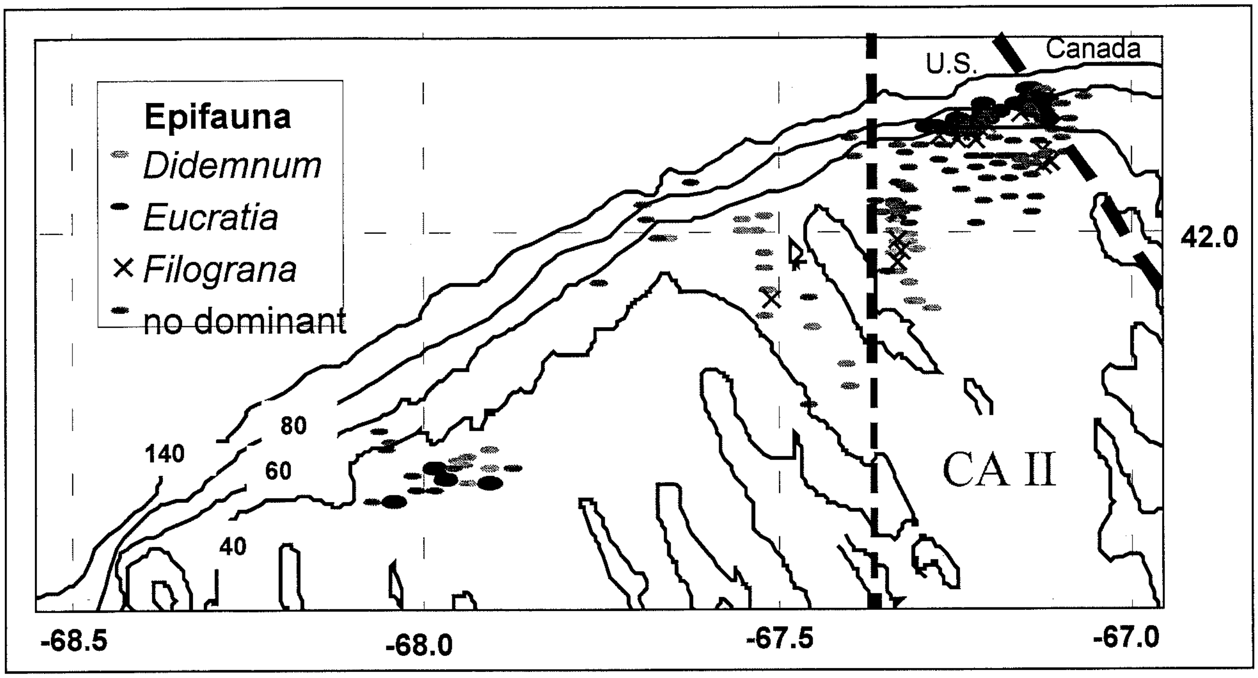


Figure 5. Fisheries resource species distribution (gadoids and scallops only) based on Seaboss observations. Juv Cod? = small gadid (~10-15 cm total length), probably juvenile cod. "None" means no gadoids or scallops; other fisheries resource species may have been present.

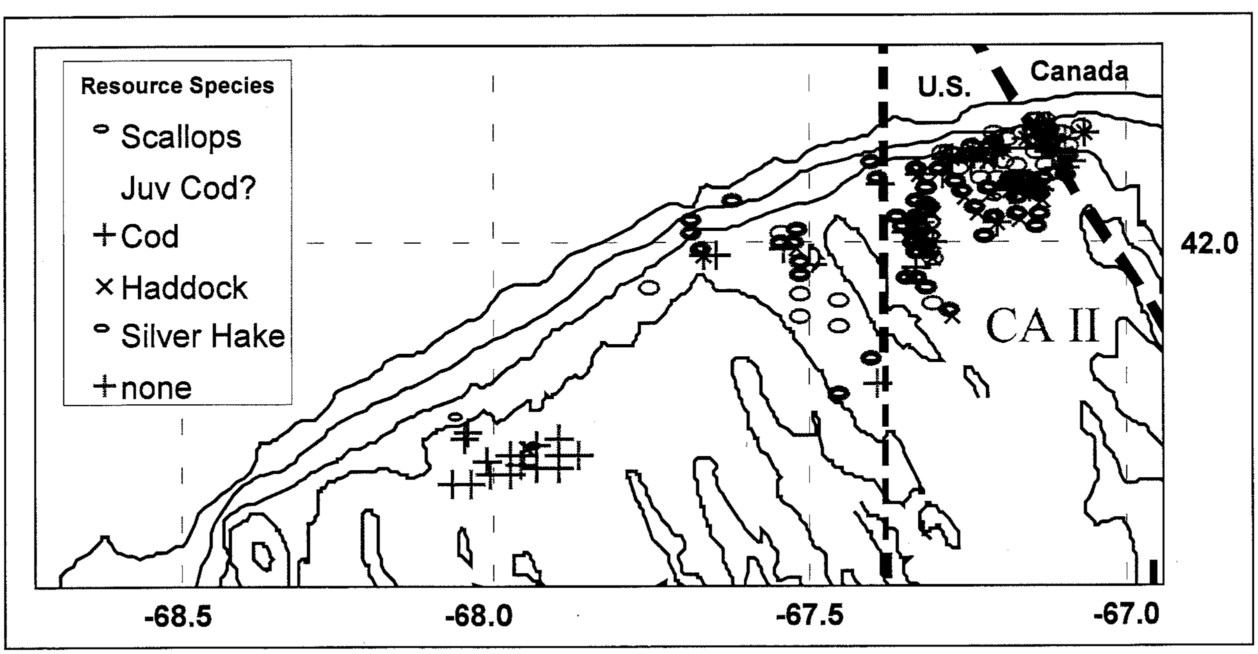


Figure 6. Water column temperature profiles for 0-45 m depth for the seven northernmost stations (numbered 1-7, north to south) in transect T19 during high tide and low tide passes. Dashed lines on upper and lower planes represent along-transect temperature profiles for surface and near-bottom waters, respectively.

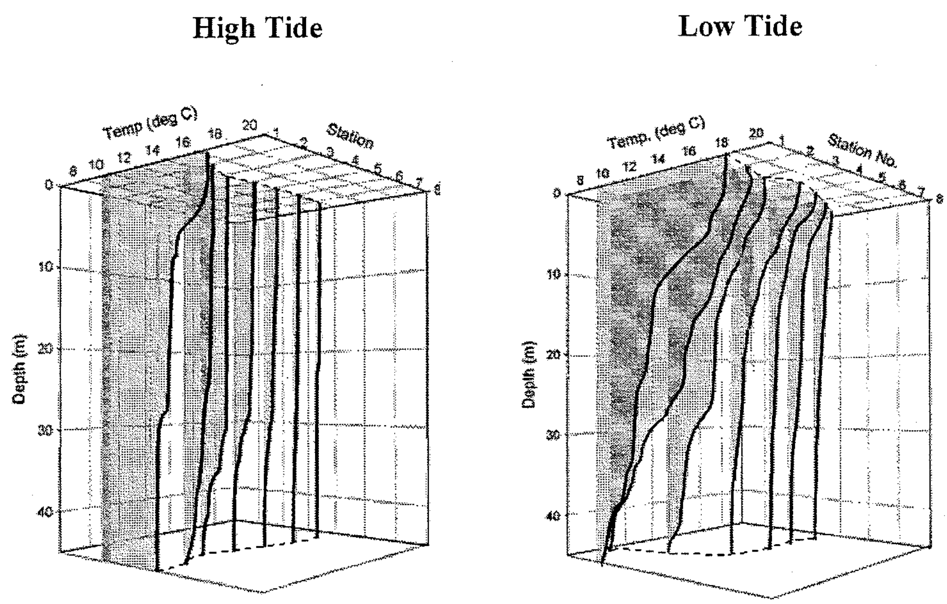


Figure 7. Bottom temperatures in degrees C at stations along transect T19 during high tide (dashed red line) and low tide (dashed blue line) and median bottom depths in meters (solid brown line). GOM is the Gulf of Maine.

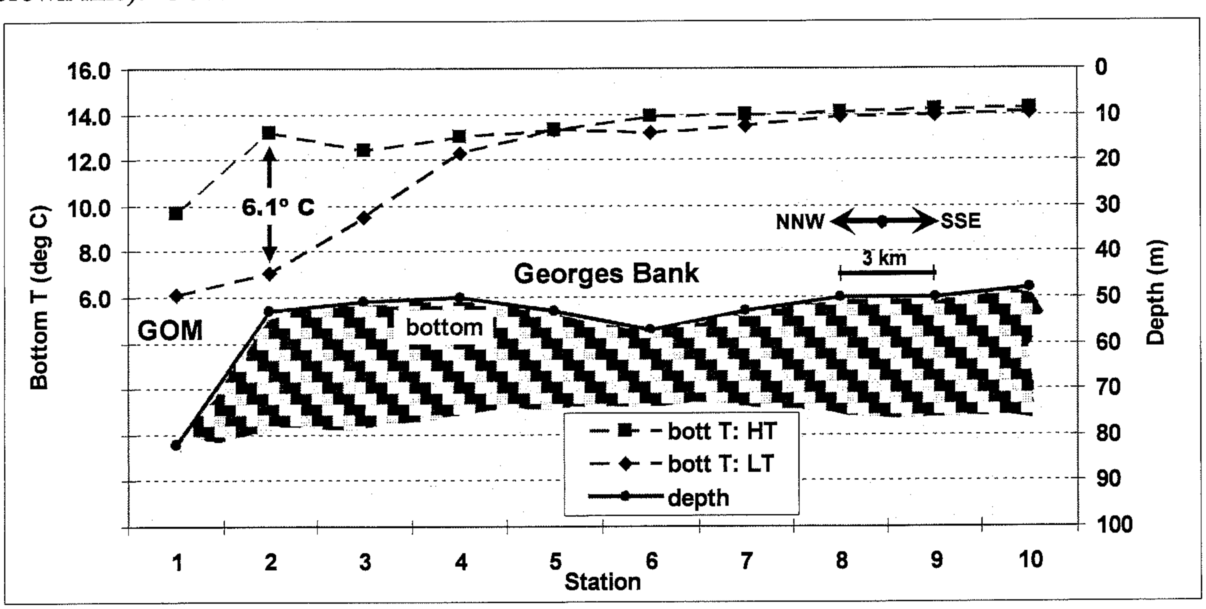


Figure 8. Low tide (minimum) bottom temperatures indicated by dot color and tidal bottom temperature ranges indicated by dot size for long hydrographic transects made during DE09-08. Transect names are labeled in blue. Bottom temperatures and ranges are in degrees Celsius, depths are in meters.

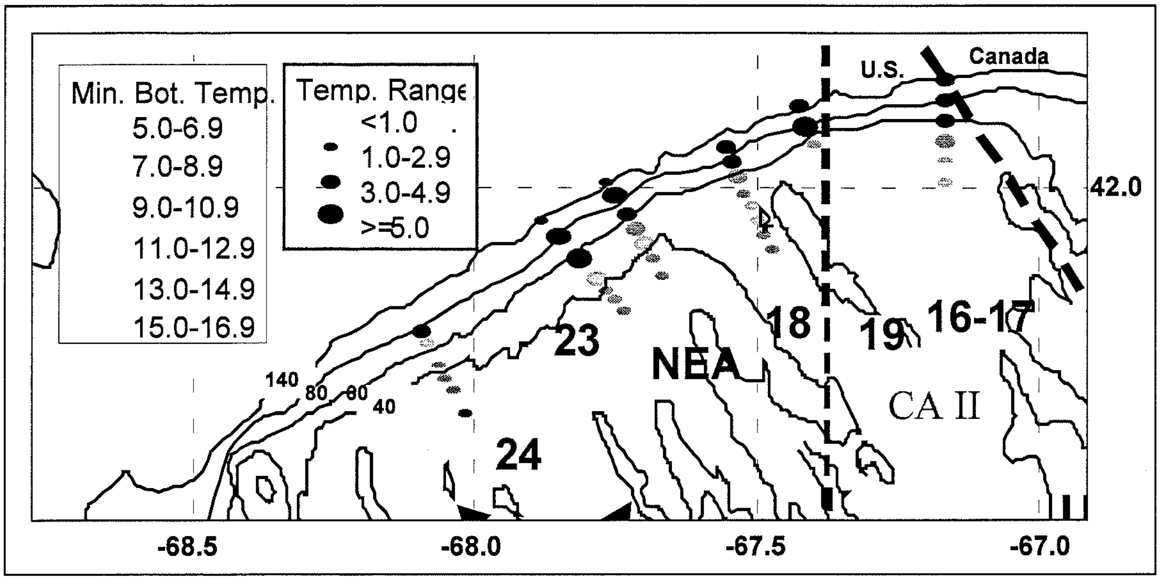
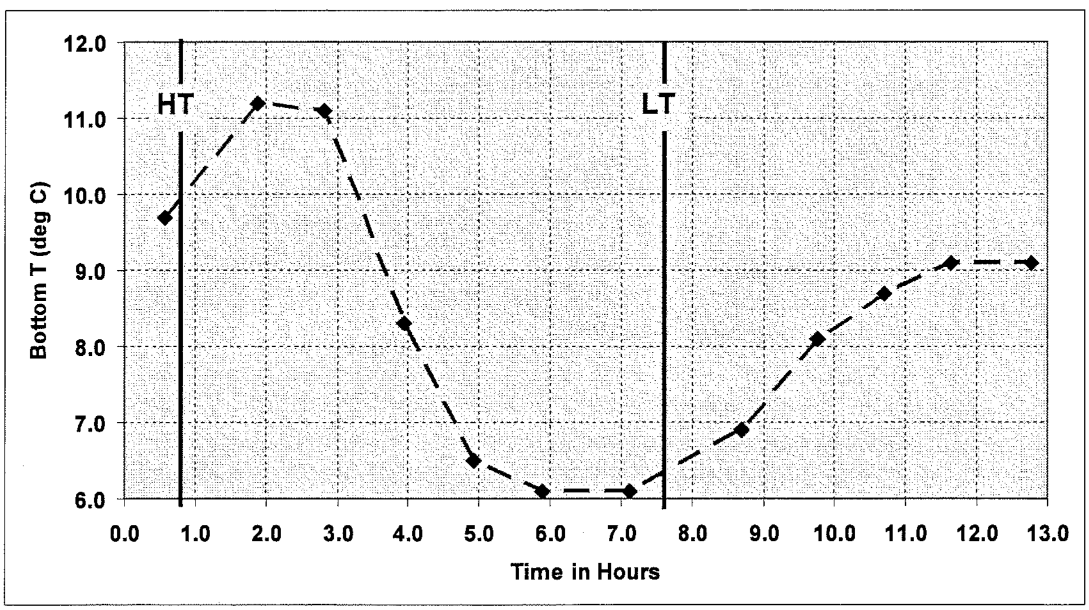


Figure 9. Bottom temperatures measured at Station 3 of hydrographic transect T19A (see Fig. 2). Predicted times of high tide (HT) and low tide (LT) are indicated by the solid black, vertical lines.



28 November 2010

CRUISE RESULTS
NOAA Ship Delaware II
DE-10-11 Benthic Habitat Cruise

Executive Summary and Highlights

- This 6-day cruise was conducted during late October along the northern edge of Georges Bank in order to explore the limits, extent and fisheries resource species associations of bottom habitats. Video and still photo images were gathered using the USGS Seaboss drift vehicle. A series of CTD hydrographic transects was also conducted in order to better understand the role of tidal hydrology in defining bottom habitats and fisheries resource associations.

- Hydrographic transects revealed that in spite of the lack of horizontal temperature gradients at the surface, the strong tidal pattern of bottom water temperature fluctuation seen in summer persists into fall. Up to 3° C total change was recorded between high and low tides. As in summer, the change lessens with distance from the bank-slope break, gradually terminating in constant warm bottom temperatures in a vertically mixed water column ~15 km south of the break. The extent of tidal temperature fluctuation was smaller (3° versus 6° C) and the zone of influence narrower (15 km versus 20 km) than in summer.

- Measurements of chlorophyll fluorescence along transects indicated a three-fold fluctuation in phytoplankton abundance corresponding to tidal temperature changes. Warmer, high chlorophyll water from Georges Bank dominated the frontal zone during high tide, while colder, low chlorophyll water from the Gulf of Maine dominated during low. This fluctuating pattern has strong implications for benthic trophic production and consequently habitat value to benthic and demersal stocks.

- Limited Seaboss observations indicated very heavy coverage of hard substrates on the Bank crest by the invasive tunicate *Didemnum vexillum* south of 42°00' N, where it had been previously reported, but little if any farther north. There was no indication of a hypothesized fall die-back, and no new northward range extension into the tidally-varying frontal zone.

- As a result of restriction of Seaboss deployments by rough weather, no herring egg beds were observed, despite the reports of large herring aggregations prior to the cruise and our use of a map of historic egg bed locations as a guide.

- Nighttime deployments of plankton light traps at surface and depths of 5 and 10 m were not successful in capturing herring larvae, unlike our success in capturing lobster juveniles in the summer of 2009. We suspect rough weather may have been rendered the traps ineffective aboard DE10-11.

Cruise Period and Area of Operations

This cruise was conducted from October 26 to October 31, 2010 with designated stations (Fig. 1) located on Georges Bank, including stations only in the U.S. EEZ. A planned sampling excursion into the Canadian EEZ was not performed due to time limitations imposed by weather.

Cruise Goals and Objectives

The objectives were to: 1) With USGS Seaboss camera/video vehicle, explore the limits, extent, and association of fisheries resource (e.g. groundfish and Atlantic herring) utilization of benthic habitats along the northern rim of Georges Bank, in U.S. and adjacent Canadian waters, 2) Conduct extensive hydrographic sampling (CTD and ADCP) in and around the northern edge of Georges Bank to characterize tidally-influenced hydrographic conditions within its varied microhabitats, 3) Conduct light trap (surface and sub-surface) operations to capture juvenile fishes within benthic and pelagic habitat areas during hours of darkness, and 4) Continue to monitor visually the presence and extent of the invasive colonial tunicate *Didemnum vexillum.*

Site Selection

Seaboss sites were selected from numbered zones on Georges Bank (Figs. 1) in order to achieve the objectives stated above. Area 19 spans the CA II boundary and is known to harbor *D. vexillum* in its southern part. Area 18 is outside CA II and contains the tunicate in its southern portion. Little *D. vexillum* had been detected north of 42°00' N in either area during past cruises. The exact positions for Sea Boss deployments within the areas were chosen based on a variety of criteria that might bear on our knowledge of habitat type and condition, (e.g. visitation on a previous cruise, logical extension of previously surveyed site, unexplored area, bathymetry suggestive of habitat type, open or closed fishery status or trans-boundary position).

Hydrographic transects (Figs. 1) were positioned so as to span some of these same areas, oriented roughly perpendicular to contours of the bank sloping into the Gulf of Maine, and also to span most of the U.S. portion of the northern boundary of Georges Bank. Transect sites were spaced at intervals of approximately 3 km to provide maximum spatial coverage over a minimum time span around each high and low tide. Transect sites within for time series (T18-2 and T19-3, Fig. 1) were chosen because they demonstrated the largest bottom temperature change over the previous tidal cycle.

Procedures

Seaboss Operations

Video drifts were conducted using the USGS Sea bottom Observation and Sampling System (Seaboss) towed video vehicle. This vehicle has two video cameras (forward and downward looking), a downward looking 35 mm camera, and a modified Van Veen grab sampler. Quartz halogen lights provide illumination for the video and an electronic flash unit provides lighting for still photography. Dual lasers provide accurate photographic range and scale information. The system is tethered by a conducting cable and essentially "flown" over the seafloor at heights ranging from 0.5 – 3 m by a shipboard winch operator while the support vessel is drifting. Images from both video cameras were recorded digitally, but were also viewed in real time, allowing collection of representative still photographic images for analysis of topography, organisms and sediments. Each deployment of Seaboss consisted of drift transects of continuous video of variable duration. Still photos of features of biological and geological interest were taken manually at irregular intervals as they appeared on video, but the average rate was one photo per minute. A total of 18 Seaboss video/photo transects were conducted, all within the U.S. EEZ, generating a total of 4.2 h of digital video footage. Transects averaged 16 min. (≈ 1 km) in length. An NEFSC Seabird 19 CTD was mounted to Seaboss and continuously recorded data internally during each Seaboss deployment. One 12-hour watch each day was planned for Seaboss operations, but this activity was severely curtailed by rough weather, hence the relatively small number of deployments. Seaboss transects were conducted only on October 27th and 29th. The planned "Seaboss" watch on the 28th was devoted to a CTD time series, which was less dependent on sea state, and on the watch on the 30th was devoted to the extra time needed to transit to Woods Hole through rough seas.

Hydrographic Transects

The other 12-hour watch each day was devoted to hydrographic operations using an SBE 19+ mounted to *DE II*'s hydrographic wire deployed from the aft starboard A-frame and controlled from a portable winch on the ship's fantail. These CTD casts were made along a series of transects approximately perpendicular to the depth contours along the Bank's northern margin (Figs. 1), a pattern based on one from a similar study on the Canadian portion of the Bank by Loder et al. 1992 (J. Geophys. Res. 97(C9):14,331-14,351) and on our previous work aboard DE09-08. CTD casts were made within transects at equal spatial intervals (± 15%) of 3 km, and timed around predicted times of local high and low tides. Those times were determined from the time of tidal current shift from N-S to E-W (i.e. slack tide) as calculated according to the method outlined on NOAA Chart 13200 (Georges Bank and Nantucket Shoal), using whichever current diagram on that chart that was closest to the transect. Timing prediction involves a temporal offset to predicted tides at Pollack Rip on Cape Cod. We felt that this would better represent local tide times than the more widely-used method of basing them on a prediction for the single Texas Tower location at Georges Shoal (temporally offset from Boston Harbor tidal predictions), roughly in the middle of Georges Bank. Offsets between temporal predictions by the two methods ranged 1-47 min. (mean ± 1 SD = 21 ± 13) for most predictions.

Two passes along the same transect were performed during each 12 h watch. As all CTD stations in a transect could not be performed simultaneously exactly at the time of the predicted tide, transects were performed as rapidly as possible, timed to bracket each tidal prediction. The first was performed about 90 min. prior to the predicted high tide, usually ending within 90 min. after the prediction. That transect was begun at the northernmost (Gulf of Maine) end so as to follow any tidal front southward from the Gulf onto the Bank. The second pass along the transect was begun about 90 min. prior to the predicted low tide, starting at the southernmost station to follow any front off the Bank, also ending within 90 min. after the predicted time. During watch time before or after tidal passes and, during the short watch of October 27th, and during the "Seaboss" watch of October 28th, CTD time series were conducted in which single stations chosen for maximum tidal temperature changes were sampled hourly.

Light Trap Operations

Experimental deployment of light traps for capture of larval fish and crustaceans was made on four occasions during DE10-11. In each case, two traps were deployed simultaneously on separate lines for periods of about 30 min. to 1 hour. One was deployed at or just beneath the surface and one at 10 m or 5 m below the surface, always between midnight and 5 AM as other timed activities permitted. Two window sash weights were hung from the bottom of light traps to carry them to 10 or 5 m depth, while a single weight was found necessary to stabilize the surface trap. Traps were deployed from the lee side of the ship, but it was clear that even with the weight the surface trap was being buffeted considerably by surface waves. Battery-powered light sticks were used in the first three deployments. The fourth deployment was made with 8-hour white chemical light sticks, which proved to be much brighter.

Results

Disclaimer: Results presented here represent a very preliminary overview of observations and data collection during cruise DE-08-01. Additional quality assurance examination needs to be applied to raw data and no attempt has been made to apply rigorous statistical tests to any existing quantitative data regarding any hypotheses. The following detailed presentation is meant only to provide the reader a general idea of the nature of the raw data available and its utility toward meeting the stated objectives of the cruise.

Objective Summaries:

Benthic Habitat and Biota Distributions

Comments herein on benthic habitat distribution are based upon preliminary notes made by Dr. Valentine during real-time monitoring of video image feed from the Seaboss vehicle. Complete analysis of video and still photo images will require considerably more time and effort ashore.

Fisheries Resources:

Given the time of year and a report from the Herring Acoustics cruise of heavy aggregation of Atlantic herring this year along northern Georges Bank in advance of spawning, we sought particularly to target beds of adhesive herring eggs with Seaboss. They were clearly seen by Dr. Valentine in a previous year on Stellwagen Bank, so we knew they would be detectable on Georges if they were encountered. Despite being armed with a herring egg bed map based on historic data from grab and ROV sampling, we were unable to find any herring egg beds. The limited number of Seaboss deployments reduced our chances of finding them. Skates were the most frequently observed fish. Seaboss use was confined to areas 18 and 19: no observations were made in the "pristine" area (16), or in Canada as originally planned.

Epifauna:

By far the most conspicuous epifaunal species was the invasive colonial tunicate *Didemnum vexillum*, associated with gravel and cobble substrates. *D. vexillum* occurred both in areas 18 and 19, where it had been seen on previous NEFSC Benthic Habitat cruises. As on previous occasions, it was noted that whereas coverage by *D. vexillum* colonies inside CA II (area 19) approached 50% of the bottom in many cases, was far less extensive outside (area 18). Reduced coverage is thought to result from bottom fishing disturbance; trawling and/or dredging may disrupt extensive growth of tunicate colonies outside the closed area, leaving smaller, isolated colonies. The new observation for this cruise is that degree of coverage did not seem to be reduced by the overall cooler bottom water temperatures. There is some question as to whether *D. vexillum* colonies regress and shrink on Georges Bank during the colder seasons. Based on observations during DE11-10, we have not seen evidence of any regression despite temperatures that were several degrees cooler than during summer, though bottom temperatures were nowhere near their expected annual minimum during the cruise.

Tidal Hydrography

CTD transect results revealed patterns of temperature and chlorophyll in space (Figs. 2,3) and time (Fig. 4). Salinity variations at all depths throughout the cruise were small in physiological terms, ranging between ~32.1 and 32.8 psu. Surface temperatures also varied little (12.4° to 13.2° C). In contrast, bottom temperatures demonstrated clear patterns of tidal variation of up to 3.5° C. Bottom temperatures were 1.0 ° and 1.1° C colder than surface temperatures during high tide passes at the northernmost stations of transects T18 and T19, respectively (Figs. 2A, 3A). This temperature difference essentially disappeared by 5 km south (bankward), indicating a mixed water column bankward of that point. During succeeding low tide passes, bottom temperatures were 3.1° and 4.3° C colder than surface temperature at the northernmost stations of T18 and T19, due entirely to declines in bottom temperatures (Figs. 2B, 3B). Surface to bottom temperature differences extended about 15 km bankward at this tidal stage. Chlorophyll fluorescence values showed parallel patterns of variation, with lower values in bottom water extending farther bankward during low tide passes than during high (Figs. 2,3). Temporal plots for single stations from both transects (Fig. 4A, B) showed patterns of convergence of bottom and surface temperatures and chlorophyll fluorescence values during and immediately after the predicted time of high tide and divergence during and immediately after the predicted time of low tide. Low tide chlorophyll value in bottom water was about one third the high tide value in each case. Thus bottom organisms were experiencing a three-fold change in chlorophyll concentration with each half tidal cycle.

Thus, in spite of the lack of evidence of the GoM-Georges Bank hydrographic front at the surface from temperature or chlorophyll data in late October, the front and its tidal movement across the northern margin of the bank were clearly evident in near-bottom data. Maximum tidal bottom temperature fluctuations at this time (2°-3° C) were smaller than during August 2009 (up to 6° C). The zone of tidal front influence also appears to be somewhat narrower. We anticipate that the tidal fluctuation and thus frontal influence on the bottom may largely disappear during late fall to winter. At that time turnover and mixing of GoM surface and intermediate water masses are known to obscure vertical temperature gradients in the GoM and blur the distinction between GoM and Bank water.

Data from CTD casts made aboard Seaboss have yet to be analyzed, but previous experience suggests that they may contain spatial anomalies, sudden changes across horizontal boundaries, that can further define the hydrodynamics of bottom water along the northern edge of Georges Bank.

Light Trap Results

A pair of light traps was deployed on four occasions during the cruise (Table 1). One member of the pair was deployed floating at or just beneath the surface, the other was deployed at a depth of 5 or 10 m beneath the surface by suspending them on a measured line with a pair of sash weights hung beneath to counteract the built-if foam float. In each case, the surface trap was severely buffeted by waves whereas the traps at 5 or 10 m appeared to ride more stably. Catches were very small and appeared to consist chiefly of copepods in all cases, even when soak time was increased to 1 hour. No larval herring were noticed upon visual inspection of catches with the unaided eye. Despite the buffeting, the surface traps consistently appeared to catch more than those at 5 or 10 m depth. While more resistant to water pressure and reusable, battery-operated LED light sticks proved much dimmer than comparably-sized 8-hour chemical light sticks. We concluded from these few tests that short-term (1 hour or less) shipboard light trapping is not an effective means of capture for photophilic plankton in seas of 2m or more. They proved far more effective with this type of deployment in calmer seas during August, 2009, when juvenile lobsters were in the water column.

