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Preliminary Analysis of Biogeographic units for the Scotian Shelf

by

Kees Zwanenburg, Tracy Horsman, and Ellen Kenchington
Department of Fisheries and Oceans, Dartmouth, Nova Scotia, Canada

Background and Introduction

In 2008 the Conference of the Parties (COP) to the Convention on Biological Diversity (CBD) adopted scientific criteria (Decision IX/20) for identifying ecologically or biologically significant marine areas (EBSAs) in need of protection (their Annex I) and scientific guidance for designing representative networks of marine protected areas (their Annex II). The criteria for identification of EBSAs are based on seven attributes:

1. Uniqueness or rarity
2. Special importance for life history of species
3. Importance for threatened, endangered or declining species and/or habitats
4. Vulnerability, fragility, sensitivity, slow recovery
5. Biological productivity
6. Biological diversity
7. Naturalness,

while the required properties and components for MPA networks are:

1. Ecologically and biologically significant areas
2. Representativity
3. Connectivity
4. Replicated ecological features
5. Adequate and Viable sites.

Delineation of spatial management units is prerequisite to establishment of an effective ecosystem approach to management of human activities in marine ecosystems. Biogeographic classification has been described as "fundamental for marine spatial planning and can serve as a framework for a number of uses from assessment and monitoring to marine protected areas network design" (CBD 2009).

Canada held a workshop in June of 2009 to evaluate various biogeographic classification schemes and to reach consensus on a single scheme to apply within its EEZ (DFO 2009). They delineated 12 biogeographic zones or ecoregions linked to physical oceanographic and geological features underpinned by the control these have on species distributions (DFO 2009, Figure 1).

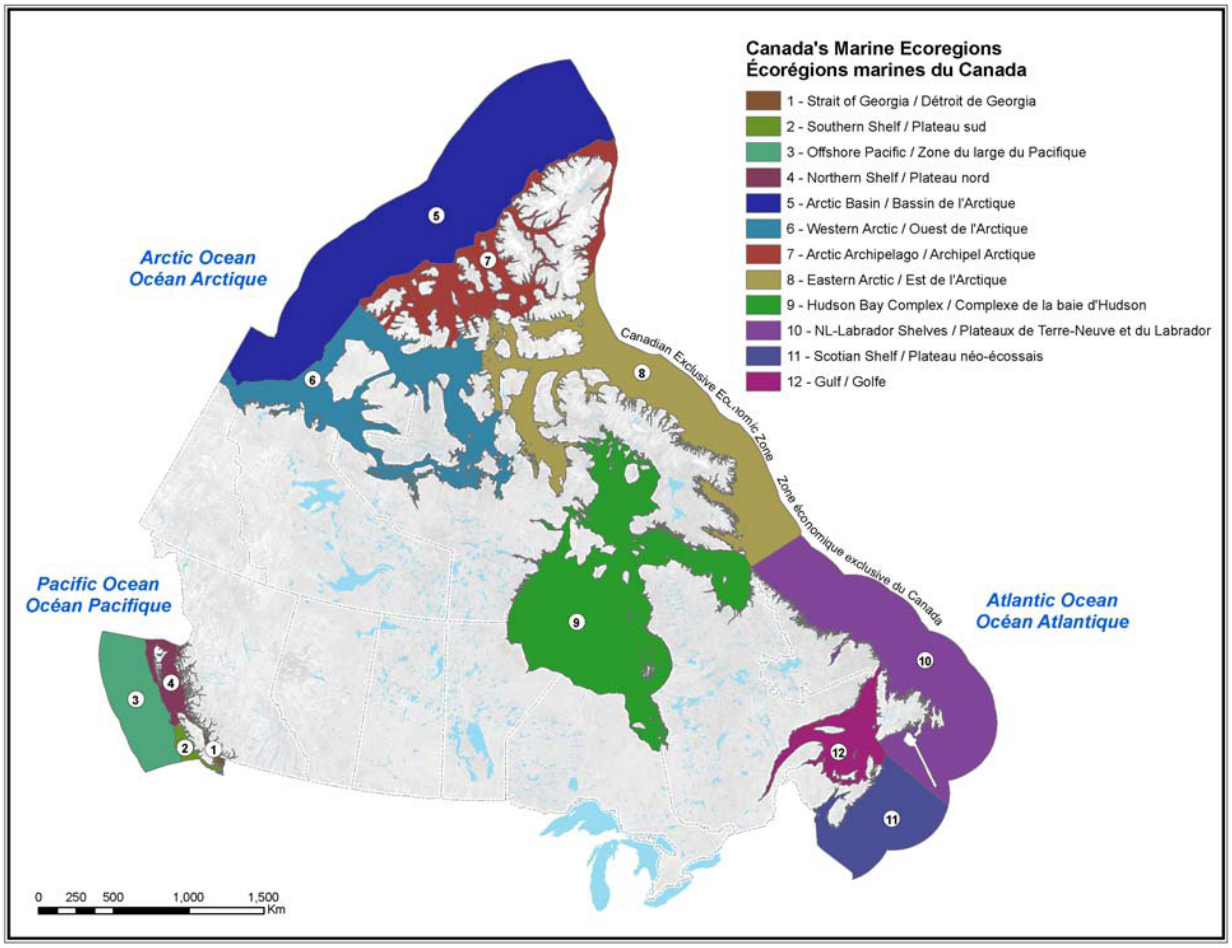


Figure 1. Canadian marine biogeographic zones recommended by the June 2009 National Workshop on Biogeographic Classification (DFO 2009).

The NAFO WGEAFM considered this issue at its first meeting in June of 2008 (NAFO 2008), specifically with its Terms of Reference 1: *To identify regional ecosystems in the NAFO Convention Area*. They presented the results of a spatially and temporally extensive set of observations of physiographic, oceanographic, and biotic variables to identify regions of biophysical similarity / dissimilarity in the US Northeast Atlantic continental shelf to delineate bioregions. This work was presented as a white paper by M.J Fogarty and C. Keith.

Here, we examine a similar set of variables to identify regions of biophysical similarity / dissimilarity on the Scotian Shelf Biogeographic Zone (Figure 1). A complementary analysis of the NL-Labrador Shelves Biogeographic Zone is also in progress. Identification of such bounded areas will allow for informed decision making in the establishment of networks of MPA's both within such zones and between zones.

Our goal is to objectively evaluate the biophysical data sets for these regions collected over the past four decades using a number of statistical and geospatial techniques to determine their spatial structure. These techniques will be used to identify the boundaries between areas of biophysical similarity and dissimilarity (essentially bio-regions).

This work contributes to the global knowledge-base and experience in the application biogeographic classification systems, a requirement identified by scientific and technical experts at the CBD expert workshop in October, 2009, convened to provide scientific and technical guidance on the use and further development of biogeographic classification systems (UNEP/CBD/EW-BCS&IMA/1/2, 2 October 2009).

Methods

To the extent possible we have attempted to replicate the analysis presented in the NEFSC discussion paper on the delineation of regional ecosystem units on the U.S. Northeast Continental Shelf (Fogarty and Keith) for the adjacent large marine biogeographic area, the Bay of Fundy and Scotian Shelf. Due to differences in the respective oceanographic and biological sampling programs between these regions exact replications of methods is not possible, but similar data are generally available.

Consistent with the Fogarty & Keith assessment, all data were aggregated at 10 minute latitude by 10 minute longitude units, where the mean value for each variable is calculated for each unit, unless otherwise stated. Maps of the aggregated data are displayed using quintiles breaks, although all analysis of these variables is based on the unclassified, mean values for the 10 minute aggregation units.

Table 1. A Comparison of the Data used in the Fogarty and Keith Delineation of Regional Ecosystem Units Project to data used in the Scotian Shelf Analysis.

Data Type/Theme	**US Data (Fogarty and Keith)**			**Canadian Data**
Physiographic	**Data Type**	**Sampling Method**	**Units**	
Bathymetry	Raster	Soundings / hydroacoustics	m	CHS's Atlantic Bathymetric Data (15 arc second resolution), raster, soundings recorded in metres
Surficial sediment	Vector	Benthic grab	Not specified	GSC surficial geology, vector, classified sediment types
Physical Oceanography and Hydrographic				
Sea surface temperature	Raster	Satellite (SeaWIFs)	C	BIO's Hydrographic Data Base 01/01/1900 - 12/17/2001. Raster data, degrees C, 12 minute resolution
Annual SST temperature span	Raster	Satellite (SeaWIFs)	C	BIO's Hydrographic Data Base 01/01/1900 - 12/17/2001. Raster data, degrees C, 12 minute resolution
Water column stratification	Vector	Shipboard hydrographic measurments	Sigma-t units	BIO's Hydrographic Data Base 01/01/1900 - 12/17/2001. Raster data, mixed layer depth (m), 12 minute resolution
Bottom temperature	Not used			BIO's Hydrographic Data Base 01/01/1900 - 12/17/2001. Raster data, degrees C, 12 minute resolution
Annual bottom temperature span				BIO's Hydrographic Data Base 01/01/1900 - 12/17/2001. Raster data, degrees C, 12 minute resolution
Biotic				
Satellite derived estimates of primary production	Raster	Satellite (SeaWIFs)	gC m^{-2} yr^{-1}	Satellite derived estimates of chlorophyll a (from SeaWiFs) [used as a surrogate for primary production]. Vector from Raster.
Shipboard estimates of surface chlorophyll	Raster	Shipboard measurements	dimensionless	Not included.
Zooplankton displacement volume	Vector	ECOMON plankton sampling	Cc 100 m^{-3}	Zooplankton wet weight data from the AZMP program is substituted. Vector.
Benthic biomass	Vector	Benthic grab/sled	g m^{-2}	Not included. No comparable data, no regional benthic survey program

				exists
Nektonic and epibenthic biomass	Vector	NEFSC groundfish survey	Kg/tow	DFO research vessel summer trawl survey.
Species richness (trawl caught organisms)	Vector	NEFSC groundfish survey	Number/tow	DFO research vessel summer trawl survey.
Presence/absence of marine mammals and sea turtles* (Endangered spp)	Vector	Arial/shipboard sighting program	Presence / absence	MarWhale data obtained from VDC. - **Note: It appears that MarWhale does NOT include observations from Whitehead Lab @ Dal.*
Presence/absence of coral*	Vector	Arial/shipboard sighting program	Presence / absence	ERD coral database, points

* considered focal species of particular management concern

Bathymetry

The bathymetric data used in our analysis is based on the Canadian Hydrographic Service (CHS) Atlantic Bathymetric Compilation (ABC) dataset. The ABC dataset has variable resolution up to 64 metre horizontal resolution in some areas. The ABC data employed in our analysis is resolved to 15 arc second (roughly equivalent to 500 metre in our study area). Using this data the mean depth was calculated for each of the 10 minute latitude by 10 minute longitude aggregation units.

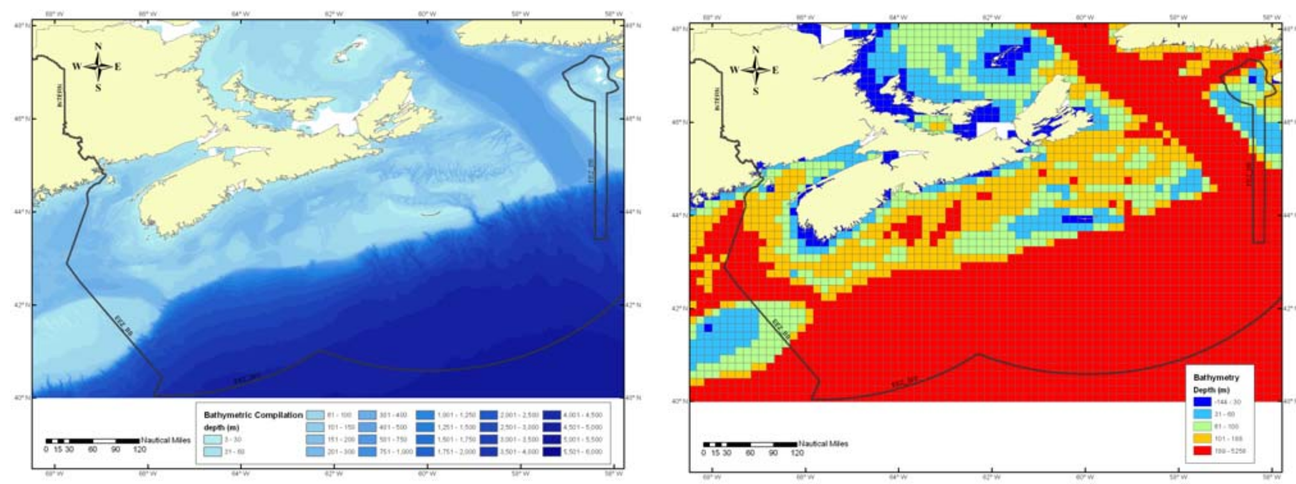
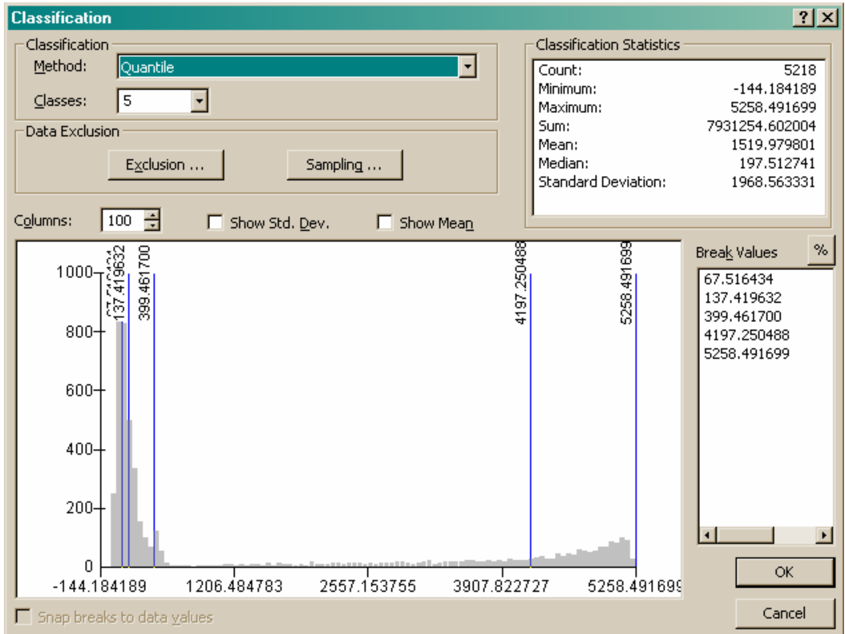


Figure 2. The map on the left shows the Canadian Hydrographic Service's Atlantic Bathymetric Compilation (ABC) data for the region. The map on the rights shows the ABC data binned in rectangles 10 minutes latitude by 10 minutes longitude for the study area showing mean depth (m) per rectangle using the same class breaks as Fogarty & Keith.

