Pilot Project to Assess Need and Initialize a Methodology to Groundtruth Existing Multibeam and Sidescan Sonar Seafloor Charts

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Abstract:

It has been hypothesized that cod aggregate on an annual basis in the winter time in the Cod Conservation Zone managed area in Massachusetts Bay. Research conducted by the Massachusetts Division of Marine Fisheries from December, 2005 to February, 2006 identified cod repeatedly in several specific locations. This data was corroborated by local commercial fishermen. This study focused on determining if habitat characteristics were correlated to the site fidelity of cod. Using USGS multibeam datasets from the area and empirical information offered by commercial fishermen, sites with very similar habitats as measured by aspect, depth, and backscatter value but with contrasting cod site fidelity were identified. At these sites, correlations between cod presence and absence and seafloor characteristics (grain size, organic carbon content, and macrofauna) were analyzed using grab samples and still photos collected in June, 2006 aboard the F/V Venture. Cod were found at sites with significantly different habitats across the Cod Conservation Zone, but no seafloor features measured could be correlated to the presence or absence of cod.

Introduction:

It has been recognized that in some areas, cod aggregate to spawn. In addition to exhibiting aggregation behavior, cod also appear to be site selective, and aggregate in the same place in successive years. In Massachusetts, the first reports of high concentrations of cod date back to the 1880's, particularly in Ipswich Bay and Massachusetts Bay (Mass Bay, (Howe 1998). Due to regional population declines of cod, the Massachusetts Division of Marine Fisheries imposed fishing restrictions during the winters of 2005-2006 and 2006-2007 in the Cod Conservation Zone, an area of Mass Bay that had high catch per unit effort in successive years from 2003-2005.

Further studies conducted during the closure found that the cod did not aggregate en masse but instead were found in multiple, spatially explicit areas. These concentrations of cod were very site specific; cod were found in the same locations in surveys over multiple months (Ford 2007). In order to better understand what environmental features may be correlated to the presence of cod, this study investigated gross seafloor characteristics including grain size, organic carbon content, and macrofauna. Sites were selected to represent areas with similar depth and backscatter characteristics but with high and low cod fidelity. The overriding objective was to examine if the seafloor characteristics at sites with cod were different than those at sites without cod.

Participants:

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Field work: Dann Blackwood, USGS; Seth Ackerman, MA CZM; Chris Hein, BU; Chris Manning, NEC.

Methods:

Site selection: Multibeam data collected by the USGS with a Simrad EM1000 in 1994-1996 was used for baseline acoustic backscatter values and to define the depth and general geologic setting (e.g. muddy basin, drumlin) for each study site. Singlebeam acoustic surveys were conducted in the winter of 2005-2006 to look at spatial and temporal distribution of cod, and this data was utilized to identify high fidelity sites (cod were identified on at least 2 of 3 of the surveys) and low fidelity sites (cod were not identified in any survey) (Ford 2007). These sites were reviewed by the participating commercial fishermen who supported their selection. Four pairs of sites were identified, for a total of 8 sites (A-H, Figure 1). Fourteen grab samples were collected in five of the sites. Three hard-bottom sites were characterized by image analysis alone. Five grab samples did not have images associated with them because of water column turbidity. These samples were not included in the statistical analysis.

Field work: Field work was coordinated by Kathryn Ford and the Massachusetts Fishermen's Partnership. The USGS SEABOSS platform was used to collect grab samples, take photos, and collect video June 5-6, 2006 (USGS 2000). The platform was lowered to the seafloor updrift of a predefined sample location and the boat drifted with the sampler and collected video and still photos. Once the sample location was reached, a grab was taken. If a grab could not be taken due to large grain size, then video collection continued until the next site or the drift was aborted. A mini-core was taken in each grab with a clear plastic tube to measure the depth of the reduction-oxidation discontinuity.
Lab work: The top 2 cm of the grabs were homogenized and processed for organic carbon by loss on ignition and grain size using a coulter counter (Poppe, Eliason et al. 2000). The still photos were georeferenced based on the time they were taken. Digital photos were analyzed manually for species and percent cover by overlaying a 100-cell grid over each one. A sediment type index was used to describe the photos (Table 1). Results of photo analysis from within 100 meters of each grab site were averaged and analyzed statistically.
Statistics: Principal components analysis was used on the environmental and species data after the data were normalized ((obs-mean)/sd). Nonmetric multidimensional scaling was used on data expressed as a percentage across several categories but within a station. Data was analyzed in PRIMER.
Problems: Sidescan sea trials were originally planned to be conducted aboard Captain Sam Novello's trawler. Since the project changed to focus on groundtruthing, and the USGS donated its SEABOSS system, the configuration of Captain Novello's gear did not permit the safe and effective usage of the equipment. As a result, Captain Peter Marshall was recruited by the MFP to participate. His scallop vessel has an A-frame and sufficient deck space to deploy the necessary video and grab sampling equipment. Captain Novello remained involved in the project and participated during sea sampling as well as by providing sampling advice. Weather delays caused substantial logistical problems and the MFP was instrumental in resolving these issues. In addition, efficiency out in the field and the willingness of the captain and crew to work very long days enabled all sites to be reached. In fact, several additional sites in Ipswich Bay were able to be examined as a potential study area.