Data Management and Disposition of Data and Samples

Data from the Ship's Computer System (SCS), including navigational, weather, and EK60 single beam sonar data, and raw CTD data are retained by the Chief Scientist at J.J. Howard Lab. In addition, the C.S. has retained copies of the raw EK60 and ADCP data at J.J. Howard Lab in addition to SCS summary files for these instruments. DVD digital copies of videotapes created during the cruise, still photographs, USGS navigational data, and logbooks from the Seaboss are retained by USGS, Woods Hole Science Center (WHSC), Woods Hole, MA for analysis.

Scientific Personnel

Dr. Vincent Guida	Chief Scientist	NEFSC, J.J. Howard Lab
Steven Fromm	Fisheries Biologist	NEFSC, J.J. Howard Lab
Dr. Page C. Valentine	Research Geologist	USGS, Woods Hole Center
Dann Blackwood	Photographer	USGS, Woods Hole Center

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Table 1. Light trap deployments during DE10-11. Light source abbreviations: LED – battery-operated light-emitting diode sticks, CHEM LS – 8 hour chemical light sticks (white).

Deploy-ment No,	Date	Station	Start Time (EDST)	Duration (min)	Depths (m from surface)	Light Source
1	29-Oct	T18-1	0:11	37	0,10	LED
2	29-Oct	T19-10	4:55	60	0,10	LED
3	30-Oct	T19-3	0:14	35	0,5	LED
4	30-Oct	T19-3	1:10	39	0,5	CHEM LS

Figure 1. Georges Bank. Red circles - Sea Boss sites; Blue diamonds - CTD transect sites; CA II – closed area 2. Alphanumerics in magenta are study areas, those in blue are transect labels. Blue arrows indicate transect sites used for time series (T18-2 and T19-3). All depths (black font) are in meters based on NGDC contours.

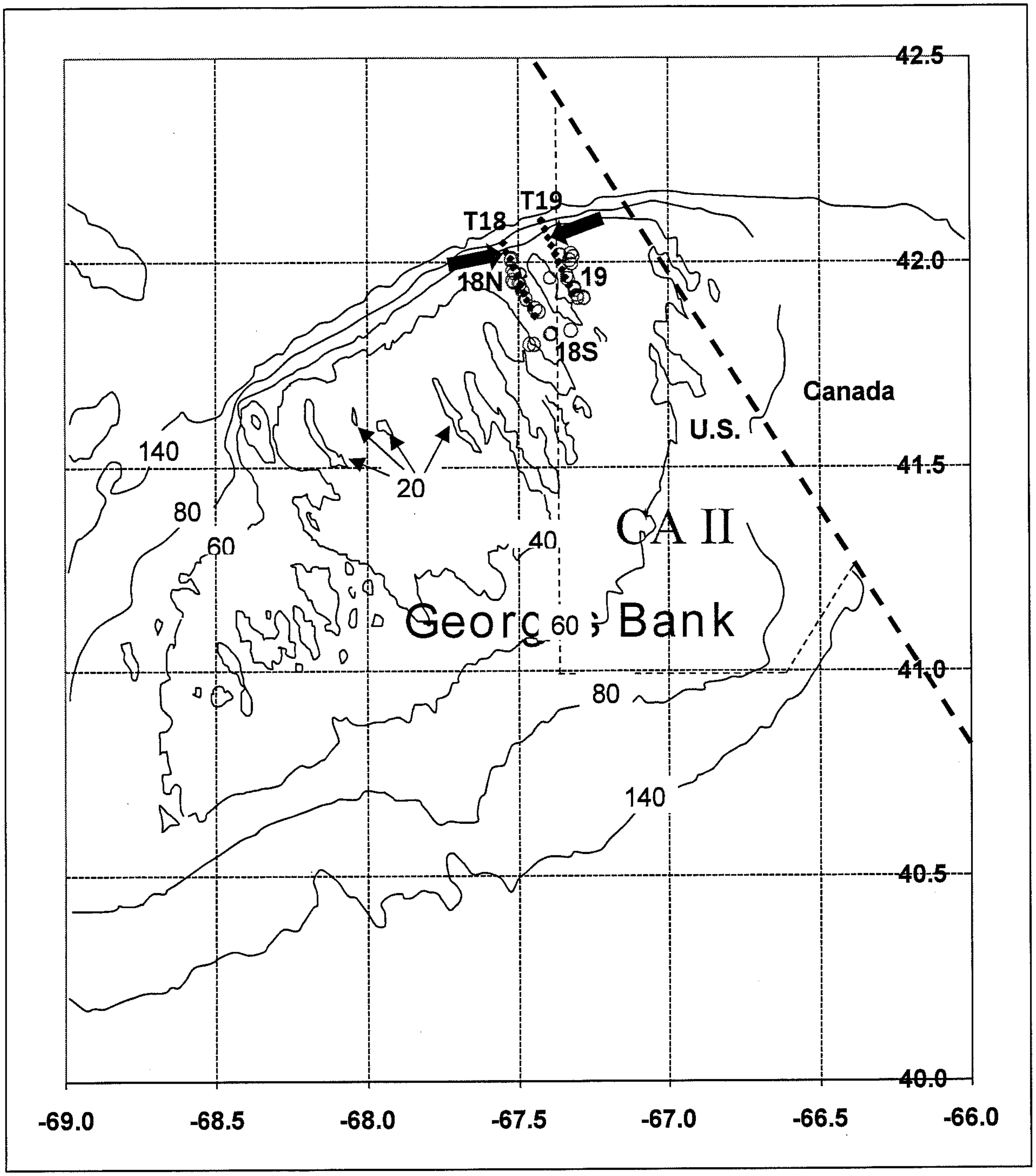
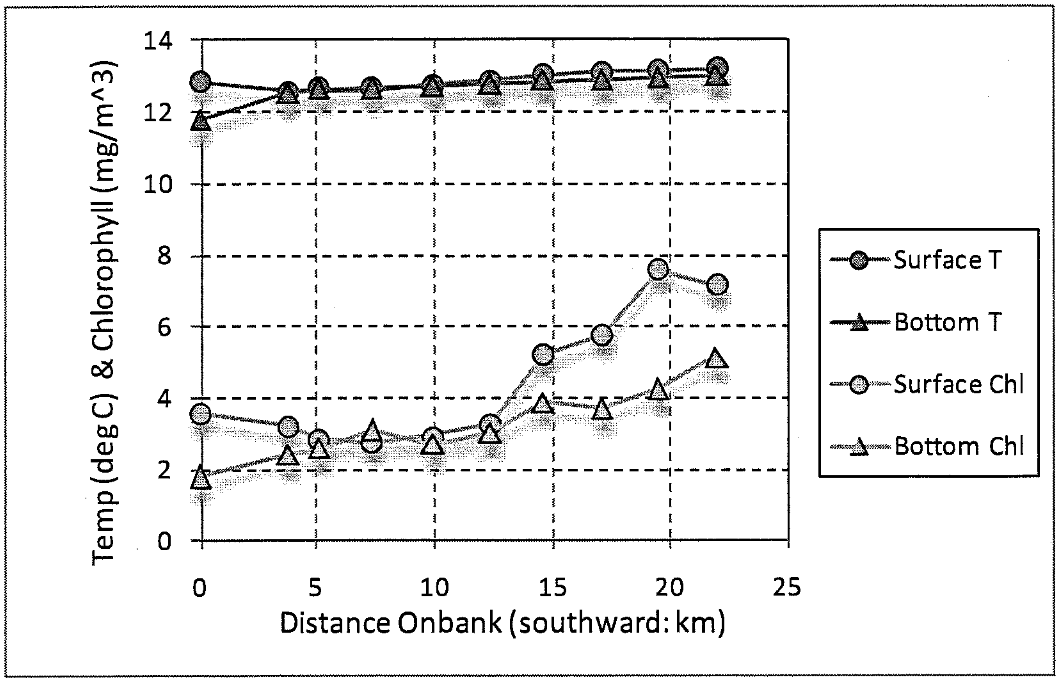


Figure 2. Spatial patterns of surface temperature and chlorophyll values along CTD transect T18 made on October 28, 2010: A. High tide pass, B. Low tide pass.

A.



B.

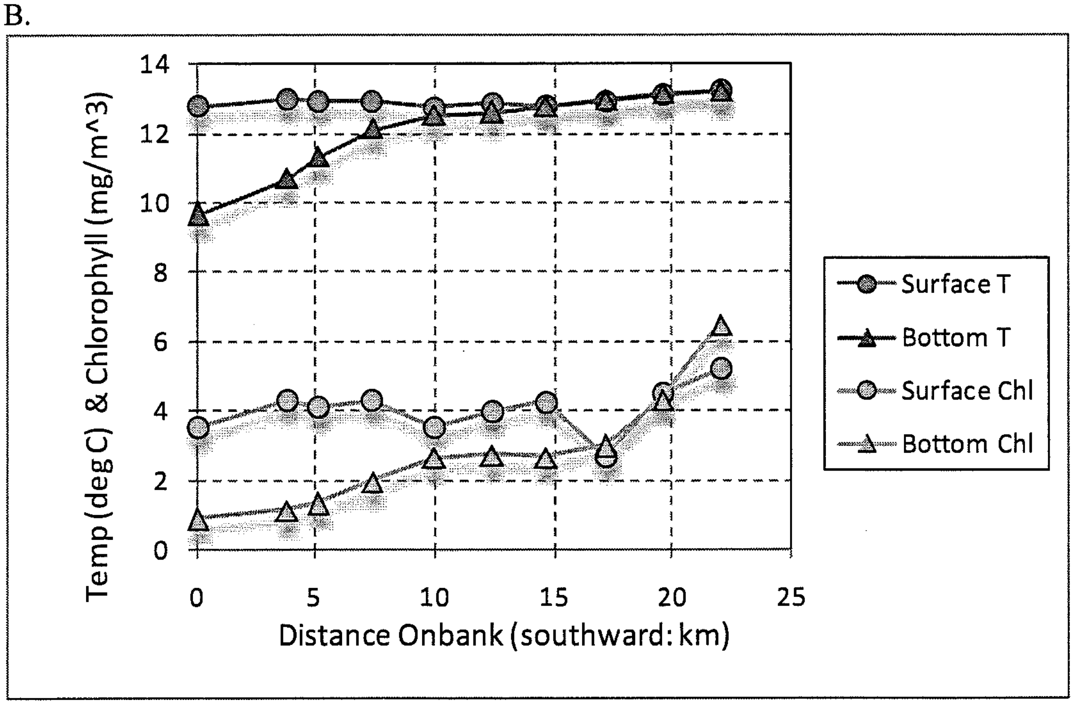
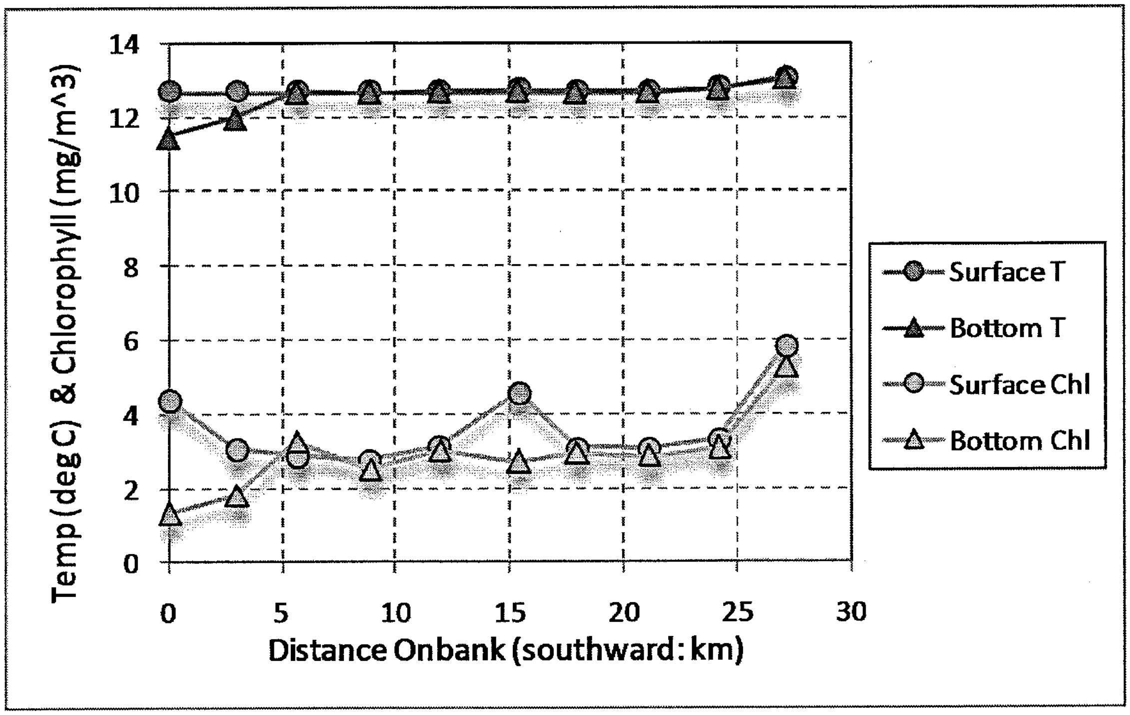


Figure 3. Spatial patterns of surface and bottom temperature and chlorophyll values along CTD transect T19 made on October 29, 2010: A. High tide pass, B. Low tide pass.

A.



B.

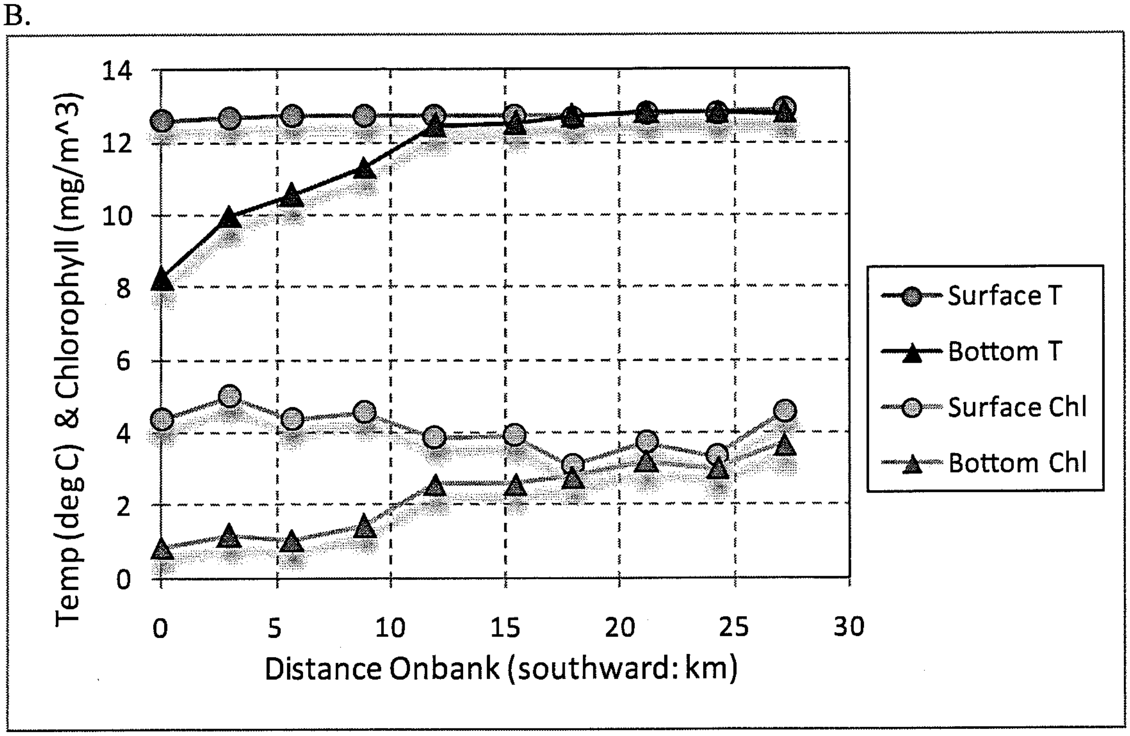
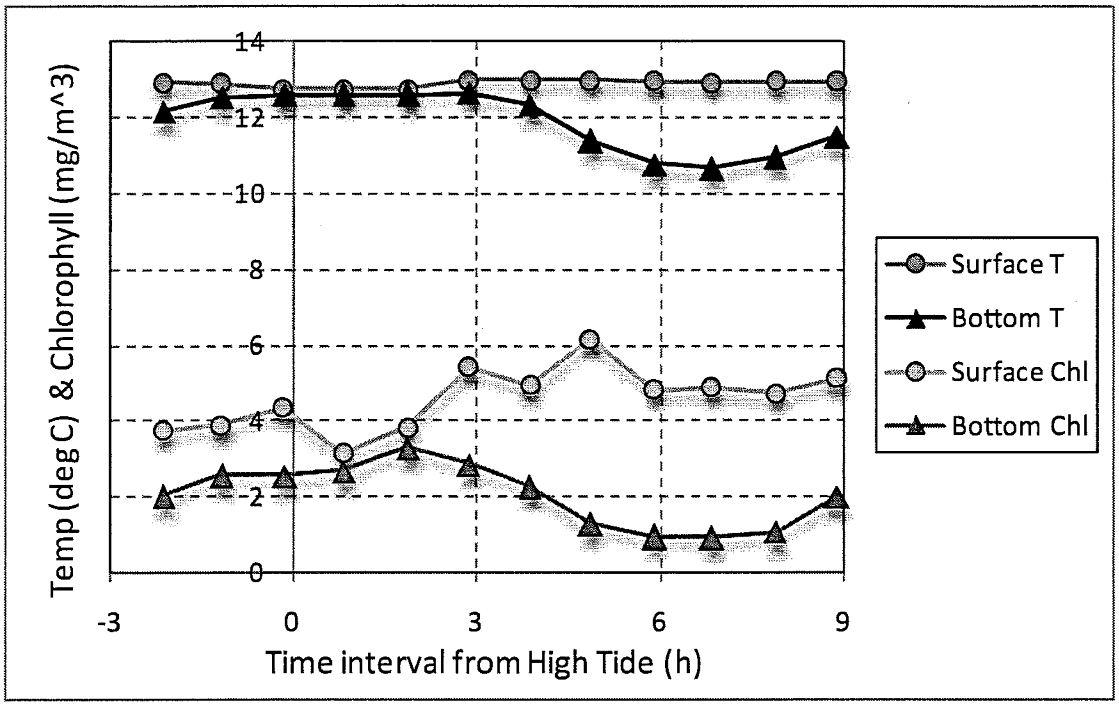
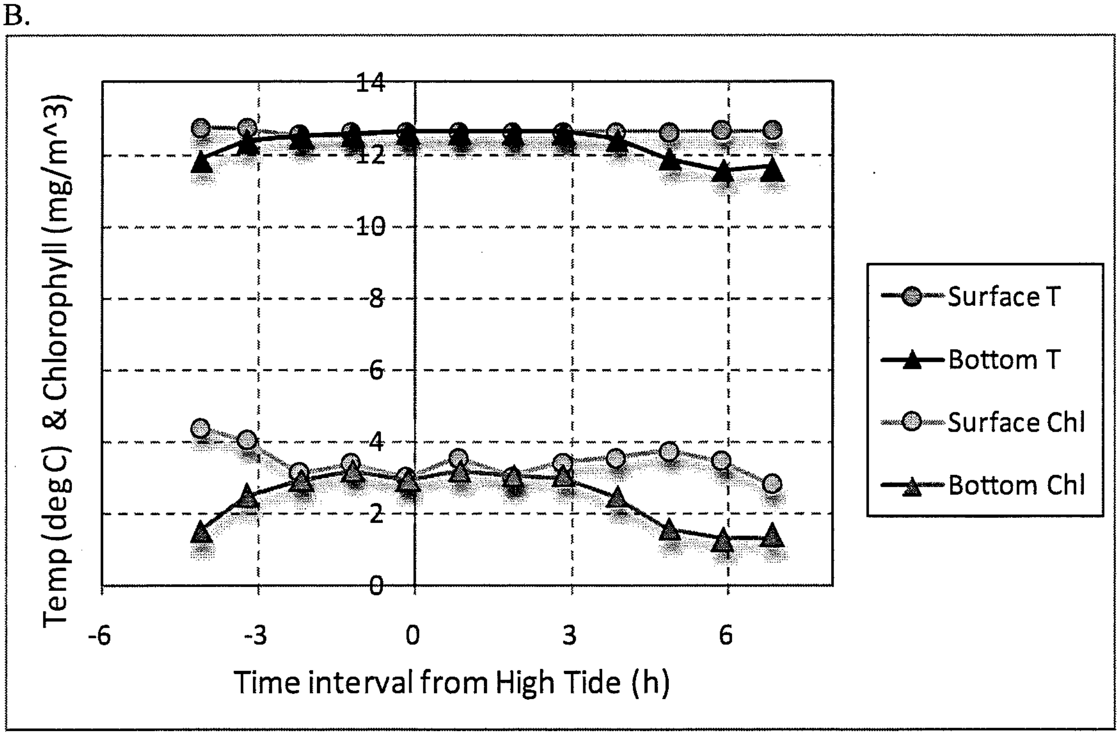


Figure 4. Temporal patterns of surface and bottom temperature and chlorophyll values made at CTD transect stations T18-2 (A) and T19-3 (B) on October 28 and 29, 2010, respectively.

A.



B.



7 November 2008

CRUISE RESULTS
NOAA Ship *Henry B. Bigelow*
Cruise HB08-05 Leg 2
Habitat Mapping Cruise (Georges Bank Leg)

Executive Summary

- A 14 day cruise was conducted in order to explore shelf habitats on the northern Georges Bank within Closed Area II. A partial exchange of scientific personnel was made at Boston, MA halfway through the cruise.
- The Kongsberg ME70 multibeam sonar was employed for extended bottom habitat mapping. Approximately 85 hours were devoted to mapping a total area of about 110 km^2. The limitations of this system in this application became evident, especially its lack of a graphic feedback facility to allow 3-D visualization of results in near real time, which is necessary for patch test calibration as well as monitoring product quality.
- Preliminary post-processing by UNH since the cruise has indicated problems with the bathymetric data. Only the central beams in each swath were configured as split beams, effectively causing severe narrowing of the usable swath width and leaving large gaps between lines. In essence, this renders the ME70 data only slightly better than the single beam EK60 trace made simultaneously. An effort is now being made to see if backscatter data, also essential to habitat characterization, can be salvaged. A great deal of time an effort may have been misspent because the ME70 in its present configuration provides no clear means of visualizing the data being collecting until post processing ashore, long after the cruise has ended. Had this problem been seen immediately, it could have been fixed during the cruise. Leg 3 will include an effort to develop an independent graphics program to do create near real time 3-D imagery from ME70 data.
- High accuracy bathymetry 140 nmi. from shore was not possible due to lack of a method for tidal correction. Tidal artifacts were evident in some resulting EK60 maps. In the future, this can be rectified with the use of a temporary tide-recording mooring deployed during mapping.
- Interpolation maps of detailed bottom topography were produced from the EK60 single beam sonar data that ran simultaneously with the ME70. These revealed details not previously known, including sand waves on the crest of the bank and strip of rough terrain along the northern rim that supports a dense epifauna and functions as an important habitat for adult cod.
- Operations were conducted with the MIT Sea Grant AUV Odyssey IV in order to test its operation in offshore waters and its utility as a platform for extending the search for infestation of the invasive colonial tunicate *Didemnum vexillum* beyond the limited capabilities of current optical technologies. Launch and recovery procedures for the AUV and its associated moored GPS buoys were successfully devised. The AUV itself ran reliably, and problems with the accompanying buoy-mounted GPS system were discovered and dealt with. The AUV's digital camera produced photographs of tunicate colonies, but its Didson imaging sonar was not adequate for reliable detection and assessment of the tunicate as hoped. Nevertheless, with some improvements in its geopositioning system and sensors, this AUV design could prove valuable for fisheries habitat studies for which accurate near bottom navigation is required.

Cruise Period and Area of Operations

This cruise was conducted from July 8 through July 21, 2008 at sites on Georges Bank for purposes of multibeam bottom mapping of critical habitat areas along the northern edge of the bank in cooperation with USGS and to conduct AUV operations with the Massachusetts Institute of Technology (MIT). A transit was made to the Boston, MA Coast Guard Station pier on July 15, 2008 in order to exchange some scientific personnel who were not able to participate in the entire cruise. *Henry B. Bigelow* returned to the operating area following that exchange.

Cruise Goals and Objectives

Habitat Mapping Cruise program (Legs 1-3): The purpose of the larger program is twofold:

1) Technology Demonstration, Training, and Development: To develop acoustic mapping tools and train NEFSC personnel in their operation, including the use of the ME70 multibeam sonar installed aboard *Henry B. Bigelow* for bottom mapping and water column fish detection, the use of AUV-mounted sonar for high resolution benthic characterization and mapping, the use of installed ADCP for 3-D current pattern measurements, and the use of the NEFSC Quester Tangent bottom classification system, and

2) Baseline Habitat Definition: Develop baseline benthic habitat maps and collection of hydrographic data for areas of critical interest where no previous high resolution maps exist along with biological groundtruth sampling where appropriate, including the following:

- Transects within the inner NY Bight (NJ and LI coasts) being investigated under the NEFSC J.J. Howard Lab "Seascapes" project that seeks to understand multidimensional habitat values and influences in the nearshore oceanic environment for such species as summer flounder and black sea bass, in the vicinity of an area under consideration for Liquid Natural Gas terminal development (Leg 1),
- Extensive shallow water reefs (natural and artificial) along the ocean coast of Maryland that appear to be critical warm season habitat for black sea bass and tautog as well as soft corals in an area under consideration for wind farm development, in cooperation with University of Maryland Eastern Shore (Leg 1),
- Commercial fishing "hotspot" associated with an unusual diversity of benthic habitats and hydrographic effects around the head of Hudson Canyon (Leg 1),
- Areas of interaction between sea scallops, groundfishes, and the invasive tunicate Didemnum sp. on Georges Bank in cooperation with MIT and USGS (Leg 2),
- Habitats of deepwater coral-rugged topography-groundfish interaction in the Jordan Basin (Gulf of Maine) and Hudson Canyon in cooperation with UCONN and Rutgers (Leg 3).

Leg 2 Objectives:

1. The *Bigelow*'s ME70 multibeam sonar was utilized to generate acoustic mapping products (topography and backscatter patterns) for demersal/benthic habitats on Georges Bank. This data will enable habitat characterization of portions of northeastern Georges Bank by providing an acoustic basis for extrapolation of the extent of benthic habitat types previously characterized via existing USGS visual ground truth and sediment analysis data. Target areas included productive scallop/cod/haddock habitats that have been colonized by the invasive colonial tunicate Didemnum vexillum inside and

outside of Closed Area II (CA II) (Fig. 1, Areas A & B), and a "pristine" area of habitat within CAII (Fig. 1, Areas C1 & C2), discovered in 2007, that has not been impacted either by recent fishing activity or the invasive tunicate. The larger objective here was to provide data to characterize both the nature and the condition of habitats for resource species acoustically.

2. The use of an AUV in for acoustic (Didson imaging sonar) and visual habitat characterization of benthic habitats will also be examined in the same vicinity as areas being mapped with the ME70. The larger objective of this operation was to develop a method for reliable detection of the invasive tunicate and its habitat modifications utilizing remote sensors, thus expanding the scope of our ability to search for this invasive well beyond what has been done to date with real-time visual imaging. This was also an opportunity to demonstrate the benefits of this AUV vehicle, including its novel hover capability and its efficiency for large-survey AUV design.

Operations

Site Selection

Site selection for both mapping and AUV operations during this cruise was based upon extensive bottom video/photo surveys and dredge sampling conducted during annual NEFSC Benthic Habitat Cruises since 2002 in cooperation with USGS and URI. Two high priority map areas were chosen for multibeam mapping. Map Area A was chosen because it represents a sea scallop habitat heavily infested with the invasive colonial tunicate *Didemnum vexillum* within Closed Area II (CA II). Map Area C includes the crest and northern slope of Georges within CA II in which an area of nearly pristine habitat with dense epifauna was found in 2007 (Fig 2).

Procedures

This cruise consists of mapping activities using various acoustic methods in the operating area, hydrographic (CTD) deployments, AUV operations, and Mocness operations.

Mapping & CTD Operations

Patch test calibration of the ME70 multibeam sonar was not performed due to the limitations of the ME70 system as presently configured for water column detection. This underway calibration of sonar response against an area of known contours in normally performed for any bottom mapping multibeam sonar in order to ensure accuracy of subsequent contour calculations. This was not possible with the ME70 in its present water column detection configuration because of the difficulty in assembling and analyzing a visual record of results from recent history; rapid feedback of recent history is essential for making such adjustments. At present, post-processing of data (not performed on cruise due to lack of onboard expertise) is needed to provide the necessary feedback. The ME70 bottom mapping package probably contains an automated feature for this purpose, much like that for the Simrad EM3002 bottom mapping multibeam system aboard *Gloria Michelle*. This and a lack of tidal height data for the areas mapped leads to inaccuracies in the depth data. However, backscatter (strength of return signal) data, indicating bottom character, is still trustworthy. Bottom detection with the single beam EK60 sonar

(18 and 38 kHz only to avoid interference with ME70) aboard *Henry B. Bigelow* was performed simultaneously with the ME70 operations.

"Mowing the lawn" navigational patterns were laid out for bottom mapping areas. Navigational patterns were laid out with ship's speed and line spacing determined utilizing a spreadsheet template devised by Tom Weber of UNH specifically for ME70 coverage calculations. Settings for ME70 power and beamforms were also done according to recommendations of Tom Weber based on his experience with the ME70 aboard NOAA vessel *Oscar Dyson*. Five mapping transects were plotted and prioritized. Of these, the two highest priorities (A and C) were actually undertaken and completed. CTD casts were made approximately six hour intervals during mappimg operations so as to provide data for water column sound velocity calculations for ME70 data correction.

