Water Quality Monitoring and Analysis for the Florida Keys National Wildlife Refuge

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BACKGROUND

The marine ecosystem of the Florida Keys is composed of several interdependent communities - from the spectacular coral reef tract, to extensive living hardbottom and patch reefs, to the largest seagrass community in the world, to hundreds of mangrove-fringed islands that are home to hundreds of wildlife species, 100,000 human residents, and host millions of visitors. It is this disparity of exceptional natural biological resources and intense concentrations of people that is creating critical problems for the continued health of the ecosystem.

The natural systems that comprise the Florida Keys ecosystem exist in dynamic equilibrium. Changes in physical and chemical attributes of the system can have profound impacts on its biology. Destruction of wetlands and mangrove shorelines by human development has created a loss of natural filtering mechanisms for terrestrial run-off, which degrades nearshore water quality. Seagrass and mangrove communities provide important functions of nutrient uptake. Coral and seagrass communities depend upon nutrient-poor, clear waters to thrive. Increasing human usage and loss of habitat from human encroachment and water quality degradation is creating severe stress or loss of many marine species. Water quality degradation is one of the most threatening stresses because of the diverse sources of pollution and its pervasive existence. At the same time, by managing the Refuges as Wilderness, the Fish and Wildlife Service is preserving an important natural filtering function and potentially enhancing the quality of waters in an otherwise over-developed segment of the ecosystem. The extent to which long-term management within the Great White Heron NWR (61 years) and Key West NWR (91 years) has contributed to regional ecosystem health and what may be the potential impacts to arise as a result of degradation are not fully understood.

Sponges are a particularly dominant structural feature of Florida Bay seagrass and hardbottom habitats. However, the importance of sponges to water quality has not been well studied. The potential for filter feeding sponges to affect water quality is great. These organisms filter large volumes of water (1 L h^{-1} cm^{-3} of body volume), with retention efficiencies between 75 and 99%. Past and present studies shown that grazing rates of some sponges are within the range of 29 to 1970 mg C m^{-2} d^{-1}. Therefore, abundant populations may exert an important grazing impact on their habitat. While all sponges convert particulate organic carbon (POC) and nitrogen (PON) to dissolved organic carbon and nitrogen (DOC and DOC), some sponges possess associated bacteria that further process the DOC and DON to inorganic forms (DIC and DIN). In addition, Diaz and Ward (1997) suggested that sponge-mediated nitrification is not uncommon in tropical marine benthic communities, and might constitute a large input of oxidized nitrogen into those habitats where sponges abound. The comparison of potential nitrification rates associated with sponges was 2 to 4 orders of magnitude higher than the previously studied active nitrification sites in coastal environments (sediments).

PROJECT DESCRIPTION

The current EPA Water Quality Protection Plan through the Florida Keys National Marine Sanctuary is an ambitious program which addresses system-wide effects of changing water quality on the grand scale. Refuge water quality monitoring focuses on the effects to and impacts of the sponge community on water column nitrogen dynamics. This project provides an estimate of the sponge biomass and community composition as well as the benthic plant community. Three factors are important in determining the impact of sponges to water quality: the pumping rate of water through each sponge, their areal biomass and distribution and the rate of C and N processes within the sponge

METHODS

Benthic Surveys

A stratified random sampling design was used to identify fifty-eight sites through out the extent of the Great White Heron National Wildlife Refuge (NWR) (Fig. 1) for six days during January 2003. At each site, a 50 m transect was extended to the north. At ten pre-selected random points along the transect a 0.5 m^2 quadrat was placed on the sediment surface and submerged aquatic vegetation (SAV) community composition was assessed *in situ* using a modified Braun Blanquet quadrat method (Table 1) (Braun-Blanquet 1972, Fourqurean, et al., 2001). All sponges within 0.5 m of the transect tape on either side was recorded for density (number of species m^{-2}). In addition to benthic composition data, surface water salinity (practical salinity scale), temperature (°C), pH and dissolved oxygen (DO, mg l^{-1}) were recorded in the field by the using a Hydrolab® Mini Sonde.

Nutrient Analysis

At all benthic sites, water column nutrients were collected. Unfiltered water samples were analyzed for total nitrogen (TN), total phosphorus (TP) and total organic carbon (TOC). Filtered samples were collected for the full suite of nutrients including ammonium (NH_4^+), nitrate + nitrite (NO_x^-), nitrite (NO_2^-), silicate ($Si(OH)_4$), soluble reactive phosphate (SRP), and Chlorophyll *a* (CHLA) by the SERC laboratory using standard methodology outlined in our Quality Assurance Plan. Some parameters were not measured directly, but calculated by difference. Nitrate (NO_3^-) was calculated as $NO_x^- - NO_2^-$, dissolved inorganic nitrogen (DIN) was calculated as $NO_x^- + NH_4^+$, and total organic nitrogen (TON) was defined as TN - DIN.

Data Analysis

The Braun Blanquet scores were used to calculate density ($\mathbf{D_i}$), abundance ($\mathbf{A_i}$), and frequency ($\mathbf{F_i}$) for each taxon (**i**) at each site (Table 2). SAV calculated density and sponge density values were interactively explored using semi-variograms generated by ESRI ArcView® Spatial Analyst software (specifically, the Nieuwland Kriging Interpolator 3.2 extension) to examine their spatial structure . Universal kriging with linear drift algorithms were used for all surface interpolations in this survey. The interpolative method of kriging was used to produce separate weighing parameter for each interpolation point and taking spatial covariances in to effect.

Benthic habitat survey locations were grouped into groups of similar benthic habitat using a hierarchical clustering algorithm calculated by *SPSS* 11.5 for windows. The Braun Blanquet (BB) densities of the benthic plant taxa and sponge densities of were used to define the groups.

The intent was to separate the original 58 stations into groups of similar benthic composition. The number of groups identified was somewhat arbitrary; for this report we found there were 3 ecologically relevant groups. A similar approach was used by Moore et al. (2000) and Fourqurean et al. (2003).

Groups created by hierarchical clustering were analyzed by *Sigma Plot* 2001 to determine there are water quality or taxa variation between cluster groups. Data were reported as box-and-whiskers plots. The box-and-whisker plot is a powerful statistic as it shows the median, range, the data distribution as well as serving as a graphical, nonparametric ANOVA. The center horizontal line of the box is the median of the data, the top and bottom of the box are the 25^{th} and 75^{th} percentiles (quartiles), and the ends of the whiskers are the 10^{th} and 90^{th} percentiles. The crosshatch (+) above and below the whisker ends are the 5^{th} and 95^{th} percentile values.

The box-and-whiskers plots that showed differences among cluster groups were further explored by Kruskal-Wallis/ Wilcoxon Ranked Sign test and Mann-Whitney U test using a *SPSS* software. Variables were tested between groups using the nonparametric Wilcoxon Ranked Sign test (comparable to the t-test) and among groups by the Kruskal-Wallis test (comparable to ANOVA) with significance set at $p \leq 0.05$. Kruskal-Wallis for several independent samples procedure was used to determine if there are a proportion of the different community classes. Groups that were significantly different were tested by Mann-Whitney U test in order to say how the groups differed by comparing medians of all paired cluster groups among all physical site parameters and/ or taxa at a level of $p<0.05$ (2-tailed test).

RESULTS

Spatial Distribution

Interpolated distributions of the nearshore benthic community and water quality survey data produced using ArcView® are shown in figures 2-33. Seagrasses and calcareous green algae were the most abundant benthic components of the Great White Heron NWR (Table 3a). Seagrasses were present at 91.4% of all survey sites. Within the seagrass group, *Thalassia testudinum* were present at all seagrass sites (91.4%) while *Syringodium filiforme* and *Halodule wrightii* were not present all of the time (17.2% and 6.9%, respectively). *Thalassia testudinum* had a maximum density of 4.7, with a median density of 2.2. Offshore (>4 km) had highest densities of *T. testudinum* along with the nearshore area NE of Sugarloaf Key around Cudjoe Key (Fig. 2). *Syringodium filiforme* were sparsely found in the eastern region of the study area (Fig. 3). Halodule wrightii had the highest density offshore and NE of Sugarloaf Key and west of Boca Chica Key (Fig. 4).

Calcareous green algae were the most abundant of the SAV (94.8% of all sites) and had a max density of 3.5 and median of 2.1 (Table 3a). Calcareous green algae were most dense in the central region of the study area (Fig. 5). The genera *Halimeda, Penicillus* and *Udotea* were among the taxa most frequently encountered; they were present at over 89.7%, 91.4% & 74.1% of survey sites. Non-calcareous green algae were present at nearly 41.4% of the survey sites (Table 3a). The genus *Caulerpa* was present at nearly 32% (maximum density of 0.9) of the survey sites, with highest density NE of Sugarloaf Key (Fig. 6), while the other green algae were concentrated close to shore (Fig. 7).

Non-drift red algae were present at 39.7% of the survey sites, with a maximum density that did not exceed 1.2 and a median of 0.4 primarily about 8 km offshore Boca Chica Key (Fig. 8). Drift red algae were found at 8.6% with a maximum density of 3.5 (Table 3a). Drift red algae

were primarily found within 6 m from shore (Fig. 9). Brown algae were only were present at 1.7% of the sites (Table 3a).

Sponges were the third most frequent taxa group represented in this study found at 63.8% of all sites. Maximum densities did not exceed 0.7 m^{-2} for any individual taxon (Table 3b). Sponge species were generally found within 8 m from shore, except for *Anthosigmella varians, Chondrilla nucula, Cinachyra sp*. and *Ircinia sp*. (Fig. 10-19).

Total nitrogen and TON concentrations and temperature were most variable within the study area (Table 4). Concentrations of Chl *a*, TON, TN and TP were highest offshore (~ 8 km) of Cudjoe Key (Fig. 20-23). Temperature was highest offshore of Cudjoe Key and Sugarloaf Key (Fig. 24). TON was the most abundant nitrogen form in the TN pool while NH_4^+ was highest for the TIN pool (Table 4). High NH_4^+ concentrations were primarily found in the nearshore region (Fig. 25), while NO_x and TIN had highest concentrations between Sugarloaf Key and Key West (Fig. 26-27). $Si(OH)_4$, DO and pH had highest levels nearshore the Cudjoe Key area (Fig. 28-30), while salinity increased in the westward direction (nearshore between Sugarloaf Key to Key West) (Fig. 31). SRP was highest along the shore with a hot spot near Boca Chica Key (Fig. 32). TOC had highest concentrations in the offshore region the study area (Fig. 33).

Community Assemblages

The results produced by hierarchal clustering algorithms showed that there were three clusters with different membership size (Fig. 34). The three clusters were labeled *Halodule wrightii* (Hw) group (n = 8), sponge-hardbottom (Sp) group (n =16) and *Thalassia testudinum* (Tt) group (n = 34). The Hw group had the highest density of opportunistic or successional type taxa, such as *Halodule wrightii* (Fig. 35a), *Caulerpa sp*. (green algae) and total green algae along with non-drift red algae (Fig. 35b). *Halodule* density was significantly higher for this group (Z for Hw group*Sp group = -2.027, $p<0.05$; Z for Hw group* Tt group = -3.658, $p<0.001$) (Fig. 36). While calcareous green algae was significantly lower (Z for Hw group*Sp group = -3.345, $p<0.001$; Z for Hw group* Tt group = -4.013, $p<0.001$) (Fig. 37). The effect of TN was highest in Hw group (Z for Hw group*Sp group = -3.919, $p<0.001$; Z for Hw group* Tt group = -4.356, $p<0.001$) and TON was second with a $p<0.05$ (Fig. 38).

The majority of the sites in the Sp group fell in the hardbottom areas reported by FMRI and NOAA in 1998 (Fig. 39) and were distinguished by the high densities and diversity of sponge species present (Fig. 40). Sponge species graphed for this report were those which showed that the Sp group was significantly different than Hw and Tt group. Total sponge species (tot sp) and drift red algae (DRA) density were highest in the SP group ($Z_{(tot\ sp)}$ for Sp group*Hw group = -2.562, $p<0.05$; $Z_{(tot\ sp)}$ for Sp group*Tt group= -4.781, $p<0.001$) ($Z_{(DRA)}$ for Sp group*Hw group = -3.562, $p<0.001$; $Z_{(DRA)}$ for Sp group*Tt group= -4.013, $p<0.001$) (Fig. 41). This group had higher salinity than that found in the Hw group (Z = -2.266, $p<0.05$) (Fig. 42).

The last group, Tt group, was dominated by *Thalassia testudinum* (Z for Tt group*Sp group = -3.914, $p<0.001$; Z for Tt group* Hw group = -5.660, $p<0.001$) (Fig. 43). *Caulerpa sp.* and *Tedania ignis* (a known nitrogen fixer) had the lowest densities ($p<0.05$) in this area (Fig. 44-45).

DISCUSSION

This investigation produced a record of benthic habitat distributions for the Great White Heron National Wildlife Reserve. Three benthic community cluster groups were present in the area: *Hadolue*, Sponge, and *Thalassia*. The *Halodule* group had the highest density of opportunistic species *(H. wrightii and Caulerpa sp*.) along with elevated concentrations of TN and TON. Low densities of calcareous green algae were observed in the Hw group. Sp group showed to have highest diversity and density of sponges. Stations that were clustered into the Sp group had greater salinities than found in the other groups and were mostly hardbottom. The *Thalassia* group appeared to be driven by the lowest concentrations of TN and TON. *Tedania ignis*, a known nitrogen fixer, showed a decreased density in the Tt group. There may be other underlying factors causing the benthic grouping which were not recorded during this snap-shot study.

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TABLES & FIGURES

Table 1. Braun Blanquet scores for recording the abundance of benthic taxa.

Braun Blanquet Scores

Score	Taxa Percent Cover
0.0	Absent
0.1	Solitary, < 5%
0.5	Sparse, <5%
1.0	Many, <5%
2.0	5% - 25%
3.0	25% - 50%
4.0	50% - 75%
5.0	75% - 100%

Table 2. Frequency, abundance and density calculations for each species from the raw observations of benthic cover in each quadrat at each site.

Calculations of Braun Blanquet scores

Calculation	Formula	Description
Frequency	$\mathbf{F_i=N_i/n}$	$\mathbf{N_i}$ is the number of quadrats at a site in which taxon **i** was present, **n** is the number of quadrats observed at a site, and the score is between 0 and 1.
Abundance	$\mathbf{A_i= (3^n_{\ j=1}\ S_{ij})/\ N_i}$	$\mathbf{N_i}$ and **n** are as described above, $\mathbf{S_{ij}}$ is the Braun Blanquet score for taxon **i** in quadrat **j**, and is between 0 and 5.
Density	$\mathbf{D_i= (F_i)(A_i)}$	$\mathbf{F_i}$ and $\mathbf{A_i}$ are as described above the score can range between 0 to 5.

Table 3a. Submerged Aquatic Vegetation taxa distribution, including the number and percentage of sites where each taxon was present and the maximum and median Braun Blanquet density. Asterisks designate taxa presence within the cluster group.