Data:

The individual site data are tabulated in Table 2. Sample images are provided in Figure 2. All images and image analysis will be submitted to the Northeast Consortium Fisheries and Ocean Database by the end of July. The data will also be available on the MFP website shortly (www.mass-fish.org). Though outside of the scope of this project, it is anticipated that the data will be made accessible via a new Division of Marine Fisheries marine habitat website by the end of August (http://www.mass.gov/dfwele/dmf/habitatmapping/ccz.htm).

Results and conclusions:

The seafloor of the Cod Conservation Zone within Massachusetts Bay has drumlin hills dominated by coarse sediment (gravel, cobble, and boulders). In some cases, the hills are covered by a sandy-silt. Coarse sand and gravel, as well as patches of sand and smaller grain size sediment, dominate in between the drumlins. The deeper portions of the CCZ (>50m) are dominated by finer sediment with clay nodules. The most common species identified included *Asterias* sea stars, *Modiolus* mussels, *Myxicola* fan worms, *Cerianthid* anemones, and *Terebratulina* brachiopods. At one site crustose algae was common, and a variety of small sponges were at most stations. Fish species identified were dominated by cunner (*Tautogolabrus*) and sculpin (*Myoxocephalus*).

The data analysis suggests that the shorter the distance between stations, the more similar the variables. The individual pairs of stations were classified separately according to NOAA CMECS (Madden, Grossman et al. 2005), and 3 distinct habitats were represented (Figure 3). However, there appears to be no relationship between cod presence/absence and the variables measured. A sample analysis is presented in Figure 4. Although this is a relatively small sample size, it emphasizes the need to incorporate other variables when looking at this complicated behavioral issue. Additional variables to examine include salinity, current speed, infauna, and a better analysis of site fidelity. Seafloor samples should also be taken contemporaneously with the cod research.

Partnerships:

MFP approached Dr. Ford shortly after she joined DMF to partner on this collaborative project and several strong partnerships resulted. First, Dr. Ford and MFP agreed on how and why commercial fishermen should participate in collaborative research and in this project particularly and are exploring future opportunities to continue to work together. The MFP also strengthened their relationships with industry members and enhanced their ability to facilitate meaningful participation by fishermen in collaborative research. In addition, the participating fishermen were exposed to both governmental and academic perspectives and vice versa, resulting in stimulating conversations and potentially revised beliefs. Lastly, the partnership formed between DMF and USGS led to a Memorandum of Agreement between the two agencies, and they continue to share resources to conduct seafloor mapping.

Impacts and applications:

Since cod aggregations have gained attention in the management community, it is absolutely critical to examine their underpinnings in order to prevent unnecessary fishing moratoria. This data is being used to directly inform DMF's management decisions regarding the CCZ and to derive additional questions such as are there area-wide changes in community composition? In turn, the answers to these types of questions directly impact the management decisions that will govern how and where fishermen may continue to fish and supply a critical public food source. Further, this information will inform on-going debates on the efficacy of areal management and its implementation in our local waters. The area studied will also likely provide a baseline dataset while we follow this body of fish over time. Also, there are many intersecting uses of our coastal zone which are directly conflicting as this is being written. Understanding seafloor habitats and how critical fish stocks utilize them is of utmost importance. Microhabitats and habitat variability may be important factors. Additionally, habitat fragmentation is a significant threat. How this impacts aggregations is unknown.