AUV Operations

The Massachusetts Institute of Technology Sea Grant (MIT SG) automated underwater vehicle (AUV) Odyssey IV was deployed during this cruise in order to test its operation in offshore waters and its utility in wide scale detection and assessment of bottom infestation with *Didemnum vexillum*. Odyssey IV (Fig. 5A) is an unthethered vehicle with self-contained power, propulsion, navigation systems. It conducts preprogrammed geo-referenced surveys with any of a variety of sensors. It is designed to maintain a constant altitude above sea floor, and can move at speeds ranging from hovering in place to 2.5 m/s (5 kt) at water depths up to 6,000 m for periods of up to 10 hours. It measures 1 X 1.5 X 2 meters, weighs approximately 500 kg, and is secured aboard ship in its custom deck cradle (Fig 5B).

For this cruise Odyssey IV was equipped with a Didson dual frequency (1.1 – 1.8 MHz) imaging sonar with a range of up to 25 m. Aboard Odyssey IV this sonar could afford image coverage two orders of magnitude larger than with conventional photography. It was also equipped with a digital camera for ground truthing sonar images. Odyssey IV was launched and recovered using the ship's port crane and with the assistance of the ship's rescue boat for detaching and attaching the AUV's lift coupling and steadying the vehicle during the hoist (Fig. 6). Four moored GPS-equipped buoys (Fig. 7) were deployed immediately around the AUV's operation area to provide location reference for the vehicle. As with the vehicle itself, deployment of these was performed with the ship's port crane and the assistance of the rescue boat. AUV operations were conducted during daylight hours and moored GPS buoys were deployed and retrieved for each day's AUV operations. All of those operations were restricted to calm sea conditions, and required the ship to loiter in the vicinity during the entire operation, although deployment of non-acoustic samplers/sensors (e.g. CTD) was possible during AUV deployments. Data stored aboard the AUV was downloaded and power batteries recharged while the vehicle was aboard *Henry Bigelow*.

Mocness Operations

The Mocness closing net now is being employed by the Environmental Processes Division Oceanography Branch to capture depth stratified plankton samples. Recently a color video plankton recorder (VPR) was mounted to this gear in order to provide a simultaneous visual record of the catch. The combined gear had not yet been successfully tested up to the time of this cruise. Deployment aboard HB08-05 Leg 2 was undertaken in order to devise a procedure for combined Mocness/VPR operation, including testing the slip ring and termination connections and adjusting the tension on the winch brakes, and demonstrate successful combined operation.

Results

Disclaimer: Results presented here represent a very preliminary overview of observations and data collection during cruise HB08-05. Additional quality assurance examination needs to be applied to raw data and no attempt has been made to apply rigorous statistical tests to any existing quantitative data regarding any hypotheses. The following detailed presentation is meant only to provide the reader a general idea of the nature of the raw data available and its utility toward meeting the stated objectives of the cruise.

Mapping

Mapping patterns varied in size, depth range, and the time required for their completion (Table 1). Mapping coverage rate varied approximately between 1.1 to 1.4 km^2 per hour. This was a considerably higher mapping rate than the 0.5 to 0.8 km^2 per hour achieved during Leg 1 as a consequence of the greater depths mapped during the current cruise. Greater depths provided larger multibeam swath widths along both the ship's keel and athwartships axes, allowing for the use of faster ship's speed over ground and wider line spacing while mapping while still achieving >100% coverage. At the time of this writing, post-processing of the ME70 multibeam data is still proceeding at UNH.

Three dimensional interpolated images of the simultaneously-collected EK60 single beam sonar (Figs. 2, 3) have been assembled since the end of the cruise and are presented below. These reveal the character of the topography on a scale of tens of meters. Map area A (Fig. 2) was dominated by two large sand hills, possibly the ends of large sand waves with heights of about 8 m and a wavelength of about 3.6 km.

What appear to be two perfectly straight furrows running down the length of Map Area A (Fig. 3), parallel to the ship's track, are tidal artifacts. These were generated as a result of stopping and starting mapping in this area several times with a hiatus of hours in between. Because no correction could be made for tidal height differences during these periods of mapping, those differences are manifested as apparent sudden changes in depth of <2 m between adjacent mapping lines made at different times. This points out the need for tidal correction in areas far from shore where no NOS predictions or monitoring are available. This can be achieved in the future through the use of depth-recording moorings placed temporarily within or near the area being mapped.

Map Area C includes that part of the crest and steep northern slope of Georges Bank within Closed Area II that lies along the Hague Line (Fig. 4). It encompasses a patch of "pristine" habitat discovered and explored by Page Valentine of USGS during a 2007 NEFSC Benthic Habitat cruise. On that cruise, this patch was found to bear an exceptionally dense epifauna little disturbed by bottom fishing. The "pristine" area seems to correspond with a patch of rough topography that stands out from the smoother surfaces on the adjoining bank crest and slope (Fig. 3). Note that this roughness is not visible on the standard contour chart (Fig. 2); the vertical scale of the rough contours is too small. On a horizontal scale the roughness occurs on a scale of tens to hundreds of meters: much larger than individual boulders. Indeed, the 40 X 40 m interpolation grids for this map can not capture features on a smaller scale. Video investigation has shown that this habitat contains is also rough on a scale of <10m, containing cobble and large boulders. In addition to the dense epifauna, video images indicate that this habitat supports moderate numbers of adult cod. The extent of the rough terrain in Fig. 4

suggests that the undisturbed habitat may extend westward beyond the limit shown in Fig. 2, where video exploration had yet to be done by the time of the present cruise.

Seventeen CTD casts were performed in conjunction with multibeam mapping in order to provide sound velocity profiles for sonar data correction. However, CTD data also revealed that bottom water temperatures tended to be substantially colder (5-9°C) in Map Area C than in Map Area A (11-14°C). This suggests that generally colder temperatures may influence the large differences in fauna that have been observed on previous cruises, in addition to differences in topographic roughness on various scales and sediment texture.

AUV Operations

Forty one runs were performed with Odyssey IV, all within Closed Area II. During these runs problems were worked out with regarding the proper length for GPS buoy mooring lines, with GPS signal processing by the buoys. The AUV itself ran well and was able to maintain an altitude of 2.0-2.5 m from the bottom during all operations. Sea state was the major limiting factor for conducting launch and recovery operations.

Didson sonar imaging did not produce results sufficient to determine the size of *Didemnum vexillum* patches. Judging from these results, it was suggested that a higher frequency Didson sonar could provide better detail, but would dictate a shorter range and consequent reduction of the size of the area scanned. This loss in size would negate the coverage advantage over survey by optical methods. Thus, Didson sonar does not appear to be a viable alternative to conventional optical methods for increasing the coverage rate for invasive tunicate surveys.

Didemnum vexillum was observed in digital photographs taken by the vehicle, although it did not appear to be as prolific or abundant as anticipated based on the results of previous Benthic Habitat cruises. The camera system and lighting system was adequate, but photos were not as clear as they could have been; upgrading of camera and lighting systems is recommended.

Mocness Operations

An operational procedure was devised for combined Mocness/VPR operation, resulting in four successful deployments with both instruments performing well. Data collected in these runs awaits analysis ashore. Larvae of the invasive colonial tunicate *Didemnum vexillum* are among the species being sought in the plankton samples.

Data Management and Disposition of Data and Samples

Ship's data from HB08-05 Leg 2 resides with Dr. Vincent Guida at NEFSC J.J. Howard Laboratory, including digital copies of continuous recordings of ship's GPS track, weather, surface hydrographic, and single beam EK60 depth soundings, raw CTD data, and ME70 multibeam sonar data. In addition, a copy of the multibeam sonar data has been distributed to Dr. Thomas Weber at UNH for post processing. Didson sonar and photographic data taken by the Odyssey IV AUV are retained at the Massachusetts Institute of Technology. Mocness data and samples were retained by Chief Scientist Elisabeth Broughton at NEFSC, Woods Hole Laboratory. A digital film was made of activities aboard HB08-05 Leg 2 by David Chevrier of the NEFSC Woods Hole Laboratory and is available from him.

Scientific Personnel

Name	Title	Organization	Dates of Participation
Elisabeth Broughton	Chief Scientist	NEFSC, WH Laboratory	8 July – 21 July
Dr. Page C. Valentine	Research Geologist	USGS, WH Field Center	8 July – 15 July
Dr. Judith Pederson	Faculty	MIT Sea Grant	8 July – 15 July
Dr. James Morash	Faculty	MIT	8 July – 21 July
Justin Eskensen	Student	MIT	8 July – 21 July
Dylan Owens	Student	MIT	8 July – 15 July
Dr. Franz Hover	Faculty	MIT	15 July – 21 July
Karl McLetchie	Student	MIT	15 July – 21 July
Dan Walker	Student	MIT	15 July – 21 July
John Blakeney	UROP	MIT	15 July – 21 July
Michael Soroka	AUV Ops manager	MIT	15 July – 21 July
David Chevrier	Fisheries Biologist	NMFS, WH Laboratory	8 July – 21 July

For further information, contact: Dr. Vince Guida, NOAA, NMFS, NEFSC, J.J. Howard Laboratory

Table 1. Summary of blocks mapped during HB08-05 Leg 2.

Cruise	Map Area	Depth Range (m)	Line Spacing (m)	Area Sq. Km.	Total hrs	Map Rate (km^2/h)
HB08-05 Leg 3	A	45-60	120	24.8	23.1	1.07
HB08-05 Leg 3	C	49-172	140-420	85.4	61.7	1.38
	Total			110.2	84.9	1.30

Figure 1. Georges Bank (NGDC contour data) showing study area rectangle in red (inset) and details below, including mapping areas (stippled) and CTD sites with colors indicating bottom temperatures (deg C).

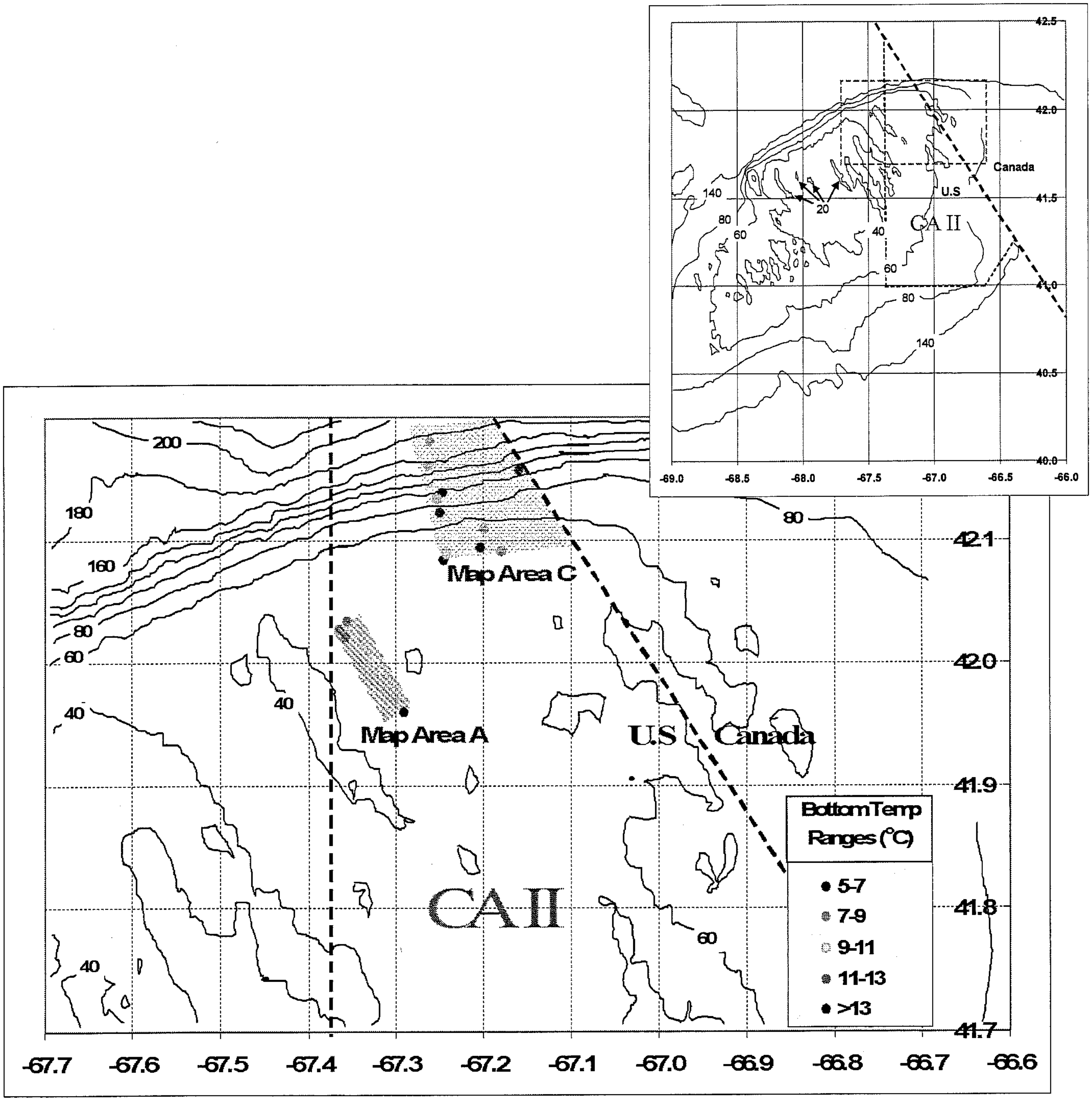
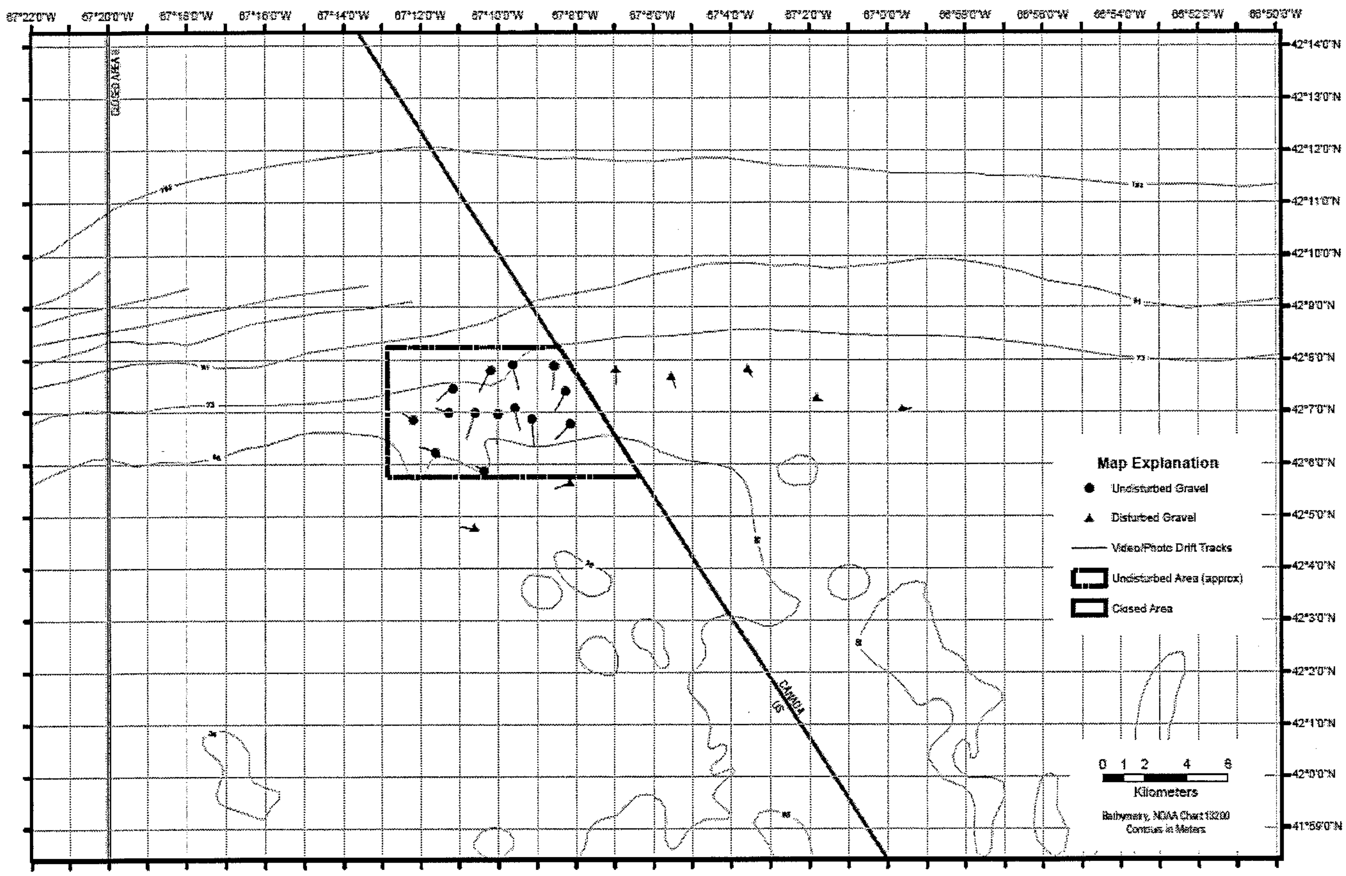


Figure 2. Plot of USGS Seaboss video transects from the 2007 Benthic Habitat cruise aboard DE II. The approximate limits of the undisturbed (pristine) habitat patch are indicated by the polygon in the center of the chart.



Closed Area II Undisturbed Gravel Habitat, July 2007

Figure. 3 Single beam sonar (EK60) 3-D interpolation bathymetric map for Map Area A. Grids are 40 m X 40 m. Red arrows indicated apparent straight furrows parallel to the ship's transit lines; these are actually tidal artifacts.

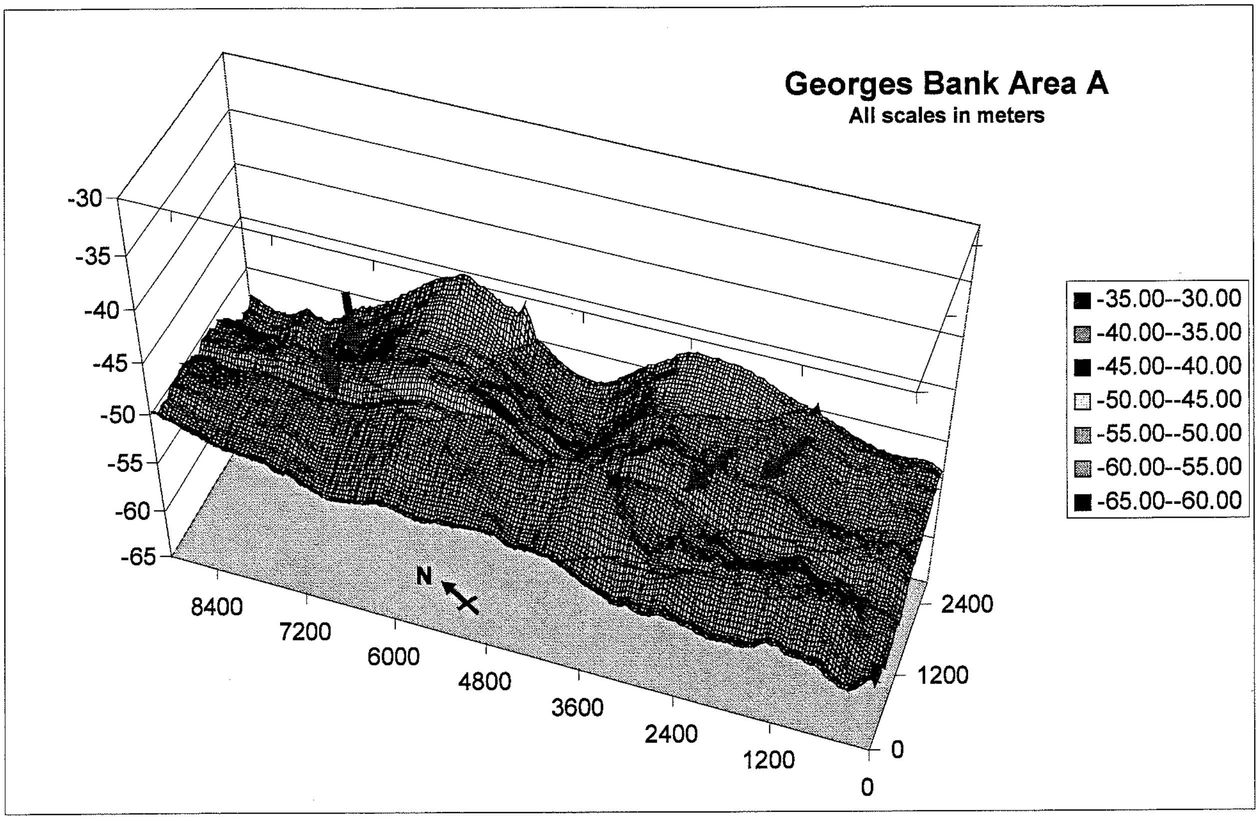


Figure 4. Single beam sonar (EK60) 3-D interpolation bathymetric map for Map Area C. Grids are 40 m X 40 m. Yellow polygon represents the approximate limits of an area described by P. Valentine as a "pristine" habitat. Zoom view to 150% to see contours more clearly. The apparent vertical cliff on the left is not a real topographic feature. It represents the termination of mapping pattern at the Hague Line (U.S.-Canada border).

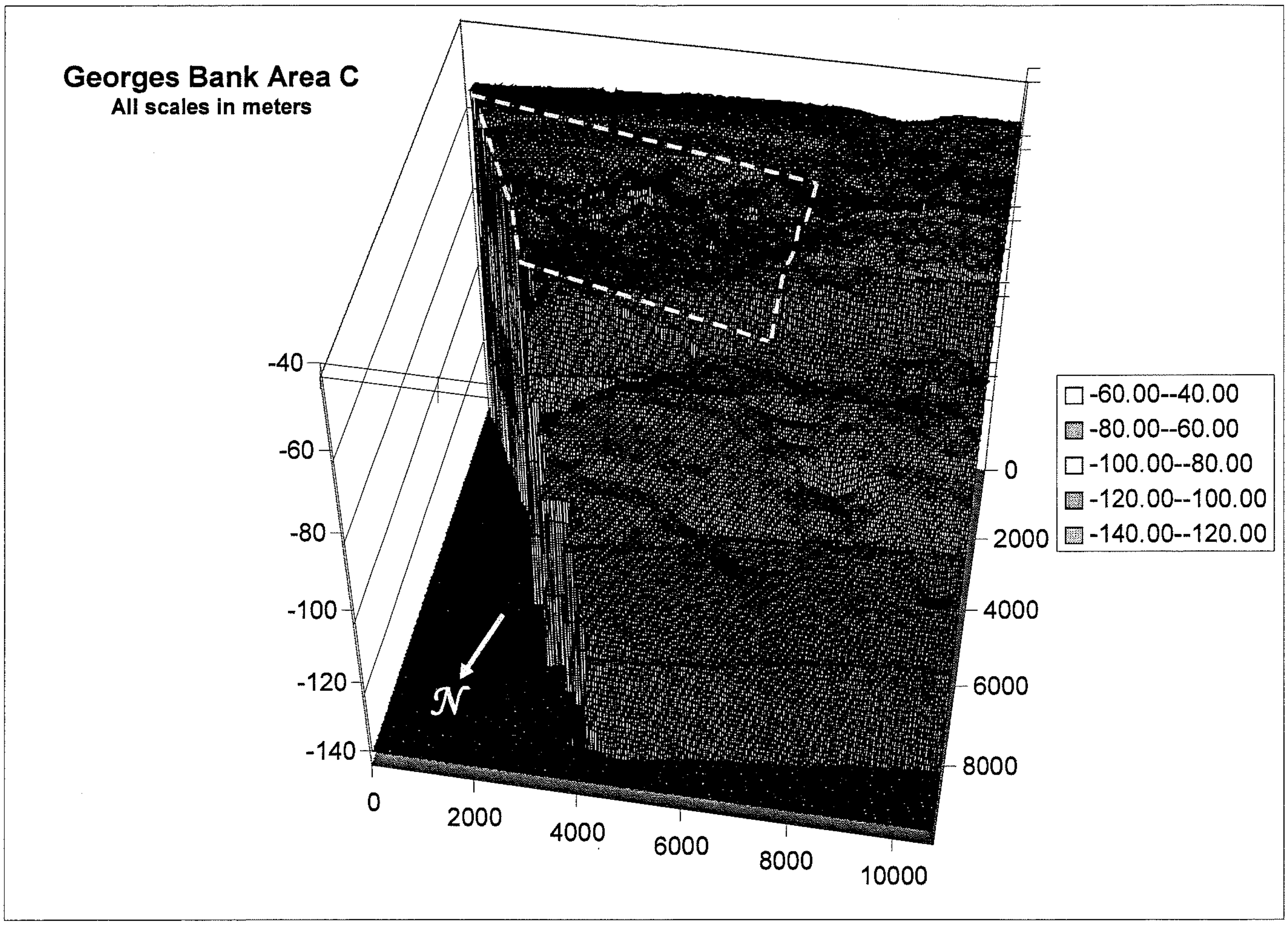
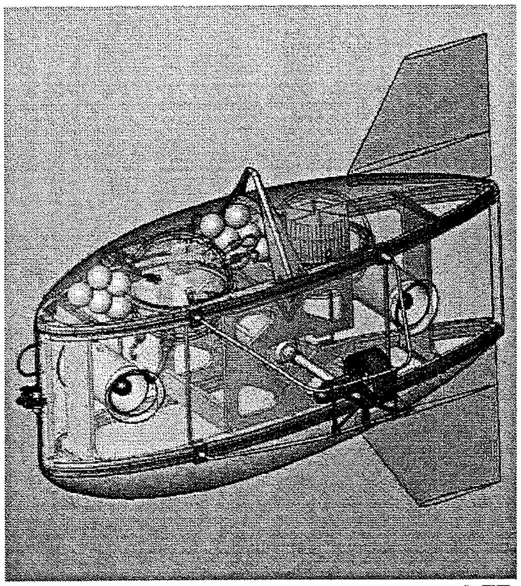


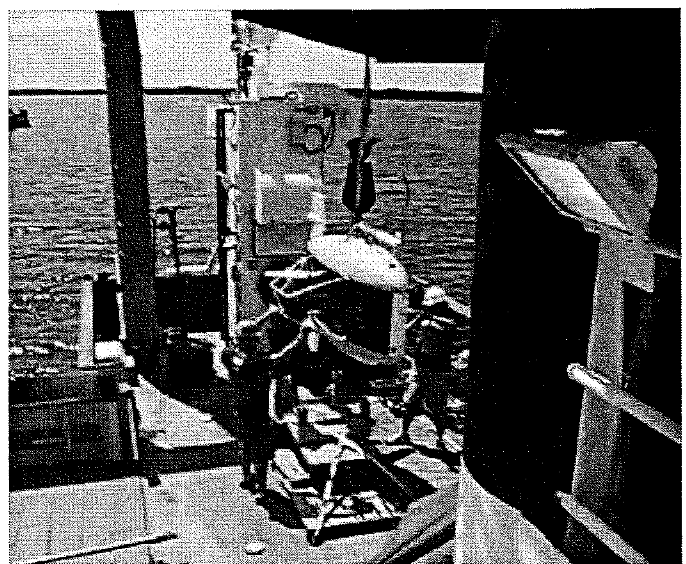
Figure 5. Odyssey IV AUV: A) Transparent view showing internal arrangement of frame, batteries, thrusters, controls, and instrument sphere, and B) During hoisting operations from its cradle aboard *Henry B. Bigelow*.

A.



MIT

B.

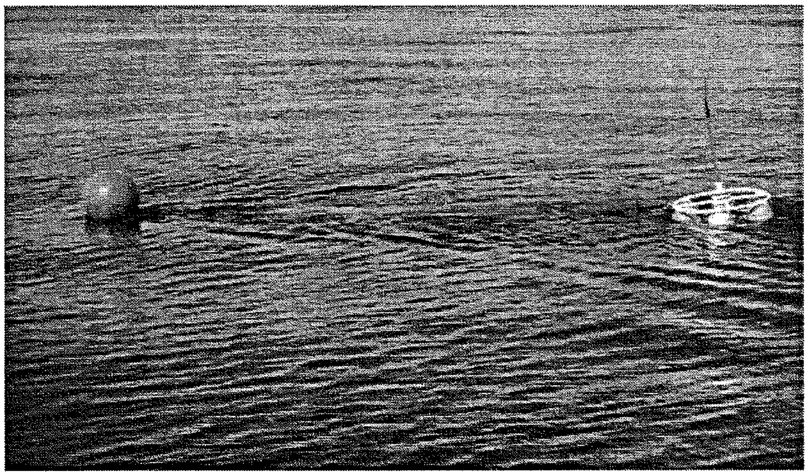


D. Chevrier

Figure. 6 Odyssey IV AUV during hoist being assisted by personnel aboard *Henry B. Bigelow's* rescue launch.

D. Chevrier

Figure 7. Moored GPS buoys deployed with Odyssey IV.