Summary of SAV Distribution

Taxa	Study Area sites		Density		Group Cluster Presence		
	# Sites	% Sites	Max	Med	HwG	SpG	TtG
Seagrass	**53**	**91.4**			*	*	*
Thalassia testudinum	53	91.4	4.7	2.2	*	*	*
Syringodium filiforme	10	17.2	1.8	0.7	*		*
Halodule wrightii	4	6.9	2.4	1.8	*	*	
Calcareous Green Algae	**55**	**94.8**	**3.5**	**2.1**	*	*	*
Genus *Halimeda*	52	89.7	3.1	1.2		*	*
Genus *Penicillus*	53	91.4	3.0	1.8	*	*	*
Genus *Udotea*	43	74.1	1.5	0.4	*	*	*
Genus *Ripocephalus*	3	5.2	0.1	0.1		*	*
Genus *Acetabularia*	7	12.1	0.2	0.1	*	*	*
Green Algae	**24**	**41.4**			*	*	*
Genus *Caulerpa*	19	32.8	0.9	0.2	*	*	*
Other Greens	16	27.6	1.2	0.3	*	*	*
Red Algae	**23**	**39.7**	**1.2**	**0.4**	*	*	*
Drift Red Algae	**5**	**8.6**	**3.5**	**0.8**		*	*
Brown Algae	**1**	**1.7**	**0.2**	**0.2**		*	

Table 3b. Sponge taxa distribution, including the number and percentage of sites where each taxon was present and the maximum and median density (no. of species m^{-2}).

Summary of Sponge Distribution

Taxa	Study Area sites		Density		Group Cluster Presence		
	# Sites	% Sites	Max	Med	HwG	SpG	TtG
Sponges	**37**	**63.8**	**1.6**	**0.2**	*	*	*
Chondrilla nucula	9	15.5	0.7	0.2	*	*	*
Nephates erectus	1	1.7	0.0	0.0		*	
Tethya crypa	1	1.7	0.0	0.0		*	
Anthosigmella varians	22	37.9	0.7	0.1	*	*	*
Lissodendoryx sp.	6	10.3	0.1	0.0	*	*	*
Adocia sp.	1	1.7	0.0	0.0		*	
Spheciospongia vesparia	19	32.8	0.3	0.1	*	*	*
Ircinia strobilina	2	3.4	0.0	0.0	*	*	*
Ircinia campana	12	20.7	0.1	0.0	*	*	*
Ircinia sp	28	48.3	0.5	0.1		*	*
Spongia barabara	1	1.7	0.0	0.0			*
Hippospongia lachne	9	15.5	0.1	0.0	*	*	*
Tedania ignis	7	12.1	0.1	0.0	*	*	*
Cinachyra sp.	10	17.2	0.3	0.0	*	*	*
Aaptos sp.	2	3.4	0.0	0.0	*	*	
Geodia gibberosa	11	19.0	0.2	0.1	*	*	*
Biemna sp.	2	3.4	0.1	0.0		*	*

Table 4: Water quality descriptive statistics.

Summary of Water Quality

	Mean	***Median***	***Max***	***Min***	***Std Dev***	***n***
NO_x (µM)	0.27	0.23	0.70	0.03	0.16	58
NO_3^- (µM)	0.22	0.19	0.63	0.00	0.15	58
NO_2^- (µM)	0.05	0.04	0.09	0.02	0.02	58
NH_4^+ (µM)	0.62	0.50	2.23	0.12	0.43	58
TN (µM)	20.78	20.64	28.64	16.93	2.35	58
TIN (µM)	0.89	0.81	2.78	0.20	0.52	58
TON (µM)	19.88	19.79	28.31	16.30	2.37	58
TP (µM)	0.28	0.31	0.66	0.01	0.15	58
SRP (µM)	0.09	0.09	0.21	0.01	0.04	58
CHL A (µg l^{-1})	0.56	0.49	2.57	0.04	0.46	58
TOC (µM)	229.79	223.40	340.13	188.54	27.42	58
$Si(OH)_4$ (µM)	0.60	0.53	2.34	0.07	0.43	58
SAL	36.05	35.83	38.04	34.89	0.69	58
TEMP (°C)	19.28	19.72	21.08	15.40	1.38	58
DO (mg l^{-1})	4.85	4.68	7.27	3.83	0.69	58
pH	7.96	7.96	8.10	7.83	0.06	58

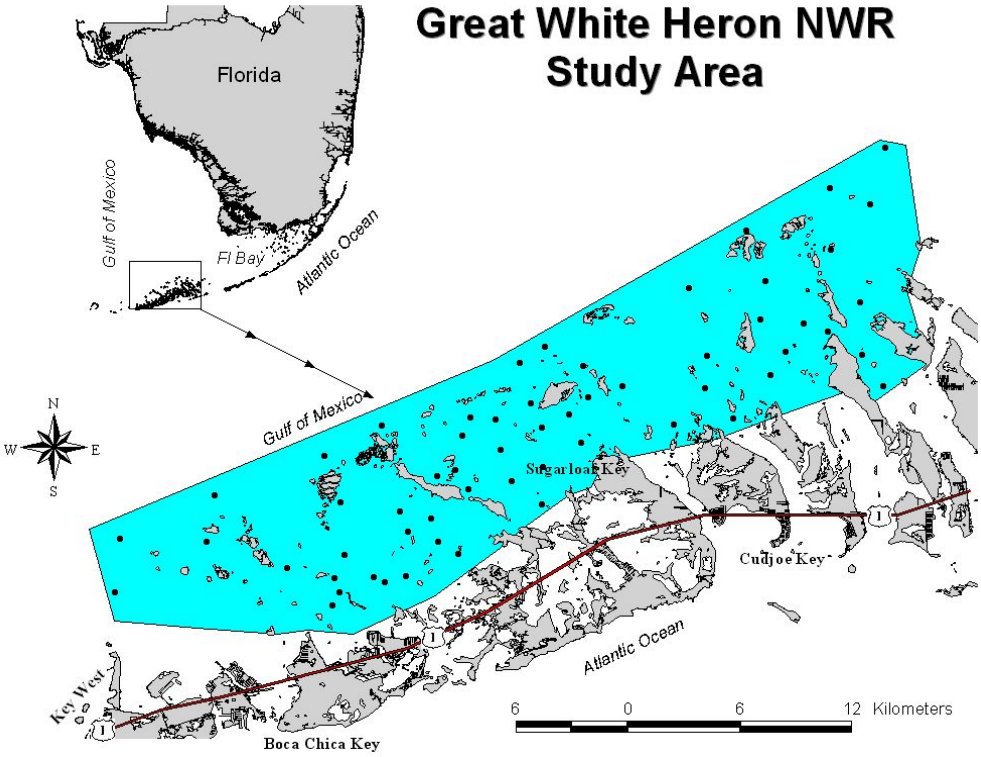

Figure 1. Great White Heron National Wildlife Reserve study area.

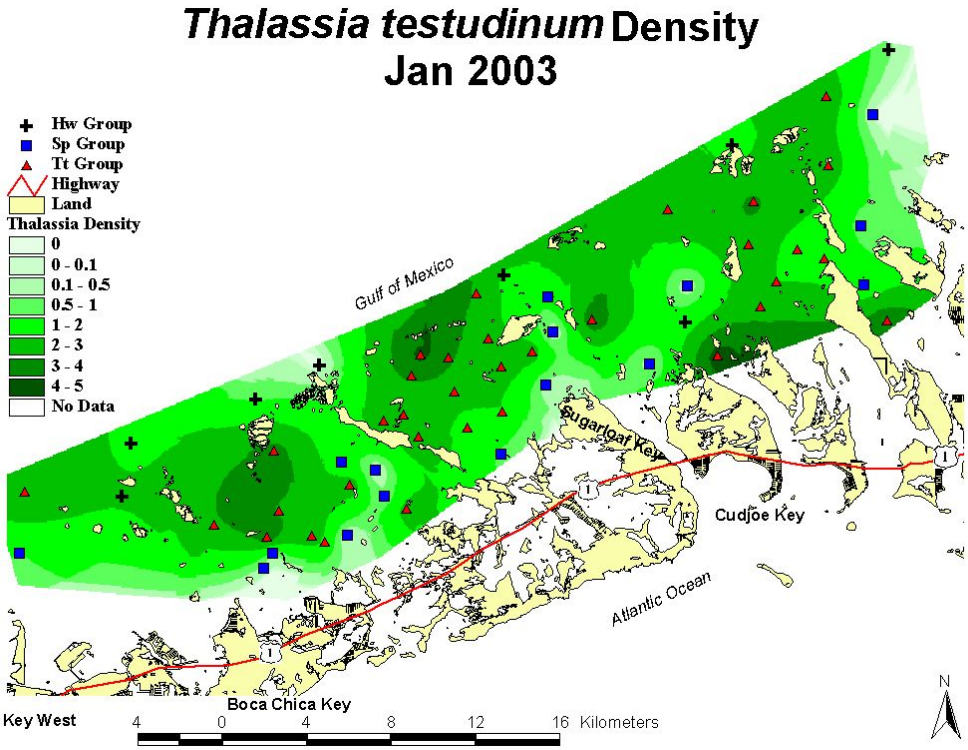

Figure 2. *Thalassia testudinum* density (Braun-Blanquet score) distribution within the study area.

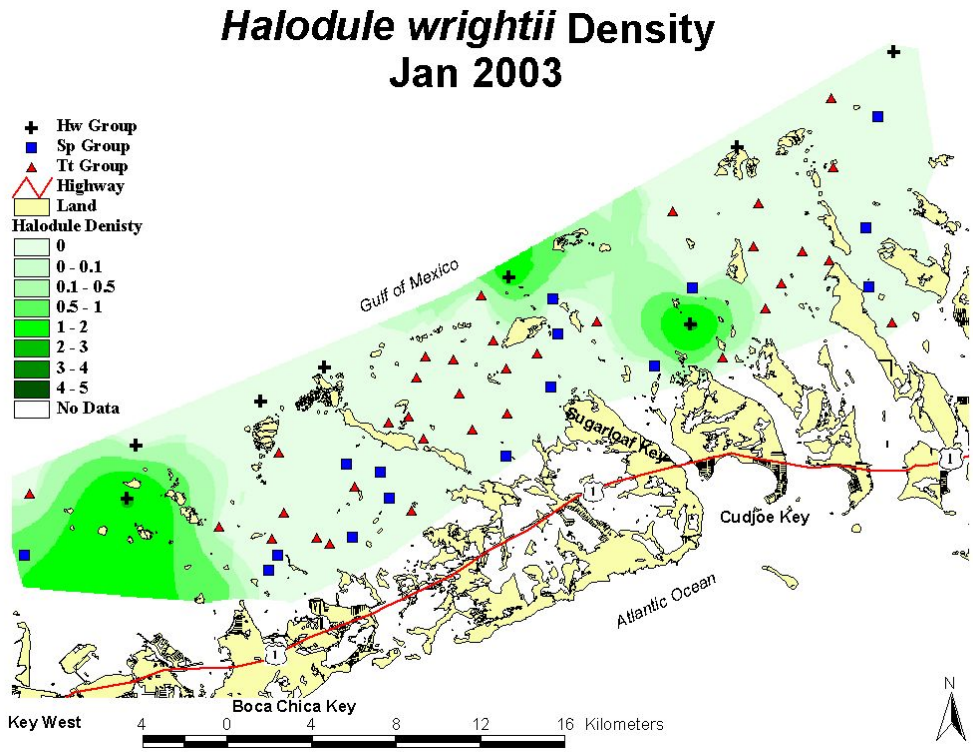

Figure 3. *Halodule wrightii* density (Braun-Blanquet score) distribution within the study area.

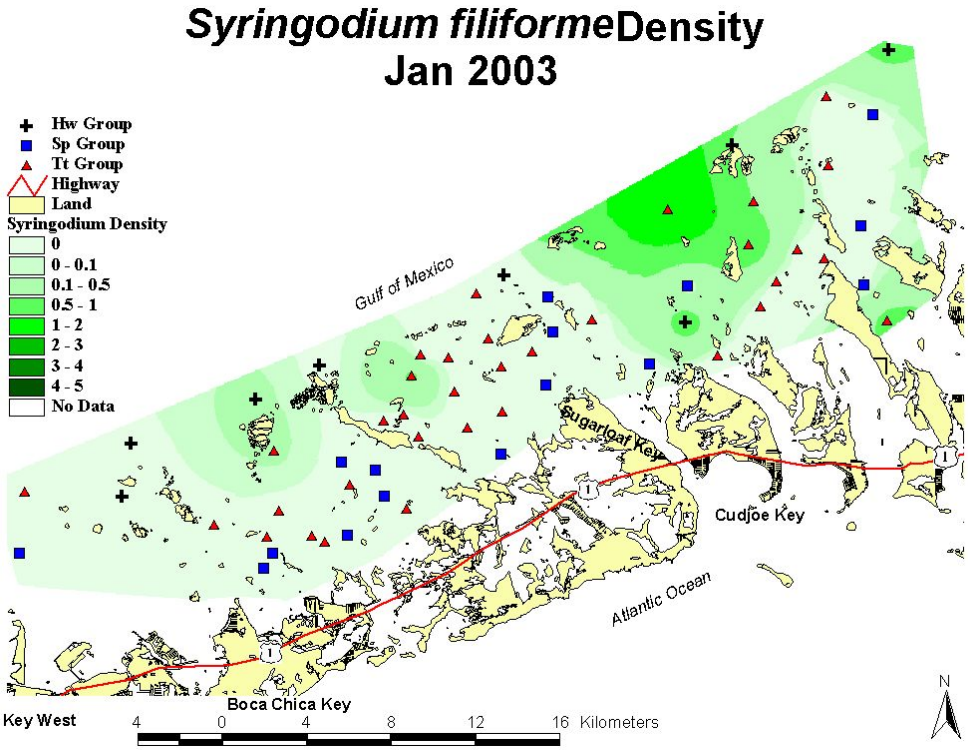

Figure 4. *Syringodium filiforme* density (Braun-Blanquet score) distribution within the study area.

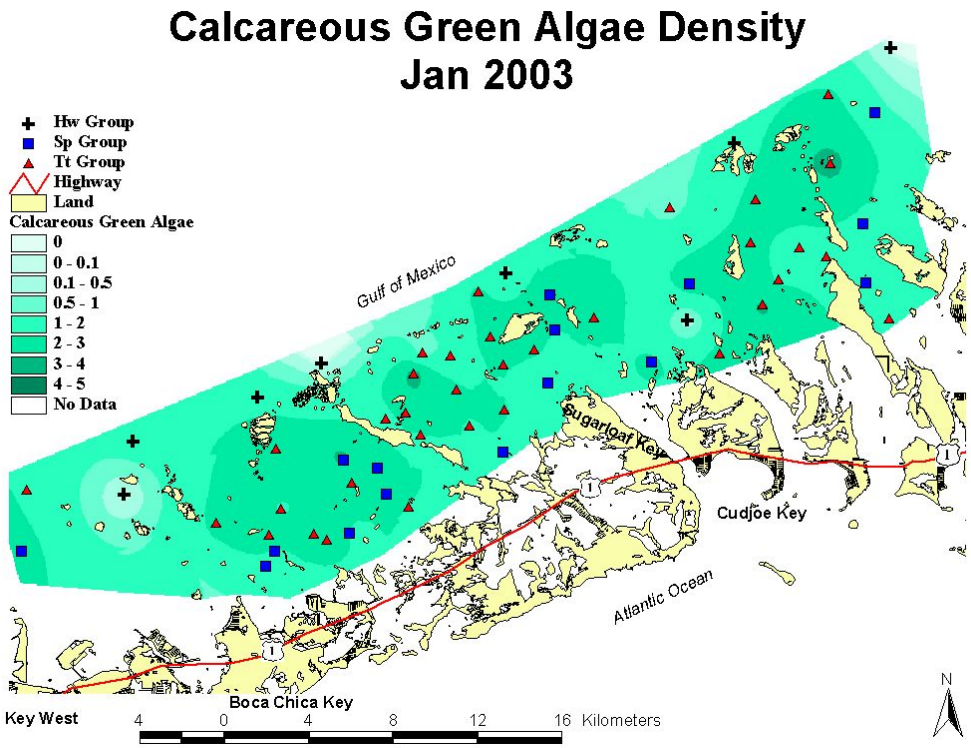

Figure 5. Distribution of calcareous green algae density (Braun-Blanquet score) within the study area.