Key end users include: Tony Wilbur, Mass CZM Tony.Wilbur@state.ma.us; Walter Barnhardt, USGS wbarnhardt@usgs.gov; ASMFC, NEFMC Habitat Committees.

Related projects:

This project was done in association with the USGS mapping of Massachusetts waters, which is a state-federal partnership. USGS provided equipment and personnel for this project. The Ipswich Bay sampling was done in association with Chris Hein's Ph.D. thesis research at Boston University.

Presentations:

Ford, K.H. 2007. Groundtruthing cod habitat. Massachusetts Fishermen's Partnership Collaborative Research Conference: Preliminary Findings and Future Directions. January 24, 2007. Boston, MA.

Student participation:

Christopher Hein, graduate student, Boston University

Future research:

More groundtruthing effort, as well as acoustic mapping effort, is still needed to determine how best to map and monitor seafloor habitats. Several conversations associated with this project described cod migratory pathways that are fairly well delineated between Jeffries Ledge-Ipswich Bay-Mass Bay-Stellwagen Bank. It would be useful to have data to define these pathways and explore why and when they are used.

References:

Ford, K. H. (2007). Cod Conservation Zone Research; December 2005-February 2006. Technical Report Series, Division of Marine Fisheries: 96.

Howe, A. B. (1998). Cod gill-net fishery in Ipswich Bay, 1880-87, Massachusetts Division of Marine Fisheries.

Madden, C. J., D. H. Grossman, et al. (2005). Coastal and Marine Systems of North America: Framework for an Ecological Classification Standard: Version II. Arlington, VA, NatureServe: 48.

Poppe, L. J., A. H. Eliason, et al. (2000). Grain-size analysis of marine sediments: Methodology and data processing. Open File Report 00-358, USGS.

USGS (2000). Seabed Observation and Sampling System. Fact Sheet 142-00: 2.

Table 1: Sediment type index	
1	soft bottom with burrows
2	soft bottom with burrows, lumpy
3	soft sediment with cobbles and gravel evident subsurface; fuzzy algae common
4	cobble bottom, sediment drape; fuzzy algae and bryozoans common
5	gravel pavement
6	cobble/boulder bottom with crustose algae