D. Chevrier

10 November 2008

CRUISE RESULTS
NOAA Ship *Henry B. Bigelow*
Cruise HB08-06
Benthic Habitat (Georges Bank Tunicate Research)

Executive Summary

- A 14 day cruise was conducted in order to investigate cod-haddock-sea scallop habitat and the relationship of the invasive colonial tunicate *Didemnum vexillum* to that habitat and its fisheries resources, including investigation of areas of known infestation since 2002, areas of newly-discovered infestation, and areas not yet colonized by the tunicate on both sides of the U.S.-Canadian border and both inside and outside of areas closed to bottom fishing in the U.S.
- Sampling methods utilized on this cruise included transects with the USGS Seaboss drift video/photo vehicle, fish sampling for species composition and trophic (gut content) analysis with the NEFSC 4-seam otter trawl, epifaunal sampling with a naturalists dredge, hydrographic profiling and water sampling (the latter for ocean acidification analysis) with a CTD/Niksin bottle combination, and bottom habitat mapping with *Bigelow*'s ME70 multibeam and EK60 single beam sonars.
- The presence of *D. vexillum* in areas along the northeast peak of the Bank in both fished (area 18) and closed (area 19) areas in the U.S. was confirmed, although the degree of coverage and thickness of colonies was somewhat less than in 2007. The extent of these areas has not expanded since 2006, probably due to limitations by sediment type and temperature. The tunicate's presence in Closed Area I, discovered in 2006, was reconfirmed. The tunicate was not found in habitats on the Bank's northern rim with the U.S., nor anywhere on the Canadian side of Georges, neither near the rim nor further into the Bank. It is thought that temperature regimes too cool to allow sexual reproduction of *D. vexillum* have prevented these areas from being colonized.
- Undisturbed habitat areas, one in the U.S. and one in Canada, were investigated. These Bank rim habitats support a dense, species-rich epifauna quite unlike elsewhere on the Bank, have experienced little trawling damage, and are free of *D. vexillum*, although they contain colonies of the native congener *D. albidum*. The one in the U.S. is within CA II and its boundaries were defined using Seaboss on this cruise. It supports high concentrations of cod and haddock, as well as some sea scallops. An area on the Canadian side of the Hague Line, immediately adjacent to the U.S. undisturbed habitat in CA II, lacks the characteristic epifauna, presumably due to fishing disturbance. Acoustic mapping results suggest this type of habitat is associated with rugged bottom contours on the scale of tens of meters. CTD data suggests that it may also be subject to substantial bottom temperature changes on a scale of hours to days, unlike areas on the Bank's peak, where consistently warm temperatures prevailed.
- Elevated numbers of two polychaete species were again associated with *D. vexillum*, and both *D. vexillum* and *D. albidum* were again found to constitute large portions of the stomach contents of some winter flounder individuals.
- Most trawl samples from Canada were dominated by haddock, while those from the U.S. were dominated by winter flounder and skate species. Although further statistical analysis is required to test hypotheses, this pattern does not appear to be related entirely to either temperature or *D. vexillum* dominance.
- Much analysis of the data collected needs yet to be done to elicit habitat-related patterns.

Cruise Period and Area of Operations

This cruise was conducted from August 13 through August 26, 2008. Operations were conducted on northern Georges Bank, both on the U.S. and Canadian sides of the Hague Line (Fig. 1).

Cruise Goals and Objectives

Use otter trawls (if available), beam trawls (if not), Naturalist Dredge, SEABOSS photography/bottom grab equipment, ship's multibeam and single beam sonars, and CTDs to conduct the following operations:

1. Determine changes in distribution and condition of invasive colonial tunicate *Didemnum vexillum* on northern Georges Bank gravel habitat. We will use the USGS SEABOSS drift vehicle to examine present status and trends of *Didemnum* distribution and abundance.
2. Explore the extent, function, and character of a newly-discovered benthic/demersal community not influenced by trawling or tunicate colonization.
3. Examine relationships between abundance of *Didemnum* and abundance and species composition of benthic fauna, fish and shellfish. Analyze gut contents of resource species for comparative analysis of diet, including evidence of ingestion and digestion of *Didemnum*.
4. Document the influence other ecosystem components, temperature regime, substrates, and disturbances, including fishing disturbances on tunicate-benthic/demersal stock interactions, utilizing comparisons of similar habitats inside and outside Closed Area II and on both sides of the U.S.-Canadian border.
5. Time permitting, conduct similar studies in other areas where depth and substrate are suitable for *Didemnum*, e. g., Great South Channel, an important habitat closer to Cape Cod.
6. Collect tunicate specimens for further study including DNA analysis and laboratory predation studies

Operations

Site Selection

Site selection for operations was made based on experience from previous Benthic Habitat cruises and from information provided by U.S. and Canadian colleagues (Figs. 1, 2). Areas for investigation included those of known *Didemnum* infestation outside (17 W, 19) and within (17, 18) the Closed Area II Habitat Area of Particular Concern (HAPC), areas in and around the "pristine habitat" (16 W) previously identified on the northern rim of the Bank within CA II, an adjacent area on the Canadian side of the border (16), an area of pristine habitat in Canada (MB in = Mussel Bed inside), and an area just outside that pristine area (MB out = Mussel Bed outside).

Procedures

During the cruise, seabed habitats were mapped and sampled using the USGS' Seaboss video/photo system. Study areas are on the northern edge of Georges Bank in U.S. and Canadian waters. Seaboss also collected bottom temperature data using HOBO Tidbit. Over 12 working days at sea, we collected data from 138 stations (Table 1) within the designated areas (16, 16W, 17, 17W, 18, 19, MB in, MB out: Fig. 2).

Trawl and dredge sampling (Table 2) were accomplished concurrently in the same areas (Fig. 2) with a four seam otter trawl and naturalists dredge, respectively. Demersal fish were collected with a standardized NEFSC 4-seam otter trawl deployed at 2-3 stations per area for 15-min with a towing speed of 3.0 knots (5.6 km/hr). Sampling efforts were directed toward at-sea examination and the preservation of fish stomach contents from a suite of benthivorous species including but not limited to haddock (*Melanogrammus aeglefinus)*, winter flounder (*Pseudopleronectes americanus*), and longhorn sculpin (*Myoxocephalus octodecemspinosus*). The number of tows conducted within the HAPC and Canadian regions of Georges Bank totaled 13 (7 undisturbed and 6 disturbed; total number of stomachs ~750), and 4 (2 undisturbed and 2 disturbed; total number of stomachs ~220) respectively.

In accordance with sampling the benthic megafaunal communities, the diets of the predominant fish species will be compared between areas (undisturbed versus disturbed) to assess the effects of bottom fishing on fish feeding (*i.e.* prey availability).

Twenty one CTD profiles were made during the cruise in support of trawl sampling and multibeam mapping operations (Fig. 3). A mowing-the-lawn pattern of parallel lines was laid out and followed for the acoustic mapping of Area C extension (Fig. 3). This supplemented habitat mapping of Georges Bank previously accomplished aboard HB08-05 Leg 2.

Samples for pH and alkalinity determination were drawn from Niskin bottom water samples that accompanied 16 CTD casts and from surface samples drawn from the ship's scientific seawater system in the dry lab aboard *Henry Bigelow*. Dry lab samples were shown to have the same pH as those from bucket samples taken from surface water on the ship's starboard side, whereas seawater drawn from the chemistry lab aboard *Henry Bigelow* were shown to have lower pH and were hence unusable. Two pH and two alkalinity measurements were made onboard HB08-06 for each surface and bottom station. All procedures and calculations were performed according to Strickland & Parsons (1972). Dr. Williams is interested in measuring the effects of increasing atmospheric CO_2 on ocean acidification.

Results and Conclusions

<u>*Disclaimer:*</u> Results presented here represent a very preliminary overview of observations and data collection during cruise HB08-05. Additional quality assurance examination needs to be applied to raw data and no attempt has been made to apply rigorous statistical tests to any existing quantitative data regarding any hypotheses. The following detailed presentation is meant only to provide the reader a general idea of the nature of the raw data available and its utility toward meeting the stated objectives of the cruise.

Seaboss Operations

On the transit from Woods Hole to our study areas, we made 2 Seaboss video/photo drifts at a location in Closed Area I (near its eastern boundary: Fig. 1) where *Didemnum vexillum* was observed in 2006 by

WHOI researchers and confirmed by us in 2007. We re-confirmed that the tunicate still persists there after at least 2 years, living on a mixed sand and pebble gravel habitat.

Our long-term study areas 18 (open to fishing) and 19 (closed to fishing) continue to be infested by *Didemnum vexillum.* The affected areas, totaling 230 sq km of gravel habitat, have not increased appreciably since our survey in 2006 because they are bounded by mobile sand which smothers the tunicate and because cold bottom water temperatures prevent the tunicate's expansion into adjacent gravel habitats. We surveyed our other long-term study areas in both U.S. and Canadian waters and did not observe *Didemnum vexillum.* It is likely that the species has not spread to these areas because the bottom water temperatures are too cold for sexual reproduction to occur.

We made an extensive survey of an area in the HAPC of Closed Area II (Area 16 U.S.) that we discovered in 2007. It is a gravel habitat in U.S. waters that is virtually undisturbed by bottom fishing gear. Surveys with the Seaboss adjacent to the Hague Line allowed us to delineate the extent of a large area of gravel seabed (primarily cobbles and boulders) that may represent a habitat type that was typical of the northern edge of Georges Bank prior to the use of bottom trawling and dredging gear. Glacial deposits of pebble and cobble gravel and scattered boulders constitute the hard substrate; loose sand lies between the cobbles and boulders. The cobbles and boulders are completely covered by attached epifauna that include bryozoa, hydrozoa, sponges, *Filograna* colonial worms, horse mussels and solitary tunicates. The colonial bryozoan *Eucratea loricata* dominates the fauna. Altogether, the attached epifauna covers 50 percent or more of the seabed. Unusually large numbers of haddock and cod were present in this area. Trawling and dredging has removed the epifauna in some places, but to a minor extent overall. Trawl/dredge scars can be recognized as open places where attached epifauna has been removed. Trawl wire was observed on the seabed wrapped around boulders. Presumably, the boulders in the area and its closure to fishing have prevented the destruction of the habitat to date, and the scars may have been made prior to the closing of the Closed Area II region in 1994.

A total of 41 Seaboss video/photo transects were conducted to delineate this habitat. Transects were typically 0.25 to 0.5 nautical miles in length. The undisturbed area extends westward from the U.S./Canada boundary approximately between the 40 and 50 fathom (55 and 73 m) isobaths, for approximately 7 nm (13 km).

Dredge Operations

Didemnum vexillum Infestation

Area 18 has been the site of dense colonies of the invasive tunicate *Didemnum vexillum* since 2003. This year, colonies of *D. vexillum* were again found in dredge samples from Areas 18 and 19. However, the colonies appeared to be present at lower density and individual colonies appeared thinner, compared to previous years. Slightly more *D. vexillum* was found in dredge samples from Area 18 than 19. Again this year, two polychaete species, *Nereis zonata* and *Harmothoe extenuata* were found in association with *D. vexillum*, but given the lower tunicate densities, there were comparatively fewer polychaetes. *D. vexillum* was not seen in dredge samples from any of the other areas. The Naturalist dredge and the ship's deck were thoroughly cleaned before leaving Area 18 to avoid spreading the invasive tunicate.

The indigenous species, *Didemnum albidum* was found in dredge samples from inside the Canadian mussel bed, and also in the US mussel bed (Area 16W). In contrast to previous years, fairly large colonies (~10 cm^2) of *D. albidum* were found in the dredge samples. Samples of *Didemnum* were preserved (formalin, ethanol, freezing) for taxonomic, genetic, and chemical analyses. Fragments of *D. vexillum* and *D. albidum* were found in several winter flounder stomachs, constituting as much as 35% of the stomach volume. The flounder appear to eat tendrils of *Didemnum* while foraging for other benthic prey species.

Effects of Bottom Fishing

A main result of this cruise was the mapping and sampling of a mussel bed in the juvenile cod HAPC. Two Naturalist dredge samples were taken inside the mussel bed. These samples consisted almost entirely of biogenic material, with very little of the underlying gravel. The main epifaunal taxon was the bushy bryozoan, *Eucratea loricata*, the shelled ectoproct. Living within the bryozoan matrix were numerous large and small horse mussels, *Modiolus modiolus*. The tube-building polychaete, *Thelepus cincinnatus*, occurs in very high densities, attached to the bryozoans. The mussel bed is also characterized by solitary tunicates, *Boltenia* and *Mogula*. This habitat appears to be even less disturbed than the Canadian mussel bed.

The areas were sampled to provide spatial comparisons between fished/unfished areas and areas inside and outside of Closed Area II. The US mussel bed (16W) was paired with 16E, which is an active scallop ground on the Canadian side of the Hague Line. The dredge samples at 16E contained clean gravel with numerous small scallops and some pandalid shrimp. The Canadian mussel bed was contrasted with an active scallop ground to the SE. The dredge samples from outside the mussel bed also contained clean gravel and numerous small scallops. Dredge samples from Area 17E (inside the HAPC) had small amounts of epifauna (e.g. *Suberites* sponge) and large scallops. In contrast, Area 17W (outside the HAPC) is characterized by bare cobble gravel, numerous small scallops, *Crangon*, and pandalid shrimp. Area 18 (outside the HAPC) is characterized by abundant shell hash (scallop, horse mussel, and razor clam).

Trawl Operations

The fish trawl catches in general varied considerably in species composition and biomass within the sampling regions of Georges Bank namely the HAPC of northern Closed Area II (U.S. waters; CAII) and the northeast peak (Canada). Trawl sampling within the central areas of the HAPC (Areas 19 and 17E) revealed substantial amounts of winter flounder (*Pseudopleuronectes americanus*), little skate (*Leucoraja erinacea*), and winter skate (*Leucoraja ocellata*) with average biomasses per trawl of 64.3 kg, 45.9 kg, and 61.1 kg respectively for Area 19, and 22.8 kg, 16.7 kg and 115.3 kg respectively for Area 17E. Areas 18 and 17W, contiguous to the HAPC and open to commercial fishing exhibited similar fish catch compositions compared to Areas 19 and 17E. In addition, longhorn sculpin (*Myoxocephalus octodecemspinosus*) and sea scallops (*Placopecten magellanicus*) were primarily observed in Area 17W with average biomasses of 36.1 kg and 81.4 kg respectively. Haddock (*Melanogrammus aeglefinus*) and Atlantic cod (*Gadus morhua*) were observed inside and outside the western HAPC region although average biomasses were consistently low for each given area with numbers < 2 kg and < 1.3 kg for haddock and cod respectively.

The Mussel Bed Areas sampled within the Canadian waters of the northeast peak of Georges Bank showed marked differences in catch biomass compared to the trawls conducted in U.S. waters. A notable increase in gadids (*e.g.* haddock and to a lesser extent Atlantic cod) was observed in this region with average biomasses for these species equaling 440.9 kg and 21.43 kg respectively for the Mussel Bed Undisturbed Area, and 341.6 kg for haddock in the Mussel Bed Disturbed Area.

Areas 16 and 16W, immediately east and west of the Canadian-U.S. border and including the eastern region of the HAPC (U.S. waters; Area 16W), in general were similar with regard to the observations made in the HAPC and Canadian regions detailed above, although in comparison to each other were quite different. The average catch biomass per trawl in Area 16 was dominated by haddock, cod, and yellowtail flounder (*Limanda ferruginea*) at 886.8 kg, 36.9 kg, and 35.9 kg respectively. These species were observed, albeit in lesser amounts in Area 16W, with average biomasses of 59.2 kg, 1 kg, and 1.5 kg for haddock, cod, and yellowtail flounder respectively. The principal species caught in Area 16W included winter skate, haddock, barndoor skate, and sea raven with average biomasses of 173.9 kg, 59.2 kg, 28.9 kg, and 47.4 kg respectively.

Juvenile cod were sampled within the HAPC. However, the highest numbers of cod were found in the Canadian areas (*e.g.* 259 individuals (45.00 kg) collected in a single tow). In comparison, haddock revealed a similar distribution in total biomass sampled with < 120 kg and > 3300 kg observed in the HAPC and Canadian areas respectively.

Much analysis remains to be done with data from this and previous years to understand the interaction of epifaunal domination by *Didemnum vexillum*, direct removal of fish by fishing, spatially differing hydrographic regimes, year-to-year climate variations, and current and historic habitat disturbance that results in such distributional patterns.

Mapping and CTD Operations

Thirty nine lines were mapped simultaneously in the Map Area C extension block with the ME70 multibeam and EK60 single beam sonars in the course of seven mapping sessions totaling 31.4 hours. This brought the total area of Georges Bank mapped in this way to about 110 km^2 (Table 4). An interpolation map created with the EK60 data (Fig. 4) reveals a relatively smooth bottom sloping gently from southeast to northwest (upper left to lower right in Fig. 4), breaking suddenly into a steep slope at the northernmost end (bottom in Fig. 4) of the block. Amid the relatively smooth surface of most of the area is a small patch irregular bottom just above the slope break on the northeast (lower left) corner of the block. The topography of this patch resembles the irregular bottom that appears to correspond with the "pristine" habitat with high epifaunal cover described above. The multibeam sonar data has not yet been post-processed, but could provide higher resolution bathymetry and valuable backscatter data.

An unfortunate consequence of mapping this block in seven separate sessions separated by 3 to 19 hours in an area far from shore is the generation of obvious tidal artifacts (Fig. 4) without means for tidal height correction. These are perfectly linear bathymetric discontinuities resulting from mapping adjacent lines at different stages of the tide. Tidal height correction of data is needed to remove these anomalies. This will require employment of a temporary mooring to monitor tide level changes during the period when mapping is being performed. Use of a tidal height prediction model might also work, but at present there is no such model for this remote area of Georges Bank.

Twenty two CTD deployments were made during this cruise (Fig. 3). Bottom temperature in areas where *Didemnum vexillum* dominates (areas 18 and 19) were consistently the warmest (13° to >15° C). Cooler bottom temperatures were recorded near the rim of the Bank, on the Bank slope, and on the Canadian side of the Hague Line. Indeed, bottom temperatures taken over the duration of this cruise near the Bank rim (Area 16 W) ranged quite widely (7° to 13° C) in a pattern that was not correlated with depth. It is thought that bottom temperatures in this are not only cooler than the rim crest where *Didemnum* prevails, but are also more variable on a short time scale (hours-days), probably related to tidal movements of thermal strata in the adjacent Gulf of Maine. What influence short-term temperature variability may have on the distribution of fishes, *Didemnum*, and other fauna is not clear.

Ocean Acidifcation Measurements

In situ pH measurements ranged from 8.040 to 8.336 for surface water and from 7.990 to 8.097 for bottom water (Table 4). *In situ* pH represents a value adjusted for the temperature and salinity of water measured at the time of collection, i.e. measured by the CTD at the collection depth. Surface water pH was generally higher than bottom water pH. Alkalinity varied from 1.720 to 2.492 milliequivalents in surface water and from 2.175 to 2.364 milliequivalents for bottom water (Table 4). These findings await interpretation in comparison with historical values, which are rare, and with recent values taken by other investigators.

Data Management and Disposition of Data and Samples

Ship's data from HB08-06 resides with Vincent Guida at NEFSC J.J. Howard Laboratory, including digital copies of continuous recordings of ship's GPS track, weather, surface hydrographic, and single beam EK60 depth soundings, raw CTD data, and ME70 multibeam sonar data. The Naturalist Dredge samples are retained and will be analyzed by Dr. Jeremy Collie at the University of Rhode Island, Graduate School of Oceanography. The fish trawl and stomach-content data are retained and will be processed by Brian Smith at the Northeast Fisheries Science Center (NEFSC), Woods Hole Laboratory. Dr. Shayla Williams at NEFSC J.J. Howard Laboratory retains the pH/alkalinity data.

Scientific Personnel

Name	Title	Organization
Vincent G. Guida	Chief Scientist	NEFSC, J.J. Howard Lab
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Table 1. Summary of Seaboss operations, including video/photo footage, HOBO bottom temperature data, sediment samples, and tunicate samples taken.

Date	Location on Georges Bank	Seaboss video/photo stations	Bottom temp stations	Sediment samples	*Didemnum vexillum* samples
Aug 14, 2008	Closed Area I	2	2	0	0
Aug 15	Area 19, CA II	17	17	0	0
Aug 16	Area 19, CA II	8	8	0	0
"	Area 17W	6	6	0	0
Aug 17	Area 17W	3	3	0	0
"	Area 19, CA II	1	1	0	0
"	Area 18	10	10	0	1
Aug 18	Area 18	12	12	1	0
Aug 19	Mussel Bed, Canada	6	6	0	0
"	Northern Edge, Canada	7	7	1	0
Aug 20	Northern Edge, Canada	6	6	2	0
"	Area 16, Canada	7	7	0	0
Aug 21	Area 16, Canada	3	3	0	0
"	Area 16, US, CA II (undisturbed area)	10	10	0	0
Aug 22	Area 16, US, CA II (undisturbed area)	13	13	0	0
Aug 23	Area 16, US, CA II (undisturbed area)	10	10	0	0
"	Area 17W	3	3	0	0
Aug 24	Area 16, US, CA II (undisturbed area)	8	8	0	0
"	Area 17, CA II	5	5	0	0
"	Area 19, CA II	1	1	0	0
Totals		138	138	4	1

Table 2. Summary of trawl and dredge operations conducted aboard HB08-06.

Date	Area	Type	Number of samples
8/14/08-8/15/08	19	Naturalist dredge	4
8/14/08-8/15/08	19	Otter trawl	3
8/16/08	18	Naturalist dredge	3
8/16/08	18	Otter trawl	2
8/18/08-8/19/08	Mussel Bed Inside	Naturalist dredge	2
8/18/08	Mussel Bed Inside	Otter trawl	2
8/19/08	Mussel Bed Outside	Naturalist dredge	2
8/19/08	Mussel Bed Outside	Otter trawl	2
8/20/08	16 East	Naturalist dredge	2
8/20/08-8/21/08	16 East	Otter trawl	2
8/21/08-8/22/08	16 West	Naturalist dredge	2
8/21/08-8/22/08	16 West	Otter trawl	2
8/23/08	17 East	Naturalist dredge	3
8/23/08	17 East	Otter trawl	2
8/24/08	17 West	Naturalist dredge	3
8/24/08	17 West	Otter trawl	2

Table 3. Summary of acoustic mapping operations aboard HB08-05 Leg 2 and HB08-06.

Cruise	Map Area	Depth Range (m)	Line Spacing (m)	Area Sq. Km.	Total hrs	Map Rate (km^2/h)
HB08-05 Leg 3	A	45-60	120	24.8	23.1	1.074
HB08-05 Leg 3	C	49-172	140-420	85.4	61.7	1.383
HB08-06	C ext	47-70	120	36.3	31.4	1.154
	Total			110.2	84.9	1.299

Table 4. Results of duplicate surface and bottom pH and alkalinity determinations from CTD cast numbers listed across the top of the table. pH values are on the standard 0-14 pH scale and alkalinities are in milliequivalents.

	105	107	109	110	111	112	114	115	116	117	118	119	120	121	123
Measured Surface pH 1	n/a	8.034	8.094	8.081	8.136	8.120	8.110	8.098	8.140	8.109	8.120	8.138	8.099	8.077	8.014
in situ Surface pH 1	n/a	8.048	8.098	8.093	8.143	8.334	8.121	8.105	8.153	8.131	8.135	8.148	8.101	8.095	8.040
Surface Alkalinity 1	n/a	2.215	2.184	2.224	2.179	2.244	2.271	2.198	2.262	2.247	2.265	2.244	2.238	2.258	1.720
Measured Surface pH 2	n/a	8.022	8.107	8.080	8.140	8.123	8.118	8.103	8.143	8.101	8.049	8.116	8.103	8.113	8.095
in situ Surface pH 2	n/a	8.042	8.110	8.096	8.148	8.336	8.133	8.113	8.157	8.125	8.086	8.130	8.136	8.117	8.097
Surface Alkalinity 2	n/a	2.175	2.161	2.340	2.160	2.260	2.221	2.203	2.208	2.230	2.247	2.258	2.235	2.226	2.492
Measured Bottom pH 1	8.042	8.024	8.014	8.083	7.987	7.954	8.047	8.015	8.013	7.947	7.965	7.998	8.008	7.971	7.947
in situ Bottom pH 1	8.063	8.036	8.012	8.097	8.020	7.993	8.074	8.052	8.039	8.012	8.025	8.033	8.030	8.040	8.009
Bottom Alkalinity 1	2.257	2.188	2.175	2.243	2.190	2.261	2.256	2.224	2.272	2.303	2.258	2.229	2.248	2.275	2.229
Measured Bottom pH 2	8.036	8.027	8.015	8.075	7.988	7.947	8.041	8.014	8.008	7.951	7.958	7.994	8.012	7.967	7.944
in situ Bottom pH 2	8.058	8.039	8.016	8.094	8.021	7.990	8.075	8.052	8.056	8.020	8.028	8.028	8.033	8.038	8.005
Bottom Alkalinity 2	2.195	2.217	2.228	2.276	2.205	2.303	2.285	2.265	2.273	2.260	2.329	2.355	2.340	2.316	2.364

Figure 1. Georges Bank (NGDC contour data) showing locations of operating areas within dashed red lines. Habitat Areas of Particular Concern (HAPCs) and the Hague Line (international boundary) are delimited with black dashed lines. HAPCs shown: Closed Area I (CA I) and Closed Area II (CA II). Red dots in CA I represent the locations of Seaboss video/photo transects made during this cruise. The boundaries of succeeding map figures correspond to those of the northern red box on this map. Depth contours are in meters.