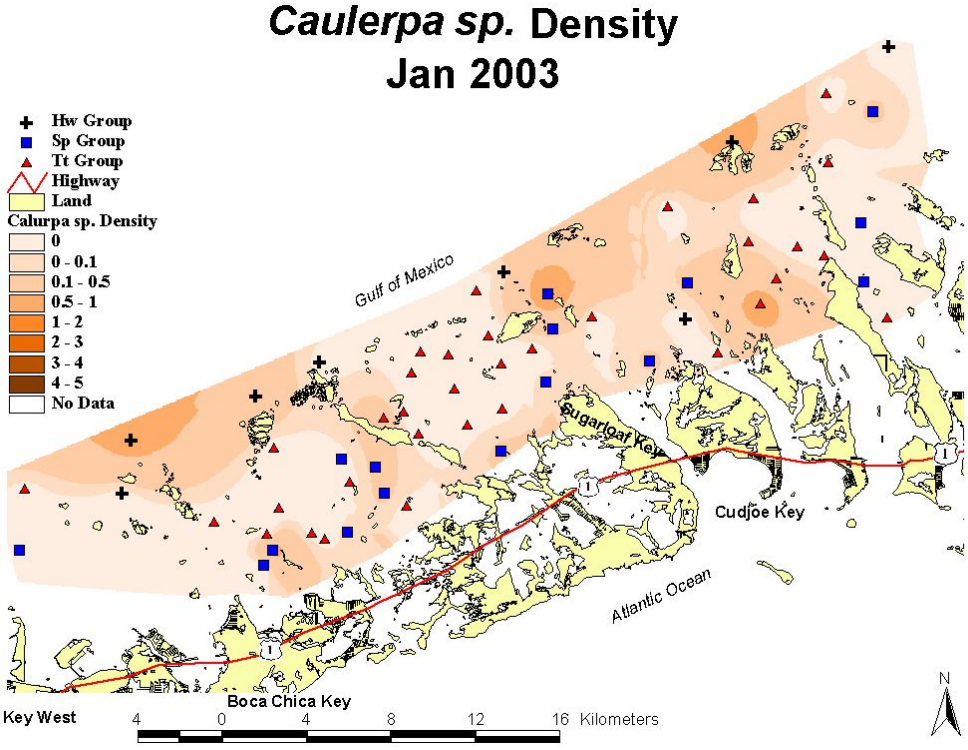

Figure 6. Distribution of *Caulerpa sp*. density (Braun-Blanquet score) within the study area.

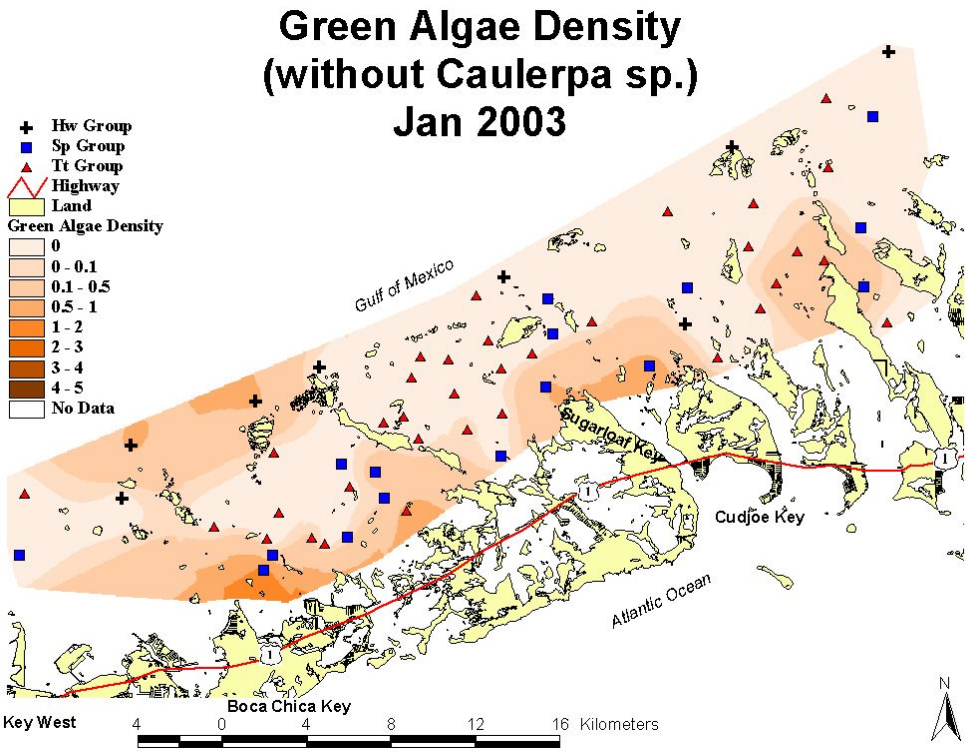

Figure 7. Distribution of green algae density (Braun-Blanquet score) within the study area (Caulerpa sp. not included).

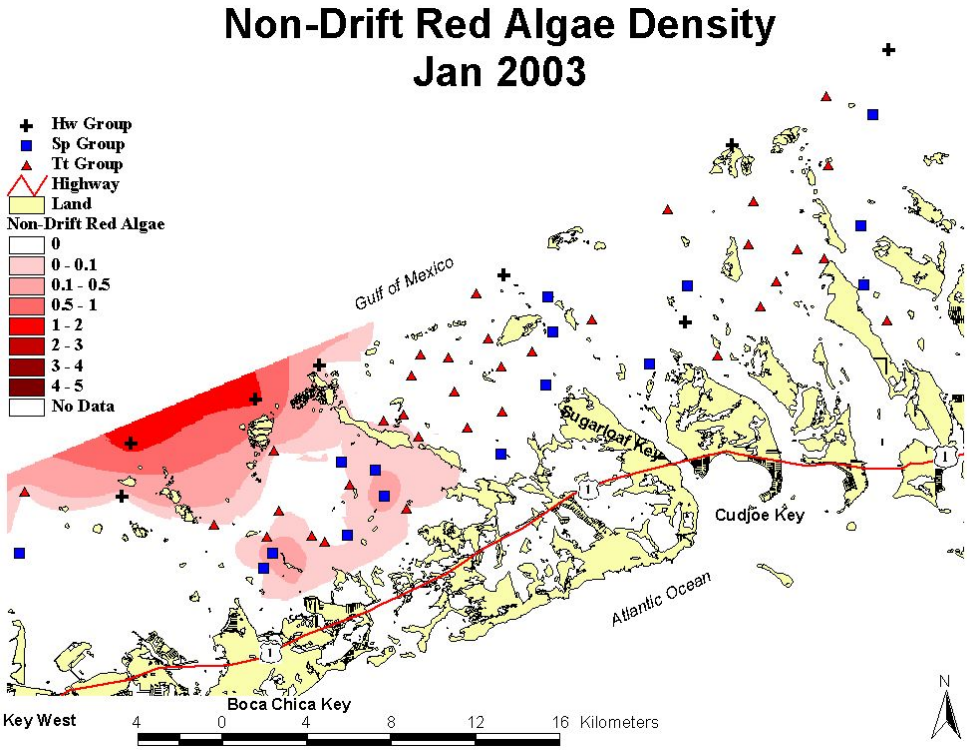

Figure 8. Distribution of non-drift red algae density (Braun-Blanquet score) within the study area.

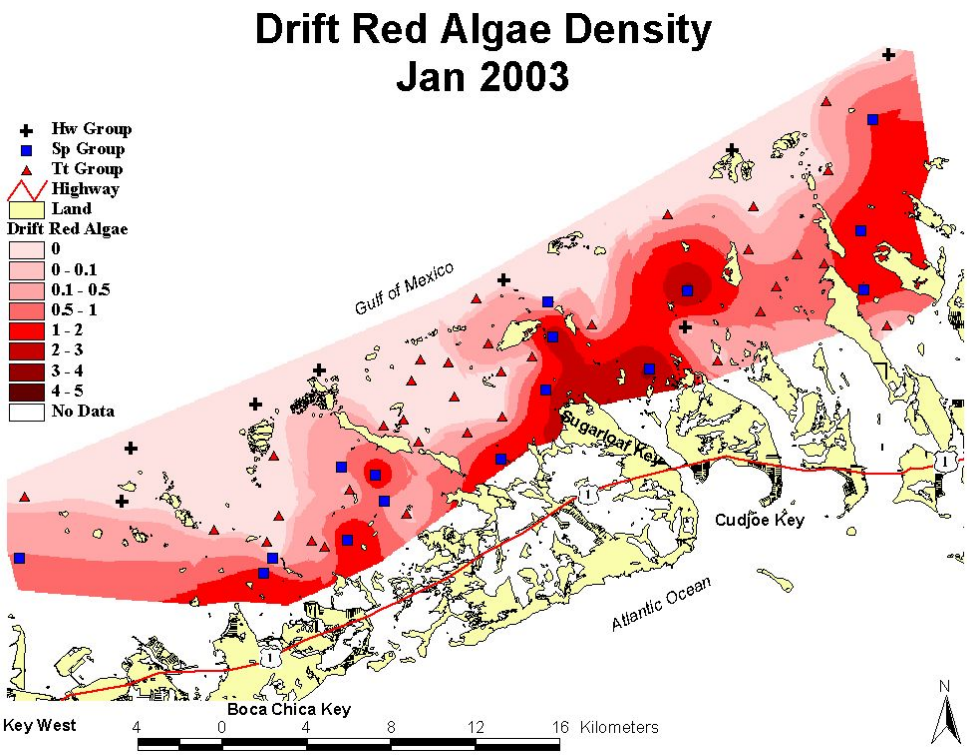

Figure 9. Distribution of drift red algae density (Braun-Blanquet score) within the study area.

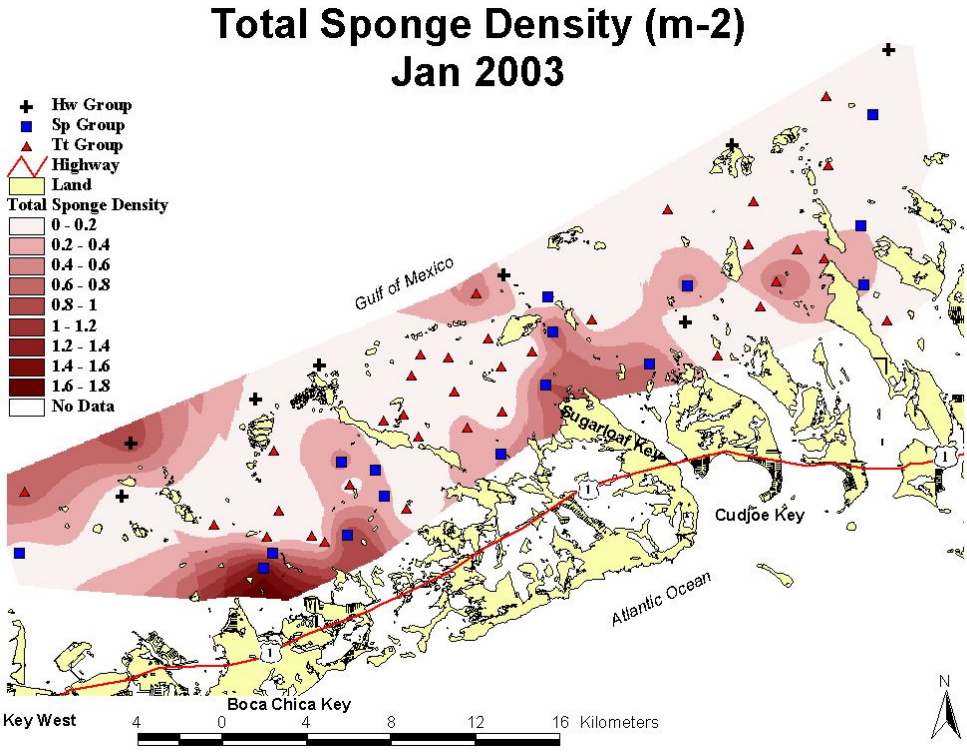

Figure 10. Distribution of total sponge density (Braun-Blanquet score) within the study area.

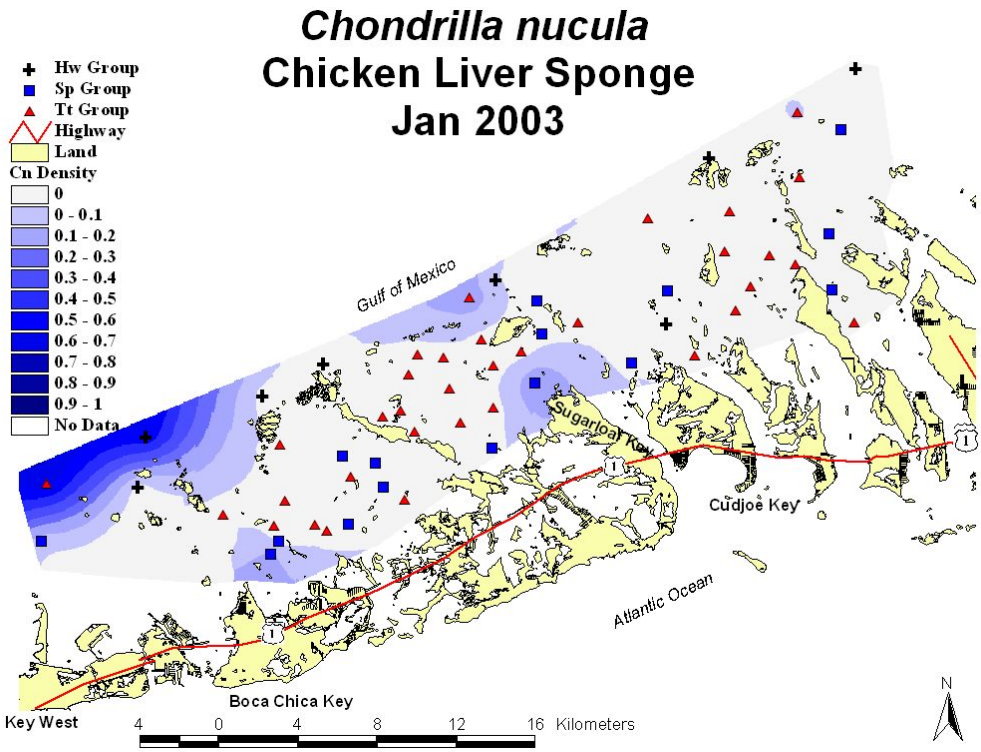

Figure 11. Distribution of *Chondrilla nucula* density (no. of species m^{-2}) within the study area.