Table 2: Site locations and results

Station	1-A	2-B	3-B	4-C	5-C	6-C	7-C	8-C	9-D	10-D	11-D	12-D	13-D	14-E	15-E	16-F	17-G	18-H
Lat	42.383	42.373	42.374	42.370	42.369	42.371	42.372	42.372	42.376	42.378	42.379	42.380	42.382	42.425	42.426	42.420	42.412	42.409
Lon	70.774	70.743	70.743	70.675	70.672	70.672	70.673	70.669	70.665	70.667	70.661	70.663	70.669	70.722	70.724	70.712	70.737	70.726
Cod present	0	1	1	0	0	0	0	0	1	1	1	1	1	0	0	1	0	1
Backscatter value	174	152	231	90	95	95	95	62	84	79	118	112	79	191	186	180	208	242
Water depth_m	30.3	39.2	39.2	63.4	63.8	63.9	63.7	65	65.9	66.1	67.4	67.6	66.6	48.8	49.1	48.8	40.1	41.9
Redox_cm	0	0	2	4.5	2	3.5	4	2	4.5	3	4	4.5	3.5	0	0	0	0	0
% Total carbon	0.0	0.0	0.0	5.5	3.0	3.6	5.4	3.1	6.5	9.0	3.5	4.8	4.3	0.0	0.0	0.0	0.0	0.0
% Organic carbon	0.0	0.0	0.0	2.4	1.3	1.6	2.3	1.3	2.8	3.9	1.5	2.1	1.8	0.0	0.0	0.0	0.0	0.0
% Gravel	100	100.0	20.54	1.25	0.16	0.19	0.49	0.12	0	0.15	0.12	0	0.18	78.14	76.14	100	100	100
% Sand	0	0	78.31	33.32	28.61	30.98	40.54	40.15	12.36	22.95	22.42	17.8	26.43	21.58	23.36	0	0	0
% Silt	0	0	0.76	52.99	55.16	55.74	47.52	45.21	60.02	60.02	55.81	64.86	59.56	0.21	0.36	0	0	0
% Clay	0	0	0.39	12.44	16.07	13.11	11.45	14.53	27.61	16.88	21.64	17.34	13.83	0.07	0.14	0	0	0
Clay nodules	0	0	1	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0
No photos averaged	4	5	2	1		1	1				1	2		7	1	6	21	9
Distance from grab_m	7.75	15.20	4.50	100.00		27.00	100.00				3.00	12.00		24.86	50.00	0	0	0
Bottom type	6.00	3.60	2.50	1.00		1.00	2.00				1.00	1.00		3.14	3.00	3.33	3.81	3.78
# *Terebratulina*	0	1.00	1.00	0		0	0				0	0		7.33	15.00	7.40	13.67	6.00
# *Cerianthid*	0	0	0	0		0	0				0	0		1.00	0	1.50	0	1.00
# Anemone other	0	0	0	0		0	0				0	0		0	0	0	0	0
# *Myoxocephalus*	0	0	0	0		0	0				0	0		0	0	0	0	0
# *Tautogolabrus*	0	0	0	0		0	0				0	1.00		0	0	0	1.00	0
# *Myxicola*	0	1.00	0	0		0	0				0	0		1.75	0	4.00	3.33	2.00
# Seastar	4.00	3.00	1.00	0		1.00	0				0	0		1.00	1.00	0	3.71	3.50
# Sea cucumber	0	0	0	0		0	0				0	0		0	0	0	1.25	0
# Barnacles	0	0	0	0		0	0				0	0		0	0	0	1.00	0
# Scallop	0	0	0	0		0	0				0	0		0	0	1.00	0	0
% Tube worms	0	0	0	0		0	0				0	0		0	0	0	0	0
% *Modiolus*	1.00	3.00	1.00	0		0	0				0	0		3.00	1.00	3.00	6.25	5.14
% Sponge	0.50	0.50	0	0		0	0				0	0		1.50	5.00	2.42	3.25	6.50
% Tunicate	0	0.50	0	0		0	0				0	0		0	0	0	1.11	0
% Crustose algae	3.75	0	0	0		0	0				0	0		0	0	0	0	0
% Unknown/other	0	0	0	1.00		0	0				0	0		0	0	0	1.17	0
% Burrows	0	1.00	0	1.00		3.00	0				0	0.50		0	0	0	0	0
% Bioturb	0	0	0	0		0	0				1.00	3.00		2.00	3.00	0	4.67	15.00
% Cover	4.13	1.76	0.55	2.00		3.00	0				1	1.75		4.23	10.50	4.75	11.72	10.38
# Species	2.25	2.00	2.00	0		1	0				0	0.5		3.29	4.00	3.33	4.67	3.22