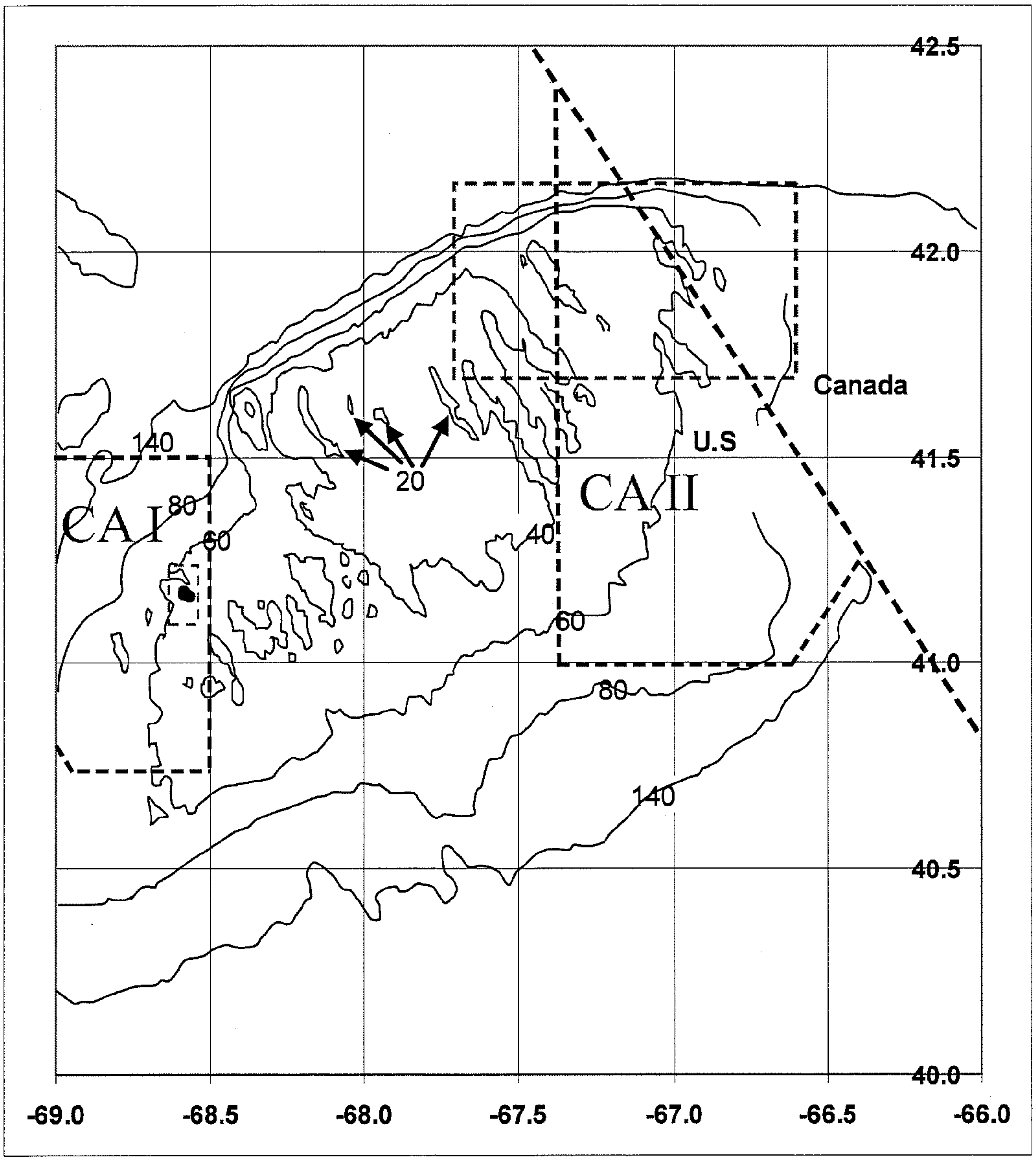
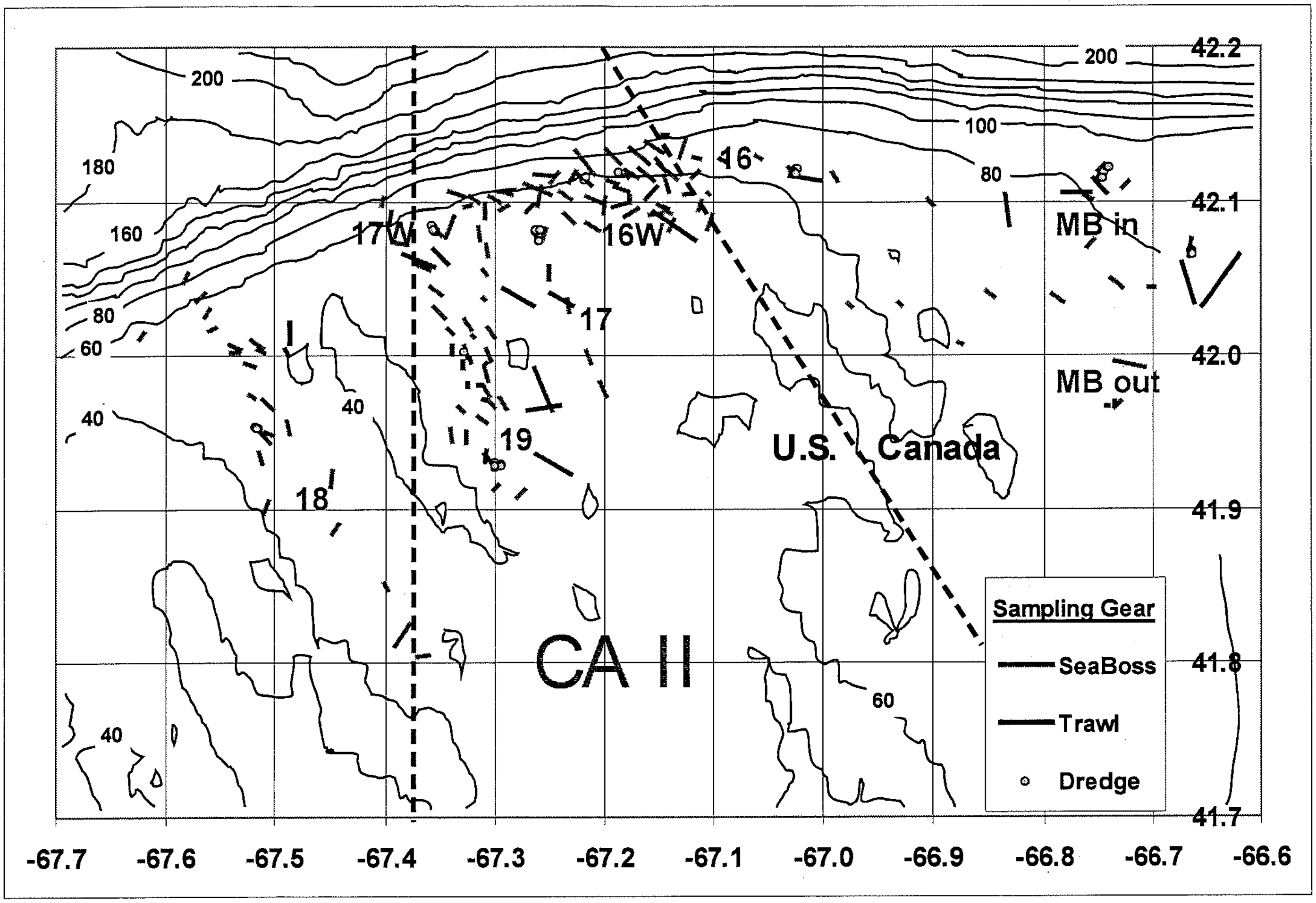


Figure 2. Northern Georges Bank (NGDC contour data) showing tracks of Seaboss drifts and 4 Seam Otter Trawl tows and locations of Naturalist Dredge samples taken during HB08-06. Labels in gray (other than CA II) are area designations referred to in the text. A, B: photos of naturalist dredge and Seaboss.



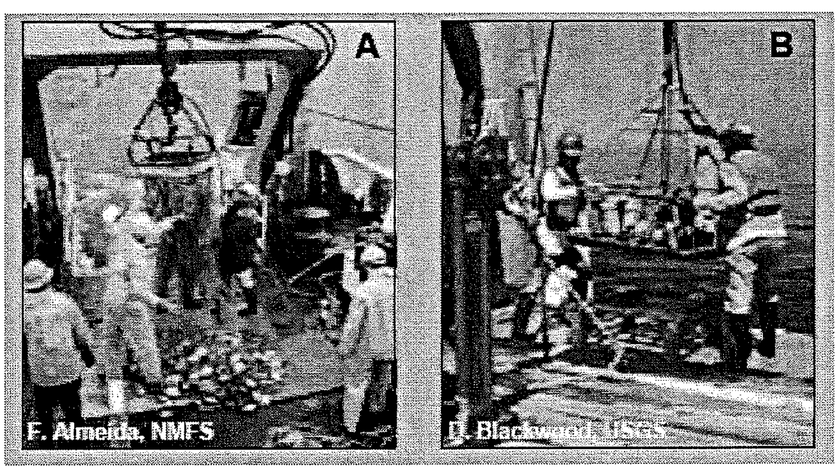


Figure 3. Northern Georges Bank (NGDC contour data) showing locations of CTD deployments during HB08-06 with symbols color coded for bottom temperature ranges. Areas subject to acoustic bottom mapping during HB08-5 Leg 2 (Areas A and C) and HB08-06 (Area C extension) are indicated with colored striping. Labels in gray (other than CA II) are area designations referred to in the text.

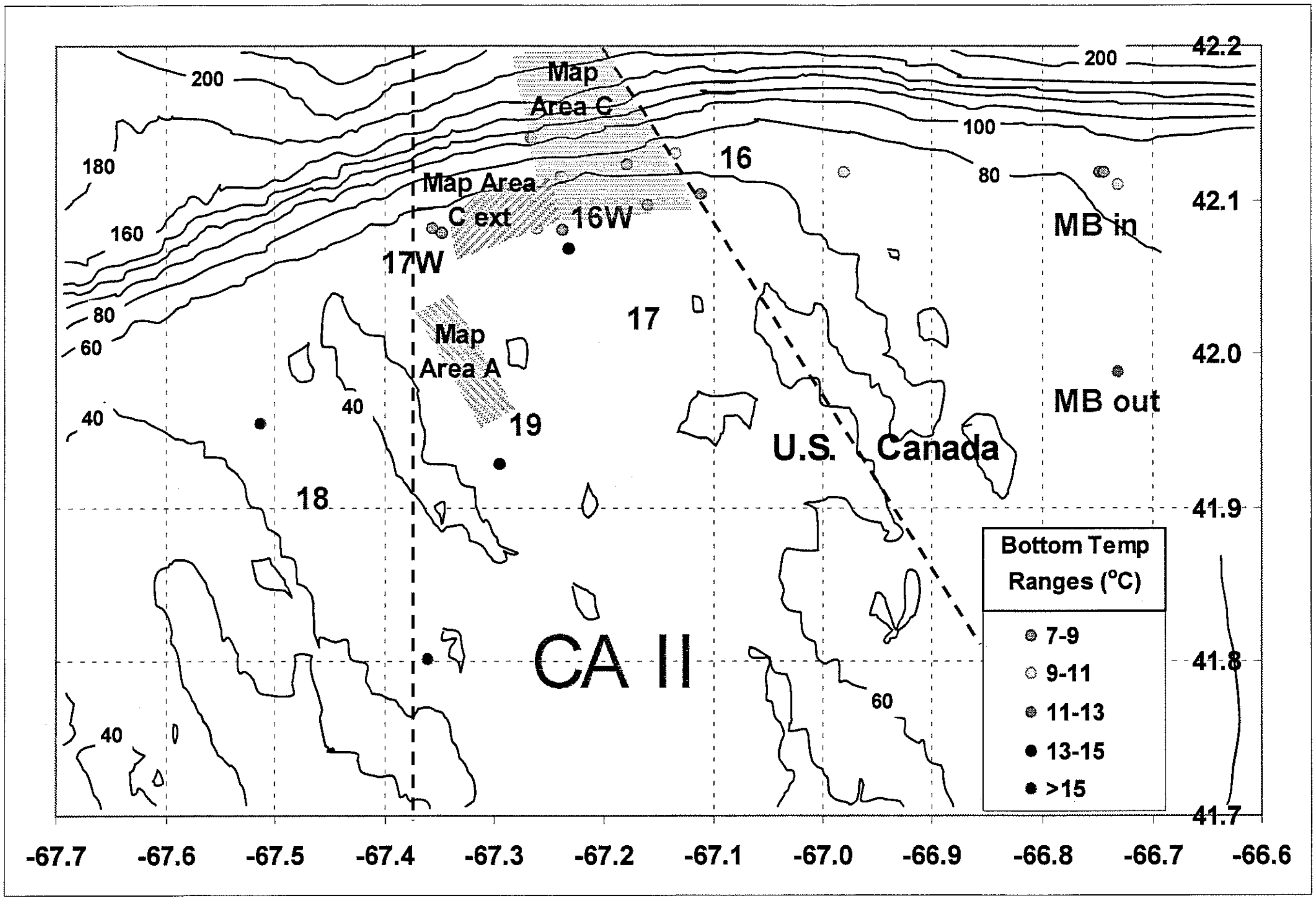
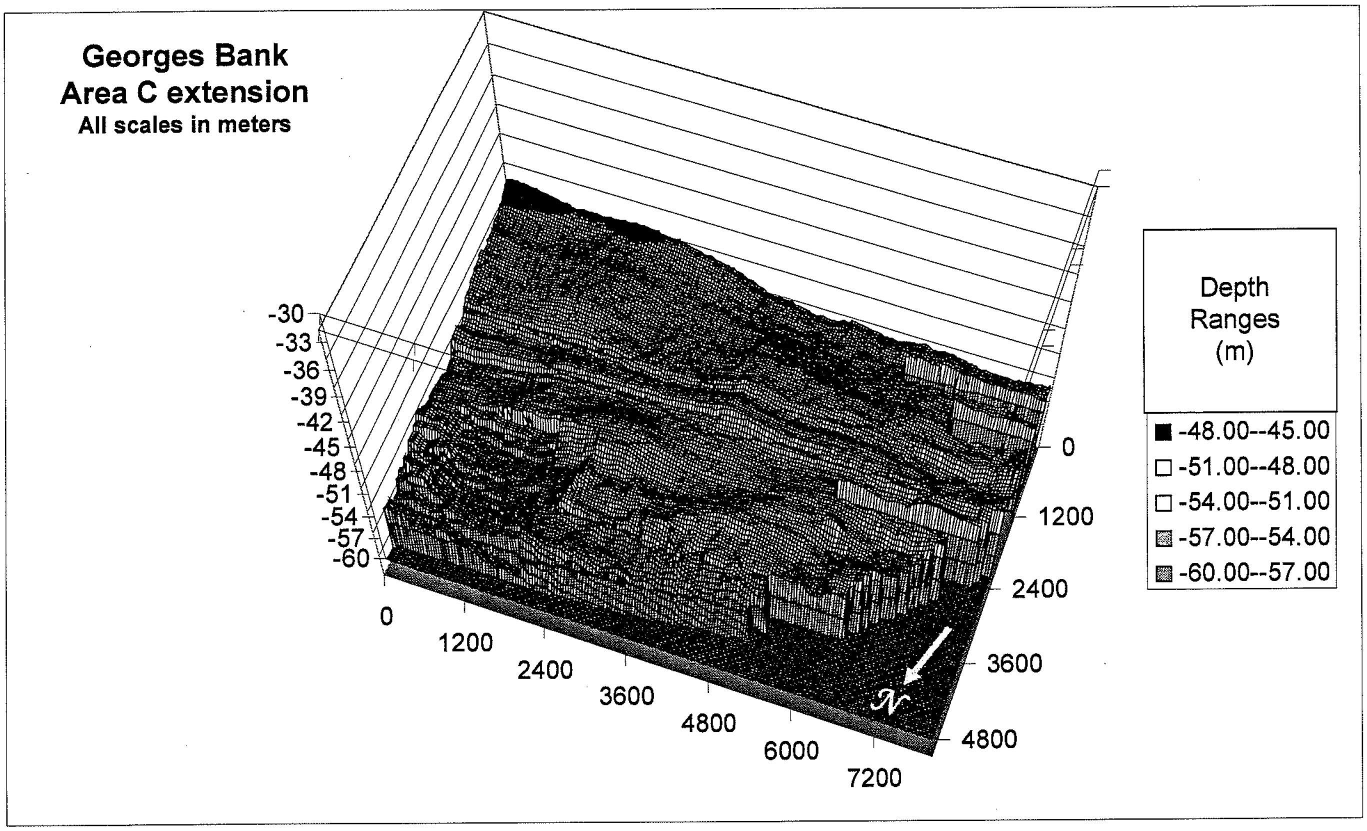


Figure 4. Three-dimensional interpolation image of EK60 single beam sonar data collected from Map Area C extension during cruise HB08-06. Grid size is 40 m X 40m. Apparent vertical walls along the right (western) edge of the image, including vertical-sided rectangular slices represent the end of the mapped area, not real bathymetric features. Straight furrows cutting across the middle of the image from east to west are tidal artifacts. Zoom image to 150% to see details more clearly.



Ship time requests and proposals

Proposal for mapping the northern margin of Georges Bank

Purpose – We request the use of a NOAA ship to conduct multibeam seabed mapping of the Northern Edge of Georges Bank. The region to be mapped extends from the US/Canadian boundary (Hague Line) westward to the western end of the bank in water depths of 50 to 100 m. We anticipate that the survey can be accomplished over a 3-year period assuming one 2-week cruise per year.

Background – The northern margin of Georges Bank comprises extensive areas of gravel habitat (pebbles, cobbles, boulders) that have been formed by the winnowing of sand from mixed sediment deposited on the bank by glaciers during the last glacial advance that ended approximately 18,000 years ago. The winnowing has been accomplished primarily by the strong semidiurnal tidal currents that flow across the shallow bank and by occasional storm-generated currents. Gravel habitats on the northern margin are separated by long shallow sand ridges that are oriented northwest-southeast and are aligned with the tidal flow. Thus, the region is characterized primarily by two highly contrasting substrates, immobile gravel and mobile sand, which support very different communities of invertebrates and fish. These substrates are valued as Essential Fish Habitat for commercial fisheries species including cod, haddock, ..., and sea scallops [Vince, please expand the species list here if warranted]. The central and southern parts of the bank are sand that was transported by water flowing southward from the glacial front and subsequently modified by tidal and storm currents.

In contrast to the US part of Georges Bank, the entire Canadian part has been surveyed using multibeam technology, and a series of 9 interpretive seabed topographic maps will be released in January, 2013.

Need – The New England Fishery Management Council and the National Marine Fisheries Service oversee the region's commercial fishery species and determine which areas of the seabed are opened and closed to fishing in order to conserve fishery stocks and to preserve habitats. To date, information on habitat types and their distribution has been based on video and photographic imagery and sediment analyses collected by various institutions and agencies. While the information provided by these data is helpful, interpretation of substrate types is sometimes conflicting. There is a need for multibeam seabed imagery which together with existing extensive video/photo and grain size analyses, will serve as a basis for identifying and accurately mapping the substrates of the Northern Edge, with a goal of contributing to improving fishery stock assessment and management.

Vessels – NOAA ships that are appropriately outfitted with multibeam mapping systems are listed below in order of decreasing seabed mapping capability for our needs. The proposed survey will be conducted in water depths of approximately 50 to 100 m except for the crests of sand ridges which can be as shallow as 10 m below the sea surface. Some sand ridge crests may be too shallow to survey.

Ferdinand Hassler: draft 3.8 m	Dual Reson 7125; 200/400 kHz; to 75 m water depth Reson 7111; 100 kHz; to 600 m
Thomas Jefferson: draft 4.3 m	Reson 8101; 240 kHz; to ~100 m Reson 8125; 455 kHz; to 120 m Simrad EM 1002; 98 kHz; to 1000 m
Nancy Foster: draft 3.9 m	Reson 7125; 200/400 kHz; to 75 m Simrad EM1002; 95 kHz; to 1000 m

Proposal for mapping the northern margin of Georges Bank aboard NEFSC Habitat Mapping and/or Benthic Habitat Cruise

Purpose – We request the use of a NOAA ship to conduct multibeam seabed mapping of the Northern Tier of Georges Bank from the Hague Line to the western end of the bank. We anticipate that the survey can be done over a 3-year period, assuming one 2-week cruise per year. The region is characterized by sand, gravel, and rock substrates that support very different communities of invertebrates and fishes and include high value Essential Fish Habitat for cod, haddock, yellowtail flounder, winter flounder and sea scallops. The entire Canadian part of the Bank has been surveyed with multibeam sonar, and a series of interpretive seabed maps will be released in January, 2013. Information on habitat distribution on the U.S. side is based on limited coverage by video and photo imagery and sediment analyses. While helpful, this data lacks a unifying high-resolution mapping framework, coverage is spotty, and interpretation of habitat types is discontinuous and sometimes conflicting. There is a need for multibeam seabed imagery that can be integrated with existing video/photo, hydrographic, and sediment data to serve as a basis for accurate mapping of Northern Tier habitats with the goal of contributing to improving fishery stock assessment, habitat suitability modeling, and management. Lacking multibeam sonar, NOAA ship ***Gordon Gunter***, currently assigned for NEFSC Habitat Mapping and Benthic Habitat cruises, is unsuitable. The proposed survey will be conducted in water depths of approximately 50 to 100 m except for the crests of sand ridges (as shallow as 10 m), possibly too shallow to survey. NOAA ships that are appropriately outfitted with multibeam mapping systems are listed below in order of decreasing seabed mapping capability for our needs:

Ferdinand Hassler:	Dual Reson 7125; 200/400 kHz; to 75 m water depth
draft 3.8 m	Reson 7111; 100 kHz; to 600 m
***Thomas Jefferson*:**	Reson 8101; 240 kHz; to ~100 m
draft 4.3 m	Reson 8125; 455 kHz; to 120 m
	Simrad EM 1002; 98 kHz; to 1000 m
***Nancy Foster*:**	Reson 7125; 200/400 kHz; to 75 m
draft 3.9 m	Simrad EM1002; 95 kHz; to 1000 m

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SHIP TIME REQUEST

Submit completed form electronically to: Shiprequest.MAOC@noaa.gov

1. REQUESTED FISCAL YEAR 2013	2. ORIGINATING OFFICE NMFS	3. DATE OF REQUEST 09/15/2011	4. RECAP ACTIVITY Habitat mapping and c

5. PROJECT NAME Benthic Habitat

6. PROJECT PURPOSE (Provide a brief description.)

Acoustic mapping, biological sampling and advanced technology (underwater vehicle ops) for ground truthing of acoustic habitat mapping operations, with emphasis on characterization of essential fish habitat for groundfish, lobsters, and sea scallops on Georges Bank

7. OBJECTIVE BASED METRICS (Measurable Accomplishments Planned - list with number required.)

Degree of accomplishment depends on length of cruise (based on previous cruises):
Area of habitat mapped acoustically – 5 sq km /day
No. of photographic transects (AUV and/or ROV) – 5 per day
Number of CTDs taken – 20 per day

8. NOAA LONG-TERM GOALS SUPPORTED BY THE PROJECT/MISSION (Check all goals that apply. Show percentages of each if more than one is checked.)

☐ CAM %	☐ WRN %	☑ HO 100 %	☐ RCCE %	☐ UNKNOWN %

9. NOAA LONG-TERM GOAL OBEJECTIVES SUPPORTED BY THE PROJECT/MISSION

Primary Long-Term Goal Objective: Improved scientific understanding

Secondary Long-Term Goal Objective: Healthy habitats sustain resources, communities

10. FIELD OF SCIENCE CATEGORY		11. NATIONAL SCIENCE FOUNDATION R&D CATEGORY	
1. (2) Applied Research %100	2. %	1. 51 Biological 70 %	2. 32 Geological Science 30 %

12. IMPACT STATEMENT (State how the absence of this data collection will negatively affect NOAA's mission, noting the products and services provided to the general public.)

Attempts to manage fisheries resources with an understanding of the role of habitats and their alteration by direct anthropogenic disturbance, invasive species, or through climate change as part of an ecosystem management scheme for Georges Bank will be severely impaired.

13. PREFERRED VESSEL OPERATOR	(If a NOAA vessel is not preferred, complete only blocks 1-13 and 37-40.)	14. PREFERRED NOAA VESSEL
NOAA vessel		

15. JUSTIFICATION FOR NOAA VESSEL PREFERRENCE

NOAA vessel equipped with bathymetric multibeam sonar is preferred because of the expertise and experience of onboard personnel in performing this task.

16A. FOREIGN PORT CALLS AND RESEARCH CLEARANCES	16B. DOMESTIC LICENSES AND PERMITS
Canadian research clearance (no port calls)	

17A. PROJECT AREA: Georges Bank

17B. PROJECT AREA COORDINATES (Indicate extreme latitudes and longitudes of the project area.)

Northern most latitude	42 °	30.0 '	N	Eastern most longitude	66 °	0.0 '	W
Southern most latitude	40 °	0.0 '	N	Western most longitude	69 °	30.0 '	W

18. OPERATIONAL AREA SEA DAY REQUIREMENT	19A. EARLIEST POSSIBLE START DATE	19B. LATEST POSSIBLE END DATE	20. PROJECT PRIORITY
Maximum 20 Days Minimum 12 Days	07/01/2013	09/30/2013	◉ Primary ◯ Piggyback

21. SUGGESTED PIGGYBACK PROJECTS	22A. STAGING PORT	22B. STAGING DAYS	22C. TRANSIT DAYS FROM
Living Marine Resources Coastal Science Center	Woods Hole, MA	2 Days	1 Days
23. INTERMEDIATE PORT CALLS	**24A. DESTAGING PORT**	**24B. DESTAGING DAYS**	**24C. TRANSIT DAYS TO**
None	Woods Hole, MA	1 Days	1 Days

25A. SCIENTIFIC BERTHS REQUIRED	25B. NUMBER	26A. FOREIGN NATIONAL PARTICIPANTS	26B. COUNTRY OF ORIGIN OF EACH FOREIGN NATIONAL
◉ YES ◯ NO	10	◉ YES ◯ NO	Canada

27. SHIP FURNISHED CAPABILITIES (Indicate project requirements of each category listed below.)

27A. ELECTRONICS	27B. OCEANOGRAPHIC EQUIPMENT	27C. SPECIALIZED GEAR HANDLING SUPPORT
Multibeam bathymetric sonar, single beam sonar, ADCP	CTD	Installation of dedicated winch for USGS SeaBoss camera vehicle and use of A-frame for launch and recovery.

28. DECK DEPARTMENT AVAILABILITY	29. SURVEY DEPARTMENT AVAILABILITY	30. ON-STATION OPERATING HOURS
A.) 24 hrs per day	B.) Less than 12 hours per set schedule	A. Static Operations 8 HOURS
		B. Trawling Operations 8 HOURS
		C. Towing Operations 0 HOURS
		D. Survey Operations 8 HOURS
		E. Anchorage Operations 0 HOURS

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31. OTHER SHIP CAPABILITY REQUIREMENTS				32. WORK BOAT AND LAUNCH CAPABILITY REQUIREMENTS			
Transit Speed (kts)	10	Wet Lab Space (ft^2)	200	Number	0	Speed (kts)	0
Survey Speed (kts)	8	Dry Lab Space (ft^2)	150	Purpose	n/a	Draft (ft)	0
Endurance (days)	20	Position Accuracy (meters)	10	OP hours / day	0	Equipment	n/a
Dynamic Positioning	Non-classed	Fisheries Calibrated to:		Passengers (each)	0	Gear Weight (lbs)	0

33A. PROVIDE REMOTELY OPERATED VEHICLE (ROV) REQUIREMENTS

See 34 below.

33B. PROVIDE AUTONOMOUS UNMANNED VEHICLE (AUV) REQUIREMENTS

n/a

33C. PROVIDE UNMANNED AIRCRAFT SYSTEM (UAS) REQUIREMENTS

n/a

33D. PROVIDE MANNED SUBMERSIBLE REQUIREMENTS

n/a

34. PROJECT FURNISHED EQUIPMENT (Provide pertinent information on project furnished equipment such as box containers, large moorings, or electronics, in the table below.)

EQUIPMENT DESCRIPTION	WEIGHT (lbs.)	POWER REQUIRED (V / A)	SPACE REQUIRED (FT^2)	LOCATION PREFERENCE
USGS SeaBoss remote drop camera system	300	120 VAC 30A	16 sq ft	near A-frame
USGS SeaBoss dedicated winch	4000	230 or 460 VAC 3ph 30A	35 sq ft	near A-frame
U Maryland towed camera system (alternative)	200	120 VAC 30A	50 sq ft	fantail deck
Single wire Naturalist Dredge or Beam Trawl	150	none	16 sq ft	fantail deck

35. ALTERNATIVE PLATFORMS

If a NOAA ship is unavailable or not economical, would a charter vessel meet project requirements? (●) YES ( ) NO

36. FUNDING SOURCE (Check all that apply.)

☑ NOAA MARINE OPERATIONS & MAINTENANCE ☑ NOAA PROGRAM FUNDING ☑ Non-NOAA FUND ☐ UNKNOWN

37. ADDITIONAL INFORMATION

38. LAB DIRECTOR APPROVAL (●) YES ( ) NO

39. PRINCIPAL INVESTIGATOR / CHIEF SCIENTIST		40. SENIOR NOAA EXECUTIVE WITH AUTHORITY TO APPROVE SHIP TIME REQUESTS	
NAME	Vincent G. Guida	NAME	Dr. Ned Cyr (or designee)
LABORATORY/OFFICE	NOAA, NMFS, NEFSC, J.J. Howard Laboratory	TITLE	Director, NMFS Office of Science & Technology
ADDRESS	74 Magruder Road	ADDRESS	1315 East West Highway
	Highlands, NJ 07732		Silver Spring, MD 20814
PHONE NUMBER	(732) 872-3042	PHONE NUMBER	(301) 427-8174
FAX NUMBER	(732) 872-3088	FAX NUMBER	(301) 713-1875
E-MAIL ADDRESS	vincent.guida@noaa.gov	E-MAIL ADDRESS	c/o allen.shimada@noaa.gov

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41. LEGISLATIVE MANDATES, EXECUTIVE ORDERS and INTERNATIONAL TREATIES

41A. Identify the Legislative Mandate (LM), Legislative Authorization (LA), Executive Order (EO), International Treaty (IT) or International Agreement (IA) met by the project. Indicate the actual reference(s) within the law, order, treaty or agreement that applies to the data collected.	List all that apply: Research in support of fisheries management: EFH identification	Reference(s) Sustainable Fisheries Act of 1996 (Public Law 104-297) 16 USC 1881c Section 404c (1) & Fisheries Conservation and

41B. How does the primary objective of this project directly support the LM, LA, EO, IT, or IA? (maximum 300 characters)

Data will define distributions of FMP species whose habitat interactions are only partly known (e.g.cod, haddock, sea scallop, American lobster) as related to habitat characteristics, disturbance and the invasive tunicate Didemnum vexillum now dominating portions of the Bank.

41C. Why is a NOAA ship the most efficient and effective platform that can acquire the required data to meet the Congressional legislation?

NOAA ships are staffed by personnel familiar with multibeam sonar mapping; this may not be true of other vessels. At present, our team has only limited experience with the shipboard operation of these systems and would benefit from expertise among the ship's crew.

41D. What are the risks incurred (e.g., law suits, voidance of existing treaties or impaired response to proposed treaties, effects on international partnerships, impacts to NOAA's leadership role, etc.) by not meeting the LM, LA, EO, IT or IA if this project is not completed? (maximum 300 characters)

1. Attempts to manage fisheries resource habitats as part of an ecosystem management scheme will be severely impaired, thus endangering the sustainability of fisheries, and
2. Failure to manage Georges Bank fisheries well may invite Environmental NGOs to bring suit.

42. IMPACT TO SOCIETY

42A. What NOAA product and/or service will be affected, if the requested sea days are not allocated? (Provide a specific name and a short description of the product and/or service affected.)

1. Habitat advice for the New England Fisheries Management Council - This council depend upon NEFSC to provide advice for management of fisheries activities in NE U.S. waters. Increasingly, advice on habitat/ecosystem issues has been requested.
2. Habitat advice for the NOAA Regional Office - NERO environmental review for offshore development depends upon knowledge of how marine resources utilize habitats.

42B. If data for this project isn't collected during the fiscal year indicated in block 1, will the NOAA product and/or service indicated in question 42A: (Choose one.)	2) Become extremely degraded

42C. What are the specific impacts to the product or service, and to the users of this product or service, by not conducting this project?

1. Habitat information, which is becoming increasingly sought for purposes of area management as an adjunct to traditional stock management. Failure to conduct this cruise will degrading the FMCs' abilities to manage FMP species in the face of advancing climate change and spreading invasion by the invasive Asian colonial tunicate, Didemnum vexillum.
2. Again, the distribution and utilization of habitats region is only partially known and without this cruise, that knowledge and future decisions that will need to be based upon the products of this cruise are hampered or degraded.