Statistics and distribution of the original bathymetry data:



Surficial Sediments

We calculated the dominant sediment type as the largest proportion of area within each of the aggregation units based on the Scotian Shelf Surficial Geology open source data from the Geological Survey of Canada (GSC) (source: http://gdr.nrcan.gc.ca/digmap/index_e.php).

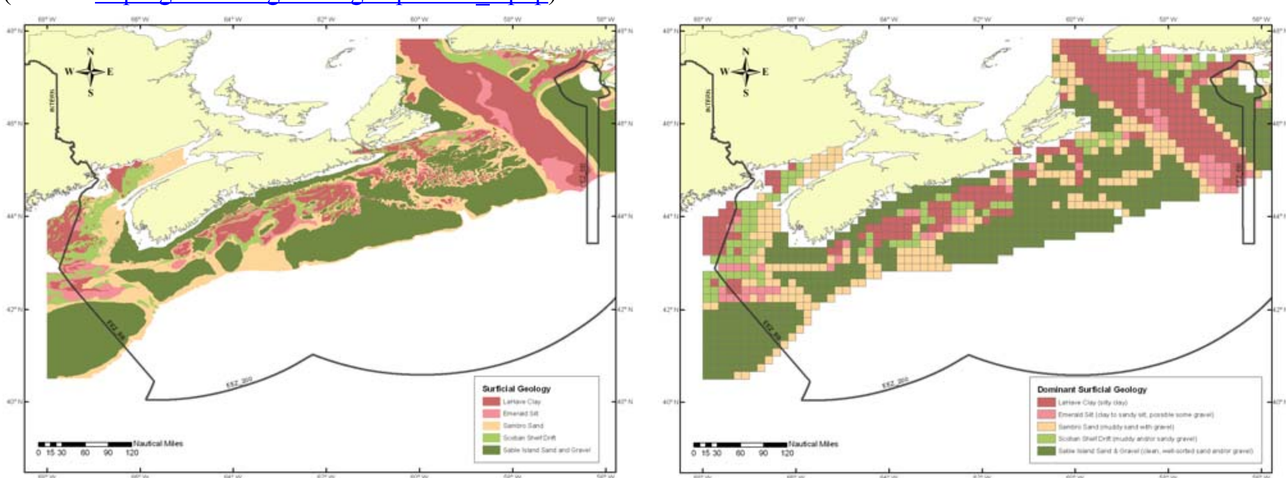
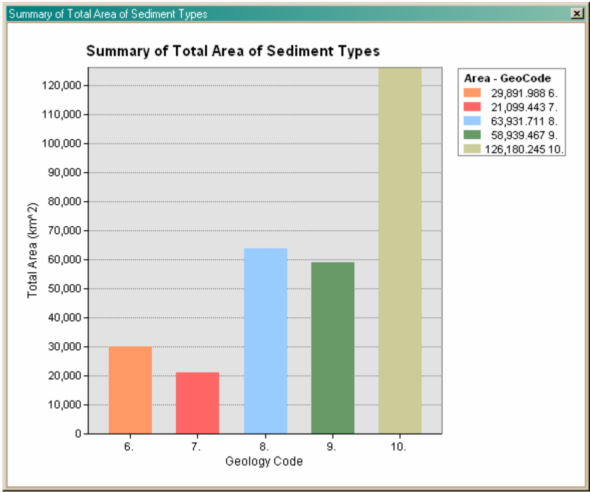


Figure 3. Map on the left shows the original surficial geology data with the sediment classifications for the Maritimes Region. The map on the right shows the dominant sediment classification for each of the 10 minutes latitude by 10 minutes longitude rectangles.

Summary of Surficial Sediments:



Geology codes:

- Scotian Shelf Drift (6)
- Emerald Silt (7)
- Sambro Sand (8)
- LaHave Clay (9)
- Sable Island Sand and Gravel (10)

Sea Surface Temperature

Sea surface temperature data was extracted from the Hydrographic Data Base at the Bedford Institute for the time interval 01/01/1900 - 12/17/2001. The data has a 12 minute resolution.

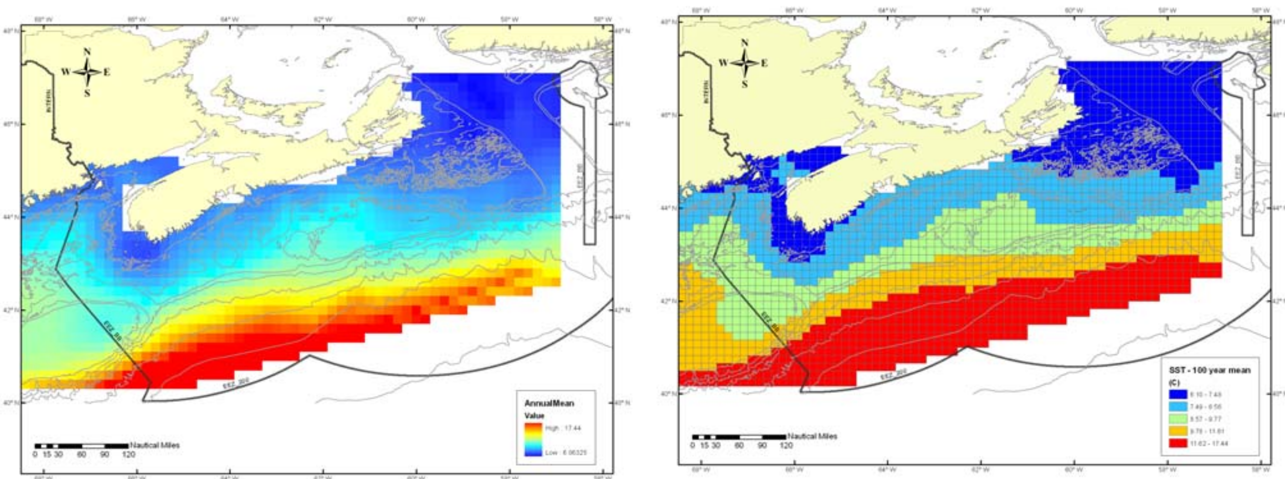
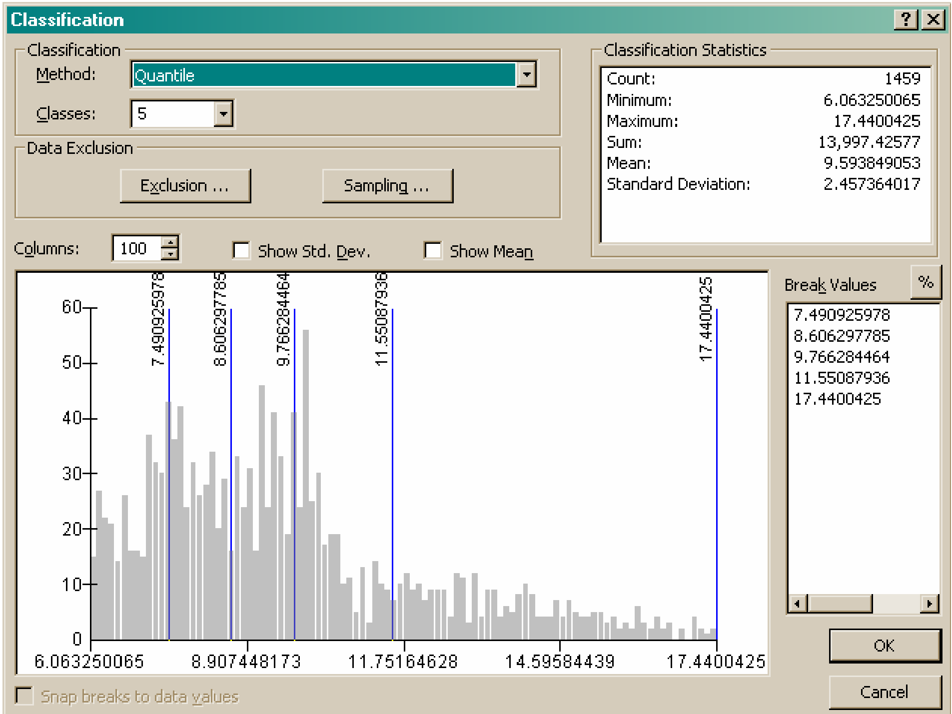


Figure 4a. The map on the left shows the 100 year mean annual sea surface temperature (^oC) for the region. The map on the right shows the same data binned in rectangles 10 minutes latitude by 10 minutes longitude for the study area showing mean annual SST per rectangle using quintile class breaks.

Statistics and distribution of the original annual mean SST data:



Bottom Temperature

Bottom temperature data was extracted from the Hydrographic Data Base at the Bedford Institute for the time interval 01/01/1900 - 12/17/2001.

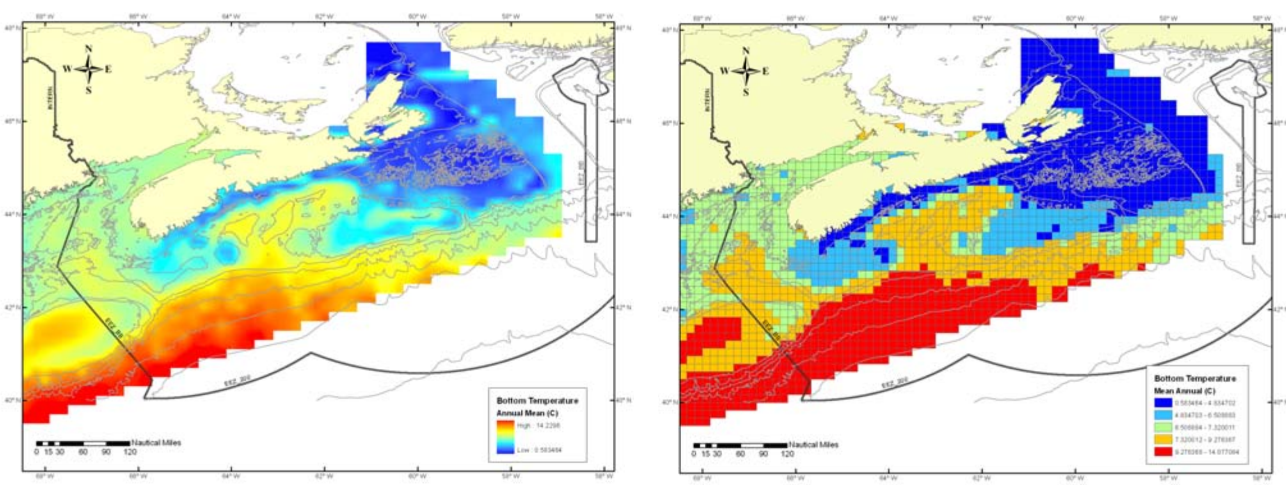
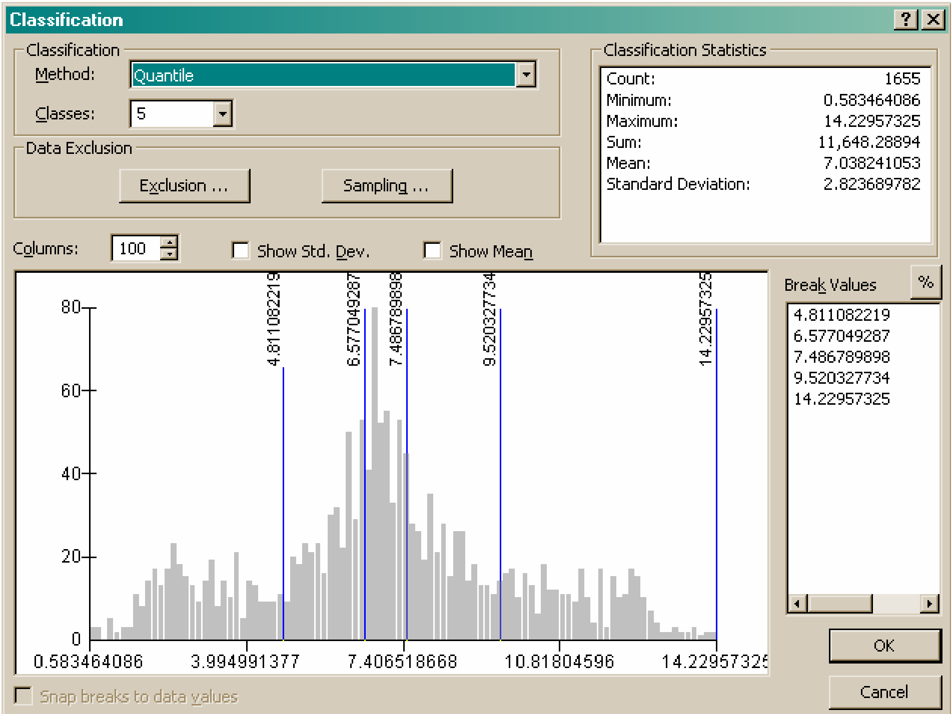


Figure 4b. The map on the left shows the 100 year mean annual bottom temperature (^oC) for the region. The map on the right shows the same data binned in rectangles 10 minutes latitude by 10 minutes longitude for the study area showing mean annual bottom temperature per rectangle using quintile class breaks.