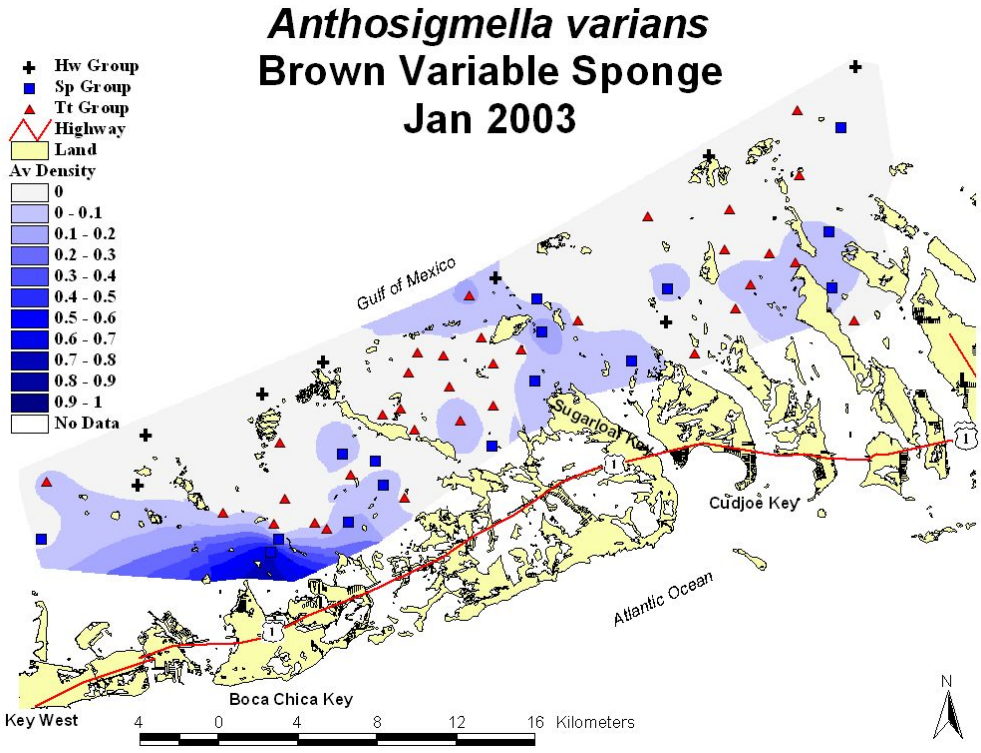

Figure 12. Distribution of *Anthosigmella varians* density (no. of species m^{-2}) within the study area.

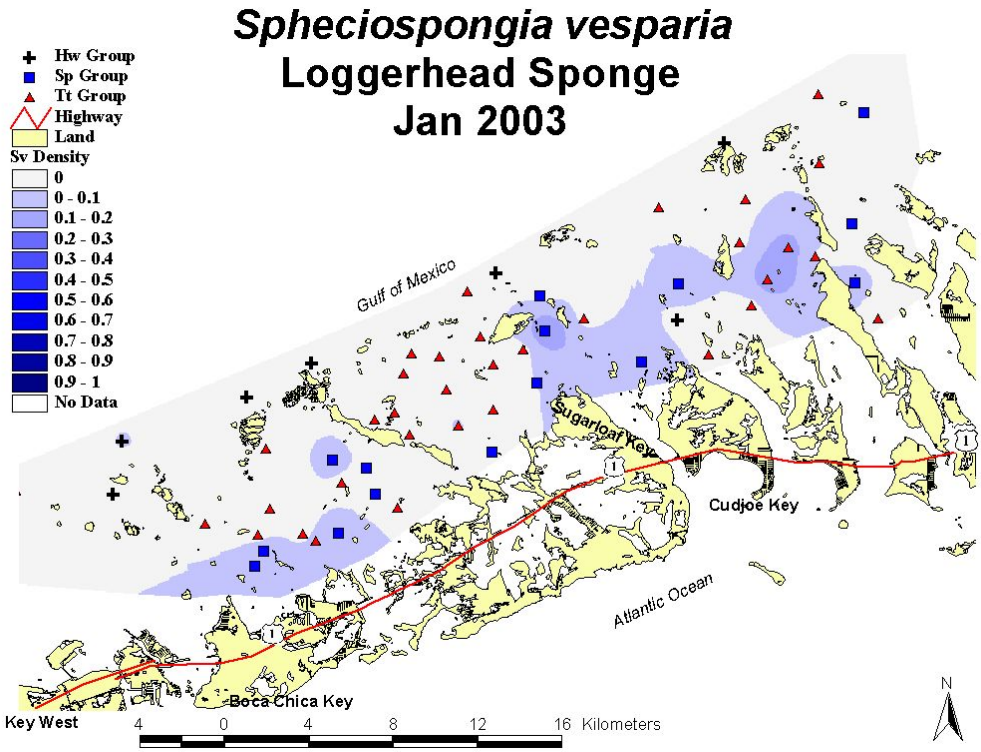

Figure 13. Distribution of *Spheciospongia vesparia* density (no. of species m^{-2}) within the study area.

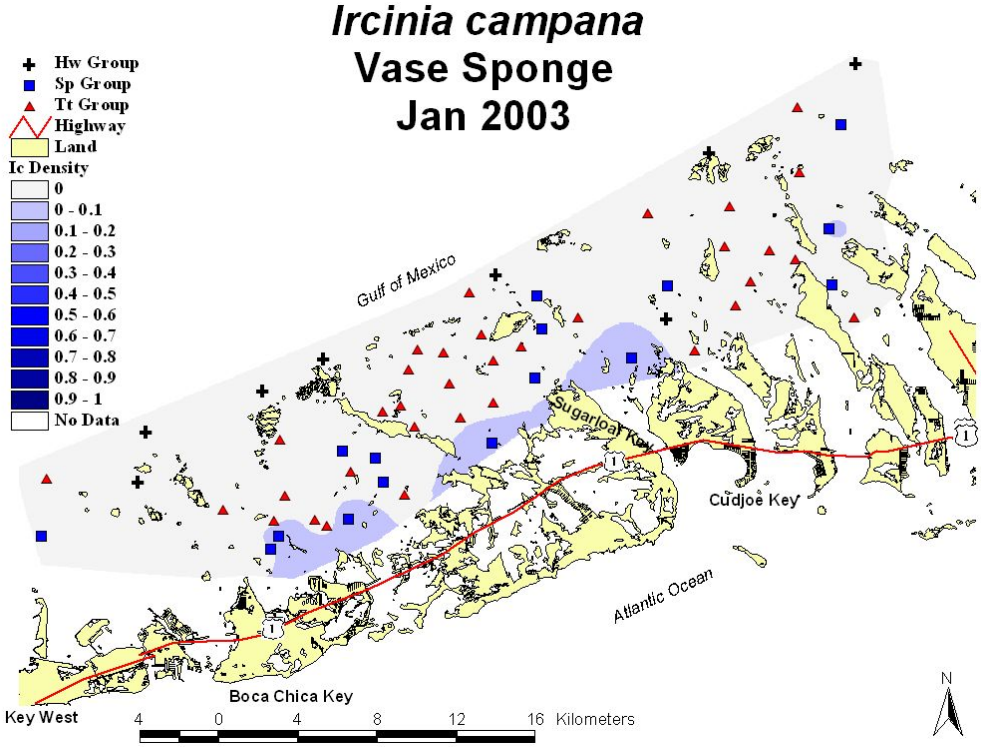

Figure 14. Distribution of *Ircinia campana* density (no. of species m^{-2}) within the study area.

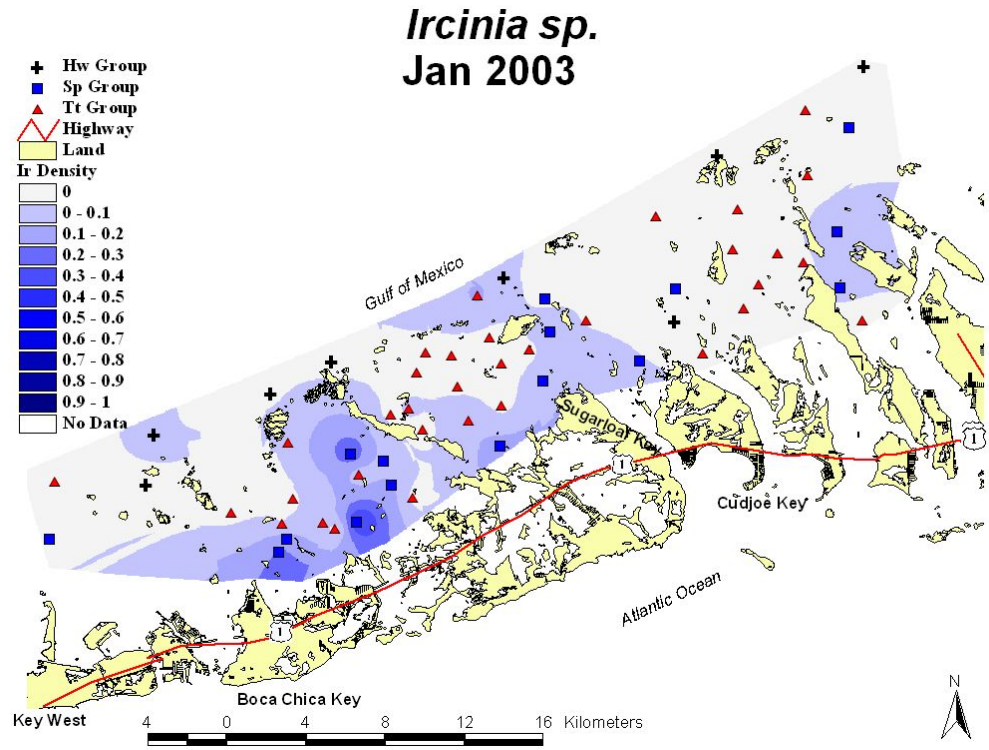

Figure 15. Distribution of *Ircinia sp.* density (no. of species m^{-2}) within the study area.

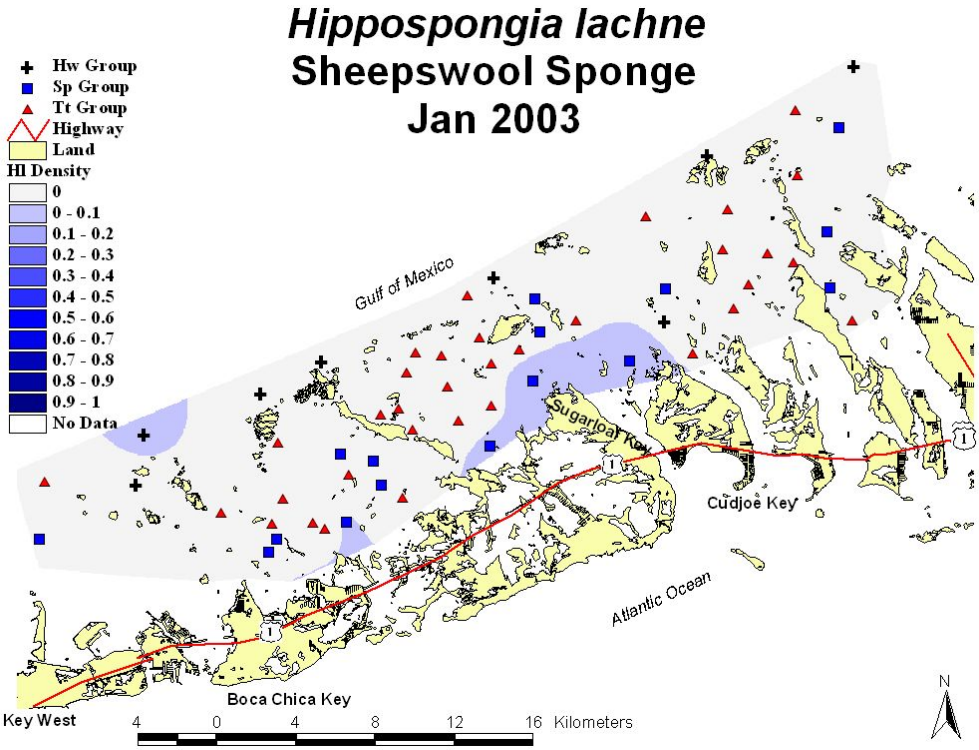

Figure 16. Distribution of *Hippospongia lachne* density (no. of species m^{-2}) within the study area.

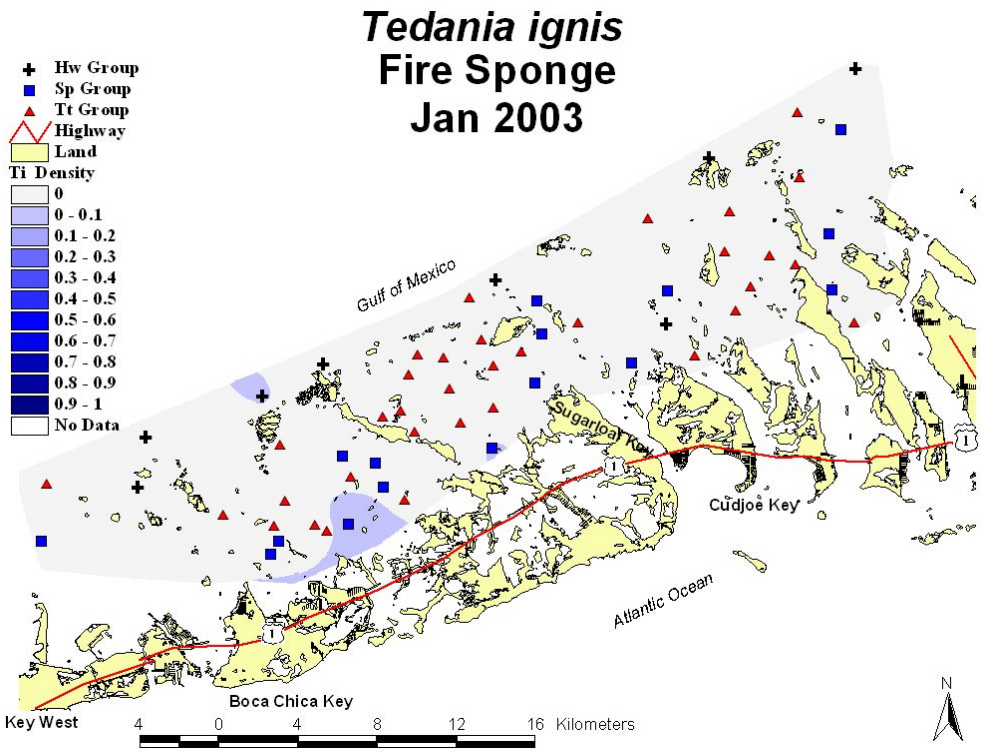

Figure 17. Distribution of *Tedania ignis* density (no. of species m^{-2}) within the study area.