42D. Does this project provide data that has a direct and timely link to a NOAA product or service that will help prevent risks to lives, economy or the environment? ○ YES ◉ NO

42E. If 42D was "Yes", how does the data collection support the stated products/services in block 42A? Provide a description of the source documentation (provide web links if available), and other supporting documents, that best state how the data has a direct and timely link to a NOAA product or service that helps prevent risks to lives, the economy or the environment.

This use of habitat data is a relatively new issue and we expect to develop a formal relationship with the NEFMC Plan Development Team (PDT) this year.

42F. If 42D was "Yes", identify the following quantitative factors that will likely result from loss of project data. (These factors must be the conclusions found in the source documentation or other supporting documents described in question 42E.)

i. Risk to human lives will likely result in:	ii. Risk to our nation's economy will likely result in the loss of:	iii. Risk to the environment will likely result in:
Choose One	Choose one	Choose one

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43. VESSEL CAPABILITY

43A. Which capabilities, unique to NOAA vessels, are absolutely required to successfully accomplish the project's primary objectives? (Select all that apply.)

- ☐ 1. Clam system
- ☐ 2. Acoustic quieting
- ☐ 3. Doppler Radar
- ☐ 4. Dedicated salinity chamber
- ☐ 5. Nitrox system
- ☐ 6. Hyperbaric chamber
- ☐ 7. Multiple survey launches

43B. If 43A indicates only one unique vessel capability, does it also need other physical capabilities that are not unique to a NOAA vessel, but provide a combination that is unique, and required to successfully accomplish the project's primary objectives? If so, identify the unique combination.

n/a

43C. How does the required unique physical capability or the combinations of physical capabilities meet the project's primary objectives or performance outcomes?

n/a

43D. Indicate any unique NOAA personnel requirements. Justify how those needed skills are required to meet the primary project objectives or performance outcomes.

NOAA ships are staffed by personnel familiar with multibeam sonar mapping; this may not be true of other vessels. At present, our team has only limited experience with the shipboard operation of these systems and would benefit from expertise among the ship's crew.

43E. Briefly describe the impacts to the project objectives or the costs to the program that would be incurred by chartering, if sea days are not allocated aboard a NOAA vessel.

The cost just to follow the cruise track in a vessel capable of an extended cruise and perform some limited amount of the work planned is simply out of the range of possibility for our habitat program; there would be no cruise, no data collected, no advice to NERO or the FMCs on deepwater issues.

44. LONG TERM DATA SERIES

44A. Is this project a long term time series according to the definition found in the instructions? ◉ YES ○ NO

44B. If 44A is "Yes", how many years has the long term data series been conducted? 14 Years

44C. What is the frequency of the data collection? (quarterly, semiannual, annual, biennial, triennial, etc.) annual

44D. What are the specific impacts to the continuity of the data, if the project is not completed during the year indicated in block 1?

The data currently being collected is not time-depedent, strictly speaking; its integrity does not depend on periodic continuity. However, maintaining the interest of essential non-NOAA (USGS) collaborators does depend upon year-to-year continuity. A break in funding may thus result in a loss of some capabilities.

44E. If 44A is "No", and the project length is 1 to 3 years, provide justification that shows the potential for becoming a long term data series of environmental or physical trends.

45. PROMOTE "One NOAA" PROJECTS

45A. Is the project a result of a formal collaboration between Line Offices promoting a single multi-purpose mission that was originally two or more separate projects under individual Principal Investigators? ○ YES ◉ NO

45B. If 45A is "Yes", provide the collaborating LOs and Principal Investigators for this project.

45C. Will this formal collaboration allow collaborators to meet their current data requirements while reducing the number of sea days historically requested? ○ YES ○ NO

45D. If 45C is "Yes", provide the best estimate of number of sea days reduced and describe how the reduction was accomplished. Number of Sea Days: Days

45E. If the project has no formal collaboration that promotes multi-purpose missions, but has a formal data sharing agreement that allows other NOAA entities to access the project data, please identify those entities (e.g., NGDC) where data can be acquired.

Although there is no formal collaboration with another LO, acoustic mapping data will be submitted to NGDC, so there is a "One NOAA" aspect to this project.

SHIP TIME REQUEST

Block 1: Requested Fiscal Year - Indicate the Fiscal Year in which this requested project will occur.

Block 2: Originating Office - Identify appropriate Line Office within NOAA.

Block 3: Date of Request - Indicate the date that the form is filled out.

Block 4: ReCap Activity - Select the Fleet Recapitalization Plan Activity that best describes the project. Further descriptions of all the current ReCap Activities can be found at: http://www.omao.noaa.gov/publications/08_ship_recap_plan.pdf Chapter 5 pp. 21-45.

Block 5: Project Name - Provide a project title/name that best identifies the scientific mission.

Block 6: Project Purpose - Provide a brief description of the project, its purpose, overall mission and expected contribution to a broader program such as a national or international effort.

Block 7: Objective Based Metrics - List the minimum required measureable accomplishments that will achieve the Project Purpose stated in block 6 including the accomplishments and the number of this accomplishment required. (e.g., Square nautical miles hydrographic multibeam data - 500, CTDs - 45, Deep bottom trawl stations - 65).

Block 8: NOAA Long-Term Goals Supported By The Project/Mission - Check the appropriate box(es) and identify the percentages supported if selecting more than one NOAA Long-Term Goal. CAM = Climate Adaptation and Mitigation, WRN = Weather-Ready Nation, HO = Healthy Oceans and RCCE = Resilient Coastal Communities & Economies.

Block 9: NOAA Long-Term Goal Objectives Supported By the Project - Select the primary and secondary objectives within the Line Office Long-Term Goals that are supported by the project. The Long-Term Goal Objectives can be found at: http://www.ppi.noaa.gov/ngsp/goals/

Block 10: Field of Science Category - Select the number and appropriate category from the following list that applies to the project. If using more than one please show percentage of each:

(1) Basic Research - Not applicable to NOAA
(2) Applied Research - Research directed towards gaining knowledge or understanding necessary for determining the means by which a recognized and specific need may be met.
(3) Development Directed - The systematic use of knowledge and understanding gained from research directed toward the production of useful materials, devices, systems, or methods, including design and development of prototypes and processes.
(4) NON R&D - Routine product testing, quality control, mapping and surveys, collection of general-purpose statistics, experimental production, and activities concerned primarily with the dissemination of scientific information and the training of scientific staff.

Block 11: National Science Foundation R&D Category - Select the number and appropriate category from the following list – if using more than one please show percentage of each:

N/A Not applicable - if NSF code is 4- Non R&D

11	Astronomy	42	Astronautical Engineering	61	Biological Psychology
12	Chemistry	43	Chemical Engineering	69	Psychological Science
13	Physics	44	Civil Engineering	71	Anthropology
19	Physical Science	45	Electrical Engineering	72	Economics
21	Mathematics	46	Mechanical Engineering	75	Political Science
22	Computer Science	47	Metallurgy & Material	76	Sociology
29	Math/Computer Science	49	Engineering	79	Social Sciences
31	Atmospheric Science	51	Biological	80	Cryogenics (NIST)
32	Geological Science	54	Environmental Biology	81	Measurement (NIST)
33	Oceanography	55	Agricultural	82	Other Engineering (NIST)
39	Environmental Science	56	Medical	99	Other Science
41	Aeronautical Engineering	59	Life Science		

SHIP TIME REQUEST

Block 12: Impact Statement - Describe the impact to NOAA and the nation if this ship time request is not allocated sea days or not funded.

Block 13: Preferred Vessel Operator - Select one of the following four options: A.) NOAA vessel, B.) Non-NOAA Federal vessel, C.) UNOLS vessel or D.) Non-Federal charter vessel. (If option B, C or D is indicated, skip to block 37).

Block 14: Preferred NOAA Vessel - Indicate the most desirable NOAA vessel as a platform for this particular project.

Block 15: Justification for NOAA Vessel Preference - Provide specific justification as to why the indicated NOAA vessel is most desired for support of this project. If other NOAA vessels could perform the project equally well, list other options.

Block 16: Foreign Port Calls and Research Clearances - Indicate the foreign ports or foreign waters that may be entered that will require foreign clearances through established diplomatic channels.

Block 16B: Domestic Licenses and Permits - Indicate any license or permit that may be required from another federal, state or local agency.

Block 17A: Project Area - Provide a specific location or ocean area of the project area. For example, if project is located in the South Atlantic Bight do not identify that project area as Atlantic Ocean.

Block 17B: Project Area Coordinates - Indicate extreme latitudes and longitudes of the operation area (to the nearest $1/10^{th}$ of a minute).

Block 18: Operational Area Sea Day Requirement - Indicate both the maximum number of days desired and the minimum days in which meaningful work could be accomplished in the project area.

Block 19A: Earliest Possible Start Date - Indicate the earliest possible start date for the accomplishment of this project. Use block 37 to describe any issues affecting this date such as environmental or biological conditions that would affect the success of the project.

Block 19B: Latest Possible End Date - Indicate the latest possible end date for the project.

Block 20: Project Type - Indicate whether this project is the primary focus of the ship or that it is a piggyback-type project with minimum interference to the principle users.

Block 21: Suggested Piggyback Projects - Indicate whether there will be time for piggyback projects or if piggyback projects could be accommodated on a noninterference basis. If there will be time for piggyback projects, indicate how much time will be available.

Block 22A: Staging Port - Indicate the preferred port to be used for staging the vessel prior to departure.

Block 22B: Staging Days - Estimate the number of business days required for staging the vessel before the project begins. A staging day is a full day in port with a significant portion of the ship's complement working a regular 8 hour work day to load, store or calibrate scientific equipment, construct scientific workstations or support the scientific party before departure.

Block 22C: Transit Days From - Indicate the number of days needed to transit from the staging port to the project area.

Block 23: Intermediate Port Calls - Indicate up to three intermediate port calls and the number of days at each location.

Block 24A. Destaging Port - Indicate the preferred port to be used for destaging the vessel after project completion.

Block 24B: Destaging Days - Estimate the number of business days required for destaging the vessel after the project ends. A destaging day is a full day in port with a significant portion of the ship's complement working a regular 8 hour work day to unload scientific equipment or samples, deconstruct scientific work stations or support the scientific party upon project completion.

Block 24C: Transit Days To - Indicate the number of days needed to transit to the destaging port from the project area.

SHIP TIME REQUEST

Block 25A: Scientific Berthing - Indicate whether scientific berthing will be required for this project.

Block 25B: Scientific Berths Required - If scientific berthing is required, indicate the number of berths needed for the scientific complement including NOAA program personnel and/or Non-NOAA personnel (i.e., scientists, technicians).

Block 26A: Foreign National Participants - Indicate whether Foreign Nationals are expected to participate in this project.

Block 26B: Foreign National Country of Origin - If applicable, indicate the country or countries these Foreign Nationals are representing.

Block 27: Ship Furnished Capabilities - Indicate special project requirements for Electronics, Oceanographic Equipment and Specialized Gear Handling Support for the project or "NONE".

Block 28: Deck Department Availability - Select the hours per day the Deck Department needs to be available for deck operations: A.) 24 hrs per day, B.) Daylight hours only or C.) Minimally.

Block 29: Survey Department Availability - Select the hours per day the Survey Department needs to be available for survey operations: A.) 24 hrs per day, B.) Less than 12 hours per set schedule or C.) Opportunistically.

Block 30: On-Station Operating Hours - Indicate the hours per day that the project will require the vessel to be conducting:
A. Static operations (to include CTD casts, small boat deployments, buoy servicing, ROV operations and bottom grabs)
B. Trawling operations (to include mid-water trawls, bottom trawls and scallop dredging)
C. Towing operations (to include plankton nets, side scan sonar, acoustic arrays, MOCNESS and other plankton nets)
D. Survey operations (vessel is constantly making way to conduct hydrographic or marine mammal surveys)
E. Anchorage operations (launch deployments or other operations that are conducted while the ship is at anchor)

Block 31: Ship Capability Requirements - In addition to the required electronic, oceanographic and gear handling requirements identified in block 27, specify other capabilities that will be required of the ship to support the project. If there is a requirement that the vessel be calibrated for trawling operations, indicate which vessel it must be calibrated with. Also indicate whether the project requires the ship to have Dynamic Positioning and if so, whether it requires a specific minimum IMO Classification:
Class 1 - Automatic and manual position and heading control under specified maximum environmental conditions.
Class 2 - Automatic and manual position and heading control under specified maximum environmental conditions, during and following any single fault excluding loss of a compartment.
Class 3 - Automatic and manual position and heading control under specified maximum environmental conditions, during and following any single fault including loss of a compartment due to fire or flood.

Block 32: Work Boat Requirements - For work boats and launches, indicate the number of science party passengers required. The ship command will determine the number of required crew. If multiple types of boats are required, explain in block 37.

Block 33A: ROV Requirements - If a Remotely Operated Vehicle (ROV) is required, provide operational details as well as ship support requirements.

Block 33B: AUV Requirements - If an Autonomous Underwater Vehicle (AUV) is required, provide operational details as well as ship support requirements.

Block 33C: UAS Requirements - If an Unmanned Aircraft System (UAS) is required, provide operational details as well as ship support requirements.

Block 33D: Manned Submersible Requirements - If required, provide operational details as well as ship support requirements.

Block 34: Project Furnished Equipment - List major equipment that will be brought aboard by the scientific party such as vans, electronics, moorings, winches, or other equipment that will need to be secured to the ship's deck or hull and provide the necessary specifications.

SHIP TIME REQUEST

Block 35: Alternative Platforms - Indicate whether a charter vessel would be capable of meeting project requirements if a NOAA ship is not available due to schedule conflicts or cost.

Block 36: Funding source (check all that apply) - Indicate by checking the appropriate box(es). NOAA Marine Operations & Maintenance Fund = OMAO base funding; NOAA Program funding = NOAA Line Office funds; Non-NOAA funds = funds from an outside agency.

Block 37: Additional Information - Please list any additional information that would be helpful in describing special circumstances of this project or clarifications to any of the above blocks.

Block 38: Lab Director Approval - Confirm the lab or science center director has approved this ship time request before going to the NOAA Line Office approving authority for signature.

Block 39: Principal Investigator/Chief Scientist (Include lab/office affiliation, complete address, phone, fax, E-mail address) - Provide contact information for ship time request. When the form has been properly submitted, a copy will be forwarded to this email address.

Block 40: Senior NOAA Executive with Authority to Approve Ship Time Requests - Provide contact information for the senior NOAA Executive Accountable for the Goal or designee. This person shall submit the ship time request (if requesting the use of a NOAA vessel) in order for OMAO to accept the request for consideration. Any request not submitted through the appropriate channel will be returned to the Principal Investigator listed in block 39. **If requesting a NOAA vessel, completion of blocks 1-45 is mandatory.**

Block 41: Legislative Mandates, Executive Orders & International Treaties - Activities carried out under NOAA's Strategic Plan are dictated, in large part, by Congressional legislation (i.e., legislative mandates/authorizations). This includes any legislation which defines a clear, on-going role for NOAA. Legislative Mandates or Legislative Authorizations do not include earmarks. Activities carried out under NOAA's Strategic Plan are also dictated by Executive Order, International Treaties and International Agreements.

Block 41A: If the primary driver for the project is a Legislative Mandate (LM) or Legislative Authorization (LA), indicate it as such with the two letter designator after the referenced Act. Review Page 10 to determine whether the primary driver is a Legislative Mandate or Legislative Authorization, or contact NOAA General Counsel.

Block 41B, 41C and 41D: Answer the questions as indicated.

Block 42: Impact to Society - This criterion measures the link between the proposed project and societal benefits such as public health, safety of life, and public welfare. Public welfare is defined in terms of the environment, property, and economic values.

Block 42A, 42B, 42C, 42D and 42E: Answer the questions as indicated.

Block 42F: Select one option for each of the three risk assessments.

i. Risk to human lives will likely result in:
   A.) Death,
   B.) Serious injury or illness or
   C.) Minor injury or illness.

ii. Risk to our nation's economy will likely result in the loss of:
   A.) Billions of dollars,
   B.) Millions of dollars or
   C.) Thousands of dollars .

iii. Risk to the environment will likely result in:
   A.) Lethal damage to large populations of aquatic or terrestrial species or extreme damage to marine or land ecosystems,
   B.) Moderate damage but not lethal or
   C.) Limited damage.

SHIP TIME REQUEST

Block 43: Vessel Capability (Unique to NOAA) - NOAA vessels have unique physical capabilities, or combination of physical capabilities, not available in the academic fleet or other charter services to support your project. Unique physical capabilities of the NOAA Fleet include the following:

1. Clam system (set of winches and clam dredges).
2. Acoustic quieting.
3. Doppler 5cm Weather Radar.
4. Dedicated chamber for conducting precision salinity measurements (+ or – one degree Celsius).
5. Nitrox filling systems.
6. Permanent hyperbaric chamber and dedicated supervisor and Diving Medical Officer.
7. Ship with multiple survey launches (i.e., 4 or more) required to complete project.

Note: NOAA vessels may provide unique skills related to the people aboard the NOAA vessel (though these are not considered physical capabilities).

Block 43A: The list of seven "unique" physical capabilities shown in the above description can only be found on NOAA vessels. Which capabilities are absolutely required to successfully complete the project's primary objectives?

Block 43B, 43C, 43D and 43E: Answer the questions as indicated.

Block 44: Long Term Data Series - Acquisition of data at a set frequency will build on a time series in order to maintain the appropriate continuity and accuracy needed to detect trends in environmental (biological, chemical or physical) changes. For this application indicate;

A.) The project is a long term data series when the project has 10 or more years of periodic data collection,
B.) The project is becoming a long term data series when the project has 4-9 years of periodic data collection or
C.) The project is in the development or research phase when the project has 1-3 years of periodic data collection.

Block 44A: Is this project a long term time series according to the definition in the above description?

Block 44B: If the answer to question 44A is "Yes", how many years has the project been in series? (e.g., 15 years, 2001-2015)

Block 44C: Indicate quarterly, semiannually, annually, biennially, triennially, quadrennially, quinquennially or decadal.

Block 44D and 44E: Answer the questions as indicated.

Block 45: Promote "One NOAA" Projects - Functioning as "One NOAA" enables integration and cooperation between NOAA Line Offices and their associated Long-Term Goals to efficiently maximize days at sea. Cooperation can take the form of NOAA collaboration on a project during a cruise, or two projects sharing the same cruise or sea day. The "One NOAA" concept promotes and encourages multi-mission project development allowing better efficiency of at-sea days by enabling more than one program to benefit from ship time. Promoting "One NOAA" projects on platforms enables data collection for applied research and repeated coverage for temporal and spatial requirements.

Block 45A, 45B, 45C, 45D and 45E: Answer the questions as indicated.

SHIP TIME REQUEST

Legislative Mandates versus Legislative Authorizations

Congress, through the laws it enacts, empowers agencies of the U.S. Government to perform responsibilities and functions in furtherance of important public policies as stated in such laws. These laws, with varying degrees of direction and specificity, authorize and, in some case, direct agencies to perform certain functions. In determining the intent of Congress, it is important to closely study the words of a statute to determine the nature of the authorization(s). The words "shall," "may" or "authorize" are frequently used in statutes to express Congressional intent and provide important insight into the nature of the authorization.

Some laws use the word "shall" when describing agency responsibilities, which is commonly interpreted as directive in nature. That is, the agency is directed by Congress to perform a certain function. Such laws are often viewed as "legislative mandates", leaving the agency little to no discretion as to whether to do the thing so directed by Congress. For example, the Tsunami Warning and Education Act of 2007 states: "The National Weather Service shall maintain or establish a Pacific Tsunami Warning Center in Hawaii and West Coast and Alaska Tsunami Warning Center in Alaska ..." Through the use of the word "shall" in this law Congress has clearly indicated that is mandating the NWS to establish these Centers. The Congress has provided the agency no discretion as to whether or not to establish such Centers. In fact, Congress has gone so far as to require that they be located in Hawaii and Alaska.

Other laws use words such as "may" or "authorize," which are commonly interpreted as discretionary in nature. These laws empower an agency to perform a certain function but do not require it, leaving it to the discretion of the agency as to whether to act on the authority so provided. The decision as to whether to act to exercise the authority can be influenced by such matters as available budget and other resources and competing agency priorities. For example, 33 U.S.C. § 883d states: "The Secretary of Commerce is authorized to conduct developmental work for the improvement of surveying and cartographic methods...", through the use of the word "authorize" Congress has made clear that it is providing authority to carry out the specified functions but is not directing that such authority be exercised. Another example is the Methane Hydrate and Development Act of 2000 which provides that the Secretary of Commerce "may" award grants, contracts or cooperative agreements to conduct basic research into methane hydrates. Again, Congress has provided the authority to make awards but is not directing that it be exercised.

When interpreting laws that make use of the terms "shall" versus "may" or "authorize", it is important to avoid an overly simplistic approach. It is not safe to assume that just because a law uses the word "shall" the agency has no discretion in carrying out the law. There are laws that mandate a certain function but also provide significant discretion to the agency in determining how to satisfy the mandate. In particular, agency discretion will often exist as to timing, resources and processes.

For example, The National Weather Service Organic Act states: "The Secretary of Commerce shall have charge of the forecasting of the weather, the issue of storm warnings ... and the taking of such meteorological observations as may be necessary to establish and record the climatic conditions of the United States ..." This law makes clear that the Secretary of Commerce is responsible for issuing weather forecasts and warnings and recording the climate of the United States. In this sense, the law provides a mandate. However, the law provides no direction as to how the Secretary is to carry out these duties. Instead, Congress, through its lack of direction, has provided the discretion to the Secretary to determine how best to satisfy this mandate. Similarly, with respect to the Tsunami Warning and Education Act of 2007, discussed above, Congress has mandated establishment of Centers in Hawaii and Alaska, but the Secretary retains significant discretion to determine how those Centers will be organized.

As the above examples make clear, the extent of Congressional direction depends upon the specific wording of the law. NOAA General Counsel should be contacted for additional guidance if the discretion afforded to the agency or the intent of Congress cannot be discerned.

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U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

SHIP TIME REQUEST

Submit completed form electronically to: Shiprequest.MAOC@noaa.gov

1. REQUESTED FISCAL YEAR 2014	2. ORIGINATING OFFICE NMFS	3. DATE OF REQUEST 09/15/2011	4. RECAP ACTIVITY Habitat mapping and c

5. PROJECT NAME Benthic Habitat

6. PROJECT PURPOSE (Provide a brief description.)
Acoustic mapping, biological sampling and advanced technology (underwater vehicle ops) for ground truthing of acoustic habitat mapping operations, with emphasis on characterization of essential fish habitat for groundfish, lobsters, and sea scallops on Georges Bank

7. OBJECTIVE BASED METRICS (Measurable Accomplishments Planned - list with number required.)
Degree of accomplishment depends on length of cruise (based on previous cruises):
Area of habitat mapped acoustically – 5 sq km /day
No. of photographic transects (AUV and/or ROV) – 5 per day
Number of CTDs taken – 20 per day

8. NOAA LONG-TERM GOALS SUPPORTED BY THE PROJECT/MISSION (Check all goals that apply. Show percentages of each if more than one is checked.)

☐ CAM %	☐ WRN %	☑ HO 100 %	☐ RCCE %	☐ UNKNOWN %

9. NOAA LONG-TERM GOAL OBEJECTIVES SUPPORTED BY THE PROJECT/MISSION
Primary Long-Term Goal Objective: Improved scientific understanding
Secondary Long-Term Goal Objective: Healthy habitats sustain resources, communities

10. FIELD OF SCIENCE CATEGORY		11. NATIONAL SCIENCE FOUNDATION R&D CATEGORY	
1. (2) Applied Research %100	2. %	1. 51 Biological 70 %	2. 32 Geological Science 30 %

12. IMPACT STATEMENT (State how the absence of this data collection will negatively affect NOAA's mission, noting the products and services provided to the general public.)
Attempts to manage fisheries resources with an understanding of the role of habitats and their alteration by direct anthropogenic disturbance, invasive species, or through climate change as part of an ecosystem management scheme for Georges Bank will be severely impaired.

13. PREFERRED VESSEL OPERATOR	(If a NOAA vessel is not preferred, complete only blocks 1-13 and 37-40.)	14. PREFERRED NOAA VESSEL
NOAA vessel		

15. JUSTIFICATION FOR NOAA VESSEL PREFERRENCE
NOAA vessel equipped with bathymetric multibeam sonar is preferred because of the expertise and experience of onboard personnel in performing this task.

16A. FOREIGN PORT CALLS AND RESEARCH CLEARANCES	16B. DOMESTIC LICENSES AND PERMITS
Canadian research clearance (no port calls)	

17A. PROJECT AREA: Georges Bank

17B. PROJECT AREA COORDINATES (Indicate extreme latitudes and longitudes of the project area.)

Northern most latitude	42 ° 30.0 ' N	Eastern most longitude	66 ° 0.0 ' W
Southern most latitude	40 ° 0.0 ' N	Western most longitude	69 ° 30.0 ' W

18. OPERATIONAL AREA SEA DAY REQUIREMENT	19A. EARLIEST POSSIBLE START DATE	19B. LATEST POSSIBLE END DATE	20. PROJECT PRIORITY
Maximum 20 Days Minimum 12 Days	07/01/2014	09/30/2014	◉ Primary ○ Piggyback

21. SUGGESTED PIGGYBACK PROJECTS	22A. STAGING PORT	22B. STAGING DAYS	22C. TRANSIT DAYS FROM
Living Marine Resources Coastal Science Center	Woods Hole, MA	2 Days	1 Days

23. INTERMEDIATE PORT CALLS	24A. DESTAGING PORT	24B. DESTAGING DAYS	24C. TRANSIT DAYS TO
None	Woods Hole, MA	1 Days	1 Days

25A. SCIENTIFIC BERTHS REQUIRED	25B. NUMBER	26A. FOREIGN NATIONAL PARTICIPANTS	26B. COUNTRY OF ORIGIN OF EACH FOREIGN NATIONAL
◉ YES ○ NO	10	◉ YES ○ NO	Canada

27. SHIP FURNISHED CAPABILITIES (Indicate project requirements of each category listed below.)

27A. ELECTRONICS	27B. OCEANOGRAPHIC EQUIPMENT	27C. SPECIALIZED GEAR HANDLING SUPPORT
Multibeam bathymetric sonar, single beam sonar, ADCP	CTD	Installation of dedicated winch for USGS SeaBoss camera vehicle and use of A-frame for launch and recovery.

28. DECK DEPARTMENT AVAILABILITY	29. SURVEY DEPARTMENT AVAILABILITY	30. ON-STATION OPERATING HOURS
A.) 24 hrs per day	B.) Less than 12 hours per set schedule	A. Static Operations 8 HOURS
		B. Trawling Operations 8 HOURS
		C. Towing Operations 0 HOURS
		D. Survey Operations 8 HOURS
		E. Anchorage Operations 0 HOURS

SUPERSEDES NOAA Form 77-65 (5-04)

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SHIP TIME REQUEST

31. OTHER SHIP CAPABILITY REQUIREMENTS				32. WORK BOAT AND LAUNCH CAPABILITY REQUIREMENTS			
Transit Speed (kts)	10	Wet Lab Space (ft^2)	200	Number	0	Speed (kts)	0
Survey Speed (kts)	8	Dry Lab Space (ft^2)	150	Purpose	n/a	Draft (ft)	0
Endurance (days)	20	Position Accuracy (meters)	10	OP hours / day	0	Equipment	n/a
Dynamic Positioning	Non-classed	Fisheries Calibrated to:		Passengers (each)	0	Gear Weight (lbs)	0

33A. PROVIDE REMOTELY OPERATED VEHICLE (ROV) REQUIREMENTS

See 34 below.

33B. PROVIDE AUTONOMOUS UNMANNED VEHICLE (AUV) REQUIREMENTS

n/a

33C. PROVIDE UNMANNED AIRCRAFT SYSTEM (UAS) REQUIREMENTS

n/a

33D. PROVIDE MANNED SUBMERSIBLE REQUIREMENTS

n/a

34. PROJECT FURNISHED EQUIPMENT (Provide pertinent information on project furnished equipment such as box containers, large moorings, or electronics, in the table below.)