Statistics and distribution of the original mean annual bottom temperature:



Sea Surface Temperature Span

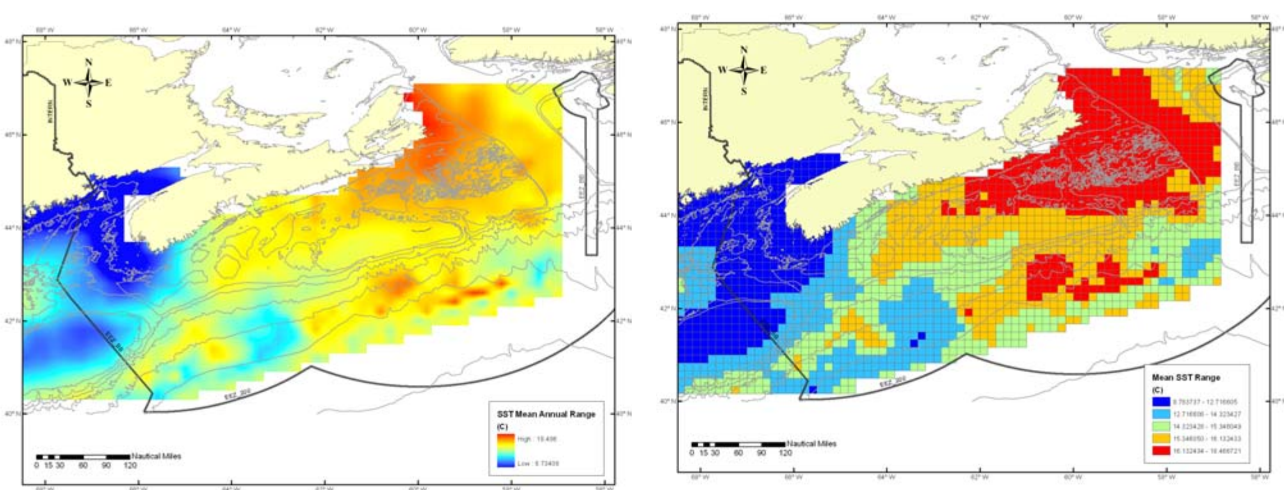
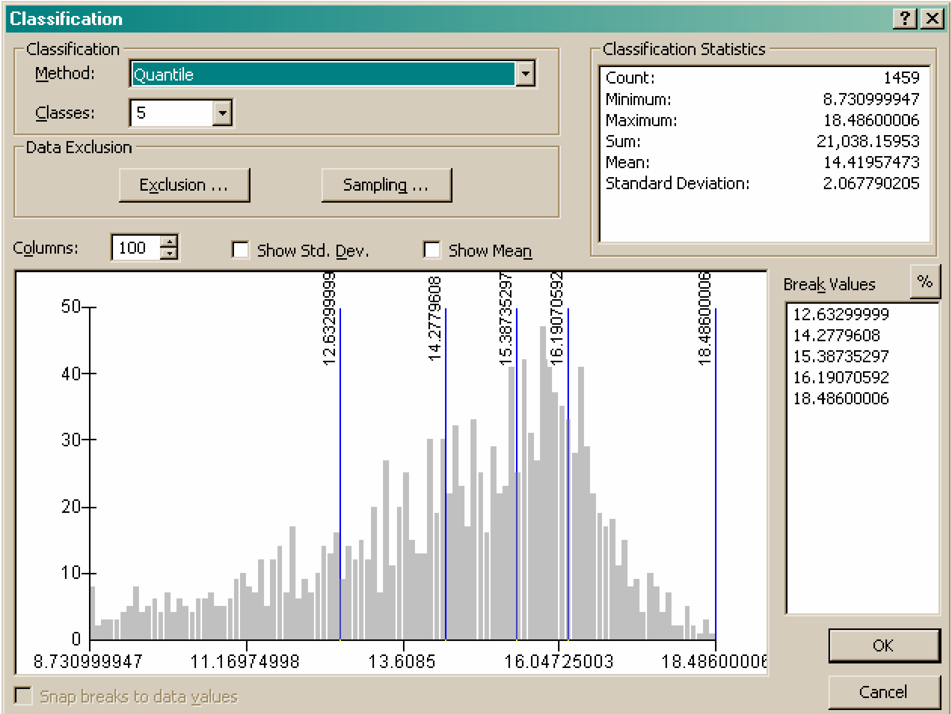


Figure 5a. The map on the left shows the 100 year mean annual range in sea surface temperature (^oC) for the region. The map on the right shows the same data binned in rectangles 10 minutes latitude by 10 minutes longitude units for the study area using quintile class breaks.

Statistics and distribution of the original annual range in SST data:



Bottom Temperature Span

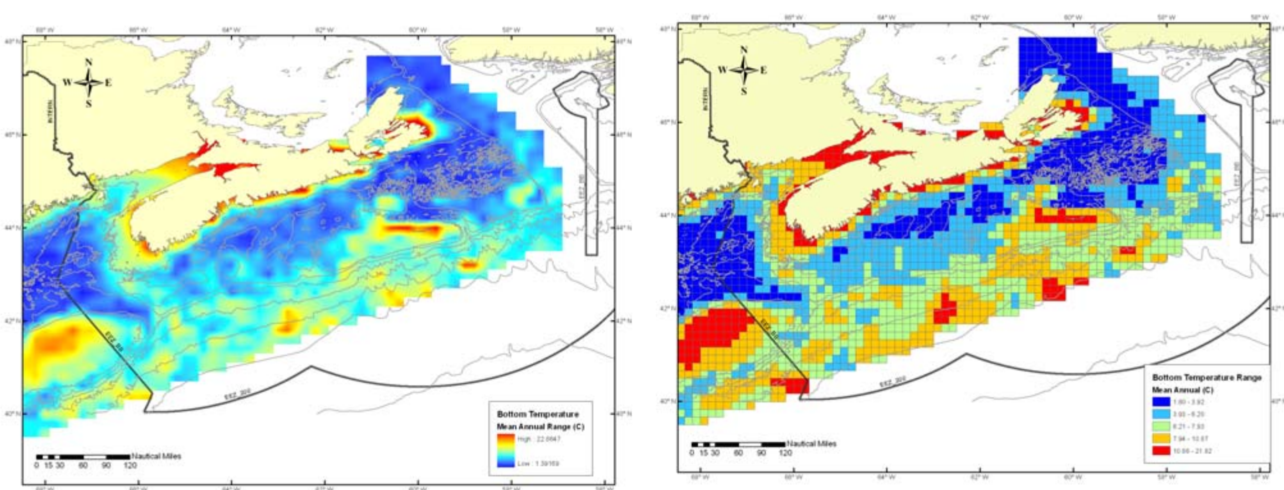
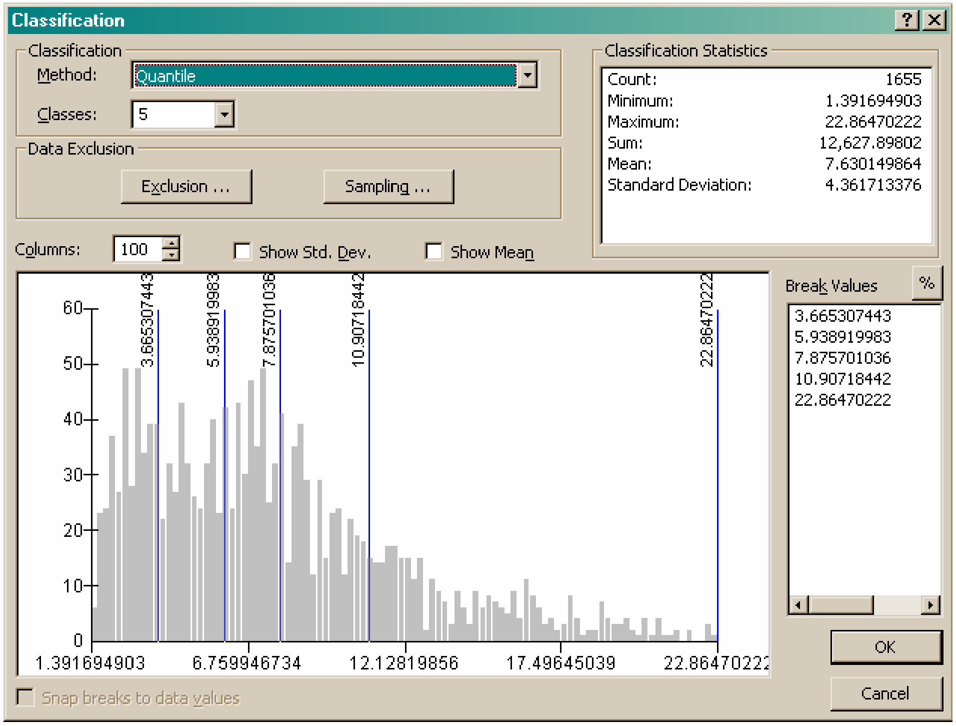


Figure 5b. The map on the left shows the 100 year mean annual range in bottom temperature (°C) for the region. The map on the right shows the same data binned in rectangles 10 minutes latitude by 10 minutes longitude units for the study area using the quintile class breaks

Statistics and distribution of the annual range in bottom temperature:



Vertical Structure - Mixed-layer Depth

The characteristics of the surface mixed layer, namely the depth and the mean temperature, salinity and density (expressed as sigma-t, σt), were calculated from temperature and salinity profiles collected over the Scotian Shelf and the Gulf of Maine areas and spanning the years 1900 - 2003 (Casault et al. 2003). The physical structure of the vertical water-column was evaluated using the mixed-layer depth determined from the observations of the minimum depth where the density gradient (gradient_z (sigma-t)) was equal to or exceeded 0.01 (kg m^{-4}). (Harrison et al. 2009).

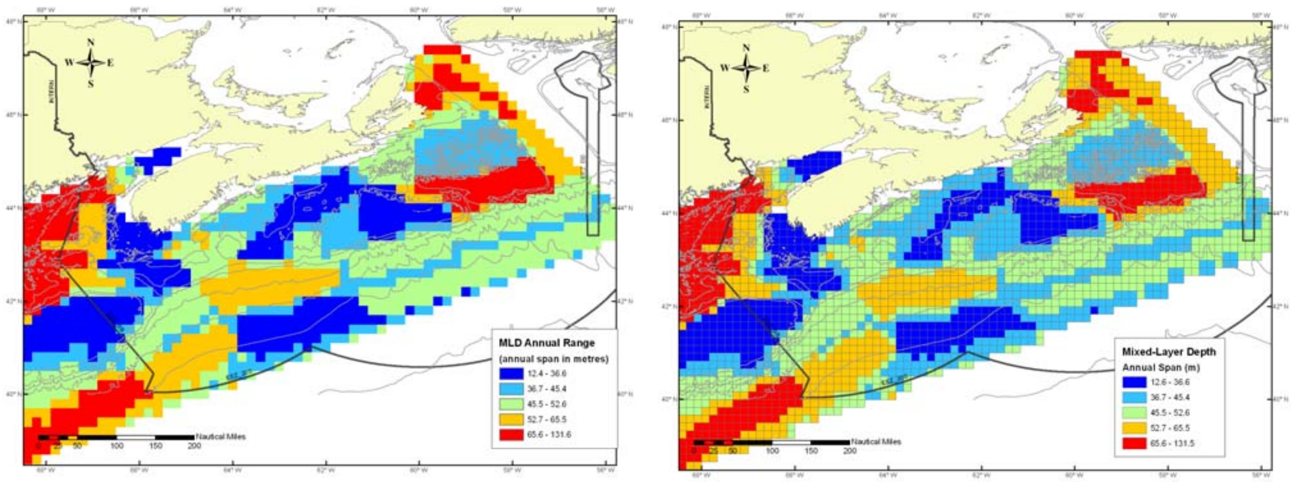


Figure 6a. Annual range of the mixed layer depth.

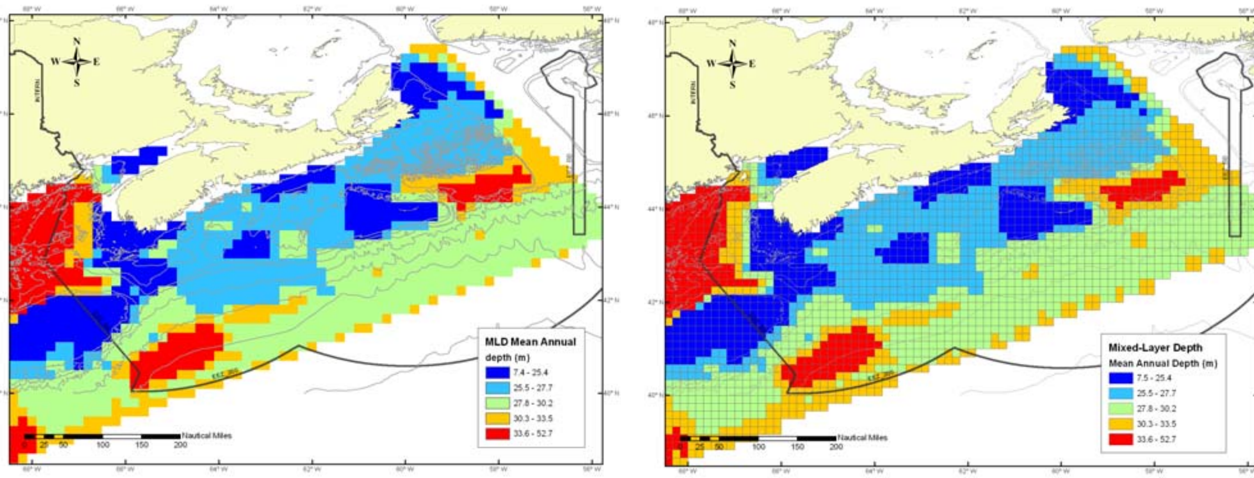


Figure 6b. The mean annual mixed layer depth.

Chlorophyll Concentration

Estimates of surface chlorophyll were obtained from DFO's Ocean Colour Database (OCDB) (http://www.mar.dfo-mpo.gc.ca/science/ocean/database/Doc2008/ocdb2008app.html) These data represent semi-monthly composites of SeaWiFS chlorophyll (chl_oc4) estimates for the North Atlantic (39N - 62.5N, 42W to 71W), from the second half of September 1997 to December 23, 2004. The raw SeaWiFS LAC data were captured at a nominal resolution of 1 km (at nadir) through the HRPT (High Resolution Picture Transmission) satellite dish operated by the Biological Oceanography section of Bedford Institute of Oceanography. The data were processed using SeaDAS (available for download from NASA) version 4.5 and 4.8. The difference between these two versions is not in the chlorophyll algorithm itself. The processed chlorophyll (chl_oc4) data were then remapped at a 1.5km x 1.5km resolution to the standard region using a Mercator projection. This slightly coarser resolution had been chosen for disk space considerations. Composites were created using SeaDAS/IDL, by taking the average of all valid chlorophyll values for a given lat/lon grid point from all remapped files corresponding to the given semi-monthly period.