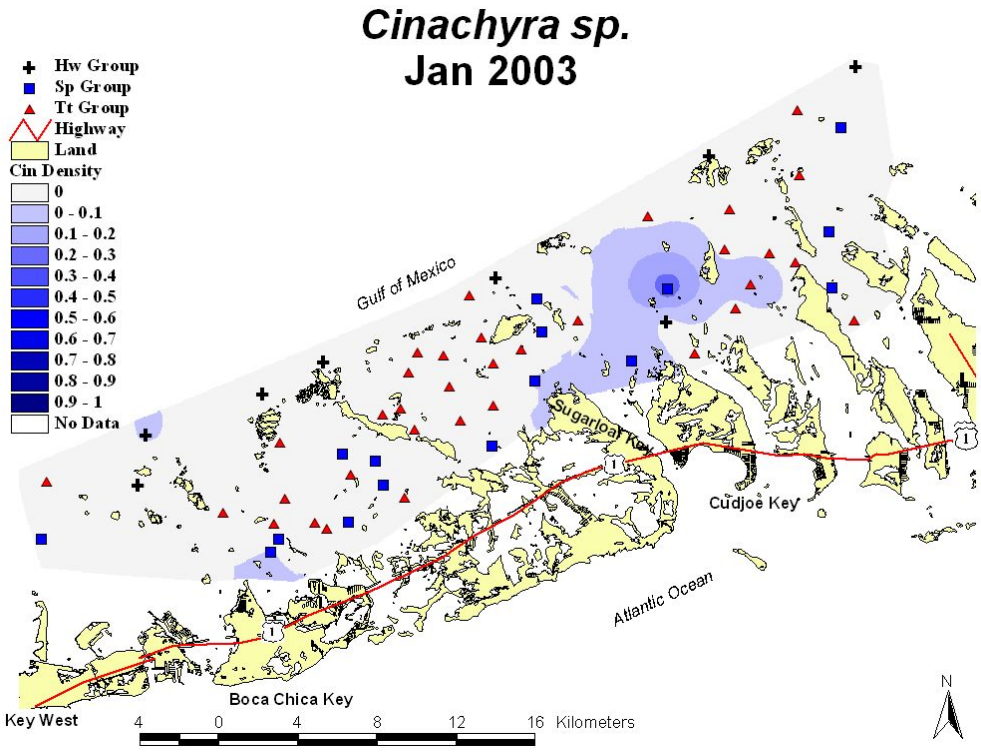

Figure 18. Distribution of *Cinachyra sp.* density (no. of species m^{-2}) within the study area.

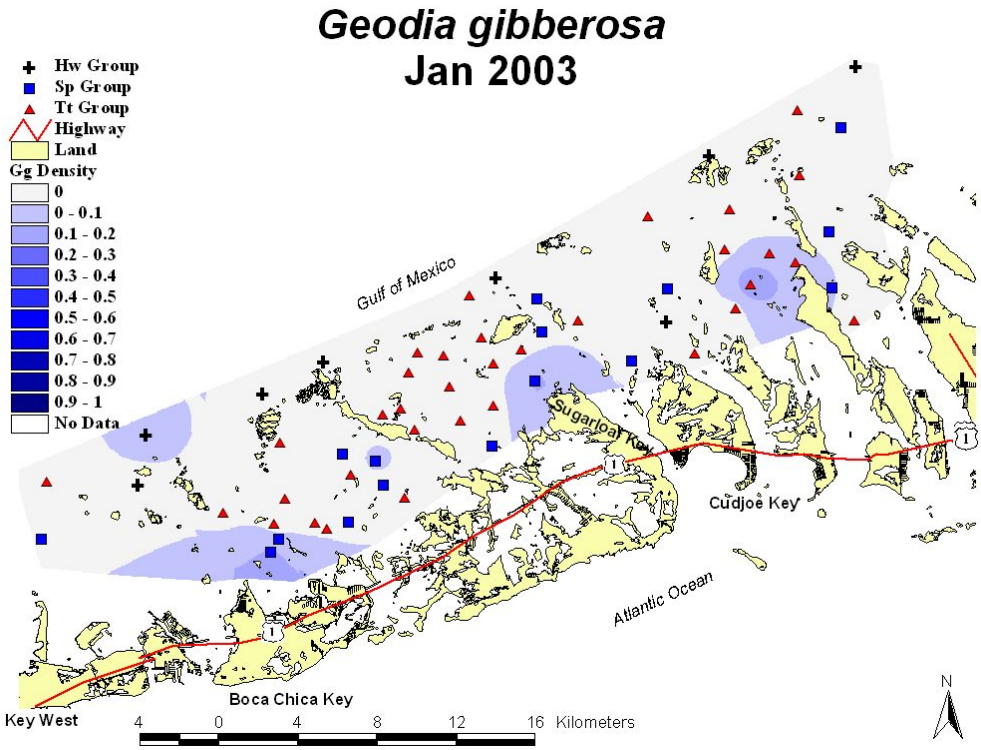

Figure 19. Distribution of *Geodia gibberosa* density (no. of species m^{-2}) within the study area.

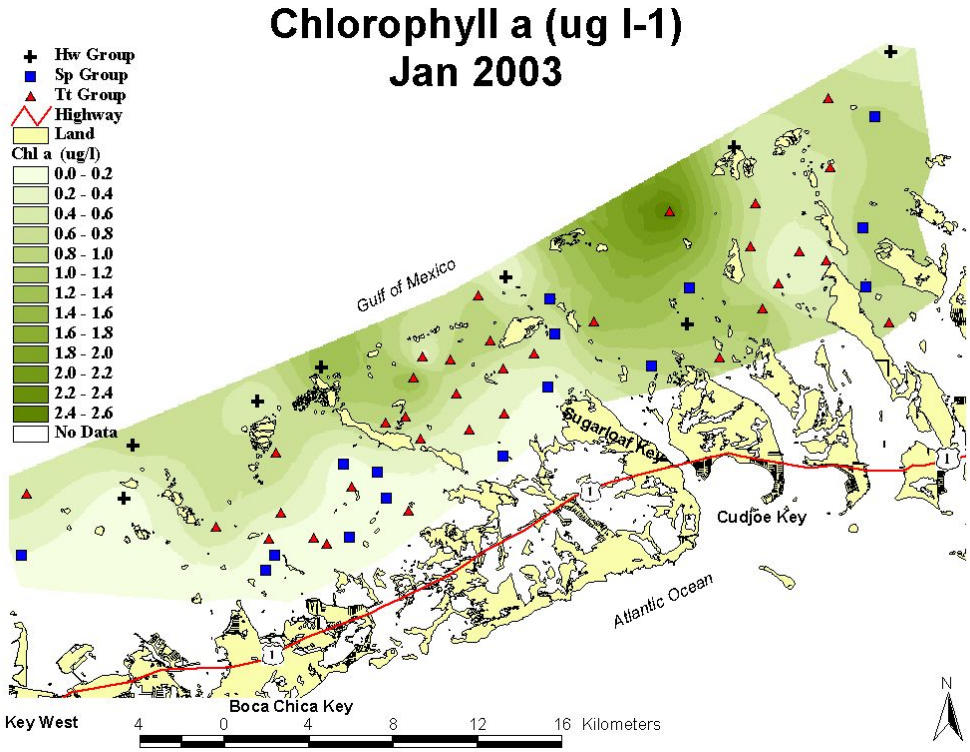

Figure 20. Distribution of chlorophyll *a* concentrations (µg l^{-1}) within the study area.

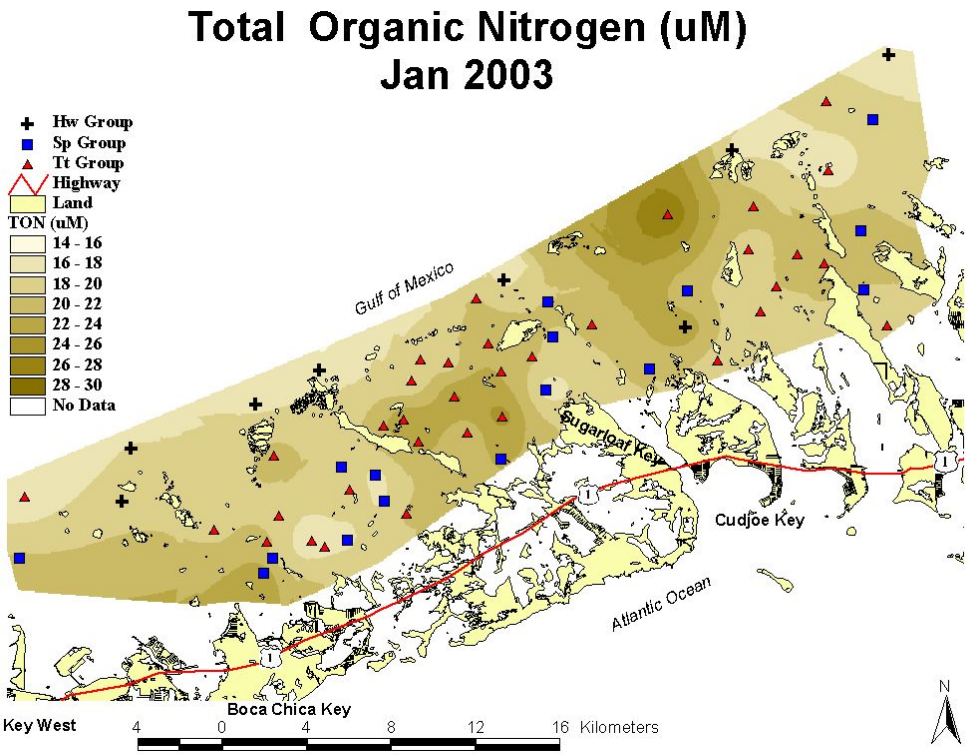

Figure 21. Distribution of total organic nitrogen concentrations (µM) within the study area.

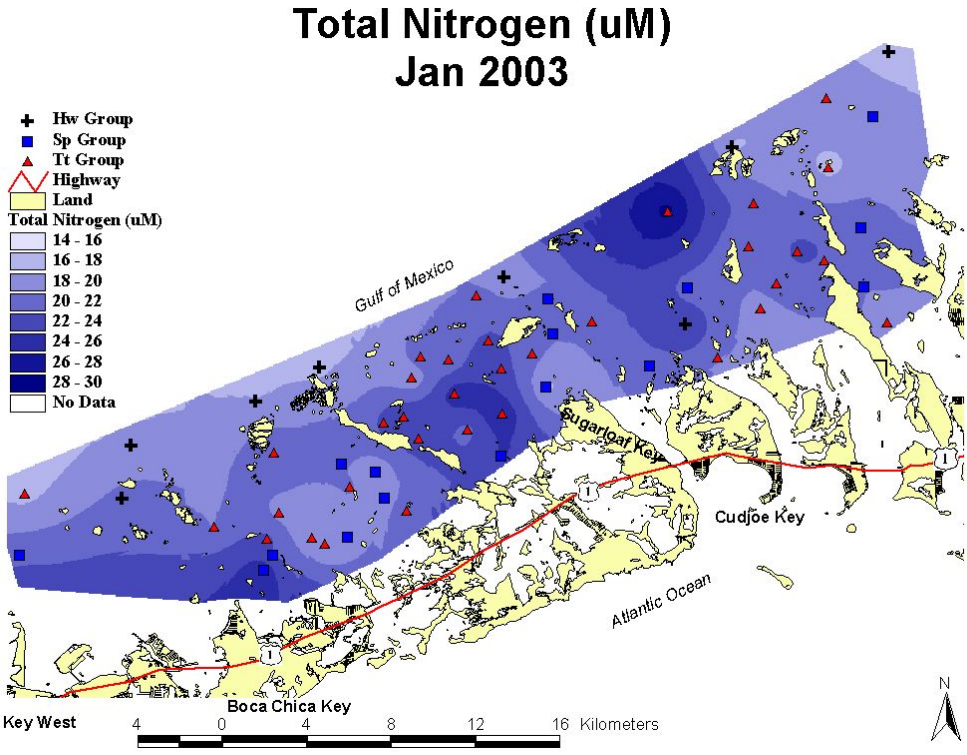

Figure 22. Distribution of total nitrogen concentrations (µM) within the study area.

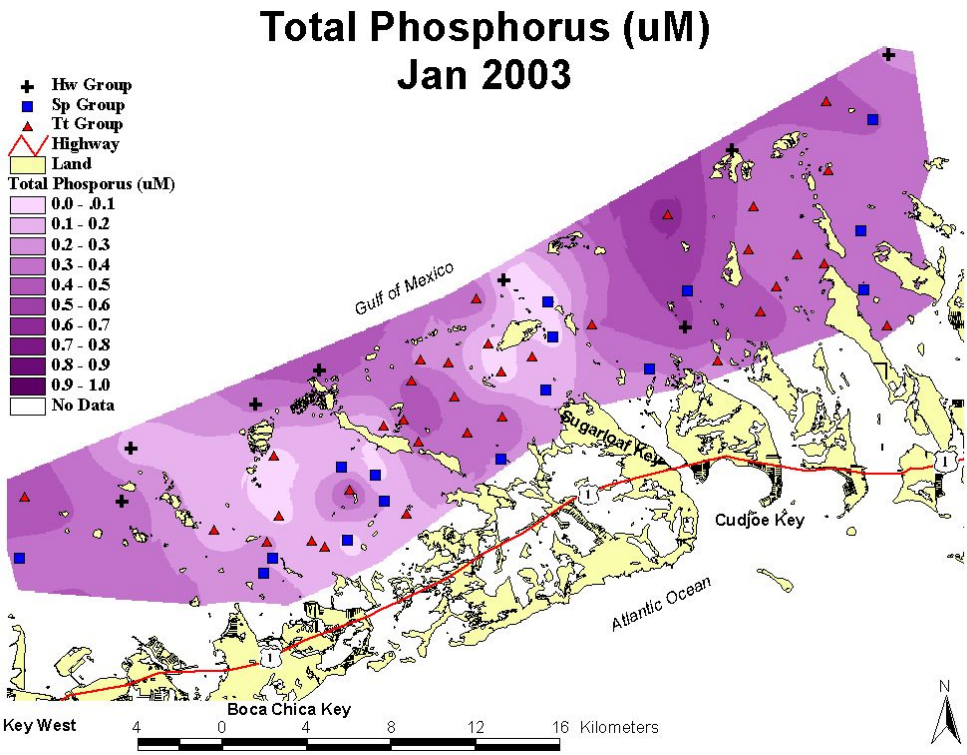

Figure 23. Distribution of total phosphorus concentrations (µM) within the study area.

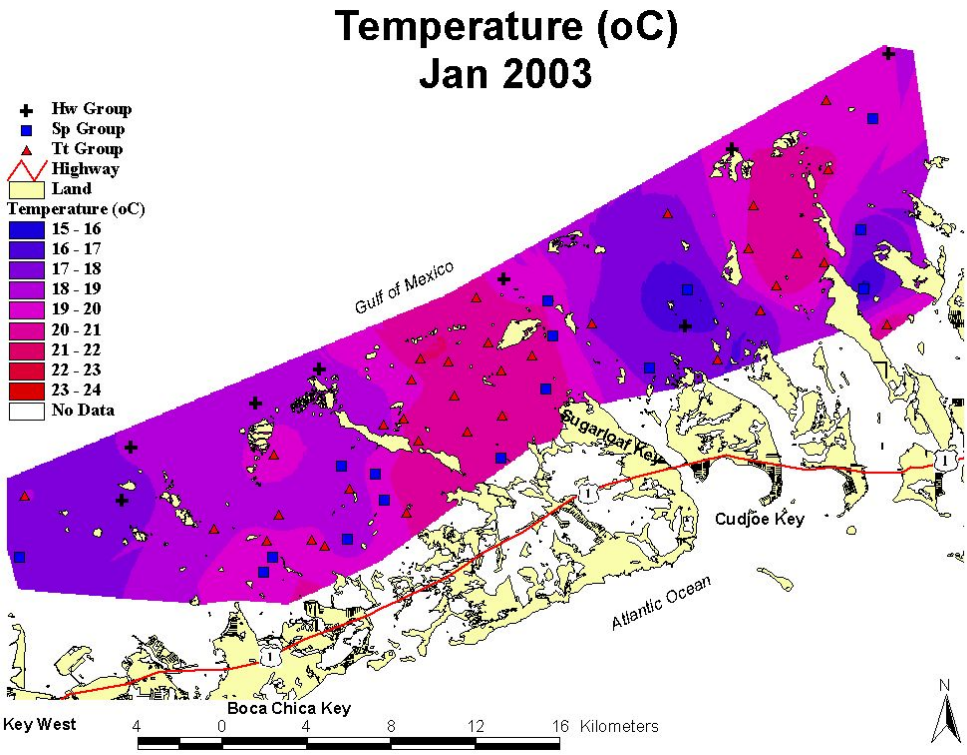

Figure 24. Distribution of temperature (°C) within the study area.