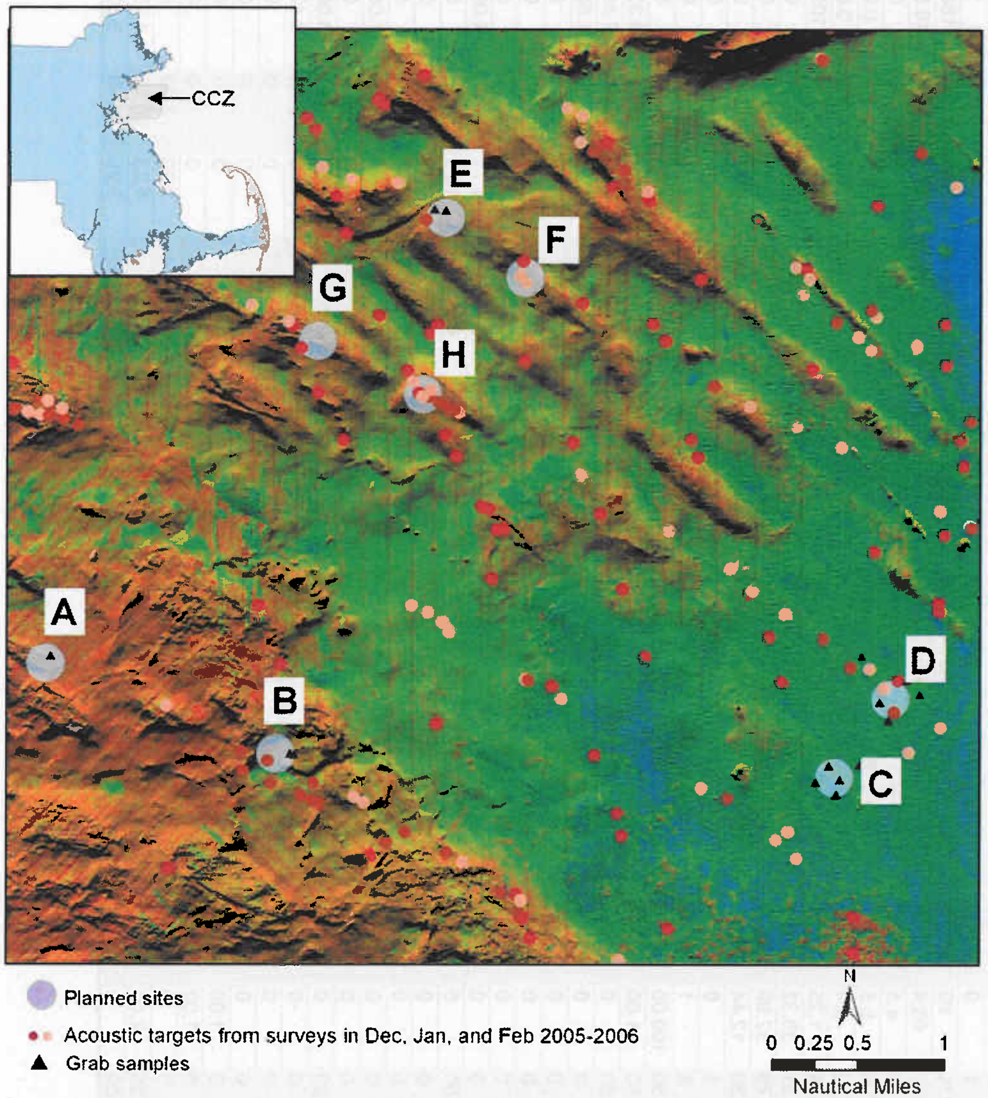


Figure 1. Site locations. Planned sites without grabs (triangles) were analyzed by photo only due to hard bottom.