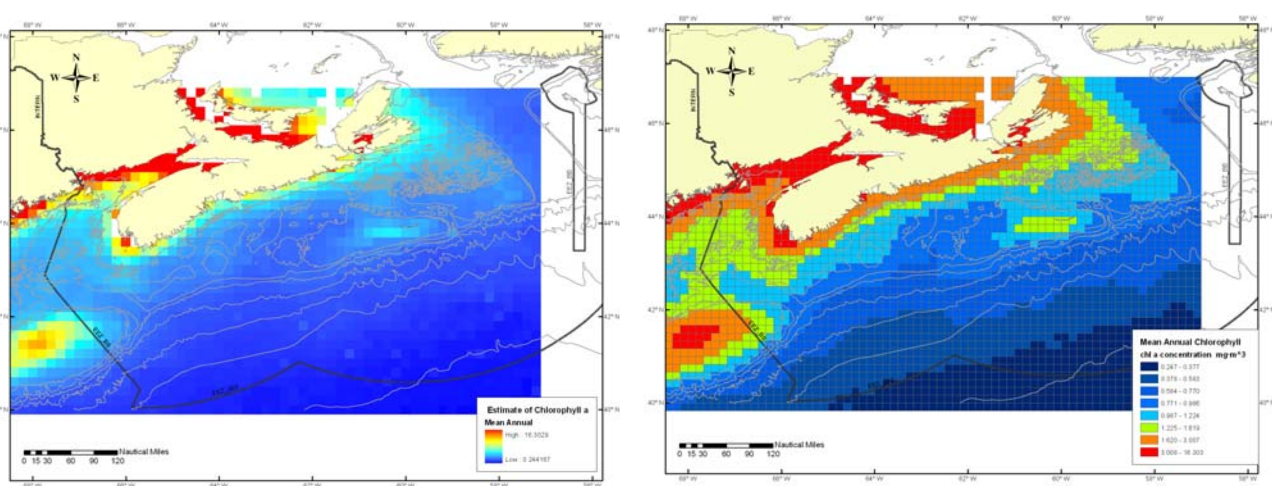
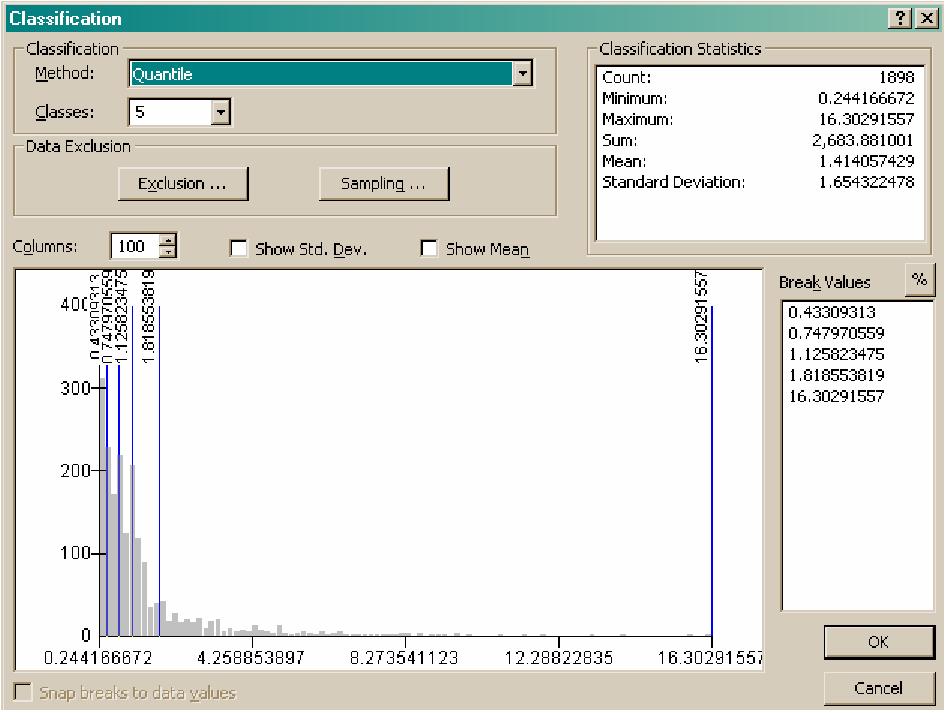


Figure 7. The map on the left shows the mean annual estimates of chlorophyll a for the region based on the semi-monthly composites from fall 1997 to winter 2004. The data has a 12 minute resolution. The map on the right shows the same data binned in rectangles 10 minutes latitude by 10 minutes longitude units for the study area using the 8 quantile class breaks.

Statistics and distribution of the estimated chlorophyll a data (12 minute resolution):



Zooplankton Biomass (Wet Weight)

The Atlantic Zone Monitoring Program (AZMP) that was implemented in 1998 is the best source of synoptic zooplankton data for the region. Figure 8a shows ongoing monitoring in the region. As illustrated in Figure 8b the distribution of sampling is not sufficient for drawing conclusions about local variations in zooplankton abundance or composition. Most of the zooplankton sampling in the Scotian Shelf biogeographic region occurs with 25 km of the AZMP lines (785 of 1434 records, ~55%). The AZMP collects and analyzes the biological, chemical, and physical field data that are necessary to: 1) characterize and understand the causes of oceanic variability at the seasonal, inter-annual, and decadal scales; 2) provide multidisciplinary data sets that can be used to establish relationships among the biological, chemical, and physical variables; and 3) provide adequate data to support the sound development of ocean activities. AZMP involves the Gulf, Québec, Maritimes, and Newfoundland regions of DFO. Its sampling strategy is based on: 1) seasonal and opportunistic sampling along “sections” to quantify the oceanographic variability in the Canadian NW Atlantic shelf region; 2) higher-frequency temporal sampling at more accessible “fixed sites” to monitor the shorter time scale dynamics in representative areas; 3) fish survey and remote sensing data to provide broader spatial coverage and a context to interpret other data; and 4) data from other existing monitoring programs such as CPR (Continuous Plankton Recorder) lines, Sea Level Network, nearshore long-term temperature monitoring, toxic algae monitoring, etc., or from other external organizations (e.g., winds and air temperatures from Environment Canada) to complement AZMP data. (http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/azmp-pmza/index-eng.html).

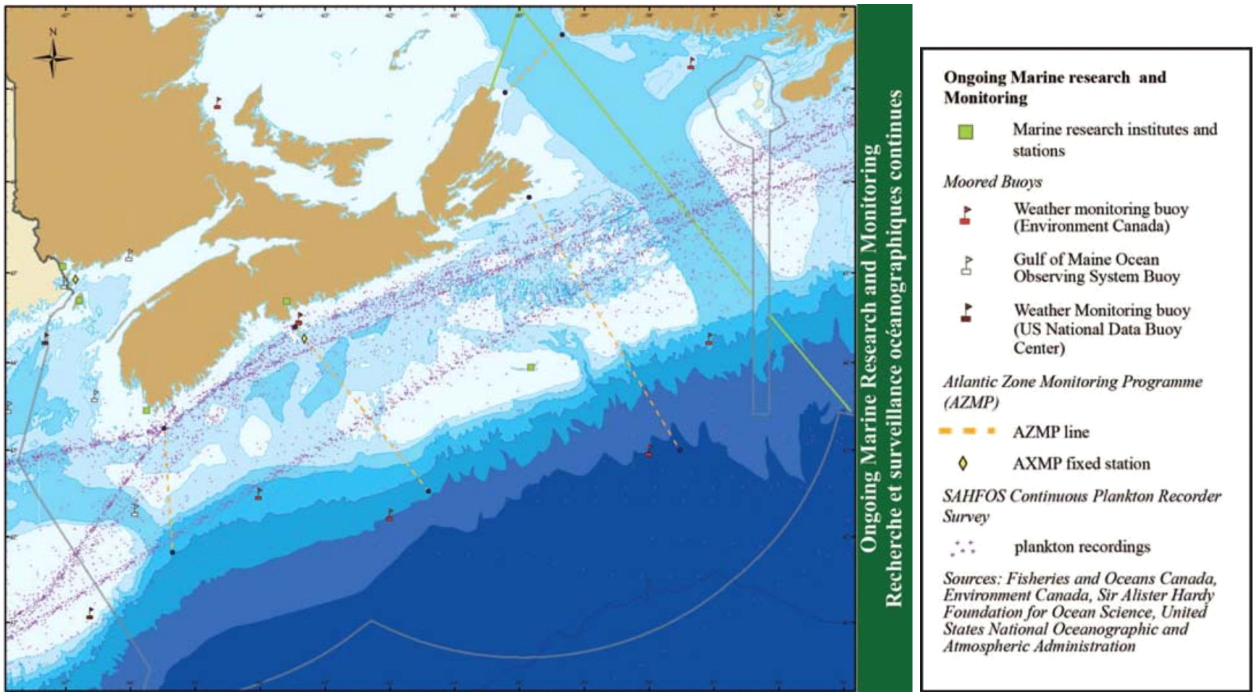


Figure 8a. Ongoing monitoring and research, excerpted from The Scotian Atlas of Human Activities (Breeze and Horsman, 2005)

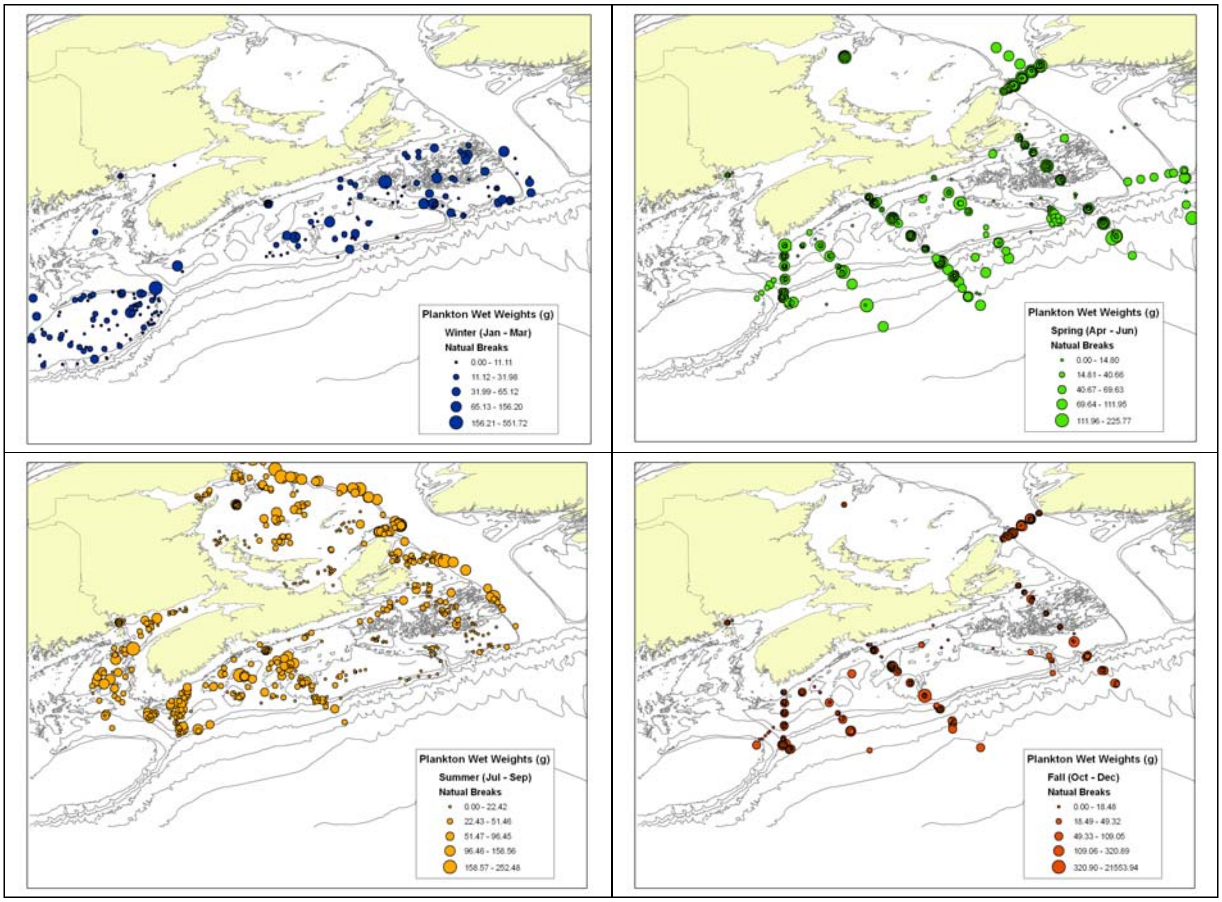


Figure 8b. Compilation of zooplankton wet weight data from 1997 to 2008 (multiple sampling programs) displayed seasonally showing the natural breaks in the data for each season.