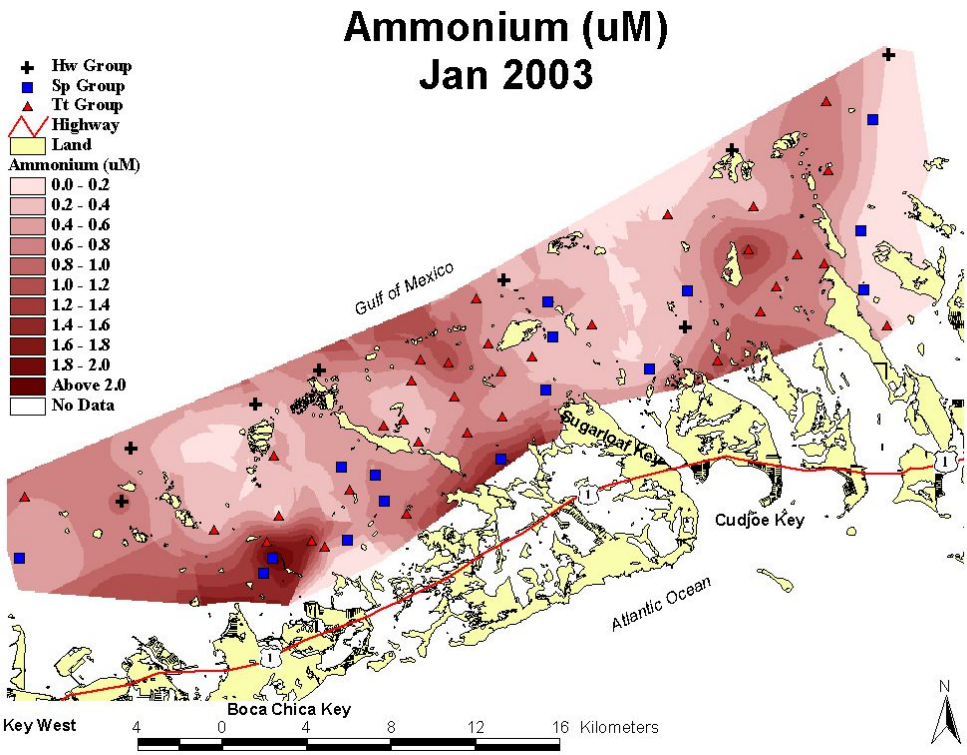

Figure 25. Distribution of ammonium concentrations (µM) within the study area.

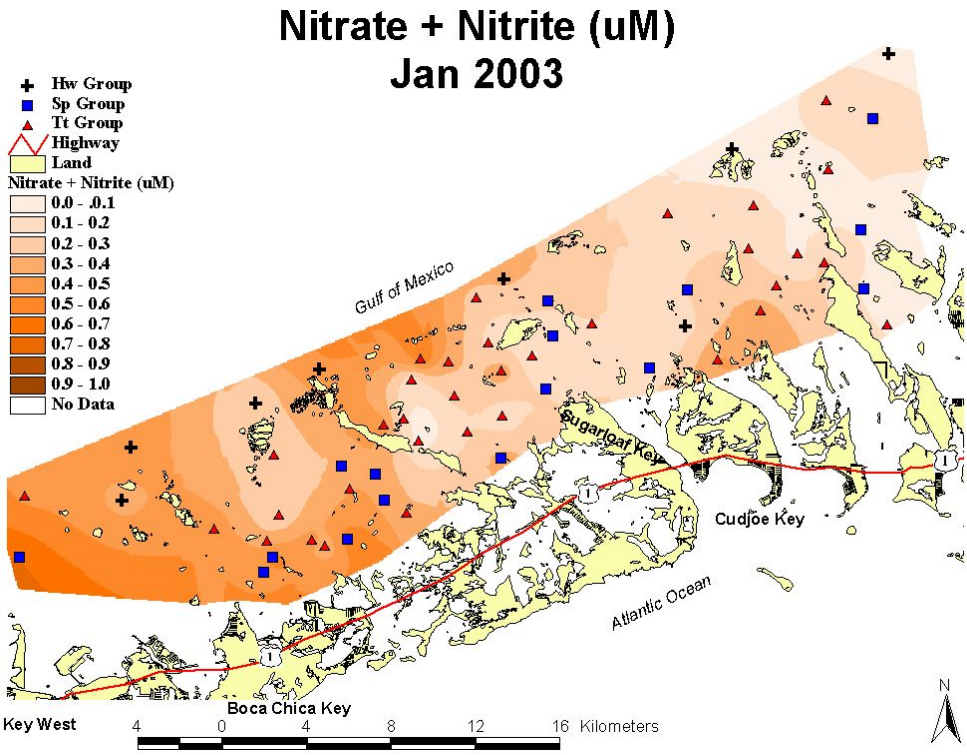

Figure 26. Distribution of nitrate and nitrite (NO_x) concentrations (µM) within the study area.

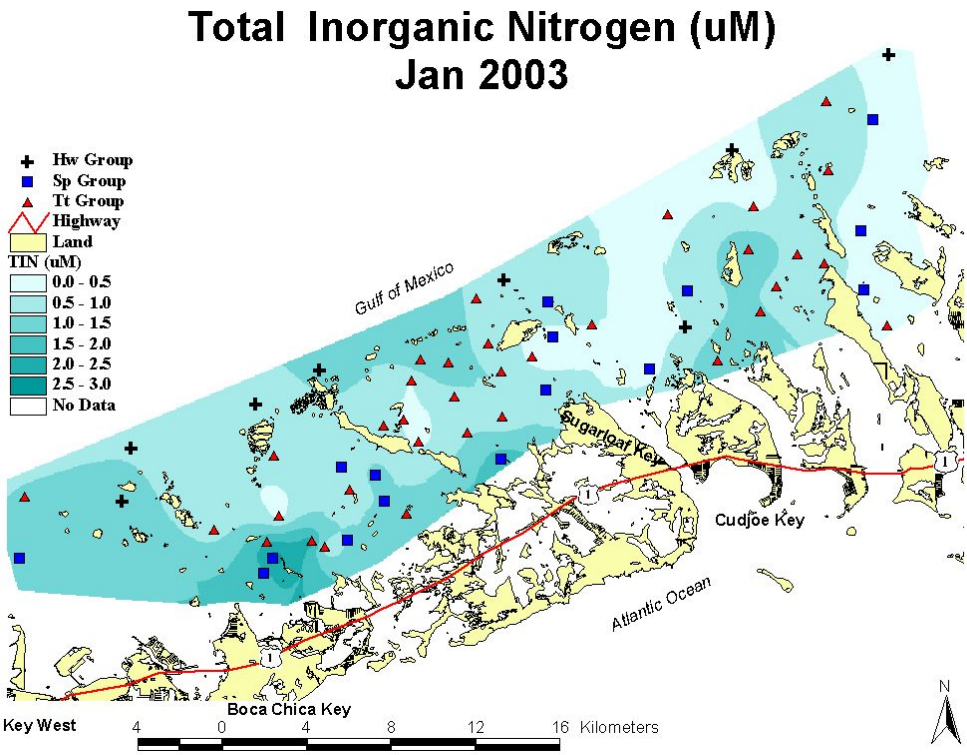

Figure 27. Distribution of total inorganic nitrogen concentrations (µM) within the study area.

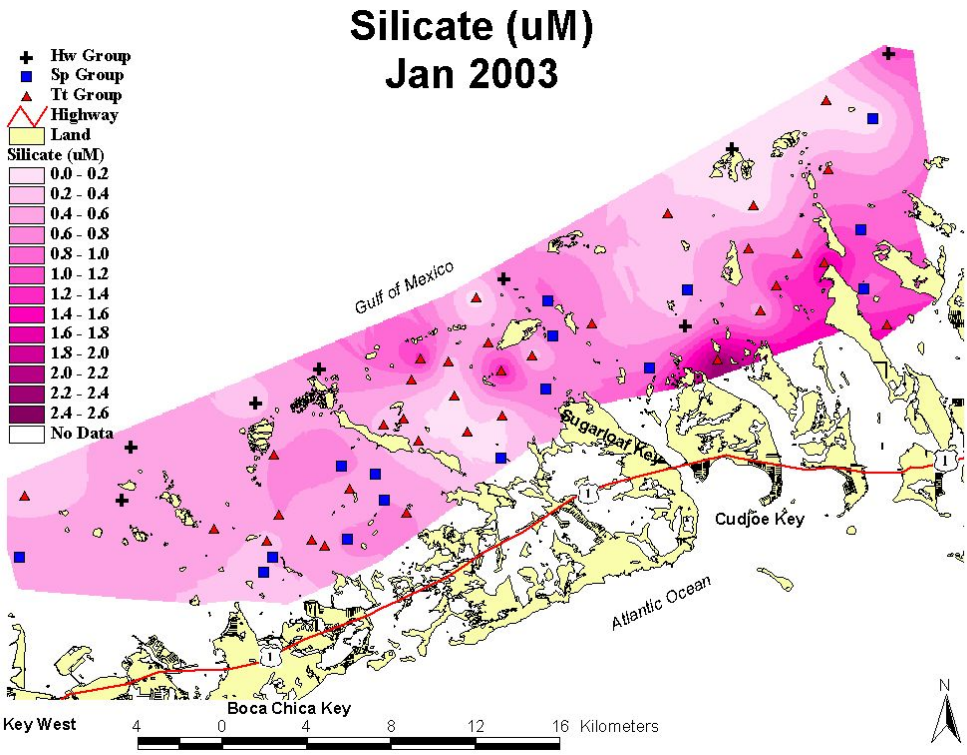

Figure 28. Distribution of silicate concentrations (µM) within the study area.

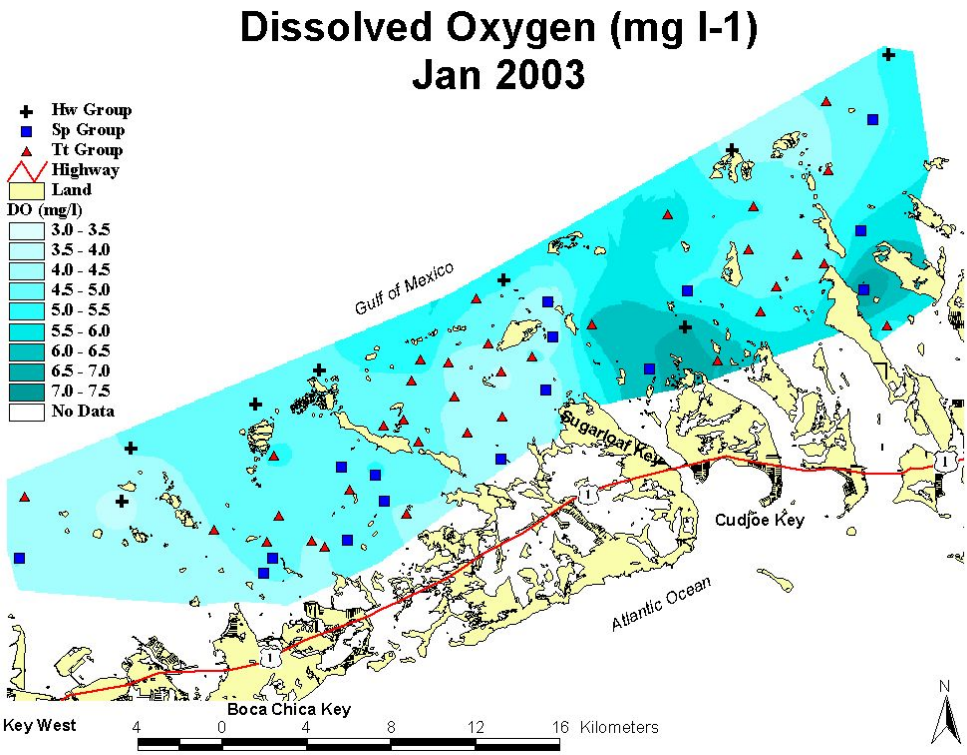

Figure 29. Distribution of dissolved oxygen concentrations (mg l^{-1}) within the study area.

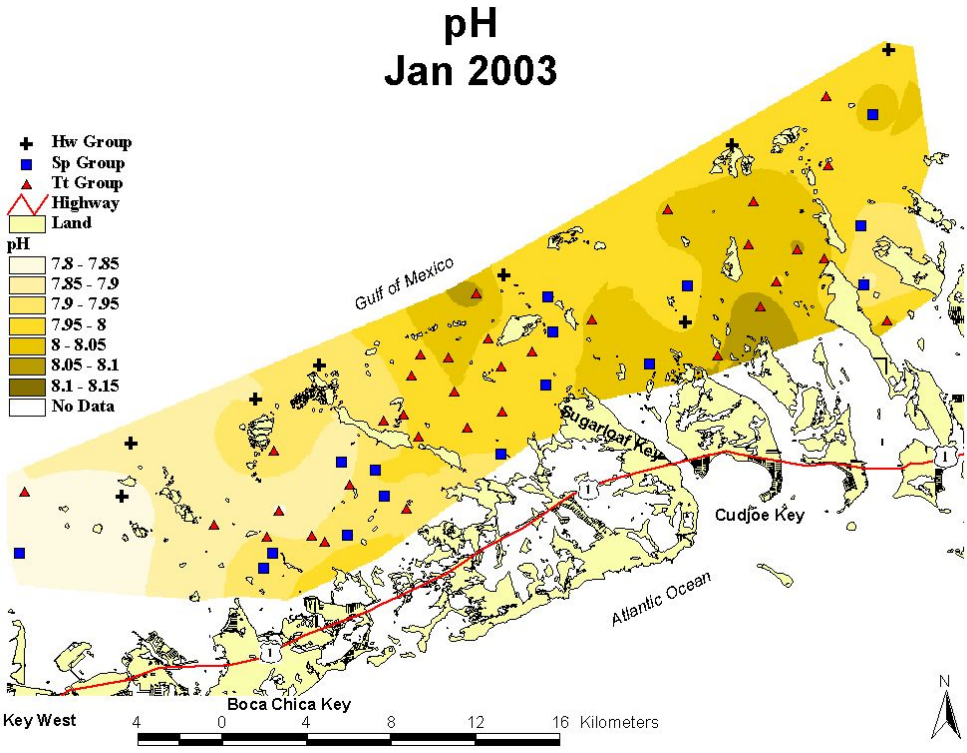

Figure 30. Distribution of pH levels within the study area.