EQUIPMENT DESCRIPTION	WEIGHT (lbs.)	POWER REQUIRED (V / A)	SPACE REQUIRED (FT^2)	LOCATION PREFERENCE
USGS SeaBoss remote drop camera system	300	120 VAC 30A	16 sq ft	near A-frame
USGS SeaBoss dedicated winch	4000	230 or 460 VAC 3ph 30A	35 sq ft	near A-frame
U Maryland towed camera system (alternative)	200	120 VAC 30A	30 sq ft	fantail deck
Single wire Naturalist Dredge or Beam Trawl	150	none	16 sq ft	fantail deck

35. ALTERNATIVE PLATFORMS

If a NOAA ship is unavailable or not economical, would a charter vessel meet project requirements? (•) YES ( ) NO

36. FUNDING SOURCE (Check all that apply.)

☑ NOAA MARINE OPERATIONS & MAINTENANCE ☑ NOAA PROGRAM FUNDING ☑ Non-NOAA FUND ☐ UNKNOWN

37. ADDITIONAL INFORMATION

38. LAB DIRECTOR APPROVAL (•) YES ( ) NO

39. PRINCIPAL INVESTIGATOR / CHIEF SCIENTIST		40. SENIOR NOAA EXECUTIVE WITH AUTHORITY TO APPROVE SHIP TIME REQUESTS	
NAME	Vincent G. Guida	NAME	Dr. Ned Cyr (or designee)
LABORATORY/OFFICE	NOAA, NMFS, NEFSC, J.J. Howard Laboratory	TITLE	Director, NMFS Office of Science & Technology
ADDRESS	74 Magruder Road	ADDRESS	1315 East West Highway
	Highlands, NJ 07732		Silver Spring, MD 20814
PHONE NUMBER	(732) 872-3042	PHONE NUMBER	(301) 427-8174
FAX NUMBER	(732) 872-3088	FAX NUMBER	(301) 713-1875
E-MAIL ADDRESS	vincent.guida@noaa.gov	E-MAIL ADDRESS	c/o allen.shimada@noaa.gov

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SHIP TIME REQUEST

41. LEGISLATIVE MANDATES, EXECUTIVE ORDERS and INTERNATIONAL TREATIES

41A. Identify the Legislative Mandate (LM), Legislative Authorization (LA), Executive Order (EO), International Treaty (IT) or International Agreement (IA) met by the project. Indicate the actual reference(s) within the law, order, treaty or agreement that applies to the data collected.	List all that apply:	Reference(s)
	Research in support of fisheries management: EFH identification	Sustainable Fisheries Act of 1996 (Public Law 104-297) 16 USC 1881c Section 404c (1) & Fisheries Conservation and

41B. How does the primary objective of this project directly support the LM, LA, EO, IT, or IA? (maximum 300 characters)

Data will define distributions of FMP species whose habitat interactions are only partly known (e.g.cod, haddock, sea scallop, American lobster) as related to habitat characteristics, disturbance and the invasive tunicate Didemnum vexillum now dominating portions of the Bank.

41C. Why is a NOAA ship the most efficient and effective platform that can acquire the required data to meet the Congressional legislation?

NOAA ships are staffed by personnel familiar with multibeam sonar mapping; this may not be true of other vessels. At present, our team has only limited experience with the shipboard operation of these systems and would benefit from expertise among the ship's crew.

41D. What are the risks incurred (e.g., law suits, voidance of existing treaties or impaired response to proposed treaties, effects on international partnerships, impacts to NOAA's leadership role, etc.) by not meeting the LM, LA, EO, IT or IA if this project is not completed? (maximum 300 characters)

1. Attempts to manage fisheries resource habitats as part of an ecosystem management scheme will be severely impaired, thus endangering the sustainability of fisheries, and
2. Failure to manage Georges Bank fisheries well may invite Environmental NGOs to bring suit.

42. IMPACT TO SOCIETY

42A. What NOAA product and/or service will be affected, if the requested sea days are not allocated? (Provide a specific name and a short description of the product and/or service affected.)

1. Habitat advice for the New England Fisheries Management Council - This council depend upon NEFSC to provide advice for management of fisheries activities in NE U.S. waters. Increasingly, advice on habitat/ecosystem issues has been requested.
2. Habitat advice for the NOAA Regional Office - NERO environmental review for offshore development depends upon knowledge of how marine resources utilize habitats.

42B. If data for this project isn't collected during the fiscal year indicated in block 1, will the NOAA product and/or service indicated in question 42A: (Choose one.) — 2) Become extremely degraded

42C. What are the specific impacts to the product or service, and to the users of this product or service, by not conducting this project?

1. Habitat information, which is becoming increasingly sought for purposes of area management as an adjunct to traditional stock management. Failure to conduct this cruise will degrading the FMCs' abilities to manage FMP species in the face of advancing climate change and spreading invasion by the invasive Asian colonial tunicate, Didemnum vexillum.
2. Again, the distribution and utilization of habitats region is only partially known and without this cruise, that knowledge and future decisions that will need to be based upon the products of this cruise are hampered or degraded.

42D. Does this project provide data that has a direct and timely link to a NOAA product or service that will help prevent risks to lives, economy or the environment? ○ YES ◉ NO

42E. If 42D was "Yes", how does the data collection support the stated products/services in block 42A? Provide a description of the source documentation (provide web links if available), and other supporting documents, that best state how the data has a direct and timely link to a NOAA product or service that helps prevent risks to lives, the economy or the environment.

This use of habitat data is a relatively new issue and we expect to develop a formal relationship with the NEFMC Plan Development Team (PDT) this year.

42F. If 42D was "Yes", identify the following quantitative factors that will likely result from loss of project data. (These factors must be the conclusions found in the source documentation or other supporting documents described in question 42E.)

i. Risk to human lives will likely result in:	ii. Risk to our nation's economy will likely result in the loss of:	iii. Risk to the environment will likely result in:
Choose One	Choose one	Choose one

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SHIP TIME REQUEST

43. VESSEL CAPABILITY

43A. Which capabilities, unique to NOAA vessels, are absolutely required to successfully accomplish the project's primary objectives? (Select all that apply.)

- ☐ 1. Clam system
- ☐ 2. Acoustic quieting
- ☐ 3. Doppler Radar
- ☐ 4. Dedicated salinity chamber
- ☐ 5. Nitrox system
- ☐ 6. Hyperbaric chamber
- ☐ 7. Multiple survey launches

43B. If 43A indicates only one unique vessel capability, does it also need other physical capabilities that are not unique to a NOAA vessel, but provide a combination that is unique, and required to successfully accomplish the project's primary objectives? If so, identify the unique combination.

n/a

43C. How does the required unique physical capability or the combinations of physical capabilities meet the project's primary objectives or performance outcomes?

n/a

43D. Indicate any unique NOAA personnel requirements. Justify how those needed skills are required to meet the primary project objectives or performance outcomes.

NOAA ships are staffed by personnel familiar with multibeam sonar mapping; this may not be true of other vessels. At present, our team has only limited experience with the shipboard operation of these systems and would benefit from expertise among the ship's crew.

43E. Briefly describe the impacts to the project objectives or the costs to the program that would be incurred by chartering, if sea days are not allocated aboard a NOAA vessel.

The cost just to follow the cruise track in a vessel capable of an extended cruise and perform some limited amount of the work planned is simply out of the range of possibility for our habitat program; there would be no cruise, no data collected, no advice to NERO or the FMCs on deepwater issues.

44. LONG TERM DATA SERIES

44A. Is this project a long term time series according to the definition found in the instructions? ◉ YES ○ NO

44B. If 44A is "Yes", how many years has the long term data series been conducted? 14 Years

44C. What is the frequency of the data collection? (quarterly, semiannual, annual, biennial, triennial, etc.) annual

44D. What are the specific impacts to the continuity of the data, if the project is not completed during the year indicated in block 1?

The data currently being collected is not time-depedent, strictly speaking; its integrity does not depend on periodic continuity. However, maintaining the interest of essential non-NOAA (USGS) collaborators does depend upon year-to-year continuity. A break in funding may thus result in a loss of some capabilities.

44E. If 44A is "No", and the project length is 1 to 3 years, provide justification that shows the potential for becoming a long term data series of environmental or physical trends.

45. PROMOTE "One NOAA" PROJECTS

45A. Is the project a result of a formal collaboration between Line Offices promoting a single multi-purpose mission that was originally two or more separate projects under individual Principal Investigators? ○ YES ◉ NO

45B. If 45A is "Yes", provide the collaborating LOs and Principal Investigators for this project.

45C. Will this formal collaboration allow collaborators to meet their current data requirements while reducing the number of sea days historically requested? ○ YES ○ NO

45D. If 45C is "Yes", provide the best estimate of number of sea days reduced and describe how the reduction was accomplished.

Number of Sea Days

Days

45E. If the project has no formal collaboration that promotes multi-purpose missions, but has a formal data sharing agreement that allows other NOAA entities to access the project data, please identify those entities (e.g., NGDC) where data can be acquired.

Although there is no formal collaboration with another LO, acoustic mapping data will be submitted to NGDC, so there is a "One NOAA" aspect to this project.

SHIP TIME REQUEST

Block 1: Requested Fiscal Year - Indicate the Fiscal Year in which this requested project will occur.

Block 2: Originating Office - Identify appropriate Line Office within NOAA.

Block 3: Date of Request - Indicate the date that the form is filled out.

Block 4: ReCap Activity - Select the Fleet Recapitalization Plan Activity that best describes the project. Further descriptions of all the current ReCap Activities can be found at: http://www.omao.noaa.gov/publications/08_ship_recap_plan.pdf Chapter 5 pp. 21-45.

Block 5: Project Name - Provide a project title/name that best identifies the scientific mission.

Block 6: Project Purpose - Provide a brief description of the project, its purpose, overall mission and expected contribution to a broader program such as a national or international effort.

Block 7: Objective Based Metrics - List the minimum required measureable accomplishments that will achieve the Project Purpose stated in block 6 including the accomplishments and the number of this accomplishment required. (e.g., Square nautical miles hydrographic multibeam data - 500, CTDs - 45, Deep bottom trawl stations - 65).

Block 8: NOAA Long-Term Goals Supported By The Project/Mission - Check the appropriate box(es) and identify the percentages supported if selecting more than one NOAA Long-Term Goal. CAM = Climate Adaptation and Mitigation, WRN = Weather-Ready Nation, HO = Healthy Oceans and RCCE = Resilient Coastal Communities & Economies.

Block 9: NOAA Long-Term Goal Objectives Supported By the Project - Select the primary and secondary objectives within the Line Office Long-Term Goals that are supported by the project. The Long-Term Goal Objectives can be found at: http://www.ppi.noaa.gov/ngsp/goals/

Block 10: Field of Science Category - Select the number and appropriate category from the following list that applies to the project. If using more than one please show percentage of each:

(1) Basic Research - Not applicable to NOAA
(2) Applied Research - Research directed towards gaining knowledge or understanding necessary for determining the means by which a recognized and specific need may be met.
(3) Development Directed - The systematic use of knowledge and understanding gained from research directed toward the production of useful materials, devices, systems, or methods, including design and development of prototypes and processes.
(4) NON R&D - Routine product testing, quality control, mapping and surveys, collection of general-purpose statistics, experimental production, and activities concerned primarily with the dissemination of scientific information and the training of scientific staff.

Block 11: National Science Foundation R&D Category - Select the number and appropriate category from the following list – if using more than one please show percentage of each:

N/A Not applicable - if NSF code is 4- Non R&D

11 Astronomy
12 Chemistry
13 Physics
19 Physical Science
21 Mathematics
22 Computer Science
29 Math/Computer Science
31 Atmospheric Science
32 Geological Science
33 Oceanography
39 Environmental Science
41 Aeronautical Engineering
42 Astronautical Engineering
43 Chemical Engineering
44 Civil Engineering
45 Electrical Engineering
46 Mechanical Engineering
47 Metallurgy & Material
49 Engineering
51 Biological
54 Environmental Biology
55 Agricultural
56 Medical
59 Life Science
61 Biological Psychology
69 Psychological Science
71 Anthropology
72 Economics
75 Political Science
76 Sociology
79 Social Sciences
80 Cryogenics (NIST)
81 Measurement (NIST)
82 Other Engineering (NIST)
99 Other Science

SHIP TIME REQUEST

Block 12: Impact Statement - Describe the impact to NOAA and the nation if this ship time request is not allocated sea days or not funded.

Block 13: Preferred Vessel Operator - Select one of the following four options: A.) NOAA vessel, B.) Non-NOAA Federal vessel, C.) UNOLS vessel or D.) Non-Federal charter vessel. (If option B, C or D is indicated, skip to block 37).

Block 14: Preferred NOAA Vessel - Indicate the most desirable NOAA vessel as a platform for this particular project.

Block 15: Justification for NOAA Vessel Preference - Provide specific justification as to why the indicated NOAA vessel is most desired for support of this project. If other NOAA vessels could perform the project equally well, list other options.

Block 16: Foreign Port Calls and Research Clearances - Indicate the foreign ports or foreign waters that may be entered that will require foreign clearances through established diplomatic channels.

Block 16B: Domestic Licenses and Permits - Indicate any license or permit that may be required from another federal, state or local agency.

Block 17A: Project Area - Provide a specific location or ocean area of the project area. For example, if project is located in the South Atlantic Bight do not identify that project area as Atlantic Ocean.

Block 17B: Project Area Coordinates - Indicate extreme latitudes and longitudes of the operation area (to the nearest $1/10^{th}$ of a minute).

Block 18: Operational Area Sea Day Requirement - Indicate both the maximum number of days desired and the minimum days in which meaningful work could be accomplished in the project area.

Block 19A: Earliest Possible Start Date - Indicate the earliest possible start date for the accomplishment of this project. Use block 37 to describe any issues affecting this date such as environmental or biological conditions that would affect the success of the project.

Block 19B: Latest Possible End Date - Indicate the latest possible end date for the project.

Block 20: Project Type - Indicate whether this project is the primary focus of the ship or that it is a piggyback-type project with minimum interference to the principle users.

Block 21: Suggested Piggyback Projects - Indicate whether there will be time for piggyback projects or if piggyback projects could be accommodated on a noninterference basis. If there will be time for piggyback projects, indicate how much time will be available.

Block 22A: Staging Port - Indicate the preferred port to be used for staging the vessel prior to departure.

Block 22B: Staging Days - Estimate the number of business days required for staging the vessel before the project begins. A staging day is a full day in port with a significant portion of the ship's complement working a regular 8 hour work day to load, store or calibrate scientific equipment, construct scientific workstations or support the scientific party before departure.

Block 22C: Transit Days From - Indicate the number of days needed to transit from the staging port to the project area.

Block 23: Intermediate Port Calls - Indicate up to three intermediate port calls and the number of days at each location.

Block 24A. Destaging Port - Indicate the preferred port to be used for destaging the vessel after project completion.

Block 24B: Destaging Days - Estimate the number of business days required for destaging the vessel after the project ends. A destaging day is a full day in port with a significant portion of the ship's complement working a regular 8 hour work day to unload scientific equipment or samples, deconstruct scientific work stations or support the scientific party upon project completion.

Block 24C: Transit Days To - Indicate the number of days needed to transit to the destaging port from the project area.

SHIP TIME REQUEST

Block 25A: Scientific Berthing - Indicate whether scientific berthing will be required for this project.

Block 25B: Scientific Berths Required - If scientific berthing is required, indicate the number of berths needed for the scientific complement including NOAA program personnel and/or Non-NOAA personnel (i.e., scientists, technicians).

Block 26A: Foreign National Participants - Indicate whether Foreign Nationals are expected to participate in this project.

Block 26B: Foreign National Country of Origin - If applicable, indicate the country or countries these Foreign Nationals are representing.

Block 27: Ship Furnished Capabilities - Indicate special project requirements for Electronics, Oceanographic Equipment and Specialized Gear Handling Support for the project or "NONE".

Block 28: Deck Department Availability - Select the hours per day the Deck Department needs to be available for deck operations:
A.) 24 hrs per day, B.) Daylight hours only or C.) Minimally.

Block 29: Survey Department Availability - Select the hours per day the Survey Department needs to be available for survey operations:
A.) 24 hrs per day, B.) Less than 12 hours per set schedule or C.) Opportunistically.

Block 30: On-Station Operating Hours - Indicate the hours per day that the project will require the vessel to be conducting:
A. Static operations (to include CTD casts, small boat deployments, buoy servicing, ROV operations and bottom grabs)
B. Trawling operations (to include mid-water trawls, bottom trawls and scallop dredging)
C. Towing operations (to include plankton nets, side scan sonar, acoustic arrays, MOCNESS and other plankton nets)
D. Survey operations (vessel is constantly making way to conduct hydrographic or marine mammal surveys)
E. Anchorage operations (launch deployments or other operations that are conducted while the ship is at anchor)

Block 31: Ship Capability Requirements - In addition to the required electronic, oceanographic and gear handling requirements identified in block 27, specify other capabilities that will be required of the ship to support the project. If there is a requirement that the vessel be calibrated for trawling operations, indicate which vessel it must be calibrated with. Also indicate whether the project requires the ship to have Dynamic Positioning and if so, whether it requires a specific minimum IMO Classification:
Class 1 - Automatic and manual position and heading control under specified maximum environmental conditions.
Class 2 - Automatic and manual position and heading control under specified maximum environmental conditions, during and following any single fault excluding loss of a compartment.
Class 3 - Automatic and manual position and heading control under specified maximum environmental conditions, during and following any single fault including loss of a compartment due to fire or flood.

Block 32: Work Boat Requirements - For work boats and launches, indicate the number of science party passengers required. The ship command will determine the number of required crew. If multiple types of boats are required, explain in block 37.

Block 33A: ROV Requirements - If a Remotely Operated Vehicle (ROV) is required, provide operational details as well as ship support requirements.

Block 33B: AUV Requirements - If an Autonomous Underwater Vehicle (AUV) is required, provide operational details as well as ship support requirements.

Block 33C: UAS Requirements - If an Unmanned Aircraft System (UAS) is required, provide operational details as well as ship support requirements.

Block 33D: Manned Submersible Requirements - If required, provide operational details as well as ship support requirements.

Block 34: Project Furnished Equipment - List major equipment that will be brought aboard by the scientific party such as vans, electronics, moorings, winches, or other equipment that will need to be secured to the ship's deck or hull and provide the necessary specifications.

SHIP TIME REQUEST

Block 35: Alternative Platforms - Indicate whether a charter vessel would be capable of meeting project requirements if a NOAA ship is not available due to schedule conflicts or cost.

Block 36: Funding source (check all that apply) - Indicate by checking the appropriate box(es). NOAA Marine Operations & Maintenance Fund = OMAO base funding; NOAA Program funding = NOAA Line Office funds; Non-NOAA funds = funds from an outside agency.

Block 37: Additional Information - Please list any additional information that would be helpful in describing special circumstances of this project or clarifications to any of the above blocks.

Block 38: Lab Director Approval - Confirm the lab or science center director has approved this ship time request before going to the NOAA Line Office approving authority for signature.

Block 39: Principal Investigator/Chief Scientist (Include lab/office affiliation, complete address, phone, fax, E-mail address) - Provide contact information for ship time request. When the form has been properly submitted, a copy will be forwarded to this email address.

Block 40: Senior NOAA Executive with Authority to Approve Ship Time Requests - Provide contact information for the senior NOAA Executive Accountable for the Goal or designee. This person shall submit the ship time request (if requesting the use of a NOAA vessel) in order for OMAO to accept the request for consideration. Any request not submitted through the appropriate channel will be returned to the Principal Investigator listed in block 39. **If requesting a NOAA vessel, completion of blocks 1-45 is mandatory.**

Block 41: Legislative Mandates, Executive Orders & International Treaties - Activities carried out under NOAA's Strategic Plan are dictated, in large part, by Congressional legislation (i.e., legislative mandates/authorizations). This includes any legislation which defines a clear, on-going role for NOAA. Legislative Mandates or Legislative Authorizations do not include earmarks. Activities carried out under NOAA's Strategic Plan are also dictated by Executive Order, International Treaties and International Agreements.

Block 41A: If the primary driver for the project is a Legislative Mandate (LM) or Legislative Authorization (LA), indicate it as such with the two letter designator after the referenced Act. Review Page 10 to determine whether the primary driver is a Legislative Mandate or Legislative Authorization, or contact NOAA General Counsel.

Block 41B, 41C and 41D: Answer the questions as indicated.

Block 42: Impact to Society - This criterion measures the link between the proposed project and societal benefits such as public health, safety of life, and public welfare. Public welfare is defined in terms of the environment, property, and economic values.

Block 42A, 42B, 42C, 42D and 42E: Answer the questions as indicated.

Block 42F: Select one option for each of the three risk assessments.

i. Risk to human lives will likely result in:
   A.) Death,
   B.) Serious injury or illness or
   C.) Minor injury or illness.

ii. Risk to our nation's economy will likely result in the loss of:
   A.) Billions of dollars,
   B.) Millions of dollars or
   C.) Thousands of dollars .

iii. Risk to the environment will likely result in:
   A.) Lethal damage to large populations of aquatic or terrestrial species or extreme damage to marine or land ecosystems,
   B.) Moderate damage but not lethal or
   C.) Limited damage.

SHIP TIME REQUEST

Block 43: Vessel Capability (Unique to NOAA) - NOAA vessels have unique physical capabilities, or combination of physical capabilities, not available in the academic fleet or other charter services to support your project. Unique physical capabilities of the NOAA Fleet include the following:

1. Clam system (set of winches and clam dredges).
2. Acoustic quieting.
3. Doppler 5cm Weather Radar.
4. Dedicated chamber for conducting precision salinity measurements (+ or – one degree Celsius).
5. Nitrox filling systems.
6. Permanent hyperbaric chamber and dedicated supervisor and Diving Medical Officer.
7. Ship with multiple survey launches (i.e., 4 or more) required to complete project.

Note: NOAA vessels may provide unique skills related to the people aboard the NOAA vessel (though these are not considered physical capabilities).

Block 43A: The list of seven "unique" physical capabilities shown in the above description can only be found on NOAA vessels. Which capabilities are absolutely required to successfully complete the project's primary objectives?

Block 43B, 43C, 43D and 43E: Answer the questions as indicated.

Block 44: Long Term Data Series - Acquisition of data at a set frequency will build on a time series in order to maintain the appropriate continuity and accuracy needed to detect trends in environmental (biological, chemical or physical) changes. For this application indicate;

A.) The project is a long term data series when the project has 10 or more years of periodic data collection,
B.) The project is becoming a long term data series when the project has 4-9 years of periodic data collection or
C.) The project is in the development or research phase when the project has 1-3 years of periodic data collection.

Block 44A: Is this project a long term time series according to the definition in the above description?

Block 44B: If the answer to question 44A is "Yes", how many years has the project been in series? (e.g., 15 years, 2001-2015)

Block 44C: Indicate quarterly, semiannually, annually, biennially, triennially, quadrennially, quinquennially or decadal.

Block 44D and 44E: Answer the questions as indicated.

Block 45: Promote "One NOAA" Projects - Functioning as "One NOAA" enables integration and cooperation between NOAA Line Offices and their associated Long-Term Goals to efficiently maximize days at sea. Cooperation can take the form of NOAA collaboration on a project during a cruise, or two projects sharing the same cruise or sea day. The "One NOAA" concept promotes and encourages multi-mission project development allowing better efficiency of at-sea days by enabling more than one program to benefit from ship time. Promoting "One NOAA" projects on platforms enables data collection for applied research and repeated coverage for temporal and spatial requirements.

Block 45A, 45B, 45C, 45D and 45E: Answer the questions as indicated.

SHIP TIME REQUEST

Legislative Mandates versus Legislative Authorizations

Congress, through the laws it enacts, empowers agencies of the U.S. Government to perform responsibilities and functions in furtherance of important public policies as stated in such laws. These laws, with varying degrees of direction and specificity, authorize and, in some case, direct agencies to perform certain functions. In determining the intent of Congress, it is important to closely study the words of a statute to determine the nature of the authorization(s). The words "shall," "may" or "authorize" are frequently used in statutes to express Congressional intent and provide important insight into the nature of the authorization.

Some laws use the word "shall" when describing agency responsibilities, which is commonly interpreted as directive in nature. That is, the agency is directed by Congress to perform a certain function. Such laws are often viewed as "legislative mandates", leaving the agency little to no discretion as to whether to do the thing so directed by Congress. For example, the Tsunami Warning and Education Act of 2007 states: "The National Weather Service shall maintain or establish a Pacific Tsunami Warning Center in Hawaii and West Coast and Alaska Tsunami Warning Center in Alaska ..." Through the use of the word "shall" in this law Congress has clearly indicated that is mandating the NWS to establish these Centers. The Congress has provided the agency no discretion as to whether or not to establish such Centers. In fact, Congress has gone so far as to require that they be located in Hawaii and Alaska.

Other laws use words such as "may" or "authorize," which are commonly interpreted as discretionary in nature. These laws empower an agency to perform a certain function but do not require it, leaving it to the discretion of the agency as to whether to act on the authority so provided. The decision as to whether to act to exercise the authority can be influenced by such matters as available budget and other resources and competing agency priorities. For example, 33 U.S.C. § 883d states: "The Secretary of Commerce is authorized to conduct developmental work for the improvement of surveying and cartographic methods...", through the use of the word "authorize" Congress has made clear that it is providing authority to carry out the specified functions but is not directing that such authority be exercised. Another example is the Methane Hydrate and Development Act of 2000 which provides that the Secretary of Commerce "may" award grants, contracts or cooperative agreements to conduct basic research into methane hydrates. Again, Congress has provided the authority to make awards but is not directing that it be exercised.

When interpreting laws that make use of the terms "shall" versus "may" or "authorize", it is important to avoid an overly simplistic approach. It is not safe to assume that just because a law uses the word "shall" the agency has no discretion in carrying out the law. There are laws that mandate a certain function but also provide significant discretion to the agency in determining how to satisfy the mandate. In particular, agency discretion will often exist as to timing, resources and processes.

For example, The National Weather Service Organic Act states: "The Secretary of Commerce shall have charge of the forecasting of the weather, the issue of storm warnings ... and the taking of such meteorological observations as may be necessary to establish and record the climatic conditions of the United States ..." This law makes clear that the Secretary of Commerce is responsible for issuing weather forecasts and warnings and recording the climate of the United States. In this sense, the law provides a mandate. However, the law provides no direction as to how the Secretary is to carry out these duties. Instead, Congress, through its lack of direction, has provided the discretion to the Secretary to determine how best to satisfy this mandate. Similarly, with respect to the Tsunami Warning and Education Act of 2007, discussed above, Congress has mandated establishment of Centers in Hawaii and Alaska, but the Secretary retains significant discretion to determine how those Centers will be organized.

As the above examples make clear, the extent of Congressional direction depends upon the specific wording of the law. NOAA General Counsel should be contacted for additional guidance if the discretion afforded to the agency or the intent of Congress cannot be discerned.

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SHIP TIME REQUEST

Submit completed form electronically to: Shiprequest.MAOC@noaa.gov

1. REQUESTED FISCAL YEAR 2015	2. ORIGINATING OFFICE NMFS	3. DATE OF REQUEST 09/15/2011	4. RECAP ACTIVITY Habitat mapping and c

5. PROJECT NAME Benthic Habitat

6. PROJECT PURPOSE (Provide a brief description.)

Acoustic mapping, biological sampling and advanced technology (underwater vehicle ops) for ground truthing of acoustic habitat mapping operations, with emphasis on characterization of essential fish habitat for groundfish, lobsters, and sea scallops on Georges Bank

7. OBJECTIVE BASED METRICS (Measurable Accomplishments Planned - list with number required.)

Degree of accomplishment depends on length of cruise (based on previous cruises):
Area of habitat mapped acoustically – 5 sq km /day
No. of photographic transects (AUV and/or ROV) – 5 per day
Number of CTDs taken – 20 per day

8. NOAA LONG-TERM GOALS SUPPORTED BY THE PROJECT/MISSION (Check all goals that apply. Show percentages of each if more than one is checked.)

☐ CAM %	☐ WRN %	☑ HO 100 %	☐ RCCE %	☐ UNKNOWN %

9. NOAA LONG-TERM GOAL OBEJECTIVES SUPPORTED BY THE PROJECT/MISSION

Primary Long-Term Goal Objective: Improved scientific understanding

Secondary Long-Term Goal Objective: Healthy habitats sustain resources, communities

10. FIELD OF SCIENCE CATEGORY		11. NATIONAL SCIENCE FOUNDATION R&D CATEGORY	
1. (2) Applied Research %100	2. %	1. 51 Biological 70 %	2. 32 Geological Science 30 %

12. IMPACT STATEMENT (State how the absence of this data collection will negatively affect NOAA's mission, noting the products and services provided to the general public.)

Attempts to manage fisheries resources with an understanding of the role of habitats and their alteration by direct anthropogenic disturbance, invasive species, or through climate change as part of an ecosystem management scheme for Georges Bank will be severely impaired.

13. PREFERRED VESSEL OPERATOR	(If a NOAA vessel is not preferred, complete only blocks 1-13 and 37-40.)	14. PREFERRED NOAA VESSEL
NOAA vessel		

15. JUSTIFICATION FOR NOAA VESSEL PREFERRENCE

NOAA vessel equipped with bathymetric multibeam sonar is preferred because of the expertise and experience of onboard personnel in performing this task.

16A. FOREIGN PORT CALLS AND RESEARCH CLEARANCES	16B. DOMESTIC LICENSES AND PERMITS
Canadian research clearance (no port calls)	

17A. PROJECT AREA: Georges Bank

17B. PROJECT AREA COORDINATES (Indicate extreme latitudes and longitudes of the project area.)