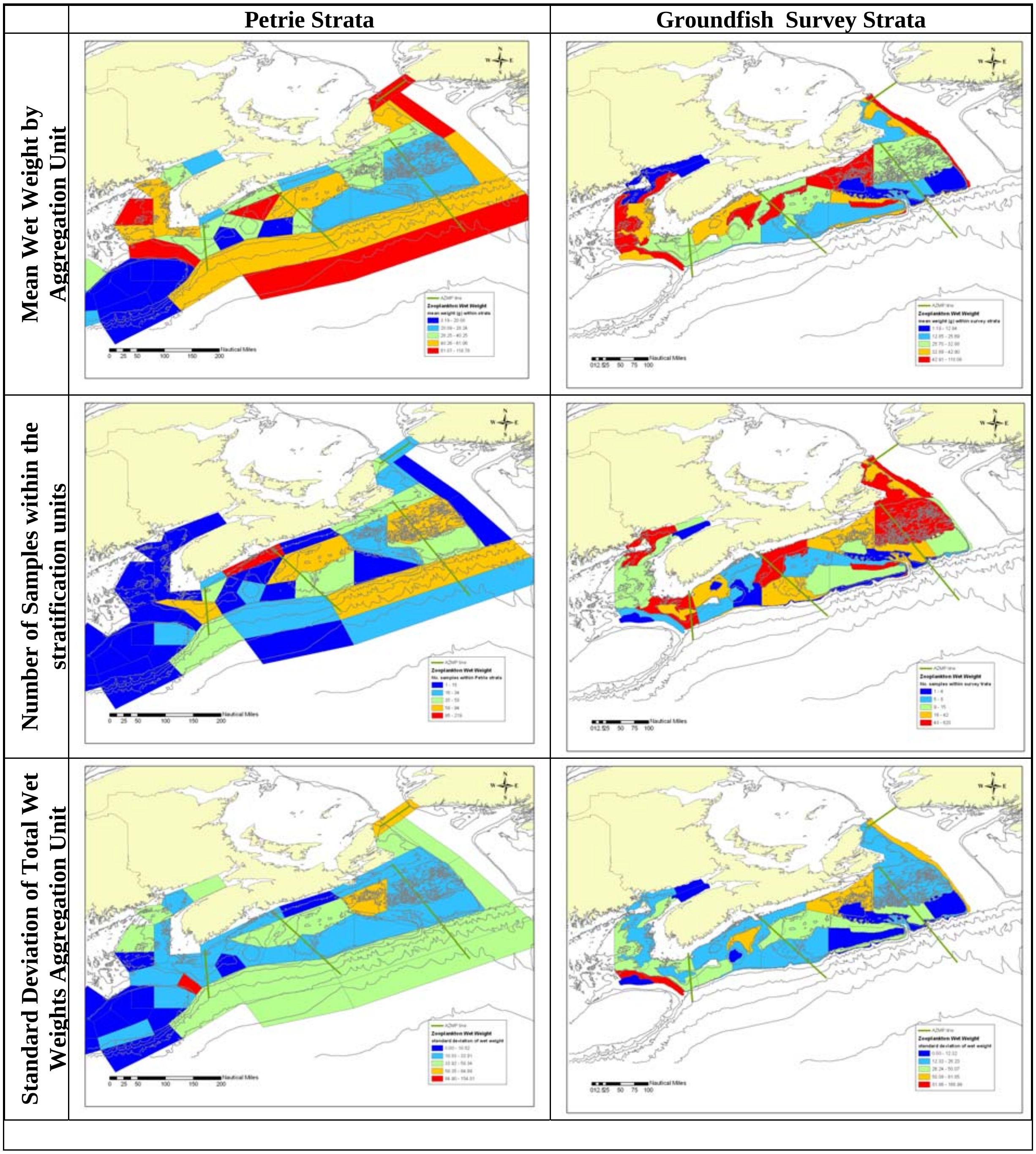


Figure 8c. Statistics for zooplankton total wet weight data aggregated on the "Petrie Boxes" (left column) and the groundfish survey strata (right column).

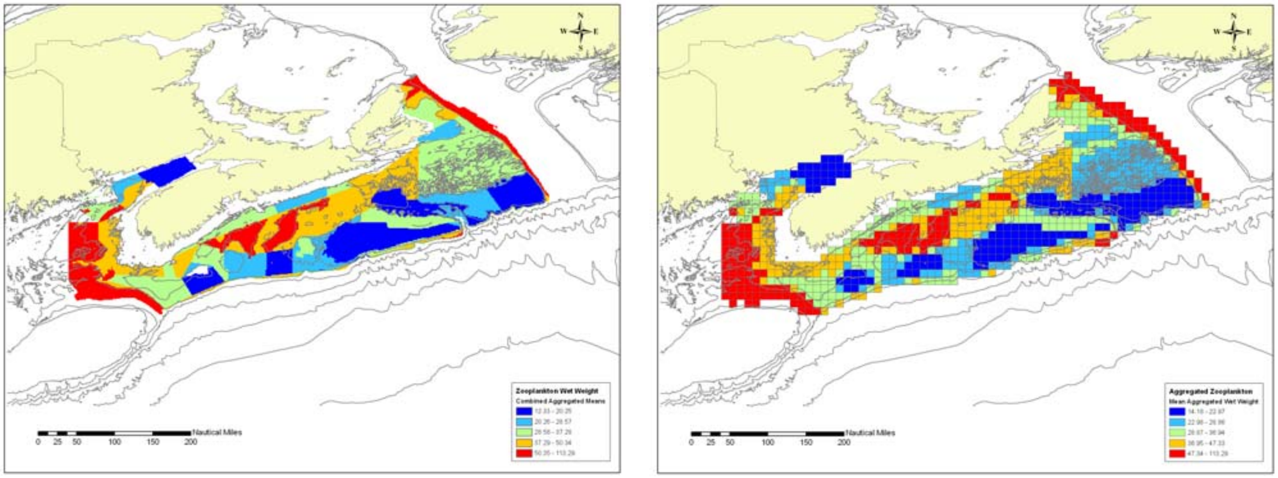
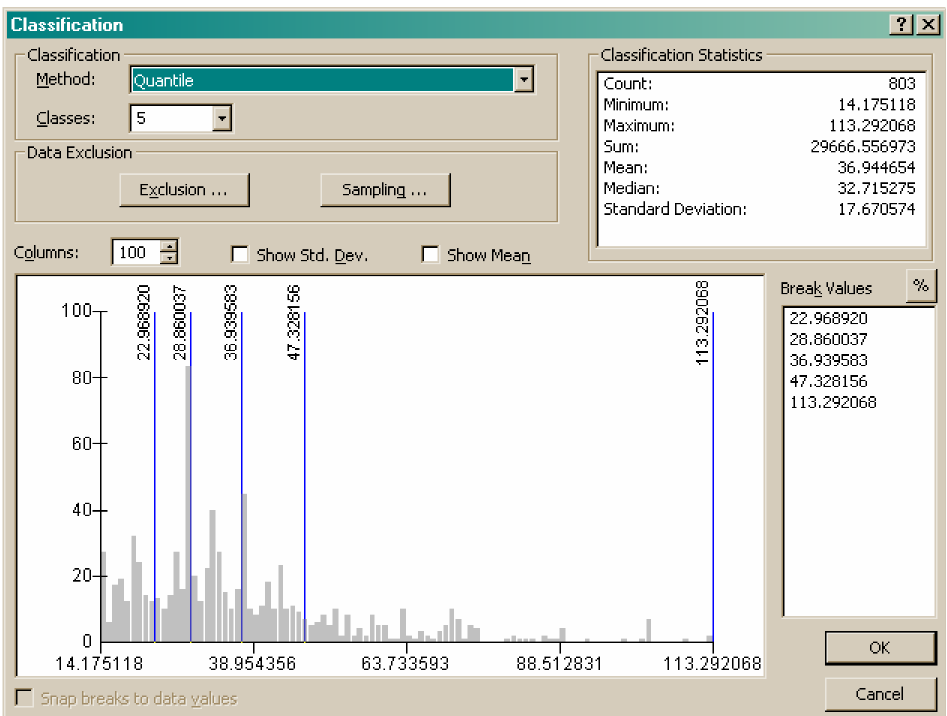


Figure 8d. The map on the left shows the mean wet weight of zooplankton for the combined stratification areas (i.e. mean wet weight was determined with the stratification units for both the Petrie and groundfish survey strata. Here, the mean was calculated between the areas of overlap). The map on the right shows the same data binned in rectangles 10 minutes latitude by 10 minutes longitude units for the study area using the quintile class breaks.

Statistics and distribution of the original zooplankton wet weight data:



Nekton Biomass and Species Richness

We determined the mean biomass of all species caught in the summer groundfish surveys conducted by DFO on the Scotian Shelf and in the Bay of Fundy. The survey uses a random stratified sampling design. The period of data analyzed is from 1970 to 2006 inclusive. Mean nekton biomass (Figure 9) was calculated as the mean weight (kg) per tow. Species richness (Figure 10) was calculated as the mean number of species observed in the tow during the period analyzed.

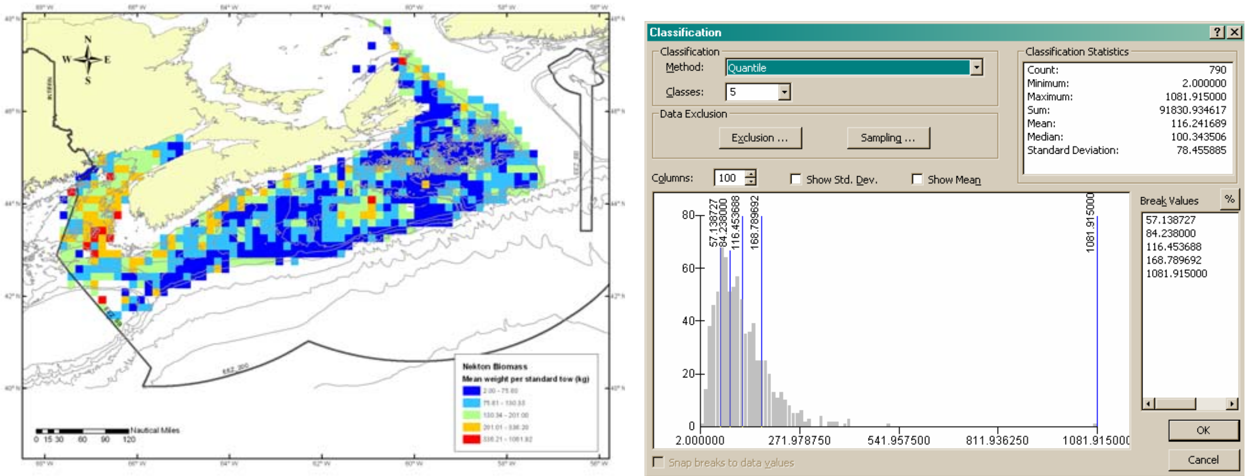


Figure 9. Map on the left shows the mean nekton biomass determined as mean weight (kg) per tow from DFO Scientific Trawl Surveys 1970-2006 binned in rectangles 10 minute latitude by 10 minute longitude. The statistics and distribution of the same data are shown to the right.

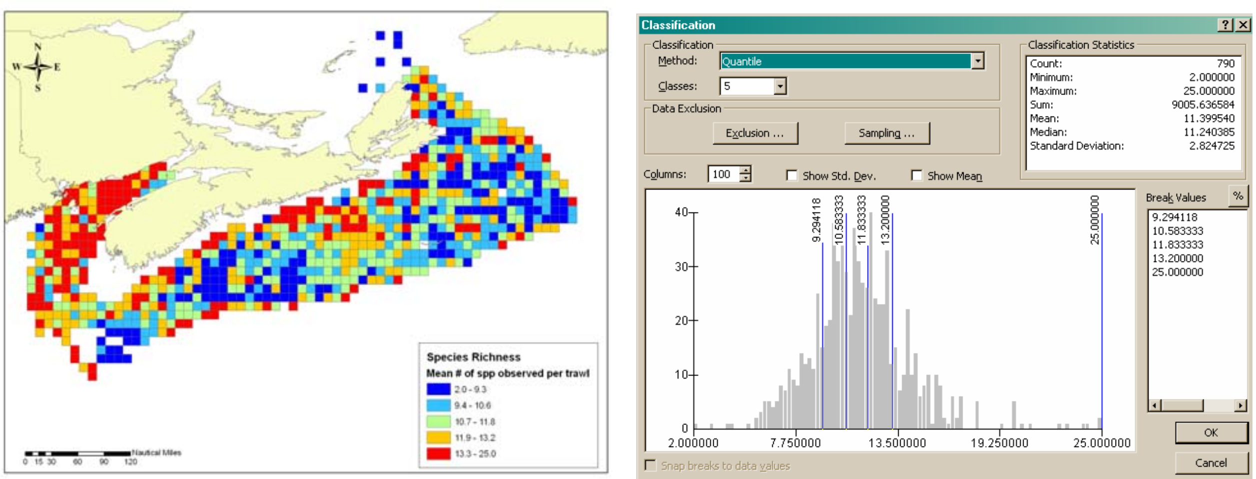


Figure 10. Map on the left shows mean number of species observed per standard tow from the DFO scientific summer survey (1970-2006) displayed in quintiles. The statistics and distribution of the same data are shown to the right.

Analysis

We used principal components analysis (PCA as implemented in Primer[1]) to examine the multivariate structure of the data listed above with the exception of marine mammal sightings and the presence or absence of coral. Given the distributional characteristics of some of the variables we transformed those that displayed right-skewed distributions and normalized all variables (x-meanx/sd) as a pre-treatment.

We plotted the spatial distribution of the principal component scores (Figures 11-16) as estimated from this analysis and also used hierarchical agglomerative clustering (as implemented in Primer) of the component scores to group sampling units (Figures 17 & 18). The choice of cluster numbers is arbitrary in this analysis and is governed mainly by the ultimate purpose of the zones identified. In general there is a lower limit of spatial extent in terms of utility as a management unit. Fogarty et al used a stopping rule based on a minimum number of sampling units (10x10 squares) in the cluster. For this exploratory analysis we examined the spatial distribution of a clusters based on a range of similarity criteria in the clustering algorithm.

The combination of biotic and abiotic variables in a single PC analysis is problematic given the probability of non-linear responses of biotic to abiotic variables. It is also likely that using nekton biomass will mask and obfuscate individual species responses to environmental conditions. We therefore also examined the variance structure of the abiotic variables in isolation. In this instance we included bottom temperature, not included in Fogarty's analysis or in the preceding analysis of the complete biophysical data set. Only the results of these agglomerative clustering of PC scores are presented (Figures 18 & 19) for this analysis. We also examined the distribution of the 30 most prevalent species for each sampling unit in relation to environmental variables by mapping the non-metric multi-dimensional species space (Primer MDS) onto the geographic distribution of sampling unit Z-scores from PC analysis of environmental variables.

Results

Complete Data Set (a la Fogarty and Keith)

The first six eigenvalues accounted for 90.4% of the variance in the Scotian Shelf biophysical data set (Table 2). This indicates that the original 9-dimensional space represented by the data can be reasonably characterized by this six dimensional representation in subsequent analyses. The first three principal components account for 63% of total variance.

Table 2. Eigenvalues and the Proportion of Variance Accounted for by the First Six Principal Components

PC	Eigenvalues	Prop.Variation	Cum. Prop. Variation
1	2.32	25.8	25.8
2	2.14	23.8	49.7
3	1.17	13.0	62.7
4	1.06	11.8	74.4
5	0.735	8.2	82.6
6	0.705	7.8	90.4

The eigenvectors show that the first principal component; which accounts for 25.8% of total variance, is dominated by nekton diversity, nekton biomass and depth. The second principal component (23.8% of variance) is driven mainly by primary production (chlorophyll a concentration), while the third principal component (13.0% of variance) is dominated by surficial geology, mixed layer depth, and nekton biomass. Principal components 4-6 account for 27.8% of variance collectively and are dominated by the annual range of SST, nekton diversity respectively.

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[1] Clarke, 1993 and Clarke & Warwick, 2001.

Table 3. Eigenvectors for the First Six Eigenvalues.