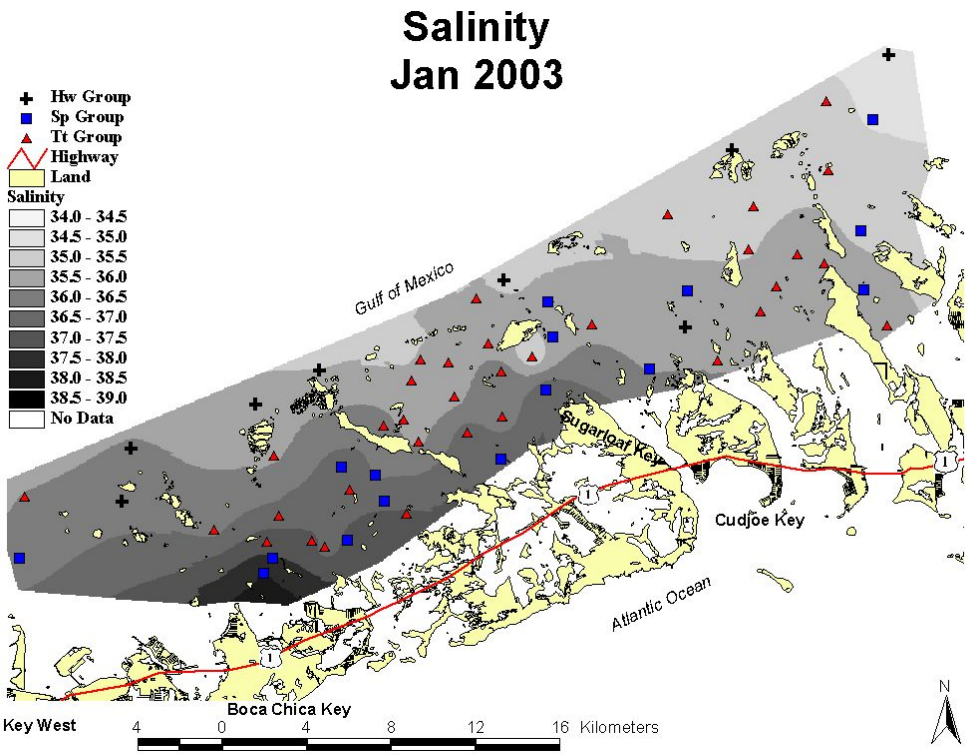

Figure 31. Distribution of salinity levels within the study area.

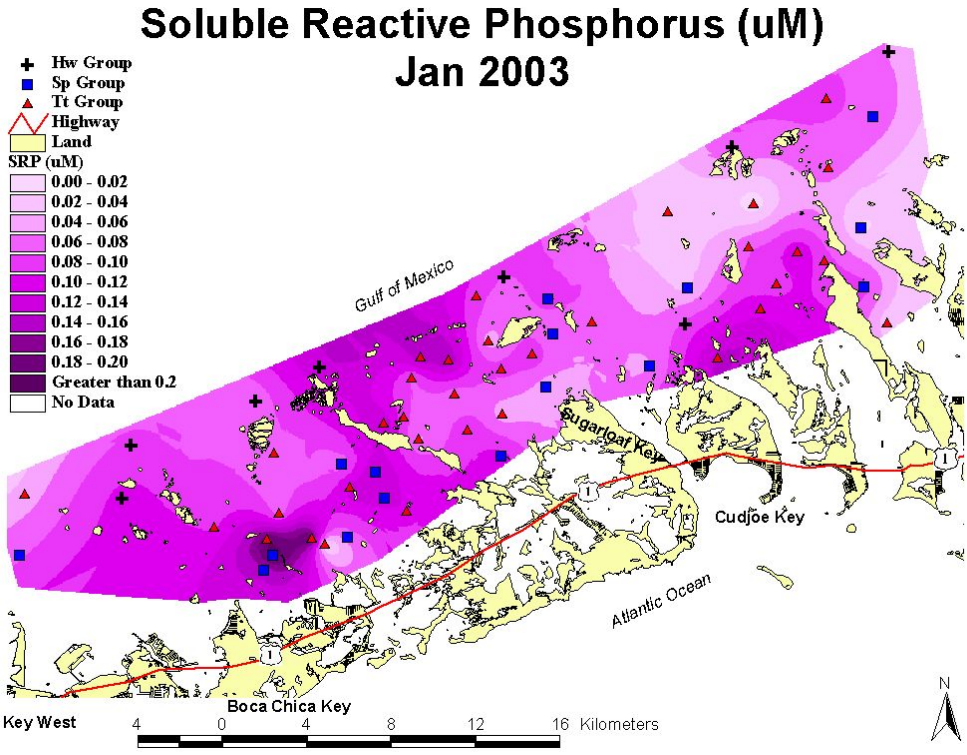

Figure 32. Distribution of soluble reactive phosphorus concentrations (µM) within the study area.

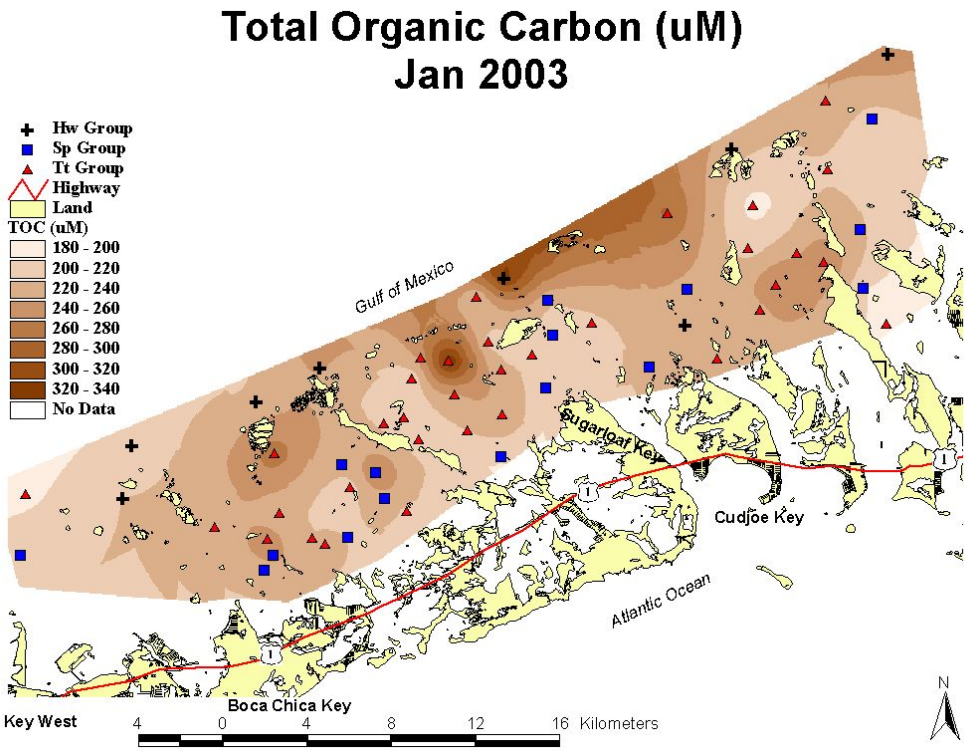

Figure 33. Distribution of total organic carbon concentrations (µM) within the study area.

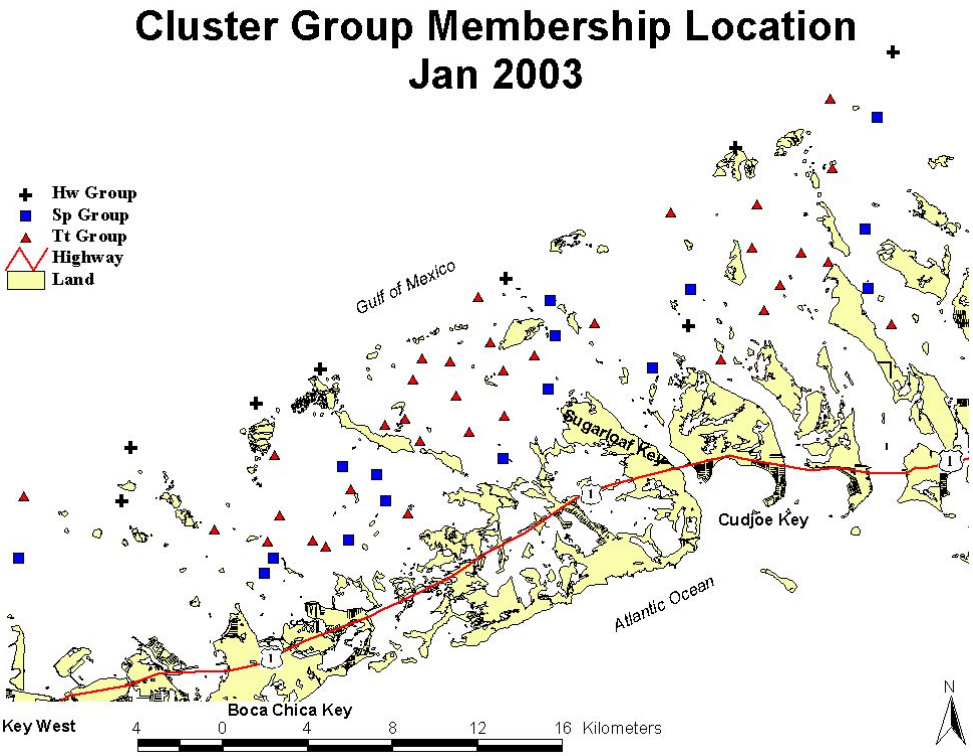

Figure 34. Illustrates the result of hierarchal clustering. Three clusters are shown, the black plus sign (✚) represents the *Halodule wrightii* (Hw) group (n=8), the blue square (■) represents the sponge hardbottom (Sp) group (n=16) and the red triangle (▲) is the *Thalassia testudinum* (Tt) Group (n=34).

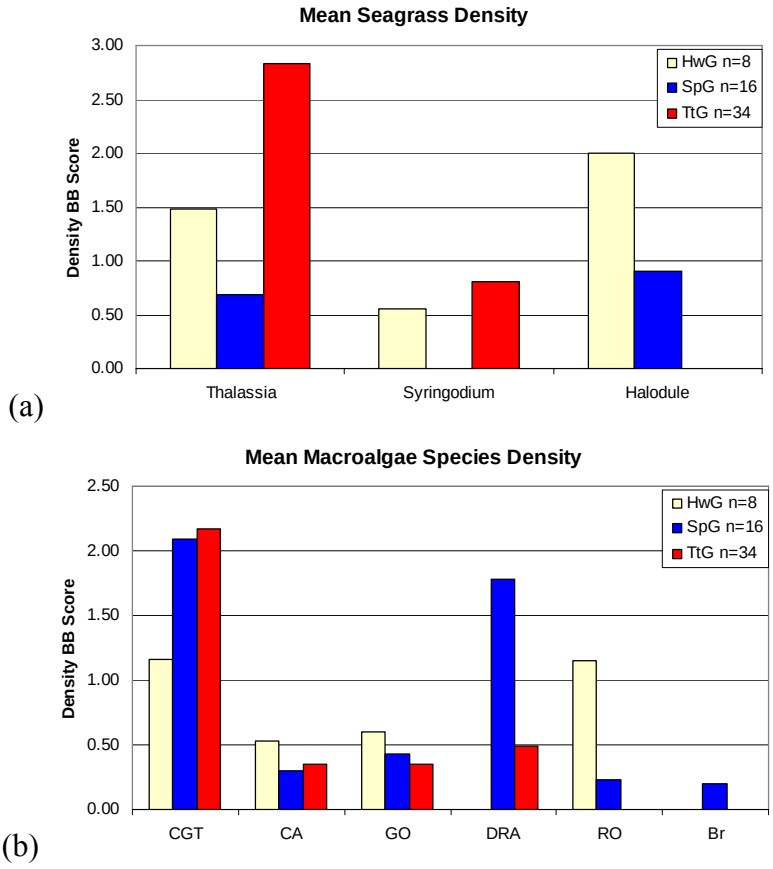

Figure 35. **(a)** Mean seagrass species Braun-Blanquet density scores plotted for each cluster. **(b)** Macroalgae taxa showing Braun-Blanquet density scores for each cluster group (CGT= Calcareous Green Total, CA= *Caulerpa sp*., GO= green algae, DRA= drift red algae, RO= non-drift red algae, and Br= brown algae).

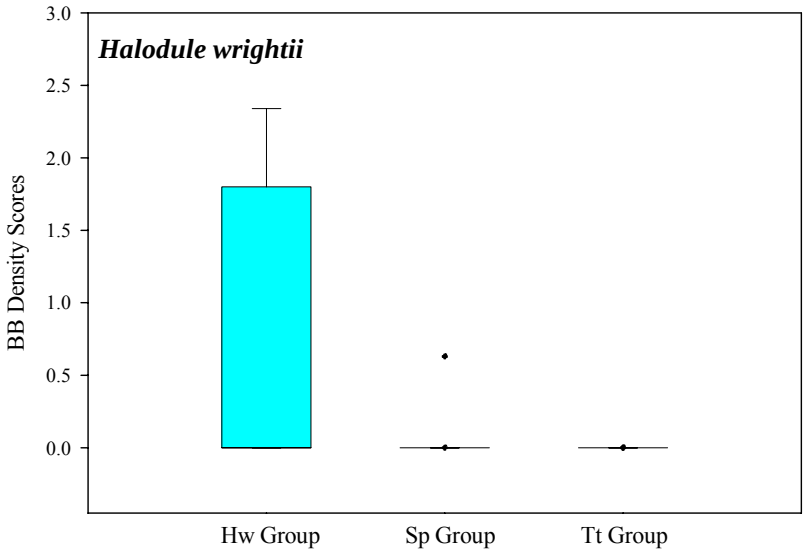

Figure 36. Box-and-whisker plot for *Halodule* density between clusters.

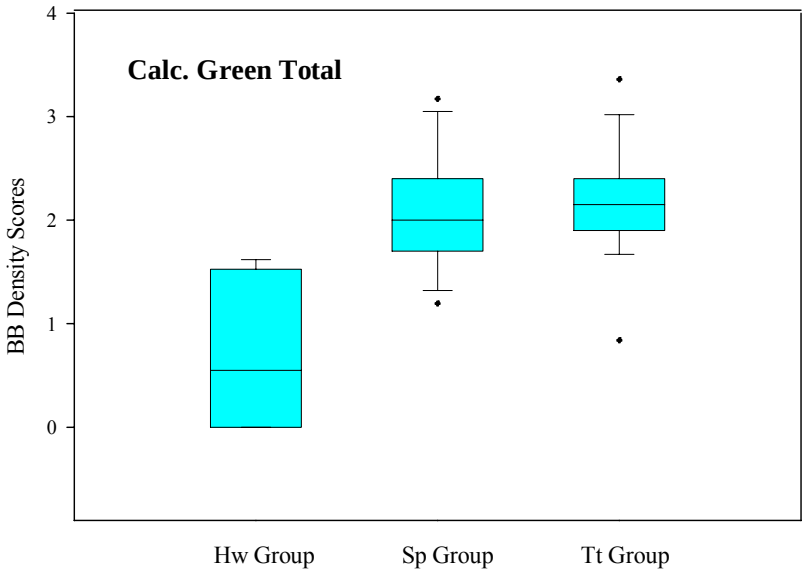

Figure 37. Box-and-whisker plot for calcareous green algae density between clusters.