Northern most latitude	42 ° 30.0 ' N	Eastern most longitude	66 ° 0.0 ' W
Southern most latitude	40 ° 0.0 ' N	Western most longitude	69 ° 30.0 ' W

18. OPERATIONAL AREA SEA DAY REQUIREMENT	19A. EARLIEST POSSIBLE START DATE	19B. LATEST POSSIBLE END DATE	20. PROJECT PRIORITY
Maximum 20 Days Minimum 12 Days	07/01/2015	09/30/2015	(•) Primary ( ) Piggyback

21. SUGGESTED PIGGYBACK PROJECTS	22A. STAGING PORT	22B. STAGING DAYS	22C. TRANSIT DAYS FROM
Living Marine Resources Coastal Science Center	Woods Hole, MA	2 Days	1 Days

23. INTERMEDIATE PORT CALLS	24A. DESTAGING PORT	24B. DESTAGING DAYS	24C. TRANSIT DAYS TO
None	Woods Hole, MA	1 Days	1 Days

25A. SCIENTIFIC BERTHS REQUIRED	25B. NUMBER	26A. FOREIGN NATIONAL PARTICIPANTS	26B. COUNTRY OF ORIGIN OF EACH FOREIGN NATIONAL
(•) YES ( ) NO	10	(•) YES ( ) NO	Canada

27. SHIP FURNISHED CAPABILITIES (Indicate project requirements of each category listed below.)

27A. ELECTRONICS	27B. OCEANOGRAPHIC EQUIPMENT	27C. SPECIALIZED GEAR HANDLING SUPPORT
Multibeam bathymetric sonar, single beam sonar, ADCP	CTD	Installation of dedicated winch for USGS SeaBoss camera vehicle and use of A-frame for launch and recovery.

28. DECK DEPARTMENT AVAILABILITY	29. SURVEY DEPARTMENT AVAILABILITY	30. ON-STATION OPERATING HOURS
A.) 24 hrs per day	B.) Less than 12 hours per set schedule	A. Static Operations 8 HOURS
		B. Trawling Operations 8 HOURS
		C. Towing Operations 0 HOURS
		D. Survey Operations 8 HOURS
		E. Anchorage Operations 0 HOURS

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31. OTHER SHIP CAPABILITY REQUIREMENTS				32. WORK BOAT AND LAUNCH CAPABILITY REQUIREMENTS			
Transit Speed (kts)	10	Wet Lab Space (ft^2)	200	Number	0	Speed (kts)	0
Survey Speed (kts)	8	Dry Lab Space (ft^2)	150	Purpose	n/a	Draft (ft)	0
Endurance (days)	20	Position Accuracy (meters)	10	OP hours / day	0	Equipment	n/a
Dynamic Positioning	Non-classed	Fisheries Calibrated to:		Passengers (each)	0	Gear Weight (lbs)	0

33A. PROVIDE REMOTELY OPERATED VEHICLE (ROV) REQUIREMENTS

See 34 below.

33B. PROVIDE AUTONOMOUS UNMANNED VEHICLE (AUV) REQUIREMENTS

n/a

33C. PROVIDE UNMANNED AIRCRAFT SYSTEM (UAS) REQUIREMENTS

n/a

33D. PROVIDE MANNED SUBMERSIBLE REQUIREMENTS

n/a

34. PROJECT FURNISHED EQUIPMENT (Provide pertinent information on project furnished equipment such as box containers, large moorings, or electronics, in the table below.)

EQUIPMENT DESCRIPTION	WEIGHT (lbs.)	POWER REQUIRED (V / A)	SPACE REQUIRED (FT^2)	LOCATION PREFERENCE
USGS SeaBoss remote drop camera system	300	120 VAC 30A	16 sq ft	near A-frame
USGS SeaBoss dedicated winch	4000	230 or 460 VAC 3ph 30A	35 sq ft	near A-frame
U Maryland towed camera system (alternative)	200	120 VAC 30A	30 sq ft	fantail deck
Single wire Naturalist Dredge or Beam Trawl	150	none	16 sq ft	fantail deck

35. ALTERNATIVE PLATFORMS

If a NOAA ship is unavailable or not economical, would a charter vessel meet project requirements? (●) YES ( ) NO

36. FUNDING SOURCE (Check all that apply.)

☑ NOAA MARINE OPERATIONS & MAINTENANCE ☑ NOAA PROGRAM FUNDING ☑ Non-NOAA FUND ☐ UNKNOWN

37. ADDITIONAL INFORMATION

38. LAB DIRECTOR APPROVAL (●) YES ( ) NO

39. PRINCIPAL INVESTIGATOR / CHIEF SCIENTIST		40. SENIOR NOAA EXECUTIVE WITH AUTHORITY TO APPROVE SHIP TIME REQUESTS	
NAME	Vincent G. Guida	NAME	Dr. Ned Cyr (or designee)
LABORATORY/OFFICE	NOAA, NMFS, NEFSC, J.J. Howard Laboratory	TITLE	Director, NMFS Office of Science & Technology
ADDRESS	74 Magruder Road	ADDRESS	1315 East West Highway
	Highlands, NJ 07732		Silver Spring, MD 20814
PHONE NUMBER	(732) 872-3042	PHONE NUMBER	(301) 427-8174
FAX NUMBER	(732) 872-3088	FAX NUMBER	(301) 713-1875
E-MAIL ADDRESS	vincent.guida@noaa.gov	E-MAIL ADDRESS	c/o allen.shimada@noaa.gov

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SHIP TIME REQUEST

41. LEGISLATIVE MANDATES, EXECUTIVE ORDERS and INTERNATIONAL TREATIES

41A. Identify the Legislative Mandate (LM), Legislative Authorization (LA), Executive Order (EO), International Treaty (IT) or International Agreement (IA) met by the project. Indicate the actual reference(s) within the law, order, treaty or agreement that applies to the data collected.	List all that apply:	Reference(s)
	Research in support of fisheries management: EFH identification	Sustainable Fisheries Act of 1996 (Public Law 104-297) 16 USC 1881c Section 404c (1) & Fisheries Conservation and

41B. How does the primary objective of this project directly support the LM, LA, EO, IT, or IA? (maximum 300 characters)

Data will define distributions of FMP species whose habitat interactions are only partly known (e.g.cod, haddock, sea scallop, American lobster) as related to habitat characteristics, disturbance and the invasive tunicate Didemnum vexillum now dominating portions of the Bank.

41C. Why is a NOAA ship the most efficient and effective platform that can acquire the required data to meet the Congressional legislation?

NOAA ships are staffed by personnel familiar with multibeam sonar mapping; this may not be true of other vessels. At present, our team has only limited experience with the shipboard operation of these systems and would benefit from expertise among the ship's crew.

41D. What are the risks incurred (e.g., law suits, voidance of existing treaties or impaired response to proposed treaties, effects on international partnerships, impacts to NOAA's leadership role, etc.) by not meeting the LM, LA, EO, IT or IA if this project is not completed? (maximum 300 characters)

1. Attempts to manage fisheries resource habitats as part of an ecosystem management scheme will be severely impaired, thus endangering the sustainability of fisheries, and
2. Failure to manage Georges Bank fisheries well may invite Environmental NGOs to bring suit.

42. IMPACT TO SOCIETY

42A. What NOAA product and/or service will be affected, if the requested sea days are not allocated? (Provide a specific name and a short description of the product and/or service affected.)

1. Habitat advice for the New England Fisheries Management Council - This council depend upon NEFSC to provide advice for management of fisheries activities in NE U.S. waters. Increasingly, advice on habitat/ecosystem issues has been requested.
2. Habitat advice for the NOAA Regional Office - NERO environmental review for offshore development depends upon knowledge of how marine resources utilize habitats.

42B. If data for this project isn't collected during the fiscal year indicated in block 1, will the NOAA product and/or service indicated in question 42A: (Choose one.) — 2) Become extremely degraded

42C. What are the specific impacts to the product or service, and to the users of this product or service, by not conducting this project?

1. Habitat information, which is becoming increasingly sought for purposes of area management as an adjunct to traditional stock management. Failure to conduct this cruise will degrading the FMCs' abilities to manage FMP species in the face of advancing climate change and spreading invasion by the invasive Asian colonial tunicate, Didemnum vexillum.
2. Again, the distribution and utilization of habitats region is only partially known and without this cruise, that knowledge and future decisions that will need to be based upon the products of this cruise are hampered or degraded.

42D. Does this project provide data that has a direct and timely link to a NOAA product or service that will help prevent risks to lives, economy or the environment? ○ YES ◉ NO

42E. If 42D was "Yes", how does the data collection support the stated products/services in block 42A? Provide a description of the source documentation (provide web links if available), and other supporting documents, that best state how the data has a direct and timely link to a NOAA product or service that helps prevent risks to lives, the economy or the environment.

This use of habitat data is a relatively new issue and we expect to develop a formal relationship with the NEFMC Plan Development Team (PDT) this year.

42F. If 42D was "Yes", identify the following quantitative factors that will likely result from loss of project data. (These factors must be the conclusions found in the source documentation or other supporting documents described in question 42E.)

i. Risk to human lives will likely result in:	ii. Risk to our nation's economy will likely result in the loss of:	iii. Risk to the environment will likely result in:
Choose One	Choose one	Choose one

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SHIP TIME REQUEST

43. VESSEL CAPABILITY

43A. Which capabilities, unique to NOAA vessels, are absolutely required to successfully accomplish the project's primary objectives? (Select all that apply.)

- [ ] 1. Clam system
- [ ] 2. Acoustic quieting
- [ ] 3. Doppler Radar
- [ ] 4. Dedicated salinity chamber
- [ ] 5. Nitrox system
- [ ] 6. Hyperbaric chamber
- [ ] 7. Multiple survey launches

43B. If 43A indicates only one unique vessel capability, does it also need other physical capabilities that are not unique to a NOAA vessel, but provide a combination that is unique, and required to successfully accomplish the project's primary objectives? If so, identify the unique combination.

n/a

43C. How does the required unique physical capability or the combinations of physical capabilities meet the project's primary objectives or performance outcomes?

n/a

43D. Indicate any unique NOAA personnel requirements. Justify how those needed skills are required to meet the primary project objectives or performance outcomes.

NOAA ships are staffed by personnel familiar with multibeam sonar mapping; this may not be true of other vessels. At present, our team has only limited experience with the shipboard operation of these systems and would benefit from expertise among the ship's crew.

43E. Briefly describe the impacts to the project objectives or the costs to the program that would be incurred by chartering, if sea days are not allocated aboard a NOAA vessel.

The cost just to follow the cruise track in a vessel capable of an extended cruise and perform some limited amount of the work planned is simply out of the range of possibility for our habitat program; there would be no cruise, no data collected, no advice to NERO or the FMCs on deepwater issues.

44. LONG TERM DATA SERIES

44A. Is this project a long term time series according to the definition found in the instructions? (●) YES ( ) NO

44B. If 44A is "Yes", how many years has the long term data series been conducted? 14 Years

44C. What is the frequency of the data collection? (quarterly, semiannual, annual, biennial, triennial, etc.) annual

44D. What are the specific impacts to the continuity of the data, if the project is not completed during the year indicated in block 1?

The data currently being collected is not time-depedent, strictly speaking; its integrity does not depend on periodic continuity. However, maintaining the interest of essential non-NOAA (USGS) collaborators does depend upon year-to-year continuity. A break in funding may thus result in a loss of some capabilities.

44E. If 44A is "No", and the project length is 1 to 3 years, provide justification that shows the potential for becoming a long term data series of environmental or physical trends.

45. PROMOTE "One NOAA" PROJECTS

45A. Is the project a result of a formal collaboration between Line Offices promoting a single multi-purpose mission that was originally two or more separate projects under individual Principal Investigators? ( ) YES (●) NO

45B. If 45A is "Yes", provide the collaborating LOs and Principal Investigators for this project.

45C. Will this formal collaboration allow collaborators to meet their current data requirements while reducing the number of sea days historically requested? ( ) YES ( ) NO

45D. If 45C is "Yes", provide the best estimate of number of sea days reduced and describe how the reduction was accomplished.

Number of Sea Days: Days

45E. If the project has no formal collaboration that promotes multi-purpose missions, but has a formal data sharing agreement that allows other NOAA entities to access the project data, please identify those entities (e.g., NGDC) where data can be acquired.

Although there is no formal collaboration with another LO, acoustic mapping data will be submitted to NGDC, so there is a "One NOAA" aspect to this project.

SHIP TIME REQUEST

Block 1: Requested Fiscal Year - Indicate the Fiscal Year in which this requested project will occur.

Block 2: Originating Office - Identify appropriate Line Office within NOAA.

Block 3: Date of Request - Indicate the date that the form is filled out.

Block 4: ReCap Activity - Select the Fleet Recapitalization Plan Activity that best describes the project. Further descriptions of all the current ReCap Activities can be found at: http://www.omao.noaa.gov/publications/08_ship_recap_plan.pdf Chapter 5 pp. 21-45.

Block 5: Project Name - Provide a project title/name that best identifies the scientific mission.

Block 6: Project Purpose - Provide a brief description of the project, its purpose, overall mission and expected contribution to a broader program such as a national or international effort.

Block 7: Objective Based Metrics - List the minimum required measureable accomplishments that will achieve the Project Purpose stated in block 6 including the accomplishments and the number of this accomplishment required. (e.g., Square nautical miles hydrographic multibeam data - 500, CTDs - 45, Deep bottom trawl stations - 65).

Block 8: NOAA Long-Term Goals Supported By The Project/Mission - Check the appropriate box(es) and identify the percentages supported if selecting more than one NOAA Long-Term Goal. CAM = Climate Adaptation and Mitigation, WRN = Weather-Ready Nation, HO = Healthy Oceans and RCCE = Resilient Coastal Communities & Economies.

Block 9: NOAA Long-Term Goal Objectives Supported By the Project - Select the primary and secondary objectives within the Line Office Long-Term Goals that are supported by the project. The Long-Term Goal Objectives can be found at: http://www.ppi.noaa.gov/ngsp/goals/

Block 10: Field of Science Category - Select the number and appropriate category from the following list that applies to the project. If using more than one please show percentage of each:

(1) Basic Research - Not applicable to NOAA
(2) Applied Research - Research directed towards gaining knowledge or understanding necessary for determining the means by which a recognized and specific need may be met.
(3) Development Directed - The systematic use of knowledge and understanding gained from research directed toward the production of useful materials, devices, systems, or methods, including design and development of prototypes and processes.
(4) NON R&D - Routine product testing, quality control, mapping and surveys, collection of general-purpose statistics, experimental production, and activities concerned primarily with the dissemination of scientific information and the training of scientific staff.

Block 11: National Science Foundation R&D Category - Select the number and appropriate category from the following list – if using more than one please show percentage of each:

N/A Not applicable - if NSF code is 4- Non R&D

11	Astronomy	42	Astronautical Engineering	61	Biological Psychology
12	Chemistry	43	Chemical Engineering	69	Psychological Science
13	Physics	44	Civil Engineering	71	Anthropology
19	Physical Science	45	Electrical Engineering	72	Economics
21	Mathematics	46	Mechanical Engineering	75	Political Science
22	Computer Science	47	Metallurgy & Material	76	Sociology
29	Math/Computer Science	49	Engineering	79	Social Sciences
31	Atmospheric Science	51	Biological	80	Cryogenics (NIST)
32	Geological Science	54	Environmental Biology	81	Measurement (NIST)
33	Oceanography	55	Agricultural	82	Other Engineering (NIST)
39	Environmental Science	56	Medical	99	Other Science
41	Aeronautical Engineering	59	Life Science		

SHIP TIME REQUEST

Block 12: Impact Statement - Describe the impact to NOAA and the nation if this ship time request is not allocated sea days or not funded.

Block 13: Preferred Vessel Operator - Select one of the following four options: A.) NOAA vessel, B.) Non-NOAA Federal vessel, C.) UNOLS vessel or D.) Non-Federal charter vessel. (If option B, C or D is indicated, skip to block 37).

Block 14: Preferred NOAA Vessel - Indicate the most desirable NOAA vessel as a platform for this particular project.

Block 15: Justification for NOAA Vessel Preference - Provide specific justification as to why the indicated NOAA vessel is most desired for support of this project. If other NOAA vessels could perform the project equally well, list other options.

Block 16: Foreign Port Calls and Research Clearances - Indicate the foreign ports or foreign waters that may be entered that will require foreign clearances through established diplomatic channels.

Block 16B: Domestic Licenses and Permits - Indicate any license or permit that may be required from another federal, state or local agency.

Block 17A: Project Area - Provide a specific location or ocean area of the project area. For example, if project is located in the South Atlantic Bight do not identify that project area as Atlantic Ocean.

Block 17B: Project Area Coordinates - Indicate extreme latitudes and longitudes of the operation area (to the nearest $1/10^{th}$ of a minute).

Block 18: Operational Area Sea Day Requirement - Indicate both the maximum number of days desired and the minimum days in which meaningful work could be accomplished in the project area.

Block 19A: Earliest Possible Start Date - Indicate the earliest possible start date for the accomplishment of this project. Use block 37 to describe any issues affecting this date such as environmental or biological conditions that would affect the success of the project.

Block 19B: Latest Possible End Date - Indicate the latest possible end date for the project.

Block 20: Project Type - Indicate whether this project is the primary focus of the ship or that it is a piggyback-type project with minimum interference to the principle users.

Block 21: Suggested Piggyback Projects - Indicate whether there will be time for piggyback projects or if piggyback projects could be accommodated on a noninterference basis. If there will be time for piggyback projects, indicate how much time will be available.

Block 22A: Staging Port - Indicate the preferred port to be used for staging the vessel prior to departure.

Block 22B: Staging Days - Estimate the number of business days required for staging the vessel before the project begins. A staging day is a full day in port with a significant portion of the ship's complement working a regular 8 hour work day to load, store or calibrate scientific equipment, construct scientific workstations or support the scientific party before departure.

Block 22C: Transit Days From - Indicate the number of days needed to transit from the staging port to the project area.

Block 23: Intermediate Port Calls - Indicate up to three intermediate port calls and the number of days at each location.

Block 24A. Destaging Port - Indicate the preferred port to be used for destaging the vessel after project completion.

Block 24B: Destaging Days - Estimate the number of business days required for destaging the vessel after the project ends. A destaging day is a full day in port with a significant portion of the ship's complement working a regular 8 hour work day to unload scientific equipment or samples, deconstruct scientific work stations or support the scientific party upon project completion.

Block 24C: Transit Days To - Indicate the number of days needed to transit to the destaging port from the project area.

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Block 25A: Scientific Berthing - Indicate whether scientific berthing will be required for this project.

Block 25B: Scientific Berths Required - If scientific berthing is required, indicate the number of berths needed for the scientific complement including NOAA program personnel and/or Non-NOAA personnel (i.e., scientists, technicians).

Block 26A: Foreign National Participants - Indicate whether Foreign Nationals are expected to participate in this project.

Block 26B: Foreign National Country of Origin - If applicable, indicate the country or countries these Foreign Nationals are representing.

Block 27: Ship Furnished Capabilities - Indicate special project requirements for Electronics, Oceanographic Equipment and Specialized Gear Handling Support for the project or "NONE".

Block 28: Deck Department Availability - Select the hours per day the Deck Department needs to be available for deck operations:
A.) 24 hrs per day, B.) Daylight hours only or C.) Minimally.

Block 29: Survey Department Availability - Select the hours per day the Survey Department needs to be available for survey operations:
A.) 24 hrs per day, B.) Less than 12 hours per set schedule or C.) Opportunistically.

Block 30: On-Station Operating Hours - Indicate the hours per day that the project will require the vessel to be conducting:
A. Static operations (to include CTD casts, small boat deployments, buoy servicing, ROV operations and bottom grabs)
B. Trawling operations (to include mid-water trawls, bottom trawls and scallop dredging)
C. Towing operations (to include plankton nets, side scan sonar, acoustic arrays, MOCNESS and other plankton nets)
D. Survey operations (vessel is constantly making way to conduct hydrographic or marine mammal surveys)
E. Anchorage operations (launch deployments or other operations that are conducted while the ship is at anchor)

Block 31: **Ship Capability Requirements** - In addition to the required electronic, oceanographic and gear handling requirements identified in block 27, specify other capabilities that will be required of the ship to support the project. If there is a requirement that the vessel be calibrated for trawling operations, indicate which vessel it must be calibrated with. Also indicate whether the project requires the ship to have Dynamic Positioning and if so, whether it requires a specific minimum IMO Classification:
Class 1 - Automatic and manual position and heading control under specified maximum environmental conditions.
Class 2 - Automatic and manual position and heading control under specified maximum environmental conditions, during and following any single fault excluding loss of a compartment.
Class 3 - Automatic and manual position and heading control under specified maximum environmental conditions, during and following any single fault including loss of a compartment due to fire or flood.

Block 32: Work Boat Requirements - For work boats and launches, indicate the number of science party passengers required. The ship command will determine the number of required crew. If multiple types of boats are required, explain in block 37.

Block 33A: ROV Requirements - If a Remotely Operated Vehicle (ROV) is required, provide operational details as well as ship support requirements.

Block 33B: AUV Requirements - If an Autonomous Underwater Vehicle (AUV) is required, provide operational details as well as ship support requirements.

Block 33C: UAS Requirements - If an Unmanned Aircraft System (UAS) is required, provide operational details as well as ship support requirements.

Block 33D: Manned Submersible Requirements - If required, provide operational details as well as ship support requirements.

Block 34: Project Furnished Equipment - List major equipment that will be brought aboard by the scientific party such as vans, electronics, moorings, winches, or other equipment that will need to be secured to the ship's deck or hull and provide the necessary specifications.

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Block 35: Alternative Platforms - Indicate whether a charter vessel would be capable of meeting project requirements if a NOAA ship is not available due to schedule conflicts or cost.

Block 36: Funding source (check all that apply) - Indicate by checking the appropriate box(es). NOAA Marine Operations & Maintenance Fund = OMAO base funding; NOAA Program funding = NOAA Line Office funds; Non-NOAA funds = funds from an outside agency.

Block 37: Additional Information - Please list any additional information that would be helpful in describing special circumstances of this project or clarifications to any of the above blocks.

Block 38: Lab Director Approval - Confirm the lab or science center director has approved this ship time request before going to the NOAA Line Office approving authority for signature.

Block 39: Principal Investigator/Chief Scientist (Include lab/office affiliation, complete address, phone, fax, E-mail address) - Provide contact information for ship time request. When the form has been properly submitted, a copy will be forwarded to this email address.

Block 40: Senior NOAA Executive with Authority to Approve Ship Time Requests - Provide contact information for the senior NOAA Executive Accountable for the Goal or designee. This person shall submit the ship time request (if requesting the use of a NOAA vessel) in order for OMAO to accept the request for consideration. Any request not submitted through the appropriate channel will be returned to the Principal Investigator listed in block 39. **If requesting a NOAA vessel, completion of blocks 1-45 is mandatory.**

Block 41: Legislative Mandates, Executive Orders & International Treaties - Activities carried out under NOAA's Strategic Plan are dictated, in large part, by Congressional legislation (i.e., legislative mandates/authorizations). This includes any legislation which defines a clear, on-going role for NOAA. Legislative Mandates or Legislative Authorizations do not include earmarks. Activities carried out under NOAA's Strategic Plan are also dictated by Executive Order, International Treaties and International Agreements.

Block 41A: If the primary driver for the project is a Legislative Mandate (LM) or Legislative Authorization (LA), indicate it as such with the two letter designator after the referenced Act. Review Page 10 to determine whether the primary driver is a Legislative Mandate or Legislative Authorization, or contact NOAA General Counsel.

Block 41B, 41C and 41D: Answer the questions as indicated.

Block 42: Impact to Society - This criterion measures the link between the proposed project and societal benefits such as public health, safety of life, and public welfare. Public welfare is defined in terms of the environment, property, and economic values.

Block 42A, 42B, 42C, 42D and 42E: Answer the questions as indicated.

Block 42F: Select one option for each of the three risk assessments.

i. Risk to human lives will likely result in:
   A.) Death,
   B.) Serious injury or illness or
   C.) Minor injury or illness.

ii. Risk to our nation's economy will likely result in the loss of:
   A.) Billions of dollars,
   B.) Millions of dollars or
   C.) Thousands of dollars .

iii. Risk to the environment will likely result in:
   A.) Lethal damage to large populations of aquatic or terrestrial species or extreme damage to marine or land ecosystems,
   B.) Moderate damage but not lethal or
   C.) Limited damage.

SHIP TIME REQUEST

Block 43: Vessel Capability (Unique to NOAA) - NOAA vessels have unique physical capabilities, or combination of physical capabilities, not available in the academic fleet or other charter services to support your project. Unique physical capabilities of the NOAA Fleet include the following:

1. Clam system (set of winches and clam dredges).
2. Acoustic quieting.
3. Doppler 5cm Weather Radar.
4. Dedicated chamber for conducting precision salinity measurements (+ or – one degree Celsius).
5. Nitrox filling systems.
6. Permanent hyperbaric chamber and dedicated supervisor and Diving Medical Officer.
7. Ship with multiple survey launches (i.e., 4 or more) required to complete project.

Note: NOAA vessels may provide unique skills related to the people aboard the NOAA vessel (though these are not considered physical capabilities).

Block 43A: The list of seven "unique" physical capabilities shown in the above description can only be found on NOAA vessels. Which capabilities are absolutely required to successfully complete the project's primary objectives?

Block 43B, 43C, 43D and 43E: Answer the questions as indicated.

Block 44: Long Term Data Series - Acquisition of data at a set frequency will build on a time series in order to maintain the appropriate continuity and accuracy needed to detect trends in environmental (biological, chemical or physical) changes. For this application indicate;

A.) The project is a long term data series when the project has 10 or more years of periodic data collection,
B.) The project is becoming a long term data series when the project has 4-9 years of periodic data collection or
C.) The project is in the development or research phase when the project has 1-3 years of periodic data collection.

Block 44A: Is this project a long term time series according to the definition in the above description?

Block 44B: If the answer to question 44A is "Yes", how many years has the project been in series? (e.g., 15 years, 2001-2015)

Block 44C: Indicate quarterly, semiannually, annually, biennially, triennially, quadrennially, quinquennially or decadal.

Block 44D and 44E: Answer the questions as indicated.

Block 45: Promote "One NOAA" Projects - Functioning as "One NOAA" enables integration and cooperation between NOAA Line Offices and their associated Long-Term Goals to efficiently maximize days at sea. Cooperation can take the form of NOAA collaboration on a project during a cruise, or two projects sharing the same cruise or sea day. The "One NOAA" concept promotes and encourages multi-mission project development allowing better efficiency of at-sea days by enabling more than one program to benefit from ship time. Promoting "One NOAA" projects on platforms enables data collection for applied research and repeated coverage for temporal and spatial requirements.

Block 45A, 45B, 45C, 45D and 45E: Answer the questions as indicated.

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Legislative Mandates versus Legislative Authorizations

Congress, through the laws it enacts, empowers agencies of the U.S. Government to perform responsibilities and functions in furtherance of important public policies as stated in such laws. These laws, with varying degrees of direction and specificity, authorize and, in some case, direct agencies to perform certain functions. In determining the intent of Congress, it is important to closely study the words of a statute to determine the nature of the authorization(s). The words "shall," "may" or "authorize" are frequently used in statutes to express Congressional intent and provide important insight into the nature of the authorization.

Some laws use the word "shall" when describing agency responsibilities, which is commonly interpreted as directive in nature. That is, the agency is directed by Congress to perform a certain function. Such laws are often viewed as "legislative mandates", leaving the agency little to no discretion as to whether to do the thing so directed by Congress. For example, the Tsunami Warning and Education Act of 2007 states: "The National Weather Service shall maintain or establish a Pacific Tsunami Warning Center in Hawaii and West Coast and Alaska Tsunami Warning Center in Alaska ..." Through the use of the word "shall" in this law Congress has clearly indicated that is mandating the NWS to establish these Centers. The Congress has provided the agency no discretion as to whether or not to establish such Centers. In fact, Congress has gone so far as to require that they be located in Hawaii and Alaska.

Other laws use words such as "may" or "authorize," which are commonly interpreted as discretionary in nature. These laws empower an agency to perform a certain function but do not require it, leaving it to the discretion of the agency as to whether to act on the authority so provided. The decision as to whether to act to exercise the authority can be influenced by such matters as available budget and other resources and competing agency priorities. For example, 33 U.S.C. § 883d states: "The Secretary of Commerce is authorized to conduct developmental work for the improvement of surveying and cartographic methods...", through the use of the word "authorize" Congress has made clear that it is providing authority to carry out the specified functions but is not directing that such authority be exercised. Another example is the Methane Hydrate and Development Act of 2000 which provides that the Secretary of Commerce "may" award grants, contracts or cooperative agreements to conduct basic research into methane hydrates. Again, Congress has provided the authority to make awards but is not directing that it be exercised.

When interpreting laws that make use of the terms "shall" versus "may" or "authorize", it is important to avoid an overly simplistic approach. It is not safe to assume that just because a law uses the word "shall" the agency has no discretion in carrying out the law. There are laws that mandate a certain function but also provide significant discretion to the agency in determining how to satisfy the mandate. In particular, agency discretion will often exist as to timing, resources and processes.

For example, The National Weather Service Organic Act states: "The Secretary of Commerce shall have charge of the forecasting of the weather, the issue of storm warnings ... and the taking of such meteorological observations as may be necessary to establish and record the climatic conditions of the United States ..." This law makes clear that the Secretary of Commerce is responsible for issuing weather forecasts and warnings and recording the climate of the United States. In this sense, the law provides a mandate. However, the law provides no direction as to how the Secretary is to carry out these duties. Instead, Congress, through its lack of direction, has provided the discretion to the Secretary to determine how best to satisfy this mandate. Similarly, with respect to the Tsunami Warning and Education Act of 2007, discussed above, Congress has mandated establishment of Centers in Hawaii and Alaska, but the Secretary retains significant discretion to determine how those Centers will be organized.

As the above examples make clear, the extent of Congressional direction depends upon the specific wording of the law. NOAA General Counsel should be contacted for additional guidance if the discretion afforded to the agency or the intent of Congress cannot be discerned.