Variable	PC1	PC2	PC3	PC4	PC5	PC6
SST_mean	0.149	-0.394	-0.045	-0.706	0.165	-0.192
SST_mean_span	-0.429	-0.228	-0.117	0.465	0.439	0.166
Mixed layer depth	0.111	-0.360	0.496	0.122	-0.454	0.531
Depth	0.373	-0.409	-0.307	0.262	0.093	0.003
Nekton Biomass	0.354	0.255	0.454	-0.078	0.291	0.206
Nekton Species count	0.428	0.216	-0.015	0.057	0.558	0.281
Chlorophyll a concentration	0.147	0.584	-0.229	0.101	-0.334	-0.041
Surficial Geology	-0.452	0.158	0.500	-0.103	0.238	-0.183
Zooplankton wet weight	0.328	-0.134	0.368	0.415	-0.018	-0.705

The spatial configuration of the first six principal components derived from this analysis are shown in Figures 13-18.

Environmental variables only (plus bottom temperature).

Results of PC analysis of only the environmental variables and including bottom temperature indicate that the first 5 eigenvalues account for 95% of the variance in these data (Table 4) with the first three accounting for just under 77%. They also show that the first principal component is dominated by bottom temperature and mean sea surface temperature. The dominance of bottom temperature in structuring these data would argue for its inclusion in subsequent analyses of biological distribution patterns, particularly demersal nekton.

Table 4. Eigenvalues and the Proportion of Variance Accounted for by the First Five Principal Components of the Analysis Including only Environmental Variables.

PC	Eigenvalues	%Variation	Cum.%Variation
1	2.37	33.9	33.9
2	1.91	27.3	61.2
3	1.06	15.2	76.3
4	0.74	10.6	86.9
5	0.626	8.9	95.8

Table 5. Eigenvectors for the First Five Eigenvalues of the Analysis Including only Environmental Variables.

Variable	PC1	PC2	PC3	PC4	PC5
BT_mean	0.586	0.169	-0.055	-0.223	0.039
log(0.1+BT_mean_span)	0.363	-0.211	0.358	0.745	-0.275
SST_mean	0.506	0.214	-0.233	-0.157	-0.550
SST_mean_span	-0.370	-0.152	-0.616	0.246	-0.509
MLD	-0.173	0.652	0.067	-0.091	-0.264
MLD_range	-0.258	0.552	0.355	0.285	-0.079
depth	0.189	0.359	-0.552	0.469	0.534

Clustering

The spatial distribution of sampling units agglomerated into 20 preliminary clusters (Figure 17) delineates major physiographic features of the Scotian Shelf and adjacent waters. Applying a minimum sampling unit stopping rule would reduce the number of clusters to a more practicable number. Reducing the clustering criterion (i.e. setting a lower threshold of similarity) compromises the utility of the results for differentiating the study area.

Clustering sampling units based solely on the environmental data (Figure 18) reveals patterns comparable to those derived from analysing the complete data set. A comparison Figures 16 and 18a indicates that these differ mainly as the result of the dominance of bottom temperature (the distinction between inner and outer shelf which results mainly from differences in SST is absent in the latter) but are otherwise quite comparable. Figure 19 merely shows the impact of lowering the agglomeration threshold.

A more informative examination of the relationship between environmental conditions and the distribution of biota results from examining the variance structure of the biotic and abiotic variables separately. We determined the "structure" of fish species distribution on the Scotian Shelf through multi-dimensional scaling (Figure 19b). The relationship between the distribution of environmental conditions and species composition is clear from examining Figures 19a and 19b.

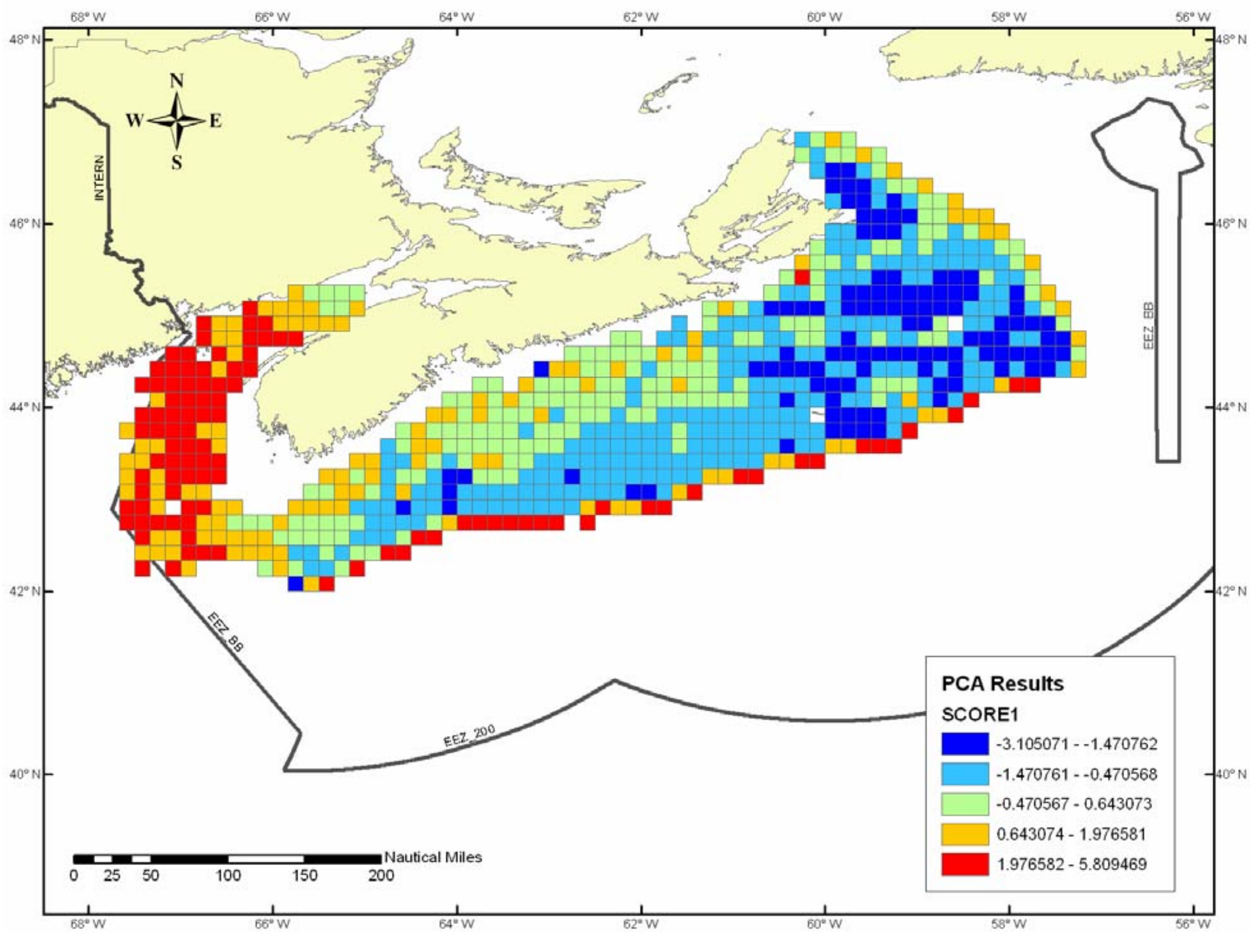

Figure 11. Spatial distribution of the 1st principal component scores from the analysis of Scotian Shelf biophysical data set.

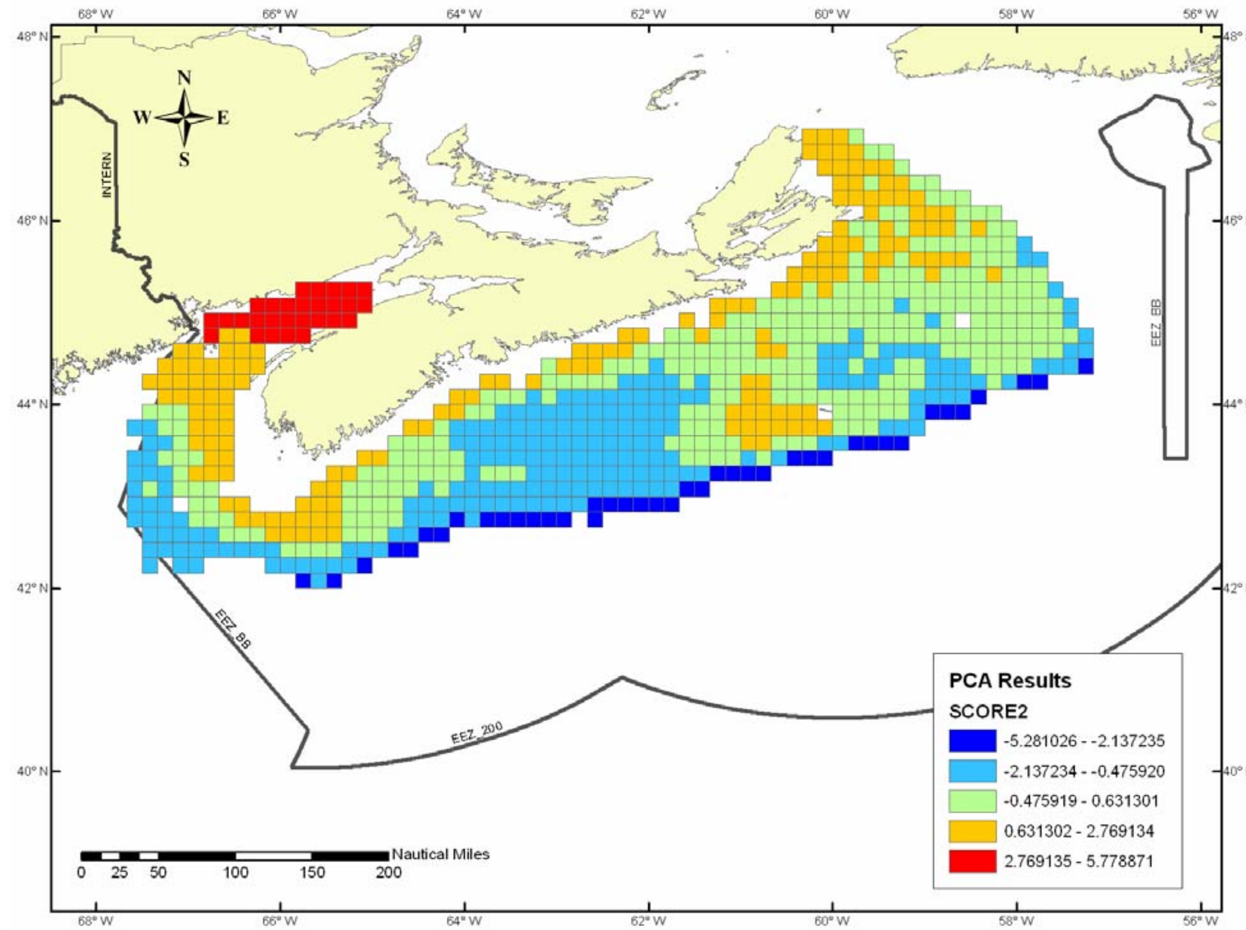

Figure 12. Spatial distribution of the 2nd principal component scores from the analysis of Scotian Shelf biophysical data set.

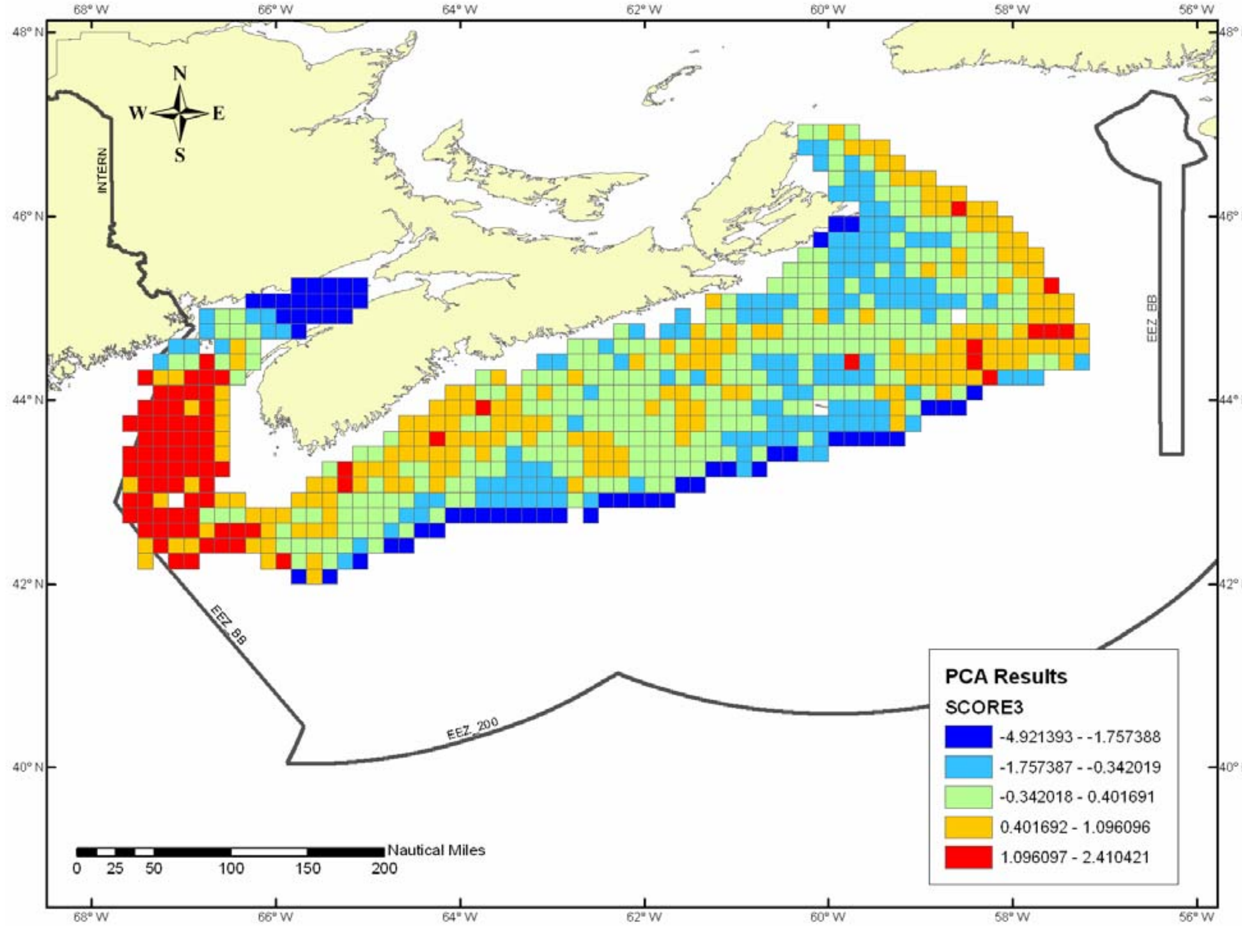

Figure 13. Spatial distribution of the 3rd principal component scores from the analysis of Scotian Shelf biophysical data set.