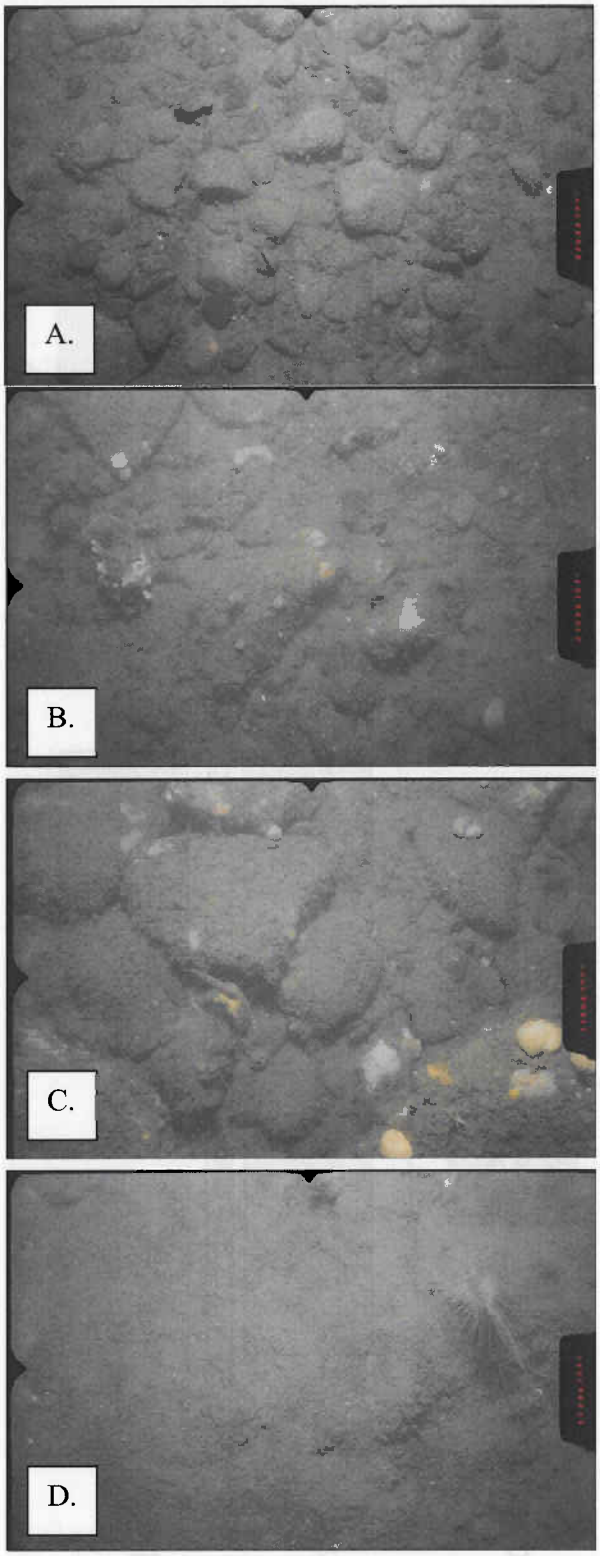


Figure 2. Sample images from study sites. A) Site 1A; B) Site 6C; C) Site 17G; D) Site 18H.

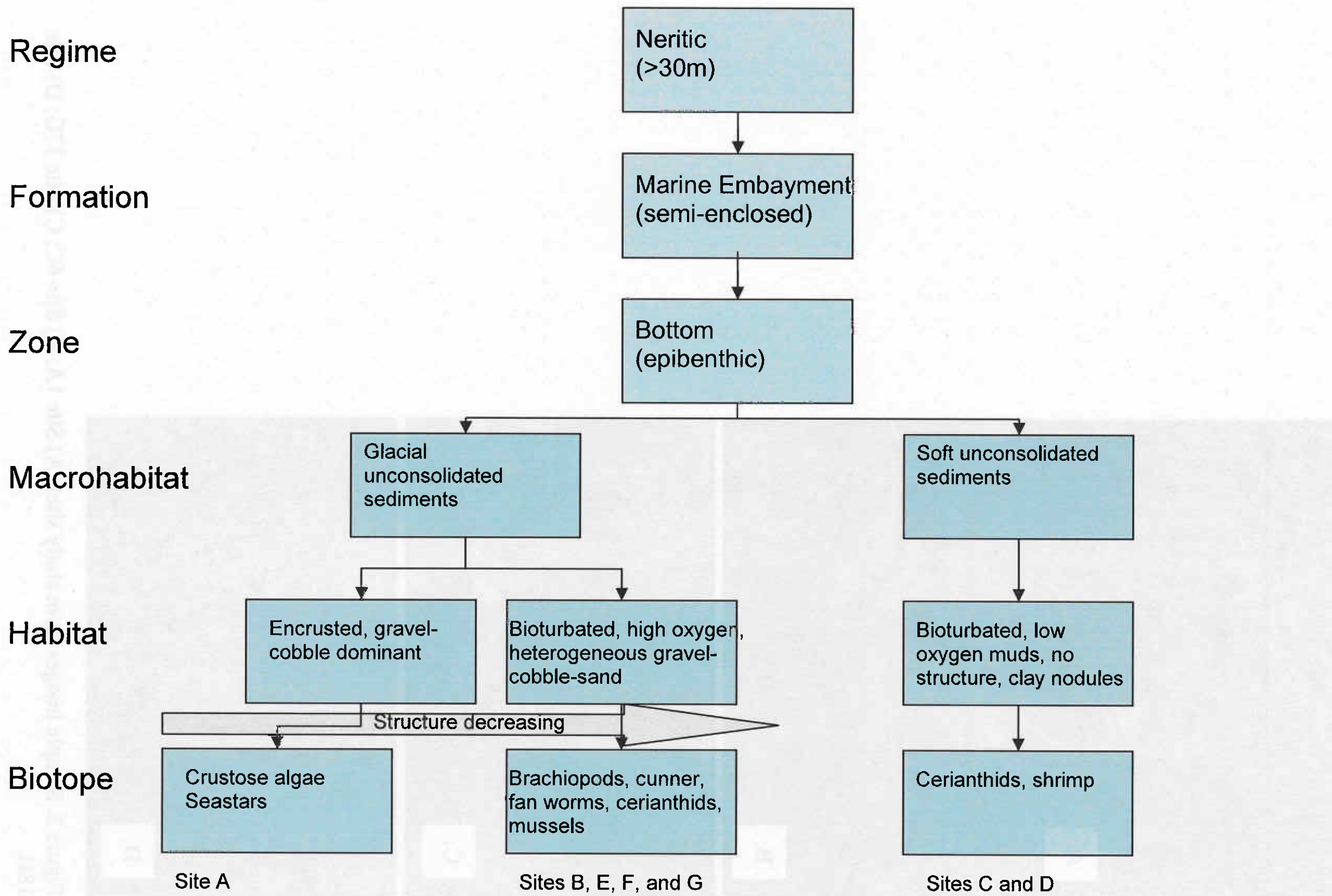
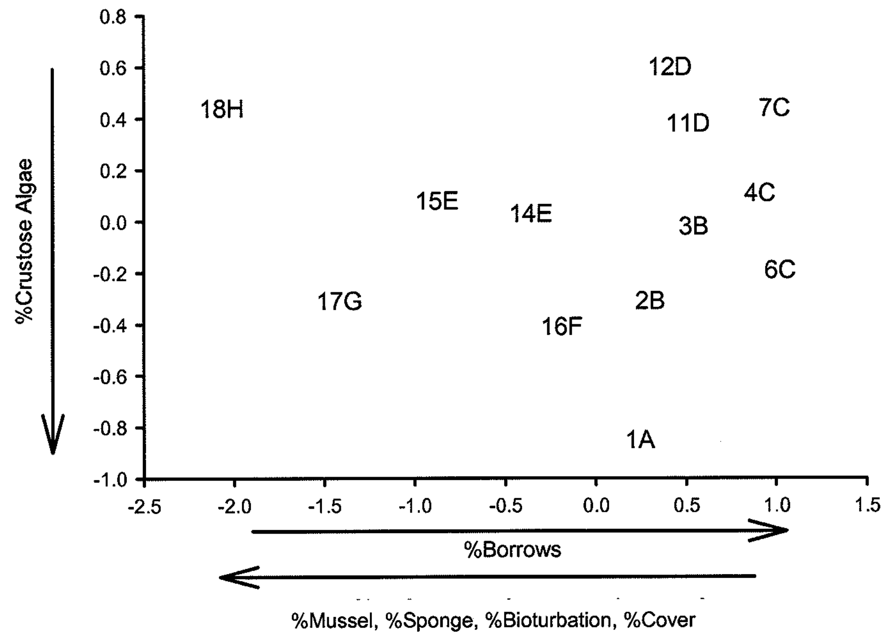