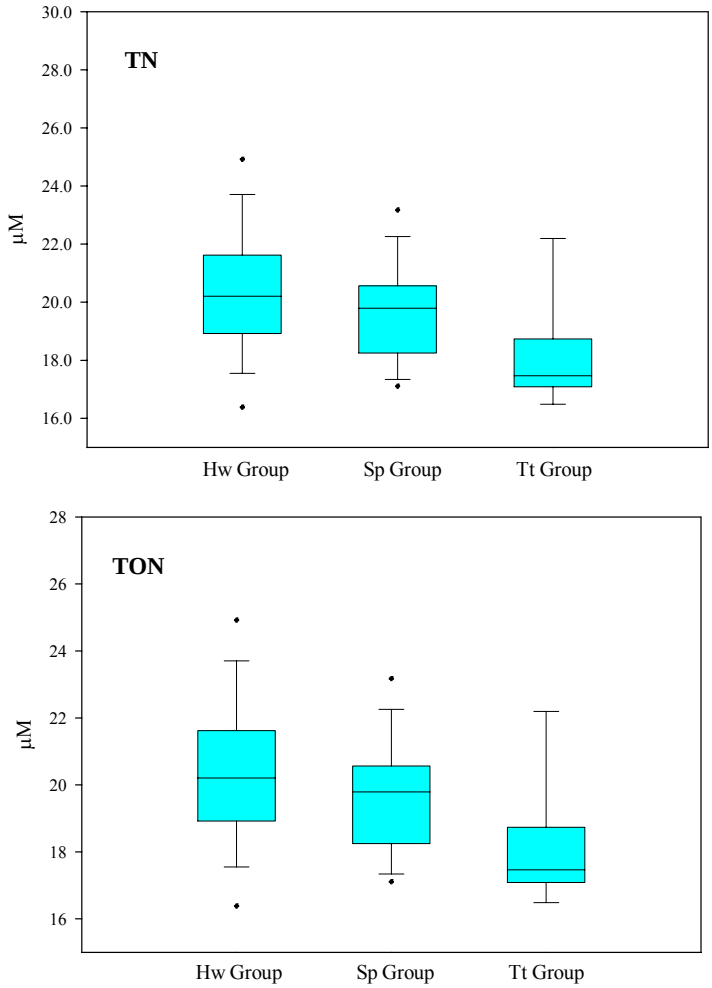

Figure 38. Box-and-whisker plot for total phosphorus and total organic nitrogen between clusters.

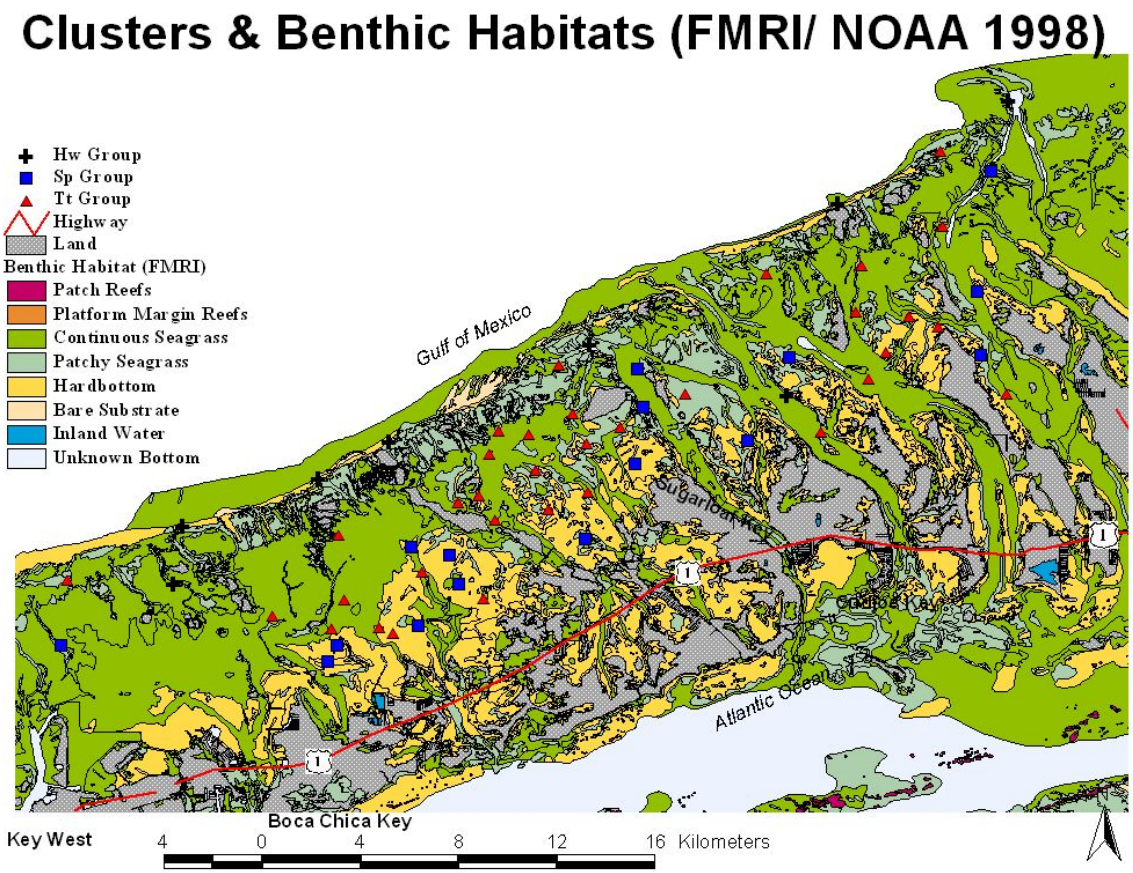

Figure 39. Great White Heron cluster membership locations plotted against benthic habitat data by FMRI/ NOAA 1998.

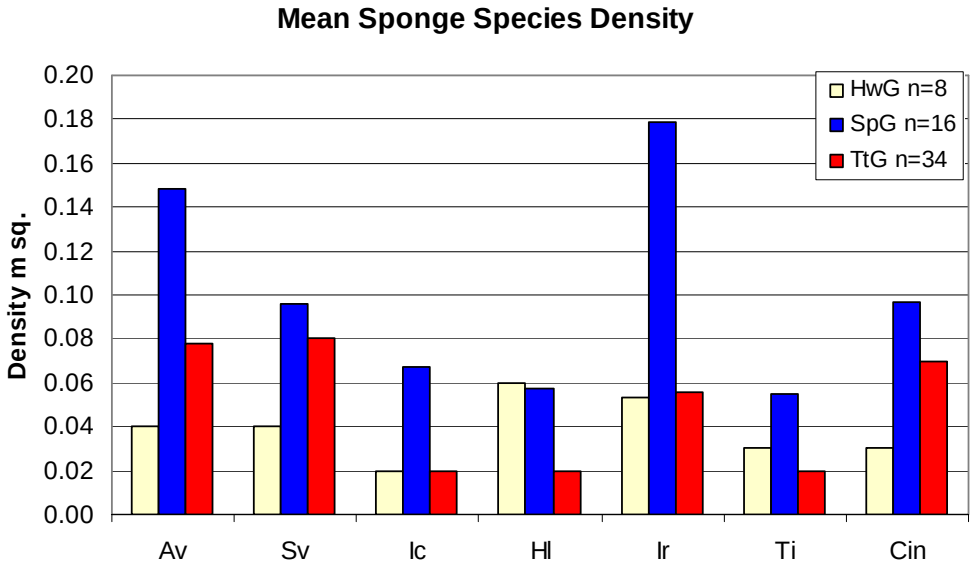

Figure 40. Mean sponge species density (no. species m^{-2}) for the species which had a significant difference between cluster groups. Species represented are *Anthosigmella varians* (Av), *Spheciospongia vesparia* (Sv), *Hippospongia lachne* (Hl), *Ircinia campana* (Ic), *Ircinia sp*. (Ir), *Trcinia sp*. (Ti), and *Cinachyra sp*. (Cin).

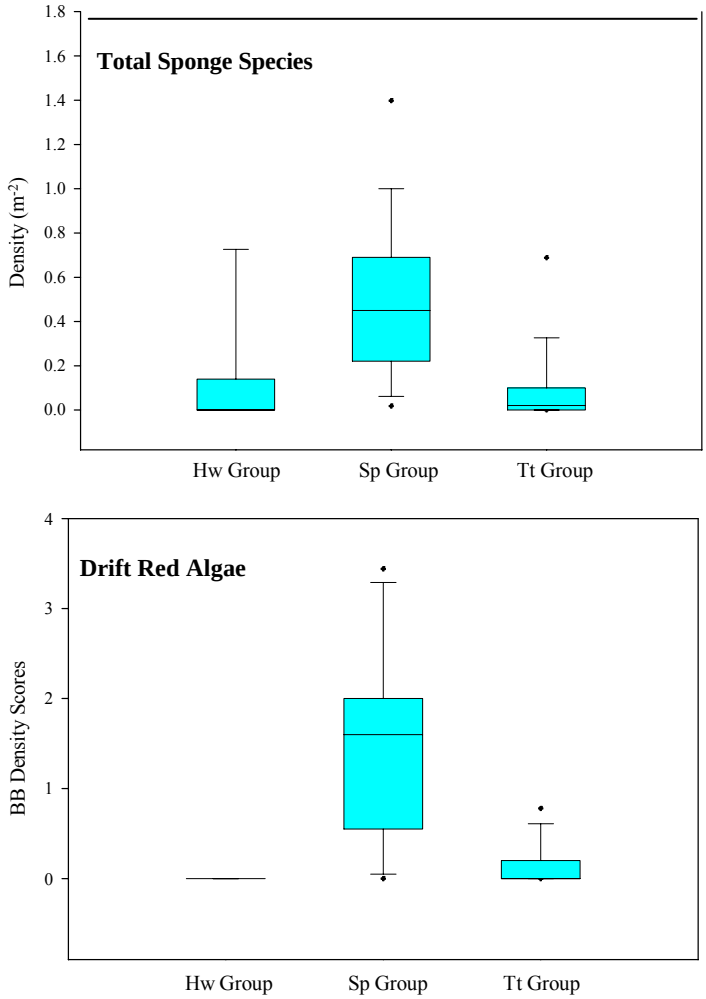

Figure 41. Box-and-whisker plot for total sponge species and drift red algae density between clusters.

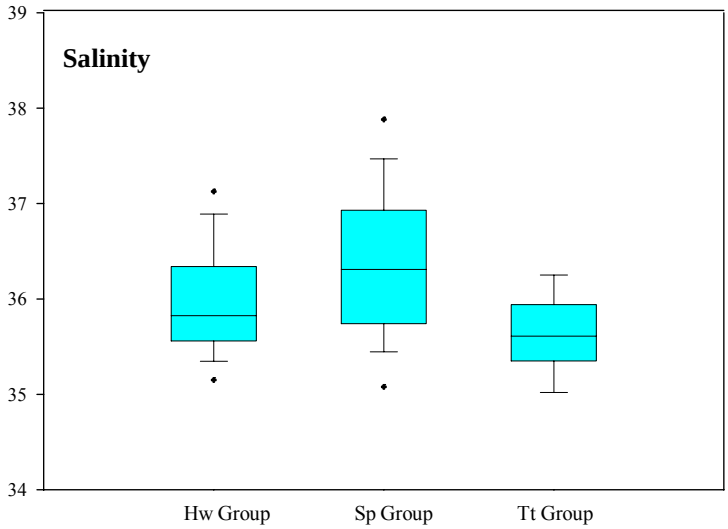

Figure 42. Box-and-whisker plot for salinity levels between clusters.

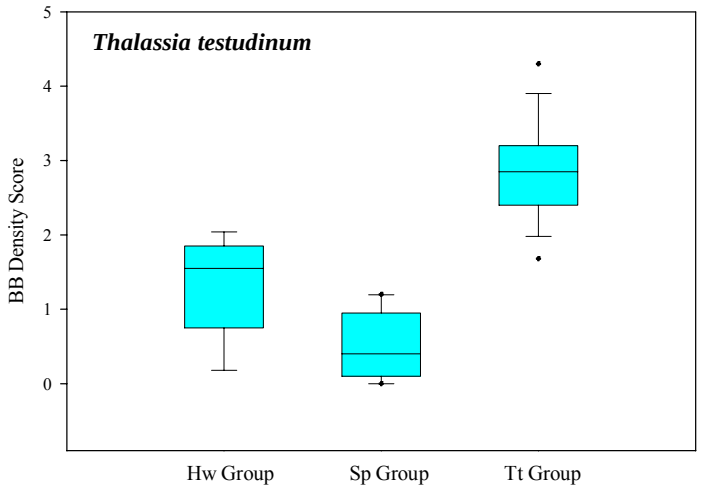

Figure 43. Box-and-whisker plot for *T. testudinum* density between clusters.

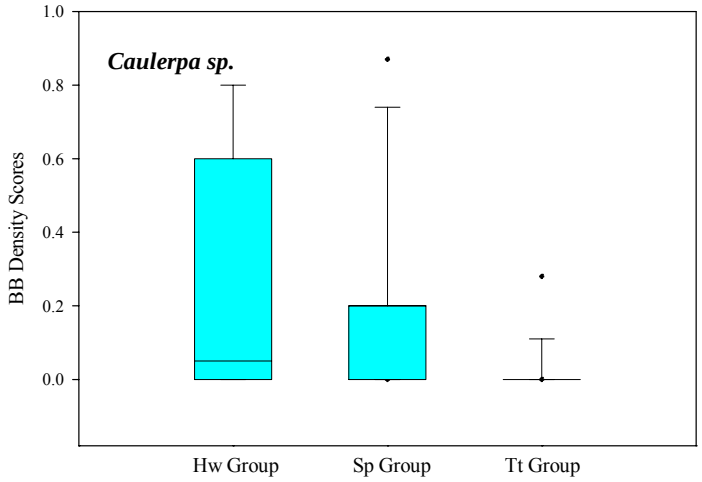

Figure 44. Box-and-whisker plot for *Caulerpa sp.* density between the clusters.

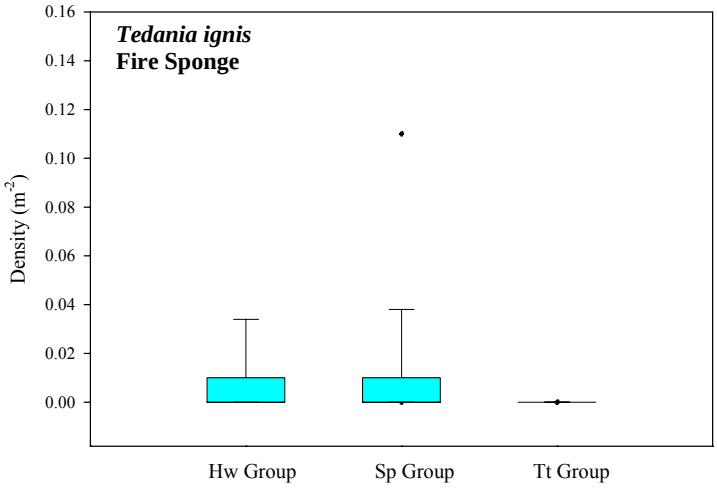

Figure 45. Box-and-whisker plot for *Tedania ignis* density between clusters.