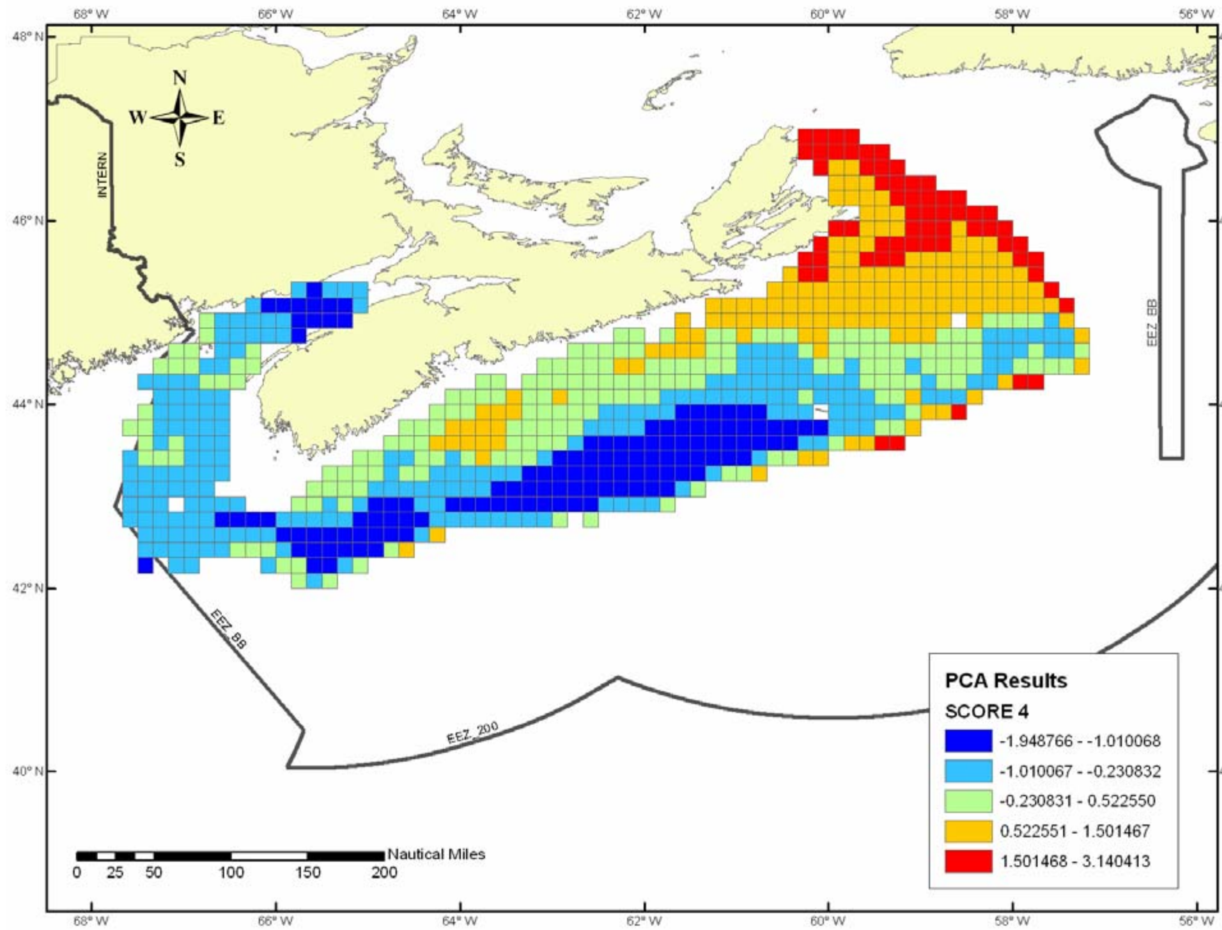

Figure 14. Spatial distribution of the 4th principal component scores from the analysis of Scotian Shelf biophysical data set.

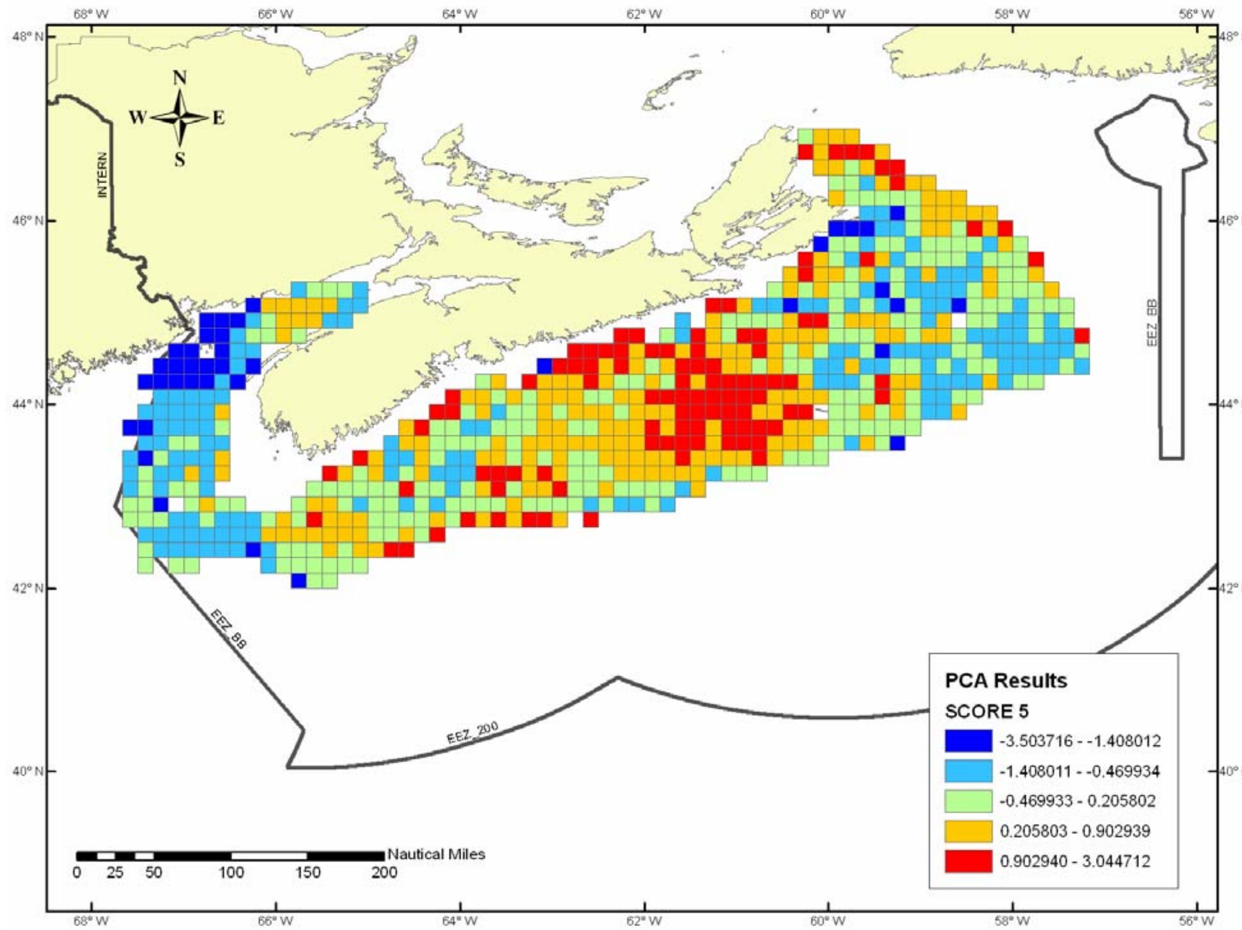

Figure 15. Spatial distribution of the 5th principal component scores from the analysis of Scotian Shelf biophysical data set.

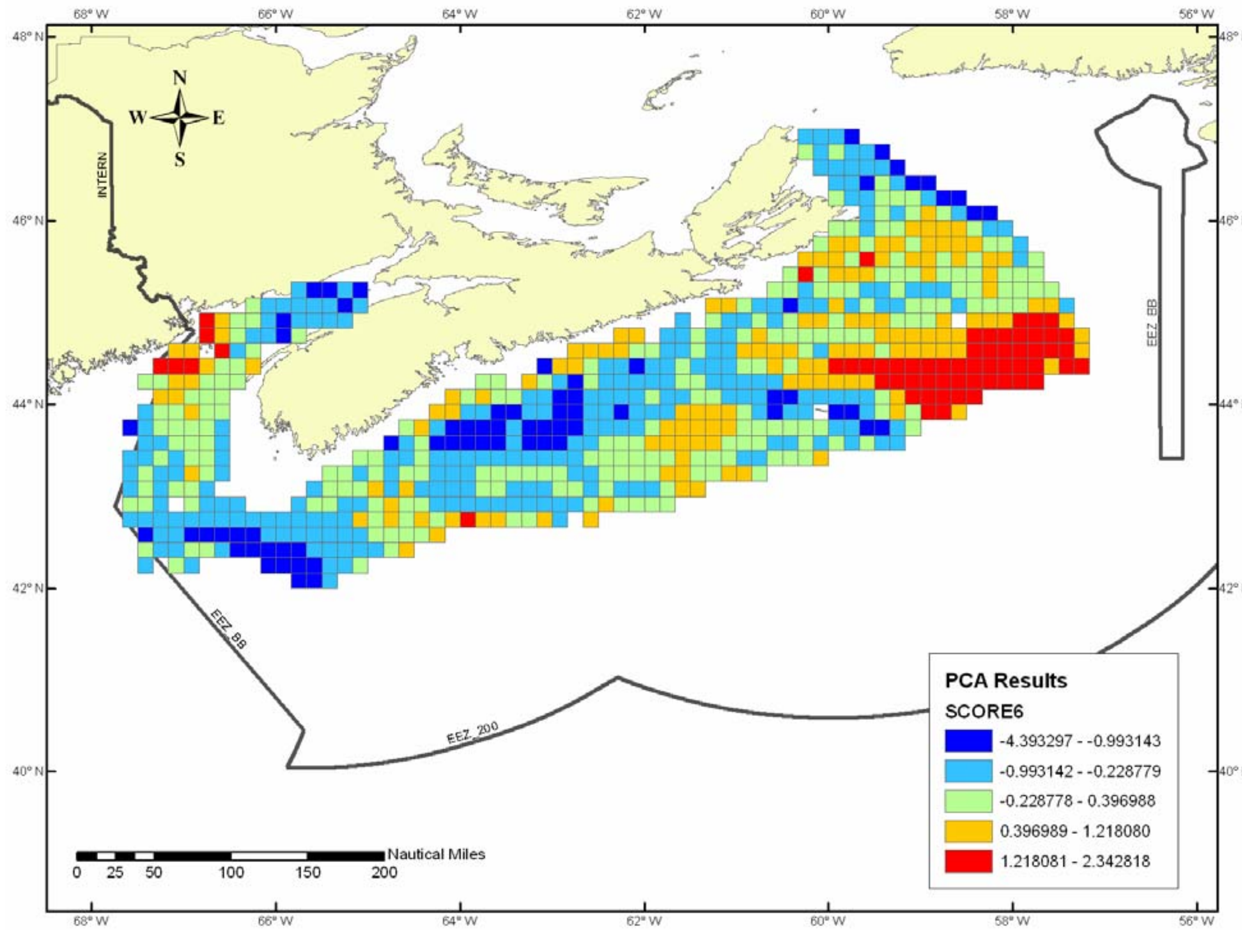

Figure 16. Spatial distribution of the 6th principal component scores from the analysis of Scotian Shelf biophysical data set.

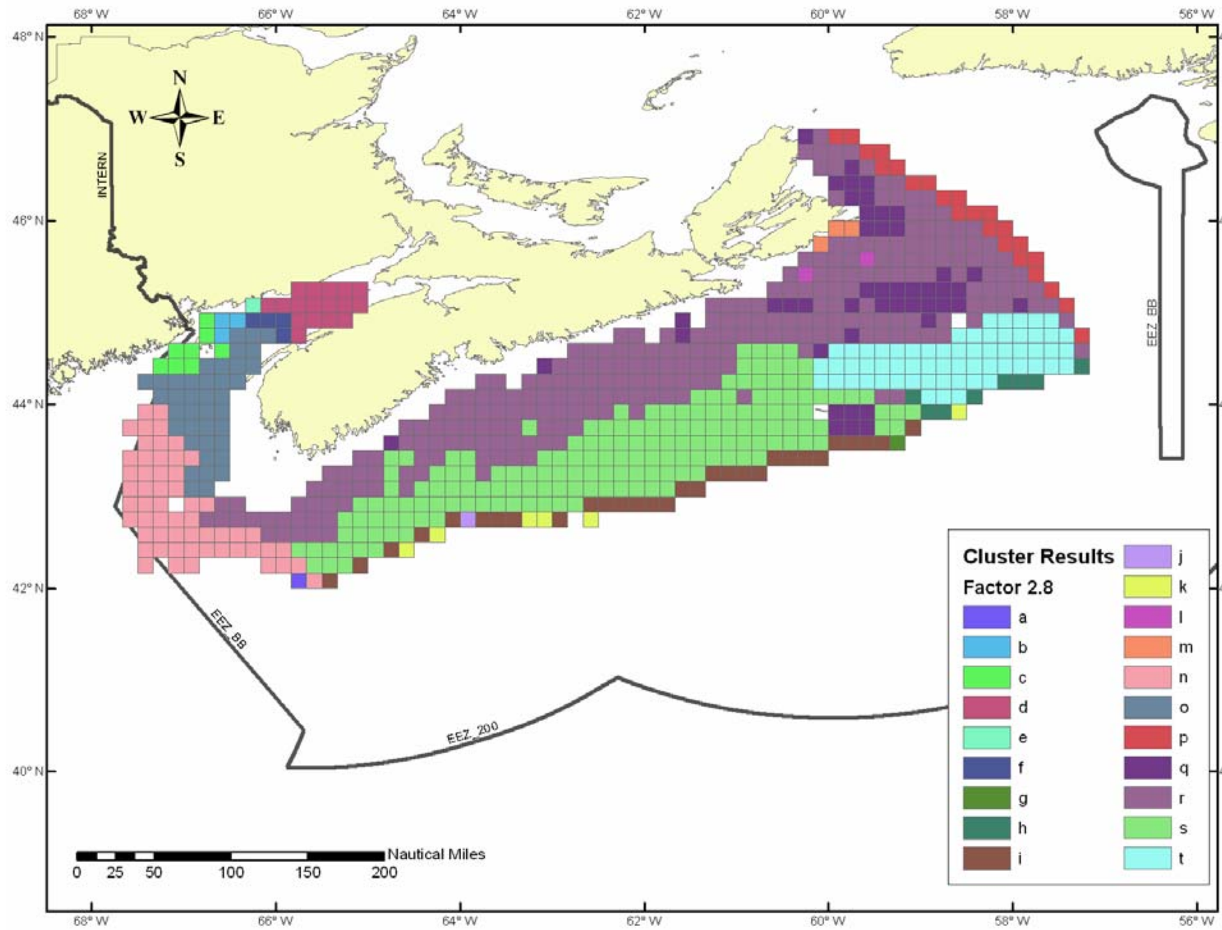

Figure 17. Cluster groupings resulting from hierarchical agglomerative clustering of PCA scores for each 10x10 sampling unit. Note that no minimum unit limit has been imposed on the clustering algorithm.