Figure 3. Classification of sites, based on the NOAA system (Madden, Grossman et al. 2005).

A.



B.

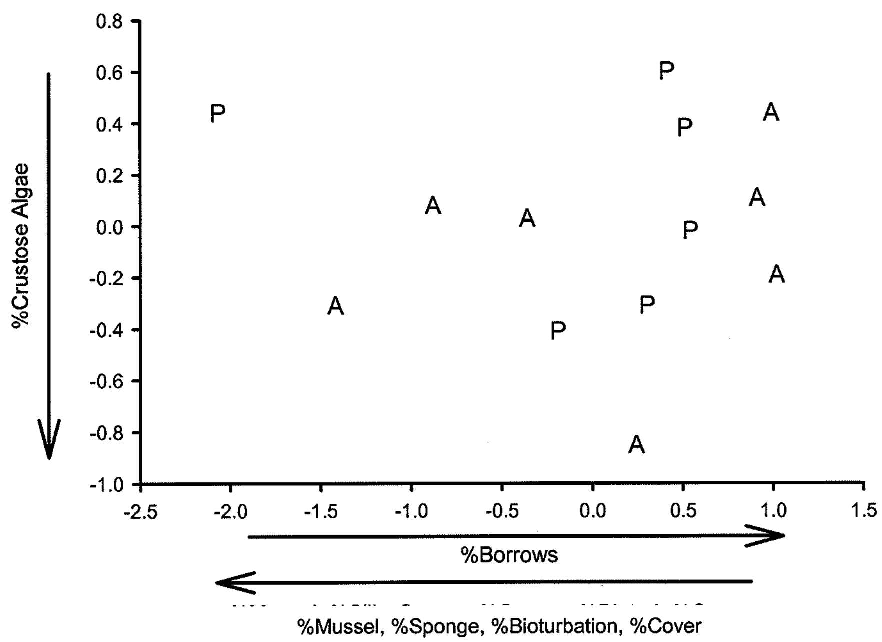


Figure 4. Nonmetric multidimensional scaling of biological data expressed as a percentage. A) With stations labeled, B) with presence (P) or absence (A) of cod labeled.