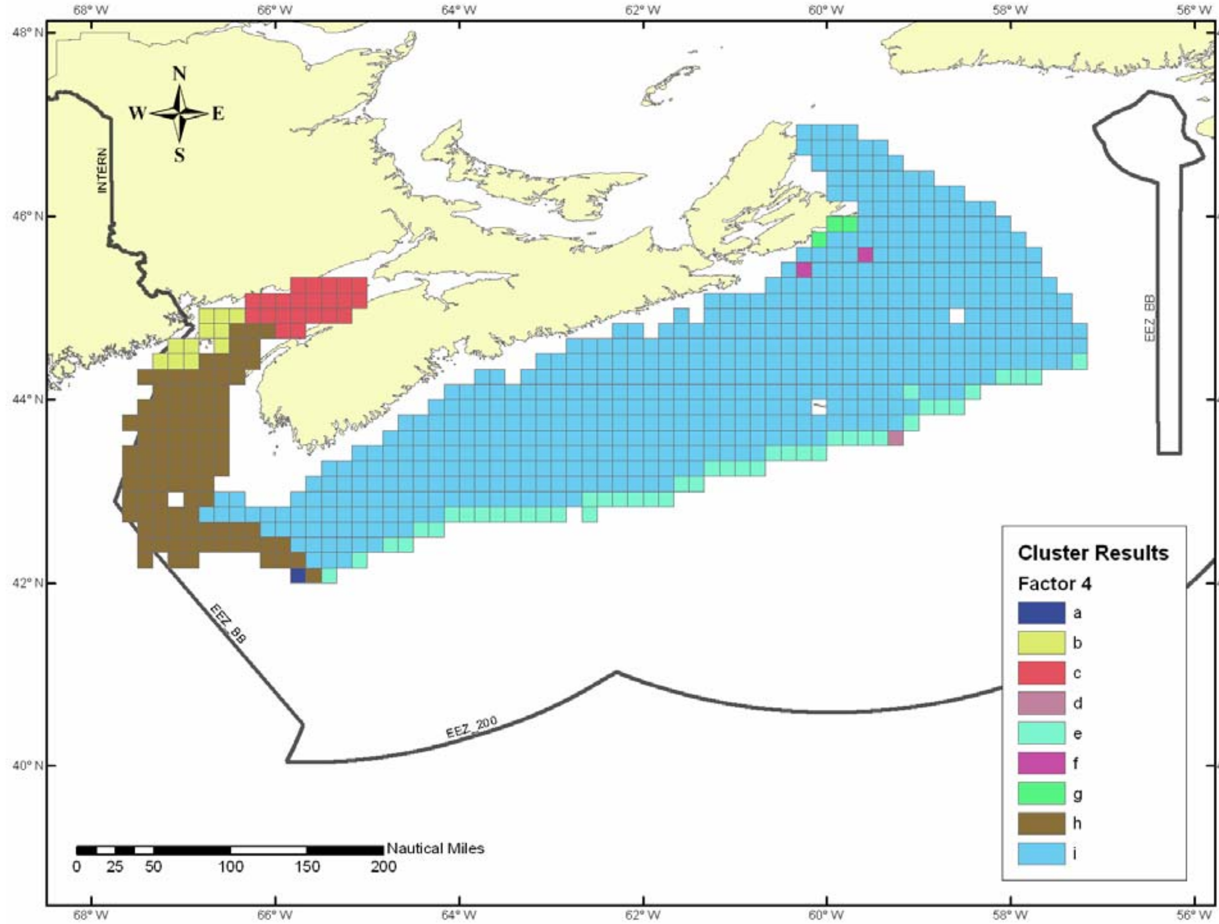

Figure 18. Cluster groupings resulting from hierarchical agglomerative clustering of PCA scores for each 10x10 sampling unit using a lower similarity criterion for grouping than in Figure 17 above. Note that no minimum unit limit has been imposed on the clustering algorithm.

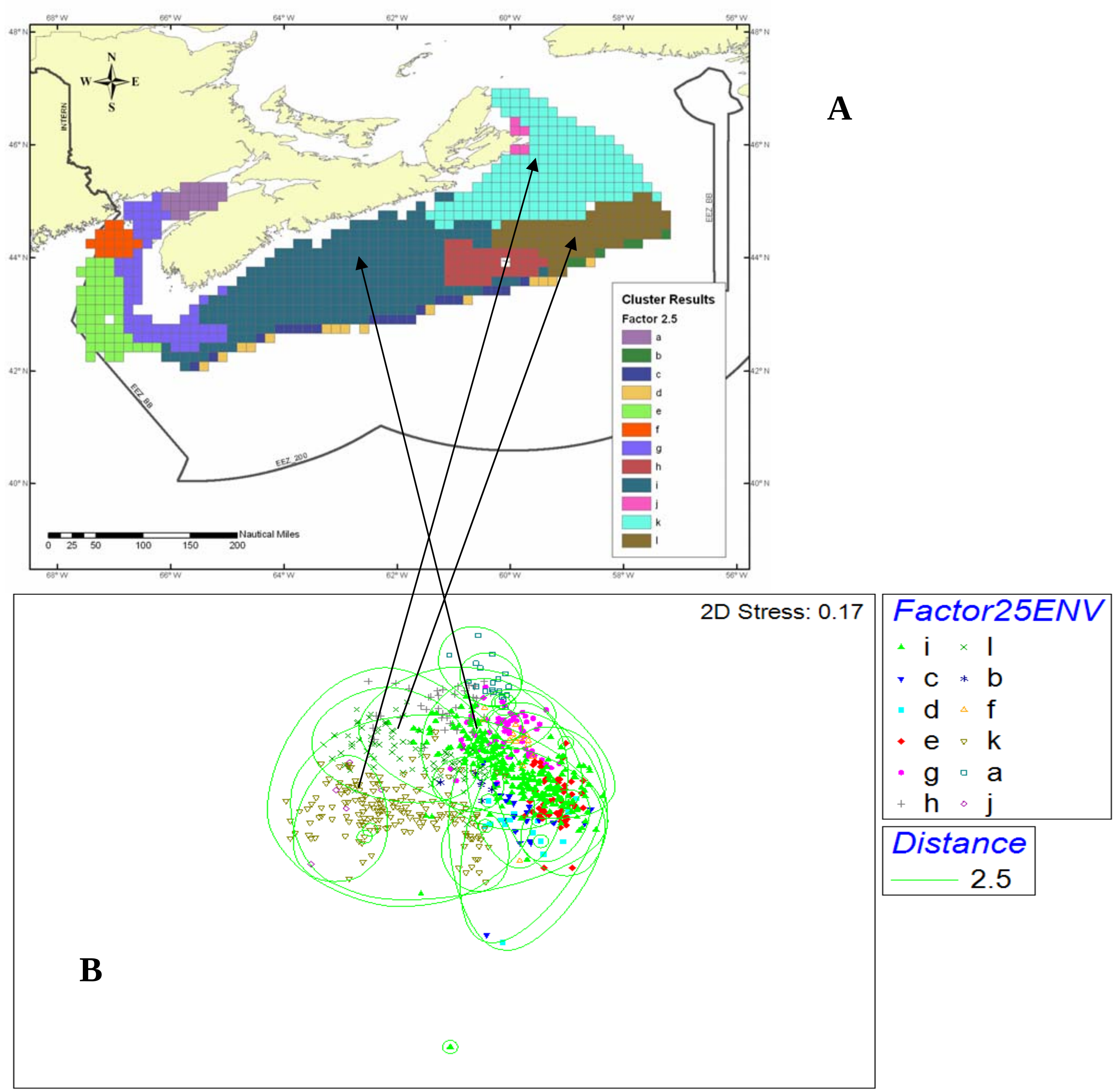

Figure 19. A) Cluster groupings resulting from hierarchical agglomerative clustering of PCA scores for each 10x10 sampling unit using only environmental variables. Note that no minimum unit limit has been imposed on the clustering algorithm. B) Non-metric multi-dimensional scaling of species abundance measures for each 10x10 sampling unit. The arrows show the correspondence between species multidimensional structure and geographic distibution of clustered z-scores from PC analysis of unit based environmental measures.

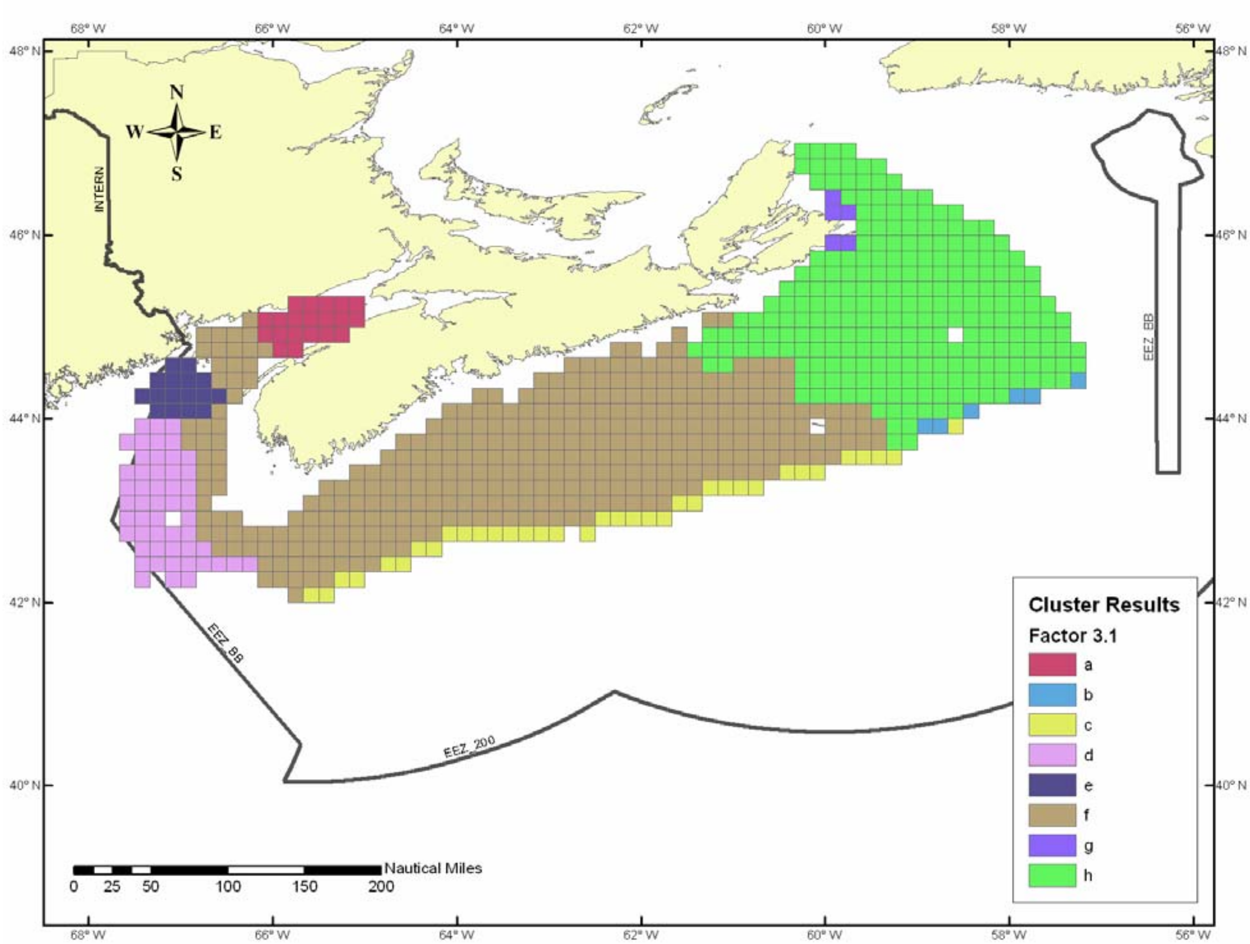

Figure 20. Cluster groupings resulting from hierarchical agglomerative clustering of PCA scores for each 10x10 sampling unit using only environmental variables and a lower similarity criterion than in Figure 19 above. Note that no minimum unit limit has been imposed on the clustering algorithm.

Conclusions

These preliminary analyses provide some direction for a more detailed analysis of biogeographic units for the Scotian Shelf proper and for the broader Northeast Atlantic. The following points are noteworthy:

1. Inclusion of both biotic and abiotic variables in a single PC analysis does not reveal significant structure above what is derived from an analysis of environmental variables alone.

2. The structure of environmental conditions on the Scotian Shelf is directly related to the structure in species composition (Spearman r=0.66 for the three dominant variables, BT, BT range, and mean SST.).

3. Environmental conditions in each of the clustered areas can now be estimated as acceptable conditions for the species composition resident in the areas.

The challenge will be to determine the consistency of boundaries between areas of differing environmental conditions and the consistence of species composition within these areas.

This is a preliminary investigation into the biophysical structure of the Scotian Shelf. Therefore the specific geographic boundaries and areas identified and characterized are considered preliminary results. The authors will investigate inclusion of a number of additional physical variables and species distributions in subsequent analyses.

The authors will also examine the temporal and spatial consistency of areas and boundaries over the four decades spanned by much of the data available..

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